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UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

UNIVERSITY OF ILLINOIS

MAR 20 1962

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January, 1962

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PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1) 415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

The static test involves application of DC power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspection.

TABLE I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	0
Core Storage Unit (4096 words) 3883	3,883	3,883	3,883	3,883	3,883	3,883	3,883	3,883		
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	8,828 1,457 10,285	7,076 3,209 10,285	5,210 2,894 8,104	4,300 3,248 7,548	3,527 1,020 4,547	1,198 0 1,198	
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,709	
Advanced Control 6800	6,200 600 6,800	5,800 600 6,400	1,950 2,350 4,300	0 869 869	0	0	0			
Drum Storage Unit 2500	2,500 0 2,500	1,100 0 1,100				0	0			
Interplay Control 3000	3,000 0 3,000	3,000 0 3,000	500 0 500			0	0			
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641		
Test Controls	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,259 175 1,434	671 0 671	
TOTALS	37,309 600 37,909	35,509 600 36,109	28,059 2,350 30,409	24,152 2,326 26,478	22,400 3,209 25,609	20,534 2,894 23,428	19,624 3,248 22,872	18,676 1,195 19,871	10,957 0 10,957	

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystems Tests

The arithmetic unit, flow gating buffer storage unit, and Fibonacci test control (approximately 11,000 transistors) were operated for 375 hours during the month. Malfunctions are summarized in Table II. The majority of these malfunctions were due to faulty stabistor bump supplies, which serve to limit the extremes of signal swings. In some cases, a faulty bump supply causes no immediate effect, since it either limits the transistor collector dissipation to 60% or less of the manufacturer's rating, or prevents saturation of the transistor. In other cases, the bump supply voltage would tend toward ground if the bump were unused; otherwise, the stabistor and paralleled capacitor would be charged to approximately the nominal value. Unfortunately, the time constant in these cases was measured in milliseconds, so that a repetitive pattern with a cycle time in several microseconds would maintain the nominal bump voltage. Thus a repetitive cycle, once established, would run correctly indefinitely; the characteristic indication of the existence of this type of fault was difficulty in establishing a pattern after the computer had been quiescent for several seconds.

Although techniques were found for dynamically finding these faulty bumps (such as slowing the control to operate at one operation every two seconds), the localization proved time consuming. A systematic measurement of each of the 1800 bump supplies in the computer was made, and additional static tests of new chassis to detect such faults have been instituted. The stabistor bump faults found during January are listed in the first four rows of Table II.

Preliminary tests of four paper tape reader and punch control chassis and of three AC₀ control chassis were made during January. Redesign of the circuits synchronizing the core memory and the AC₀ control will be required.

3. Core Memory

The rewiring of Y driver lines for 2048 words was completed and the stack reinstalled on January 12. The driver noise now coupled to the sense lines is now negligible.

TABLE II FAULTS DURING JANUARY

Nature of Fault	Test Controls	Arithmetic Unit	Flow-Gating Storage	Total
Wiring Error Affecting Stabistor Bump		4	1	5
Open Stabistor Bump Connection	1	14	2	17
Faulty Stabistor		5	1	6
Faulty Bump Circuit Reason Unknown			2	2
Open or Intermittent Connection	4	2		6
Unsoldered Indicator Bulb		1		1
Faulty Socket Pin		2		2
Faulty Transistor			3	3
Open Resistor	1		1	2
Totals	6	28	10	44

The "boot strap" which will be required for operation of the machine in the initial program-running phase was wired into the core memory and checked out.

The remainder of the month was spent in preparing for unattended test runs of the memory. These runs were begun at the end of the month.

(S. Ray)

4. Magnetic Drum Memory

The Magnetic Drum Read Amplifier shown in the July, 1961, progress report was found to introduce distortion for some bit patterns. A new amplifier design was sought to provide:

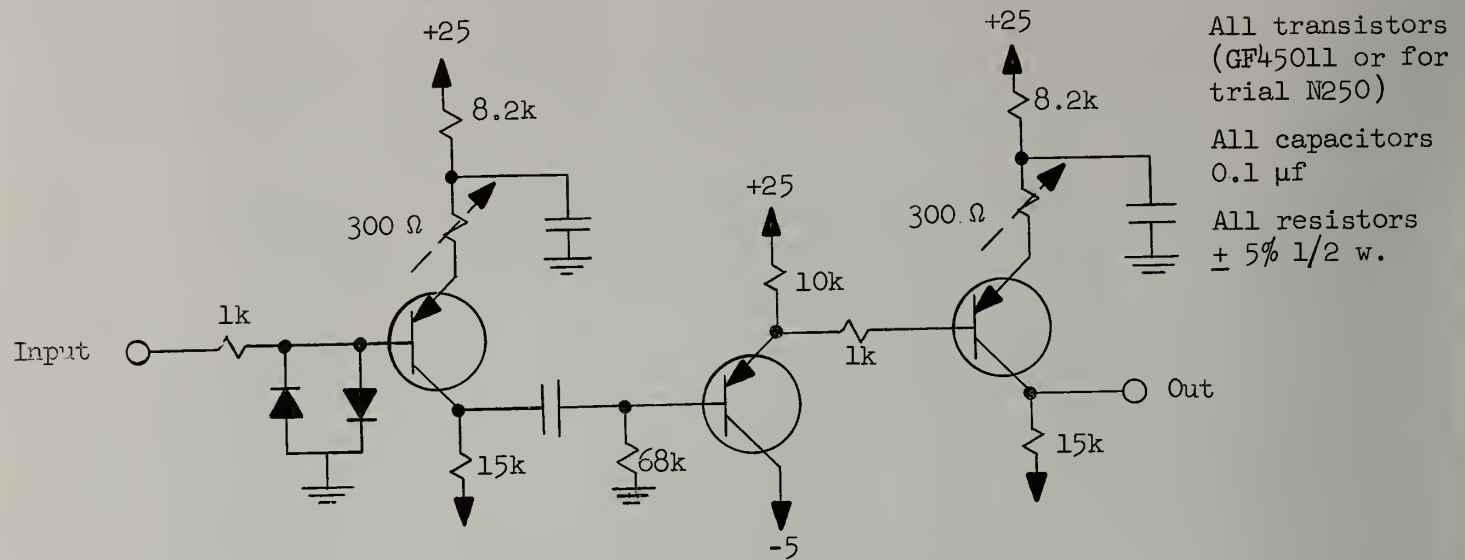
- (1) Adequate output, i.e., > 10 volts peak to peak.
- (2) Flatter frequency response.
- (3) Independence of transistor parameters.
- (4) A convenient means for gain control.

The distortion in waveshape of the earlier amplifier was realized to have been caused by high emitter resistance of the N250 transistors. Changing the transistors to 6F45011's reduced the distortion, but also reduced the gain. The answer was to use two stages of amplification and negative feedback. Two designs were tested--one a single ended amplifier with emitter feedback as shown in Figure 1 and the other a differential amplifier with collector-base AC feedback as shown in Figure 2. The resistors which may be varied to provide gain control are indicated by dotted arrows. The differential amplifier was preferred because of its flatter frequency response as shown in Figure 3 and its inherent suitability for the type of input available from the head selection switch.

A new simplified error correcting read circuit using peak detection is being considered. A final design for the read amplifier will not be attempted until the detector circuit input requirements are known more reliably.

(P. V. S. Rao)

Figure 1 Single Ended Read Amplifier



$$\text{Gain} = \frac{\text{Output (I or II)}}{(\text{Input I}) - (\text{Input II})}$$

$$\approx 400$$

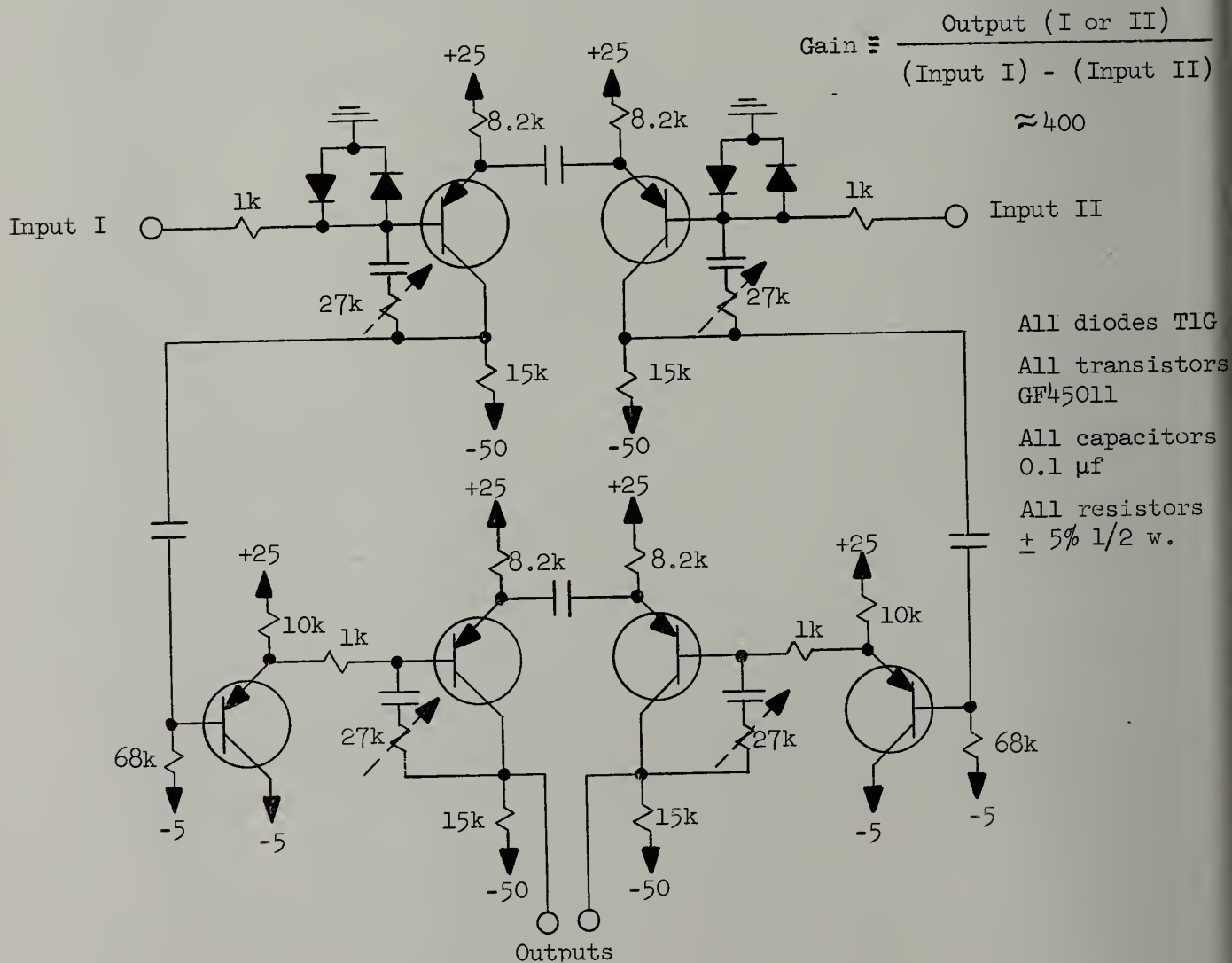


Figure 2 Differential Read Amplifier

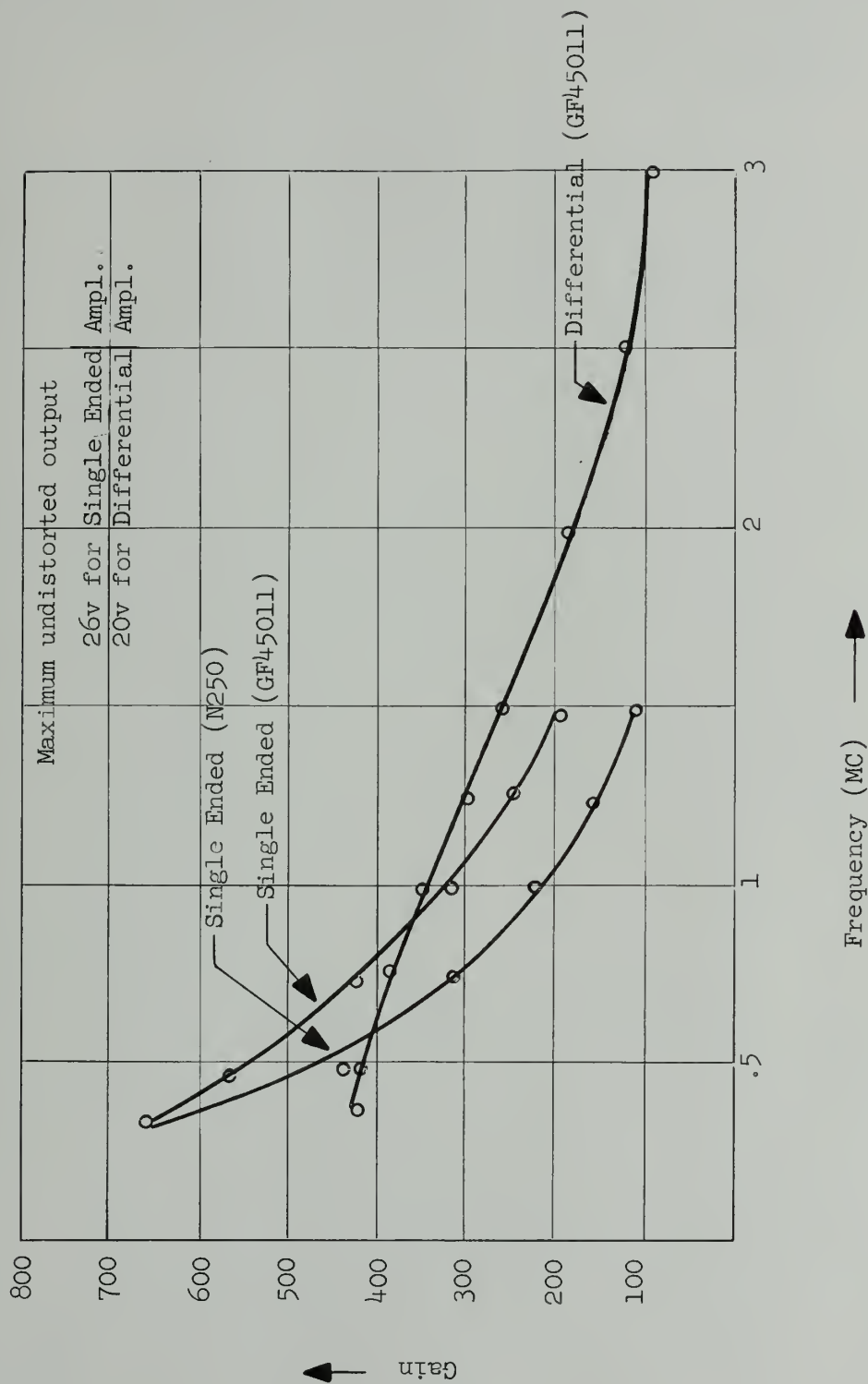


Figure 3 Read Amplifier Frequency Response

The Drum Parity Circuit converts from the one-parity-per-13-bit-character scheme used by the Magnetic Drum Memory to the one-parity-per-52-bit-word scheme used by the Core Memory. During the month, an earlier parity circuit was redesigned to reduce the transistor count and to avoid some race conditions. The new circuit is described in "Parity Circuit for the Magnetic Drum Memory," File No. 434.

(H. C. Brearley)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

T. Moto-Oka developed the theory of a mono-stable multivibrator using a single tunnel-diode and a delay line. Conditions for the characteristic impedance of this delay line are established and the switching times optimized. H. Guckel worked on strip-line transformers (to be reported on another time) and on the slower stages of the proposed 2000 mc counter.

J. Hill together with J. MacDonald spent some time comparing the gains to be derived from failsafe circuitry in (a) the case of a continuously running computer (b) the case of a "well-serviced" machine (i.e. with all elements alive at $t = 0$) running during a critical time interval. It turns out that practically no benefit is obtained in the former case i.e. failsafe circuits do not prolong the average lifetime of a computer very considerably. The advantages of such a system for "critical period" machines is, however, very great.

T. Burnside designed some of the hardware for the sampling units to be used in the statistical analyzer.

2. Theoretical Tunnel-Diode Work

The Theory of a TD Mono-stable Multivibrator with a Delay Line

The circuit shown in Figure 1 works as a mono-stable multivibrator, when some conditions are satisfied.

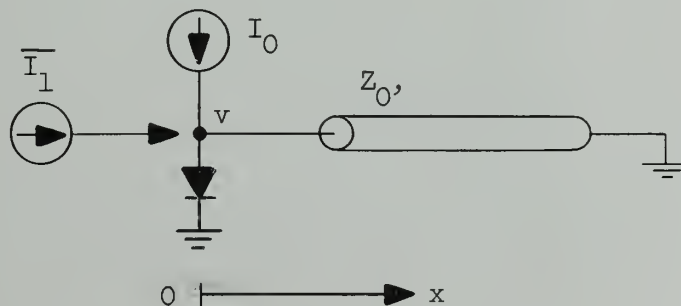


Figure 1

TD Mono-stable Multivibrator with a Delay Line

In order to get the design conditions of this circuit; we attempt to analyze its switching characteristics.

General Theory

We assume that the equivalent circuit of a tunnel-diode is given by the parallel circuit of a capacitance C and a nonlinear conductance which is given by $i = f(v)$, and that the trigger input is the constant current pulse $\overline{I_1}$, the width of which (t_i) is longer than the rise time (t_1) of the output waveform and is shorter than twice the delay time (t_0) of the delay line, that is, $\overline{I_1} = I_1(1 - e^{-st_i})$, where $t_1 < t_i < 2 t_0$. Under these assumptions, the switching characteristics of the output voltage (v) are given by the following equations.

i) During $t_1 > t \geq 0$, if we assume that $v = 0$ at $t = 0$,

$$C \frac{dv}{dt} + f(v) = I_0 + I_1 - \frac{v}{z_0}, \quad \overrightarrow{V} = v, \quad \overleftarrow{V} = 0, \quad (1)$$

where \overrightarrow{V} and \overleftarrow{V} are voltages of forward and backward traveling wave of the delay line at $x = 0$, and the characteristic impedance of the delay line is z_0 .

ii) During $2 t_0 > t \geq t_1$

$$C \frac{dv}{dt} + f(v) = I_0 - \frac{v}{z_0}, \quad \overrightarrow{V} = v, \quad \overleftarrow{V} = 0 \quad (2)$$

iii) During $t > 2 t_0$

$$C \frac{dv}{dt} + f(v) = I_0 - \frac{v}{z_0} - \frac{2k}{z_0} \overrightarrow{V} (t - 2 t_0)$$

$$\overrightarrow{V}(t) = v(t) - \overleftarrow{V}(t) = v(t) + k \overrightarrow{V}(t - 2 t_0) \quad (3)$$

$$\overleftarrow{V}(t) = k \overrightarrow{V}(t - 2 t_0),$$

where we assume that the delay line is an ideal one having an attenuation factor $R/2d$ and having no phase distortion.

Approximate Theory

If we assume that the nonlinear characteristic is given by an N-shaped linear approximation shown in Figure 2, the equations shown above are reduced to the following equations in the range of $0 < v < E$.

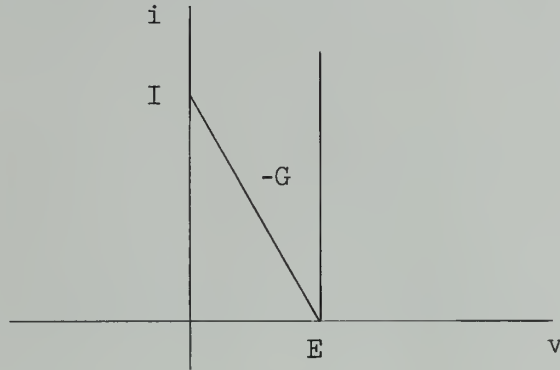


Figure 2

N-Shaped Characteristic of a Tunnel-Diode

i) During $t_i > t \geq 0$

$$C \frac{dv}{dt} + (I - Gv) = I_0 + I_1 - \frac{v}{Z_0} \quad (4)$$

Putting $t = CZ_0 T$, the equation (4) becomes

$$\frac{dv}{dt} + (1 - GZ_0) v = (I_0 + I_1 - I) Z_0 \quad (4)$$

If we assume that $v = 0$ at $t = 0$, and $I_0 + I_1 - I > 0$

$$v = \frac{JZ_0}{a} (1 - e^{-at}), \quad (5)$$

where $a = 1 - GZ_0$, $J = I_0 + I_1 - I$. $J = I_0 + I_1 - I > 0$ is the necessary condition for triggering.

The rise time ($t_1 = CZ_0 T_1$) of the output voltage which is the time necessary to change from $v = 0$ to $v = E$, is given by

$$t_1 = \frac{1}{a} \ln \frac{JZ_0}{JZ_0 - aE} \quad (6)$$

In case of $a = 0$ we have

$$t_1 = \frac{E}{JZ_0} \quad (6)$$

The necessary and sufficient conditions for complete switching are

$$JZ_0 > aE \text{ and } J > 0, \quad (7)$$

because we assumed that the rise time (t_1) is shorter than the input pulse duration (t_i). The output voltage is kept at E after t_1 .

ii) During $2t_0 > t \geq t_i$

$$\frac{dv}{dt} + av = (I_0 - I) Z_0 \quad (8)$$

(a) If $Z_0 I_0 - E \leq 0$, that is $Z_0(I_0 - I) - aE > 0$, the output voltage v is being E in this interval.

(b) If $Z_0 I_0 - E \leq 0$, the circuit begins to fly back after $t = t_i$. In this case,

$$v = \left(\frac{J'Z_0}{a} - E \right) [1 - e^{-a(t-t_i)}] + E, \quad (9)$$

where $J' = I_0 - I$ and $t_i = Z_0 C t_1$.

iii) During $t \geq 2t_0$

(a) In a case of $Z_0 I_0 - E > 0$ that is, $Z_0 J' \geq aE$ the value of the output voltage is kept at E until t becomes $t_2 + 2t_0$ which is given by

$$Z_0 J' - aE = \frac{2kJZ_0}{a} [1 - e^{-at_2}] \quad (10)$$

During $t_1 + 2t_0 > t > t_2 + 2t_0$,

$$\frac{dv}{dt} + av = Z_0 J' - \frac{2kJZ_0}{a} [1 - e^{-a(t-2t_0)}] \quad (11)$$

then

$$av = (J'Z_0 - aE - \frac{2kJZ_0}{a}) \left[1 - e^{-a(t-t_2-2t_0)} [1 + a(t-t_2-2t_0)] \right] + aE \quad (12)$$

In the above equation, if v is less than zero at $t = t_1 + 2t_0$, the fall time $t_3 = CZ_0 t_3$ of the output voltage is given by

$$(J'Z_0 - aE - \frac{2kJZ_0}{a}) [1 - e^{-at_3(1+at_3)}] + aE = 0 \quad (13)$$

The output voltage is usually kept zero after $t = t_3 + t_2 + 2t_0$.

If v is v_0 larger than zero at $t = t_1 + 2t_0$

$$\frac{dv}{dt} + av = Z_0 J' - 2kE, \quad (14)$$

then

$$av = (Z_0 J' - 2kE - av_0) (1 - e^{-a(t-t_1-2t_0)}) + av_0 \quad (15)$$

In this case, the fall time t_3 of the output voltage is given by

$$t_3 = -\frac{1}{a} \ln \left| \frac{J'Z_0 - 2kE}{Z_0 J' - 2kE - av_0} \right| + t_1 \quad (16)$$

- (b) In a case of $Z_0 I_0 - E < 0$, the equation (11) is applied during $t_1 + 2t_0 > t > 2t_0$ under the initial condition that

$$v = (E + \frac{J'Z_0}{a}) [1 - e^{-a(2t_0-t_1)}] + E \text{ at } t = 2t_0.$$

The procedure after that is the same as for (a). The result of the calculations of the rise time (t_1), the dead time (t_2) and the fall time (t_3) of the output waveforms are shown in Figure 3, where $I = 1a$, $E = 1v$, $G = 1\Omega$, $I_0 = 0.8a$, $I_1 = 0.4a$, $k = 1$ and Z_0 values vary from 1.0 to 3.75 G.

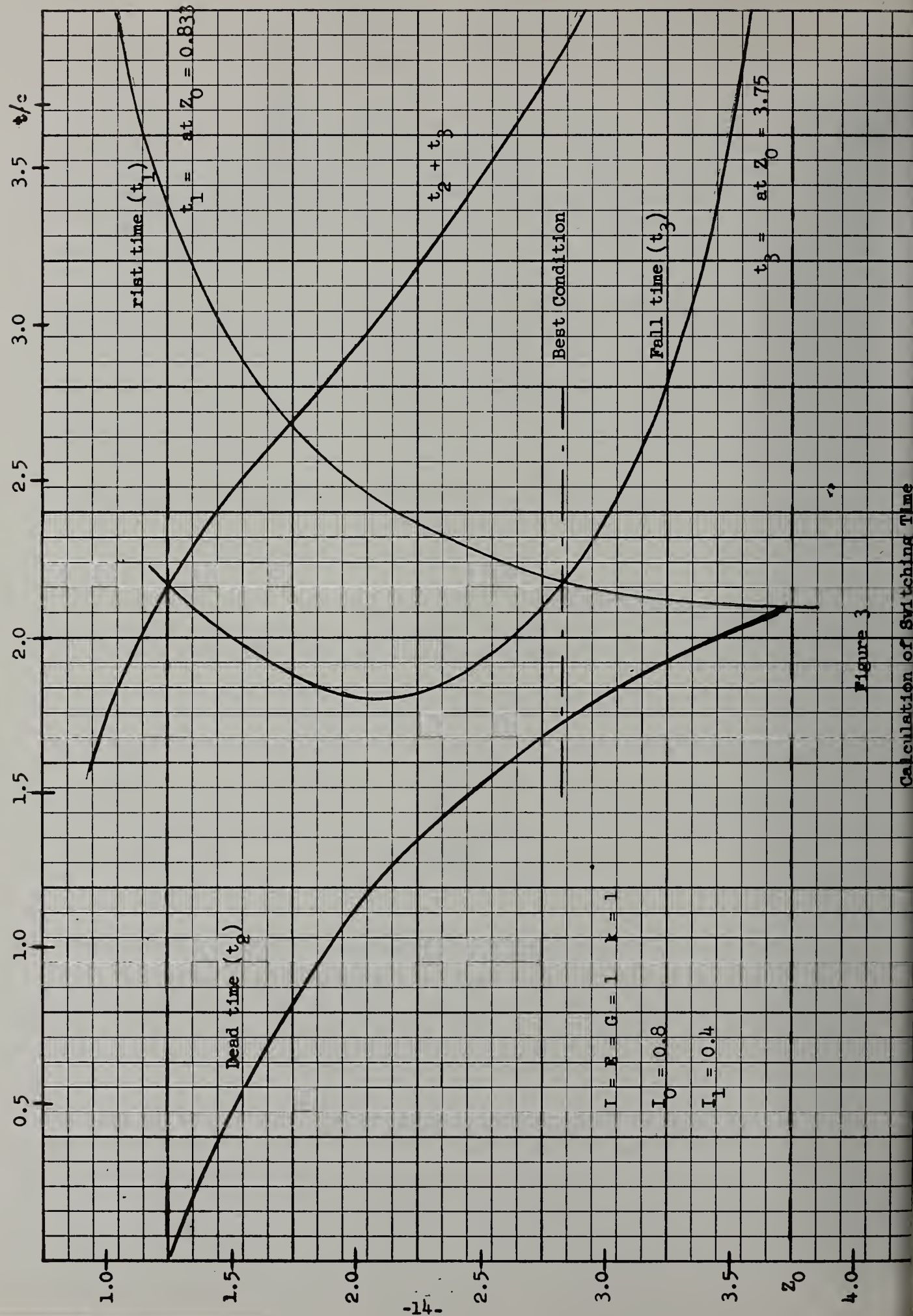


Figure 3
Calculation of Switching Time

Conclusion

From this calculation, we can get the best value of the characteristic impedance of the delay line, in which we can make the length of the delay line minimum and the fall time becomes equal to the rise time. The waveform is shown in Figure 4. The best value of the characteristic impedance is approximately $2.8 G$ under the condition of this calculation. In order that the circuit is switched off by the backward wave of the delay line, the characteristic impedance of the delay line must be kept between 1.25 and $3.75 G$. If it is less than 1.25 , the circuit will fly back by itself after eliminating the input signal. If it is larger than 3.75 , the circuit is not switched off by the backward wave.

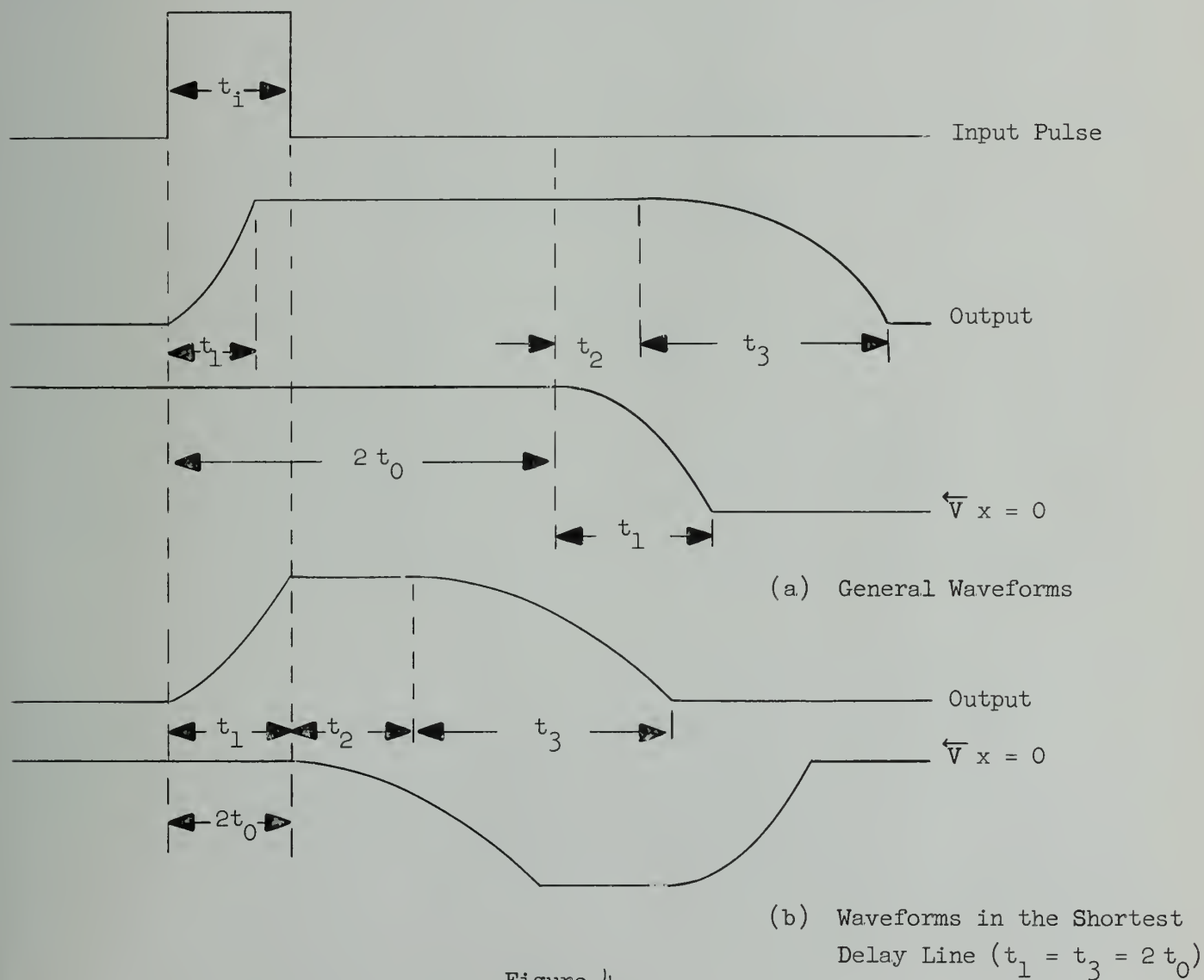


Figure 4
Output Waveforms

3. Experimental Tunnel-Diode Work

Counter

Experimental 6 bit ring counter and gates were tested and found to run satisfactorily as 20mc. An Amperex Z-500M decimal indicator was tested with 10 volt signal swings and found suitable as a readout device for the counter. Printed circuit boards for "one flipflop and two three input ANDs" complexes were finished; some modifications are still necessary.

Coupled Transmission Lines

Several models of the following geometry, shown in Figure 5, were made.

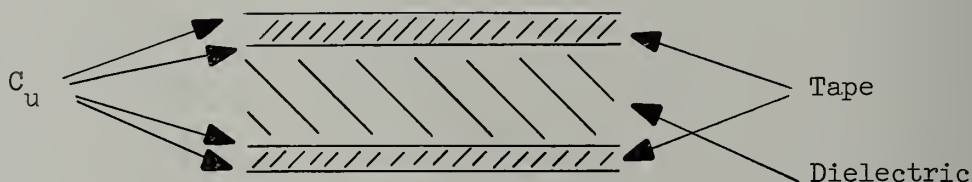


Figure 5

Coupled Transmission Lines

The results so far are the following: Single strip lines form good pulse connectors. Coupled strip-lines are usable to obtain suitable matching conditions. What exactly matched means in this connection is, however, not clearly understood. A mathematical analysis was attempted but has so far not been completed due to the complexity of the physical situation.

Tunnel-Diode Measurements

It seems to be fairly reasonable to say that the unusual characteristics of the device reported earlier are due to oscillations. Attempts to shunt the diode (see Figure 6) have failed even at the impedance levels indicated. Measurements using the high frequency bridge have been unsuccessful because of stability problems.

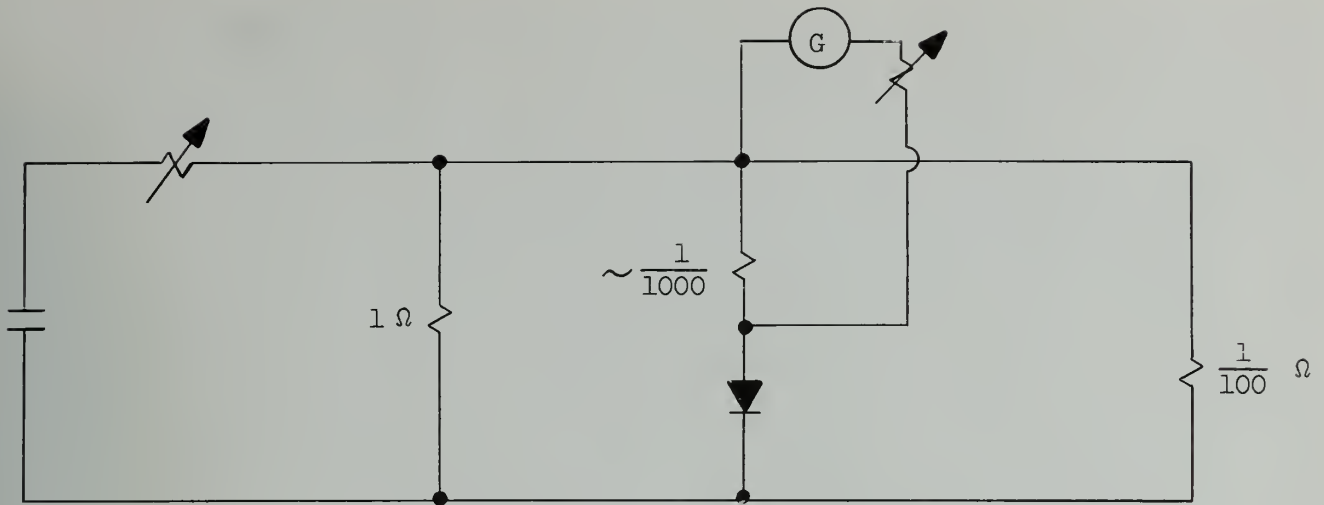


Figure 6
New Test Setup for Tunnel-Diodes

4. Failsafe Circuits

Failure Law

Life testing of large groups of components has shown that the failure rate is approximately proportional to the number of components left in the group. This proportion is only a little optimistic since the failure rate is higher than this during the beginning of the testing and also after most of the components have failed. Now if we let $P(t)$ be the probability that the lifetime of a component is less than time t and $1/T$ be the proportionality constant, the proportion gives the following formulation:

$$\frac{dP(t)}{dt} = \frac{1}{T} (1 - P(t)).$$

Therefore, $P(t) = 1 - \exp. (- t/T)$ as one can check by substitution into the differential equation and by the boundard values, $P(0) = 0$, $P(\infty) = 1$.

Figure 7 shows this law graphically.

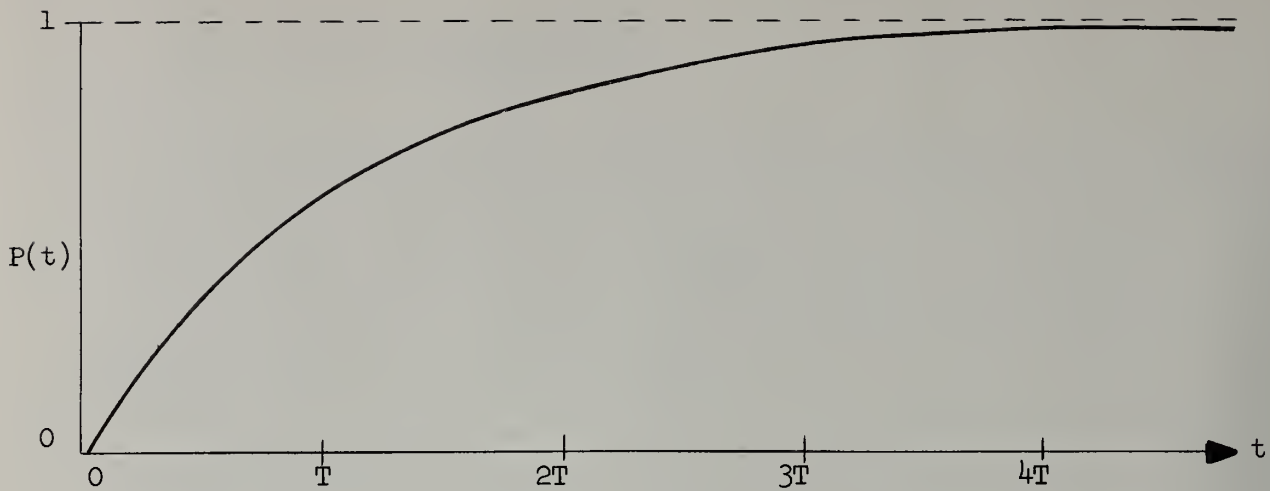


Figure 7
Failure Law

Average Life of a Component

The average life of a component is the average length of time that it functions properly. For example, given a large group of components and a long enough period of time so that they all have failed; the average lifetime is computed by averaging all the components individual lifetimes. Therefore, the average lifetime, L , of a unit is defined by

$$L = \int_0^1 t \, dP(t)$$

where $dP(t)$ is the infinitesimal fraction failing at time t . After changing variables from $P(t)$ to t by taking the differential of $P(t)$ from the solution, we get

$$L_1 = \int_0^{\infty} t \exp(-t/T) \, dt = T.$$

Thus, the average life of a component is just the time constant of the function $P(t)$.

Life of a Compound Transistor Circuit

Consider replacing a one transistor circuit with a two transistor circuit with the property that one of its transistors may fail and the circuit will still function properly. There is only one manner in which this circuit

will fail; when both transistors fail. If $P_1(t)$ is the probability that one transistor will fail at time t , then $P_2(t) = [P_1(t)]^2$ is the probability that both will fail by time t . Then

$$L_2 = \int_0^1 t d[P(t)]^2 = 2 \int_0^1 t P(t) dP(t).$$

Upon changing the range of integration to the time axis, we get

$$L_2 = 2/T \int_0^{\infty} t [1 - \exp(-t/T)] \exp(-t/T) dt = 3/2 T$$

which represents only a 50% increase in the circuit life over using one transistor to do the job.

To get an idea of how the circuit lifetime increases with added redundancy, consider a one transistor circuit replaced by a ten transistor circuit in which nine transistors may fail and the circuit will still function properly. All ten must fail for the circuit to fail; therefore $P_{10}(t) = [P_1(t)]^{10}$ and the average life, L_{10} , of the compound circuit is

$$L_{10} = \int_0^1 t [dP_1(t)]^{10} = 3.00 T.$$

This is a rather small increase in lifetime for the excess number of elements that went into the circuit.

Short Term Reliability Increase

From the above calculations, it can be readily seen that just letting one "failsafe" circuit run until it fails yields a very little lifetime improvement. However, there is a beneficial increase in reliability early in the circuits life as is clearly shown by the graphs of the former probability functions (see Figure 8). For a numerical example take transistor life T as 10,000 hours, and consider the first 100 hours of operation. The probability of a one transistor circuit failing in this time is $P_1(100) = .01$. However, the probability of the two transistor "failsafe" circuit failing is $P_2(100) = .0001$,

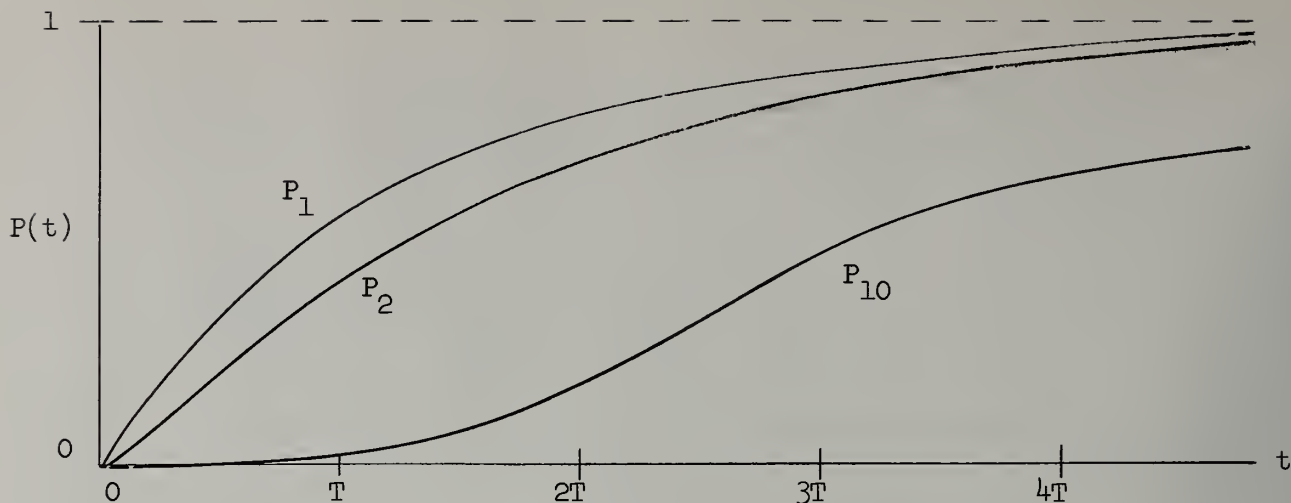


Figure 8

Compound Failure Law

which represents a rather marked increase in reliability. One could make continuous use of this short term reliability of "failsafe" circuits if one had a means for replacing the failed components at regular intervals. Replacing the failed components is equivalent to setting the time back to zero and starting again. In order to replace the failed components, one must know where they are; this calls for a scheme to check the operation of individual components. The check could possibly be made by building a logical system in the machine that continually monitors the operation of the various logical function, or by a scheme with circuits interconnected with those of the computer that continuously watch for component failures and give local indication. In these cases, the monitors must have the property of indicating failures within themselves too. In summary, it appears that "failsafe" circuits are not the whole answer to increase computer reliability over long ranges of time. They are a tremendous improvement if the "well-serviced" computer functions during "critical times" like the take-off time of a missile.

5. Statistical Analyzer

A low impedance switch and its triggering circuit has been developed. This circuit, shown in Figure 9, has a triggering signal of amplitude 2 volts peak to peak. At a frequency of about 2 kc the circuit works quite well and the switching voltage drop is negligible compared to 1/2 volt or more. These low impedance switches are used to switch on and off 8 diodes, one at a time, in succession. The 8 triggering pulses come from a modulo 8 counter. The circuit is clocked by a pulse generation. Figure 10 shows the logical design of the counter and decoding circuit.

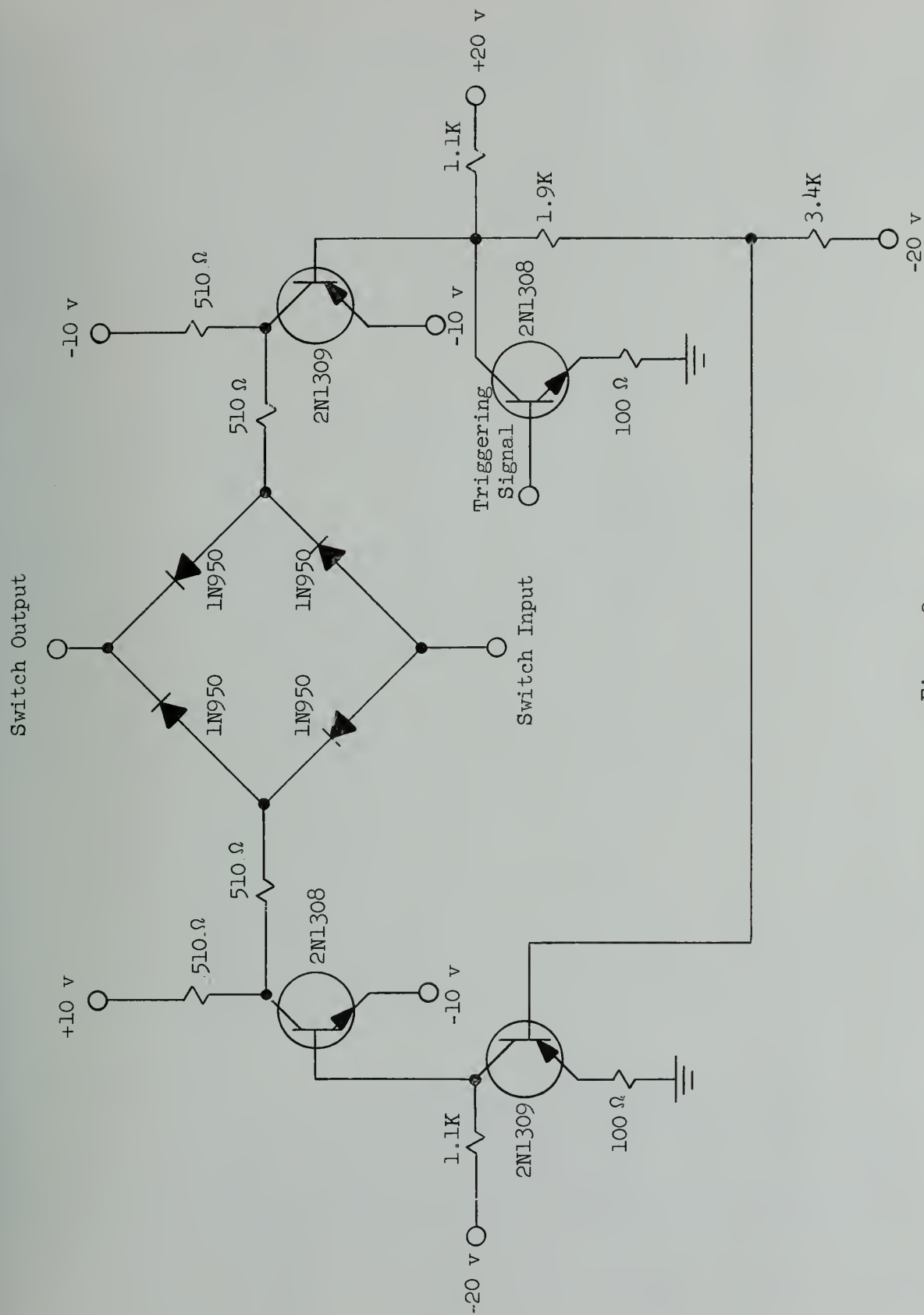


Figure 9
Impedance Switch

PART III
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Scope Delay

The high resolution scope, subcontracted to Digital Equipment Corporation of Maynard, Massachusetts, was to have been shipped this month when the central portion of the #1 tube scope face was accidentally burned out. The deflection amplifier circuitry is being modified to protect against reoccurrence of this situation.

(B. McCormick)

II. Scope Image Distortion Analysis

Appropriate adjustment of the many mechanical and electrical parameters of the experimental high resolution scope can only be done if image distortion can be readily detected and analytically analyzed. For this purpose it is proposed that a precalibrated rectangularly ruled raster be scanned under control of Illiac and the digital scope address of all lattice points be automatically recorded. The mathematical least square procedures for analyzing this data, allowing for up to cubic distortion terms, has been formulated.

(B. McCormick, M. Shirazi)

III. PRU End Connections

The pattern recognition unit (PRU), as presently conceived, has four basic registers:

1. S, the 2-dim. shift register.
2. U, uppermost bits of all stalactites.
3. K, input/output register for transfer buffer.
4. M, marker plane for programming facility.

The transfer orders interconnecting these registers are called end connections, by analogy with arithmetic computer parlance. The contents of any one plane (S, U, K, M) can not only be transferred to any other plane, but also certain

boolean functions of the contents of two (and even three planes) can be formed in the transfer. Which end connections to employ depends jointly upon (1) programming facility engendered and (2) the percentage additional cost to physically provide this enriched order code.

Divilbiss earlier was able to demonstrate that by appropriate arrangement of the transfer logic between the S, U, K, and M planes over a hundred transfer orders could be realized for a 10-20% increment in hardware. A restricted highly symmetrical subset of these end connections were deduced and incorporated into the PRU simulation routine.

(J. Divilbiss, B. McCormick, J. Stein)

IV. Digitized Bubble Chamber Pictures for the PRU Simulator

The older digitized bubble chamber pictures are normally transferred from paper tape to the Illiac drum. A routine to take an arbitrary subraster of a digitized picture stored on the drum and punch it out in a format appropriate as input to the PRU simulator has been written.

(J. Ehrman, J. Stein)

V. Mechanical Stage

The precision mechanical stage of the phase I Spiral Reader (LRL) has generously been loaned us by Dr. Luis W. Alvarez of the Lawrence Radiation Laboratory. The original Moire fringe photometric digitizers (least count 2.5μ) are currently standard on the Frankenstein measuring projectors at Berkeley, and were therefore retained. Two Moire fringe digitizers, handwheels, and a joy stick--all following original Reader design--will be subcontracted for from LRL drawings.

VI. Darkroom

A temporary film processing darkroom with facilities for handling 35 mm. and 105 mm. film has been installed on the first floor, ERL. This facility should make rapid feedback of results from the high resolution scope possible.

(B. McCormick, J. Snyder, J. Wenta,
and L. Whyte)

PART IV
ILLIAC USE AND OPERATION

New Illiac Codes

During the month of January, no new routines were added to the Illiac Library.

Illiac Usage

During the month of January, specifications were presented for 12 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2126. Numbers followed by T are for theses.

2126 Psychology. Cluster Analysis Program. A program to conduct a cluster analysis by the ramifying linkages method will be written. This program will use the output of the K-8 program for data (i. e., a triangular correlation matrix). The program will deal only with those correlations in the matrix that lie beyond a certain criterion value. Once such correlations are found, the only numbers the program will deal with will be the numbers assigned to the variables to be correlated. One of the primary operations will be comparing series of numbers and recording those that occur more than once.

2127 Physics. Calculation of a Polynomial $f(x,y)$. The research problem consists of writing dispersion relations for the strong interaction parts of the non-leptonic hyperon decays. These lead to coupled integral equations which, when put on the mass shell (energy equal to mass of hyperon), yield sets of three simultaneous linear equations in three unknowns. The condition of tractability of these linear equations yields values for the sigma-pion and lambda-pion coupling constants x and y .

Each determinant is a polynomial function in x and y . The routine to be used will calculate the powers of x and y and $f(x,y)$ in the physical region of x and y .

2128 Physics. An Auxiliary Eigenvalue Problem. A program is being developed for the solution of the Boltzmann equation for the slowing down of neutrons in media containing fissile materials. The CDC 1604 will be used for this purpose.

Input data for this program require preliminary processing, and in particular, the solution of about ten equations of the form

$$\sum_{n=0}^N A_n z^n = 0 \quad (1); A_n \text{ complex, } N = 3, 4, 5, 6,$$

is required.

Illiac routines are available for the solution of this equation and it is proposed to use Illiac for this auxiliary calculation, needed for the large program described elsewhere.

2129T Agricultural Economics. Optimal Seasonal Pork Supply. The problem is to determine the optimum seasonal pattern of pork production and marketing on Illinois farms, taking into account the alternative action available to the farmer. Use of the Illiac linear programming routines can help in the solution of this problem.

Only standard library routines will be used.

2130T Chemistry. Low Energy Electron Impact Studies. The research is aimed at determining the location of low lying excited triplet states in simple organic molecules such as ethylene. This is done using low energy electron impact techniques. The data obtained consists of a curve of scattered electron current versus voltage on one of the grids in the spectrometer. It is desired to smooth this curve and obtain its derivative at successive points on the curve.

To do this, seven successive points will be fitted to a seven term Taylor series expansion; the coefficients of the series obtained; and the derivative at the center point calculated. The next point on the curve will then be read, a new series obtained along with a new derivative at the center point, and so on until the entire curve has been treated.

2131 Psychology. A Study of Third-Order Personality Factors in Adults. Data from previous researches are available from which the intercorrelations of second-order personality factors in adults can be computed. These data are the starting point for the present analysis. The resulting matrix of second-order factor intercorrelations will be factor analyzed, and the third-order factors obtained obliquely rotated to simple structure.

This study is the first research on third-order personality factors ever done.

2132T Agricultural Economics. Conditions Necessary for Contract Egg Production. A linear programming problem is to be solved by simplex procedures, to find organizations of a laying flock enterprise that maximizes income in the presence of alternative farm resources, financing and marketing arrangements. The alternative farm resources entail varying capital constraints; the alternative marketing arrangements entail varying product prices as well as contractual agreements. It is anticipated that only standard library routines will be used (M-32-298).

2133 Psychology. Studies of Cognitive Interaction. The intercorrelation matrices between two sets of numbers is needed. Each set involves 26 variables. The correlations are to be based on 25 observations.

2134T Civil Engineering. Analysis of Shallow Shell. The problem is to study the behavior (state of stress and deformations) for some classes of shallow shells with complex boundary conditions (restrained edges and elastic supports), and to accumulate numerical results for the values of the different forces and displacements which can be helpful to designers.

The analysis will be carried out by using "Vlassov's Variational Method". The resulting sets of three simultaneous ordinary differential equations are to be solved.

2135 Chemistry. Molecular Orbital Calculations. The problem involves determining spin densities in large organic free radicals. Simple LCAO (linear combination of atomic orbitals) molecular orbital theory is used for the calculations. A number of symmetric matrices must be solved for both eigenvalues and eigenvectors. Initially, only 6 x 6 and 2 x 2 matrices will be encountered.

2136 Coordinated Science Laboratory. PLATO II Evaluation. PLATO is the name of a research project in the field of automatic teaching systems currently under way at the Coordinated Science Laboratory. The main aim of project PLATO is to develop an automatic teaching system sufficiently flexible to permit experimental evaluation of a large variety of ideas on automatic instruction.

This goal is to be realized by developing a series of machines--each embodying improvements indicated by experience with earlier models. So far two machines have been developed. The first, PLATO I, was completed in October of 1960 and is described in CSL Report I-103. PLATO II, the machine currently in use, was completed in October of 1961. It differs from its predecessor primarily in its ability to handle more than one student concurrently. The aim in developing PLATO II was to study the problems of multiplexing and time-sharing which arise in the multiple-student case. For this reason, the logic of the program was written so as to handle an arbitrary number of students, but ILLIAC speed and storage capacity for data precluded having more than two student sites.

At the beginning of the second semester (February 8) ten volunteers from the elementary computer programming course (Mathematics 195) will be asked to participate in several teaching sessions with PLATO II in lieu of attending the first four or five lectures of the course. Instructional material for this purpose has been prepared. The results of the study should yield substantial additional information on data rates to be expected in future systems, as well as information on the use of teaching systems in the college environment.

2137 Electrical Engineering. Second Order Solution of Faraday Rotation. The Faraday rotation is the rotation of the electric vector of a radio wave traversing a magneto-ionic medium.

The Faraday rotation between an artificial satellite (T) and a monitoring station (R) is calculated by the second order approximation formula:

$$\alpha = K_1 \int_T^R N dl + K_2 \int_T^R N^2 dl$$

where

α = Faraday rotation

$K_1; K_2$ = constants

N = electron density

dl = element of length of a straight line between satellite and station.

The electron density is given by:

$$N = N_0 e^{\frac{1}{2} (1-z-e^{-z})}$$

where

$$z = \frac{h - h_o}{H}$$

N_o = maximum electron density of the ionosphere

h = height of a given point

h_o = height of maximum electron density

H = scale height

The integrals are calculated with subroutine E3.

The Faraday rotation can be written in functional form:

$$\mathcal{R} = \mathcal{R}(N_o, h_o, H)$$

A function ϕ is formed which is the summation of the square of the difference between the values of Faraday rotation calculated above and those measured from experiment.

The values of N_o , h_o , and H which minimizes the function $\phi = \phi(N_o, h_o, H)$ are sought.

2138 Chemistry. Spectrum Synthesis. An attempt will be made to synthesize a derivative absorption spectrum composed of a number of overlapping peaks. The area, width, and position of each peak will be varied. The line shape for all peaks will be Gaussian in the first attempts and possibly Lorentzian later in the study. The synthesized spectrum will be printed on the Dataplotter.

Table I shows the distribution of Illiac machine time for the month of January. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min	
Scheduled Maintenance	65:02	
Unscheduled Maintenance	19:38	
Drum Engineering	9:14	
Leapfrog	11:06	
Library Development	:02	
Classes	4:33	
RAR	:14	
Wasted	:04	
Demonstrations	<u>1:56</u>	
	111:49	
Use by Departments		
Aeronautical Engineering	2:15	
Agricultural Economics (APPRAISAL 47 15 05 334)	:59	
Agricultural Economics	4:36	(4:23)
Agronomy		(:02)
Animal Science	3:33	(1:31)
Astronomy (NSFG 14834)	2:44	
Bureau of Economic and Business Research	:52	(:09)
Bureau of Educational Research (PH-M1839)	:28	
Chemistry	60:53	(8:22)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	1:31	
Civil Engineering (DA-104)	:51	
Civil Engineering	81:12	(14:25)
Coordinated Science Lab. (DA-36-039-SC56695)	74:12	
Digital Computer Lab. (AEC AT (11-1)-415)	:02	
Digital Computer Lab. (US TR AEC-1018)	2:02	
Economics	:02	
Education	1:49	
Electrical Engineering (NONR 1834(22))	:59	
Electrical Engineering (NASA-NSG 24-59)	11:06	
Electrical Engineering (AF 33(616)6079)	:07	
Electrical Engineering (AF 7043)	12:20	
Electrical Engineering (NSFG 19005)	3:33	
Electrical Engineering	40:32	(2:45)
Finance (IHR-71)	:30	
Food Technology	6:39	
Geology	:15	(:37)
Inst. of Communications Res. (44-28-20-378)	:21	
Inst. of Communications Res. (USPHM-3941)	:32	
Institute of Communications Research	:17	
Institute for Research on Exceptional Children	:34	(:44)
Mechanical Engineering (NSG 13-59)	2:02	
Mechanical Engineering	57:26	(1:26)
Mining and Metallurgical Eng. (TRUS AF 6770)	:22	
Mining and Metallurgical Engineering	:11	
Music	2:54	(:28)

Office of Instructional TV (OE 7-11-107.00)	5:54	
Office of Instructional TV	:03	
Physical Education	2:26	(:06)
Physics (NONR 1834(05))	14:47	
Physics (NAVY C)	:07	
Physics (NSF 14 308)	:17	
Physics (NONR 1834(05)A)	12:09	
Physics (NSFG-17428)	1:09	
Physics	25:07	(5:59)
Psychology (1715)	:31	
Psychology (MD 2060)	:40	
Psychology (AF 41-657-279)	1:32	
Psychology (AF 49(638)371)	2:48	
Psychology (USPH-45-32-66-373)	6:41	
Psychology (M1774)	1:39	
Psychology (ONR 1834-36)	:12	
Psychology	46:43	(18:56)
Sociology	4:12	
State Water Survey	5:22	
State Water Survey (DA-36-039-SC75055)	2:15	
Theo. and Appl. Mech. (NOBS 72069)	:27	
Theo. and Appl. Mech. (DA-11-070-508 ORD)	12:53	
Theo. and Appl. Mech. (DA-01-021 ORD 11878)	:18	
United States Navy	:50	
	<u>527:43</u>	<u>(59:53)</u>
		<u>699:25</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog

code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	4
Reader	2
Power Supplies	3
Air Conditioner Overhaul	2
Runover of Morning Engineering	1
Unknown	<u>5</u>
	17

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/2/62	20:55	:22	2:43	1	(1) Memory failure, pos. 2 ⁻¹³ and 2 ⁻²⁷ .	:00	:49	1
1/3/62	20:38	:00	3:22	0		:00	:16	0
1/4/62	19:59	:00	4:01	0		:00	:18	0
1/5/62	21:40	:00	2:20	0		:00	:26	0
1/6/62	15:19	:13	:00	1	(1) Reader "J" making errors.	:00	:00	0
1/8/62	17:06	4:56	1:58	1	(1) +150 V power supply out, caused by short in reader "D".	:00	:17	0
1/9/62	20:31	:00	3:29	0		:00	:39	0
1/10/62	21:06	:00	2:54	0		:00	:20	0
1/11/62	20:46	:00	3:14	0		:00	:28	0
1/12/62	21:51	:00	2:09	0		:00	:21	0
1/13/62	23:51	:09	:00	1	(1) Unknown	:00	:25	0
1/14/62	23:52	:08	:00	1	(1) Unknown	:00	:22	0
1/15/62	21:15	:00	2:45	0		:00	:03	0
1/16/62	20:21	:00	3:39	0		:00	:21	0
1/17/62	20:48	:00	3:12	0		:00	:27	0
1/18/62	20:53	:00	3:07	0		:00	:47	0
1/19/62	21:27	:00	2:29	0		:04	:09	0
1/22/62	16:54	3:37	3:29	1	(1) Overhauling air conditioner on drum.	:00	:00	0
1/23/62	20:41	:00	3:19	0		:00	:07	0
1/24/62	19:01	2:30	2:29	1	(1) Bad solder joint memory pulser.	:00	:15	1
1/25/62	19:50	1:03	2:07	3	(1) Morning engineering ran over into production time. (2) DC power failure. (3) Unknown.	:00	:35	1

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/26/62	20:16	1:14	2:30	1	(1) Memory failure pos. 2 ⁻² .	:00	:23	0
1/27/62	23:47	:13	:00	1	(1) Reader "I" failing.	:00	:00	0
1/28/62	23:23	:37	:00	2	(1) Unknown. (2) Unknown.	:00	:28	1
1/29/62	21:10	:00	2:50	0		:00	:00	0
1/30/62	17:20	3:14	3:26	2	(1) Memory pos. 2 ⁻¹⁴ . (2) -2000 V power supply too high.	:00	:34	0
1/31/62	19:54	1:36	2:30	1	(1) Overhauling Illiac air conditioner.	:00	:48	0
TOTALS	554:34	19:52	65:02	17		:04	9:38	4

PART V
INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of January, no new routines were added to the International Business Machines 650 Library.

International Business Machines 650 Usage

During the month of January, specifications were presented for 11 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 357'. Numbers followed by T are for theses.

357' University of Southern California. Emotional Concepts and Differences. Sixteen emotional concepts have been measured. From each emotional concept, three factor scores were obtained. The 48 factor scores are to be fed into the D^2 statistic program (K1) so that a comparison of score sets and profiles can be made. The standard deviations, sums of squares and means of the scores will also be utilized in making further comparisons.

358' School of Business. Carnegie Institute of Technology Management Game. Preliminary work on the game will be carried out in order to prepare for a pilot play during the spring semester.

359' Physics. Molecular Collisions. The problem of which this calculation is a part is that of vibrational deactivation in molecular collisions. This particular calculation concerns the matching of an exponential expression to the Lennard-Jones potential which describes the inter-molecular field.

Experiments indicate that collisions of Cl_2 with CO are much more effective in describing the vibrations of Cl_2 than collisions of Cl_2 with N_2 (which is chemically very similar to CO). It has been suggested that the high efficiency of the Cl_2 - CO collisions is due to the fact that there exists a chemical force between Cl_2 and CO (but not between Cl_2 and N_2). The present calculation is set up to test this hypothesis.

360'T Entomology. Computation of Dosage Mortality Regression Lines and ED50 Values by the Maximum Likelihood Method for the IBM 650. This research problem involved the collection of dosage mortality data for each of two species of insects when exposed to various dieldrin treated soils. The responses of these insects are to be compared on the basis of ED50 (median effective dose) values.

The Probit III routine for the IBM 650 may be used to fit the regression lines to the dosage mortality data and to compute the ED50 value. This is done by the so-called Maximum Likelihood Method. Since this method is a standard application of the method of least squares, the procedure is iterative and normally stops when two successive regression coefficients agree within 1/100th of their standard error.

361'T Civil Engineering. Relative Wear Resistance of Soil Aggregate Mixtures. The objective is to establish the relation and the inter-relation between the type of material, gradation of the mixture, the plasticity index of the mix, and the relative wear of the mix when used as a surfacing material for low cost roads.

The IBM 650 will analyze the data by the method of least squares.

362' Civil Engineering. Beam-Column Connections. This program will primarily compute moments and curvatures for a given reinforced concrete section at the three following stages of behavior: yield, crushing and ultimate. The properties of the cross-section are fed into the machine as input data.

The program will compute the mentioned quantities using a successive approximation procedure. Only elementary mathematics is involved. No standard library routines are used.

363'T Mining and Metallurgical Engineering. Calculation of X-Ray Patterns. The research problem involves the indexing of an unknown crystal structure. The IBM 650 will give the d-spacings for all possible values of the lattice parameters of a crystal structure. The formulae used are $\lambda = 2d \sin \theta$ and

$$\frac{1}{d^2} = \frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}$$

where d is the lattice spacing and h, k, and l are the crystal indices. a, b and c are the lattice parameters and are constants for any one crystal. The program is given the wavelength λ and the probable a, b and c values. From

these values, the program will give all possible d-spacings. From these values, one can find the correct indexing if these values are correct, or the fact that these lattice parameters are not correct for this crystal structure.

364'T Chemical Engineering. Chemical Kinetic Rates. A least squares analysis will be used to find the best of ten proposed rate mechanisms from experimental data. These data will consist of partial pressures of the reactants, and rates of reaction. A set of simultaneous linear equations will be set up for each mechanism. These equations will be expressions for minimizing the error with respect to each constant. Subroutine M1' will be used to solve the equations. The solutions will then be further operated on to get equilibrium constants for each mechanism. The constants will then be printed.

The research being done is to find the best mechanism for the reaction of sec-butyl alcohol going to methyl ethyl ketone, catalyzed by brass.

365' Theoretical and Applied Mechanics. Response of a Linear Two Degree of Freedom System to Multiple Excitations. The response, displacements and phase angles of a vibrating two degree of freedom system subjected to multiple excitations depends on eight parameters. The four equations involved can be solved by a lengthy straightforward calculation as the frequency of excitation is varied from one value to another for a given set of parameters. The process is repeated for another set of parameters and is continued until the response to various parameter changes is calculated.

The solution consists of two displacements and two phase angles. Data will be used to plot curves of phase angle and displacement versus frequency of excitation.

366' Physics. K^- Emulsion Events. Emulsion tracks of K^- mesons have been scanned and the projected angles and dips of each scatter measured.

This simple routine calculates the space angle (actual scattering angle), momentum (from range), recoil momentum, and kinetic energy. After calculation of some statistical weight factors, each event will be sorted into a bin in q (recoil momentum) and kinetic energy. The resulting array is the experimental cross section for K^- mesons scattered by emulsion nuclei.

367'T Electrical Engineering. Helical Antenna. In finding the electromagnetic fields of a helical antenna a characteristic equation is obtained for the propagation constant β_0 in terms of the parameters k frequency, ψ pitch angle at the helix and δ the width of the tape of which the helix is wound. The propagation constant β_0 is complex since the fields are attenuated as well as propagated. β_0 is determined by solving

$$0 = \frac{\beta_0^2 - \frac{k^2}{\sin^2 \psi}}{k^2 \operatorname{ctn}^2 \psi} - \frac{A_{+1} + A_{-1} - 2A_0}{2A_0}$$

$$\text{where } A_m = \sum_{n=-\infty}^{\infty} I_n(\tau_{n+m}) K_n(\tau_{n+m}) D_n$$

I_n and K_n are Bessel Functions

$$\tau_n^2 = [(\beta_0 + n)^2 - k^2] \operatorname{ctn}^2 \psi$$

$$D_n = \frac{\sin \left[(\beta_0 + n)^2 - k^2 \right]^{1/2} \frac{\delta}{2} \operatorname{ctn} \psi}{\left[(\beta_0 + n)^2 - k^2 \right]^{1/2} \frac{\delta}{2} \operatorname{ctn} \psi}$$

Table I' shows the distribution of the International Business Machines 650 machine time for the month of January.

TABLE I'

		Hrs:Min
Scheduled Engineering		12:52
Unscheduled Engineering		41:53
Air Conditioning		2:45
Tape Test		:16
Computer Operator		:24
Log Summary		:28
Library Development		57:03
Agronomy Library	11:10	
DCL Library	<u>45:53</u>	
Classes		80:34
CE	15:35	
MATH	63:28	
ME	1:26	
Nuclear Engineering	<u>:05</u>	
Instruction		:29
Demonstration		:58
Wasted		<u>4:39</u>
		202:21

Use by Departments

Agricultural Economics		2:10
Agronomy		12:11
Business Administration		:32
Chemistry		11:37
Civil Engineering		22:33
Coordinated Science Laboratory		:16
Electrical Engineering		16:29
Entomology		1:14
Mechanical Engineering		4:08
Mining and Metallurgical Engineering		:13
Physics		8:10
Psychology		:22
Small Homes Council		:36
Speech and Theater		1:06
State Water Survey		6:24
Statistical Service Unit		82:45
Bureau of Community Planning	9:13	
Bureau of Educational Research	2:53	
Business Office	10:58	
DHIA	44:30	
Education	13:09	
Inst. of Communications Research	:04	
Mining and Metallurgical Engineering	:58	
Physical Education	:55	
Statistical Service Unit	<u>:05</u>	

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for January.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

Air conditioning		1
Compressor unit	<u>1</u>	
407 accounting machine		3
Spacing when should not	1	
Does not print when should	1	
Cycles off line	<u>1</u>	
533 card read punch		6
Punches incorrectly	1	
Fails to punch	1	
Constant card feed stops	1	
Card jam in read side	1	
Fails to read	<u>2</u>	
650 console		14
Blank or multiple bits in registers	11	
False distributor light	1	
False storage unit light	1	
Positions on drum blank out	<u>1</u>	
653 high speed storage, floating point and index registers		2
Multiple bits in IAS	1	
Blown diodes in IAS	<u>1</u>	
727 and 652 tape units and tape control		2
Reads tape incorrectly	<u>2</u>	
TOTAL		28

TABLE III

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
1/2/62	2:08	1:25	9:42		6	2:45	(1) Air conditioning unit in basement lost gas. (2)(3) Blank bits in program register. (4) Multiple bits in IAS. (5) Blank bits in distributor. Errors 2,3,4,5 were caused by a bad head on the drum. (6) Undetermined difficulty with IAS as machine was ready to be turned off. Found 20 blown diodes in IAS.
1/3/62	15:05		1:47	:04	2		(1) 407 spaces when should only cycle. Bad relay. (2) 407 does not obey 74 orders. Bad connector in relay.
1/4/62	16:48			:10	0		
1/5/62	17:29			:09	1		(1) Blank bits in program register. Reason unknown.
1/8/62	13:08	3:57			0		
1/9/62	16:37			:20	5		(1) Multiple bits in program register. (2) Column 12 did not punch on 533. (3)(4) Blank bits in distributor. (5) False distributor light. Reasons for all 5 errors unknown.
1/10/62	16:06		7:33	:21	4		(1) False storage unit lights many times. Cause undetermined--finally disappeared. (2) 533 fails to read. Bad switch. (3) Card jam in 533 read side. Removed. (4) False storage unit lights and positions 0189-0198 blank. Bad tube causing 75 orders to be picked when none existed in programs.
1/11/62	1:45		16:10		0		

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
1/12/62	15:23		1:45	:12	1		(1) Quinary bit in distributor lost. Reason unknown.
1/15/62	16:54			:10	1		(1) Multiple bits in program register. Reason unknown.
1/16/62	16:45			:09	0		
1/17/62	14:48		2:05	:16	1		(1) 533 would not read. Broken pin found. Also out of timing.
1/18/62	16:48			:19	0		
1/19/62	16:02		:44	:07	3		(1) 407 cycles off line. Found burnt relay points. (2) Fifty word records could not be read from tape. Reason unknown. (3) 71 punch orders would not execute. Card lever needed adjust- ment.
1/22/62	13:17	4:03			0		
1/23/62	16:42			:27	0		
1/24/62	15:52			:09	0		
1/25/62	16:10			:20	0		
1/26/62	16:09			:07	0		
1/29/62	11:05	3:27	1:37	:00	1		(1) Tape would not read correctly from any tape or any unit. Reason unknown.
1/30/62	15:16		:30	:32	1		(1) Constant card feed stops on 533 read. Read feed adjusted.
1/31/62	15:09			:47	2		(1)(2) Lost quinary bits in program register. Reason unknown.
TOTALS	315:26	12:52	41:53	4:39	28	2:45	

PART VI
INSTRUCTIONAL USE OF COMPUTERS

During the month of January, specifications were presented for two new problems.

35 Mechanical Engineering 406. Problem 2. ILLIAC. Maximum Temperature Difference of Cylinder Wall. The temperature distribution is approximated by the first five terms of the Fourier series. The maximum temperature variation is evaluated by pointwise determination of the function.

36 Civil Engineering 391. Problem 3. IBM 650. Moment Distribution. This problem, together with problems 1 and 2, completes the analysis of an indeterminate continuous beam. The method of analysis used is the Hardy Cross moment distribution procedure which, for an m-span beam, consists essentially of solving m-1 simultaneous linear equations by relaxation, for which the coefficients and column vectors have been computed in problems 1 and 2. The procedure is considered to have converged when the unbalanced moment at each joint (i. e., the residual in each equation) is less than a prescribed tolerance.

PART VII
CONTROL DATA CORPORATION 1604

During the fall semester, 1961-62, a Control Data Corporation 1604 was acquired by the Coordinated Science Laboratory of the University of Illinois. The configuration obtained accepts punched paper tape and magnetic tape as input and outputs to magnetic tape, punched paper tape, or the console typewriter. This machine has been made available to the general research program of the University through the Digital Computer Laboratory. Effective December 14, 1961, three and one-half hours per day were made available for this purpose.

This machine can make a significant contribution to the research programs of this University through two channels.

- (a) Personnel of the Coordinated Science Laboratory have prepared a program, SIMILE, which simulates the Illiac. Using this program, the 1604 can aid in the reduction of the already large Illiac backlog.
- (b) The 1604 is also available for direct use via CODAP, an assembly system, or via a compiler which accepts the FORTRAN input language.

In order to facilitate this latter use of the 1604, this Laboratory is preparing an IBM 650 program which will convert input on cards to an input 1604 magnetic tape and which will convert a 1604 output magnetic tape to line printing.

This latter category of users of the 1604 facility submit problem specifications which will be reported in these monthly Technical Progress Reports.

This month, six problem specifications were submitted for the Control Data Corporation 1604. Numbers followed by T are for theses.

1 Chemistry. Numerical Quadrature Formulas. The problem consists of finding points and weights for certain quadrature formulas. These formulas are to be used in a double precision application and so their computation will be done accurately to 30 decimal places using a triple precision routine written at the University of Wisconsin. About one-half of this work will be done on the 1604 at Wisconsin.

2 Chemistry. Two Coupled Three Dimensional Differential Equations. The solution of a set of two coupled non-linear partial differential equations will be solved. Work has been done on the Illiac using a 70 x 70 grid and it is found that this is not large enough. A 150 x 150 grid will be attempted on the 1604. If FORTRAN, which is about 50 per cent efficient on the 1604, proves to be too slow, this may be programmed in machine language.

3 Chemistry. Decomposition of a Polyatomic Molecule. The research problem consists in integrating Hamilton's classical equations of motion for an energized polyatomic molecule and determining the time it takes for it to decompose as a function of initial conditions. The mathematical methods involve mainly the use of standard library routines such as the Runge-Kutta-Gill integration procedure for systems of ordinary differential equations, the exponential function routine, etc.

4 Physics. Exact Solution of the Boltzmann Equation for Slowing Down of Neutrons. The Boltzmann equation for the energy dependent neutron flux $\varphi(E)$ is solved by a method which leads to an algebraic equation expressing $\varphi(E - \Delta E)$ in terms of the cross sections $\sigma_a(E)$, $\sigma_s(E)$, and $\sigma_f(E)$ for absorption, scattering, and fission, and of the flux at energies $E > E - \Delta E$. Since for $E > 10$ kev one may assume an asymptotic flux $\varphi(E) \sim 1/E$, it is possible to obtain $\varphi(E)$ in the energy region of particular interest for reactor physics applications. The program, written in FORTRAN, uses two separate subroutines. The first one specifies the line shape functions $\psi(x, \xi)$ and $x(x, \xi)$, defined in Born, Optik. The second subroutine calculates the Doppler-broadened Breit-Wigner cross sections needed for the specification of the kernels of the Boltzmann equation.

Specifically, an investigation of the effects of overlapping resonances on the neutron spectrum, especially in media containing Th_{232} and U_{238} will be made.

In the future, the neutron spectrum in media containing fissile materials (U_{235} , Pu_{239} , U_{232}) will be investigated. In this case, a further subroutine will be used which calculates the cross sections directly from the scattering matrix used in the Wigner-Eigenbud formulation.

5T Physics. Analysis of Pion Photoproduction in H_2 and P_2 . The computer will be used to analyze bubble chamber photographs taken by the Illinois Bubble Chamber. A run of about 400,000 photographs has been completed. The photoproduction of π^+ and π^0 mesons from protons will be studied, particularly near threshold. Another run with deuterium will be carried out in February or March to study the photoproduction of π^- from neutrons.

6T Civil Engineering. Response of Underground Structures to Blast Loading. The soil is represented by a lumped-mass system supported by a yielding spring system with the structure represented by a similar lumped-mass spring system. The response is determined using numerical integration.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part IV.

CDC 1604 TIME DISTRIBUTION
January, 1962

Department	SIMILE	NON-SIMILE	MAINTENANCE	TOTALS
Agricultural Economics	4:23			4:23
Agronomy	:02			:02
Animal Science	1:31			1:31
Bur. Econ. and Bus. Res.	:09			:09
Chemistry	8:22	2:10		10:32
Civil Engineering	14:25	:52		15:17
Electrical Engineering	2:45			2:45
Geology	:37			:37
Inst. for Res. on Exceptional Children	:44			:44
Mechanical Engineering	1:26			1:26
Music	:28			:28
Physical Education	:06			:06
Physics	5:59	:35		6:34
Psychology	18:56			18:56
Maintenance			4:13	4:13
Totals	59:53	3:37	4:13	67:43

PART VIII
GENERAL LABORATORY INFORMATION

Seminars

"Some Mathematical Aspects of Parallel Computation," by Dr. Theodore J. Rivlin, Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York, January 15, 1962

"The Use of Computers in the Monitoring of Laboratory Experiments in the Behavioral Sciences and the Construction of Simple Economic Games for the Study of Human Behavior," by Professor Austin Hoggatt, Director, Computer Center, University of California, Berkeley, California, January 29, 1962.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Research Associates	6	0	6.0
Graduate Research Assistants	12	19	21.7
Graduate Teaching Assistants	3	0	1.5
Administrative and Clerical	6	0	6.0
Other Nonacademic Personnel	<u>40</u>	<u>14</u>	<u>45.17</u>
TOTAL	79	35	93.37

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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Physics

UNIVERSITY OF ILLINOIS
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TECHNICAL PROGRESS REPORT

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- PART II - CIRCUIT RESEARCH PROGRAM
- PART III - MATHEMATICAL METHODS
- PART IV - DATA REDUCTION METHODS
- PART V - ILLIAC USE AND OPERATION
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- PART VII - INSTRUCTIONAL USE OF COMPUTERS
- PART VIII - CONTROL DATA CORPORATION 1604
- PART IX - GENERAL LABORATORY INFORMATION

February, 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1) 415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

The static test involves application of DC power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspection.

TABLE I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	0
Core Storage Unit (4096 words) 3937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	3,883 54 3,937	0	0
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	10,285	10,285	8,104 1,477 9,581	7,548 1,718 9,266	4,547 3,874 8,421	1,198 501 1,699	0
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,709	0
Advanced Control 6800	6,800	6,400 0 6,400	4,300 900 5,200	869 1,282 2,151	0 1,667 1,667	0				
Drum Storage Unit 2500	2,500	1,100 0 1,100	0	0	0	0				
Interplay Control 3000	3,000	3,000	500 1,600 2,100	0	0	0				
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641	0	0
Test Controls	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	0
TOTALS	37,909 54 37,963	36,109 54 36,163	30,409 2,554 32,963	26,478 1,336 27,814	25,609 1,721 27,330	23,428 1,531 24,959	22,872 1,772 24,644	19,871 3,928 23,799	10,957 501 11,458	0

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystems Tests

During the month, ten of the smaller chassis, containing 501 transistors, were installed in the center wall of the main frame. These chassis contain circuits for the selector mechanisms, and for providing the power amplification necessary to drive all digits of a register from a single point in the control.

Considerable modification of the Fibonacci test control was required. The majority of the malfunctions, listed in Table II, were due to these modifications, and to the temporary connections and changes in the center wall chassis necessary for compatibility with the test control. In particular, all of the new circuits installed were error-free, since all 14 malfunctions listed were due to errors in the process of modification.

The tests were concluded with an error-free run of 63.8 hours over the weekend of February 23-26.

3. Core Memory

After locating and correcting several wiring errors and faulty components, the memory was able to operate at 1.8 μ s. cycle for about 12 hours with a reversing test on 4 bits.

Subsequently, the sense amplifiers were altered to provide more gain (see January, 1962, Progress Report).

Upon returning the sense amplifiers to operation, the +65 v. power supply shorted causing the loss of several driver transistors. At month's end the memory was approaching the operational ability stated above.

A memory test using the MAU as a Fibonacci pattern generator was ready to begin.

(S. Ray)

TABLE II MALFUNCTIONS DURING FEBRUARY

Nature of Fault	Power Supply	Repetitive MAU Chassis	Center Wall Chassis	Flow Gating	Test Controls	Totals
Faulty Transistor	2	1				3
Shorted Tantalum Capacitor	6					6
Blown Fuse	1					1
Wiring Error	3		3		2	8
Transistor Not Inserted in Socket			11			11
Intermittent or Open Connection		3		1	9	13
Shorted Connection					1	1
Unknown				1		1
Total	12	4	14	2	12	44

4. Interplay

Block layout of the drum channel of interplay and of the selector which chooses words and addresses to be sent to the core memories was started. A basic driver circuit to satisfy all the large fanout requirements of interplay was designed and tested based on the MM488 transistor.

(C. S. Wallace)

5. Paper Tape Editing Equipment

Further delays in the supply of the editing equipment occurred due this time to a delay in ordering the special type face required. Delivery is expected in mid-March.

(C. S. Wallace)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Introduction

The work on both the theoretical and experimental aspects of tunnel diode circuits by T. Moto-oka and H. Guckel has led to the design of a very elegant counter using reflections in an open-ended transmission line to cancel (conditionally) the second portion of a compound input signal, i. e., a signal formed of a positive and a negative pulse in sequence. It is easily proved that a tunnel diode at the input to such a line will only change state for every second input sequence.

T. Burnside has developed some more circuitry for the circuit sampling system used in the probabilistic analysis of circuits. It has been decided to replace the spectrum analyzer at the output by counters reacting also to the "tails" of the output distribution.

T. Hill is now designing a small system using his failsafe and failure-indicating circuits. This system will have a shifting register and an adder and will cycle through a series of additions.

S. Ribeiro has prepared a complete report on the behavior of transistors in saturation and in supersaturation.

2. Transmission Line Counter

The circuit consisting of a tunnel diode and an open-ended transmission line as shown in Figure 1 (a) has the characteristics of a binary counter for a bipolar signal as shown in Figure 1 (b). The most interesting property of this counter is its simplicity and the very high speed attainable. The disadvantages are the necessity of an uncommon input signal and the complicated interstage circuitry.

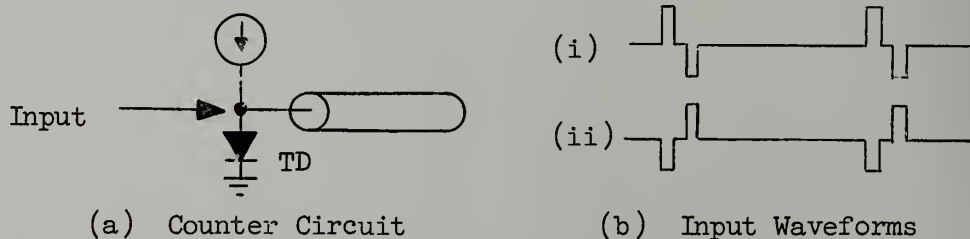


Figure 1 Tunnel Diode Counter

Principle of the Transmission Line Counter

We assume that each input signal train consists of a positive pulse followed by a delayed negative pulse. (A negative pulse and a delayed positive pulse can also be considered.) When the tunnel diode is in the low voltage state, the first positive pulse sets the tunnel diode to the high voltage state and sends a positive forward wave to the transmission line. The delayed negative input pulse would reset the tunnel diode to the low voltage state, but the positive backward wave of a transmission line generated by a positive input pulse cancels the negative input pulse and inhibits the device from returning to the low voltage state, i. e., the input signal sets the circuit, which is in a low voltage state, to a high voltage state.

If the tunnel diode is in a high voltage state, the first positive pulse of an input signal does not change the state of the tunnel diode and sends only a small (positive) forward wave into the transmission line. But now the negative portion of the input pulse resets the circuit to a low voltage state: we have one circuit change per two input signal sequences.

Theory of the Transmission Line Counter

It is assumed that the input signal is supplied to a tunnel diode counter through a transmission line, as shown in Figure 2, where Z is the equivalent impedance of the tunnel diode, and Z_o the characteristic impedance of the transmission line and Z_o' the characteristic impedance of the output (counter) transmission line.

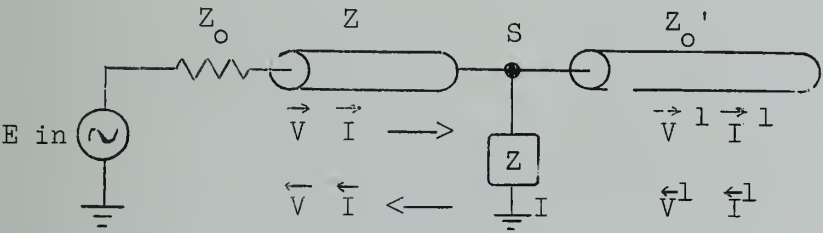


Figure 2 Equivalent Circuit of a Tunnel Diode Counter

The equivalent impedance of a tunnel diode, Z , is given by the following equation:

$$\frac{v}{Z} = I = C \frac{dv}{dt} + F(v) - I_o \tag{1}$$

where v is a tunnel diode voltage, C its stray capacitance, $F(v)$ its non-linear DC characteristic and I_0 its constant supply current.

If we call the forward and backward wave voltages of the input and counter transmission lines $\vec{V}, \vec{V}', \overleftarrow{V}, \overleftarrow{V}'$, the circuit equations are given by

$$\left. \begin{aligned} \vec{V} + \overleftarrow{V} &= v = ZI = \vec{V}' + \overleftarrow{V}' \\ \vec{I} + \overleftarrow{I} &= I + \vec{I}' + \overleftarrow{I}' \\ \frac{\vec{V}}{\vec{I}} &= -\frac{\overleftarrow{V}}{\overleftarrow{I}} = Z_0 \\ \frac{\vec{V}'}{\vec{I}'} &= -\frac{\overleftarrow{V}'}{\overleftarrow{I}'} = Z_0' \end{aligned} \right\} \quad (I)$$

The input signal and the backward wave of the counter transmission line are

$$\left. \begin{aligned} \vec{V} &= \frac{E_{in}}{2} e^{st} = \frac{E_0}{2} (1 - e^{st_1}) - \frac{E_0}{2} (1 - e^{st_2}) e^{st'} = \frac{\bar{E}}{2} \\ \overleftarrow{V}' &= k\vec{V}' (t - 2T_0) \end{aligned} \right\} \quad (II)$$

where K is the attenuation factor of the counter transmission line which is supposed to have a delay time T_0 . The pulse widths of positive and negative input pulses are called T_1, T_2 , and the delay time of a negative pulse T' .

From equations (I), (II)

$$v = \frac{Z \left\{ Z_0' \bar{E} + 2Z_0 k\vec{V}' (t - 2T_0) \right\}}{Z_0 Z + Z_0' Z + Z_0' Z_0} \quad (2)$$

$$\overleftarrow{V} = \frac{(ZZ_0' - Z_0 Z - Z_0 Z_0') \frac{\bar{E}}{2} + 2ZZ_0 k\vec{V}' (t - 2T_0)}{Z_0 Z + Z_0' Z + Z_0' Z_0} \quad (3)$$

$$\vec{V}' = \frac{ZZ_0' \bar{E} + (ZZ_0 - ZZ_0' - Z_0 Z_0') k\vec{V}' (t - 2T_0)}{Z_0 Z + Z_0' Z + Z_0' Z_0} \quad (4)$$

Using equations (1) and (2)

$$C \frac{dv}{dt} + F(v) + \left(\frac{1}{Z_0} + \frac{1}{Z_0'} \right) v = I_0 + \frac{\bar{E}}{Z_0} + \frac{2R}{Z_0'} \vec{V}' (t - 2T_0) \quad (5)$$

Experiments

The basic experiment confirming the principle of this counter behavior was done. The experimental circuit is shown in Figure 3, in which a 5mA tunnel diode and a 50 Ω transmission line are used. It was ascertained that this circuit worked in a normally wide range of supply and input voltages (see Figure 4).

Concerning the counting speed, it is necessary to do further experiments using a high-speed pulse generator. The maximum counting rate is expected to be $1/(4 \sim 6) T_r$ where T_r is the rise time of the tunnel diode alone. A high-speed pulse generator is being designed now.

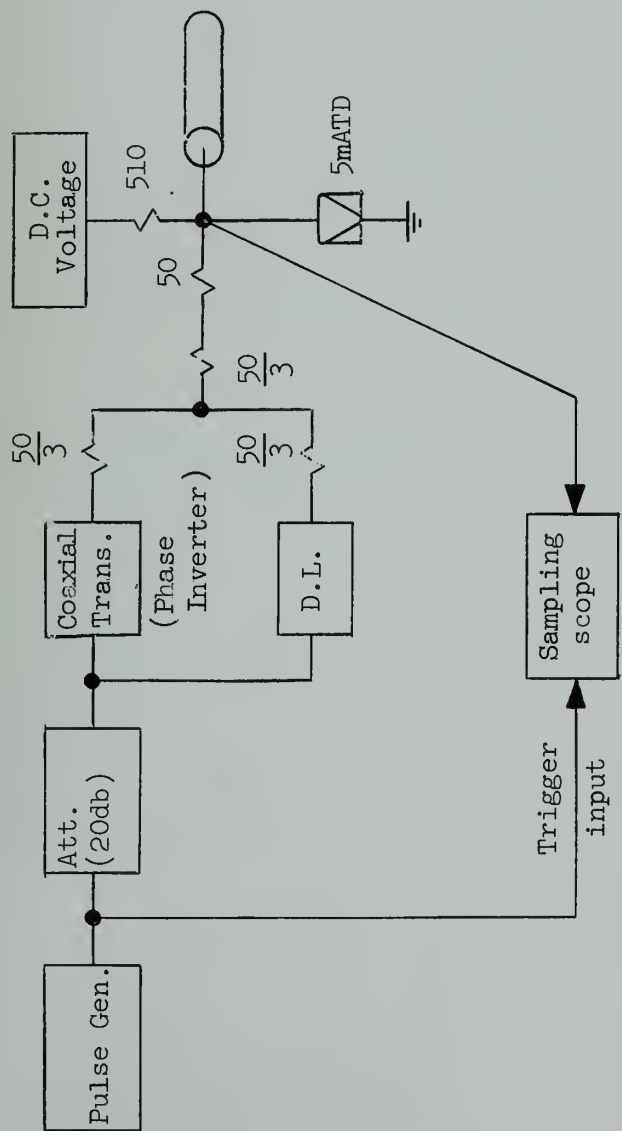


Figure 3 Experimental Circuit

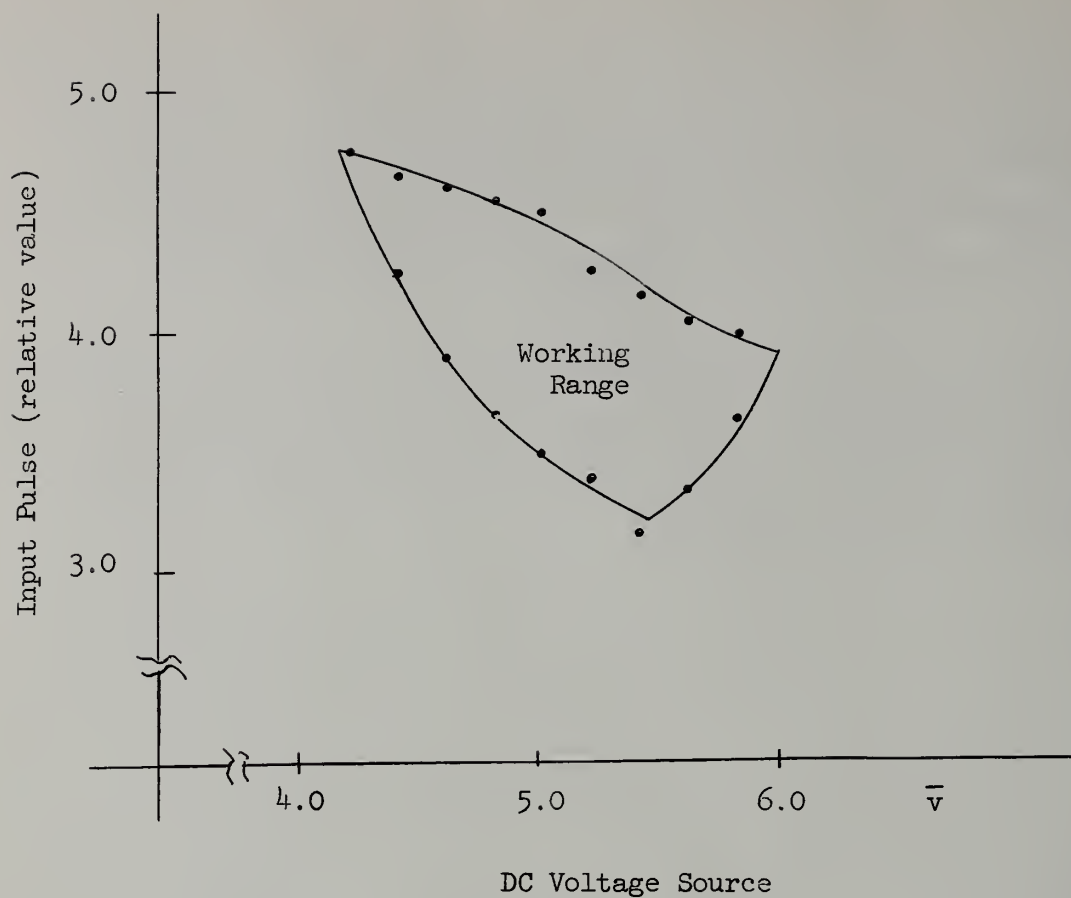


Figure 4 Working Range of TD Counter

3. Statistical Circuit Analysis

The flipflop in Figure 5 was designed for the counters in the sampling system.

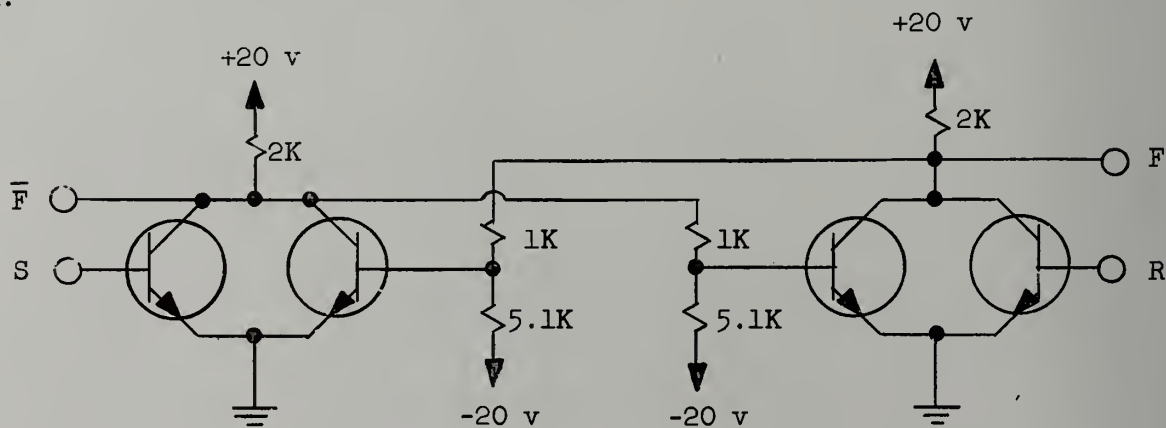


Figure 5 Flipflop for Sampling System

Type 2N1308 switching transistors are used with 5% resistors. The two output states are +7 volts and ground.

The outputs of the flipflops are decoded to provide switching signals and to set the flipflops to the next state in the counting sequence. Figure 6 shows the decoding circuit.

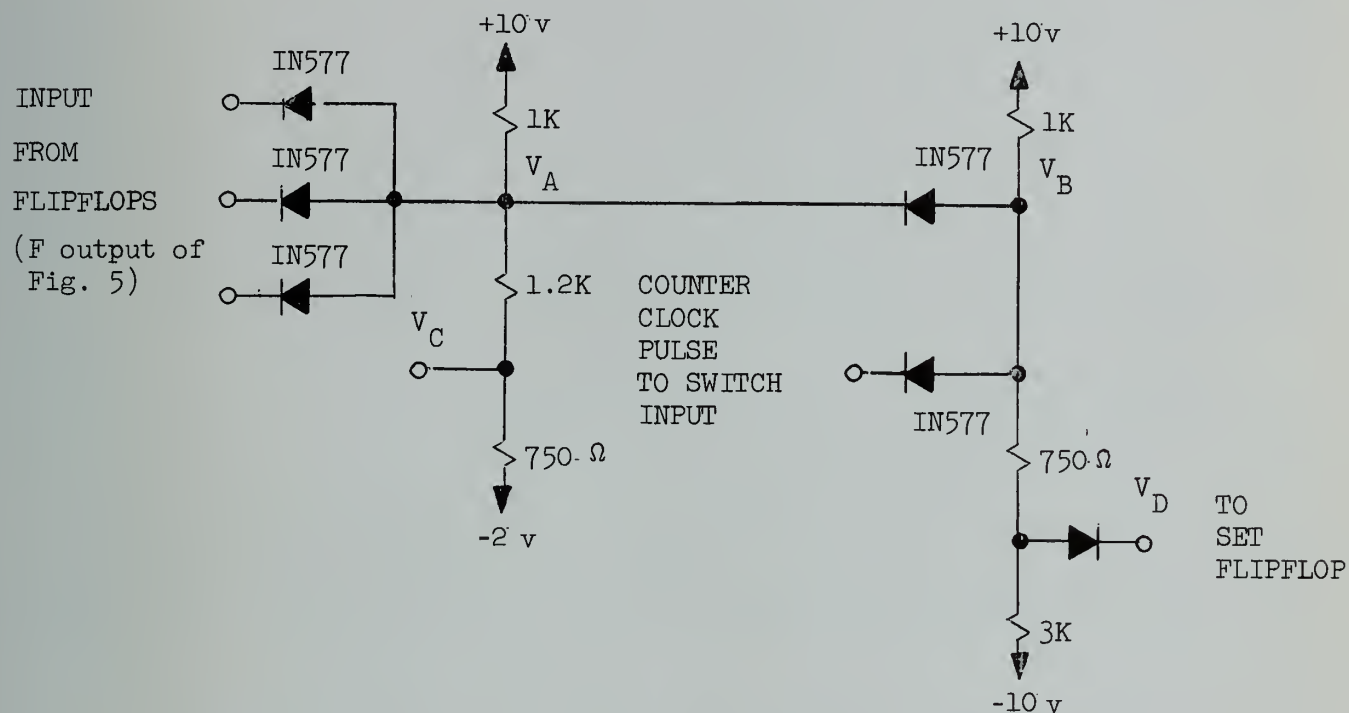
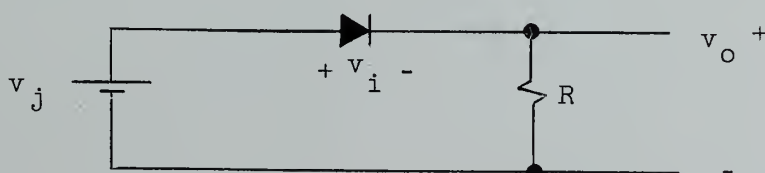


Figure 6 Decoding Circuit

Assume the clock pulse present: If all three inputs are +7 volts, then $v_A = v_B = +6$ volts, $v_C = +1$ volt, and $v_D = +3$ volts. If one or more of the inputs is at ground, then $v_A = 1/2$ volts, $v_B = 1$ volt, $v_C = v_D = -1$ volt.

The following sampling technique is being considered.



V_i is the voltage of the i th diode when there are 8 diodes. V_j is the j th voltage source of 8 sources. n will represent the n th clock pulse.

$$n = 0, 1, 2, \dots$$

If the i th diode is switched into the circuit and the other 7 out, then

$$i = n \pmod{8}$$

If the j th voltage source is switched into the circuit and the rest out, then

$$j = \frac{(n - i)}{8} \pmod{8}$$

After 64 clock pulses, all 64 possible output voltages have appeared and have been sampled. The output voltage range is divided into 8 equal intervals and the number of voltage pulses appearing in each channel is recorded. From this information, the probability density of the output voltage can be found.

4. Failsafe Circuits

Lifetime of an Ordinary Computer

Assume that a computer has n transistor circuits, each with a mean lifetime T and that the circuits obey the exponential failure law. The mean lifetime L of this computer is then

$$L = \int_0^{\infty} t dP(t) = \int_0^{\infty} t \frac{d}{dt} [1 - P(t)] dt,$$

where $P(t)$ is the probability distribution function of the lifetime of the computer. Upon integrating by parts we get

$$L = \int_0^{\infty} [1 - P(t)] dt$$

Since any one circuit failure causes a computer failure, the probability that the computer fails, P_f , is expressed in terms of the probability that an individual circuit fails, P , as follows:

$$P_f = P(\text{ckt \#1 fails or ckt \#2 fails or ... or ckt \#N fails})$$

which by DeMorgan's law gives

$$P_f = 1 - P(\text{ckt \#1 doesn't fail and ... and ckt \#N doesn't fail}).$$

Assuming all failures equally likely we get

$$P_f = 1 - [P(A \text{ ckt doesn't fail})]^N$$

$$[1 - P_f(t)] = [1 - P_1(t)]^n$$

But from the previous report $P_1(t) = (1 - e^{-t/T})$ and the lifetime becomes

$$L = \int_0^{\infty} e^{-nt/T} = \frac{T}{n},$$

which is just n^{-1} times the lifetime of a single circuit.

Computer with Failsafe Elements

Now consider a computer with n compound circuits, each with two transistors. The computer only fails if both transistors in one of its compound circuits fails. These compound circuits were analyzed last month and their probability distribution function $P_2(t) = (1 - e^{-t/T})^2$. Hence

$$L' = \int_0^{\infty} [1 - P_2(t)]^n dt = \int_0^{\infty} e^{-nt/T} [2 - e^{-t/T}]^n dt$$

Using repetitive integration by parts this integral breaks down to the sum

$$L' = \frac{T}{n} + T \sum_{i=1}^n \frac{(n-1)(n-2) \dots (n+1-i)}{(n+1)(n+2) \dots (n+i)} = \frac{T}{n} + T \sum_{i=1}^n \Phi_i$$

Since each Φ_i is positive and T/n is the mean life of the ordinary n element computer, L' is greater than L . When n is large one can make a close approximation to Φ_i by expanding it in a sum of logarithms, making a large number approximation, and then taking the antilogarithm we get

$$\Phi_i = \frac{1}{n+1} e^{-(i^2 - 1)/n}$$

Again for large numbers one may replace the sum by an integral and we get

$$\sum_{i=1}^n \Phi_i \doteq \int_0^{\infty} \frac{1}{n+1} e^{-(i^2 - 1)/n} di = \frac{1}{n+1} e^{+1/n} \sqrt{\frac{\pi n}{4}}$$

Finally neglecting the $e^{1/n}$ we get the formula

$$L' = \frac{T}{n} + \frac{T}{n+1} \sqrt{\frac{\pi n}{4}}$$

which gives an answer 10% off for $n = 1$, 1% off for $n = 100$, and proportionally less for large n .

The fractional improvement in average lifetime by using failsafe circuits instead of ordinary circuits is thus

$$\frac{L'}{L} = \frac{T/n + \frac{T}{n+1} \sqrt{\frac{\pi n}{4}}}{T/n} = 1 + \frac{n}{n+1} \sqrt{\frac{\pi n}{4}} .$$

For $n = 10$, $L'/L = 3.3$; for $n = 100$, $L'/L = 9.4$. The average lifetime of the failsafe machine goes down as $n^{-1/2}$, whereas that of the regular computer goes down as n^{-1} , hence the compound machine lasts $n^{1/2}$ times longer before it fails.

PART III
MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

1. Monte Carlo Methods in Quantum Statistics

Some computations were made with program NUMBER 6 (see TPR September, 1961) with two interacting particles. The interaction potential energy $V(r)$, for two particles separated by distance r , is specified by

$$\begin{aligned} V(r) &= \infty & \text{if } r < a \\ V(r) &= -v & \text{if } a \leq r < b \\ V(r) &= 0 & \text{if } b \leq r \end{aligned}$$

In the present computations $a = 0$ (no hard core) and different v and b were used.

It does not appear to be possible to evaluate the partition function exactly in this case, hence an exact check on the Monte Carlo results is not available. The qualitative behavior of the results was as expected. In particular it was found that when the mean de Broglie wave length

$$\lambda = \hbar \sqrt{\frac{1}{kTm}}$$

was $16b$ and $8b$ (b = radius of potential "well") the results were the same as for $v = 0$, but when $\lambda = 4b$ (i.e., well diameter = $\frac{\lambda}{2}$), the presence of the potential well affected the results.

(L. D. Fosdick)

2. Analysis of Rounding Procedures in Iterative Processes with Floating-point Arithmetic (Supported in part by the National Science Foundation under Grant G16489.)

Let r be a real number and $G(x)$ be a function such that

$$|x + G(x) - r| \leq b |x - r| \text{ with } 0 \leq b < 1 \text{ for any } x; \quad (1)$$

then the sequence

$$x_{n+1} = x_n + G(x_n) \quad (2)$$

converges at least linearly to r for any x_0 .

Suppose we want to realize (2) on a binary floating-point computer, i.e. the numbers are of the form $\alpha \cdot 2^\beta$, where α is an exact binary fraction and β is an integer.

A number will be called normalized if 1) $0.5 \leq |\alpha| < 1$, 2) α is an exact binary fraction representable by N bits and the sign, 3) $\beta \geq -p$ (N and p are fixed numbers); furthermore there exists a real zero, representable for example by $\alpha = 0$, $\beta = -p$; for greater simplicity, this zero will also be included in the class of normalized numbers.

We assume that in the realization of (2) on the computer, both x_n and $G(x_n)$ are represented by normalized numbers; of course $G(x)$ cannot be computed exactly in general; so we assume that value effectively computed, $\bar{G}(x)$, satisfies the relation:

$$\bar{G}(x) = (1 + \eta) G(x) + \xi, \quad |\eta| \leq d, \quad |\xi| \leq a; \quad (3)$$

where η and ξ are function of x , but d and a are fixed numbers.

The effective process is given by the operation

$$Y_{n+1} = [Y_n + \bar{G}(Y_n)]_r \quad (4)$$

where Y_n and Y_{n+1} are normalized numbers; Since $Y_n + \bar{G}(Y_n)$ cannot be generally represented by a normalized number, it must be rounded as indicated by $[\]_r$.

We concentrate our attention on the rounding procedures in (4) and consider two types of rounding procedures:

1) Normal rounding $Y_{n+1} = [Y_n + \bar{G}(Y_n)]_N$; Y_{n+1} is a normalized number such

$$| Y_{n+1} - (Y_n + \bar{G}(Y_n)) | = \text{minimum}$$

When two different normalized numbers satisfy the above relation, any of them can be chosen as Y_{n+1} .

2) Anomalous rounding $Y_{n+1} = [Y_n + \bar{G}(Y_n)]_A$ If $\bar{G}(Y_n) \geq 0$ let

Z be the smallest normalized number such that $Z \geq Y_n + \bar{G}(Y_n)$,

W be the greatest normalized number such that $W \leq Y_n + \bar{G}(Y_n)$;

if $\bar{G}(Y_n) \leq 0$ let

Z be the greatest normalized number such that $Z \leq Y_n + \bar{G}(Y_n)$,

W be the smallest normalized number such that $W \geq Y_n + \bar{G}(Y_n)$;

then

$$[Y_n + \bar{G}(Y_n)]_A = W \quad \text{if } W \neq Y_n$$

$$[Y_n + \bar{G}(Y_n)]_A = Z \quad \text{if } W = Y_n$$

Theorem a) For any Y_0 , by using the normal rounding, there exists a finite number M such that

$$| Y_n - r | \leq B_N \equiv \frac{2^{-N} | r | + a (1 + 2^{-N})}{2 + 2^{-N} - (1 + d) (1 + b) (1 + 2^{-N})} \quad \text{for } n > M.$$

b) For any Y_0 , by using the anomalous rounding, there exists a finite number of such that

$$| Y_n - r | < B_A \equiv | r | 2^{-N+1} + 2^{-p-1} + \frac{a (1 + 2^{-N+1})}{2 - (1 + d) (1 + b)} \quad \text{for } n > M.$$

If B_N or B_A is negative, it must be replaced by $+\infty$.

In order to compare these results, first suppose $a = 0$. Then B_A is independent of b and d and furthermore remains very small; in case of slow conveyence, i.e., when $b \approx 1$, B_N can become very large. The increase of magnitude of the bounds when $a > 0$ is almost the same for B_A and B_N for reasonable cases, so that the amonalous rounding can be considered safer than the normal rounding.

- Remarks: 1) The relations of normal and anomalous rounding procedures are very similar in fixed-point and in floating-point arithmetics;
- 2) The bounds B_A and B_N are reached only in trivial cases, however, examples show that they remain realistic in every case.

(J. Descloux)

3. Approximation in L^p and Tchebycheff Approximation (Supported in part by the National Science Foundation under Grant G16489.)

Introduction It is known that the best Tchebycheff approximations are not always unique.

Recently J. R. Rice has tried to define in a reasonable way a particular and unique best Tchebycheff approximation (Tchebycheff Approximation in a Banach space; Research Laboratories, General Motors Corporation, Detroit, Michigan); his definition applies only in the case of discrete approximations. Here we give an equivalent definition; however, it seems that it cannot be generalized for not discrete approximations.

Let $f_1(x), f_2(x) \dots f_n(x), F(x)$ be real functions defined in a finite set of points $x_1 \dots x_m$. We suppose that the matrix $\| f_i(x_j) \|$ has the rank n . For any set of value $a_1 \dots a_n$, $f(x) = \sum_{i=1}^n a_i f_i(x)$ is an approximation of $F(x)$.

$f^{(p)}(x) = \sum_{i=1}^n a_i^{(p)} f_i(x)$ is the best approximation in L^p of $F(x)$ if the coefficients $a_i^{(p)}$ minimize the function

$$\sum_{i=1}^m | f(x_i) - F(x_i) |^p.$$

It is known that for $p > 1$, $f^{(p)}$ exists and is unique.

$f^{(t)}(x)$ is a best Tchebycheff approximation of $F(x)$ if the coefficients $a_i^{(t)}$ minimize the function.

$$\text{Max}_{i=1..m} | f(x_i) - F(x_i) |$$

There always exists a Tchebycheff approximation which may not be unique.

Theorem $\lim_{p \rightarrow \infty} f^{(p)}(x)$ exists and is a best Tchebycheff approximation.

Remarks: 1) $f^{(p)}(x)$ converges for $p \rightarrow \infty$ to an approximation called a strict approximation by J. R. Rice.

2) Unfortunately this theorem cannot be generalized easily for functions defined on a continuum; it is possible to construct a continuous function $F(x, y)$ defined on the square $0 \leq x, y \leq 1$ such that the linear best approximation $f^{(p)} = a^{(p)} x + b^{(p)} y + c^{(p)}$ in L^p does not converge for $p \rightarrow \infty$.

(J. Descloux)

4. Note on Convex Programming (Supported in part by the National Science Foundation under Grant G16489.)

Let r and \wedge be two disjoint compact sets in the n -dimensional euclidian space E^n , b be a continuous real-valued function on r and c be a continuous real-valued function on \wedge .

The vectors of r and \wedge are supposed to satisfy the Haar condition, i.e. each set of n vectors belonging to r or \wedge or both are independent.

For two vectors A and x of E^n , we denote their scalar product by $[A, x]$. Let

$$F(x) = \max_{A \in r} \{ [A, x] - b(A) \}$$

$$G(x) = \max_{A \in \wedge} \{ [A, x] - c(A) \}$$

The problem of convex programming is to minimize $F(x)$ under the condition $G(x) \leq 0$. We suppose that the set $\Theta = \{ x \mid G(x) \leq 0 \}$ is non-empty and that $\inf F(x) = \bar{f}$ is finite.

E. W. Cheney and A. A. Goldstein have found an algorithm $x \in \Theta$ for solving this problem when r and \wedge possess only a finite number of elements. (Newton's Method for convex programming and Tchebycheff approximation, Numerische Mathematik 1, 253-268 (1959). In fact this algorithm is also valid when r and \wedge are any compact set; (of course the algorithm may not be finite).

In order to explain the algorithm, let us introduce some definitions: Let T be the family of all sets S of $(n+1)$ vectors such that the coefficients of their linear combination can be chosen positive, i.e. if $S = (A^{(1)} \dots A^{(n+1)}) \in T$, there exist $\lambda^{(1)} > 0, \dots, \lambda^{(n+1)} > 0$ such that $\sum_{i=1}^{n+1} \lambda^{(i)} A^{(i)} = 0$

A basis is a set $I \in T$ such that $I \cap r \neq \emptyset$; it can be proved that, under the above assumptions, there exists at least one basis. For any basis I , we consider the problem of minimizing the function

$$F_I(x) = \max_{A \in I \cap r} \{ [A, x] - b(A) \}$$

under the condition

$$G_I(x) = \max_{A \in I \cap \wedge} \{ [A, x] - c(A) \} \leq 0 \text{ (if } I \cap r = \emptyset, G_I(x) \equiv 0 \text{)}$$

this problem has one and only solution $x(I)$ with $F[x(I)] = f(I)$, where $x(I)$ and

$y(I)$ are determined by the system:

$$\left. \begin{aligned} [A, x(I)] - b(A) &= f(I) & \text{for } A \in I \cap r \\ [A, x(I)] - c(A) &= 0 & \text{for } A \in I \cap \wedge \end{aligned} \right\} \quad (1)$$

(if $I \cap \wedge = \emptyset$, there are no equation of the second type).

Algorithm At the k^{st} cycle of the algorithm, a basis I_k is given:

- 1) Solve the system (1) for I_k and find x_k and f_k ;
- 2) if $G(x_k) \leq 0$ and $F(x_k) = f_k$, then x_k is the solution; otherwise let $w_k = \max \{F(x_k) - f_k, G(x_k)\}$ and find a vector A_{k+1} such that $[A_{k+1}, x_k] - b(A_{k+1}) = f_k + w_k$ if $A_{k+1} \in x$
 $[A_{k+1}, x_k] - b(A_{k+1}) = w_k$ if $A_{k+1} \in \wedge$;
- 3) find the basis I_{k+1} containing A_{k+1} and k vectors of I_k (I_{k+1} exists and is unique).

Theorem

- a) the problem has one and only one solution \bar{x} .
- b) there exists a basis \bar{I} with $x(\bar{I}) = \bar{x}$ and $f(\bar{I}) = \bar{f}$.
- c) there exist the constants $p \geq 0, 0 \leq q < 1, 0 \leq r < 1$, such that $|\bar{f} - f_{k+1}| \leq r |\bar{f} - f_k|$ and $||\bar{x} - x_k|| \leq pq^k$,
 where $||\bar{x} - x_k||$ is the euclidian norm of the vector $\bar{x} - x_k$.

(J. Descloux)

PART IV

DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. PRU Simulator

The Illiac interpretative routine to simulate the order code of the pattern recognition unit (PRU) is essentially complete. A full writeup of the routine and its use is in progress.

(J. Stein)

II. Illiac-Scope Connections

Logical and circuit design for the modification of Illiac to permit flexible transfer of information between Illiac and the high resolution scope is now complete. All 80 bits of A and Q registers of Illiac will be assessible in parallel outside Illiac both for entry into Illiac of new data and for external readout of the contents of these registers. Designs of the modification of the order decoder to allow Illiac to run slave to an external machine are now complete. Layout has only started.

(J. deMontlivault, B. McCormick)

III. Pattern Recognition Routine Using Output of the PRU

The facility to preprocess a pattern in the PRU prior to digitally tracking its outline allows procedures for which there is no previous experience. To compare more readily with known means of analysis, a set of digitized hand-written alpha-numeric characters have been keypunched as specimen tapes and will be exhaustively studied by the newly developed "automatic list-processing" type tracking procedure. That is, by prior PRU processing, it is possible to plant under each bit of the filtered image the relative address of the next point on the chain.

A simple first tracking routine using the above mentioned PRU derived link information as well as information from the cruder first projective image (2×2 macro cell \rightarrow 1 point in projective image; black if $2/4$ macro cell black) has been written and is now in the early checkout stage.

(B. Mayoh, R. Narasimhan)

IV. Hardware for the Control Computer

The control computer will initially comprise three processors:

- (i) high resolution scope control processor
- (ii) prototype (4 x 4) pattern recognition unit (PRU)
- (iii) I/O to - from a general purpose computer of units (i) and (ii)

A. Scope Control Processor

A set of I/O orders appropriate for optimum coupling of the CRT scope and pattern recognition computer utilizing a 32 x 32 PRU (see File No. 403) will be realized in the scope control unit. Initially it is planned to simulate the full 32 x 32 pattern recognition unit within the fastest general purpose computer available upon completion of the scope control.

The logical design will be optimized for the high resolution CRT, but will be directly applicable to any device generating an X - Y digitally addressed raster: CRT, TV-Vidicon, mechanical stage, storage tube, photodiode array, mechanical flying spot digitizer (Hough-Powell device), etc. Channel multiplexing will be provided to sample, or control, more than one channel, but only very simple time sharing is planned.

In particular the scope control processor must provide:

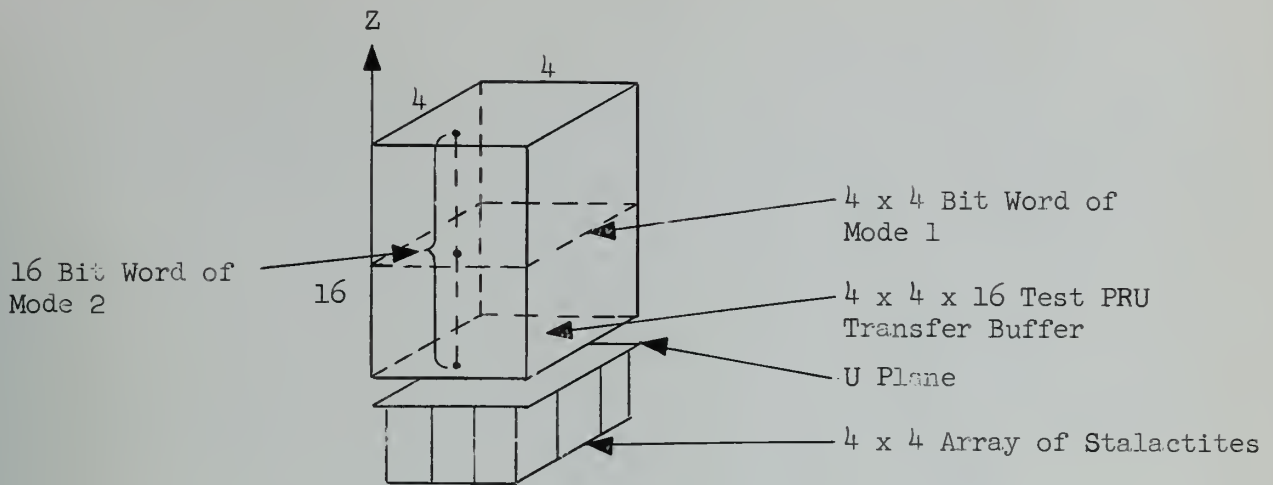
- 1) index arithmetic for generating the read (write) raster
- 2) internal or external digital sweep synchronization
- 3) precision coordinate digitization when reading in the precision measuring mode
- 4) buffering for full raster width sweeps
- 5) primitive blanking and encoding facilities

B. Prototype (4 x 4) Pattern Recognition Unit (PRU)

This unit will consist of 16 experimental prototype stalactite registers (10 MC logic), not discussed further here, the stalactite test control, and the 4 x 4 x 16 PRU transfer buffer (see sketch below).

The test PRU transfer buffer is a transistor flip-flop buffer memory (see current switching logic below) providing two modes of operation:

- 1) transfer of the U plane (4 x 4 = 16 bits) of the stalactite assembly to - from any one of 16 parallel planes, or
- 2) read (write) any one of 16 words (of 16 bits) parallel to the Z axis.



Sketch of Prototype (4 x 4) PRU
(control not shown)

Preliminary specification for the PRU test transfer buffer calls for a read access time (or write time) of 100 μ sec. This test register will be able to

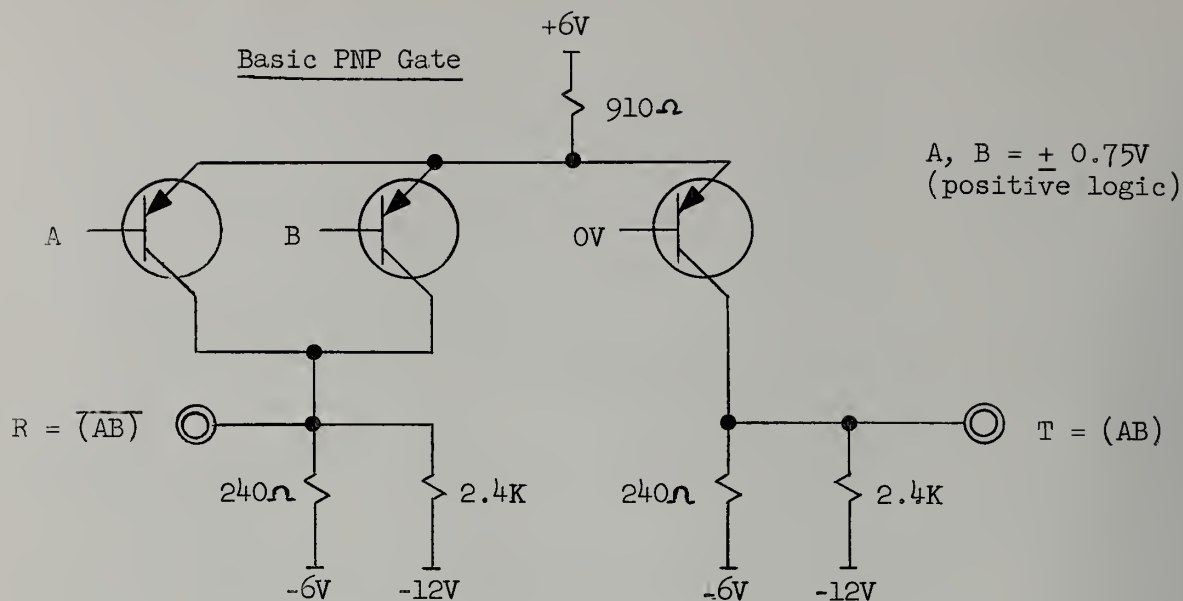
- 1) fully exercise any 4 x 4 array of experimental stalactites
- 2) study mechanisms of transfer buffer control
- 3) give an excellent test of the printed circuit logic (in closed cycle control)
- 4) provide experimental checkout of stalactite registers intended for the ultimate 32 x 32 PRU array.

Upon completion of tests and checkout, the printed circuit boards are directly applicable in other parts of the system.

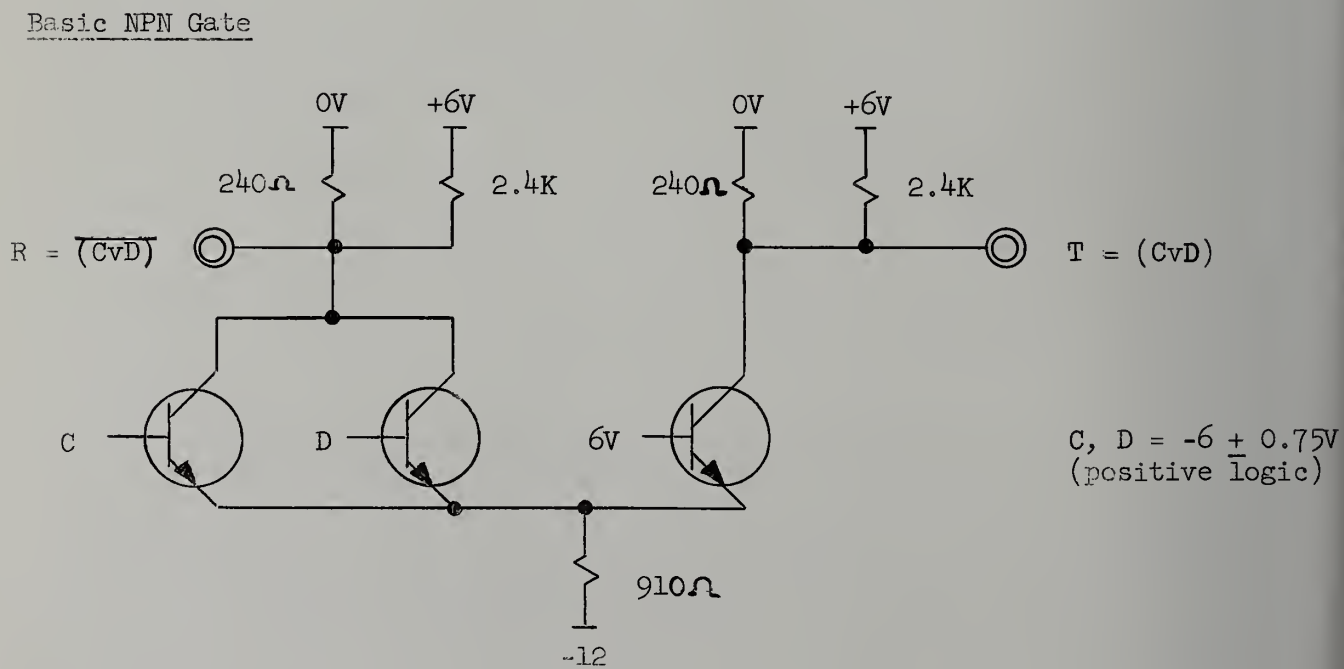
C. Circuitry

A decision has been made to fabricate the control computer using current switching logic similar to modules previously developed by Taussig, Salvador and McCormick at LRL. The transistor types will of course be updated: The 2N711A for the PNP; the 2N797 for the NPN. Circuit design will be consistent with the standard commercial transistor specification.

Four voltage levels (+6, 0, -6, -12) are used in the system. The PNP gate requires an input of $\pm 0.75V$, the NPN gate an input of $-6 \pm 0.75V$. The basic gates (preliminary design) are shown below:



(all transistors 2N711A)



(all transistors 2N797)

An experimental 3000 transistor system designed by Salvador at LRL using the above voltage levels and resistor values, but with the older 2N1499 and 2N706, has logged 6.3×10^6 transistor hours with a total of one transistor failure. At one place in the system the design calls for propagation through 50 stages of logic (with no intermediate FF's) within 1 μ sec - and this condition has been met without fail. A thorough AC analysis of this circuitry, including the FF (2 gates back-to-back) is reported in UCRL-9035 Salvador and Pederson, "Current Switching Circuitry (revised)". Characteristically they predict rise, fall, delay, maximum pulse resolution of the gates and flip-flop to 20%.

D. Printed Circuit Packaging

The basic logical modules have been chosen to be:

Bd. Designation	#Units/Bd.	Description of Unit	Transistors	
			PNP	NPN
2K	10 (5P, 5N)	2-input gates (P and N)	15	15
2P	10	2-input gates (P)	30	
2N	10	2-input gates (N)		30
6P	5	6-input gates (P)	35	
6N	5	6-input gates (N)		35
F	5	flip-flops *	15	15
G	5	flip-flops, each * with 2 parallel inputs	20	20

For all gates both true and reflected (inverted) outputs are available.

The seven logical modules (A, B, -----, G) will be laid out, one module/printed circuit card. Two sided boards using

*For flip-flop boards both PNP and NPN level output signals are provided. For type H, however, reflected outputs are not available.

1-ounce copper foil with 15 μ inch plated gold overlay will be used. An additional 40 μ inch rhodium plating will be used on the contact fingers. Board stock will be glass epoxy. To minimize lead length, as well as optimize packing density, landless circuit layout (plated through holes, no tabs) will be employed, and the 44 pin Viking taper-pin connector used. In particular both the 2N711A and the 2N797 are available in the TO-18 can lead spacing, which will be retained in the board. A plastic washer will be inserted under the transistor can, and the transistor soldered directly to the board. All voltages will be filtered upon entrance to the board through a 0.47 μ f bypass condenser and a 10 Ω lead in. A printed component identification will be over printed on each board. Preliminary board layout has been discussed with the Photocircuits Corporation, Los Angeles.

E. Wiring Program WEB

The original 704 wiring program (logic diagrams to back panel wiring) designed specifically for the current switching logic by Grasselli, McCormick and McMullen has been resurrected. Plans call for modification of the incomplete routine (currently 3400 words) to

- (i) match the newly proposed printed circuit packaging,
- (ii) adapt the program to the 709 and hence 7090 and
- (iii) extend the logic tracing facilities of the routine.

At present one printout per connector giving all interconnector wiring - with wire lengths (grouped and color coded) - is provided.

F. Main Frame

The main frame will consist of 1 specially designed (19" panel width) rack, for the power supplies, and 2 wings - each wing containing an upper and a lower planar bay. Each bay is capable of holding 320 printed circuit cards (5 rows of 64 connectors each). The racks and wing superstructure will largely conform to IRL Assembly Drawing 7V5813A originally designed by E. J. Hendrickson and B. H. McCormick.

However, the printed circuit bays will be fabricated out of modular-constructed plastic printed circuit bins commercially produced by Applied Development Corporation of San Diego. Tentatively the Viking 44 pin taperpin connector will be used unless a superior wirewrap connector can be found.

G. Power Distribution

The four system voltages will be +6, 0, -6, 12, where all four above are used in the digital logic, the east -12V will in addition be used to feed all indicator lamps. The four system voltages will be bussed by brass strips embedded in epoxy and bounded by an aluminum U-shaped extrusion. This extrusion will run between consecutive rows of printed circuit connectors.

Each bay will be bussed directly to its own group of four power supplies: +6, -6, -12 volts. Maximum current of any power supply will be 22 amperes. Limited voltage variation Behlman-Invar supplies are proposed. These supplies are normally provided without meters. Separate over voltage protection using a power zener diode per supply will be provided by DCL. Standard meter relays, separately monitoring current and voltage will provide additional failsafe protection. A double system of E-frame breakers will be used. All power supply subsystems will be interlocked by relays so that any one supply going out of regulation will kill power for all supplies within two msec. Thermoswitch cards for overheating protection will be distributed throughout the four bays.

(B. H. McCormick)

PART V
ILLIAC USE AND OPERATION

Mr. Merlin Foster has prepared a "Handbook for Statistical Users of Illiac", File Number 429, dated January 26, 1962. The purpose of this pamphlet is to present, in a consistent form, a brief description of each of the Statistical Library Routines available to users on Illiac.

The condensed routine writeups will give, when pertinent, information on:

1. General purpose of routine.
2. Operator's Instructions.
3. The preparation of tapes to be used.
4. Estimated time for running problem.
5. FF stops (usually indicative of an error), if any.
6. Routines, if any, that will utilize the output with little or no change on output tape.
7. Comments that, it is hoped, will facilitate the use of these routines.

Copies of this Handbook can be obtained from the Laboratory.

Illiac Usage

During the month of February, specifications were presented for 14 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2138. Numbers followed by T are for theses.

2138 Chemistry. Spectrum Synthesis. An attempt will be made to synthesize a derivative absorption spectrum composed of a number of overlapping peaks. The area, width and position of each peak will be varied. The line shape for all peaks will be Gaussian in the first attempts and possibly Lorentzian later in the study. The synthesized spectrum will be plotted on the Dataplotter.

2139T Physical Education for Women. The Interrelationship of Specific Gravity, Cholesterol, Basal Metabolism Rate and Endurance of Adult Women. The purpose of the research problem is to evaluate factors such as specific gravity

of the total body, blood cholesterol content, basal metabolism rate, and endurance in young adult women, and to determine the relationship, if any, between the factors specific gravity, cholesterol and basal metabolism rate; further, to find out if there is a correlation of these three factors to endurance as measured by the one best accepted endurance test.

Finally, if the relationship proves sufficiently rectilinear, it might be possible to set up a prediction equation to predict certain types of fitness such as cardiovascular condition.

The Illiac will be used to run a fairly large number of experimental simple and multiple correlations between variables observed, such as cholesterol, specific gravity and basal metabolism rate.

The sample size is of the order of magnitude of 100 and the number of possible variables in each observation is of the order of magnitude of 50.

2140 State Water Survey. Rainfall Area Depth Analysis. For engineering design purposes, a knowledge of detailed area-rainfall depth relations for small areas is often essential. To obtain detailed information on the characteristics of the area-depth curve for small watersheds, the Water Survey has collected rainfall data on densely-gaged networks in Central and Southern Illinois. From these data, the Water Survey plans to study a two-dimensional representation of rainfall distribution over area.

The analytical procedure will consist of several steps: rank the individual raingage recordings on a given network for a selected storm duration, compute the network average, determine the ratio of the largest amount (rank #1) to the network average, the ratio of the average of ranks 1 and 2 to the network average, etc.; the ratios will be transformed to logarithms and stored in a sequence convenient for (Pl9) and the dataplotter. These steps will be repeated for all storms of the selected duration over a given gage network to generate a series of ratios for each of the areas they represent.

2141 Psychology. Guilt, Religion and Personal Ethics. The problem is an exploratory study involving analysis of variance and factor analysis of three questionnaires of sixty questions each, given to subjects divided among three religions. As each phase of the procedure depends upon the results of the previous ones, it is difficult to specify in advance exactly which programs

will be used. The operations break down as follows: analysis of variance, computation of correlation matrices, estimation of communalities, factor analysis, plotting factor pairs, and rotation of axes. The correlation matrices will be of order 60.

2142T Electrical Engineering. K-Band Accelerator. Synthesis of Electromagnetic field distributions for electron bunching accelerators will be studied. The following equations will be solved

$$\frac{d\beta}{d\theta} = -\alpha \left\{ 1 - \beta^2 \right\}^{3/2} \sin \Delta$$

$$\frac{d\xi}{d\theta} = \beta$$

where

$$\Delta = \left\{ \int_{\theta_e}^{\theta + \theta_e} \frac{\beta}{\beta_w} d\theta - \theta - \theta_e \right\}$$

$$\beta_w = \sqrt{1 - \frac{1}{\mu^2}}, \text{ and } \mu = \left(\frac{m_e}{m_0} + \alpha \xi \sin A \right)$$

$$\beta = \frac{v}{c} = \text{relative electron velocity}$$

$$\alpha = \text{normalized electric field strength}$$

$$\theta = \omega t - \theta_e, \text{ t is time, } \omega \text{ is angular frequency of electric field}$$

$$\xi \text{ is normalized distance}$$

$$\frac{m_e}{m_0} = \text{ratio of relativistic electron mass to its rest mass.}$$

2143 University of Southern California. Emotional Concepts and Differences. Sixteen emotional concepts have been measured. From each emotional concept, three factor scores were obtained. It is desired to obtain means, standard deviations and a D^2 statistic on each of 295 samples. A comparison of score

sets and profiles can then be made from these results. Obtained sums of squares of these samples can also be used in making comparisons.

2144T Psychology. Individual Differences in Perceived Personality Trait Relationships. This study concerns the determination of "qualities" of interpersonal perceptions and the differences that exist between individuals. Factor analyses of several groups of individuals are applied to sums of squares and sums of cross-products matrices of ratings of similarity-dissimilarity between pairs of trait names.

2145T Physics. Least Square Fits. This problem arises in connection with an experiment in electron spin resonance. At present, the spatial variation of the magnetic field of a newly installed magnet is to be studied. The least squares method for finding polynomial fits will be used to determine the relation between magnetic field and current through the magnet.

2146 Physical Education. Factorial Study of Psychological and Physiological Variables. The purpose of the study is to classify a set of data involving 26 psychological and 30 physiological tests by means of a centroid factor analysis and rotation of the factors to an oblique simple structure solution. The specific library routines involved in such an analysis are K-8, product moment correlations; KSL 1.20-251, centroid factors with fixed communalities; KSL 1.90-288, oblimax rotation of factors; and KSL 1.96, combined rotation routine.

2147 Psychology. Second Order Integration. Eleven studies have been done to determine the second order personality factors through the use of a test called the 16PF. Each study found slightly different factors because of sample difference and differences of analysis and rotation. The present study seeks to integrate these studies so that the nature of the second order factors can be determined.

The work will proceed by combining and averaging the correlation matrices from each of the studies into two new correlation matrices. One of these will be based on those studies utilizing a college sample, and the other on those based on a more general sample. Both matrices will be analyzed by the principal axis method of factor analysis and rotated to simple structure.

The two resulting sets of factors will then be compared and matched by the analytical methods of the Statistical Library. Conclusions will then be drawn as to the "established" second order personality factors.

2148T Psychology. National Morale and Morality. Several factor analyses of data on nations have been done and some ten factors confirmed. Among the replicated factors appears one labeled "poor cultural integration and morale versus good morale and morality", and is the major concern of the present study. Major markers for this factor include the death rates from syphilis and alcoholism, restriction in divorce, and the extent of railroads (sic). An attempt will be made to clarify the exact nature of the factor and uncover other possible relationships and markers which were not uncovered in the other studies due to the limited number of variables in this particular area.

The present field study is of a correlational and factor analytic nature. Twenty variables from previous studies have been selected to act as markers to obtain some degree of continuity across studies. Twenty-four more variables are being selected to measure various facets of morale and morality.

After collection of the data for some 50 nations, the marker variables and other selected variables will be correlated, factorized by the principal axis method, and rotated to simple structure. The new variables not in the factor analysis will be related to the analysis by the Dywer extension method utilizing the following formula:

$$C \left[V_0 (V_0' V_0)^{-1} \right] \lambda$$

where C is the correlation matrix of variables in the factor analysis and the extension variables.

V_0 = principal axis matrix of factor loadings.

λ = transformation matrix to final rotation.

A similar extension will be performed on random numbers to empirically estimate the significance of the extension variables' loadings.

The factors so determined will be related to the previous studies in the area.

Also, the reliabilities of the measures will be determined by correlation.

2149T Digital Computer Laboratory. Investigations in Speed Independent Logic. In the very early stages of the planning for the new Illinois computer, it was decided that the arithmetic control logic should operate in a speed independent manner. Although this has been the objective throughout the design of the arithmetic control, there are several ways in which the final circuitry fails to meet the requirements of speed independence. Since the design of sequential logic, like many other synthesis procedures, does not produce a unique topology, it is possible that a different form of logic might have fewer practical difficulties in meeting the requirements of the mathematical model of a speed independent circuit. It is the objective of this investigation to determine and evaluate several alternative approaches to the problem. During the investigation, the circuit logic routines Q3, Q4 and Q5 will be used to examine logic diagrams for speed independent operation and the various circuit analysis routines will be used to design circuit elements which more nearly satisfy the specifications of the speed independent model.

2150T Physics. Ground State Functional of a Quantum Field Theory. It is desired to find variational solutions for the ground-state functional $\Psi_0 [\phi(\vec{x}, t)]$ of a quantum field theory with nonlinear interaction. The field satisfies the Hamiltonian equation

$$H = \pi^2(x) + m^2 \phi^2(x) + g_0 \phi^4(x) + (\text{grad } \phi)^2,$$

where m and g_0 are parameters and $\pi = \frac{d\phi}{dt}$.

Illiac will be used in several ways: to solve six-dimensional matrix equations arising from a lattice-space discretization of the field equation; to evaluate the ground-state functional using matrix or linear equations; to solve integral equations for optimal values of various parameters; to evaluate integrals of distribution functions for the fields and associated functions; to solve for eigenvalues and eigenfunctions of differential equations governing the field behavior in the lattice-space cells; and to integrate numerically trial functions to find transition and scattering properties and probabilities.

2151T Chemistry. Formic Acid Rate Constants. The solution of the kinetic data in order to obtain various rate constants for the photochemical decomposition of formic acid involves solving a set of five linear equations in five unknowns.

The experimental data produced many different sets of such equations. The initial calculation will be used in solving a number of different sets in order to determine whether further sets will have to be calculated.

Table I shows the distribution of Illiac machine time for the month of February. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min	
Scheduled Maintenance	59:04	
Unscheduled Maintenance	17:39	
Drum Engineering	6:46	
Leapfrog	11:37	
Library Development	2:37	
Classes	3:20	
RAR	:05	
	<hr/>	
	101:08	
Use by Departments		
Aeronautical Engineering	3:25	
Agricultural Economics	6:42	(4:23)
Agronomy	:05	
Animal Science	2:18	(:18)
Astronomy (NSFG 16569)	:06	
Astronomy (NSFG 14834)	8:30	
Bureau of Economic and Business Research	1:37	(:15)
Bur. of Educational Res. (PH-M1839)	1:09	
Chemistry (NSFG 7336)	1:01	
Chemistry (NSFG 5907)	4:33	
Chemistry (PH-A3551)	:17	
Chemistry	55:15	(2:28)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	4:31	
Civil Engineering (DA-104)	:06	
Civil Engineering	45:29	(8:32)
Coordinated Science Lab. (DA36039)	117:25	
Digital Computer Lab. (AEC AT(11-1)-415)	1:27	
Digital Computer Lab. (USTR AEC-1018)	3:52	
Digital Computer Lab. (NONR 1834(27))	:20	
Digital Computer Laboratory	:49	
Economics (NSFG 7056)	:34	
Electrical Eng. (NONR 1834(22))	:34	
Electrical Eng. (NASA-NSG 24-59)	22:47	
Electrical Eng. (AF7043)	9:08	
Electrical Eng. (NOBSR 64723)	:20	
Electrical Eng. (SC 85173)	1:09	
Electrical Eng. (AF 33(616)6079)	:07	
Electrical Eng. (NSFG 19005)	1:22	
Electrical Eng. (NSFG 14894)	4:38	
Electrical Engineering	16:58	(3:04)

Food Technology	21:56	(8:41)
Geology	:30	
Inst. of Comm. Res. (44-28-20-378)	5:06	
Inst. of Comm. Res. (USPHM-3941)	3:17	
Inst. for Res. on Exceptional Children	:13	
Mechanical Eng. (DA-11-022-ORD 1980)	:12	
Mechanical Eng. (NSG-13-59)	4:22	
Mechanical Engineering	66:31	(:04)
Min. and Met. Eng. (TRUS AF 6770)	:08	
Music	2:06	(2:36)
Office of Inst. TV (OE 7-11-107.00)	7:05	
Physical Education	1:10	(:12)
Physics (NONR 1834(05)A)	:69	
Physics (NSF 14 308)	:56	
Physics (NSFG-17428)	:27	
Physics	4:38	
Psychology (MD 2060)	:17	
Psychology (AF 41-657-279)	:20	
Psychology (AF 49(638)371)	:08	
Psychology (USPH 45-32-66-373)	6:56	
Psychology (ML774)	3:10	
Psychology (ONR 1834-36)	:28	
Psychology	63:55	(18:00)
Sociology		(:33)
State Geological Survey	:04	
State Water Survey (DA-36-039-SC75055)	4:56	
State Water Survey	4:58	
Theo. and Appl. Mech. (DA-11-070-508ORD)	5:19	
Theo. and Appl. Mech. (DA-01-021ORD11878)	3:20	
Theoretical and Applied Mechanics	1:40	
University of Southern California	1:03	
United States Navy	1:05	
	<u>570:52</u>	<u>(45:18)</u>
		<u>672:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of

the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Control	1
Memory	5
Drum	10
Power Supplies	2
Punch	4
Reader	3
Unknown	<u>4</u>
Total	29

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/1/62	20:19	:00	3:41	0	(1) Drum failure. (2) Drum failure.	:00	:25	0
2/2/62	21:20	:23	2:17	2	(1) Drum failure.	:00	:15	0
2/3/62	23:50	:10	:00	1	(1) Reader "I" failed. (2) Drum failure.	:00	:05	0
2/4/62	22:03	1:57	:00	2				
2/5/62	20:49	:00	3:11	0		:00	:36	0
2/6/62	23:00	:00	1:00	0		:00	:39	0
2/7/62	20:22	:00	3:38	0		:00	:31	0
2/8/62	20:50	:00	3:10	0		:00	1:00	0
2/9/62	21:33	:00	2:27	0		:00	:20	0
2/10/62	20:22	3:38	:00	2	(1) Drum failure. (2) Drum failure.	:00	:00	0
2/11/62	18:35	5:25	:00	5	(1) Memory failure, pos. 2-36. (2) Leapfrog, unknown. (3) -2000 v power supply. (4) Leapfrog, unknown. (5) Drum failure.	:00	1:10	2
2/12/62	21:30	2:30	:00	0		:00	:09	0
2/13/62	20:41	:45	2:30	3	(1) Reader "B" failed. (2) 2000 v. power supply. (3) Punch 3 jammed.	:00	:21	0
2/14/62	20:33	:45	2:42	2	(1) Unknown. (2) Punch 3 jammed.	:00	:14	0
2/15/62	20:13	1:17	2:30	3	(1) Memory pos. 26 and pos. 36. (2) Unknown. (3) Punch 1 failed.	:00	:17	0
2/16/62	20:45	:45	2:30	1	(1) Address generator erratic (memory).	:00	:13	0
2/17/62	24:00	:00	:00	0		:00	:00	0
2/18/62	24:00	:00	:00	0		:00	:17	0
2/19/62	20:38	:18	3:00	1	(1) Control error.	:00	:15	0
2/20/62	21:00	:00	3:00	0		:00	:15	0
2/21/62	20:33	:00	3:27	0		:00	:30	0
2/22/62	20:12	:28	3:20	1	(1) Drum failure.	:00	:19	0
2/23/62	21:15	:05	2:40	1	(1) Punch number 1 failed.	:00	:42	0
2/24/62	24:00	:00	:00	0		:00	:10	0
2/25/62	23:36	:24	:00	1	(1) Reader "H" failed.	:00	:22	0
2/26/62	19:43	:40	3:37	2	(1) Memory failure, regeneration chassis replaced. (2) Drum failure.	:00	:31	0
2/27/62	19:41	1:46	2:33	2	(1) Memory control. (2) Drum failure.	:00	:20	0
2/28/62	20:48	:00	3:12	0		:00	:49	0
TOTALS	596:11	18:46	57:03	29		:00	10:45	2

PART VI
INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

New International Business Machines 650 Codes

During the month of February, three new routines were added to the International Business Machines 650 Library.

X14' - 86' TRANSCRIBE - 1604 Fortran-Codap Pre and Post Editor.

This 650 routine has been prepared to facilitate production and service usage of the Coordinated Science Laboratory's CDC 1604. The routine allows 1604 FORTRAN or 1604 CODAP cards to be translated to magnetic tape on the 650 in such a way that the 1604 can subsequently read this tape.

It also permits a 1604 output magnetic tape to be read by the 650 and printed on the 407.

X13' - 85' Drum, High Speed Memory, and Register Clear Routine.

This program clears the entire drum, the entire I.A.S., the upper and lower accumulator, the distributor, all three index registers, and leaves the timing ring at 9000. The program exits to the storage entry switches.

K10' - 79' Statistical Matrix Processor (STAMP). STAMP is a system of compatible programs for doing a number of basic matrix operations and some related statistical computations. Every assembled program deck consists of the control deck plus the appropriate sub-decks from the STAMP library to do the problem. Data matrices having up to 249 columns (variables) are read from data cards and recorded as floating point numbers on magnetic tape. Each sub-program reads the data from a designated tape unit, processes it and writes the computed information on another tape unit, thus alternating between two tape units 8010

and 8011 until the system is completely processed. Several problems can be done in one run by batching the data and using the proper sequence of control cards.

STAMP can recognize many of the more common errors. This information is coded and printed on-line with enough information to identify its nature and position. If there is more than one problem being processed, only the data matrix having the error is by-passed.

International Business Machines 650 Usage

During the month of February, specifications were presented for 13 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 368'. Numbers followed by T are for theses.

368' Civil Engineering. Stress-Strain Curve for Granular Medium. The problem consists of solving four simultaneous non-linear differential equations which have to be solved numerically rather than in a closed form. The main object is to get the stress-strain curve of a granular medium under general conditions.

369' Civil Engineering. Anchorage Zone Stresses in Pre-Stressed Concrete. The stresses in the end block of a pre-stressed concrete beam can be expressed by a fourth order differential equation

$$\frac{\delta^4 \phi}{\delta x^4} + 2 \frac{\delta^2 \phi}{\delta x^2 \delta y^2} + \frac{\delta^4 \phi}{\delta y^4} = 0$$

where ϕ is the stress function.

This equation is written at all the interior node points of a grid-work, by expressing it in terms of finite difference equations. The finite difference equations are solved by successive approximations using the Gauss-Seidel procedure.

When the value of ϕ at all points has been obtained, the stresses are calculated using finite difference equations.

370' Animal Science. Interrelationships and Estimations of Gross Chemical Components of Porcine Musculature. The calculation of means, standard deviations and simple correlations for eight different variables describing pork quality will be carried out.

371' Physics. Deuteron Break-Up. The problem is to calculate Deuteron Break-Up, including final state interaction and multiple scattering corrections. The cross-section for the process is written as a series of terms, leading terms of which contain expressions of the type

$$\frac{1}{a^2 + k^2 \pm k\mu}$$

and the products of such terms which have to be evaluated for different values of k , μ and a . Multiple scattering correction forms have principal value integrals to be performed numerically, and are of the form

$$P \int_0^{\infty} \frac{f(k)}{k_0^2 - k^2} dk,$$

where $f(k)$ contains forms of the type

$$\frac{1}{a^2 + k^2 \pm k\mu}$$

and products of such forms. It is proposed to integrate this by first plotting

$$\frac{f(k)}{k_0^2 - k^2}$$

for a given k_0 (which will indicate how much of the range around k_0 could be omitted in the principal value integral) and then to evaluate the integral in the range thus found. This process will have to be repeated for a set of k_0 .

In the terms of the form

$$\frac{1}{a^2 + k^2 \pm k\mu}$$

a typical term is

$$\frac{1}{\beta^2 + |(\vec{p}-\vec{k})|^2} = g(\beta, p, k)$$

where one may write

$$a^2 = \beta^2 + p^2, \mu = 2 p \cos \theta,$$

(where β = range of nuclear force, k = momentum of one particle, p = momentum of another and θ = angle between p and k).

372'T Physics. Search for Regge Trajectories. The problem is first to solve the differential equation (Schrodinger Equation with no potential)

$$\frac{d^2 f(x)}{dx^2} + \left(1 - \frac{\lambda^2 - 1/4}{x^2}\right) f(x) = 0$$

for complex $\lambda = \mu + i\nu$ by using a series solution to set up $f(x_0)$ and $f'(x_0)$ for some x_0 and then integrate the differential equation from x_0 out to some x . The solutions are $\sqrt{x} J_{\mu+i\nu}(x)$ and $\sqrt{x} N_{\mu+i\nu}(x)$ (Bessel Functions). The method is chosen because of the nature of the rest of the problem and because it may be the best way to determine the Bessel Functions separately, without finding a linear combination, by choosing x_0 properly. Once this is accomplished, one then solves the problem with a potential

$$f_{\lambda}''(x) + \left(1 - \frac{v(x)}{k^2} - \frac{\lambda^2 - 1/4}{x^2}\right) f_{\lambda}(x) = 0$$

as an eigenvalue problem with k as a parameter. One wishes to find the values of $\lambda(k^2) = \mu(k^2) + i\nu(k^2)$ for which the equation has a solution satisfying the boundary condition of outgoing waves beyond the range of the potential, i. e., one matches the logarithmic derivative of $f_{\lambda(k^2)}(x_1)$ to that of $\sqrt{x} H_{\lambda}^{(1)}(x_1)$ (Hankel Function). The ultimate information required is a graph of the values of $\lambda(k^2)$ for which the equation has a solution of the outgoing wave type.

The problem is of interest because of recent conjectures by elementary particle physicists concerning the nature of an analytic continuation of scattering amplitudes into the complex angular momentum plane.

373'T Physics. Spherical Bessel Functions. This is a subroutine to calculate the spherical Bessel functions of the first and second kind to be used in a larger program. The spherical Bessel functions $j_\ell(x)$ and $n_\ell(x)$ are defined for the first two values of ℓ as

$$j_0(x) = \frac{\sin x}{x}$$

$$n_0(x) = -\frac{\cos x}{x}$$

$$j_1(x) = \frac{\sin x}{x^2} - \frac{\cos x}{x}$$

$$n_1(x) = -\frac{\sin x}{x} - \frac{\cos x}{x^2}$$

Bessel functions of higher order are calculated using the following recursion relation

$$\frac{2\ell+1}{x} z_\ell(x) = z_{\ell-1}'(x) + z_{\ell+1}'(x)$$

where z is either n or j .

The functions of the second kind $n_\ell(x)$ are calculated by evaluating $n_0(x)$ and $n_1(x)$ and using the recursion relation. Those of the first kind are calculated by starting at a value of ℓ larger than the maximum one required and working back to smaller values. If the initial value of $\ell = \ell_m$ is large enough the function calculated using the recursion relation is independent of the initial value of $j_m(x)$, except for a constant of proportionality. This constant is calculated by comparing the value of $j_0(x)$ evaluated with the recursion relation to the actual one $\frac{\sin x}{x}$. The value of ℓ_m is found from the equation

$$x^{2(\ell_m - N+1)} \frac{(2N+1)!!(2N-1)!!}{(2\ell_m+3)!!(2\ell_m+1)!!} < \epsilon$$

ϵ is the maximum allowable error

$$N = [\ell + x + 1]$$

$$(2N+1)!! = (2N+1)(2N-1)(2N-3)\cdots 5 \cdot 3 \cdot 1$$

374' Agronomy. Field Crop Weed Control. This research involves the testing of new weed control chemicals on various agronomic crops. Often different rates of the chemicals will be used to see at what concentration the material is harmful to the crops. Analysis of variance will be used to calculate differences in

rates of materials as well as giving the means associated with the different rates.

375'T Civil Engineering. Analytical Study of Composite Beam with Inelastic Shear Connection. The problem is to investigate the behavior and ultimate strength of a composite beam structure with inelastic shear connection. A range of variables is chosen in order that a certain criteria which may be applied to the design of highway bridges can be developed. A trial and error procedure is used to handle the problem when the beam is in the plastic range. The problem is formulated in difference equations which form a band matrix.

376'T University of Kentucky. Analysis of Cantilevered Folded Plates. In the past, the advantages of using folded plate analysis have been partially offset by the time consuming calculations required for the design. Folded plates with cantilevers are even more complex than simply supported ones, and due to this great complexity, no analyses for this type of structure have been carried through.

It is the purpose of this thesis to study the parameters which affect the stress magnitudes in such a structure by programming a numerical analysis based upon an extension of Simpson's method for simply supported folded plates.

The program requires an IBM 650 with floating point arithmetic, tape storage, core storage and index registers. The program itself will be contained on a tape which will be read in as needed and the intermediate results will also be written on tape. The final results will be punched on cards. It is not certain at this time whether two or three tape units will be needed. The time of running will vary with the number of plates and is roughly estimated to average thirty minutes per structure.

377' Chemistry. Chemistry Subject Pool. This program assigns teaching assistants to the chemistry courses they are required to teach. It does this on the basis of capability of assistant versus difficulty of course, number of hours required of assistant to teach versus number hours credit given by teaching the course, and the hours available on the part of the assistant to teach versus the hours the courses meet.

This program will require approximately 1 hour, 45 minutes once a semester. The time needed will fall the day before classes meet for the first time in each semester.

378'T Civil Engineering. Effect of Beam Torsion on Bending of Plate-Beam Systems. The effects of beam torsional stiffness on the bending behavior of a typical plate-beam system will be investigated via finite difference approximations. Node points will be defined by a square grid superimposed on the plate, and a program will be written to write the finite difference equations on tape. Using L1' - 71', one will solve for the deflection under a given system of loading. If a sufficiently fine grid is used, the number of equations would exceed the capacity of the drum memory. Thus, each loading case will be broken up into four symmetric and anti-symmetric cases, thereby retaining the fineness of the grid. For each loading case, four sets of 60 equations will be written and solved. Thus, a separate program will be written to combine the results.

379'T Physics. T-Matrix Off Energy Shell. The t-matrix off the energy shell $t(q, q_0, q_1)$ is to be calculated for a square well for an arbitrary partial wave. Since the t-matrix goes to zero as the momenta go to zero, it is more convenient to calculate another quantity. $T_l(q, q_0, q_1) = t_l(q, q_0, q_1)/(q_0^l q_1^l)$. The ratio of the off-energy to on-energy t-matrices

$$R = \frac{t_l(q, q_0, q_1)}{t_l(q, q, q)}$$

is to be calculated. The input data are

l = order of partial wave

$$R = \sqrt{-\frac{2m V_0}{h^2}} = \text{well depth}$$

q = momentum on energy shell

q_0 = incoming momentum

q_1 = outgoing momentum.

The t-matrix and the ratio R will in general be complex. The expressions to be evaluated are

$$T_l(q, q_0, q_1) = \frac{\beta^2(q^2 - q_0^2)}{\alpha^2 - q_0^2} f(q_1, q_0) + \frac{\beta^2 f(\alpha, q_1)}{\alpha^2 - q_0^2} \left[\frac{(q_0^2 - q^2)g(q_0, q) + i(q^2 - q_0^2)f(q_0, q)}{g(\alpha, q) - i f(\alpha, q) g^l} \right]$$

where $\alpha = \sqrt{\beta^2 + q^2}$

$$f(x, y) = \frac{x j_\ell(y) j_{\ell+1}(x) - y j_\ell(x) j_{\ell+1}(y)}{x^{\ell+1} y^{\ell+1} (x^2 - y^2)}$$

$$g(x, y) = \frac{x n_\ell(y) j_{\ell+1}(x) - y j_\ell(x) n_{\ell+1}(y)}{x^{\ell+1} (x^2 - y^2)}$$

$j_\ell(x)$ = spherical Bessel function

$n_\ell(x)$ = spherical Neumann function.

A subroutine has been written to calculate these functions. The output will consist of

Real part of $t_\ell(q, q_0, q_1)$.

Imaginary part of $t_\ell(q, q_0, q_1)$.

Real part of R.

Imaginary part of R.

δ = phase shift.

$$\delta = \tan^{-1} \frac{\text{Im } t_\ell(q, q, q)}{\text{Re } t_\ell(q, q, q)}.$$

380' Civil Engineering. Queueing Theory in the Design of Construction Operations. The design of construction operations with variable demand and supply is being studied by the application of the theory of queues. The effects of various forms of discrete probability distributions for these quantities on the results of a design procedure is the subject of this initial pilot study.

The computer will be used to obtain answers to previously derived closed solutions of sets of "detailed-balance" differential equations, i. e., birth and death functions in their steady-states.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of February.

TABLE I'

		Hrs:Min
Scheduled Engineering		14:28
Unscheduled Engineering		32:08
Air Conditioning		3:08
Tape Testing		5:03
Log Summary		:43
CDC Preparation		1:54
Library Development		31:55
Agronomy Library	1:37	
DCL Library	<u>30:18</u>	
Classes		6:53
Civil Engineering	:28	
Electrical Engineering	:49	
Mathematics	3:02	
Mechanical Engineering	:16	
Nuclear Engineering	1:56	
Physics	<u>:22</u>	
Demonstrations		1:26
Wasted		<u>10:36</u>
		108:14

Use by Departments

Agricultural Economics		3:18
Agronomy		8:28
Chemistry		21:51
Civil Engineering		25:25
Electrical Engineering		7:12
Entomology		:15
Food Technology		3:37
Graduate College		11:53
Graduate School of Business		1:51
Mechanical Engineering		10:37
Mining and Metallurgical Engineering		1:02
Physics		13:42
Psychology		:34
Small Homes Council		:16
State Water Survey		11:12
Statistical Service Unit		96:55
Agricultural Economics	5:55	
Bureau of Community Planning	10:51	
Bureau of Educational Research	:15	
Bureau of Institutional Research	2:04	
Bursar's Office	7:08	
Business Office	12:25	
DHIA	37:23	

Education	14:52	
Mining and Metallurgical Engineering	3:28	
Statistical Service Unit	:04	
Student Counseling	<u>2:30</u>	
Theoretical and Applied Mechanics		1:03
University of Kentucky		<u>:31</u>
		<u>219:42</u>
		<u>327:56</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for February.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

Clock		1
Air conditioning		1
Outside fans	<u>1</u>	
533 card read punch		5
Does not read	2	
Reads incorrectly	2	
Card jam	<u>1</u>	
653 high speed storage, floating point and index registers		2
Fuse	<u>2</u>	
650 console		2
Loops on computer reset	1	
Extra bits picked up	<u>1</u>	
652 tape control		1
Fuse	<u>1</u>	
407 accounting machine		9
Spaces incorrectly	2	
Prints incorrectly	4	
Would not print	2	
Restores improperly	<u>1</u>	
	TOTAL	21

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
2/1/62	15:28		:12	:15	1		(1) 407 spacing incorrectly when on line; bad relay points found.
2/2/62	15:35		:28	:12	1		(1) 533 read not reading cards correctly; side plates adjusted.
2/5/62	10:18	3:50	1:37	:10	1		(1) Main fuse in 653 blew. Replaced.
2/6/62	10:53		6:35	:12	4		(1) Fuse blew in 652. (2) Fuse blew in 653. (3) Digit 3 of word 3 not printing on line; bad tube. (4) Word 3 digits 1,2, and 3 printing alpha incorrectly. Bad tube in 655 found.
2/7/62	14:24		1:43	:13	1		(1) Word 3 printing incorrectly. New circuit breakers installed in 407.
2/8/62	12:56		4:15	:19	1		(1) Could not do a computer reset and go to 8000. Bad tube in 653 found.
2/9/62	14:55		:50	:10	0		(1) Outside air conditioning fans needed adjustments.
2/12/62	10:02	3:35			1	2:18	
2/13/62	16:51			:10	0		(1) 407 not printing digit 9 in word 5. Bad tube found in 655.
2/14/62	15:29		:05	:19	1		
2/15/62	16:34			:21	0		(1) Card jam in 533 read. (2) 407 would not print on line. Reason unknown.
2/16/62	15:15		:23	:20	2		
2/19/62	12:20	3:40	4:27	2:08	0		(1)-(2) Cards cycle through 533 read but are not read. Clutch needed adjustment. Later found armature needed adjustment.
2/20/62	10:12				2		(1) All lights come on during first read cycle. Defective tube caused extra bits to be picked up.
2/21/62	12:25		3:08	:33	1		
2/22/62	15:52			:20	0	:50	
2/23/62	13:03		2:50	:11	0		
2/26/62	10:56	3:23	:08	1:12	1		(1) 407 restore key not behaving properly. Discovered paper was working off the track.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
2/27/62	12:03		1:19	3:18	2		(1) 407 giving extra spaces both on line and off line. Carriage relay cleaned. (2) Clock not advancing. Needed to be oiled.
2/28/62	12:05		4:08	:13	2		(1) 407 refused to print on line. Print start relays cleaned. (2) 533 reading multiple bits. Cleaned and adjusted upper and lower points on card levers.
TOTALS	267:36	14:28	32:08	10:36	21	3:08	

PART VII
INSTRUCTIONAL USE OF COMPUTERS

During the month of February, specifications were presented for nine new problems.

37 Nuclear Engineering 490. Problem 1. IBM 650. Multi-Energy Group Reactor Dynamics. The dynamics of a fast reactor will be simulated by a linearized model, using three neutron energy groups and six precursor nuclei which emit delayed neutrons. The reactor response to step and sinusoidal changes in reactivity will be studied, and comparison will be attempted with the results of a simple non-linear model.

The program will involve the solution of nine first order differential equations relating the neutron flux in the three energy groups to the precursor densities.

The program will be written in GAT.

38 Mechanical Engineering 409. Problem 1. ILLIAC. Eigenvalue. A solution of the matrix equation $A - B\lambda = 0$ will be obtained. A and B are matrices of third or higher order.

39 Chemistry. Informal Course. Problem 1. ILLIAC. Prime Factors of an Integer. Write a program which will read integers from a data tape of the form

```
+ D---DN
+ D---DN
+ D---DN
-----
+ D---DN
J
```

and compute the factors of the integers.

The program should read one integer from the tape, print one CR/LF and print the smallest prime factor. If the factor is repeated print five spaces and print the number of times it is repeated. Then print CR/LF and the next largest prime factor and multiplicity. If the factor occurs only once, do not print its multiplicity. When all factors and their respective

multiplicities have been printed, print CR/LF four times and repeat until a J is encountered. Then stop. Use N12 and P16 for reading and writing, respectively.

40 Mathematics 395. Problem 1. IBM 650. Machine Problem #1. A GAT program for the determination of certain functions of a square matrix array is required. The values of the elements will be provided in the form of data cards in the GAT format. The names of the elements of the array are $X_1, X_2, \dots, X(KO)^2$, where KO , the order of the matrix, is furnished on one of the data cards. Assume that KO will not exceed 10 and that the matrix variable correspondence is as given on page 26 of the GAT manual.

A. The program will calculate, in floating point, and using GAT language in the ATHOS system:

1. The sum of the elements in each row.
2. The sum of the elements in each column.
3. The Trace (sum of the diagonal elements).
4. The number of elements equal to zero.
5. The sum of the elements lying below (but not on) the diagonal, omitting from the sum all elements whose absolute value is greater than 1.

Your name and course are to appear at the head of the compilation and the words "PROBLEM ONE - RESULTS" are to be printed after the compilation and before the results.

B. Make a flow diagram using the conventions given in class keeping in mind the functioning of GAT object programs.

C. List the meanings of all of the GAT variables in a table.

D. Call for a full GAT dump (GATFL) after execution. Do not punch!

Turn in:

1. The flow diagram.
2. The entire final printout.
3. The table of variable definitions.
4. A list of subroutines your program will use.

Assume that your goal is to keep the source program as short as possible. Excluding executive statements you should be able to do it with 30 statements. See if you can do it in 20!

41 Physics 341. Problem 1. IBM 650. Low Resistance. This problem will calculate the experimental low resistances and resistivity from data received from a Kelvin double bridge. GAT will be used.

42 Electrical Engineering 453. Problem 1. Fourier Transformation. Given the sampled values of a function $f(t)$, find its Fourier transform

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t} dt$$

and plot the results as amplitude and phase versus $\log \omega$.

The sampled values of $f(t)$ are given as a deck of data cards. Choose a convenient value for Δt . Choose a sufficient number of ω_i so that the plots are clear and unambiguous. Start with a reasonably small value of ω (you can't start with zero, of course), and extend ω so that the plots cover a range of at least 40 db. Let the level for zero db be set by the value of $|F(0)|$.

Plot the results on semi-log paper, i.e., do the calculation of db on the machine. You may use any method of integration you wish. The GAT manual shows a sample of Simpson's rule integration.

43 Industrial Engineering 283. Problem 1. IBM 650. IE283-Problem 1. This is a payroll problem. Each student has punched payroll cards for three employees for each of 14 days. The program computes and prints gross pay, social security tax, income tax, union dues, charity, deductions and net pay. A SOAP routine is used.

44 Mechanical Engineering 442. Problem 1. IBM 650. Analytical Force Analysis of a Slider Crank Mechanism. The analytical force analysis of a slider crank mechanism calls for calculating the forces at the ends of the crank for various crank angles. The conventional laws of statics and dynamics are used.

45 Mathematics 457. Problem 1. ILLIAC. Solution of Linear Differential Equation by Milne's Method. This routine will solve

$$y' = y - \frac{2x}{y} \quad \begin{array}{l} 31 \leq x \leq 60, \\ (x = 60, y = 11.00000) \end{array}$$

for steps of length 1.

A first approximation to Y_{k+1} will be obtained by using

$$y_{k+1} = y_{k-3} + 4hy'_{k-1} + \frac{8}{3} h (y'_{k-2} - 2y'_{k-1} + y'_k).$$

This first approximation will be used in the iterative equation:

$$y_{k+1} = y_{k-1} + \frac{h}{3} (y'_{k-1} + 4y'_k + y'_{k+1}).$$

Five decimal accuracy is required.

The three sets of past data (i. e., y'_{k-3} , y'_{k-2} , y'_{k-1}) will be obtained by Taylor's Series:

$$y'_{k-j} = y'_k + y''_k (-jh) + y'''_k \frac{(-jh)^2}{2!} + \dots$$

PART VIII
CONTROL DATA CORPORATION 1604

During the month of February, specifications were presented for three new problems. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 7T. Numbers followed by T are for theses.

7T Chemistry. Unimolecular Dissociation Reactions. A molecular model for a chain molecule is taken as four point masses in a line. The equations of classical motion are assumed valid, and a modified Morse function is taken to represent the potential energy between atoms. This work is designed as a test of two commonly used theories of reaction mechanisms, i. e., that of Slater and that of Kassel.

8T Civil Engineering. Stresses Around a Cylindrical Hole in an Infinite Medium Due to a Plane Wave. A cylindrical wave is allowed to propagate outward from a line source so that a cylindrical boundary around the source has no stress because the outgoing stress and incoming stress cancel one another at the boundary. The stresses for both the incident and outgoing waves are written in terms of Fourier series. The incident wave is completely known, and the Fourier coefficients for the outgoing wave are adjusted so that the boundary condition is satisfied. This must be done for each time step, and there are two simultaneous equations from the two boundary conditions at each time step. Most of the computer time will be used in numerical integrations. The form of the two equations to be solved is

$$\begin{aligned} \frac{\sigma}{2\pi} \left[(1-\bar{v}) \sin \alpha + \frac{1}{3} (1-\bar{v}) \sin 3\alpha \right] &= (\lambda+2\mu) \left[\int_G \frac{-1}{3} \int F''''(\xi) (1+\eta^2) d\eta \right. \\ &+ \frac{1}{rc_2^2} \int G''(\xi) \sqrt{1+\eta^2} d\eta + \frac{1}{r^2 c_2^2} \int G'(\xi) d\eta \left. \right] + \frac{\lambda}{r} \left[\frac{1}{c_1^2} \int F'(\xi) \sqrt{1+\eta^2} d\eta \right. \\ &- \frac{1}{r^2 c_2^2} \int G'(\xi) d\eta + \frac{1}{rc_1} \int F'(\xi) d\eta - \frac{1}{c_2^2} \int G''(\xi) \sqrt{1+\eta^2} \end{aligned}$$

where

μ, λ = Lama's constants

ν = Poisson's ratio

$$\xi = (t = \frac{a}{c_1} \sqrt{1 + \eta^2})$$

t = time

a = radius of hole

c_1 = velocity of dilatational wave

c_2 = velocity of shear wave

r = radial distance from center of hole

$$\eta = \frac{z}{a}$$

z = distance down the center of the hole from which waves have had time to travel

$\alpha = \cos^{-1} (1 - \frac{tc}{a})$ = the angle which gives the location of the front of the plane wave as it crosses the hole.

These are solved for $F'''(\xi)$ and $G'''(\xi)$. From these values the potential functions, and therefore the stresses, may be found. An important point is that for each time step all the integrations must be started again, since for the new time step, the values of the partials of F and G do not correspond to the same values of η as on the last time step.

9 Chemistry. Monte Carlo Diffusion Kinetics. The research problem is the same as that described under Illiac number 2028. It is an investigation of correlation effects in radiation chemistry diffusion kinetics. A random walk model will be used for diffusion, and chemical "reactions" will take place among the free-radical particles according to pre-assigned probabilities. Results will be compared with previous calculations based on an analytical model neglecting correlation.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part V.

CDC 1604 TIME DISTRIBUTION

February, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	4:23			4:23
Animal Science	:18			:18
Bur. of Economic and Bus. Res.	:15			:15
Chemistry	2:28	4:01		6:29
Civil Engineering	8:32	1:14		9:46
Electrical Engineering	3:04			3:04
Food Technology	8:41			8:41
Mechanical Engineering	:04			:04
Music	2:36			2:36
Physical Education	:12			:12
Physics		7:10		7:10
Psychology	18:00			18:00
Sociology	:33			:33
Maintenance			:56	:56
TOTALS	45:18	12:25	:56	58:39

PART IX
GENERAL LABORATORY INFORMATION

Seminars

"New Console Control Technique in the Numerical Solution of Large Scale Arithmetic Computations," by Dr. G. C. Culler, Associate Director of Research Laboratory, Ramo-Wooldridge Corporation, February 5, 1962

"Some Properties of the Lyapunov Mapping $X \rightarrow AX + XA^*$," by Wallace Givens, Department of Engineering Sciences, Northwestern University, Evanston, Illinois, February 12, 1962

"The Use of Computers in the Monitoring of Laboratory Experiments in the Behavioral Sciences and the Construction of Simple Economic Games for the Study of Human Behavior," by Professor Austin Hoggatt, Director, Computer Center, University of California, Berkeley, California, February 19, 1962

"Context Free and Programming Languages," by Professor Marcel P. Schuetzenberger, Medical School, Harvard University, Boston 15, Massachusetts, February 26, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Research Associates	7	0	7.0
Graduate Research Assistants	10	20	22.0
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	8	0	8.0
Other Nonacademic Personnel	<u>39</u>	<u>18</u>	<u>44.75</u>
TOTAL	76	42	95.75

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

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- PART VII - IBM 7090-1401
- PART VIII - INSTRUCTIONAL USE OF COMPUTERS
- PART IX - CONTROL DATA CORPORATION 1604
- PART X - GENERAL LABORATORY INFORMATION

March, 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1) 415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1) 415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Table I summarizes the progress during the month toward completion of the computer. Entries in Table I indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of Table I, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

The static test involves application of DC power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspection.

TABLE I

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	
Core Storage Unit (4096 words) 3937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	10,285	10,285	9,581 704 10,285	9,266 1,019 10,285	8,421 1,864 10,285	1,699 2,244 3,943	
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,709	
Advanced Control 6800	6,800	6,400 0 6,400	5,200 0 5,200	2,151 983 3,134	1,667 999 2,666	0 1,296 1,296	0 832 832	0 505 505	0	
Drum Storage Unit 2500	2,500	1,100 0 1,100	0 0			0				
Interplay Control 3000	3,000	3,000	2,100 0 2,100	0		0				
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641	0 641 641	
Test Controls	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	1,434 -671 763	
TOTALS	37,963 -671 37,292	36,163 -671 35,492	32,963 -671 32,292	27,814 312 28,126	27,330 328 27,658	24,959 1,329 26,288	24,644 1,180 25,824	23,799 1,698 25,497	12,221 6,151 18,372	

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests can occur when sufficient equipment is assembled to run programs read from punched tape.

2. Subsystem and System Tests of the New Computer

During the period beginning March 2, the core memory and arithmetic interconnections were made, and the Fibonacci test control and arithmetic unit were used as a pattern generator to test the core memory. During the weekend of March 17-18 an error-free run of 42.9 hours was obtained.

During the week of March 19, a test of the multiply inner loop was performed. Malfunctions found during this period are listed in Table II. The time for execution of the inner loop was found to vary from 6.0 to 8.9 μ sec, depending on multiplier digit patterns, with the average expected to be 8.2 μ sec. Changes now anticipated to increase the speed of operation are expected to reduce the average time to 6.5 or 7.0 μ sec.

Beginning March 23, approximately 6,000 additional transistors were installed, bringing the total for the month up to approximately 8,500. Check-out of the computer, with 2,048 words of core memory, all of the arithmetic control (DC), a simplified instruction sequencing control (AC_0), two of the ten flow gating registers, and a paper tape punch and reader, began on that date. The first programs, using only the simplest of the arithmetic instructions, were successfully run in the early morning hours of March 27. By the end of the month, a number of programs had been checked and were in use, including a bootstrap input routine, a sexadecimal machine language input routine, a sexadecimal memory dump, two simple memory tests, and a few miscellaneous special purpose engineering tests.

Malfunctions found during the period March 23-31 are listed in Table III.

TABLE II
MALFUNCTIONS FOUND DURING CHECKOUT
OF MULTIPLY INNER LOOP TESTS

	<u>Previously Installed Equipment</u>	<u>Newly Installed Equipment</u>	<u>Total</u>
Design or Planning Errors		11	11
Transistor insertions		10	10
Errors in temporary wiring		1	1
Faulty Components	2	4	6
Transistor		1	1
Indicator bulb	1		1
Open diode		1	1
Open resistor	1	1	2
Socket pin		1	1
Fabrication Errors	4	18	22
Wiring error		5	5
Component missing		6	6
Extra component added		1	1
Bent transistor pin		3	3
Open connection	4	2	6
Shorted connection		1	1
Power Supply and Miscellaneous			
Regulating transistor	1		1
TOTAL	7	33	40

TABLE III
MALFUNCTIONS FOUND DURING THE PERIOD MARCH 23-31, 1962

	<u>Previously Installed Equipment</u>	<u>Newly Installed Equipment</u>	<u>Total</u>
Design or Planning Errors	3	14	17
Transistor insertions		3	3
Logical design error	2	5	7
Circuit design error		1	1
Oscillations	1		1
Error in temporary wiring		5	5
Faulty Components	3	13	16
Transistors	1	3	4
Diodes		1	1
Zener diodes		4	4
Resistor	2	4	6
Indicator bulb		1	1
Fabrication Errors	4	35	39
Wiring error	3	8	11
Component missing		8	8
Extra component added		2	2
Bent or broken transistor pin		5	5
Main frame pin		2	2
Open connection	1	6	7
Shorted connection		1	1
Incorrect component value		3	3
Power Supply and Miscellaneous	1	5	6
Regulating transistor		3	3
Wiring		2	2
Fuse	1		1
TOTALS	11	67	78

3. Core Memory

Early in this month the memory was placed in the information loop of the Fibonacci sequence. Thus, each operand of the sequence was written into and read from the memory. This was the first occasion in which the write operation was used.

Several troubles were located and corrected after which a 43 hour error-free run was attained at 2.2 μ s cycle time.

Programmed operation was begun during the month. It is expected that programmed tests will aid in improving memory operation. A cycle time of 1.8 μ s is now considered an attainable goal.

(S. Ray)

4. Magnetic Drum Memory

Design of the Magnetic Drum Read Amplifier (with differential inputs and collector-base AC feedback) was finalized. Slight modifications may be needed in the light of future experiments of the whole setup. The circuit was found to operate satisfactorily for various bit patterns. A file describing the Amplifier is being written up.

Work was done on the Read Out Register and the necessity of error correction circuitry. The main reason for this is the spreading of a pulse indicating a change from a long string of 1's into a sequence of 0's. The margin between the maximum height of an unwanted pulse (one bit period prior to a legitimate flux change) and the minimum height of a wanted pulse (indicating a flux change) was quite small. It would, therefore, not be possible to provide a guaranteed safe threshold between these two so as to operate safely under worst case conditions (taking into account amplitude modulation, crosstalk, noise, amplifier gain fluctuation, etc.). Error correction is thus necessary. A simplified Peak Detecting Error Correction Read Out Circuit was designed, built, tested and found to operate properly for all the bit patterns tried. Peak detection involves strobing the amplitude waveform only when the derivative is in the neighborhood of zero. A peak is thus indicated when the amplitude exceeds a positive or negative threshold. This peak detector compares quite favorably with one of earlier design (File No. 421, M. Falleni) using only a little over half the number of transistors therein. Details will be given in a file number under preparation.

A Peak Detecting Clock Pulse Generator has also been designed and built, since simple amplitude threshold detection for clock pulse generation introduces phase modulation as a function of amplitude fluctuation.

The head selection matrix is being systematically tested in conjunction with the read amplifier for recovery after selection, writing, etc. Some problems still exist.

(P. V. S. Rao)

5. Paper Tape

The editing set arrived and, after considerable modification of some circuits, is now running without the proper typeface. Specifications for additional key-punch and printer sets were prepared.

(C. S. Wallace)

6. Interplay

Block layout is proceeding slowly. Some twelve chassis have been roughly laid out. Of these seven are in a fairly advanced stage of layout. The areas involved are the drum buffer registers, WOB selector (which selects words from either core memory and sends them to the interplay channels), and MWB-CA selector (which selects words and addresses from either the advanced control, the drum channel, or the other interplay channels, and sends them to the core memories).

(C. S. Wallace)

7. Power Supply Procurement

The reevaluation of Power Supply modules, prior to our purchase of twelve additional units, resulted in File No. 421, "Modification to Power Supply Modules", used in the bid request. A subsequent investigation of the cause of failure of the regulating transistors in the -50v supply led to the findings of File No. 431, "Voltage Rating of Power Supply Module Pass Transistors". For the regulating transistors in the -50v supply, 2N1537 transistors will be installed in place of the 2N1146A because of their increased BV_{cb}s rating.

The reevaluation of the module emphasized once more the unsatisfactory operation of the module over/under voltage circuits. Two features of their operation appeared particularly undesirable:

- 1) The two controls for each circuit are extremely interdependent. Since at least three variables, the value of input voltage, the threshold sensitivity, and the output signal swing, are dependent on the two control settings, the "best" adjustment must be only a poor compromise.
- 2) The reference supply and one of the controls for the circuit are part of the module itself. Thus the over/under circuit card is not directly interchangeable from module to module, in the sense that all eight controls, for the four monitored voltages, must be readjusted if cards are interchanged.

Accordingly, using the same general ideas advanced in File No. 389 "Over/under Voltage Detector" a new circuit board has been designed with circuit and operation as described in File No. 444, "Modified Over/under Voltage Card for NJE Modules". This card features self contained controls and references and the availability of a "prediction output." A prototype model has been fabricated and is under test in one module.

(K. C. Smith)

8. Zener Diode Reliability

Concerning failures in zener diodes resulting from the appearance of a shunt conductance, the manufacturer has offered some comment. Samples of the failures were sent to them and concerning these they say, "These...old style packages...(have) been modified...to...greatly reduce...difficulties.... (The) ...oxidation and surface contamination...have been...reduced. Better passivation...(should eliminate) the defective characteristics found...."

It would appear that we may expect more trouble with old units already installed, e.g., in Flow-Gating. However, more recently manufactured units should be greatly improved. Considering the fairly low failure rate thus far observed it seems reasonable to await further developments before any other action is taken.

(K. C. Smith)

9. Circuits

A delay circuit for use in Delayed Control and elsewhere has been designed and tested as indicated in File No. 437, "Delay (Non-Inverting)." Delay lines having impedances ≥ 750 ohms are easily accommodated. In addition, for initial investigations before the correct value of delay is established, capacitors can be used to give approximate delays. It is recommended that for very short delays (< 50 ns) that a capacitor be used as a permanent element.

Measurements of the response time of a multiple input AND/ $\overline{\text{AND}}$ (drawing B1108) were made as indicated in File No. 438, "Response Times of the AND/ $\overline{\text{AND}}$ (B1108)." These indicate that the speed of the AND output is essentially independent of the number of inputs up to 20, and is generally faster than the $\overline{\text{AND}}$ output. In some cases a faster $\overline{\text{AND}}$ output may be obtained using an inverter following the AND output. Further, there is a marked difference in the operation time of either output depending on which of the 0/1 or 1/0 transitions is considered. This difference is quite load dependent, that is it is affected by the number of output emitter followers and their base currents. It is recommended in those special cases of light load (< 5 EF) and where speed in the positive-going transition is important, that a resistive load to +25v be added, consistent with the number of absent emitter-followers.

A tolerance design was completed for a possible Drum Write Amplifier. This design was constructed and appears satisfactory, with a possible question of output swing capability. This decision must await more experiments on the drum.

(K. C. Smith)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Introduction

Tohru Moto-oka designed a new kind of pulsed oscillator in which a tunnel diode is pulled into the high impedance state by a control pulse and thus establishes, at the termination end of a line fed by a second tunnel diode, the correct reflected phase for oscillations to continue. This oscillator will be pulsed by a source producing the sweep in a sampling scope and its output (at ~ 1 kmc) will drive the circuitry under study.

Sergio Ribeiro wrote a complete report on his investigations involving saturating transistors. The final conclusion is that the Early effect becomes of paramount importance at low collector voltages, at least in mesa transistors.

Thomas Burnside has produced the first sampling switches for the "Statistical Analyzer" program. It seems entirely feasible to sample with pulses having rise and fall times of about $.3 \mu s$. He has also designed the logic for the system.

John Hill has added to his set of failsafe and indicating circuits a clock source (oscillator and some logic) which is itself failsafe. Some recalculations and additional buffering has been necessary after examining chains of modules all having the worst type of failure (short).

2. Pulsed Tunnel Diode Oscillator

In order to observe a very high speed phenomenon through a sampling scope, it is necessary to synchronize it with the comparatively slow trigger signal of a sampling scope. A pulsed oscillator was designed as a possible solution and the 1 kmc oscillator output waveform was observed. In order to inject this waveform into another circuit, a separation circuit and an amplifier are needed. The design of these circuits is in progress.

The idea is to pulse a tunnel diode with a low frequency signal (scope trigger signal) and to insert this unit as a load in a delay line closed by a second tunnel diode. When the second tunnel diode is in the high impedance state, it reflects without phase inversion and oscillations set in.

Experiment

The circuit configuration of a pulsed oscillator is shown in Figure 1. The oscillating tunnel diode is a 2 mA Ge tunnel diode of the type 1N2969 (GE) having 8 pF capacitance. The tunnel diode used as a load resistance is a 50 mA GaAs tunnel diode. This GaAs tunnel diode can possibly be replaced by a carbon resistor. The characteristic impedance of the strip line is approximately 130Ω . The oscillating waveform is in a steady state after the first one or two cycles. For frequencies lower than 300 mc, the waveforms have flat parts at peaks and approximately 500 mv peak to peak amplitude. For frequencies higher than 300 mc, the amplitude of the oscillations decreases.

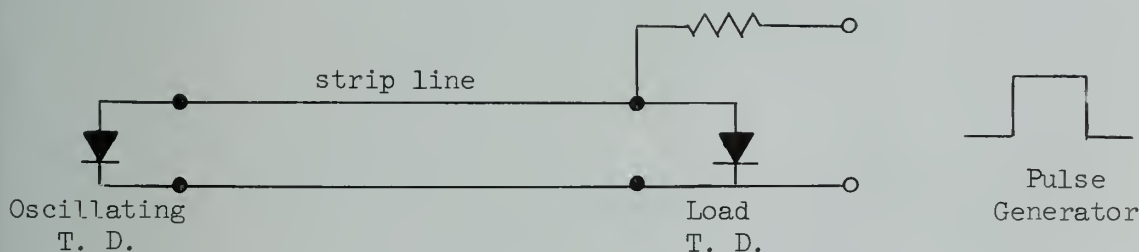


Figure 1 Pulsed Oscillator

Theory

The simplified equivalent circuit of the pulsed oscillator is given in Figure 2.

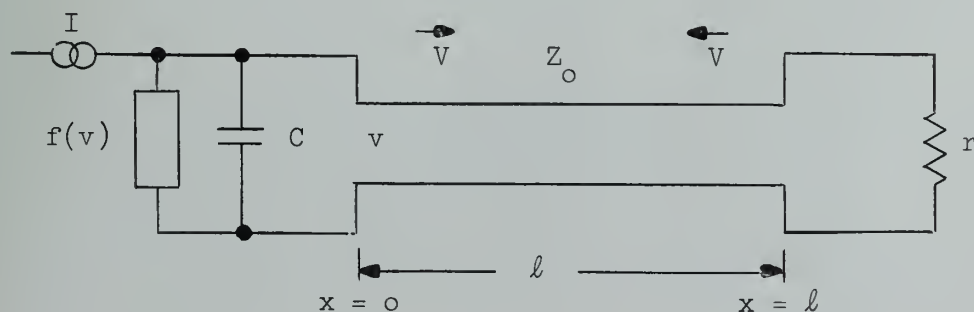


Figure 2 Simplified Equivalent Circuit

The circuit equations are as follows:

$$\vec{V}_0 = \frac{ZZ_0}{Z + Z_0} I + \frac{Z - Z_0}{Z + Z_0} \overleftarrow{V}_0 \quad (1)$$

$$v = \vec{V}_0 + \overleftarrow{V}_0 \quad (2)$$

$$\overleftarrow{V}_0 = \frac{r - Z_0}{r + Z_0} \sum \text{---}^{st_0} \vec{V}_0 \quad (3)$$

$$\frac{v}{Z} = f(v) + sCv \quad (4)$$

where \vec{V}_0 , \overleftarrow{V}_0 are the voltages of the forward and backward travelling waves at $x = 0$, and t_0 is twice the delay time of a strip line of length ℓ .

It is supposed that the oscillation frequency is given by $f = 1/2 t_0$ and that in the oscillating state the average negative resistance of the tunnel diode, $-R$, satisfies the following relation:

$$\frac{Z_0 + R}{Z_0 - R} \frac{Z_0 - r}{Z_0 + r} = 1 \quad (5)$$

The details of the theoretical analysis will be reported later.

3. Saturation Program

A final report on the saturation program has been prepared. Under the title "A Study of Saturation Phenomena," it deals with saturation and supersaturation effects.

Experimental procedures and results are described and a theoretical analysis is carried out for a simplified model. Theoretical formulas for the equivalent circuit parameters qualitatively agree with experimental curves.

Supersaturation backward current gain is explained by the Early effect on a qualitative basis.

Switch Output

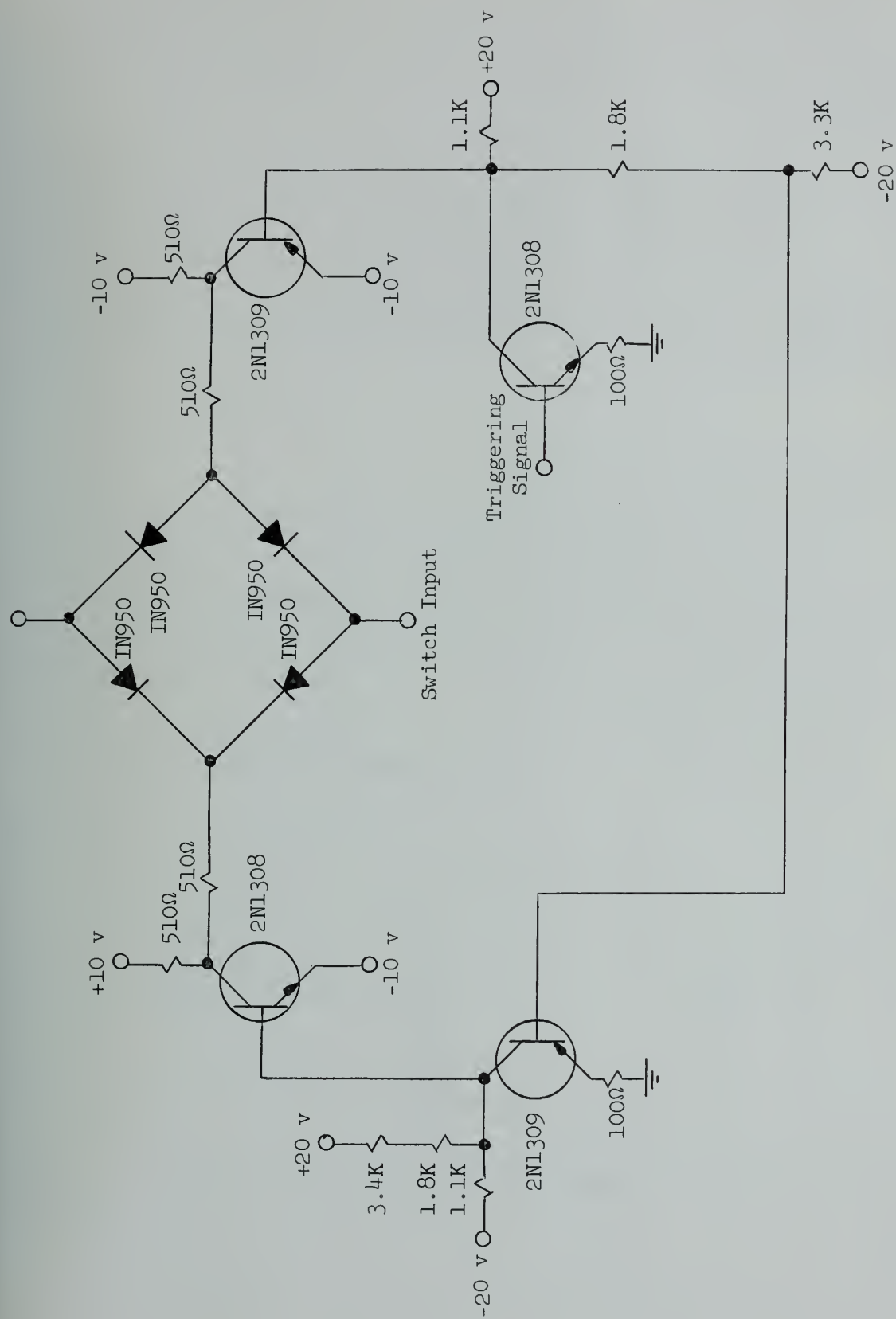


Figure 3 Corrected Low Impedance Switch

No quantitative theoretical results are sought because of the difficulty involved in analyzing a non-symmetrical structure such as the one of the GF-45011. However, a numerical example based on experimental data is presented with the sole purpose of illustrating the order of magnitude of variables and parameters involved in the theoretical expression for the backward current gain.

Finally, the influence of the Early effect on the measurement of equivalent circuit parameters is investigated on a simplified model, and, as expected, it indicates that, under saturation, the Early effect is of primary importance; under certain conditions (supersaturation) it becomes the dominant phenomenon with respect to transistor parameters and, consequently, transistor performance.

4. Statistical Analyzer

Printed circuits have been made for the flipflop and decoding circuitry of the modulo-8 counter and the corresponding low impedance switch. These circuits are being tested to check that they operate properly at a frequency of 1 megacycle per second. The low impedance switch, whose corrected circuit is shown in Figure 3, operates at 1 megacycle with a switching rise time of about .1 microsecond.

Each of the eight sample voltage sources will be produced as shown in Figure 4.

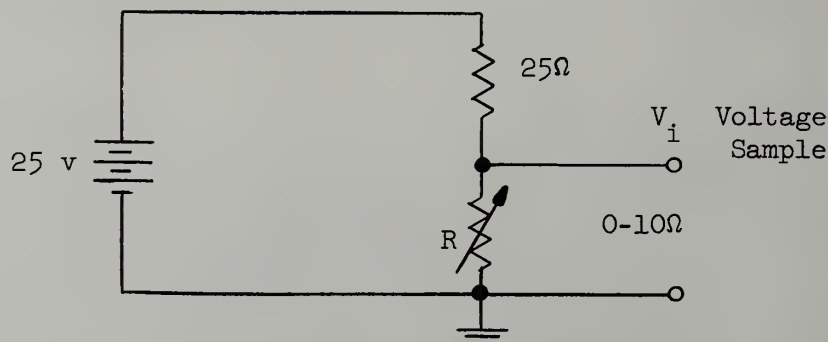


Figure 4 Production of Sample Voltages

The voltage divider is to be operated with V_i varying from about .5 to 1.5 volts. So R will be set at around 1Ω . The current flowing will be about one ampere which is essentially constant relative to 10 ma used by the diode circuit which it drives.

A pulse generator is being designed to generate a 1 megacycle, 0-6 volt pulse to clock the modulo-8 counters.

Figure 5 shows the logical layout of the counting system that switches the 8 sample voltage sources and the 8 sample diodes into the circuit to be statistically analyzed.

The initial states of the flipflops are $A = 1$, $B = 0$, $C = 0$, $D = 1$, $E = 0$, and $F = 0$. After completing the 64 possible combinations the flipflops will be in the states:

$$\begin{array}{ll} A = 0 & D = 0 \\ B = 0 & E = 0 \\ C = 0 & F = 0 \end{array}$$

The diode counter is to go from 0, 0, 0 to 0, 0, 1 each time except when the voltage source counter is in the state 0, 0, 0. This is accomplished by the function

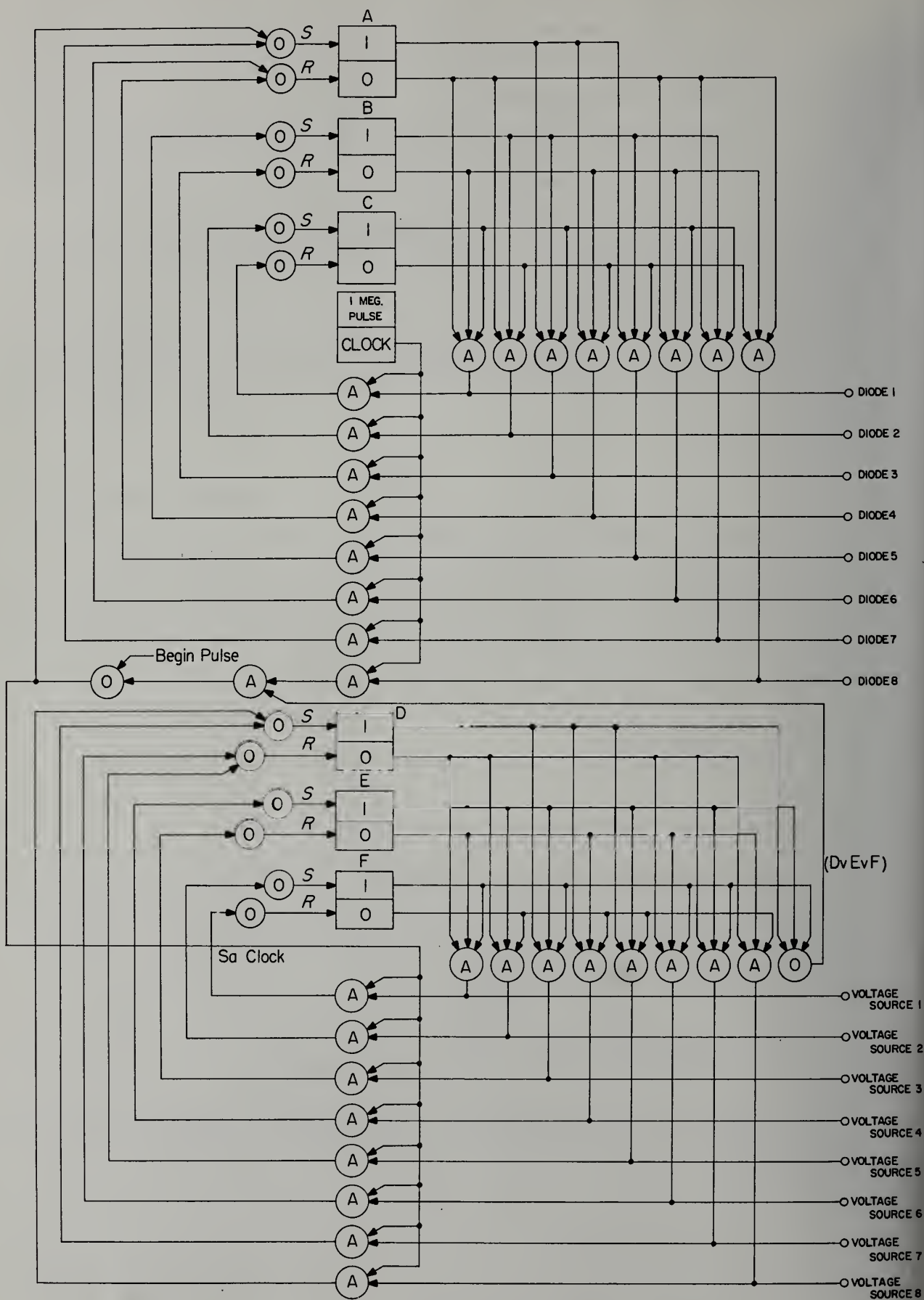
$$S_A = P\bar{A}\bar{B}\bar{C}(DvEvF)$$

where $S_a = 1$ sets flipflop A to 1, P is the clock pulse.

This arrangement allows the system to sample all 64 combinations of the element and then stop. To start over the system must be set to its initial states by pushing the button that initiates the "begin experiment pulse." This is accomplished by the functions

$$S_A = P\bar{A}\bar{B}\bar{C}(DvEvF) \vee B_g$$

where B_g is "begin pulse." Notice that the clock pulse for the voltage source counter is S_a .



LOGIC OF STATISTICAL ANALYZER

Fig 5

5. Failsafe Circuits

Lifetime Extension of "Failsafe" Circuits with Repair

Consider a two transistor failsafe circuit in which one transistor may fail and the circuit will still function properly. Now, instead of letting this circuit run to failure (expected lifetime is $3/2 T$) let its defective transistors be replaced every $t_0 \ll T$ hours. This is equivalent to starting with a new circuit at times $0, t_0, 2 t_0, \dots, n t_0 \dots$. Now let the circuit run this way until it fails between some repair periods. The probability distribution function of the circuit failing by time t is $P_2(t) = [1 - \exp(-t/T)]^2$.

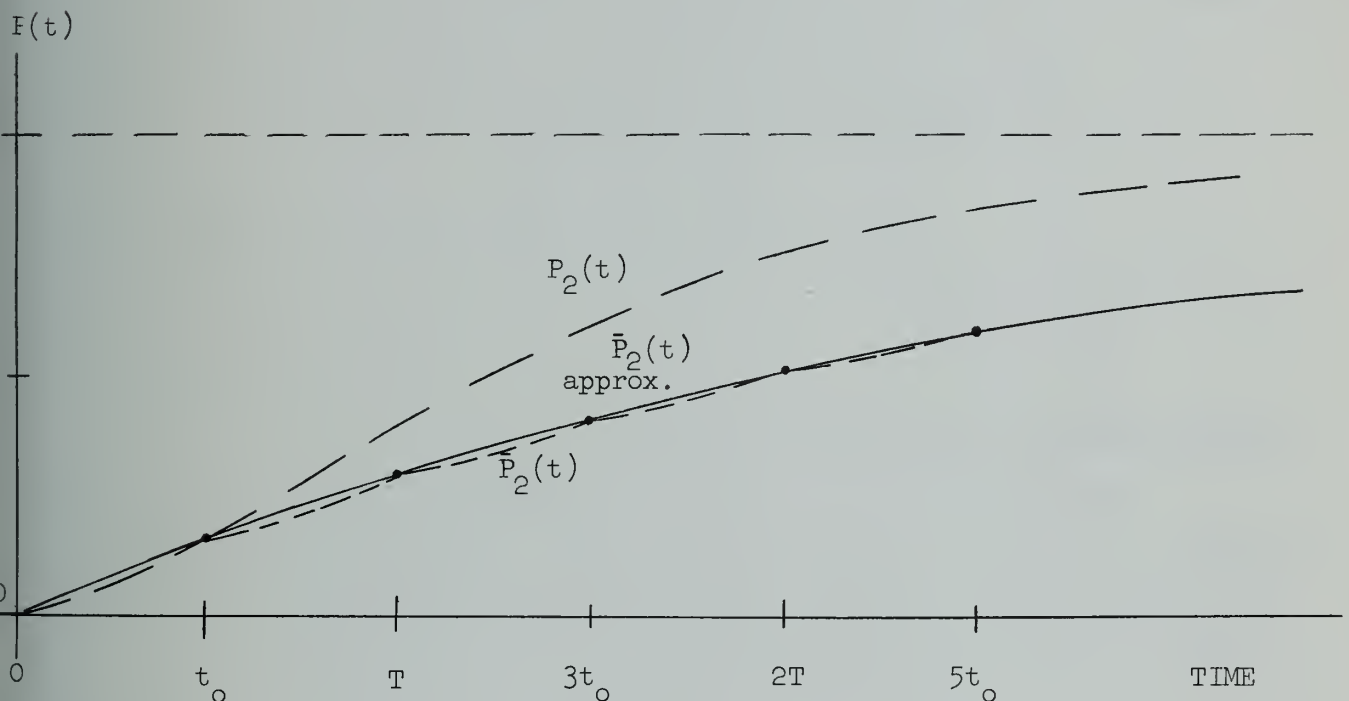


Figure 6 Example with $t_0 = 1/2 T$

The repair affects the distribution function as shown in Figure 6. In effect, the differential equation from which $P_2(t)$ is obtained is solved after each t_0 interval with a new initial condition. The value of $\bar{P}_2(t)$ at integral multiples of t_0 forms the geometric series $\bar{P}_2(t) = 1 - [1 - P_2(t_0)]^n$ where n is the number of service periods. For a smooth approximation that

runs through these points we replace n by t/t_0 and get

$$\bar{P}_2(t) = 1 - [1 - P_2(t_0)]^{t/t_0}$$

Now substituting in the value given for $P_2(t)$ above and making some approximations valid when $t_0 \ll T$ we get

$$\bar{P}_2(t) = 1 - \exp \left[-t \frac{t_0}{T^2} \right]$$

Since the time constant of an exponential distribution function is its mean lifetime and since $L_2 = 3/2 T$ we have by inspection:

$$\bar{L}_2 = \frac{T^2}{t_0} = \frac{2}{3} \frac{T}{t_0} \times [\text{mean life of the circuit without repair}]$$

For example, if $T = 1 \text{ year} \doteq 10^4 \text{ hours}$ and $t_0 = 100 \text{ hours}$ then the mean life of the circuit $\bar{L}_2 = 100 \text{ years}$.

Lifetime Extension of a "Failsafe" Computer

Consider an n circuit computer that uses the "failsafe" circuits just described. Let it be serviced every $t_0 \ll T/\sqrt{n}$. From last month's report we deduce that the lifetime of an n circuit computer, in terms of its circuit's probability distribution function $P(t)$, is

$$\bar{L}_n = \int_0^\infty [1 - \bar{P}_2(t)]^n dt$$

Now substituting in the value of $\bar{P}_2(t)$ we get

$$\bar{L}_n = \int_0^\infty \exp \left[-t \frac{nt_0}{T^2} \right] dt = \frac{T^2}{nt_0}$$

Recall that the lifetime of an n circuit machine without repair is $L_n \doteq \sqrt{\pi/4n} T$. Then if we make $t_o = 1/k L_n$ we have

$$\bar{L}_n \doteq Tk \sqrt{\frac{4}{\pi n}}$$

Given $T = 10^4$ hours, $k = 10$, $n = 10^4$ circuits we have:

- (1) expected lifetime of ordinary machine, $T/n = 1$ hour
- (2) expected lifetime of "failsafe" machine, $L_n \doteq T/\sqrt{n} = 100$ hours
- (3) expected lifetime of "failsafe" machine with repair every 10 hours, $\bar{L}_n \doteq kT/\sqrt{n} = 1,000$ hours.

Note that an ordinary computer has failure trouble when $T \approx n$. A "failsafe" computer as described has the same problem when $T \approx n^2$. However, a failsafe computer with periodic repair has failure trouble when $T \approx kn^2$.

PART III
MATHEMATICAL METHODS

1. Monte Carlo Methods in Quantum Statistics (Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Some early computations, described in File No. 361, were repeated using an improved random number generator. The results of these computations have not been thoroughly examined yet, but they do not appear to be very different from the earlier results. The reason for repeating these computations was that the random number generator used in the original computations contained a small bias.

During this month an attempt was made to calculate analytically (i.e., without Monte Carlo sampling) the integrals evaluated by program NUMBER 6 (September, 1961, TPR) for the purpose of determining the error due to the approximations made, excluding Monte Carlo, in this program. In one special case it was possible to make this calculation and it was possible to prove, in this case, that the convergence to the limit, as higher approximations are taken, is from above. This is consistent with the behavior seen in the Monte Carlo computations, though they were applied to a more complex case than the one considered here. We are now trying to extend this analysis to more complex cases.

(L. D. Fosdick)

2. Conservation Laws and Variational Principles in General Relativity (Supported in part by the National Science Foundation under grant G16489.)

Special relativistic field theories involving tensor fields and derivable from a variational principle are generalized to general relativistic theories. It is assumed that the Lagrangian is a function of the tensor field components and their first derivatives. The Lagrangian is first written in a general coordinate system in Minkowski space-time and then the restriction that the underlying space-time is flat is removed. The Einstein field equations for the gravitational field may be derived as was shown by Hilbert and the matter energy tensor is obtained as a function of the tensor field. The technique of E. Noether is used to derive conservation laws and relations between the various matter energy tensors which arise.

(A. H. Taub)

PART IV
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Pattern Recognition: Experimental Programming

1) Pattern Recognition Study

The somewhat idealized "linguistic" approach to pattern recognition work as set forth in File No. 422 has undergone considerable modification and revision. In its present tentative formulation, its adequacy is being computer-tested using digitized (1) bubble-chamber data and (2) alpha-numeric characters.

The scheme, as currently being developed, still consists of two well-defined phases:

- 1) a parallel processing phase, and
- 2) a sequential compiling phase.

The principal features of the two phases and their current state of development are summarized below. Their detailed descriptions, with results of simulations studies on experimental data, will be issued as File Notes in the coming months.

2) Phase I. Parallel Processing

The object of parallel processing is twofold:

- a) noise cleaning and idealization of the input picture, and
- b) abstracting of local properties for use in phase II of the recognition procedure.

Both objectives are accomplished by means of "homogeneous logical transformations," i.e., by means of specific Boolean operations performed in parallel on the immediate neighbors of each digitized point of the picture.

The noise cleaning and idealization consist principally of gap-filling, edging, thinning, and line-smoothing. After this preprocessing has been completed, further Boolean transformations are applied to select out points and neighborhoods with specified topological properties. In the idealized line drawings under consideration here, points which define terminal

neighborhoods, junctions, crossings, bends, corners, etc., are selected out. These are the basic syntactic categories in terms of which the "grammar" used in phase II is defined.

3) Phase II. Tracking and Compiling

The Principal operations involved in this sequential phase is one of tracking along the lines in the idealized picture subject to the "rules of grammar" which implicitly define the class of patterns under consideration. As the tracking proceeds, a compilation is made of the "syntactic structure" of the particular picture under view. This compiled information is then used to identify the pattern (or patterns) in the picture.

It is envisaged that, ultimately, this sequential phase will consist of a hierarchical, recursive program with its principal part functioning very much like the syntax-compilers used in automatic programming.

4) Current State of Development

Phase I processing is being studied on Illiac by James H. Stein, Jr., using the PRC Simulator code already developed by him. Each specific homogeneous logical transformation used in the parallel processing sequence is being programmed as a subroutine in the PRC simulator order code. The basic routines for gap-filling and edging have been tested out. A method of thinning has been developed which is currently being programmed. The transformations for abstracting the syntactic units have been formulated but remain to be programmed. Simultaneous with machine programming, some bubble-chamber pictures (80 x 80 input raster) and letter diagrams have been hand processed to test out the transformations.

To serve as a basic building block for phase II, a tracking program has been designed. This tracks along a line diagram (or along the outer edge of a figure, if unthinned) given the starting point, starting direction and the end condition. This program has been coded for the Illiac and tested out by B. H. Mayoh. The next stage is to expand this program so that tracking conforms to a specified set of grammar rules. To begin with, a set of rules is being incorporated to enable tracking along beam tracks and spirals in bubble-chamber data. Compilation features will be introduced only in the third stage.

(B. Mayoh, R. Narasimhan, J. H. Stein, Jr.)

II. Prototype Threshold Logic Element

Several prototype versions of the iterative section of a Threshold Logic Element have been designed and tested. This element consists of a string of flipflops coupled by simple diode-resistor gates to allow propagation in either direction, of logical signals between adjacent member flipflops. In operation, if the contents of the element, viewed from its input end were 11100000, then upon an add (subtract) pulse, the 10 interface may propagate one position to the right (left).

The several versions of the threshold element, all of which use a capacitor for intermediate storage and gating, differs in complexity and speed. At present it appears that the slowest and cheapest element could operate with a 200 nanosecond shift period. Data on the faster and more expensive versions is not yet complete.

The difficulty encountered in fabricating suitable test control circuits, which though simple are not usual, argues strongly for the existence of "building block" circuits in the laboratory.

(D. C. Hall, K. C. Smith)

III. Pattern Recognition Unit (PRU), Associated Control Computer (CC), and Console

1) Racks for PRU and CC

Design of an integrated system of racks for the transistor circuitry of the PRU and the CC is now complete. Specifications for these racks have been issued in File No. 441. This file number and the set of 35 drawings are being used as a basis of a bid prior to subcontracting the fabrication of the racks.

2) Console

Initial design of the modular instrument enclosure for the console is complete. Fabrication of these racks has been subcontracted to Amco Engineering Company of Chicago. The console racks will ultimately house:

- 1) 40 x 40 indicator display of the two dimension shift plane of the PRU.

- 2) display scope and associated digital control
- 3) paper tape I/O
- 4) mechanical stage digital control, including joy stick and handwheel manual controls
- 5) vidicon digital control
- 6) decimal display of critical machine registers
- 7) manual control switches

3) Indicator Display

Displayed at the console will be a 40 x 40 rectangular array of indicator lights--one (1) for each bit of the 40 x 40 two-dimensional shifting plane of the PRU. A plastic mosaic, purchased from Hydro Molding, is being adapted as a 40 x 40 indicator bulb-array array for panel mounting at the console.

4) Back Panel Wiring

Taper pin wiring and taper pin printed circuit connectors will be used throughout the system. An initial bid request for 50,000 AMP series 53 gold plated taper pins has been placed. The ultimate assembly will require approximately 50,000 back panel wires. Negotiations are in progress with AMP for the extended loan of a semi-automatic taper pin header.

72,000 feet of plastic hookup wire is on order.

5) Printed Circuit Connector

Specifications modeled on the Viking 2VH22/1AW5, a 44-contact printed circuit connector, have been issued as File No. 447. Bids have been let for an initial 1,000 connectors using this specification and associated drawings. This connector, selected from a field of approximately 40 likely candidates, will be standard for the entire system--apart from the transfer memory.

6) Bus Bar Strips

Bus bar strips, encased in a specially designed aluminum extrusion, bus the three (3) system voltages (+6, -6, -12v). The aluminum extrusion

also is drilled as the support member for a row of printed circuit connectors (see 5 above). Currently on bid are 6⁴ strips of 68 bds/strips, 10 strips of 32 bds/strip, and 2⁴ strips of 2⁴ bds/strips.

7) Printed Circuit Card Guides

The dimensions of the aluminum extrusion bus bar strips (above) have been chosen to match and support nylon printed circuit guides designed by Applied Development Corporation of California. Appropriate card guides and spaces for the PRU, CC transistor bays and the console bins have been let for bid.

8) Printed Circuit Layout of Current Switching Logic

Preliminary layout (first iteration) for the seven (7) printed circuit boards for the current switching logic of the control computer and console are now nearly complete. It is anticipated that the second iteration will be used as a basis for bid for the printed circuit board construction.

9) Coaxial Cable for PRU/Transfer Memory Communication

2000 feet of ribbon coaxial cable (16 miniature coaxial cables/ribbon) has been purchased to transmit I/O between the (planar) transfer memory and the 102⁴ individual stalactites distributed in the PRU. Preliminary sketches of wiring trays for this bulk of cable have been completed and are consistent with the rack design of section 1.

10) Magnetic Amplifier Power Supplies

A preliminary but detailed evaluation of the power requirements for the entire pattern recognition computer has been prepared and will be issued next month. In brief, the magnetic amplifier--local regulating module design employed on the new Illinois computer--will be used. This choice seems highly recommended on the basis of allowing uniform maintenance throughout the Laboratory, and yet allows us to incorporate modifications suggested by the new computer experience to date.

A complete set of drawings of the NJE model CS65TRM01, CS65TRM02 magnetic amplifiers (nominal 14 and 34 volts respectively at peak current of 300A), checked against units currently in use is being prepared. An 18 volt unit, designated CS65TRM03, is being designed. Construction of this unit is common with the 01, 02 models, but the values of the input transformers, condenser banks, etc., are interpolated from the 01, 02 design.

Initially three units: two (2) CS65TRM01 and one (1) CS65TRM03 will be required, and will be let to bid on the DCL edited and updated NJE drawings. Physically the magnetic amplifier units will be housed in the present basement power supply room of the new computer.

11) Heat Sink Modules for Power Regulation Funnel

Heat sink modules for the power regulating modules (one per bus strip) have been designed around the Modine radiator wall type heat sink. Approximately 250 units will be required and will be let for bid this coming month. Transistors will not be supplied initially, and inserted only as actual power consumption warrants.

12) Room Layout, Air Conditioning

An initial room layout for the pattern recognition computer as placed in room 223 of DCL has been prepared. Projected units (by rack) include:

- 1) PRU: 4 transistor bays and associated 84" rack
- 2) CC: 4 transistor bays and associated 84" rack
- 3) Power regulation funnel: 24" x 24" x 84"
- 4) Console: 38" x 25" x 78" rack
- 5) Paper tape I/O station
- 6) High Resolution Scope: 57" x 25" x 78"
- 7) Mechanical Stage and associated Vidicon scanner:
19" x 25" x 48"
- 8) Control Computer (CC) Memory (as yet unspecified)

Initial air conditioning estimates have been made and will be issued in the power distribution file note. In brief it now appears that direct ducting of heat from the power regulation funnel up and directly

out through the ceiling immediately above would drop the overall heat dissipation load of the room to where two window air conditioning units, augmenting the current air conditioning of the room would suffice. A fresh air bypass for winter months would also be required. A preliminary estimate of the roof venting and supplemental air conditioning is being prepared by Lee Whyte.

(B. H. McCormick, K. C. Smith)

PART V
ILLIAC USE AND OPERATION

The Illiac will be withdrawn from service on December 31, 1962.

Illiac Usage

During the month of March, specifications were presented for nine new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2152. Numbers followed by T are for theses.

2152 Nuclear Engineering. Reactor Kinetics with Temperature Coefficient. The reactor kinetics equations constitute a system of nine ordinary linear differential equations, if six groups of precursors and two temperatures of influence on the reactivity are assumed. The perturbation is introduced into the steady state system by an arbitrary variation of the reactivity (small sine variation, ramp-function, etc.).

A parameter study of the characteristic parameters of the perturbation (amplitude and frequency of sine wave, slope of ramp) as well as of system parameters (temperature coefficient, temperature relaxation time) is made.

This routine uses library subroutine F6. It has been tried out previously on the Illiac and ran successfully. One step of integration takes ~4.8 seconds. In order to get sufficient accuracy and conclusive solutions the program would have to run for about two hours (12 minutes for each set of parameters, nine sets of parameters).

2153 Digital Computer Laboratory. Pattern Recognition Test. In order to test the output of the pattern recognition system, this program is made to plot on the CRT screen a set of vertical or horizontal lines, rectangular rasters, concentric circles, and star shapes.

2154 Psychology. Three Dimensional Analysis of School Administration. This study is a trial application of a principal component method of factor analysis for three dimensional matrices of data. The data are the scores of 232 individuals on 40 scoring categories obtained in three sessions. Three

correlation matrices have been obtained, a 3×3 matrix, a 40×40 matrix and a 120×120 matrix.

The following steps are required to complete the solution. Find the latent roots and vectors of the 3×3 and the 40×40 matrices. A matrix ${}_{120}^H{}_{120}$ is to be constructed from these latent vectors.

Multiply $H^t R H$ where R is the above mentioned correlation matrix of 120×120 . The latent roots and vectors of this matrix are required. Since this is beyond computer capacity, an approximation method will be developed by the experiments.

Subsequently, the latent vectors will be rotated to simple structure by the varimax method. Any additional computation will depend on the nature of the results.

2155 Chemistry. Matrix Diagonalization. It is desired to find the eigenvalues and eigenvectors of the symmetric matrix generated by maleic anhydride ($C_4H_2O_3$) through the Hückel Molecular Orbital Approximation. The resulting matrix is of dimension 7.

Library routine M25-262 can diagonalize the matrix and give the required eigenvectors.

2156 Office of Instructional Television. The Use of Television by Experienced and Inexperienced Teachers. There are two phases to this problem: whether experienced teachers can use tapes (television) more effectively than inexperienced teachers; and whether a class taught by television and the direct method does as well as a class taught only by the direct method.

The data includes motor fitness scores, routines, quizzes, a final and an attitude score. It will be treated statistically with an analysis of covariance and analysis of variance.

2157 Digital Computer Laboratory. Eigenvalue Problem. The routine will carry out a test of a matrix transformation by computing the eigenvalues of the original matrix and the transform.

2158 Mathematics. Learning Experiments Adaptable Program (LEAP). The purpose of the program to be developed is primarily for basic research in certain

techniques by which machines may be programmed to learn to do a simple task. The simple task in this case will be playing the game of tic-tac-toe.

The basic method to be used is described in "Trial and Error" (Donald Michie, Penguin Science Survey, 1961, Vol. 2), and the mathematical games section of the March, 1962 Scientific American. It consists of storing in some kind of table all the possible unique configurations of the game board and the possible legal moves for each configuration, each move having a corresponding probability. Initially, for each configuration the probabilities of the various moves would be equal.

On each move, a random number would be generated by V9, and it would be compared with the move probabilities for the configuration corresponding to the state of the game board. Certain information such as the sequence of moves and the winner of the game, if any, would be recorded and perhaps dumped on tape to save memory space if the information might be useful later.

The method of learning is a system of "reward" and "punishment". After determining the outcome of the game, the probabilities of the moves the machine made would be adjusted by some increment. How much to increment and in what direction would depend on what kind of tic-tac-toe player the experimenter wanted to create. One might, for example, penalize draws as heavily as losses, or even more heavily, to generate a player which would exhibit a tendency toward risky play. Undoubtedly, within the very limited scope of the experiment, there would be some psychological conclusions which could be drawn.

Two input-output modes would be provided. The first mode would be similar to that used on the current Illiac tic-tac-toe demonstration routine, using the Williams memory display tube and the black and white switches. This mode would be used for experiments based on human-machine contests. The second mode would read and write in a buffer area in the memory. This mode would be used in experiments where two such programs in different portions of the memory would compete, thus comparing results of various systems of punishment and reward, or simply to speed up the learning process. Because of the relative simplicity of the game, after a certain number of games the learning element might not affect the nature of the probability table measurably.

2159T Psychology. Factor Analysis of Wechsler Intelligence Scale for Children. The purpose of this study is to obtain the factor analytic structure of the

Wechsler Intelligence Scale for Children. Illiac will be used for centroid analysis (KSL 1.20), for varimax rotation (KSL 1.80) and for obtaining regression weights (M-28).

2160T Chemical Engineering. Growth of Bubbles. In the study of boiling it has been found that the growth of bubbles plays a significant role. At the present time, all theoretical predictions are either for a case of a hemisphere on a wall, or a spherical bubble in an infinite medium. Neither of these cases is commonly found in practice. At the present time, it is proposed to investigate one type of departure from these conditions, specifically a spherical bubble tangential to a solid plane boundary, in a semi-infinite medium of infinite extent and homogeneous composition where diffusion is the controlling factor.

Table I shows the distribution of Illiac machine time for the month of March. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min	
Scheduled Maintenance	65:45	
Unscheduled Maintenance	13:54	
Drum Engineering	14:20	
Leapfrog	21:20	
Library Development	1:05	
Classes	3:48	
Demonstrations	<u>20:55</u>	
	144:07	
Use by Departments		
Aeronautical Engineering	:45	
Agricultural Economics	15:41	(1:10)
Agronomy	2:06	
Animal Science	3:57	(:34)
Astronomy	7:01	(2:16)
Bureau of Economic and Business Research	1:28	(:56)
Bureau of Educational Research (PH-M1839)	1:39	
Chemistry (PH A3551)	1:06	
Chemistry	62:30	(7:11)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	4:10	
Civil Engineering	65:29	(7:10)
Coordinated Science Lab. (DA-36-039-SC56695)	85:03	

Digital Computer Laboratory (AEC AT(11-1)-415)	1:54	
Digital Computer Laboratory (USTR AEC-1018)	11:39	
Digital Computer Laboratory (NONR 1834(27))	11:59	
Digital Computer Laboratory	1:03	
Economics (NSFG 7056)	2:08	
Electrical Engineering (NASA-NSG 24-59)	24:47	
Electrical Engineering (AF 7043)	38:04	
Electrical Engineering (NSFG 14894)	1:16	
Electrical Engineering	5:25	(1:32)
Food Technology	5:02	(2:49)
Geological Survey	1:09	
Inst. of Communications Res. (44-28-20-378)	5:02	
Inst. of Communications Res. (USPHM-3941)	:24	
Institute of Communications Research	:13	(:11)
Mechanical Engineering	99:03	(:12)
Mining and Metallurgical Eng. (TRUS AF 6770)	:40	
Mining and Metallurgical Eng. (PCA BEAM COLUMN)	:06	
Mining and Metallurgical Engineering	:10	
Music	3:55	
Nuclear Engineering	1:29	
Office of Instructional TV (OE 7-11-107.00)	6:46	
Physical Education	1:46	(1:08)
Physics (NONR 1834(05)A)	:09	
Physics (NSF 14 308)	1:21	
Physics (AF 49(638))	:06	
Physics (NSFG-17428)	2:41	
Physics	13:21	
Psychology (MD 2060)	:50	
Psychology (AF 49(638)37)	:30	
Psychology (USPH 45-32-66-373)	7:43	
Psychology (ML774)	1:39	
Psychology (ONR 1834-36)	1:16	
Psychology	57:42	(8:29)
Sociology	2:00	(:06)
State Water Survey (DA-36-039eSC75055)	13:19	
State Water Survey	5:22	
Theoretical and Applied Mech. (DA-11-070-508 ORD)	4:23	
Theoretical and Applied Mech. (DA-01-021 ORD11878)	:55	
Theoretical and Applied Mechanics	6:20	(1:47)
	<u>599:53</u>	(35:31)
		<u>744:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of

the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Control	2
Arithmetic	2
Drum	5
Reader	2
Memory	1
Power Supply	1
Unknown	<u>2</u>
Total	15

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPEROG	FAILURES STOPPING LEAPEROG
3/1/62	20:53	:00	3:07	0	(1) Control error.	:00	:08	0
3/2/62	21:09	:19	2:32	1	(1) Filaments on Illiac too high.	:00	:00	0
3/3/62	23:34	:26	:00	1	(1) Reader "G" error.	:00	:00	0
3/4/62	23:52	:08	:00	1	(1) Drum failure. (2) Drum failure.	:00	:32	0
3/5/62	20:17	:36	3:07	2	(1) Drum failure. (2) Drum failure.	:00	:39	0
3/6/62	20:47	:00	3:13	0		:00	:21	0
3/7/62	22:08	:00	1:52	0		:00	:24	0
3/8/62	21:48	:00	2:12	0		:00	:20	0
3/9/62	20:04	1:26	2:30	2	(1) Drum failure. (2) Drum failure.	:00	:14	0
3/10/62	24:00	:00	:00	0		:00	:00	0
3/11/62	24:00	:00	:00	0		:00	:36	0
3/12/62	21:38	:00	2:22	0		:00	3:00	0
3/13/62	20:47	:00	3:13	0		:00	:55	0
3/14/62	21:35	:00	2:25	0		:00	:28	0
3/15/62	21:26	:00	2:34	0		:00	:19	0
3/16/62	21:58	:00	2:02	0		:00	1:29	0
3/17/62	23:57	:03	:00	1	(1) Reader "F" failed.	:00	2:09	0
3/18/62	24:00	:00	:00	0		:00	1:55	0
3/19/62	15:49	1:36	3:35	2	(1) Memory failure 2 ⁻¹¹ . (2) Control error.	3:00*	:00	0
3/20/62	20:45	:00	3:15	0		:00	:44	0
3/21/62	20:03	:52	3:05	1	(1) Arithmetic error.	:00	1:02	0
3/22/62	20:19	:07	3:34	1	(1) Unknown	:00	:34	0
3/23/62	21:14	:00	2:46	0		:00	:28	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/24/62	24:00	:00	:00	0	(1) Drum failure.	:00	:00	0
3/25/62	15:35	8:25	:00	1		:00	:00	0
3/26/62	20:33	:00	3:27	0		:00	:12	0
3/27/62	20:39	:00	3:21	0		:00	:05	0
3/28/62	20:27	:29	3:04	1	(1) Illiac failing because of experimental chassis connected to 2 ³⁹ in arithmetic section.	:00	:35	0
3/29/62	20:27	:00	3:33	0		:00	:11	0
3/30/62	21:34	:00	:00	0		:00	:49	0
3/31/62	23:38	:22	:00	1	(1) Unknown	:00	:00	0
					*Water to Illiac air conditioner turned off (March 19).			
TOTALS	662:56	14:49	63:15	15		3:00	18:58	0

PART VI

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

The International Business Machines 650 currently in use will be removed and replaced during August, 1962.

The routine X14-686', TRANSCRIBE--1604 Fortran-Codap Pre and Post Editor, described in the February Monthly Report, was written by F. Fischer.

The routine X13'-85', Drum, High Speed Memory, and Register Clear Routine, described in the February Monthly Report, was written by W. Wulf.

The routine K10'-79', Statistical Matrix Processor (STAMP), described in the February Monthly Report, was written by F. Fischer.

International Business Machines 650 Codes

During the month of March, specifications were presented for 13 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 381'. Numbers followed by T are for theses.

381' Agronomy. Soil Fertility. Two forms of nitrogen (NO_3 and NH_4) were applied at two rates (40 and 80 pounds/acre) at one of three times (fall, spring and summer). Treatments (13) were all combinations of the three above factors plus no nitrogen applied. The same set of treatments were applied to 26 locations for three years.

Analysis of variance including single degree of freedom analysis for treatments will be computed for yields in bushels/acre and tons/acre.

382'T Theoretical and Applied Mechanics. Numerical Solutions of Stresses in Tapered Thick-Walled Cylinders. The computer will be used to solve a large number of simultaneous equations, 120-170. The matrix of coefficients corresponding to the set of equations will be sparsely populated, and hence the (L-1') program will be used to solve the equations. However, there is a question of convergence, and it is anticipated that (L-1') will become a sub-routine in a larger iteration scheme. Several smaller problems will be solved first to check convergence of the solution, before the problem involving 120-170 equations is attempted.

The solution of the above equations will yield values of two stress functions at discrete points in a region corresponding to the cross-section of solids of revolution. In particular, stress functions will be determined for tapered thick-walled cylinders. With the stress functions so determined, it is possible to find the stresses in the cylinder wall.

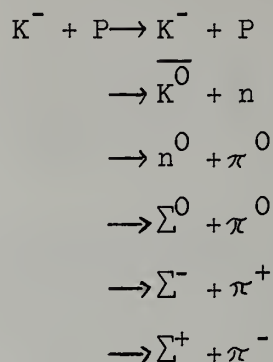
383'T Chemical Engineering. Optimal Control of a Pseudo-Markov Type Chemical Reactor. The problem under analysis is the determination of the optimal decision policy for a chemical reactor which receives disturbances in the form of catalyst activity variations. In order to determine this policy for a given set of control settings on catalyst flow and other reactor parameters, NC^2 nonlinear algebraic equations must be solved where N is 2-5, C is 10 or 20. N is a normalized valve position in the chemical reactor. C is the number of concentration increments being considered (either 11 or 22). Once these equations are solved, $N, C \times C$ matrices are built up, a similar number of matrices are read in via punched cards, and matrix multiplication is carried out. These results are stored on tape and then brought back into memory during the next and last stage, which is the solving of a $C \times C$ matrix four or five times. Due to the large amount of input-output data needed, the 650 was chosen in preference to the Illiac.

384' Physics. Analytic Continuation. In connection with the problem of finding the poles of the scattering amplitude in the complex ℓ -plane (Regge poles), it is proposed to calculate the scattering amplitude along the real axis of ℓ , and to analytically continue it into the complex plane by numerical integration of the Cauchy-Riemann relationships.

As a first attempt, the scattering amplitude for a delta-function potential, which can be expressed simply in terms of Bessel functions of real fractional order, will be considered. An elementary but important improvement is to calculate not the poles of the amplitude but the zeros of its inverse. This will avoid outraging the Runge-Kutta-Gill numerical integration subroutine.

It is difficult to see how this method will compare in accuracy or speed. It is suspected that it will provide a fast but rough first indication of a pole but that for the fine details, the other procedure will be necessary. Probably for arbitrary analytically untractable potentials, it will be too long to be useful.

The technique of numerical analytic continuation is probably worth studying for other possible applications to high-energy physics.



are being considered. There exists a $b \times b$ matrix (in this case $1 \times b$), i. e., a linear transformation which relates the scattering amplitudes in the incoming channels to that in the outgoing channels. Analytical expressions for six cross sections which involve six parameters (which are essentially equivalent to the $b = 1 \times b$ real elements of the above mentioned matrix) have been found. The IBM 650 is to be used to calculate the six cross sections varying the momentum in the initial $K^- + P$ channel from 20 Mev to 250 Mev in steps of 20 Mev with ten different choices of the b -parameters. The most complicated expression for the cross section looks like

$$\begin{aligned}
 d\sigma_{11} &= |A_{11}|^2 d\Omega \\
 A_{11} &= \frac{\eta}{K_1} \operatorname{cosec}^2 \left(\frac{\theta}{2} \right) \exp \left[2i\eta \log_e \sin \left(\frac{\theta}{2} \right) \right] + \frac{1}{K_1} c^2 K_1 T_{11} \\
 T_{11} &= \frac{\lambda_1 + \mu_1 - 2iK_2 \lambda_1 \mu_1}{2 [1 - is(\lambda_1 + \mu_1) - P'_1 K_1 \lambda_1 \mu_1]}
 \end{aligned}$$

where λ_1, μ_1 are complex parameters (i. e., four real parameters), and K_1 is the initial momentum, η, c^2, s, K_2 and P'_1 are given functions of K_1 .

Eventually, a search is to be made for λ_1, μ_1 and two other real parameters which best fit the given experimental data.

386'T Civil Engineering. An Analytical Investigation of the Inelastic Stability of Rectangular Steel Frames. This problem will consist of two parts. Part one will be a straightforward solution of second degree algebraic equations to generate tables of interaction curve ordinates. These ordinates will be

placed on cards for subsequent reloading and storage on tape in part two. Two such tables will be required for each entry into part two.

Part two will consist of the determination by numerical integration of a state of stable, inelastic equilibrium, for several loading conditions.

387' Physics. F_2 Color Center Theory. The problems of F_2 color centers render investigation by using the box-potential approximation. Several integrals of spherical Bessel and Hankel functions which must be numerically evaluated are necessary in the theory. The integrals are of the following form:

$$\int_{\rho_1}^{\rho_2} \int_{\theta_1}^{\theta_2} \left(\frac{\sin \alpha_1 \rho}{\alpha_1^2 \rho^2} - \frac{\cos \alpha_1 \rho}{\alpha_1 \rho} \right) \left(\frac{\sin \alpha_1 |\vec{\rho} - \vec{a}|}{\alpha_1^2 |\vec{\rho} - \vec{a}|^2} - \frac{\cos \alpha_1 |\vec{\rho} - \vec{a}|}{\alpha_1 |\vec{\rho} - \vec{a}|} \right) \\ \cos \theta \cdot \frac{\rho^2 - a^2 - |\vec{\rho} - \vec{a}|}{2a |\vec{\rho} - \vec{a}|} d\vec{s}$$

over such a domain such as the area common to two intersecting circles. Each integral will have to be evaluated for at least two sets of the constants α , a , and R . Some of the double integrals will be evaluated by approximations such as $\iint f(\rho, \theta) d\vec{s} \approx \sum f(\rho, \theta) \Delta s$. Other double integrals may be reduced to single integrals, whereupon they will be evaluated by Simpson's 1/3 Rule. In no evaluation will special subroutines such as Bessel function subroutines be employed.

388' Sociology. Sampling Errors for Complex Samples. This program is derived from a University of Michigan IBM 650 procedure and is designed to compute exact sampling errors for cluster samples. These cluster samples can be either multi-stage or uni-stage city directory samples composed of city directory address clusters and supplementary block samples. The sampling errors are computed for ratio estimators which can be means or percentages which fail to fulfill the requirements of simple random sampling.

389'T Chemistry. Kinetic and Thermodynamic Properties of Metal Trifluoroacetylacetonates. Metal trifluoroacetylacetonates may exist

in two geometrically isomeric forms. The purpose of the research is to determine the rate at which the two forms are interconverted and to evaluate the thermodynamic functions which describe the equilibrium between the two forms. Two types of data plots are obtained: a log (function of concentration and equilibrium constant) versus time and a log (equilibrium constant) versus (temperature)⁻¹. Both of these plots are linear. The information needed is the slope of the line and the probable error in the slope. This information can be obtained most readily by use of 650 Library Routine K7'-68'.

390' Agricultural Engineering. Soil Compaction Study. Eight soil compaction treatments are used on two soil types (a light soil and heavy soil). Two levels of nitrogen are supplied to each of the eight compaction treatments, making an 8 x 2 factorial set of treatments. The treatments are applied to the same plots each year and will be for a period of five to six years.

Corn is planted each season and numerous yield measurements are made (total grain yield, ear losses, grain losses) as well as plant measurements (lodged plants, erect plants, total plants, etc.).

Analysis of variance will be used to determine treatment differences for the different soils in each year and over all years (two at present) for each different set of data.

391'T Civil Engineering. Plate Analog Analysis. L1' will be used to solve three to six sets of 40 equations each for the deflections in a laterally loaded plate. The answers will be used to check a program solving the problem by relaxation on the CDC 1604.

392'T Agronomy. Corn-Teosinte Interspecific Hybrid Study. Corn-teosinte interspecific hybrids (48 males crossed onto each of two females) are being studied with respect to heritability. Analysis of variance is being used to estimate components of variance--that is, how much of the variability is due to environment, males, females, different families, etc.

393'T Agronomy. Solonetzic Soil Research. This research problem involves testing the elemental homogeneity and degree of weathering of solonetzic and non-solonetzic soils at three locations in Southern Illinois. A solonetzic

soil is one high in sodium salt content. Three horizons--A, B and C--containing two silt fractions--50-20 μ and 20-5 μ --have been analyzed for content of five elements--Na, K, Ca, Ti and Zr. A split-split-plot analysis of variance including single degree of freedom comparisons is necessary to determine significant differences between the above characters.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of March.

TABLE I'

		Hrs:Min
Scheduled Engineering		10:40
Unscheduled Engineering		13:47
Air Conditioning		:41
Log Summary		:16
CDC Preparation		5:11
Library Development		23:00
Agronomy Library	1:25	
DCL Library	<u>21:35</u>	
Computer Operator		2:03
Classes		70:39
Agricultural Engineering	:40	
Business Administration	6:13	
Civil Engineering	12:35	
Electrical Engineering	18:48	
Industrial Engineering	2:11	
Mathematics	28:34	
Mechanical Engineering	1:03	
Theoretical and Applied Mechanics	<u>:35</u>	
Instruction		:25
Wasted		<u>4:20</u>
		131:02

Use by Departments

Agricultural Economics	4:31
Agricultural Engineering	1:23
Agronomy	9:13
Chemistry	18:04
Civil Engineering	22:38
Digital Computer Laboratory	:04
Electrical Engineering	6:49
Entomology	:57
Graduate College	7:30
Graduate School of Business	1:31
Mechanical Engineering	4:17

Mining and Metallurgical Engineering	1:18	
Physics	34:32	
Psychology	:17	
Small Homes Council	1:14	
State Water Survey	1:27	
Statistical Service Unit	120:05	
Bureau of Community Planning	8:51	
Bursar's Office	5:43	
Business Office	26:17	
DHIA	49:01	
Education	25:21	
Mining and Metallurgical Engineering	<u>4:52</u>	
Theoretical and Applied Mechanics	7:34	
University of Kentucky	<u>:15</u>	
		<u>243:39</u>
		<u>374:41</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for March.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

407 accounting machine		1
Prints incorrectly	<u>1</u>	
533 card read punch		4
Reads incorrectly	2	
Card jam	<u>2</u>	
650 console and magnetic drum unit		3
Lost bits	2	
Clock not operating properly	<u>1</u>	
653		2
Fuse	<u>2</u>	
727 tape units		4
Tape read errors	2	
Would not rewind or unload	<u>2</u>	
Air conditioning		<u>1</u>
TOTAL		15

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
3/1/62	14:49		1:09	:09	5	:41	(1) Lost quinary bit in distributor. (2) Tape unit would not rewind or un-load. Had to manually force roller back. (3) Outside air conditioning fan belts had to be tightened. (4) 533 would not read. Broken wire found. (5) Many tape read errors.
3/2/62	9:58		6:01	:16	0		Special engineering time scheduled due to malfunction of 407 and tape units.
3/5/62	13:12	4:05			0		Tape unit 2 had trouble due to the capston motor shaft sticking caused by dirt. Relays and tubes replaced in the 407. Many tubes replaced in the 652.
3/6/62	16:38			:22	0		
3/7/62	16:35		:05	:14	1		(1) 407 not printing position 6 of word 8 when on-line. Buffer tubes replaced.
3/8/62	16:45			:07	1		(1) Card read errors. Reason unknown.
3/9/62	16:50			:14	0		
3/12/62	13:03	3:42	:27		1		(1) Clock orders will not execute. The connectors on the clock were sticking.
3/13/62	12:04		4:43	:20	2		(1) Lost quinary bits in program register. (2) Reads tape incorrectly from all units. Bad tube in 652.
3/14/62	16:45			:10	0		
3/15/62	16:30		:25	:04	1		(1) Fuse blew in 653. Replaced.
3/16/62	16:34			:26	0		
3/19/62	14:02	2:53			0		
3/20/62	16:14		:40	:09	1		(1) Fuse blew in 653. Replaced.
3/21/62	17:14			:07	0		

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPE OF FAILURES CAUSING REPAIR TIME
3/22/62	16:48			:11	0		
3/23/62	16:58			:07	0		
3/26/62	17:06			:09	0		
3/27/62	16:45			:38	0		
3/28/62	16:31			:26	1		(1) Tape unit 3 does not recognize reflective spot. Bad tube found.
3/29/62	16:42		:09	:08	1		(1) Card jam in 533 punch side.
3/30/62	17:10		:08	:03	1		(1) Card jam in 533 punch side.
TOTALS	345:13	10:40	13:47	4:20	15	:41	

PART VII
INTERNATIONAL BUSINESS MACHINES 7090-1401

In August, 1962, this Laboratory will acquire a 7090-1401 computing system with the following configuration:

The 7090

7108 and 7109 central processing unit with extended precision arithmetic, 7 index registers, interval timer and storage cell clock.

7151 console control unit.

7302 core storage.

7608 power converter.

7618 power control.

7607 III data channel with:

711 card reader.

716 printer.

721 punch.

740 and 780 cathode ray oscilloscopes.

Five 729 VI tape drives.

7617 data channel console.

7607 IV data channel with:

Direct data connection.

Five 729 VI tape drives.

7617 data channel console.

7606 multiplexor.

The 1401.

1401 Model E-3 processing unit.

1402 card reader and punch.

1403 II printer.

Two 7330 tape units.

The compiling routines, assembly routines and library to be used with this system are currently under study and development.

PART VIII
INSTRUCTIONAL USE OF COMPUTERS

During the month of March, specifications were presented for 11 new problems.

46 Agricultural Engineering 336. Problem 1. IBM 650. Governor Weight Balance. The problem pertains to a new governor design. The problem is set up to find the moment about the point of weight attachment, including inertial and centrifugal force effects. The weight, dimensions and angular velocity are varied to find the moment for different relationships.

47 Mathematics 195. Problem 1. IBM 650. Table of Powers of X. Write a machine language program to compute a table of the floating point numbers X , X^2 , X^4 , X^8 for $X = 0 (1) 20$. Follow the same output procedure as used in the demonstration program; the last instruction executed by your program must be 0000008000. Prepare your program deck as described in the handout, "PREPARING THE FIRST MACHINE LANGUAGE PROBLEM".

48 Business Administration 581. Problem 1. IBM 650. IBM Management Decision Making Laboratory. This is a business simulation exercise. Students (36) and faculty (18) will be divided into nine companies and three distinct industries. Three companies will constitute an industry and will compete with each other for sales and profits. The competitive framework is such that each company makes a series of decisions related to pricing, promotion, research, production, capital expenditures, and transportation costs. These decisions are fed into the IBM 650 to yield the results of each company during a three month period. The 650 output must be printed on the IBM 407. Results are returned to their respective teams which will then make another set of decisions. A series of 14 decisions will be made during the day.

Since there are nine companies, there will be three industries which are separate and distinct. The decisions of each industry will be cycled in order to make full use of computer facilities.

49 TAM 252. Problem 1. IBM 650. Twisting of a Shaft. The twisting of a uniform shaft of non-circular cross section results in a Dirichlet type boundary value problem for a Poisson equation.

The students are to replace the partial differential equation by a simple finite difference equivalent and are to solve the resulting system of linear algebraic equations by using library routines.

50 TAM 252. Problem 1. ILLIAC. Twisting of a Shaft. The twisting of a uniform shaft of non-circular cross section results in a Dirichlet type boundary value problem for a Poisson equation.

The students are to replace the partial differential equation by a simple finite difference equivalent and are to solve the resulting system of linear algebraic equations by using library routines.

51 Mathematics 195. Problem 2. IBM 650. Free Falling Body. The motion of a body which is dropped (zero initial velocity) and falls under the influence of gravity is described by the equations

$$v = gt$$

$$s = 1/2 gt^2,$$

where v is the velocity of the body t seconds after being dropped and s is the distance that the body has traveled in this time interval. The values of g at the equator and north pole are:

$$g = 32.09 \text{ ft/sec}^2 \text{ (equator)}$$

$$g = 32.26 \text{ ft/sec}^2 \text{ (north pole)}.$$

Write a GAT program to make a table of t , v (equator), s (equator), v (pole), s (pole) for $t = 0$ (0.1) 2; to represent these five quantities, use the GAT variables Y1, Y2, Y3, Y4, Y5, respectively.

52 Civil Engineering 391. Problem 1. IBM 650. Influence Lines for Continuous Beams. The assigned program involves the computation of influence lines for moment in a two-span continuous beam. The influence line is stored in memory and will be used in problem number 2 for the design of the beam and coverplate. The method of solution is left up to the student. While most students are using the conjugate beam method to obtain a closed, iterative solution for the influence ordinates, several other approaches, including Newmark's numerical procedure, are being used.

53 Civil Engineering 497. Problem 1. IBM 650. Design Coefficients for Hyperbolic Paraboloids. The problem will consist of the construction of several tables of dimensionless coefficients which will provide for the determination of normal, shear and edge bending forces in a general hyperbolic paraboloid. This will involve the solution of several algebraic expressions.

54 Mathematics 195. Problem 3. IBM 650. Simple Pendulum. The period, P , of a simple pendulum (see any elementary physics text) with length L and amplitude θ_0 is given by the infinite series expression

$$P = 2\pi \sqrt{\frac{L}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 k^2 + \left(\frac{1 \cdot 3}{2 \cdot 4}\right)^2 k^4 + \left(\frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6}\right)^2 k^6 + \dots \right\}$$

where

$$k = \sin \frac{\theta_0}{2}$$

and g is the gravitational acceleration. When θ_0 is very small $k = \sin \frac{\theta_0}{2} \approx 0$ and we have the approximation to P given by

$$P' = 2\pi \sqrt{\frac{L}{g}}.$$

When θ_0 is large enough to make k significantly different from zero, then more terms in the series must be included in order to get a good approximation to P . Consider the approximation which includes terms up to those involving k^8 and neglects terms involving higher powers of k ; call this approximation P'' . Make a table of θ_0 , P'' , E , where

$$E = \frac{P'' - P'}{P''}$$

$$\theta_0 = 1^\circ \quad (2^\circ) \quad 21^\circ$$

$$L = 1 \text{ ft.}$$

$$g = 32.258 \text{ ft/sec}^2.$$

Use GAT variables Y1, Y2, Y3 for θ_0 , P'' , E , respectively.

WARNING: Notice that the argument for the SIN subroutine must be in radians.

55 Electrical Engineering 320. Problem 2. IBM 650. Switching Problem. Assume a vibrating contact, closed for 0.1 seconds, and open for 0.1 seconds, alternately, is inserted across a 40 ohm resistor in series with another 40 ohm resistor, a 20 henry choke and a 240 volt battery. Assuming the switch closes at $t = 0$ and that $i(0) = 0$, program the IBM 650 to calculate values of i at the end of each 0.1 second interval. Use GAT variables X1 and X2 to represent current with switch closed (i_c) and open (i_o), respectively. Print the results in two columns (at the end of each 0.2 seconds).

X1

X2

Use the criterion

$$|i_o(t_1) - i_o(t_1 + 0.2)| < 10^{-5}$$

to stop the process.

$$\epsilon = 2.7182818.$$

56 Civil Engineering 314. Problem 1. IBM 650. King Post Truss. The object of this problem is to determine the configuration of a truss structure which will optimize certain design criteria. The criteria to be determined are least weight, total overload capacity, maximum efficiency proportions, and optimum conditions for a given deflection at the center.

PART IX
CONTROL DATA CORPORATION 1604

During the month of March, specifications were presented for two new problems. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 10T. Numbers followed by T are for theses.

10T Physics. Search for Regge Trajectories. In view of the current interest in solutions of quantum mechanical scattering problems for complex angular momentum, an attempt will be made to solve the radial Schrodinger equation

$$U(x)'' + \left(1 - \frac{V(r)}{K^2} - \frac{\lambda^2 - 1/4}{X^2}\right) U(x) = 0.$$

λ = complex parameter (angular momentum).

$V(r)$ = potential.

K^2 = energy, in proper units.

$X = Kr$.

U = radial wave function.

This is an eigenvalue problem. For fixed K^2 there will be one (or a few) values of λ for which there exists a solution with the asymptotic form of an outgoing wave. Since $\lambda = \mu + iv$ is complex, for each K^2 one has a two-dimensional eigenvalue problem, with a boundary condition (proper outgoing wave) which changes with λ . Finally, a curve (or curves) of λ as a function of K^2 in the entire complex λ - plane, is to be obtained so the eigenvalue problem must be solved many times. Since no tables of Bessel functions of complex order (solutions of the equation for $V(r) = 0$ and required for the boundary condition) exist, these will have to be computed as part of the program.

11 Civil Engineering. Simultaneous Analysis and Design of Building Frames. The simultaneous analysis and design of a general building frame of n columns and m stories, including allowable offsets, will be considered with respect to the following: study of hybrid structures, study of rates of convergences, study of structure weight with respect to method of convergence used, and study of effects of unbalancing moments of inertia of two or more members. The mathematical methods used will be primarily matrix algebra and some statistical techniques.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part V.

CDC 1604 TIME DISTRIBUTION

March, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	1:10			1:10
Animal Science	:34			:34
Astronomy	2:16			2:16
Bur. of Ec. and Bus. Res.	:56			:56
Chemistry	7:11	4:49		12:00
Civil Engineering	7:10	4:06		11:16
Electrical Engineering	1:32			1:32
Food Technology	2:49			2:49
Inst. of Comm. Res.	:11			:11
Mechanical Engineering	:12			:12
Physics		12:02		12:02
Physical Education	1:08			1:08
Psychology	8:29			8:29
Sociology	:06			:06
Theo. and Appl. Mechanics	1:47			1:47
Maintenance			:29	:29
TOTALS	35:31	20:57	:29	56:57

PART X
GENERAL LABORATORY INFORMATION

Seminars

"A New Logical Organization for a High Speed Arithmetic Processing Unit," by Mr. Philip Merryman, Aeronca Manufacturing, March 5, 1962

"Programming for the AC Phase of the New Computer," by Professor Gernot Metze, Digital Computer Laboratory, University of Illinois, March 12, 1962

"The Core Memory of the New University of Illinois Computer," by Dr. Sylvian R. Ray, Digital Computer Laboratory, University of Illinois, March 26, 1962

Special Lecture Series

"Introduction to ALGOL and Its Application," by Professor H. Rutishauser of the Swiss Federal Institute of Technology, every Wednesday, Thursday, and Friday for the period March 14 through April 11

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Visiting Faculty	0	1	.5
Research Associates	7	0	7.0
Graduate Research Assistants	10	20	21.7
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>40</u>	<u>16</u>	<u>45.2</u>
TOTAL	76	41	95.4

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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Physics

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

JUN 28 1962

JUN 28 1962

1962

TECHNICAL PROGRESS REPORT

- PART I - CIRCUIT RESEARCH PROGRAM
- PART II - ILLIAC USE AND OPERATION
- PART III - IBM 650 USE AND OPERATION
- PART IV - INSTRUCTIONAL USE OF COMPUTERS
- PART V - CONTROL DATA CORPORATION 1604
- PART VI - 7090-1401 COMPUTING SYSTEM
- PART VII - GENERAL LABORATORY INFORMATION

April, 1962

PART I
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834915).)

1. Introduction

Tohru Moto-Oka refined his analysis of tunnel diodes coupled into transmission lines and has obtained bounds for the maximum oscillator frequency. By diverse approximations the equations can be simplified to become directly usable in the design of hardware.

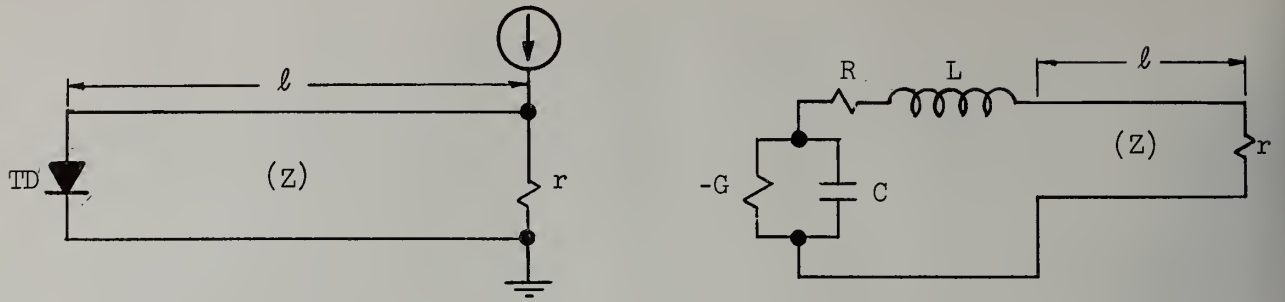
Henry Guckel has further examined coupled transmission lines and has found closed solutions in the case of a system of two pairs of parallel wires, one driven by a source and terminated by a mismatch, the second pair being mismatched at both ends. He has also used a new bridge method to measure tunnel diode characteristics which overcomes certain stability problems.

Thomas Burnside has designed some more accessory circuitry for the statistical analyzer. Below is the description of a 1 mc clock-source which has a wide range of adjustments for repetition rates, amplitudes, rise-times, etc.

John Hill has designed a failsafe clock to be used in his failsafe shifting register. A complete line of indicating failsafe modules is now in existence and the assembly of a demonstration unit has begun.

2. Tunnel Diode Circuit Theory

For the transmission line type TD amplifier and TD oscillator discussed in last month's report the theoretical analysis has been completed and rather interesting results were obtained: an upper limit of the oscillating frequency is now known.



(a) TD Oscillator with a transmission line with a length l and a characteristic impedance Z

(b) The equivalent circuit for small signal operation

Figure 1 TD Oscillator

The equivalent circuit for small signal operation of the TD oscillator shown in Figure 1(a) is given by Figure 1(b).

The oscillating conditions are as follows:

$$\left\{ \begin{array}{l} G = R \left(\frac{1}{R + j\omega L + Z \frac{1 + \rho e^{-j2\omega t_0}}{1 - \rho e^{-j2\omega t_0}}} \right) \end{array} \right. \quad (1)$$

$$\left\{ \begin{array}{l} \omega C = -I \left(\frac{1}{R + j\omega L + Z \frac{1 + \rho e^{-j2\omega t_0}}{1 - \rho e^{-j2\omega t_0}}} \right) \end{array} \right. \quad (2)$$

where $\rho = \frac{r - Z}{r + Z}$ and $t_0 = \sqrt{\mu \epsilon} l$

These equations can be rewritten as

$$\left\{ \begin{array}{l} G = \frac{R(1+\rho^2-2\rho \cos 2\omega t_0) + (1-\rho^2)Z}{(R^2 + \omega^2 L^2)(1+\rho^2-2\rho \cos 2\omega t_0) + 2\{R(1-\rho^2) - 2\rho \omega L \sin 2\omega t_0\}Z + (1+\rho^2 + 2\rho \cos 2\omega t_0)Z^2} \end{array} \right. \quad (1a)$$

$$\left\{ \begin{array}{l} \omega C = \frac{\omega L(1+\rho^2-2\rho \cos 2\omega t_0) - 2\rho \sin 2\omega t_0 Z}{(R^2 + \omega^2 L^2)(1+\rho^2-2\rho \cos 2\omega t_0) + 2\{R(1-\rho^2) - 2\rho \omega L \sin 2\omega t_0\}Z + (1+\rho^2 + 2\rho \cos 2\omega t_0)Z^2} \end{array} \right. \quad (2a)$$

that is

$$\left\{ \begin{aligned} & [G\{(R^2 + \omega^2 L^2 + Z^2)(1 + \rho^2) + 2ZR(1 - \rho^2)\} - R(1 + \rho^2) - (1 - \rho^2)Z] \\ & - 2\rho \cos 2\omega t_0 \{G(R^2 + \omega^2 L^2 - Z^2) - R\} - 2\rho \sin 2\omega t_0 (2\omega LGZ) = 0 \end{aligned} \right. \quad (1b)$$

$$\left\{ \begin{aligned} & \omega C \{(R^2 + \omega^2 L^2 - \frac{L}{C} + Z^2)(1 + \rho^2) + 2ZR(1 - \rho^2)\} \\ & - 2\rho \cos 2\omega t_0 \omega C (R^2 + \omega^2 L^2 - \frac{L}{C} - Z^2) - 2\rho \sin 2\omega t_0 (2\omega^2 LC - 1)Z = 0 \end{aligned} \right. \quad (2b)$$

$$\left\{ \begin{aligned} & (1 + \rho^2) [G(R^2 + \omega^2 L^2 + Z^2) - R + \left(\frac{1 - \rho^2}{1 + \rho^2} \right) (2GR - 1)Z] \\ & - 2\rho \sqrt{\{G(R^2 + \omega^2 L^2 - Z^2) - R\}^2 + 4(\omega LGZ)^2} \sin(2\omega t_0 + \alpha) = 0 \end{aligned} \right. \quad (1c)$$

$$\text{where } \alpha = \text{Arc tan } \frac{G(R^2 + \omega^2 L^2 - Z^2) - R}{2\omega LGZ}$$

$$\left\{ \begin{aligned} & (1 + \rho^2) \omega C \{R^2 + \omega^2 L^2 - \frac{L}{C} + Z^2 + \left(\frac{1 - \rho^2}{1 + \rho^2} \right) 2ZR\} \\ & - 2\rho \sqrt{\omega^2 C^2 (R^2 + \omega^2 L^2 - \frac{L}{C} - Z^2)^2 + (2\omega^2 LC - 1)^2 Z^2} \sin(2\omega t_0 + \beta) = 0 \end{aligned} \right. \quad (2c)$$

$$\text{where } \beta = \text{Arc tan } \frac{\omega C (\omega^2 L^2 + R^2 - \frac{L}{C} - Z^2)}{(2\omega^2 LC - 1)Z}$$

If the circuit constants are given, these equations determine the oscillating frequency and the negative conductance.

The negative conductance is considered as being the average negative conductance of the large signal operation of the device. Some information about amplitudes can be obtained in this way.

Maximum Oscillating Frequency

The upper frequency limit $f_m = \frac{\omega_m}{2\pi}$ of oscillations is deduced easily by considering Equation (2c):

$$\omega_m^2 C^2 \left\{ R^2 + \omega_m^2 L^2 - \frac{L}{C} + Z^2 + \left(\frac{1-\rho^2}{1+\rho^2} \right) 2ZR \right\}^2 \quad (3)$$

$$= \frac{4\rho^2}{(1+\rho^2)^2} \left\{ \omega_m^2 C^2 (R^2 + \omega_m^2 L^2 - \frac{L}{C} - Z^2)^2 + (2\omega_m^2 LC - 1)^2 Z^2 \right\}$$

At maximum frequency the length of the transmission line must be

$$\ell_m = \frac{t_{om}}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu\epsilon}} \frac{1}{2\omega_m} \left\{ \frac{3}{2} \pi + 2n\pi - \text{Arc tan} \frac{\omega_m C (\omega_m^2 L^2 + R^2 - \frac{L}{C} - Z^2)}{(2\omega_m^2 LC - 1)Z} \right\} \quad (4)$$

also, the conductance must be

$$G_m = \frac{R(1+\rho^2+2\rho \sin\beta_m) + (1-\rho^2)Z}{(R^2 + \omega_m^2 L^2)(1+\rho^2+2\rho \sin\beta_m) + 2\left\{ R(1-\rho^2) + 2\rho\omega_m L \cos\beta_m \right\}Z + (1+\rho^2-2\rho \sin\beta_m)Z^2} \quad (5)$$

$$\text{where } \beta_m = \text{Arc tan} \frac{\omega_m C (\omega_m^2 L^2 + R^2 - \frac{L}{C} - Z^2)}{(2\omega_m^2 LC - 1)Z}$$

If we assume that $\rho = -1$, these relations are simplified and the maximum frequency and conductance are given by

$$\omega'_m = \frac{1}{2RC} \quad (3)'$$

$$G'_m = \frac{R(1 - \sin\beta'_m)}{(R^2 + \omega_m'^2 L^2 + Z^2) - (R^2 + \omega_m'^2 L^2 - Z^2) \sin\beta'_m - 2\omega'_m LZ \cos\beta'_m} \quad (4)'$$

Equation (4)' can be rewritten as follows

$$G'_m = \frac{R}{R^2 + \left(\omega'_m L \pm \sqrt{\frac{1 + \sin\beta'_m}{1 - \sin\beta'_m}} Z \right)^2} = \frac{1}{2R} \quad (4a)'$$

From Equation (3)' (4a)'

$$\omega_m' = \frac{G_m'}{C} \leq \frac{G_o}{C} \quad (5)$$

where G_o is a maximum absolute value of the negative conductance.

Therefore, the actual upper frequency limit is given by

$$\omega_m' = \text{Min.} \left(\frac{G_o}{C}, \frac{1}{2RC} \right) \quad (6)$$

If we assume that the series impedance of a TD equivalent circuit can be neglected, the maximum oscillating frequency becomes

$$\omega_m'' CZ = \frac{-2\rho}{1-\rho^2} \quad \text{or} \quad \omega_m'' = \frac{1}{2Cr} \left(1 - \frac{r^2}{Z^2} \right) \quad (3)''$$

and for

$$G_m'' Z = \frac{1+\rho^2}{1-\rho^2} \quad \text{or} \quad G_m' = \frac{1}{4r} \left(1 + \frac{r^2}{Z^2} \right) \quad (4)''$$

From these equations, the upper frequency limit is given by

$$\omega_m'' \leq \frac{-2\rho}{1+\rho^2} \frac{G_o}{C} \leq \frac{G_o}{C} \quad (5)'$$

for a tunnel diode of negligible series impedance.

3. Experimental Tunnel Diode Work

Strip Line Coupling

In order to get a more readily solvable set of equations the geometry in Figure 2 was analyzed.

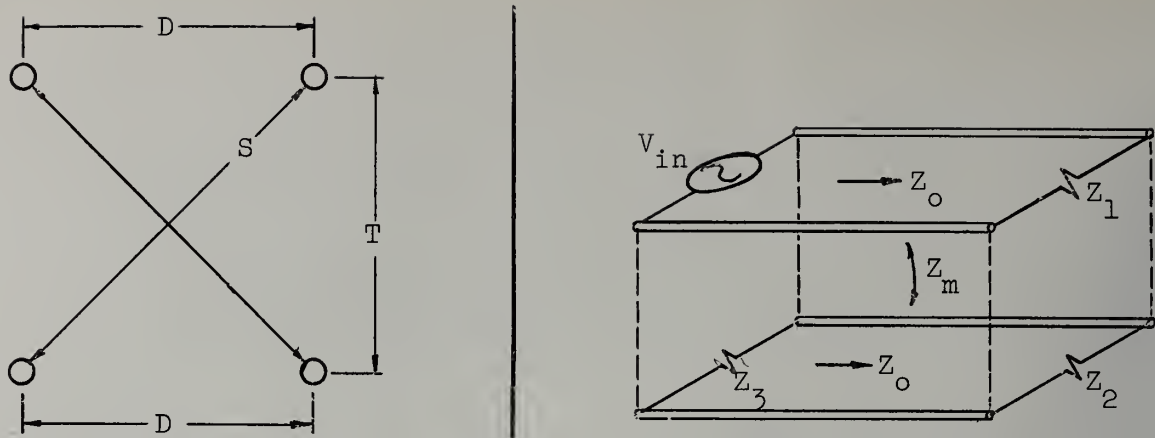


Figure 2 Coupled Lines

This system is solvable. A general solution, which has the property of having only forward running waves, depends on the solution of a fourth order equation involving Z_1 , Z_2 , Z_3 , Z_0 and Z_m as variables.

Tunnel Diode Measurement

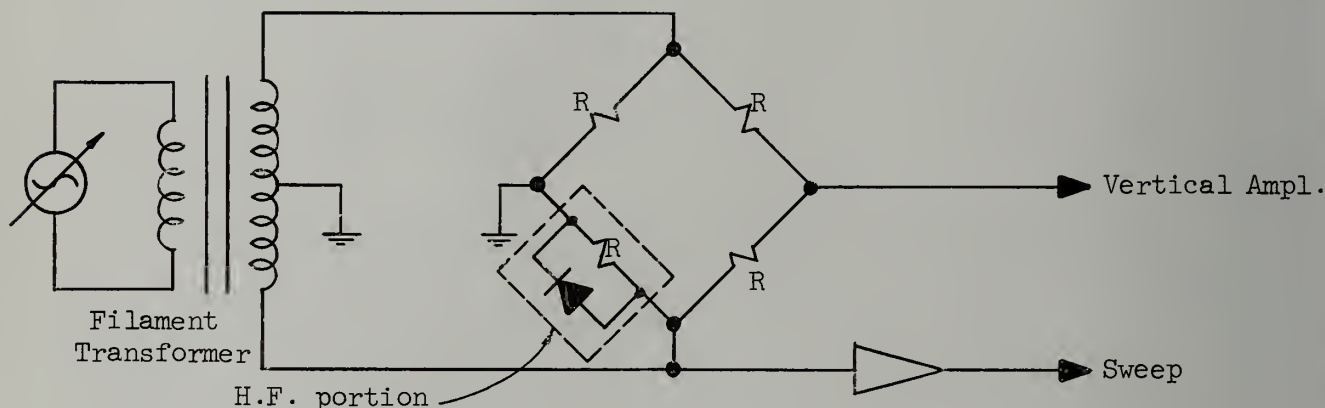


Figure 3 Bridge Measurement of Tunnel Diodes

The arrangement in Figure 3 was used to observe the entire tunnel diode characteristic with the scope. The value of R is selected in such a way that the R -TD combination is just stable. Only this part of the bridge has to be a H.F. circuit. After this measurement the R -TD circuit was measured with the Rhode-Schwarz bridge. These data are being reduced.

4. Work on the Statistical Analyzer

The following pulse generator shown in Figure 4 has been designed.

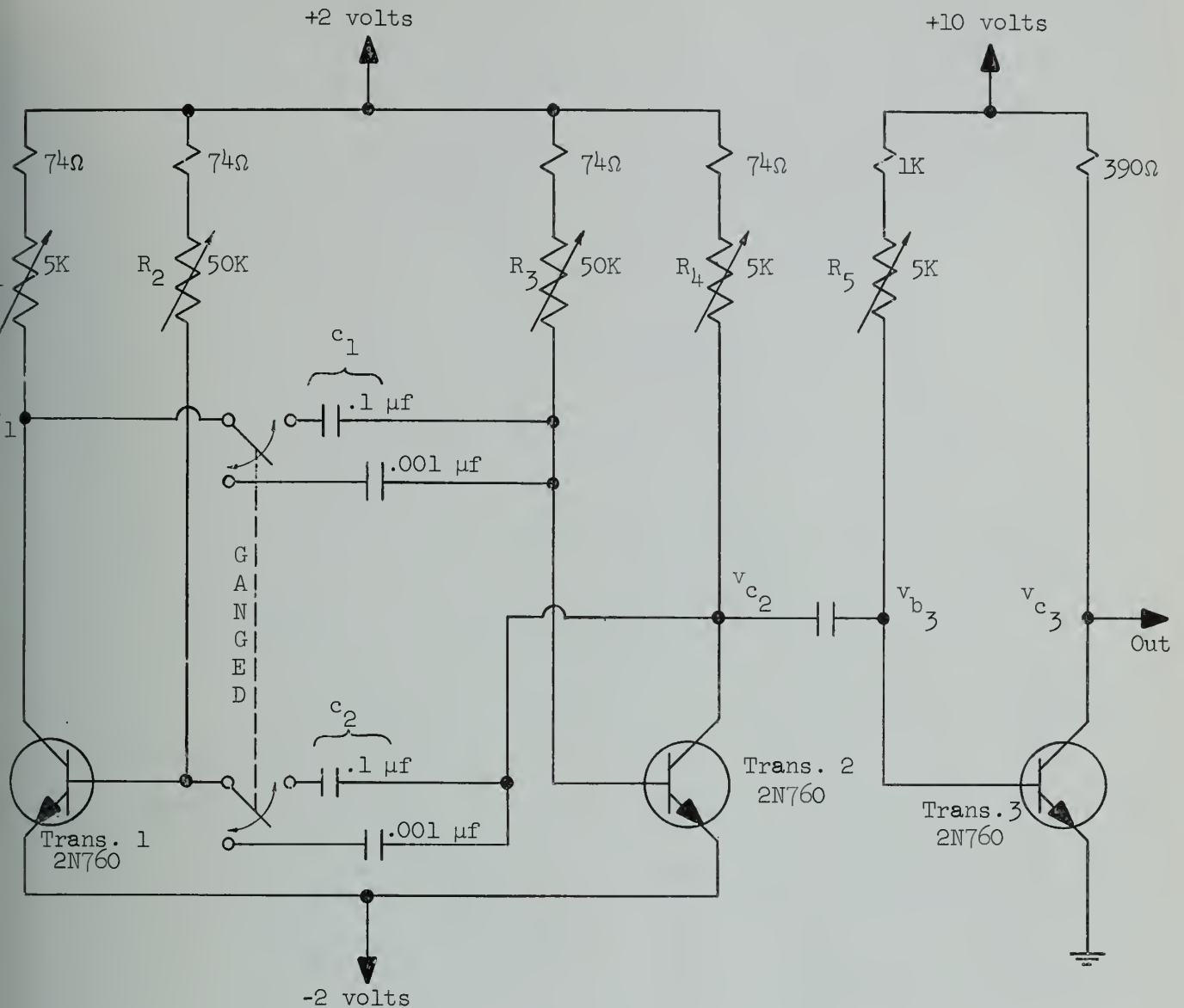


Figure 4 1 Megacycle Pulse Generator

The first two stages on the left oscillate at a frequency varying from 260 cps to 13 KC when $C_1 = C_2 = .1 \mu\text{f}$. When $C_1 = C_2 = .001 \mu\text{f}$, the frequency varies from 20 KC to 1 megacycle. The frequency of operation is inversely proportional to R_2 and R_3 , while the slope of the transition from one state to the other is inversely proportional to R_1 and R_4 .

Below in Figure 5 is a sketch of v_{c2} versus time

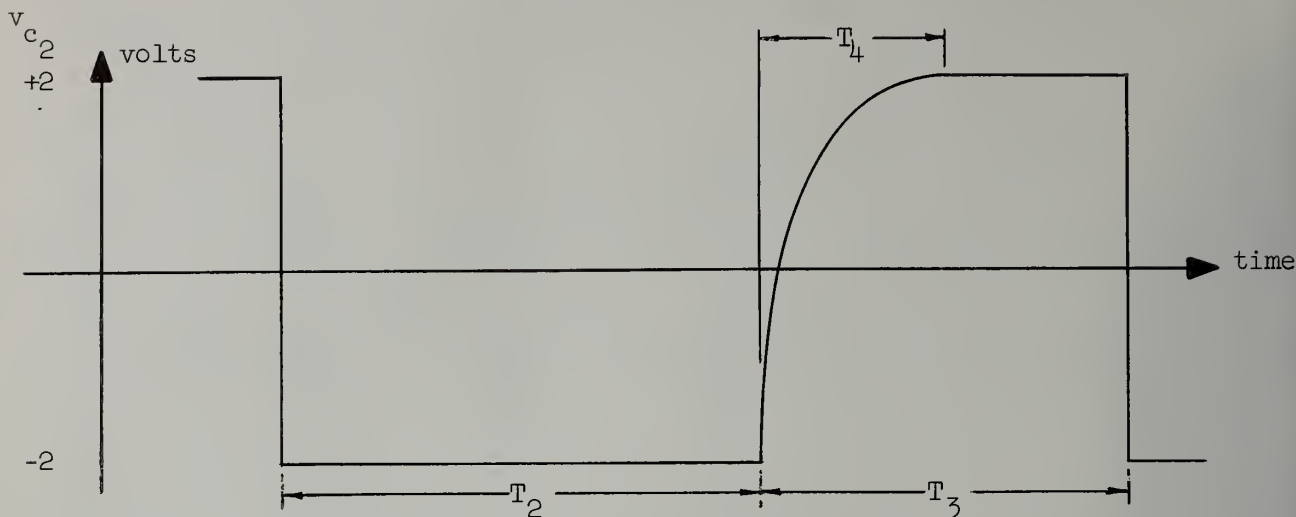


Figure 5 Collector Voltage of Transistor 2 Versus Time

T_2 is directly proportional to R_2 , T_3 is directly proportional to R_3 , and T_4 is directly proportional to R_4 .

The last stage on the right determines the width of the final voltage pulse output at v_{c3} . Consider that initially transistor 3 is conducting and transistor 2 is not conducting. Initially, then, $v_{b3} = v_{c2} - 2 = 0$ volts. When transistor 2 is turned on v_{c2} suddenly drops from +2 volts to -2 volts. Then, momentarily, v_{b3} is still $v_{c2} - 2$ volts or -4 volts and transistor 3 is turned off. The capacitor is charged from the +10 volt source and transistor 3 is turned on again .1 μ sec to .5 μ sec later. This is the pulse width used to trigger the flipflops at a rate of 1 megacycle on the sampling system.

5. Indicating Failsafe Circuits

Failsafe Clock Generator

The circuit in Figure 6 provides a 2 mc sine wave with a 4 volt peak-to-peak amplitude. It is essentially composed of two separate AC amplifiers, each with loose inductive coupling to a common tank circuit. The two oscillators thus formed run in phase and have identical output signals. Each of the two emitter follower output stages feed the identical

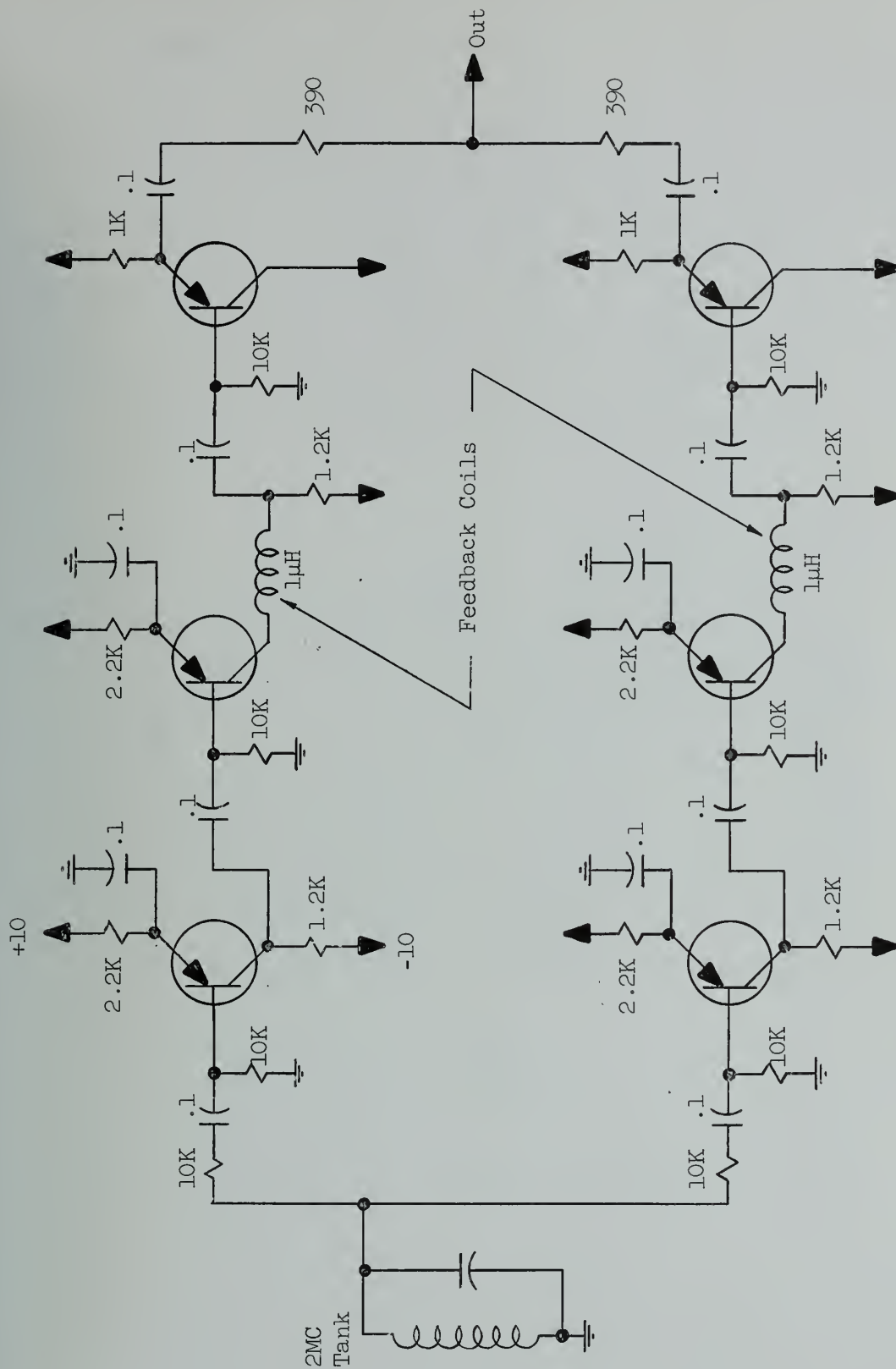


Figure 6 Clock Generator

sine waves through their series resistors to the output. The circuit has the property that any one transistor in it can be opened or shorted between any set of terminals and the circuit will still function. The failure analysis is quite straightforward. If any such failure occurs it only kills one of the two circuit chains between the tank and the output. Since the tank circuit is isolated by a 10K resistor from the amplifier inputs, an amplifier failure has no loading effect on the tank, and the remaining chain sustains the oscillations. When one of the chains fails there is one active output and one dead one. In this case the two output resistors form a 2:1 voltage divider and hence the output voltage is one-half that of the normal voltage. The effects of this reduction are overcome by having the oscillator give twice as much voltage as one needs with no failure.

Failsafe "Rectifier" Circuit

This circuit (shown in Figure 7) performs the half wave rectification of an AC input signal, i.e., only the positive or the negative portion of the input signal appears at the output. NPN transistors make it a positive rectifier and PNP a negative one. The circuit performs the rectification by emphasizing the non-linear properties of an emitter follower with a very high emitter resistor and a low resistance AC emitter load. Since the three transistors in parallel are each isolated from the input by a series resistor, any one of the transistors may open or short and the basic circuit operation will not be effected. However, the event of a failure reduces the input impedance and the ability to drive other circuits.

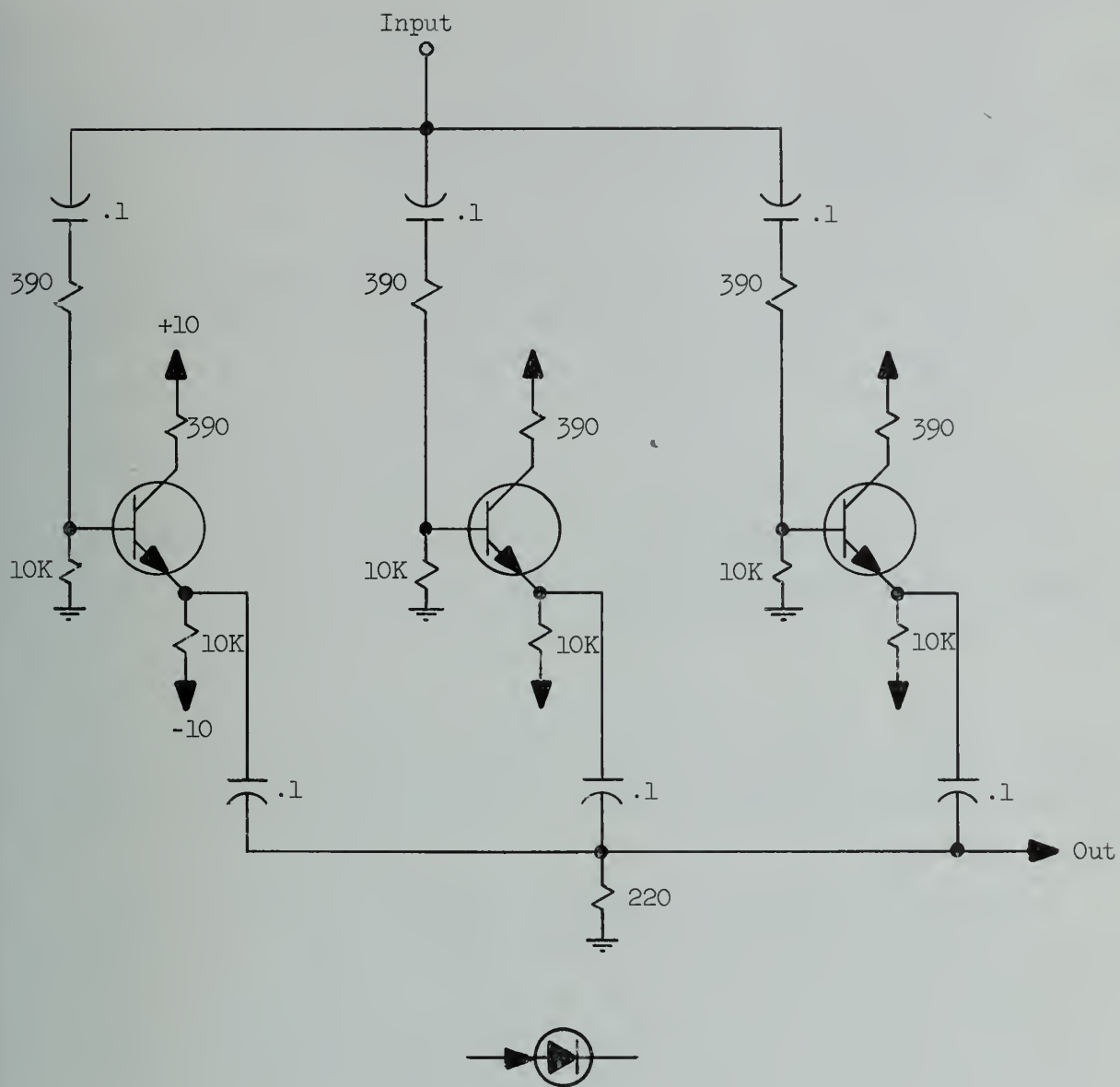


Figure 7 Failsafe "Rectifier" Circuit

PART II
ILLIAC USE AND OPERATION

Illiac Usage

During the month of April, specifications were presented for ten new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2161T. Numbers followed by T are for theses.

2161T Electrical Engineering. Electron Beam Harmonic Analysis. The harmonic content of a sinusoidally deflected electron beam is to be analyzed in terms of the deflection amplitude and beam size.

2162T Agricultural Economics. Structure of the Oilseeds Market. Five sets of approximately seven equations each are to be used to describe the structure of the oilseeds market. Each set contains approximately 14 variables with 34 observations over each variable. Each of the equations must be fitted using least squares or limited information methods of estimation.

2163T Sociology. Factor Analysis of Parents' Rankings of Ten Life Goals for Children. Fathers and mothers in 365 families ranked a list of ten life goals for boys in order of importance as they perceived it and as they hoped boys would rank them.

Correlation matrices are available (computed on Illiac) for the responses of both fathers and mothers to life goals for boys. It is proposed to factor analyze these matrices for two purposes: in order to gain information for research purposes concerning the factors underlying the parental responses to the ten life goals, and in order to determine the effect on the factor matrices of using fixed communalities as opposed to estimated communalities and of using rotation procedures which give orthogonal simple structure as opposed to those giving oblique simple structure.

Accomplishment of the second purpose listed above will aid greatly in enabling sound decisions regarding the use of factor analytic techniques in the future.

KSL 1.20 will be used in the initial factorization of the matrices in order to estimate k, the number of common factors. KSL 1.52 will be used to estimate communalities. KSL 1.80 will be used to rotate the factor matrices to orthogonal simple structure. KSL 1.90 will be used to rotate the factor matrices to oblique simple structure.

2164T Civil Engineering. Effect of Beam Torsional Stiffness on Plate Beam Systems. Influence surfaces are to be drawn for moments at various points in a square plate beam bridge simply supported on the ends, with the edges free. The ordinates of the influence surfaces will be obtained by the method of finite difference equations. One program will be written to write the finite difference equations for various values of stiffness parameters. These equations will be solved separately by L7-230. The results will be combined by means of a separate program.

2165 Electrical Engineering. Least Squares Coefficient Determination. Least squares coefficients are to be determined for the polynomial representation of a two parameter set of curves. These will be used by a larger program which is still in preparation.

2166 Psychology. Family Attitudes. A battery of tests are being prepared to study the attitudes between members of the family to determine the motivational content of the relationship.

The battery will be graded and standard scores calculated across attitudes for each subject, by means of KSL 4.15 and KSL 4.16 (cumulative proportion and T-score programs). These will then be correlated (K-8), factored (KSL 1.20 and KSL 1.21) and submitted for analytic rotation using Oblimax (KSL 1.90), Varimax (KSL 1.80), and Rotoplot (KSL 1.96).

Factor scores will be calculated on the best rotated position and correlated (K-8) with individual item scores to ascertain the best items for a reduced battery.

The reduced battery of tests will be administered to another population with additional tests; and this data will be correlated, factored and rotated in sections to test hypotheses concerning factored relationships.

2167T Psychology. Interpersonal Perceptions and Deviant Behavior of Junior High Children. The purpose of this research is to determine whether there is a relationship between interpersonal perceptions and observed behavior, both normal and deviant, of children of junior high age. The interpersonal perceptions will be measured by the use of the Osgood Semantic Differential type of test with 26 scales and six concepts. Two types of data will be collected on the behavior of these children, ratings done by their teachers in school and objective test data gotten in a situation conducive to cheating.

Six factor analyses will be done, one for each of the six concepts, using the 26 scales as the variables taken across subjects. These factor structures will be examined for similarity after a Varimax rotation of each of the six structures. Then, after possible combination of these structures, if they are "similar" to a sufficient degree as determined by some method to measure factor structure similarity, factor scores will be derived. Upon the basis of these factor scores, comparisons will be made between the behavioral groups. These comparisons will involve tests for differences in means and possibly correlations and D scores.

2168 Animal Science. Factors Affecting Beef Carcass Yields. This is an analysis of data on the portions into which beef carcasses are divided, aimed at learning what are the characteristics of carcasses which prove to be of high value when cut. The mathematical method is the method of least squares.

2169 Education. A Study of Social Desirability Over Successive Age Levels. A test of social desirability has been administered to two groups of students differing in age. A factor analysis is required of the correlation between items to determine whether a general tendency toward answering the items can be accounted for by a "social desirability factor". A comparison of this factor between the two groups would then be made.

2170 Preventive Medicine. Interindividual Variations in Mood. Mood becomes a relevant variable when studying the effects of certain experimental conditions. This is a pilot study which aims at an initial definition of some of the common factors in descriptions of mood.

Four subjects have described their moods daily for 60 consecutive days. The instrument, basically an adjective check-list in which each adjective is rated on a four point scale, was constructed by another investigator for use in studies evaluating the effects of certain drugs. Although the way in which it was constructed poses certain questions, it has been used in order to compare our results with those of the original investigator.

Thus, four sets of data have been obtained. Each set consists of a matrix of order 60 x 133. The cell entries are the single, unsigned digits 1 through 4, inclusive. For each set of data an Oblimax rotational solution in terms of both the reference vector structure and the primary factor pattern will be obtained.

The results of these analyses will be used to improve the technique for measuring moods.

Table I shows the distribution of Illiac machine time for the month of April. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min
Scheduled Maintenance	63:36
Unscheduled Maintenance	29:17
Drum Engineering	10:34
Leapfrog	10:35
Library Development	:08
Classes	24:56
RAR	:06
Wasted	<u>1:32</u>
	140:44

Use by Departments

Aeronautical Engineering	:14	(:25)
Agricultural Economics	7:55	(1:35)
Agronomy (00 15 65 330 38)	:19	
Agronomy	:15	
Animal Science	3:44	(:04)
Bureau of Educational Research (PH-M1839)	2:08	
Chemistry	113:35	(3:52)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	4:38	
Civil Engineering (DA-104)	:09	
Civil Engineering	23:57	(3:59)
Coordinated Science Lab. (DA-36-039-SC56695)	51:08	

Digital Computer Lab. (US TR AEC-1018)	6:30	
Digital Computer Lab. (NONR 1834(27))	1:06	
Digital Computer Laboratory	111:17	
Economics (NSFG 7056)	8:31	
Electrical Engineering (NASA-NSG-24-59)	19:07	
Electrical Engineering (AF 7043)	8:30	
Electrical Engineering (NSFG 14894)	2:37	
Electrical Engineering	3:47	(:09)
Finance (IHR-71)	:39	
Geological Survey	:33	
Inst. of Communications Res. (44-28-20-378)	3:30	
Inst. of Communications Res. (USPHM-3941)	:02	
Institute of Communications Research	:05	(:06)
Institute for Research on Exceptional Children	:17	(:05)
Mechanical Engineering	19:53	
Mining and Metallurgical Eng. (TRUS AF6770)	:21	
Mining and Metallurgical Eng. (NSFG 146-41)	1:37	
Music	1:08	(2:19)
Natural History	:09	
Nuclear Engineering	:27	
Office of Instructional TV (OE 7-11-107.00)	1:17	
Physical Education	1:21	
Physics (AF 49(638)661)	:18	
Physics (NONR 1834(05)A)	:17	
Physics (NSF 14308)	2:04	
Physics (NSFG-17428)	:38	
Physics	11:57	
Psychology (MD2060)	:46	
Psychology (AF 49(638)371)	2:03	
Psychology (M1774)	3:36	
Psychology (ONR 1834-36)	1:16	
Psychology	63:43	(11:22)
Sociology	2:34	(2:21)
State Water Survey (DA-36-039-SC75055)	23:30	
State Water Survey	9:25	
Theoretical and Applied Mech. (NOBS 72069)	:18	
Theo. and Appl. Mech. (DA-01-021 ORD 11878)	6:40	
Theoretical and Applied Mechanics	:46	
UCLA	:37	
	<u>531:16</u>	<u>(26:58)</u>
		<u>672:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between

10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table II

Punch	3
Reader	5
Arithmetic	1
Input-Output	2
Memory	2
Drum	6
Power (Filament Voltage Low)	1
Unknown	<u>5</u>
TOTAL	25

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/1/62	23:38	:22	:00	1	(1) Punch number 3 erred.	:00	:00	0
4/2/62	20:24	:00	3:36	0		:00	:12	0
4/3/62	19:47	:00	4:13	0		:00	:12	0
4/4/62	20:37	:00	3:23	0		:00	1:26	0
4/5/62	20:26	:22	3:12	2	(1) Unknown. (2) Filament on Illiac low.	:00	:19	0
4/6/62	21:27	:00	2:33	0		:00	:16	0
4/7/62	24:00	:00	:00	0		:00	:00	0
4/8/62	23:59	:01	:00	1	(1) Punch error 1.	:00	:00	0
4/9/62	21:08	:00	2:52	0		:00	:21	0
4/10/62	20:30	:00	3:30	0		:00	:16	0
4/11/62	21:31	:00	2:29	0		:00	:32	0
4/12/62	20:08	:46	3:06	4	(1) Reader H. (2) Unknown. (3) Unknown. (4) Punch number 4 erred.	:00	1:06	1
4/13/62	17:00	4:30	2:30	2	(1) Arithmetic. (2) Input-output.	:00	:32	0
4/14/62	21:00	3:00	:00	3	(1) Reading incorrectly. (2) Drum failure. (3) Drum failure.			
4/15/62	15:07	8:53	:00	1	(1) (Drum) Continuation of number 3 on April 14.	:00	:00	0
4/16/62	20:54	:00	3:06	0		:00	:30	0
4/17/62	21:02	:00	2:58	0		:00	:20	0
4/18/62	15:57	4:45	3:18	1	(1) Drum failure.	:00	:24	0
4/19/62	18:53	1:34	3:33	3	(1) Drum failure. (2) Unknown. (3) Reader "G" failed.	:00	:15	0
4/20/62	21:00	:00	3:00	0		:00	:18	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/23/62	21:04	:00	2:56	0		:00	:02	0
4/24/62	21:11	:00	2:49	0		:00	:12	0
4/25/62	20:47	:00	2:13	0		:00	:38	0
4/26/62	19:22	1:04	3:34	3	(1) Reader K failed. (2) Unknown. (3) Unknown, seems to be input trouble.	:00	:10	0
4/27/62	21:19	:00	2:41	0		:00	:29	0
4/28/62	24:00	:00	:00	0		:00	:00	0
4/29/62	20:26	3:34	:00	2	(1) Memory pos. 2 ⁻²⁶ . (2) Drum failure.	:00	:59	0
4/30/62	20:55	1:15	1:50	2	(1) Reader K failed. (2) Memory pos. 33.	:00	:22	1
TOTALS	577:32	30:06	64:22	25		:00	10:27	2

PART III
INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

International Business Machines 650 Usage

During the month of April, specifications were presented for 14 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 394'. Numbers followed by T are for theses.

394' Civil Engineering. Pointing Error in Solar Observations. This problem is an attempt to determine the pointing error in solar observations used for the determination of azimuth of a line in surveying. The IBM 650 is to be used to compute the azimuth of the sun and the error in this computed azimuth due to an error in time.

395' Animal Science. Factors Affecting Protein Use by Rats. The study involves the effect of four variables, age, weight, feed intake, and protein level of diet, on protein utilization by young albino rats. Twenty-four animals were used in each of two experiments and 36 in a third experiment. Each of the three experiments contained three periods of observation. The STAMP program will be used to find the contribution of each variable and of their interactions to protein utilization.

396'T Home Economics. Antioxidants and Frozen Storage of Pork. The general topic of study is the use of antioxidants in the frozen storage of pork chops and sausage.

The main objective of the study is to see whether the addition of an antioxidant or a combination of antioxidants to pork chops or pork sausage would delay onset of rancidity and thus increase freezer storage of the product. Two lots of sausage of three replications and one lot of pork chops of three replications were frozen and stored at +10°F or 0°F. Seven, eight or ten treatments were used per lot. The meat was analyzed after 0, 8, 16 and 24 weeks of freezer storage by means of chemical tests (free fatty acids, TBA values) and palatability ratings (including aroma, color, flavor, rancidity, juciness and tenderness). The IBM 650 will be used for analysis of variance of the data collected in the above tests.

397' Animal Science. Evaluation of Lamb Carcass Characteristics. A least squares solution will be used to analyze lamb carcass characteristics of four groups of animals. The STAMP program (K-15) will be used to compute product moment correlation coefficients between all measurements as well as to compute a number of prediction equations expressing dressed carcass variables in terms of experimental treatments and other measurements made prior to slaughter.

398'T Marketing. Levels of Living and Petroleum Consumption. The study tries to find out whether petroleum consumption has any correlation and in what direction with the component of living such as per capita income, school enrollment, infant mortality rate, protein requirements, etc.

To find this out, petroleum is correlated to some aspect of living for individual countries through time and for a group of countries which are to a considerable extent under the same social system. Thus, the grouping of countries has been according to non-centrally planned countries, centrally planned countries and under-developed countries.

There are missing data in the series (1951-1959). As a matter of fact, the missing data, if available, will not materially affect the results because the changes in most variables over time is not drastic. The general trend is more important to the study rather than the exact measurement. In other words, an exact measurement in level of living has not yet been derived. At best, the trend through time is dealt with. In some variables, there is just one observation. This is due to the fact that the change cannot be rounded even for a number of years. People working in agriculture are of that type. In the last nine years, the figures seem to be constant.

399' Agronomy. Rotation Experiments. Ten rotations and eight fertilizer treatments are set up in a split-block design to determine if there are effects of different fertilizers on the rotations and whether the rotations are different from each other. The fertilizer treatments consist of not fertilizer, plus nitrogen, plus phosphorous, plus potash, plus iron, plus all minor elements and plus all major and minor elements. Rotations consist of continuous corn, corn and rice sequence, and sequences of corn, rice and legumes (soybeans, peanuts and mung beans) as well as a (corn, rice, sweet potato) and (sorghum, rice, soybean) rotation. Analysis of variance will be used to determine fertilizer difference, rotation difference, season difference and any interaction difference.

400' Chemistry. Distribution of End-to-End Distances. This is a simple problem designed to compute the distribution of end-to-end distances of a polymer. The input data to this problem are IBM cards containing, among other data, squared end-to-end distances of polymers generated on the Illiac in programs 1505 and 1793. The program here will accumulate this data, normalize it, and print it on the 407. The program will then read in a deck containing degeneracy data pertaining to the tetrahedral lattice appropriate to this problem and utilize this input to renormalize the accumulated distribution data. This renormalized output will then be printed out.

401' Mechanical Engineering. Pressure Angle. A calculation of the pressure angle for various cam angles will be carried out.

α = pressure angle

θ = cam angle

$$\delta = f [1 - 10\theta^3 + 15\theta^4 - 6\theta^5]$$

$$\frac{d\delta}{d\theta} = f [-30\theta^2 + 60\theta^3 - 30\theta^4]$$

where f = a constant.

$$\text{Then } \alpha = \arctan \left[\cot \delta + \frac{L}{C} \frac{1 - \frac{d\delta}{d\theta}}{\sin \delta} \right]$$

A series will be used to calculate the arctangent.

402' Education. Methods of Programming Materials for Efficient Learning on Self Instructional Devices. Twenty-five children learned 25 words; five words within each of five concepts. These words were taught under all possible combinations of the combined conditions called 1, 3, 6, 9, 12. For example, there were conditions of 1-1, 1-3, 1-6, 1-9, 1-12; 3-1, 3-3, 3-6, etc., to 12-12. These conditions were different exposures under two programming principles, designated as prompting and confirmation. Prompting always preceded confirmation. A Greco-Latin square design was utilized and repeated five times. The Greco square corresponded to prompting, the Latin square to confirmation. The five repetitions were made to include the 25 words. The present analysis is to test the experimental design for orthogonality.

403'T Aeronautical and Astronautical Engineering. Free Vibrations of Continuous Panels. The natural frequencies of vibration for continuous skin-stringer panels are to be determined.

The equations consist of a 4×4 determinant, each element containing hyperbolic and circular trigonometric functions, to be expanded. This determinant contains the natural frequencies of vibration and is coupled with another equation containing only circular functions.

A typical structure of this type is a flight vehicle fuselage.

The elements of the above mentioned determinant can be reduced analytically to functions of one variable, resulting in an expression of the form $f(x) = 0$. The specific algorithm to be used to find the roots is given in Communications ACM, November, 1960 ("Rootfinder III", John G. Herriot, Stanford University).

404' Electrical Engineering. Optimum Angle Between Two Mirrors for Repeated Reflection of Laser Beam. A laser beam is to be reflected 50 times between two mirrors. It is necessary to calculate the angle between the two mirrors which will result in the 49th and 50th reflected rays being far enough apart that they can be detected separately. The thickness of the glass mirrors is of the same order as the distance between them so the path of the light inside the glass must be considered.

The resulting equation involves the summation of four double summations with the independent variable raised to some power in each term.

The iteration method used will be Newton's method of chords.

405' Civil Engineering. Linear Program Construction Operations. This problem involves the testing of proposed mathematical models involving linear programming to determine the validity of results when applied to specific construction operations.

406'T Aeronautical and Astronautical Engineering. Dissociation of Diatomic Gases. A program is under development for solving equations for the one-dimensional flow of a dissociating diatomic gas, containing both thermodynamic and chemical variables. When one specifies the variation of atom species concentration with respect to axial position along the duct, it becomes necessary to integrate two simultaneous, first-order, ordinary, differential equations to obtain the solution. The Runge-Kutta method of integration will be used.

407'T Civil Engineering. Calculation of Varied Flow Functions. If, across a stream flowing with a normal depth " y_n " and a free surface, an obstruction like a dam is placed, the surface profile changes and takes on a new form. The new surface more or less coincides with the one due to the original normal depth as long as some distance L away from the obstruction is exceeded. The problem under question concerns the determination of the surface profile near the obstruction.

The new surface profile is obtained by integrating the equation

$$\frac{dy}{dx} = s_0 \frac{1 - \left(\frac{y_n}{y}\right)^N}{1 - \left(\frac{y_c}{y}\right)^N} \quad \text{where } \frac{dy}{dx} \text{ represents the slope of the surface}$$

profile at any distance x from the assumed origin. y_c is the height of the obstacle. s_0 is a constant.

Putting $u = \frac{y}{y_n}$ this equation can be written for dx as

$$dx = \frac{y_n}{s_0} \left[1 - \frac{1}{1-u^N} + \left(\frac{y_c}{y_n}\right)^M \frac{u^{N-M}}{1-u^N} \right] du$$

integrating

$$x = \frac{y_n}{s_0} \left[u - \int_0^u \frac{du}{1-u^N} + \left(\frac{y_c}{y_n}\right)^M \int_0^u \frac{u^{N-M}}{1-u^N} du \right] + \text{const.}$$

For known values of $y = y_c$ at $x = L$, and $y = y_n$ at $x = 0$, the length L can be evaluated.

For assumed values of y_1, y_2 , etc. for the depths, the distance x_1, x_2 can be computed and the surface profile can be plotted.

The integral $F(u, N) = \int_0^u \frac{du}{1-u^N}$ is the varied flow function.

The computer problem in hand is one of evaluating $\int_0^u \frac{du}{1-u^N}$ by expanding it in series for two ranges of u .

1. $u < 1$
2. $u > 1$

Table I' shows the distribution of the International Business Machines
650 machine time for the month of April.

TABLE I'

		Hrs:Min
Scheduled Engineering		10:45
Unscheduled Engineering		21:53
Air Conditioning		:34
Log Summary		:33
CDC Preparation		6:07
Library Development		12:45
Agronomy Library	:24	
DCL Library	<u>12:21</u>	
Classes		68:05
Business Administration	1:19	
Civil Engineering	3:00	
Electrical Engineering	3:09	
Industrial Engineering	:21	
Mathematics	51:55	
Mechanical Engineering	2:13	
Nuclear Engineering	5:20	
Theoretical and Applied Mechanics	<u>:48</u>	
Instruction		:05
Wasted		<u>10:37</u>
		131:24

Use by Departments

Aeronautical and Astronautical Engineering	:30
Agricultural Economics	5:38
Agricultural Engineering	:12
Agronomy	9:13
Animal Science	:22
Chemistry	42:12
Civil Engineering	28:17
Education	:28
Electrical Engineering	21:57
Graduate College	3:52
Mechanical Engineering	2:09
Mining and Metallurgical Engineering	:03
Physics	17:48
Sociology	:15
State Water Survey	3:27
Statistical Service Unit	82:18
Aeronautical and Astronautical Eng.	:55
Agricultural Economics	:47
Animal Science	4:11
Bureau of Community Planning	6:09
Bursar's Office	5:41

Business Office	9:32	
DHIA	32:33	
Education	18:48	
Mining and Metallurgical Engineering	:35	
Statistical Service Unit	3:07	
Theoretical and Applied Mechanics		3:56
University of Kentucky		<u>:19</u>
		222:56
		<u>354:20</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for April.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		16
Reading errors	10	
Stops on read orders	3	
Card jam	2	
Cards off punched	<u>1</u>	
650		1
Blank bits	<u>1</u>	
407 accounting machine		7
Stops cycling when on line	4	
Stops printing	1	
Prints incorrectly	1	
Printing out of adjustment	<u>1</u>	
727 tape units		4
Load rewinds improperly	1	
Reading errors	2	
Roller sticking	<u>1</u>	
Fuse blew		<u>2</u>
	TOTAL	30

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
4/2/62	7:53	3:48	5:17		1		(1) Cannot read alphanumeric. Bad tube found.
4/3/62	13:56		2:19	:09	2	:34	(1) 533 stopping on read orders. Broken wire to read clutch. (2) Fuse 162 blew. Replaced.
4/4/62	17:13			:06	1		(1) 407 stopped many times when cycling on line. Reason unknown.
4/5/62	16:51		:07	:07	2		(1) 407 stopped many times when cycling on line. Reason unknown. (2) 533 punch jam. Removed.
4/6/62	17:00			:15	0		
4/9/62	14:14	2:50			0		
4/10/62	12:47			3:18	0		
4/11/62	14:49		(:40)*	1:09	2		(1) 407 stops printing off line. When started again a card is skipped. Reason unknown. (2) Print wheel 99 not printing 9's. Worn sensing bar found.
4/12/62	14:44		1:01	1:00	1		(1) Tape unit 1 gave constant errors. Four bad tubes found.
4/13/62	9:01		4:34	2:20	3		(1) Trouble reading alphanumeric. Tubes changed in buffer 1 and in alpha information delay latch. (2) Reading errors in alphanumeric. Reason unknown. (3) Card read errors in numeric field. Reason unknown.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
4/16/62	14:11		3:04	:05	5		(1) Tape read errors. (2) Card read errors. (3) Blown fuse. (4) 533 will not read cards. Start switch had to be replaced. (5) Word eight constantly reads incorrectly.
4/17/62	14:25		2:20	:05	1		(1) Cannot read alphanumeric at all. Adjusted read brushes in pos. 1 and many tubes changed.
4/18/62	14:56		1:55	:05	2		(1) Missing bits in program register. Reason unknown. (2) Constant alpha read errors. Common brush in read 1 not making contact.
4/19/62	16:40			:05	0		(1) 407 stops cycling when on line. Reason unknown. (2) Card jam in 533. Removed.
4/20/62	16:50			:10	0		
4/23/62	16:33	:22		:00	0		
4/24/62	16:46			:09	0		
4/25/62	16:50		:05	:14	2		
4/26/62	15:51		1:07	:08	3		(1) Cards not reading properly. Reason unknown. (2) 533 start key not operating properly. Broken wire. (3) Tape unit 3 does not rewind properly.
4/27/62	15:43		(1:00)*	1:12	3		(1) Reader sticking on tape unit. Shaft cleaned and oiled. (2) Errors in reading alpha. (3) Tape unit 3 does not rewind properly. Found bad head down micro switch.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME (:30)*	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
4/30/62	13:18	3:45	:04		2		(1) 407 not printing on a line. Type bar adjusted. (2) Cards are off punched in 533. Trouble disappeared.
							* Unscheduled engineering done while the IBM 650 is still running. Not counted in the totals.
TOTALS	310:31	10:45	21:53	10:37	30	:34	

PART IV
INSTRUCTIONAL USE OF COMPUTERS

During the month of April, specifications were presented for ten new problems.

57 Theoretical and Applied Mechanics 252. Problem 2. ILLIAC. Vibrations of a Beam. A beam is divided into n discrete masses. The method of influence coefficients is employed to establish a system of homogeneous linear equations whose coefficients contain a parameter. By a suitable substitution the equations are made symmetric and the problem is reduced to a standard eigenvalue problem for a matrix.

58 Mathematics 295 and Sociology 495. Problem 1. ILLIAC. Sexadecimal Multiplication Table. The students are asked to write their name and course number using 92 orders and then to compute and print a 15×15 matrix of two digit sexadecimal products using as multipliers the sexadecimal digits 1, 2, ... K, S, N, J, F, L.

59 Mathematics 295 and Sociology 495. Problem 2. ILLIAC. Area of Triangles. The area of a triangle expressed in terms of its sides is given by the formula

$$K = \sqrt{S(S - A)(S - B)(S - C)},$$

where $S = \frac{1}{2}(A + B + C)$ and A , B , and C are the lengths of the sides. The problem is to write a program for Illiac using the SADOI input routine to calculate a set of areas, K_j ($j = 1, 2, \dots, P$), and print the results. A data tape is furnished which includes the program parameter P followed by an N , and P rows of sides, A , B , and C , with each row terminated by an N .

60 Industrial Engineering 283. Problem 2. ILLIAC. This problem will consist of the solution of linear programming exercises using Library Routine M15-183. Each student will make up such a problem pertaining to a hypothetical company chosen from such cases which have been used in the course during the semester. The problems usually concern the flow of products between either machines or plant locations.

61 Theoretical and Applied Mechanics 422. Problem 1. IBM 650. Principal Stress Computation. This computer program is to solve for the principal stresses on an infinitesimal element in a state of static equilibrium. The mathematical method includes the solution of a cubic equation by the method of successive approximation.

62 Mathematics 395. Problem 2. IBM 650. Machine Problem 2. Write, check and run a SOAP program to effect an internal sort by address calculation of data on Magnetic Tape #1 subject to the following:

1. The information on Magnetic Tape Unit #1 is made up of records of five blocks, each block consisting of ten alphanumeric words in the proper format.
2. The file will consist of no more than ten records and the file is protected.
3. The alphanumeric words consist of a letter of the alphabet followed by a four digit number, with duplication possible.
4. The data is to be sorted alphabetically and then numerically increasing on the four digit number within each alphabetic set.
5. The approximate frequency of alphabetic characters corresponds with the frequency of letters in the English language, viz.:

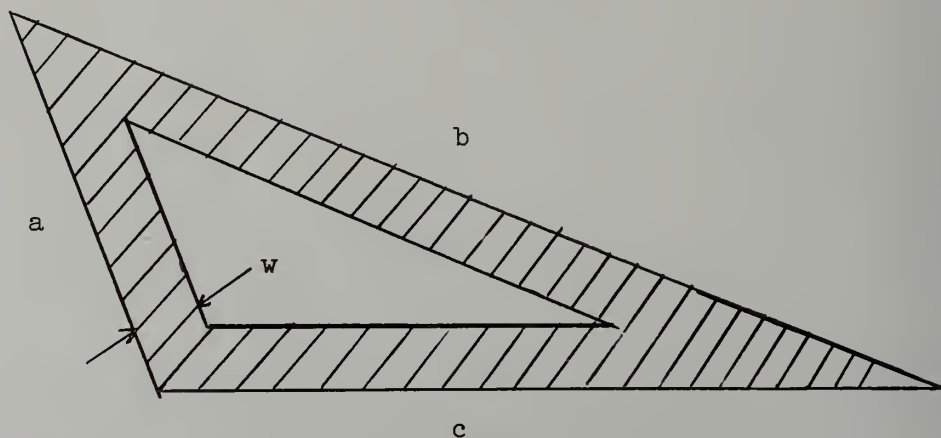
A	8.2	J	0.1	S	6.1
B	1.4	K	0.4	T	10.5
C	2.8	L	3.4	U	2.5
D	3.8	M	2.5	V	0.9
E	13.1	N	7.1	W	1.5
F	2.9	O	8.0	X	0.2
G	2.0	P	2.0	Y	2.0
H	5.3	Q	0.1	Z	0.1
I	6.3	R	6.8		

6. The program must be fully checked before running on the furnished data. You will have exactly one run with the actual data. In checking out your program you may read and write on Magnetic Tape Unit #1 at will.
7. Condense your program to 7 words/card.

8. Do not reSOAP for minor changes. Make these changes directly and reserve the reSOAP operation for major modifications.
9. Turn in:
 - a. Your flow diagram.
 - b. The original coding forms.
 - c. The final assembled program.
 - d. A printout of the sorted data, your name, the designation Math 395, and the date (see instruction 10).
 - e. A time estimate as a function of sample size.
10. When your program is ready for running on the data, it will be turned in with a note so stating. The final printout will not be returned after that run.

63 Mathematics 195. Problem 4. IBM 650. Cost of Painting a Web. A plant manufactures steel webs of various sizes which must be painted. You are to write a GAT program which will compute the paint cost for batches of these webs.

The dimensions of a web are indicated by the drawing below. The three outer edges have lengths a , b , c , respectively, and w is the distance between the inside edge and the outside edge. All webs are one inch thick. The paint cost is \$7.20 per gallon and one gallon covers 1,000 square feet.



The data is to be read by the program from data cards. There will be two data cards in a read group. The first card will contain

a: cols. 1 - 10, floating-point value in inches
b: cols. 11 - 20, _____"
c: cols. 21 - 30, _____"
w: cols. 31 - 40, _____"
N: cols. 41 - 50, the number (in floating-point form) of webs in
this batch.

The second card will contain

I: cols. 1 - 10, identification number (in fixed-point form) for
this batch.
*: col. 75

Although not explicitly indicated, it is supposed that the variable name is, in each case, punched in the appropriate columns of the data card. Use these GAT names:

X1 for a	X4 for w
X2 for b	X5 for N
X3 for c	I1 for I

Your program should be designed to handle an arbitrary number of these data groups so your program should end on a READ statement. Print the cost (in dollars) of painting (top, bottom, and edges) each batch of N webs; use GAT variable Y1 to represent this. Also print the identification number, I1, for the batch.

Make up your own data cards (not more than ten groups) for testing your program. You may assume that a, b, c do not exceed 72" and N does not exceed 1,000.

When you turn your problem in, turn in your program deck. We will check your program by running it with our own set of data cards. To be counted correct, your program must produce correct results for our data. We will allow an error of \$.05 but no more than this. Also, to receive full credit for this problem, your program must contain less than fourteen statements, including all executive statements. In any case, your program must not exceed a total of twenty-five statements, including all executive statements.

Hint: "Mathematical Tables from Handbook of Chemistry and Physics" or similar tables will contain some of the required formulas. Suppose that A is the area of the web assuming that the inside triangular area is not cut out. Suppose that A' is the area of the triangular part that is cut out. One can derive a formula which has the form

$$A' = k A$$

where k depends on a, b, c, and w.

64 Mathematics.295. Problem 6. ILLIAC. Sine-Cosine Table. The problem is to print a table of values for $\sin \frac{\pi}{2} X$ and $\cos \frac{\pi}{2} X$ from -0.5 radians to +0.5 radians with increments of 0.1 radians. The students are expected to evaluate the following polynomial approximation:

$$\sin \frac{\pi}{2} X = C_1 X + C_3 X^3 + C_5 X^5 + C_7 X^7 + C_9 X^9$$

where $C_1 = 1.57079631847$, $C_3 = -.64596371106$, $C_5 = .07968967928$, $C_7 = -.00467376557$, and $C_9 = .00015148419$, and

$$\cos \frac{\pi}{2} X = \sin \frac{\pi}{2} (1 - |X|).$$

65 Civil Engineering 391. Problem 2. IBM 650. Analysis of Continuous Beam. Problem number 1 developed the necessary tool for the analysis of a two-span continuous beam with non-uniform rigidity. This problem deals with the analysis of the beam subjected to specified loads. The procedure to be used is essentially one of successive approximations, where two conflicting constants must be satisfied simultaneously. Only the end result is specified, and the student is free to choose any iterative scheme he desires to accomplish this result.

66 Industrial Engineering 286. Problem 1. ILLIAC. Williams Memory Routine for Linear Programming by Simplex Method (M15-183). The problem is a linear programming problem to be solved using the simplex technique. The model for the problem is to be designed by the student from a problem statement, after which the student will punch the data and parameter tapes necessary to use M15-183.

PART V
CONTROL DATA CORPORATION 1604

During the month of April, specifications were presented for seven new problems. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 12. Numbers followed by T are for theses.

12 Civil Engineering. Effects of a Shock Wave Incident on a Cylindrical Shell in an Elastic Medium. The problem to be considered consists of analyzing the response of a cylindrical elastic shell in an infinite elastic medium subjected to a plane pressure wave which envelops the shell. A cylindrically symmetric potential function represented as emanating from the axis of the shell acts to produce the effects of a reflected pressure wave.

Modal equations of motion with generalized coordinates and forces are derived to describe the dynamic interaction of the shell and the medium. An additional set of integral equations insures compatibility of velocities and displacements.

The potential function is represented by Fourier series of which just the first three terms are considered.

An iterative type solution using the Newmark Beta method of integration is used to solve the problem. An estimated 28,000 spaces in memory will be required.

13 Civil Engineering. Approximate Methods of Analysis of Shallow Shells. The problem is to analyze some shallow shells with complex boundary conditions using the following three approximate techniques: Rayleigh-Ritz Method, Trefftz Method, and Vlassov's General Variational Method.

Vlassov's Method will be used extensively. Using this method, the governing partial differential equations are reduced to systems of ordinary differential equations, the solution of which is carried out by finite difference method.

Tabulated values for the stresses and displacements at different points of the shell will be given which can be used for the design of these shells.

14 Physics. K-Meson Interactions with Nuclei. Part of the calculation of the K-meson nuclear optical potential is the evaluation of the scattering K matrix. With the approximation being employed, this simplifies to the evaluation of a two-dimensional integral, the integrand of which is a function of a two-dimensional integral and other empirical functions. The integrand also involves the K-meson optical potential which it is the purpose of the K-matrix to find, i.e., a rather involved non-linear integral equation has to be solved. This is solved by iteration of the whole scheme (as is done by Brueckner).

The calculations which comprise part of Hetherington's thesis performed these integrations on Illiac, using a Monte Carlo technique. These were somewhat limited in accuracy, and it is not known if it was entirely due to the Monte Carlo errors. A more pedestrian integration scheme will be used to redo the calculations with the more recently obtained K-nucleon parameters.

15 Civil Engineering. Soil Pressure-Velocity. The problem of soil-structure interaction is being studied for the purpose of determining the distribution of pressure and soil particle velocity when a buried structure is loaded to failure by pressure applied at the ground surface. This problem will then be extended to include the dynamic response of the structure and the interacting soil mass to study the time dependent behavior of the system under the action of transient surface pressures.

16 Electrical Engineering. Control Program for Ultrasonic Surgery. The problem is that of computing a sequence of ultrasonic irradiation sites for experimental studies of the brain. The program will receive x-ray data consisting of certain landmarks and check points in the brain of the particular animal to be irradiated plus other data in abbreviated form which describes the region to be irradiated. These later data come from composite normalized maps that are modified as new knowledge of the structure under study is obtained. The program will then compute the coordinates to be set on the irradiation apparatus for each of the individual irradiations, and will also determine the spacing to be used and the dose necessary to correct for the various depths of tissue at different locations.

This first version of the program requires more than the capacity of the Illiac high speed memory, and it is expected that the program will be expanded almost immediately after it begins to give useful results.

17 Chemical Engineering. Analysis of Markov Processes. The problem involved is the study of optimal policies in Markov type systems. This involves the repeated solution of eleven simultaneous equations. However, before solving these, the coefficients must first be determined by solving 121 non-linear algebraic equations.

These equations have at least two solutions of which at most only one is correct and possibly both will lack physical significance.

The 650 is being used at present but has two important shortcomings: (1) insufficient memory, and (2) lack of freedom of output format.

18 Civil Engineering. Three Dimensional Transformation of Coordinates with Least Squares Adjustment. The problem deals with the three dimensional transformation of coordinates (from photogrammetric machine coordinates to terrestrial land coordinates) based on a least square adjustment. For the purpose for which this program is to be used, a limit of ten points, common to both systems, will be observed ($10 \times 3 = 30$ observations, unknowns = 7, redundants = $30 - 7 = 23$). Only standard routines will be involved in the program.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part II.

CDC 1604 TIME DISTRIBUTION

April, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	1:35			1:35
Aeronautical Engineering	:25			:25
Animal Science	:04			:04
Chemistry	3:52	5:35		9:27
Coordinated Science Lab.		:04		:04
Civil Engineering	3:59	8:07		12:06
Electrical Engineering	:09	:13		:22
Geological Survey	:41			:41
Inst. of Communications Research	:06			:06

Inst. for Res. on Excep. Children	:05			:05
Music	2:19			2:19
Physics		13:17		13:17
Psychology	11:22			11:22
Sociology	2:21			2:21
Maintenance			:24*	
TOTALS	26:58	27:16	:24	45:38

*One noontime period was eliminated because of engineering. Time for this period not listed in above.

PART VI
7090-1401 COMPUTING SYSTEM

The Operating System and Problem Processing on the 7090-1401

The Digital Computer Laboratory is designing an automatic operating system which will be able to take advantage of the speeds and size of the coming 7090 computer. The aims of this system are to facilitate user needs (input and output conversion, dynamic and post-mortem dumps, etc.), to minimize human intervention, to automate the updating and checking of laboratory records, to enable fast and direct communication between the user and the computer, and, above all, to maintain maximum flexibility.

The possible specific components of the system are under close scrutiny in order to determine which will be most useful and which can be inserted most expeditiously in the interval prior to the arrival of the 7090-1401. The highest priority will be given to incorporating as many as possible of the following features in the programming and operating system.

1. The SHARE Compiler-Assembler Translator, SCAT, or one of its variants (assembly language);
2. The IBM Formula Translator II, Fortran II (algebraic compiler language);
3. An Algorithm Language Translator, ALGOL (algebraic compiler language);
4. The University of Michigan Algorithm Decoder, MAD (algebraic compiler language);
5. An extensive subroutine library accessible by all of the above four translators;
6. Dump routines to aid in program checkout;
7. Input/output routines which allow efficient use of magnetic tapes with minimum trouble to the user;
8. A 650 simulating program;
9. The ability to execute in any desired order or frequency the various segments of a multiple core-load job.

The inclusion of more than one algebraic language translator is a result of the recognized complementary features of these compilers. For example, Fortran II has a restricted source language, while MAD's is quite flexible; MAD's compilation

time averages ten times faster than Fortran's; but on the other hand, Fortran's object program in general contains 20 per cent fewer instructions and operates up to twice as fast as MAD's. Therefore, users should take these facts into consideration when choosing an algebraic source language for their problems, for example, choosing MAD for short, infrequently run but frequently compiled problems, and Fortran II for exceptionally long running problems.

Later, an evolving statistical package will be included in the system. This package will ultimately consist of a control program and an extensive library of statistical routines. It is also expected that statistical users will desire to make some use of the algebraic compilers.

As in the past, persons desiring to run problems on the 7090 will submit to the Laboratory information about their problems previous to coding them, e.g., purpose of problem, mathematical methods employed, source language chosen for programming, etc. If the problem is then approved by the Laboratory, a Problem Specification Number is assigned which the user will use when running on the computer. In general, the user will use the standard system facilities, including the input/output routines, but he will be able to receive special permission for non-standard usage of the system (extra output copies, mounting and saving of special tapes, use of the full memory, on-line input/output, etc.) when necessary.

The flow of a problem through the system can be expected to be as follows:

1. The user submits his deck (the make-up conforming to the system format) at a designated location in the computer laboratory;
2. Submitted decks are collected until a 7090 input tape is to be written;
3. The 1401 reads the batched decks which are loaded on a magnetic tape destined for input to the 7090;
4. The input tape is processed by the 7090 according to the specifications in the user's deck and a batched output tape is created;
5. The 1401 processes the output tape (appropriately printing and punching the information on it);
6. The card input and generated output are collated and placed in a central location for the user to pick up.

It is expected that the 1401 computer will be used almost exclusively for the above mentioned functions of 7090 input/output tape processing. It is expected that there will be no direct input/output to the 7090 itself other than via magnetic tape.

The system will be designed in such a manner as to allow the addition of other facilities as they become available, such as new compilers like IPL V, COBOL, COMTRAN; sort and report generators; computer class grading and processing programs, etc.

Classification of the Digital Computer Laboratory IBM 7090 Library

The Digital Computer Laboratory will organize and construct a library of routines, complete programs and subroutines for carrying out various mathematical, statistical and data handling procedures. Some of these routines will originate within the Laboratory but others will be acquired by exploiting the great amount of programming which has been done by IBM 700 and 7000 series machines. All routines available to users will be gathered into a single library classified in a uniform fashion to be described below. This classification scheme is compatible with and an extension of that used by SHARE, the cooperative organization of IBM 704-709-7090 users.

Those routines of the Digital Computer Laboratory Library which are most heavily used will be incorporated into the master system tapes in such a form that they will be automatically available for insertion into programs by the compilers, assemblers, and other sub-systems that make up the master system. The rest of the library will reside on cards for manual insertion into programs by the users.

Each routine will be assigned a number made up of five parts:

1. Classification Code--One letter and one number designating the primary and secondary class to which the routine belongs according to the SHARE classification below.
2. Installation Code--Two or three letters identifying the origin of the routine (MU = MURA, UOI = University of Illinois, BC = University of California, Berkeley, etc.).
3. Internal Identification Code--These four characters will be used to identify the routine semi-mnemonically.
4. Serial Number--A simple sequence number which advances by one for each routine added to the library.

5. Characters describing the language in which the program is available:

F - FORTRAN
A - ALGOL
M - MAD
S - SCAT (Full Symbolic)
Z - SQUOZE (Compressed Symbolic)
B - Binary (Absolute)
R - Binary (Relocatable)
X - Routine is on System Tape

For example,

B₄ - UOI - SQR3 - 17 - RX

would stand for the 3rd square root routine (SQR3) (also B₄) written at the University of Illinois (UOI). It is on the system tape, is in relocatable binary and is the 17th routine admitted to the library.

SHARE Routine Classification Scheme

A. Arithmetic Routines

- | | |
|--------------------|--|
| 1. Real Numbers | May include multiple precision fixed and floating-point operations. |
| 2. Complex Numbers | May include multiple precision, fixed and floating-point operations. |
| 3. Decimal | BCD single or multiple precision arithmetic operations. |

B. Elementary Functions

- | | |
|--------------------------------|---|
| 1. Trigonometric | Also pertains to inverse trigonometric functions. |
| 2. Hyperbolic | |
| 3. Exponential and Logarithmic | |
| 4. Roots and Powers | Refers to roots of quantities, not polynomials. |

SHARE Routine Classification Scheme

C. Polynomials and Special Functions

1. Evaluation of Polynomials
2. Roots of Polynomials
3. Evaluation of Special Functions
4. Simultaneous Non-Linear Algebraic Equations
5. Simultaneous Transcendental Equations

D. Operations on Functions and Solutions of Differential Equations

1. Numerical Integration
2. Numerical Solutions of Ordinary Differential Equations
3. Numerical Solutions of Partial Differential Equations
4. Numerical Differentiation

E. Interpolation and Approximations

1. Table Look-up and Interpolation
2. Curve Fitting
3. Smoothing

F. Operations on Matrices, Vectors and Simultaneous Linear Equations

1. Matrix Operations
2. Eigenvalues and Eigenvectors
3. Determinants
4. Simultaneous Linear Equations

G. Statistical Analysis and Probability

- | | |
|--|--|
| 1. Data Reduction | Refers to the calculation of the more common statistical parameters such as mean, median, standard deviation, etc. |
| 2. Correlation and Regression Analysis | Includes curve fitting which is explicitly for statistical purposes. |

3. Sequential Analysis
4. Analysis of Variance
5. Random Number Generators

H. Operations Research and Linear Programming

I. Input

1. Binary Pertains to program input or data input in the binary mode (via card, tape or disc).
2. Octal Pertains to program input or data input in the octal mode (via cards).
3. Decimal Pertains to program input and data input in the decimal mode (via card or tape).
4. BCD (Hollerith) Pertains to program input or data input in the BCD or Hollerith mode (via card, tape or disc).
5. Composite A combination of any of the above, which is not primarily one of the above, such as a general purpose input program.

J. Output

1. Binary Pertaining to program output (card to tape) or data output (card, tape, or disc) in the binary mode.
2. Octal Pertains to program output (printer) or data output (card or printer) in the octal mode.
3. Decimal Pertains to program output (card, tape or printer) or data output (card, tape, or printer) in the decimal mode.
4. BCD (Hollerith) Pertains to program output (card, tape, printer or disc) or data output (card, tape, printer or disc) in the BCD mode.

- 5. Analog (Plotting) CRT
- 6. Composite A combination of any of the above, which is not primarily one of the above, such as a general purpose output program.

K. Internal Information Transfer

Generally denotes core-to-core, tape-to-tape, and core-to-tape movements.

- 0. Tape Any tape read/write, editing, duplicating, or comparing, etc., program.
- 2. Relocation Pertains to core-to-core relocation only, not input with relocation.

L. Executive Routines

- 1. Assembly
- 2. Compiling
- 3. Monitoring
- 4. Preprocessing
- 5. Disassembly and De-Relativizing
- 6. Relativizing

M. Data Handling

- 1. Sorting
- 2. Conversion and/or Scaling Pertains to any conversion and scaling routine (packed or unpacked, single or multiple precision) such as card image to BCD, BCD to card image, binary to BCD, BCD to binary, fixed to floating, etc. The primary function of programs in this category must be conversion or scaling, not input-output.
- 3. Merging

N. Debugging

1. Tracing: Trapping
2. Dumping Core, tape, disc, console printouts
 (on- or off-line).
3. Memory Verification and Searching
4. Breakpoint Printing

O. Simulation and/or Interpretation

0. Computers Pertains to programs which simulate
 or interpret other machines on the
 704, 709, or 7090.
1. Off-line Equipment Any program which simulates off-line
 equipment.
2. Other Such as simulation of theoretical or
 pseudo-computers.

P. Diagnostics

Pertains to any program which checks
for malfunctioning of the computer
or its components.

Q. Service or Housekeeping

Pertains to any routine of a utilitarian
nature which performs a service for the
programmer such as executing the
equivalent of pushing a button on the
console, setting a dial, or accumulating
a check sum.

1. Clear/Reset Programs
2. Check Sum Accumulation and Correction
3. Restore, Rewind, Tape Mark, Load Cards, Load Tape, etc.; Programs

Z. All Others

This category contains all routines for
which no primary class has yet been

Z. All Others (continued)

designated. Routines which are covered by a primary class but which are not adequately described by a sub-class are assigned the applicable primary classification with a sub-class designation of zero.

PART VII
GENERAL LABORATORY INFORMATION

Seminars

"Eigenvalues of Composite Matrices," by Professor Bernard Friedmann, Chairman, Department of Mathematics, University of California, Berkeley, California, April 6, 1962

"Automatic Scanning of Bubble Chamber Negatives," by Professor John R. Pasta, Digital Computer Laboratory, University of Illinois, April 23, 1962

"Some Theoretical and Practical Aspects of Tunnel Diode Switching Circuits," by Mr. Henry Guckel, Digital Computer Laboratory, University of Illinois, and Professor Tohru Moto-oka, Digital Computer Laboratory, University of Illinois, April 30, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Visiting Faculty	0	1	.5
Research Associates	6	1	6.5
Graduate Research Assistants	10	20	21.7
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>40</u>	<u>16</u>	<u>45.1</u>
TOTAL	75	42	94.8

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

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TECHNICAL PROGRESS REPORT

- PART I - CIRCUIT RESEARCH PROGRAM
- PART II - MATHEMATICAL METHODS
- PART III - DATA REDUCTION METHODS
- PART IV - ILLIAC USE AND OPERATION
- PART V - IBM 650 USE AND OPERATION
- PART VI - INSTRUCTIONAL USE OF COMPUTERS
- PART VII - CONTROL DATA CORPORATION 1604
- PART VIII - GENERAL LABORATORY INFORMATION

May, 1962

PART 1
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

This month a new project has been started: Sergio Ribeiro will be investigating the phase-plane behavior of two common types of flipflops. These types are (a) the Schmidt Trigger type and (b) the Eccles-Jordan type. In the past attention was mostly focused on mathematical models. We now propose to study actual physical models. Hopefully this project will lead to some simple rules giving approximate phase-plane transition curves for given circuit values and, more important yet, rules for the rapid calculation of transition times and overshoot might be developed.

Tohru Moto-Oka and Henry Guckel, helped by Thomas Murrell investigated the emitter-follower oscillations that had occurred in certain chassis of the new Illinois computer. They replaced the old equivalent circuit theory by a new charge-storage theory which gives results in excellent agreement with experiment. A detailed report will be published soon.

John Hill wrote a complete report on his AC-coupled failsafe circuits; it will be available in a few weeks. He also tried some experiments on DC-coupled failsafe circuits. Up to now this line does not seem to be too promising.

Thomas Burnside is in the process of writing up his results on the statistical analyzer. He has also developed some ideas for the spectrum analyzer at the output of the statistical analyzer.

2. Phase-Plane Analysis of Flipflops

The asymmetric flipflop (Schmidt circuit) is being studied. The circuit is represented in Figure 1 where the following simplifying assumptions are made:

a) $i_0 = \text{const}$

b) $i = \text{const}$

- c) C_1 and C_2 , the parasitic capacitances, are also assumed constant (they actually depend on collector-base voltages)
- d) $i_{b1} = i_{b2} = 0$
- e) For the transistors, the following characteristics are assumed:

$$i_1 = i_{s1} \left(e^{\frac{g v_1}{kT}} - 1 \right); \quad i_2 = i_{s2} \left(e^{\frac{g v_2}{kT}} - 1 \right)$$

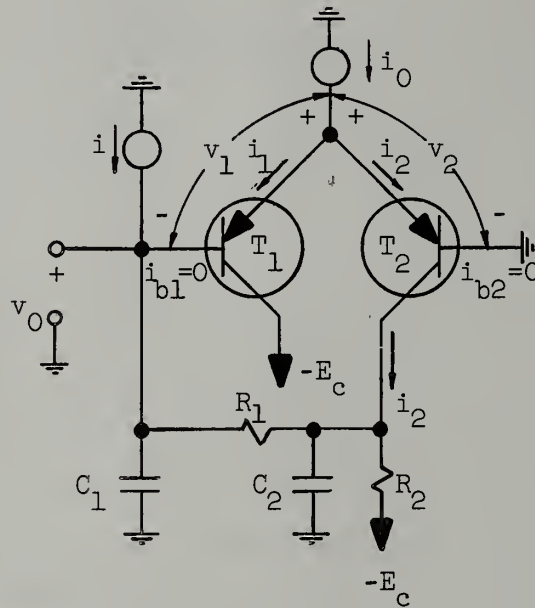


Figure 1 Asymmetric Flipflop. $v_0 = V_0 + i_2 R_2$ in Either Stable State

Analysis of the circuit under these assumptions lead to the following equation:

$$\ddot{x} + \left\{ f(x) \dot{x} + \lambda \right\} \dot{x} + g(x)x + h(x) = 0 \quad (1)$$

where:

$x = i_2$	$h(x) = \frac{1}{K_2} \frac{\psi_2 - \psi_1 - V_0}{\psi_2' - \psi_1'}$	$\psi_1 = \frac{kT}{q} \ln \frac{x + i_{s2}}{i_{s2}}$
$f(x) = \frac{\psi_2'' - \psi_1''}{\psi_2' - \psi_1'}$	$\lambda = \frac{K_1}{K_2}; \quad V_0 = \left\{ i(R_1 + R_2) - E_c \right\}$	$\psi_2 = \frac{kT}{q} \ln \frac{i_0 - x + i_{s1}}{i_{s1}}$
$g(x) = - \frac{R_2/K_2}{\psi_2' - \psi_1'}$	$K_1 = (R_1 + R_2)C_2 + R_1C_1$	<p>And the primes indicate derivatives with respect to x.</p>
	$K_2 = R_1R_2C_1C_2$	

Setting $\frac{dx}{dt} = y$ (2)

$$\frac{dy}{dt} = - \left\{ f(x)y + \lambda \right\} y - g(x)x - h(x) \quad (3)$$

So that $\frac{dy}{dx} = - \frac{\left\{ f(x)y + \lambda \right\} y + g(x)x + h(x)}{y}$ (4)

which is the differential equation of the phase-plane trajectories for this flipflop.

The singularities occur at the solutions of

$$\begin{aligned} g(x)x + h(x) &= 0 \\ y &= 0 \end{aligned} \quad (5)$$

More explicitly, (5) becomes: with $\frac{q}{kT} = \eta$

$$\frac{1}{R_2\eta} \ln \frac{i_{s1}(i_{s2} + x)}{i_{s2}(i_{s1} + i_0 - x)} = x + \frac{V_0}{R_2} \quad (6)$$

if x is restricted to the interval (0, i_0).

It is easy to show that this equation will have:

only one solution if:

$$i_0 < \frac{(i_{s1} + i_{s2})}{R_2 \eta i_{s1} i_{s2}} \left\{ (i_{s1} + i_{s2}) - i_{s1} i_{s2} R_2 \eta \right\} = i_{crit}. \quad (7a)$$

three solutions if:

$$i_0 > i_{crit}. \quad (7b)$$

Naturally, the case where $i_0 = i_{crit}$. has no practical interest.

Conditions (7a) and (7b) can be simplified if we make the further assumptions that $i_{s1} = i_{s2} = i_s$ and $2i_s R_2 \eta \ll 4$:

We get then:

$$i_{crit.} = \frac{4kT}{qR_2} \quad (8)$$

These singularities can be analyzed and we find that:

a) $i < i_{crit.} \Rightarrow$ one singularity:

If $i_0 < \frac{4kT}{qR_2} (1 - \frac{K_1}{4K_2})$ the singularity is a stable focus.

If $\frac{4kT}{gR_2} (1 - \frac{K_1^2}{4K_2^2}) < i_0 < \frac{4kt}{gR_2}$ the singularity is a stable node.

b) $i > i_{crit.} \Rightarrow$ three singularities: $x_1 < x_0 < x_2$. The singularity at x_0 is a saddle-point; also, a detailed analysis shows that x_1 and x_2 are stable nodes.

Detailed proof of (a) and (b) is lengthy and will not be presented here; we will indicate, however, that it should be done by expansion of the functions $f(x)$, $g(x)$ and $h(x)$ in Taylor series, and constructing a new system (called the system of the first approximation) using only their first non-vanishing terms. This system is linear and behaves as the original nonlinear system in a sufficiently small neighborhood of the singular points. Study

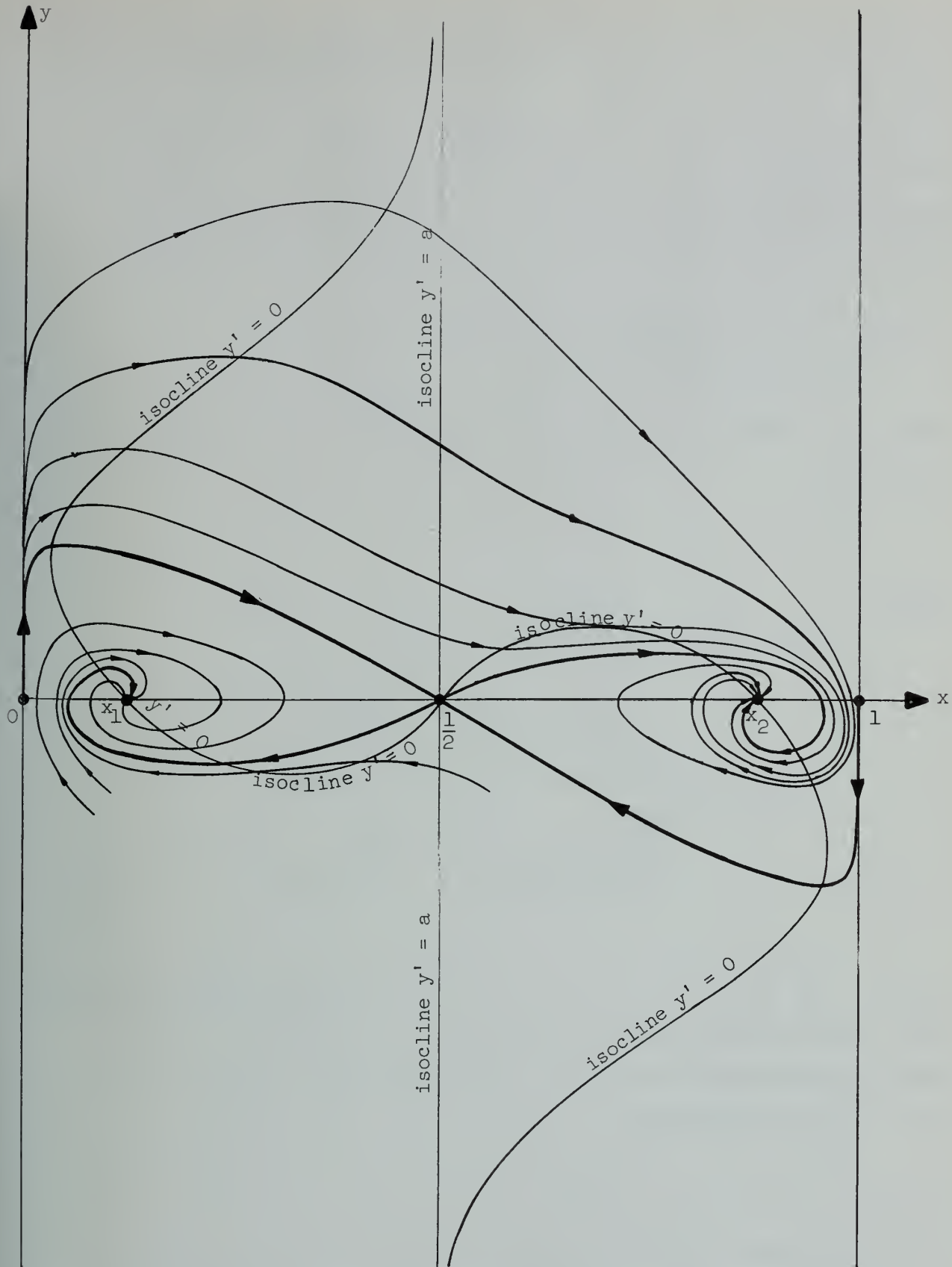


Figure 2

A Qualitative Phase-plane Portrait of
the Asymmetric Flipflop, with $v_g = 0$

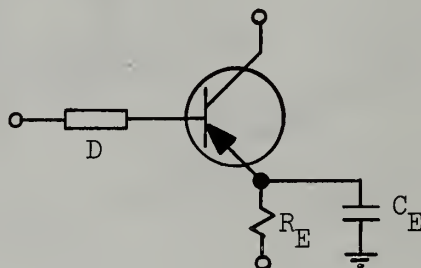
of the characteristic roots of this system reveals the nature of the singular points. There are some relations between the circuit parameters which must be taken into account; for example, the fact that $K_1^2 > 4K_2$ implies that x_1 and x_2 are stable nodes rather than stable foci as has been often assumed. We point out, however, that our model is an approximate one; the transistors are assumed instantaneous and no inductances are considered in the circuit. Stable foci could conceivably result in a more sophisticated treatment.

3. Emitter-Follower Oscillations

Reconsideration of the EF problem has led to the design of a compensator or damper and an extension of the earlier theory. A computer study of the effect of transistor parameters as well as load and stray parameters is in progress:

Damper

D is the combination shown in Figure 3.



L - 10 turns on CF 101-Q-1 Core
(Ferramic)
R - 240Ω

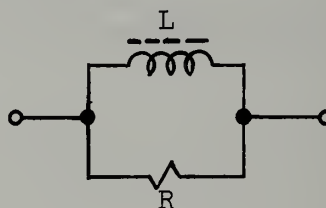


Figure 3
Damper

Experiments performed on the chassis of the new computer showed good results if all interconnected emitter-followers in a group are compensated. Pulse response of the network is reasonable. The additional delay was measured to be about 2×10^{-9} sec. The advantage is, of course, that DC tolerances are not affected.

Theory

In the earlier work it was pointed out that the α -approximation used in the equivalence circuit is most important. A better theory can be achieved by using stored charge theory, the calculations are based on work by J. J. Sparkes. The results are:

1. Necessary condition for stability:

$$\frac{\alpha_N \omega_N}{1.22} > \frac{1}{R_E C_E} \quad (1)$$

where ω_N is the collector cut-off frequency and r_b the base resistance.

2. Sufficient condition for stability with worst case wiring:

$$r_b^2 + \frac{r_b}{\Gamma} \geq \frac{(C_C + C_E)T_B}{4G} \left(\frac{1}{T_E \Gamma} - \frac{1 + r_b \Gamma}{C_C + C_E} \right)^2 \quad (2)$$

where

$$\left\{ \begin{array}{l} \Gamma \equiv G + \frac{C_C}{T_E} + \frac{C_E}{T_B} \\ T_E = \frac{1.22}{\omega_N}, \quad T_B = \frac{1.22}{\omega_N(1-\alpha_N)}, \quad G = \frac{1}{R_E} \end{array} \right.$$

R_E being the external emitter resistance.

3. Worst case wiring inductance (in series with base):

$$L_{wC} = \frac{T_B}{2G} (C_C + C_E) \left(\frac{1}{\Gamma T_E} - \frac{1 + r_b \Gamma}{C_C + C_E} \right) \quad (3)$$

4. DC Failsafe Emitter-Follower

Up to now we have had only studied AC-coupled failsafe circuits. Below we show a possible approach to a PNP-NPN failsafe emitter follower. Any one of its four transistors can have any open or short combination between any of its electrodes and the circuit will still function. The transistor multiplication factor is two since the normal PNP-NPN emitter follower has two transistors. This circuit has several limitations, however, which the ordinary AC-coupled emitter-follower circuit does not have. In future circuit investigation these shortcomings should be improved upon in order to get a more usable emitter follower. These limitations are:

- 1) The beta of the transistors must be fairly high, approximately $\beta = 100$.
- 2) The current gain under the worst failure is only $1/4$ of that of the normally operating circuit.
- 3) The voltage gain is about 0.7 under the worst failure condition.
- 4) The circuit is much slower than regular circuits because of the high series base resistor. The rise time of the emitter-follower is determined by the base capacity and the input resistance.
- 5) DC-monitoring of operation is impossible.

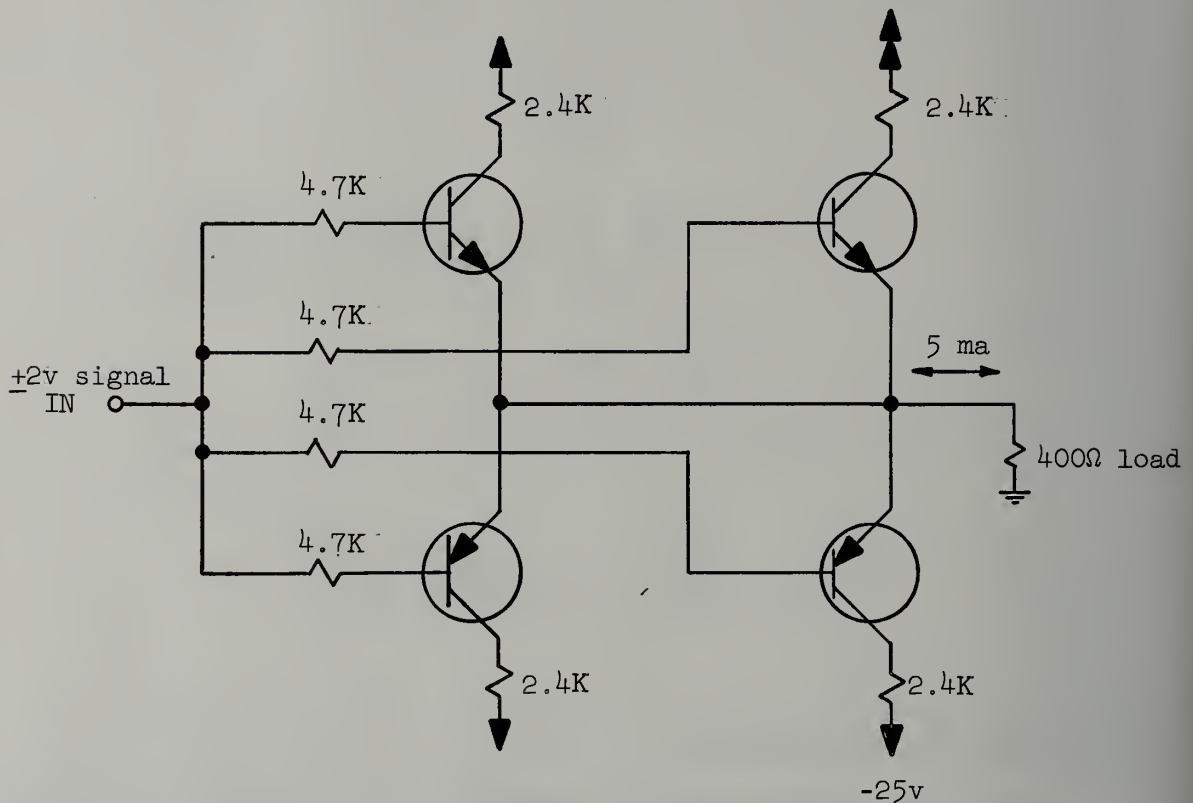


Figure 4 Failsafe Emitter-Follower

5. Statistical Analyzer

Consider the diode circuit which we will investigate by the statistical analyzer shown in Figure 5.

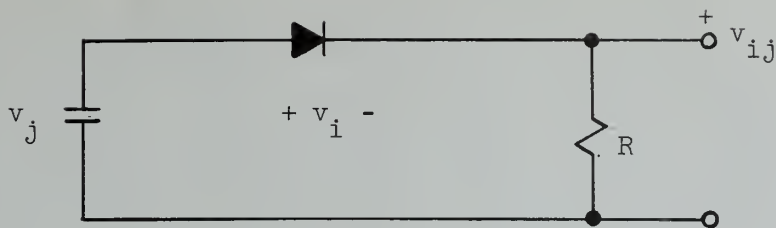


Figure 5 Diode Circuit

We are using the notation introduced in the February monthly report:

"n" is the nth clock pulse and $i = n \pmod{8}$

$$j = \frac{(n - i)}{8} \pmod{8}.$$

Some thought is being given to the design of a device that will sample v_{ij} , the output voltage.

It is planned to switch diodes every $\mu\text{sec.}$ with a transient of about $.1 \mu\text{sec.}$ in between v_{ij} and $v_{(i+1)j}$. The output must be sampled each $\mu\text{sec.}$ but only after the transient has died out. Essentially we are making DC measurements on a different circuit each $\mu\text{sec.}$ The sampling requirements may be seen in Figure 6 (page 10) which shows a possible voltage versus time plot for v_i , v_j , and v_{ij} . The voltages v_i and v_j appear in an order such that the change from v_i to v_{i+1} is not too large. This helps the transient voltage to be less noticeable in case the "on" times for successive diodes overlap slightly.

By using a sampling pulse which is $.3 \mu\text{sec.}$ wide and which occurs $.5 \mu\text{sec.}$ after each switching operation, all 64 v_{ij} 's can be sampled in the DC state. To produce the sampling pulse we will delay the regular 1 megacycle clock by a time Δ and then possibly reshape the pulse. It is seen that

$$\Delta = (.5 \mu\text{sec.}) - (\text{delay in decoder}) - (\text{delay in circuit to be analyzed})$$



Figure 7 Delays in Samples

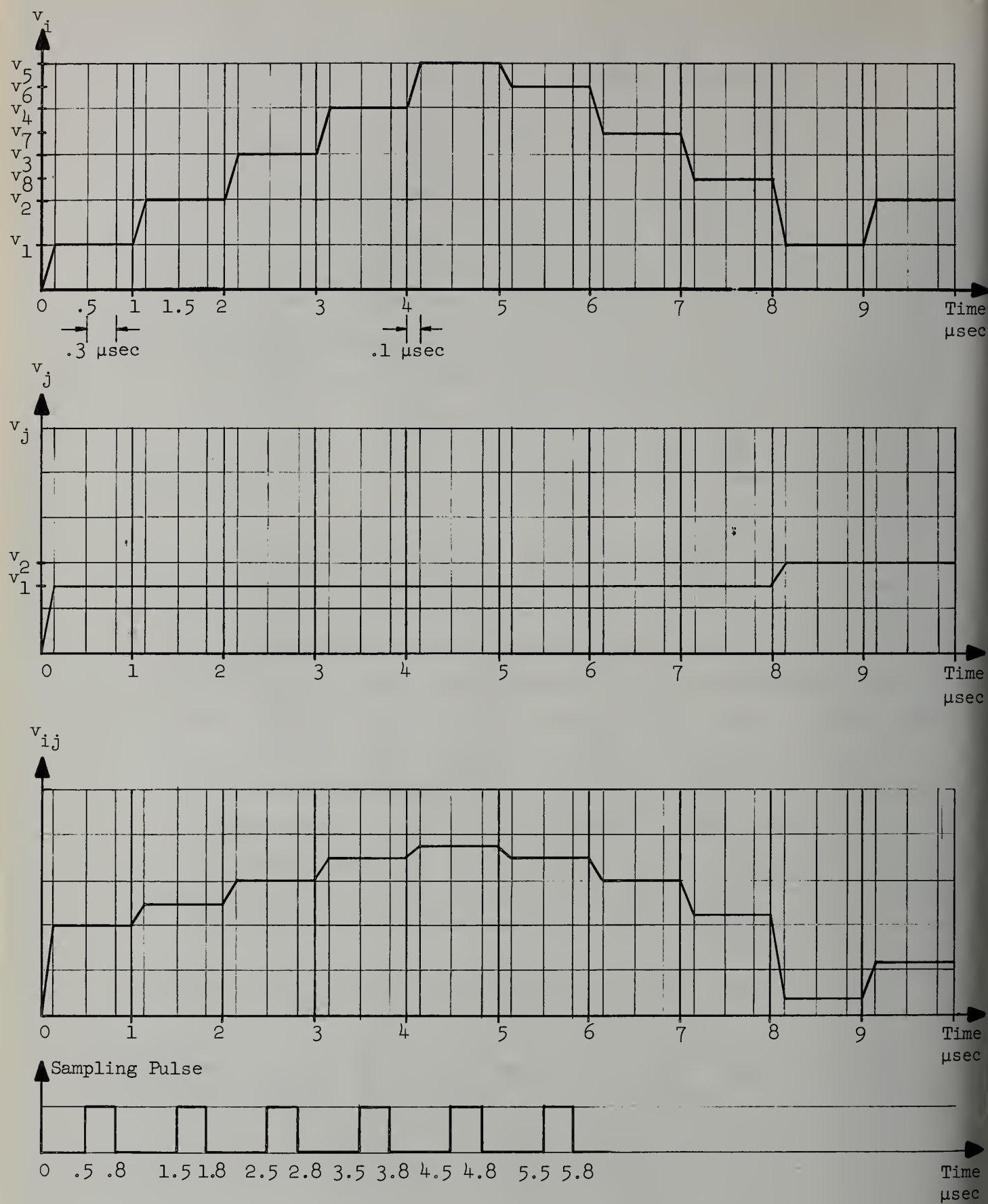


Figure 6 Sampling Pulses and Signals

the output voltage is divided into eight intervals by v_k ($k = 1, 2, 3, 4, 5, 6, \text{ or } 7$) as shown in Figure 8.

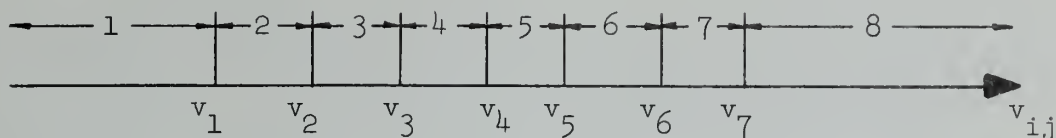


Figure 8 Output Voltage Ranges

Eight circuits are being designed which have a logical output = 1 if and only if $v_k < v_{ij} < v_{k+1}$. A modulo 64 counter will be pulsed whenever the 1-output occurs. Note that only one output counter is necessary. It can be moved from out output circuit to the next and the experiment can be repeated.

PART II
MATHEMATICAL METHODS

1. Monte Carlo Methods in Quantum Statistics (Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

A detailed report of this research has been written; it is called "Numerical Estimation of the Partition Function in Quantum Statistics," Digital Computer Laboratory Report No. 118. The abstract of this Report follows:

A method for estimating the partition function of a quantum mechanical system is described. The method is based on a technique for evaluating the Wiener integrals in terms of which the partition function may be expressed. This technique involves, first, an approximation of the Wiener integral by an n-dimensional integral and, second, a Monte Carlo estimation of the value of the n-dimensional integral. Application of the method to a harmonic oscillator and a pair of interacting particles in a box in two dimensions is described.

(Lloyd Fosdick)

2. A Bound for the Spectral Norm of Functions of Matrices (Supported in part by the National Science Foundation under grant G16489.)

Let A be a square matrix of order n with complex coefficients a_{ij} and eigenvalues $\lambda_1, \dots, \lambda_n$ and $f(z) = \sum_{i=0}^{\infty} d_i z^i$ be an analytic function for $|z| < R$.

We introduce the following definitions and notations:

$||\vec{x}|| = \sqrt{\sum |x_i|^2}$ is the Euclidian norm of the vector \vec{x} with components x_1, x_2, \dots, x_n .

$\sigma(A) = \max_{||\vec{x}||=1} ||A\vec{x}||$ is the spectral norm of A .

$\Delta(A) = \sqrt{\sum_{i,j} |a_{ij}|^2 - \sum_i |\lambda_i|^2}$ is the "departure from normality of A " (notion introduced by Henrici).

$f(z_1, z_2, \dots, z_{k+1})$ is the k th divided difference of $f(z)$ at the points z_1, \dots, z_{k+1} ; since f is analytic, the difference is also defined when the arguments z_1, \dots, z_{k+1} are not different.

$$\delta_{k-1} = \max_{1 \leq i_1 < i_2, \dots, i_k \leq n} |f(\lambda_{i_1}, \lambda_{i_2}, \dots, \lambda_{i_k})|, \quad k = 0, 1, \dots, n.$$

Assertion. If $|\lambda_i| < R$, $i = 1, 2, \dots, n$, the function $f(A) = \sum_0^\infty d_i A^i$ exists and

$$\sigma(f(A)) \leq \sum_{k=0}^{n-1} \delta_k (\Delta(A))^k.$$

A more complete report with the proofs has been written.

(Jean Descloux)

PART III
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. High Resolution CRT Scope System

The high resolution scope system, subcontracted to the Digital Equipment Corporation of Maynard, Massachusetts, has arrived. Installation has been initiated for use with the Illiac Computer. The system comprises three bays (approximately one bay of digital circuitry, one bay of CRT power supplies, and one bay for the DAC conversion, dynamic focus correction, and spot intensity modulation); a 30" x 60" magnetic shield for the tube containing deflection yokes, focus coil and dynamic focus coil; and finally three cathode ray tubes (7" O.D.). Level converters to (from) DEC levels (-3, 0 volts) from (to) Illiac levels (+1, -20 volts) have not yet been supplied.

Four tube chassis for a total of 50 cathode followers and like number of silicon diode in-gates have been fabricated and installed in Illiac. Internal rewiring of Illiac is not yet complete. DC checkout of the integrated Illiac-CRT system will not begin until next month. Appropriate check out routines have been prepared.

(B. McCormick, M. Shirazi, J. Wenta)

II. Programming

1) Pattern Recognition Computer Simulator

A simulator of the original version of the pattern recognition unit of J. Divilbiss and B. H. McCormick (File No. 403) has been prepared for the Illiac computer. Full details will be found in the following report:

File No. 449: "Use of the Pattern Recognition Computer (PRC) Simulator" by James H. Stein, Jr., April 24, 1962

2) Image Thinning Routines

The intuitive idea behind thinning is to "shrink" the original digitized image to a line drawing overlay preserving all connectivity of the

original. Digital procedures for thinning have been found and successfully simulated using the PRC simulator above.

(A. Amon, R. Narasimhan, R. Rice)

3) A Gap-filling Routine

The image idealization resulting from the removal of gaps, for example in bubble chamber negatives, is central to any successful preprocessing scheme. A code, to be separately reported on later, which seemingly fulfills the normal psychologically-defined concept of a connected line, is being prepared and is written in the language of the PRC simulator.

(A. Amon, B. Mayoh, R. Narasimhan)

4) Structural Linguistics Applied to Pattern Recognition

A theory of pattern recognition wherein the raw digitized image is successively thinned, gap-filled, and idealized to an abstract graph of nodes (end points, junction points, ...) and branches (straight and curving line segments, ...) is being developed. The reduction of a picture (bubble chamber negative for example) to an abstract graph of line elements and associated nodes has appeared more and more advantageous to us these past few months. R. Narasimhan however has gone further and shown the connection between the classification of these graphs and the problems and techniques of structural linguistics.

(B. McCormick, R. Narasimhan)

III. Computer Hardware

1) Printed Circuitry

The following file notes have been issued:

File No. 447: Specification for a Taper Pin Printed Circuit Connector for 44 Contacts (March 22)

File No. 451: Specifications for Assembly of Printed Circuit Boards (May 2)

(B. H. McCormick)

2) Logical Design Conventions

The following file note has been issued:

File No. 453: Combinatorial Logic with Complementary Current Switching Circuitry: Standard Boards, Conventions, and Symbols (May 15)

Printed circuit layout of the seven boards described in File No. 403 is now essentially complete.

(B. H. McCormick)

3) Power Distribution within the Pattern Recognition Computer System

The following file notes have been issued:

File No. 448: General Specifications for Main Power Supply Units (Magnetic Amplifier Type) (April 11)

File No. 454: Preliminary Estimates of Power Requirements for a Pattern Recognition Computer (May 3)

A detailed redesign and experimental investigation of the regulating modules has been undertaken. This circuitry and the associated power transistor heat sink module will be reported separately.

(J. de Montlivault, B. McCormick,
K. Smith)

4) Display Console

The custom-designed display console has been fabricated from modular Amco parts, and delivered. The 1600 bulb lamp display unit for flipflop indicators of the PRU has been designed but not released to the shop.

(J. Burrell, B. McCormick)

5) Air Conditioning

Drawings have been prepared of the remodeling of room 223 to install adequate additional air conditioning (7 tons) to handle the heat load of the computer system. A closed (i.e., recirculating) air conditioner, roof-mounted, has been selected. Bids are being prepared by Plant Maintenance.

(L. Whyte)

PART IV
ILLIAC USE AND OPERATION

Illiac Usage

During the month of May, specifications were presented for eight new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2171. Numbers followed by T are for theses.

2171 Inter-Fraternity Council. Fraternity Rush Analysis. Correlation is to be performed on data concerning fraternity rush procedures. It is hoped that the rush procedure may be improved with respect to number of men pledged, quality of men pledged, reduction of time spent on rush, or reduction of cost of rush.

2172T Mechanical Engineering. Ionized Gas. This program involves the evaluation of the boundary layer thickness in an ionized gas flowing in a duct. A relaxation method will be used for this purpose.

2173 Civil Engineering. Analysis of the Dynamic Response of Simple-Span, Right, Multigirder Highway Bridges. This problem is concerned with the development of a method for the analysis of the dynamic response of simple-span, right, multigirder highway bridges when subjected to the action of moving vehicles. The bridge will be analyzed as a continuous plate over flexible beams.

In the first part of the investigation it is desired to obtain an extensive number of additional solutions to study the influence of those parameters that cannot be considered when the bridge is analyzed as a beam.

2174 Agriculture Economics. Optimum Farm Plans for Diversified Farms. A model of a typical Illinois farm is constructed to show resources available, production alternatives and resource requirements of these alternatives. By use of variable resource linear programming, the optimum combination of productive activities will be determined to maximize the net income to fixed resources on the farm.

The results will be used to recommend to farmers types and sizes of enterprises that maximize farm income.

2175 Chemistry. Diagonalization of Hamiltonian. The calculation of the energy levels of a family of large aromatic compounds by simple molecular orbital methods involves matrices of order up to 24 which must be diagonalized.

2176T Agricultural Economics. Hog Price and Income Policy. Standard routines will be used with time series data on relevant variables to make alternative estimates of the parameters of a sector model of livestock - feed economy with the hog components measured separately. These estimates will be used to appraise the effect of proposed government programs affecting hog supplies or prices.

2177 Institute of Communications Research. Testing the Congruity Hypothesis. This study is an attempt to discover the semantic factor structures in Japanese, American and Finnish cultures, and to test the congruity hypothesis on the basis of discovered semantic structures.

Analysis I includes the investigation of the factor structures measured by the psychological instrument, the Semantic Differential. 4 color, 4 form, and 16 color/form compound stimuli will be used as concepts and a total of 10 verbal scales will be used in each culture. Only (scale) x (scale) intercorrelations will be taken in this study. Factor analysis will be done according to the Thurstone centroid routine and then rotated by the Kaiser Varimax scheme. Rotated factors will be cross-culturally compared by means of the Wrigley-Neuhaus coefficient of factorial similarity.

Analysis II involves computations of the "predicted" scores of congruity for each subject in each culture and the correlations of the "predicted" and the "obtained" congruity scores across subjects in each culture. The extent of "predictability" will then be tested by means of multiple regression analysis (Hotelling's T^2) along each semantic dimension, cross-culturally.

Analysis III consists of "congruity retest" which will be done by multiple regression analysis. This is supposed to represent the extent of "predictability" of congruence, which will be obtained by the "obtained" score and two component (color and form) scores. This analysis will be done separately in each culture.

Results thus derived from analyses II and III will finally be compared.

2178T Chemistry. Madelung Constant. The optical and magnetic properties of transition metal complexes may adequately be described by the use of ligand-field theory. Ligand--a negative or neutral coordinating species attached to a metal ion. For example, in the $\text{CuBr}_4^{=}$ ion - Bromide ion (Br^-) is the ligand. The current interest is to examine the crystal spectra of some transition - metal halide complexes.

In particular, the charge transfer band appearing in the visible region in the tetrabromocuprate (II) ion ($\text{CuBr}_4^{=}$) is interesting. At liquid nitrogen temperatures, this band is split into a triplet and it is desired to assign the observed transitions using ligand-field theory. In doing this, it is necessary to compute the potential at the bromine ions taking into account the effect of all other ions in the lattice. In effect, a Madelung constant calculation is needed.

Table I shows the distribution of Illiac machine time for the month of May. Times in parentheses are simulations on the CDC 1604. :

TABLE I

	Hrs:Min	
Scheduled Maintenance	70:30	
Unscheduled Maintenance	15:05	
Drum Engineering	8:03	
Leapfrog	9:44	
Library Development	:24	
Classes	26:48	
Demonstrations	1:13	
Wasted	:03	
	<hr/>	
	131:40	
Use by Departments		
Aeronautical Engineering	:19	
Agricultural Economics	9:04	(1:13)
Agronomy (00 15 65 330 38)	:52	
Agronomy	:12	
Animal Science	1:26	
Astronomy	6:45	(1:45)
Bureau of Educational Research (PH-M1839)	1:32	
Chemistry	94:30	(3:45)
Civil Engineering (HIGHWAY BRIDGE IMPACT)	2:45	
Civil Engineering	85:00	(14:52)
College of Medicine	:18	
Coordinated Science Lab. (DA-36-039-SC56695)	50:31	
Digital Computer Lab. (US TR AEC-1018)	12:11	
Digital Computer Lab. (NONR 1834(27))	19:28	
Digital Computer Laboratory	68:50	

Economics (NSFG 7056)	2:18	
Economics	:14	
Electrical Engineering (NASA NSG 24-59)	10:30	
Electrical Engineering (AF 7043)	3:07	
Electrical Engineering (NSFG 19005)	1:37	
Electrical Engineering (NSFG 14894)	6:39	
Electrical Engineering	21:53	
Finance (IHR-71)	:05	
Geological Survey	:39	
Geology	1:01	
Inst. of Communications Res. (44-28-20-378)	3:36	
Inst. of Communications Res. (USPHM-3941)	3:40	
Institute of Communications Research	1:12	(:46)
Institute for Research on Exceptional Children	:23	
Interfraternity Council	:03	(:30)
Mechanical Engineering	8:12	
Mining and Metallurgical Eng. (TRUS AF 6770)	:23	
Mining and Metallurgical Eng. (NSFG 146-41)	3:11	
Mining and Metallurgical Engineering	:24	
Music	:35	(:21)
Natural History Survey	6:23	(:24)
Nuclear Engineering	:14	
Office of Instructional TV (OE 7-11-107.00)	7:08	
Physics (NONR 1834(05)A)	1:04	
Physics (AF 49(638)661)	:06	
Physics (NSFG-17428)	:33	
Physics	1:03	
Psychology (MD 2060)	:26	
Psychology (ML774)	4:33	
Psychology (ONR 1834-36)	1:36	
Psychology	105:00	(7:38)
Sociology	1:42	
State Water Survey (DA-36-039-SC75055)	39:43	
State Water Survey	11:55	
Theo. and Appl. Mechanics (DA-11-070-508 ORD)	:05	
Theo. and Appl. Mechanics (DA-01-021 ORD 11878)	4:07	
Theoretical and Applied Mechanics	:05	
	<u>588:20</u>	<u>(31:44)</u>
		<u>720:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine

is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Reader	7
Punch	1
Memory	2
Drum	4
Line Voltage Fluctuations	7
Power Supplies	2
Unknown	<u>9</u>
Total	32

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/1/62	20:24	:23	3:13	1	(1) Memory failure 2 ⁻³³ .	:00	:00	0
5/2/62	19:23	1:26	3:11	6	(1) Failure because of marginal voltages. (2) Unknown. (3)-(4)-(5) Unknown. (6) +150 V on Illiac low.	:00	:00	0
5/3/62	20:18	:00	3:42	0		:00	:22	0
5/4/62	23:13	:00	:47	0		:00	:26	0
5/5/62	24:00	:00	:00	0		:00	:00	0
5/6/62	24:00	:00	:00	0		:00	:00	0
5/7/62	21:10	:44	2:06	2	(1) Unknown. (2) Drum failure.	:00	:19	0
5/8/62	21:12	:00	2:48	0		:00	:23	0
5/9/62	20:18	:00	3:42	0		:00	:42	0
5/10/62	20:22	:30	3:08	1	(1) Memory failure 2 ⁻² .	:00	:34	0
5/11/62	21:25	:02	2:33	1	(1) Reader I failed.	:00	:09	0
5/12/62	23:22	:38	:00	2	(1) Reader K failed. (2) Unknown.	:00	:19	0
5/13/62	23:13	:47	:00	1	(1) Drum failure.	:00	:00	0
5/14/62	17:15	3:05	3:40	4	(1) Reader I failed. (2) Fluctuating line voltage. (3)-(4) Unknown.	:00	:24	0
5/15/62	20:17	1:31	2:12	1	(1) Line voltage drop caused failure.	:00	:36	0
5/16/62	20:41	:00	3:19	0		:00	:27	0
5/17/62	19:08	1:20	3:32	4	(1) Marginal voltage failure. (2)-(3) Reader J failed. (4) Filament voltage on Illiac high, outside storm.	:00	:25	0
5/18/62	21:30	:00	2:30	0		:00	:05	0
5/19/62	24:00	:00	:00	0		:00	:20	0
5/20/62	23:16	:44	:00	2	(1) Unknown. (2) Punch 5 failing.	:00	:27	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/21/62	19:21	1:43	2:56	2	(1) Reader I failed. (2) Filament on Illiac incorrect.	:00	:00	0
5/22/62	20:46	:09	3:05	1	(1) Reader I failing.	:00	:17	0
5/23/62	20:19	:31	3:10	1	(1) 300 volt power supply failing.	:00	:12	0
5/24/62	14:29	:00	9:31	0		:00	:05	0
5/25/62	21:42	:15	2:03	1	(1) Drum failure.	:00	:00	0
5/26/62	24:00	:00	:00	0		:00	:34	0
5/27/62	24:00	:00	:00	0		:00	:30	0
5/28/62	21:38	:00	2:22	0		:00	:24	0
5/29/62	21:26	:00	2:31	0		:03	:27	0
5/31/62	18:26	2:09	3:25	2	(1) Low line voltage. (2) Drum failure.	:00	:38	0
TOTALS	634:34	15:57	69:26	32		:03	9:05	0

PART V
INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

International Business Machines 650 Usage

During the month of May, specifications were presented for 10 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 408'. Numbers followed by T are for theses.

408' Horticulture. Strawberry Irrigation. Five commerical strawberry varieties are under test to see if the use of irrigation will increase yields. Two irrigation levels (None and Irrigation) are the main plots with the 5 varieties the subplots within each Irrigation Level. The fruit is harvested 6-7 times during the season and the following data taken: yield, average berry size, number of fruits per quart and number of berries per harvest. Analysis of variance will be used to determine if there are differences among the varieties, with the irrigation and whether the varieties respond the same to irrigation.

409' Chemistry. Equilibrium Constant Determination. The program will first read in six absorbances and six concentrations, and fit these points to a line using the method of least squares. This line will be used to transform raw data into numbers which will be used in later computations.

The program will then read a set of eleven initial concentrations of acid and base in the chemical reaction being observed. From these data eleven points will be calculated. These points will be printed out, and fitted to a line, again by least squares. An iterative loop will apply a multiplicative correction factor to the abscissae of the line, and the least squares fit is redone. The iteration is stopped when

$$\frac{\text{slope}_n - \text{slope}_{n-1}}{\text{slope}_n} < .01$$

At each iteration the slope and intercept will be printed out.

At the conclusion of the iteration, the program will print out the coordinates of the final line, then stop. All calculations are done in floating point.

410' Chemistry. The Calculation of the Concentrations of Nitrosoxylenol, Diphenoquinone, Xylenol, and Biphenol from Absorbance Measurements and the Derivatives thereof. In the reaction under study two compounds, 2,6 xylenol and sodium nitrite, are added to a given medium. During the course of the reaction, three compounds, nitrosoxylenol; 3,5, 3',5' tetramethyl diphenoquinone; and 3,5, 3',5' tetramethyl biphenol are formed. The overall objective is to determine the way in which the nitrosoxylenol concentration varies with time so as to arrive at some conclusion as to the manner in which the three compounds given above are produced from sodium nitrite and 2,6 xylenol. An outline of the calculations necessary to arrive at this objective will be given in order to show what use will be made of the IBM 650.

At some time t_i let

Z_i = moles/liter of nitrosoxylenol

W_i = moles/liter of diphenoquinone

X_i = moles/liter of remaining xylenol

Y_i = moles/liter of biphenol

These quantities bear the following relationship

$$\text{Total xylenol added} = Z_i + X_i + 2Y_i + 2W_i$$

The concentrations of Z_i and W_i are determined directly from absorbance measurements at appropriate wavelengths. The concentrations of Y_i and X_i must be found by means of the above equation since both compounds absorb at the same wavelength. Thus Z_i , W_i , X_i , and Y_i are to be calculated with the help of the above equation and measurable experimental quantities.

Secondly the validity of the rate equation

$$\frac{dZ}{dt} = N_i X_i \quad N_i = \text{Concentration of nitrite at time } t_i$$

must be ascertained. The derivative of nitrosoxylenol may be calculated by means of a three point formula over equal intervals. However, preliminary examination has shown that the instantaneous concentration of nitrite is related to the concentrations of biphenol, diphenoquinone, and nitrosoxylenol by means of the following

$$N_i = N_o - \left[\frac{W_i + Y_i}{n} + Z_i \right]$$

where n may equal 1.5 or 2. N_0 is the amount of nitrite added at time $t = 0$. Therefore, N_i will be calculated when $n = 1.5$ and $n = 2$. A plot of the rate, dZ/dt versus $N_i X_i$ when $n = 1.5$ or $n = 2$ should be linear and pass through the origin since as $t \rightarrow \infty$ $N_i \rightarrow 0$. Finally the derivatives dW/dt , dY/dt and dX/dt will be calculated by means of a three point formula over equal intervals in order to obtain some idea as to the formation of dihydroquinone and biphenol.

411'T Physical Education. Comparison of Highly Skilled and Novice Fencers in Movement Time and Depth Perception. The problem of the thesis is to determine if highly skilled fencers differ in the characteristics of movement times (arm, leg and total body) and depth perception.

The 650 would be used for analysis of variance, covariance and multiple covariance.

412' Office of Instructional Research. Student Evaluations of Instruction. In this study the K2' subroutine to compute means, standard deviations, correlations, and regression coefficients for a collection of data will be used. The data consists of 8,000 mark-sensed cards which were filled out by the residents of MRH over a period of two semesters. These cards contain the following information: (1) the instructor's name, (2) the instructor's department, (3) the student's evaluation of the instruction on five criteria, (4) the student's semester grade in the course.

In the first run, the cards will be prepared for processing by sorting them alphabetically by instructor's name. The output will consist of eight cards per instructor and will contain (1) the means and standard deviations for the five evaluation criteria, the combined criteria, and the students' grades, (2) the regression coefficients and correlations between each variable and the student's semester grade. All data except that pertaining to the students' grades will be printed at this time. The regression coefficients and inter-correlations between the grades and the other variables will undergo further processing.

For the second run the data cards must be sorted by department and sub-sorted by the students' grades. The output will be the same as in the first run except that the results will apply to the various individual departments. Also, the output will be listed by the various student grade levels.

The third run will merely be an extension of the second run whereby the results of each department are combined to give an all university standard of reference.

The main purpose of this study is to find out if there is a significant correlation between the grade the student received in a course and his evaluation of the instructor. Also, an attempt will be made to determine for which grade level the correlations is a maximum.

413' Electrical Engineering. Circular Antenna Array Pattern Calculation. The problem is to calculate the radiation patterns of a proposed, multielement, circular, beam scanning direction finding antenna array where the basic elements of the array are identical, vertically polarized, unidirectional log periodic antennas.

414' Agronomy. Methods for Evaluation of Forages. An extensive experiment was set up involving the following factors: management (graze or clip both moderate and heavy), planting systems (spaced plants, rows and drilled all with and without brome), and alfalfa varieties (Vernal, Buffalo, DoPuits, Rambler, Ranger, Teton). The study was conducted over a 2 year period with three harvests per year. The design was a split-plot and will be analyzed as such making appropriate single degree of freedom comparisons for the above listed factors.

415' Civil Engineering. Trapezoidal Venturi Flume. A numerical analysis of the problem of flow in trapezoidal channels with trapezoidal Venturi flumes will be made. Solutions are obtained by successive approximations. The solutions for a number of representative designs are obtained and generalized parameters are computed so that the behaviour of the flow can be predicted for cases not solved directly.

416' Chemistry. Ion Binding to Proteins. Poisonous metal ions can be bound to proteins in the blood. This binding may be detected by x-ray diffraction. The diffraction curve may be fitted analytically by a Fourier series which should give the positions and the number of metal ions bound.

417T Horticulture. Manganese Toxicity in Apple Trees. Thirty-two seedling apple trees were grown in nutrient solution in such a manner that the root system was vertically divided into top and bottom with no mixing of nutrient solution between the two root portions. Combinations of high and low calcium with high and low manganese were applied to the roots and the trees were grown in this way for two weeks. The trees were then harvested and cut up into new leaves, old leaves, shoots, stems, top roots and bottom roots. These plant parts were ashed and the ash taken up into solution which was analyzed for calcium and manganese. Other data taken included shoot growth, fresh weight increase, percentage nitrogen in the old leaves and loss of water over a 24 hour period. From each root portion, a study was made to assess the affect, if any, of calcium on the absorption of manganese by apple trees.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of May.

TABLE I'

	Hrs:Min
Scheduled Engineering	13:03
Unscheduled Engineering	19:52
Tape Test	:25
Log Summary	:43
CDC Preparation	5:04
DCL Library Development	5:29
Classes	129:44
Aeronautical and Astronautical Eng.	:58
Business Administration	6:46
Civil Engineering	23:42
Electrical Engineering	:01
Industrial Engineering	2:24
Mathematics	91:51
Mechanical Engineering	1:10
Physics	:03
Psychology	1:52
Theoretical and Applied Mechanics	<u>:57</u>
Computer Operator	:41
Wasted	<u>2:31</u>
	177:32

Use by Departments

Aeronautical and Astronautical Engineering	2:10
Agricultural Economics	:49
Agronomy	5:38
Animal Science	2:19

Chemistry		33:33
Civil Engineering		20:16
Digital Computer Laboratory		1:38
Electrical Engineering		15:09
Horticulture		:49
Mechanical Engineering		:12
Office of Instructional Research		1:17
Physical Education		:21
Physics		5:22
Small Homes Council		:34
Sociology		1:59
State Water Survey		1:34
Statistical Service Unit		95:03
Aeronautical and Astronautical Eng.	1:54	
Animal Science	1:42	
Bureau of Community Planning	1:48	
Bursar's Office	5:15	
Business Office	11:23	
DHIA	40:50	
Education	15:49	
Forestry	:39	
Mining and Metallurgical Engineering	:26	
Marketing	4:48	
Psychology	:55	
Student Counseling	<u>9:34</u>	
Theoretical and Applied Mechanics		<u>11:18</u>
		<u>200:01</u>
		<u>377:33</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for May.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

533 card read punch		8
Not punching	2	
Not reading correctly	4	
Not feeding cards	<u>2</u>	
407 accounting machine		9
Stops cycling	1	
Not printing correctly	5	
Spaces incorrectly	2	
Fuse blew	<u>1</u>	

650 console		1
Fuse blew	<u>1</u>	
Tapes, 652 tape control, and 727 tape units		7
Tape reels came off	1	
Writes incorrectly	1	
Reads incorrectly	1	
Not reading or writing	1	
Tapes broken	2	
Will not select	<u>1</u>	<u> </u>
TOTAL		25

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
5/1/62	15:52		1:05	:04	1	(1) 533 not punching 0 in column 30. Bad tube.
5/2/62	16:19		1:05	:10	2	(1) 407 stops cycling on line. Counter coming through the board. (2) Tape reels will not stay on unit. Stripped thread on knob.
5/3/62	15:38		1:44	:06	2	(1) 407 printing incorrectly. Interchanged two filters and trouble was temporarily corrected. (2) Tape unit 1 not writing correctly. Reason unknown.
5/4/62	16:48			:07	0	
5/7/62	13:10	3:26	:17	:00	2	(1) Column 80 not reading correctly. (2) ATHOS tape would not read correctly from any unit.
5/8/62	15:36		1:47	:12	3	(1) Column 16 reading incorrectly into drum. Reason undetermined. (2) 407 printing incorrectly. Dirty circuit breaker. (3) Tape unit 1 broke a tape.
5/9/62	15:11		2:14	:08	3	(1) Alpha read errors. Could not repeat failure. (2) 407 printing incorrectly after a page eject. High speed clutch adjusted. (3) 407 blew fuse due to a grounded wire in panel. Engineering resulted in locating past read errors. Bad circuit found in 533.
5/10/62	13:47		4:06	:07	1	(1) 407 drops pos. 10 of word six. Bad tube.
5/11/62	17:08		:04	:13	1	(1) Tape unit 1 would not select. Bad tube.
5/14/62	13:25	3:27		:05	0	
5/15/62	16:30		:39	:05	1	(1) 650 blew a fuse. Replaced.
5/16/62	16:43		:42	:10	1	(1) 533 will not read. Broken wire in the read clutch.
5/17/62	17:37		:25	:11	1	(1) 533 will not read alpha numbers. Bent connector in 533.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
5/18/62	17:07		:04	:05	1	(1) 533 punch side not feeding cards. Cards seemed to be badly warped.
5/21/62	13:57	2:56		:05	0	
5/22/62	16:51			:03	0	
5/23/62	16:47		:10	:10	1	(1) Tape unit 1 broke a tape. Bad tube.
5/24/62	17:05			:05	1	(1) Tape units will not read or write when tape is at load point. Bad tube in unit 3.
5/25/62	16:30			:06	0	
5/28/62	10:38	3:14	:32	:06	3	(1) 407 not spacing properly. Oil found in circuit breaker. (2) Broken wire in 533 read clutch. Fixed. (3) 407 not spacing properly. Error in board wiring.
5/29/62	12:38		(3:48)* 4:18	:08	1	(1) 407 not printing correctly. Probably due to a sticking relay point.
5/31/62	16:50			:05	0	
TOTALS	342:07	13:03	19:52	2:31	25	*Engineering time spent on some equipment but the IBM 650 continued to operate. Time not included in the totals.

PART VI
INSTRUCTIONAL USE OF COMPUTERS

During the month of May, specifications were presented for 14 new problems.

67 Civil Engineering 316. Problem 1. IBM 650. Linear Programming. In order to become familiar with the use of a linear programming code on the 650, the students are required to prepare the data cards for the following linear programming problem:

$$\text{Maximize: } x_1 + x_2 + x_3$$

$$\text{Subject to: } 4x_1 + 2x_2 + x_3 \leq 8$$

$$2x_1 + 2x_2 + 2x_3 \leq 8$$

$$x_1 + 3x_2 + 2x_3 \leq 8$$

68 Industrial Engineering 283. Problem 2. IBM 650. A production control office is to be located in an existing factory. The objective is to locate the office so that the total distance traveled is a minimum.

69 Mathematics 195. Problem 5. IBM 650.

1. Give the approximation to $\tan x$ obtained by expanding $\tan x$ in a Taylor series about $x = 45^\circ$ up to and including the term involving the second derivative of $\tan x$. Give the expression for the Taylor series remainder.
2. Give the second degree polynomial approximation (Lagrange interpolation formula) for $\tan x$ which is identically equal to $\tan x$ at $x = 20^\circ, 45^\circ, 70^\circ$. Give the expression for the error in this interpolation formula.
3. Write a GAT program to compute a table of:
 - a) $\tan x$ from the Taylor series approximation (GAT variable Y1);
 - b) $\tan x$ from the Lagrange interpolation formula (GAT variable Y2);
 - c) $\tan x$ from the formula $\tan x = \sin x / \cos x$ where $\sin x$ and $\cos x$ are evaluated by the SINE - COSINE subroutine (GAT variable Y3).

Tabulate these three quantities for $x = 10^\circ(5^\circ)80^\circ$ (use GAT variable X1 for x).

Make the tabulation in four columns:

X1

Y1

Y2

Y3

4. At $x = 60^\circ$ obtain an upper bound for:

- a) the Taylor series remainder;
- b) the error in the Lagrange interpolation formula.

Compare these bounds with the errors in the two approximations at 60° in your table. Under what circumstances might these upper bounds be less than the observed errors?

70 Physics 341. Problem 1. IBM 650. Millikan Oil Drop Experiment.

A GAT program will be used to calculate n_e from laboratory data of Physics 341 experiment.

As well as involving extensive "simple" calculations the integral part of the program is the evaluation of the formula:

$$n_e = \frac{3.35 \times 10^{-8} (V_E + V_g)(V_g)^{1/2}}{\left(1 + \frac{.631}{P\sqrt{V_g}}\right)^{3/2} (E)}$$

where:

E is electric field

V_g is velocity of oil drop due to gravity

V_E is velocity of oil drop due to the electric field

P is atmospheric pressure

n_e is electronic charge multiple.

71 Mathematics 295. Problem 1. IBM 650. Placement Examination Means.

The IBM operator will have a deck of cards. On each card is punched biographical information and a test score for two college students. The information included will be: a. ID number of the student; b. Telephone number; c. Sex of the student (0 indicates female; 1 indicates male); d. Year in college (3 indicates a junior; 4 indicates a senior); e. Test score on a placement examination.

The information will appear on a card in the following order:

	<u>Card columns</u>	<u>Example</u>	<u>Interpretation</u>
Student j	1 - 10	0000056789 ⁺	Student ID number
	11 - 20	0000073686	Telephone number
	21 - 30	0000100004	Col. 25 indicates the student is male; Col. 30 indicates the student is a senior
	31 - 40	0000000078	Score of 78 on examination
Student j + 1	41 - 50	0000144439	Student ID number
	51 - 60	0000367221	Telephone number
	61 - 70	0000000004	Col. 65 indicates the student is female; Col. 70 indicates the student is a senior
	71 - 80	0000000100	Score of 100 on examination

Part I. Write a program in machine language which will read the data, calculate and print on the 407 accounting machine the following statistics:

- The total group mean on the examination
- The mean for females
- The mean for males
- The mean for juniors
- The mean for seniors

Part II. Write the same program in symbolic form acceptable to SOAP. If time permits, have the program SOAPed and return the output program.

72 Aeronautical and Astronautical Engineering 211'. Problem 1. ILLIAC and IBM 650. Isobars. The velocity field for flow which is uniform at infinity and passes a circular cylinder with circulation Γ is given by a well known equation. From the velocity field, using Bernoulli's equation, the pressure field can be derived.

The student will calculate the pressure field (60 net points) for each of four values of Γ and plot isobars by hand.

73 Civil Engineering 391. Problem 2. IBM 650. Design of Two-Span Beam with Cover Plates. The problem deals with the design of a two-span continuous beam with variable rigidity under both static and movable loads. Starting with a given beam, the site of the cover plate must be such that the stress both at the center support and in the positive regions is less than a specified limit; the problem is thus primarily an exercise in reconciling conflicting design criteria. Only the end result is specified, and the method of solution is left entirely up to the students.

74 Mathematics 195. Problem 6. IBM 650. Hmwk # 11. Recalling Homework 7, the period of a simple pendulum is given by

$$P = 2\pi \sqrt{\frac{L}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 k^2 + \left(\frac{1 \cdot 3}{2 \cdot 4}\right)^2 k^4 + \left(\frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6}\right)^2 k^6 + \dots \right\}$$

where $k = \sin \frac{\theta_0}{2}$.

In this calculation we will approximate the period of P^* which is obtained by retaining only the first four terms in the series for P , i.e.

$$P^* = 2\pi \sqrt{\frac{L}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 k^2 + \dots + \left(\frac{1 \cdot 3 \cdot 5 \cdot 7}{2 \cdot 4 \cdot 6 \cdot 8}\right)^2 k^8 \right\}$$

Write a GAT program in which you use the Newton-Raphson method to find the amplitude θ_0 which will yield the period $P^* = 1.645$ sec. given that

$$L = 2 \text{ ft}$$

$$g = 32.258 \text{ ft/sec}^2$$

Use the GAT variable Y1 to represent θ_0 (in degrees). Your result for θ_0 must have a relative error which does not exceed 10^{-4} . Show that your result has this accuracy by calculating P^* for $\theta_0 = \theta_0^* (1 \pm 10^{-4})$ where θ_0^* is the result you obtain from the Newton-Raphson procedure. Use the GAT variable Y2 to represent P^* .

75 Civil Engineering 311. Problem 1. IBM 650. Multi-degree of Freedom Systems. The problem consists in finding the natural frequencies of multi-degree

of freedom systems and represents part of the requirement for a term paper in the TAM 311 course in Theory of Mechanical Vibrations.

The method employed is the Holzer technique, in which one parameter becomes zero at each of the natural frequencies. By changing the frequency until a residual is obtained which is within an allowable margin, the natural frequencies are obtained. As a criterion for a first approximation, the program varies the frequency until the correct number of nodes is obtained for the particular mode being considered. Subsequently the frequency is varied on the basis of the residuals of the two previous cycles of the iteration process. Besides the natural frequencies, the program will compute the normal mode shape for each natural frequency.

76 TAM 294. Problem 1. ILLIAC. Roots of a Cyclic Difference Equation
A fourth order polynomial is to be solved using an iterative method to find the positive root to 4 places.

$$y_{n+1}^4 + 2y_{n+1}^3 y_n - 2y_n^3 y_{n+1} - y_n^4 - \frac{\pi^2}{2} = 0$$

$$n = 1, 2, 3, \dots 20$$

where $y_1 = 1$.

77 Electrical Engineering 388. Problem 1. ILLIAC. Antenna Patterns.
One student is going to run the following problem on Illiac for comparison with Analog Computer results.

Two vertical transmitting antennas spaced a distance d apart are fed with currents I_1 and I_2 . I_1 and I_2 will be kept equal in magnitude, but the phase angle α by which I_2 leads I_1 may be varied. It is desired to find the radiated electric field intensity patterns of this antenna array for various values of α and d . Such patterns plot the magnitude of the intensity $|E|$ at a constant radius from the array for all angles φ , from -180° to $+180^\circ$.

It is known that the intensity obeys the equation:

$$|E| = |K \cos \left(\frac{\pi d}{\lambda} \cos \varphi + \frac{\alpha}{2} \right)|$$

73 Civil Engineering 391. Problem 2. IBM 650. Design of Two-Span Beam with Cover Plates. The problem deals with the design of a two-span continuous beam with variable rigidity under both static and movable loads. Starting with a given beam, the site of the cover plate must be such that the stress both at the center support and in the positive regions is less than a specified limit; the problem is thus primarily an exercise in reconciling conflicting design criteria. Only the end result is specified, and the method of solution is left entirely up to the students.

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$$P = 2\pi \sqrt{\frac{L}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 k^2 + \left(\frac{1 \cdot 3}{2 \cdot 4}\right)^2 k^4 + \left(\frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6}\right)^2 k^6 + \dots \right\}$$

where $k = \sin \frac{\theta_0}{2}$

In this calculation we will approximate the period of P^* which is obtained by retaining only the first four terms in the series for P , i.e.

$$P^* = 2\pi \sqrt{\frac{L}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 k^2 + \dots + \left(\frac{1 \cdot 3 \cdot 5 \cdot 7}{2 \cdot 4 \cdot 6 \cdot 8}\right)^2 k^8 \right\}$$

Write a GAT program in which you use the Newton-Raphson method to find the amplitude θ_0 which will yield the period $P^* = 1.645$ sec. given that

$$L = 2 \text{ ft}$$

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Use the GAT variable Y1 to represent θ_0 (in degrees). Your result for θ_0 must have a relative error which does not exceed 10^{-4} . Show that your result has this accuracy by calculating P^* for $\theta_0 = \theta_0^* (1 \pm 10^{-4})$ where θ_0^* is the result you obtain from the Newton-Raphson procedure. Use the GAT variable Y2 to represent P^* .

75 Civil Engineering 311. Problem 1. IBM 650. Multi-degree of Freedom Systems. The problem consists in finding the natural frequencies of multi-degree

using Simpson's rule with $n+1$ points

$$I_n^* = \frac{h}{3} \left\{ y_0 + 4y_1 + 2y_2 + \dots + 4y_{n-2} + 2y_{n-1} + y_n \right\}$$

where, for this problem,

$$y_i = \frac{1}{1+x_i} \quad .$$

Calculate I_n^* for $n = 3(2) 15$. Calculate an upper bound for the error $E_n = I - I_n^*$ for each value of n ; you may neglect roundoff error and consider only the truncation error of Simpson's rule.

This integral can be calculated directly from the standard formula

$$\int \frac{dx}{x} = \ln x$$

and it follows that

$$I = \ln 2 = 0.69314718$$

to 8 significant figures. Compare your observed errors E_n with the upper bound that you have estimated.

Use GAT variables as follows:

$$I1 = n$$

$$X1 = x$$

$$Y1 = I_n^*$$

$$Z1 = \text{upper bound for } E_n$$

What is the smallest value of n that would be required to guarantee that I_n^* is correct to fifteen significant figures (assuming that the machine word length was adequate for this); as before, you may neglect roundoff errors. In answering this question show how you arrived at your result.

PART VII
CONTROL DATA CORPORATION 1604

During the month of May specifications were presented for one new problem. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 19. Numbers followed by T are for theses.

19 Physics. Deuteron Break-up Reaction by Protons. A study of the energy distribution of protons obtained from the break up of the deuteron by an incident proton beam is to be made. It is intended to analyse in detail the effect of multiple scattering on the proton energy spectrum. The transition matrix for the process is therefore written as a sum of terms representing different orders of approximation, like the impulse approximation, the final space interaction with exchange scattering, etc. Each such form involves certain matrix elements which are to be computed numerically. The numerical problem consists of evaluating a large number of algebraic functions and integrals for a given set of fixed (potential) parameters and different sets of energy and angle parameters, corresponding to the experimental results to be explained by theory. A typical integral to be evaluated looks like

$$\int_0^1 \frac{f(x) dx}{d^2 + x^2},$$

where $f(x)$ contains logarithmic, exponential, and circular functions of arguments like $[\beta^2 + (k \pm x)^2]$, where α, β are fixed parameters and k is the energy variable.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part IV.

CDC 1604 TIME DISTRIBUTION
May, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	1:13			1:13
Astronomy	1:45			1:45
Chemistry	3:45	8:23		12:08
Civil Engineering	14:52	8:09		23:01
Electrical Engineering	:	:11		:11
Inst. for Communications Res.	:46			:46
Interfraternity Council	:30			:30
Music	:21			:21
Natural History Survey	:24			:24
Physics		9:11		9:11
Psychology	7:38			7:38
Maintenance			:30	:30
TOTALS	31:44	25:54	:30	57:38

PART VIII
GENERAL LABORATORY INFORMATION

Seminars

"Delay in Sequential Machines," by Herschel H. Loomis, Jr., Massachusetts Institute of Technology, The Research Laboratory of Electronics, Cambridge, Massachusetts, May 7, 1962

"Design of Computers of the Polish Academy of Sciences," by Dr. Jacek Karpinski, Director of Computer Research, Polish Academy of Sciences, Warsaw, Poland, May 10, 1962

"Design of the Pattern Recognition Computer," by Professor Bruce H. McCormick, Digital Computer Laboratory, University of Illinois, May 21, 1962

"A 3.4 Million Bit Magnetic Drum Memory," by Professor Harrington C. Brearley, Digital Computer Laboratory, University of Illinois, May 28, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Research Associates	7	0	7.0
Graduate Research Assistants	11	19	22.0
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>39</u>	<u>18</u>	<u>46.25</u>
TOTAL	76	41	96.25

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbuam, J. E. Robertson, K. C. Smith, and J. N. Snyder.

Physics

DIGITAL COMPUTER LABORATORY
UNIVERSITY OF ILLINOIS

URBANA, ILLINOIS

TECHNICAL PROGRESS REPORT

- PART I - HIGH-SPEED COMPUTER PROGRAM
- PART II - CIRCUIT RESEARCH PROGRAM
- PART III - DATA REDUCTION METHODS
- PART IV - ILLIAC USE AND OPERATION
- PART V - IBM 650 USE AND OPERATION
- PART VI - INSTRUCTIONAL USE OF COMPUTERS
- PART VII - 7090-1401 COMPUTING SYSTEM
- PART VIII - CONTROL DATA CORPORATION 1604
- PART IX - GENERAL LABORATORY INFORMATION

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June, 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research. This report covers the second quarter of 1962.

1. Construction Progress

Tables I, II, and III summarize the progress during each month toward completion of the computer. Entries in each table indicate the number of transistors which have completely passed through the phase of design or construction indicated by the column heading. Within one rectangle of each table, the three figures from top to bottom indicate completions, respectively, at the beginning of the month, during the month, and at the end of the month. The transistor counts are intended to reflect the amount of work directly applicable toward completion of the computer, rather than total effort expended. For example, if the wiring of a chassis has to be modified, it is removed from the "completed" list, and indicated as having been wired again during the month in which the modification is made.

Completion of systems design indicates that the general strategy of design has been worked out in some detail. For a control, for example, a mnemonic order code would be fixed on completion of systems design, although the numerical equivalents for each order would be unknown. Logical design completion would be indicated by a logical diagram in which circuit restrictions on fanout and cascading are observed, but physical distances and consequent cable driver circuits are not included.

Physical placement is completed when chassis boundaries are fixed, and cable driving circuits included in the logical diagram. In block layout, the function of each transistor on a chassis is indicated by circuit block symbols. Information sufficient for drafting, frame wiring, component layout, and power supply requirements is available on completion of block layout.

Component layout requires as many as 14 drawings for each chassis, showing successive phases of wiring of the chassis.

TABLE I--April

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	
Core Storage Unit (4096 words) 3937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	3,943 3,140 7,083	0
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,709 278 3,987	0
Advanced Control 6800	6,800	6,400	5,413	3,134 1,566 4,700	2,666 1,568 4,234	1,296 1,430 2,726	832 884 1,716	505 327 832	0	
Drum Storage Unit 2500	2,500	1,100	0						0	
Interplay Control 5180	5,180	5,180	2,100 0 2,100	0 827 827	0 684 684	0 228 228	0	0	0	
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641	641	
Test Controls	763	763	763	763	763	763	763	763	763	
TOTALS	39,472 0 39,472	37,672 0 37,672	32,505 0 32,505	28,126 2,393 30,519	27,658 2,252 29,910	26,288 1,658 27,946	25,824 884 26,708	25,497 327 25,824	18,372 3,418 21,790	0

TABLE II--May

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	0
Core Storage Unit (4096 words) 3937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	0
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	7,083 3,202 10,285	0
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	
Advanced Control 6800	6,800	6,400	5,413	4,700 713 5,413	4,234 1,179 5,413	2,726 1,332 4,058	1,716 1,946 3,662	832 1,689 2,521	0	
Drum Storage Unit 2500	2,500	1,100	0 500 500	0						
Interplay Control 5180	5,180	5,180	2,100 1,200 3,300	827 732 1,559	684 0 684	228 456 684	0 684 684	0		
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641	641	
Test Controls	763 96 859	763 96 859	763 96 859	763 96 859	763 96 859	763	763	763	763	
TOTALS	39,472 96 39,568	37,672 96 37,768	32,505 1,796 34,301	30,519 1,541 32,060	29,910 1,275 31,185	27,946 1,788 29,734	26,708 2,630 29,338	25,824 1,689 27,513	21,790 3,202 24,992	0

TABLE III--June

	Systems Design	Logical Design	Physical Placement	Block Layout	Component Layout	Chassis Wiring	Visual Insp.	Static Test	Subsystems Test	System Test
Repetitive M.A.U. 5379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	5,379	0 5,379 5,379
Core Storage Unit (4096 words) 3937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	3,937	0 3,937 3,937
Delayed Control, EAU, and End Connections 10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285	0 10,285 10,285
Flow Gating (Buffer Storage) 3987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	3,987	0 1,200 1,200
Advanced Control 6800	6,800	6,400 0 6,400	5,413 0 5,413	0 5,413 5,413	0 5,413 5,413	4,058 1,355 5,413	3,662 1,751 5,413	2,521 2,892 5,413	0 2,034 2,034	0
Drum Storage Unit 2500	2,500	1,100	500 600 1,100	0	0	0	0	0	0	0
Interplay Control 5180	5,180	5,180	3,300 1,880 5,180	1,559 1,657 3,216	684 1,083 1,767	684 179 863	684 179 863	0	0	0
Paper Tape Input-Output 641	641	641	641	641	641	641	641	641	641	0 641 641
Test Controls	859	859	859	859	859	763 96 859	763 96 859	763 96 859	763 96 859	0 763 763
TOTALS	39,568 0 39,568	37,768 0 37,768	34,301 2,480 36,781	32,060 1,657 33,717	31,185 1,083 32,268	29,734 1,630 31,364	29,338 2,026 31,364	27,513 2,988 30,501	24,992 2,130 27,122	0 22,205 22,205

The static test involves application of DC power to the chassis before transistors are plugged into sockets. Voltage measurements at all nodes indicate faulty components, wiring errors, etc., not caught during visual inspection.

A subsystems test is a dynamic test of several thousand transistors using a relatively simple fixed program usually generated by a small special purpose control to be discarded later. Systems tests occur when sufficient equipment is assembled for stored program operation.

2. Subsystem and Systems Tests of the New Computer

The second quarter of 1962 covers all but the first week of systems checkout of the so called AC_0 phase of operation of the computer. The AC_0 control, discarded on July 5, permitted stored program engineering tests during the period of construction of advanced control. For simplicity of the AC_0 control, the AC_0 computer used one instruction per word, had no index registers, and concurrency of operation was limited.

The general strategy of checkout was to initially employ the logical instructions and the fractional part of the arithmetic unit as a 45 bit fixed point computer. When this structure was reliable, additional diagnostic tests of the exponent arithmetic unit and the more complex floating point instructions were used to find machine faults.

During June a subsystems test of the Address Arithmetic Unit of Advanced Control was completed.

3. Core Memory

During April the effort to bring the memory to a satisfactory speed and reliability level was continued. It was found that the bias level of the sense amplifiers shifted at higher speeds ($\leq 1.8\mu s$ cycle). This condition was easily corrected.

The memory cycle time was normally set for $1.8\mu s$ during April. The error rate during tape input and output was still above acceptable levels, but was being steadily improved.

The switch cores of the second core stack (2048 words) were revised to decrease radiated noise.

During May and June the second half core-stack was installed in the memory bringing the total number of words to 4096. Three words of the new stack were found to have open word lines. These were repaired and the stack re-installed. Three other words were found to cause errors; their word line currents were, in each case, well below the tolerable value. After several days of program testing, when no other low-quality words had been found, the three words were repaired. All three had switch-core turns which did not thread through the entire core. This is possible since the switches are composed of a stack of small cores which were not, in many cases, glued together as originally specified.

After the above repairs, it was found that errors still occurred occasionally, these appearing to be related to the information pattern. This condition is at least partially due to digit-sense line crosstalk which can be reduced to about 1/4 its present magnitude by suitable changes in digit line geometry. This change, however, has not yet been undertaken because of a conflict in scheduling with the installation of Advanced Control.

The Advanced Control bootstrap (3 words) was wired into the core.

(S. Ray)

4. Magnetic Drum Memory

Experiments were continued on the Head Selection Matrix in conjunction with the bit-pattern generator, read amplifier, etc. Among the properties investigated were recovery of the system after selection and writing, crosstalk between selected and unselected heads during reading and writing, unwanted currents flowing through unselected heads during selection, etc. The main problem was recovery of the read-amplifier after writing, due to the extremely large voltages incident on the input. Diode limiting on the input of the amplifier was not sufficient. The solution was to use transformer coupling between the matrix and the read amplifier, with provision for isolating the two with back biased diodes.

Tolerances in the voltage drop across the semiconductors connecting the selected head and the transformer are of some concern, possibly necessitating matched matrix diode pairs and matched column select transistor pairs. Experiments seem to indicate that this matching should be within about 100 MV in order

to limit the magnitude of the voltage step applied to the read circuit at the time of head switching. In order that this does not alter the D.C. level of the amplifier output, A.C. coupling is necessary, with the low-frequency cutoff determining the recovery time of the amplifier from this step function input. A compromise should be effected between fast recovery and the necessity of transmitting 2 μ sec read pulses without distortion or droop.

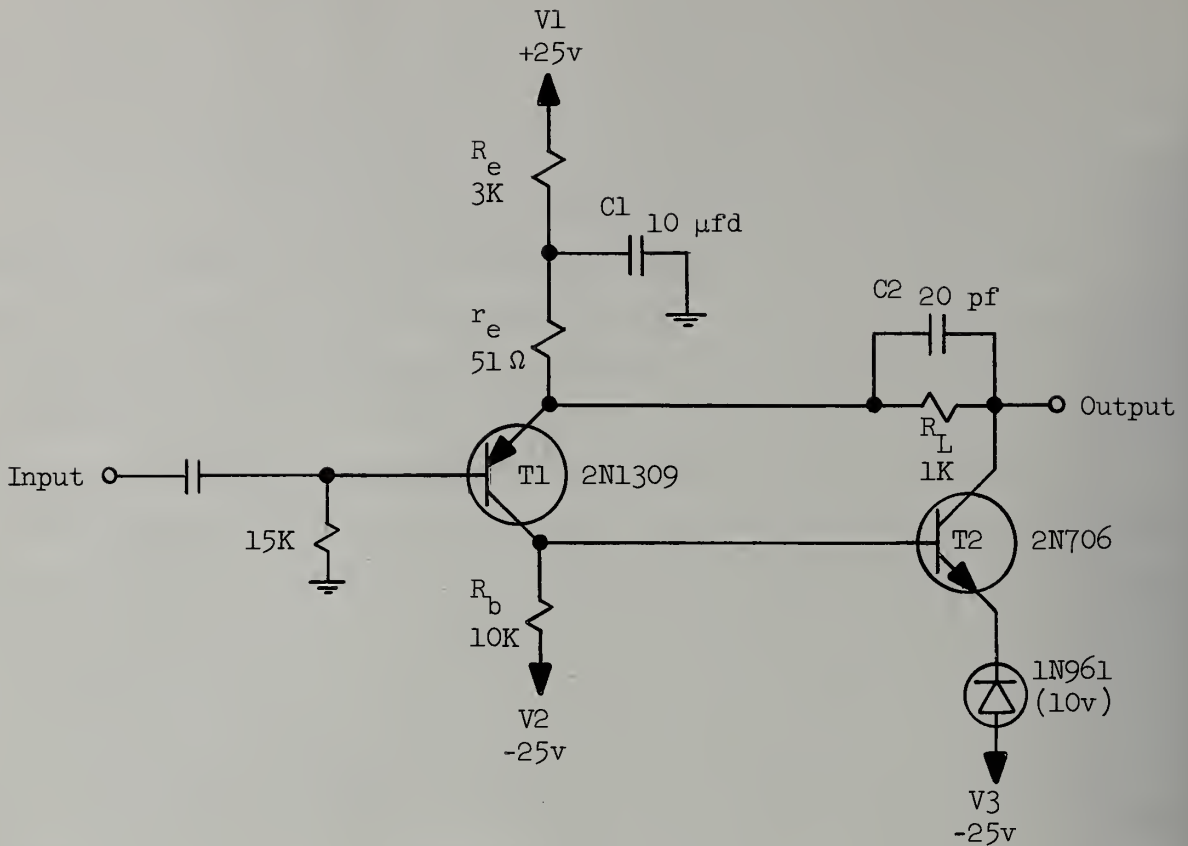
The peak detecting clockpulse generator has been tested and operated as expected. Phase modulation of the clock pulses, which occurs in the conventional threshold detector type of clock pulse generator, was eliminated. File No. 455 describing the simplified peak detection system was published.

A new feed-back read amplifier (with A.C. interstage coupling) has been designed and tested (Figure 1). This has the advantage of high input impedance, low output impedance, and highly stabilized gain, D.C. output level, and high frequency response, all due to the high A.C. and higher D.C. feedback. A tendency to have a peak in the high frequency end of the gain-frequency curve was due to the phase shift in the feedback network at high frequencies. This was eliminated by cutting off the high frequency response at somewhat lower frequencies with capacitive loading of the output, as shown. Cascading of the amplifier is simple, too, due to the impedance levels. Details will be given in a forthcoming File Number.

(P. V. S. Rao)

Some of the testing of the Magnetic Drum Memory, both for initial checkout and for maintenance, will be done using a computer program to generate test signals and interpret the results. However, there will be other occasions when off-line testing will be required. Some test equipment for this purpose has been designed. It allows the Magnetic Drum Memory to be effectively disconnected from Interplay and the rest of the computer without disconnecting any cables. The disconnection is done partly by transistor gates and partly by pegging various control signals to levels which disable the Drum-Interplay link. No relays or manual switches were added in any signal path.

The test equipment allows manual selection of the block to be accessed and manual choice of (1) write once, (2) read once, (3) read block repeatedly, or (4) read whole band containing designated block continuously. The test



Transistor parameters and component tolerances:

$$\beta_1 \text{ and } \beta_2 > 25$$

$$\frac{r'_{b1}}{\beta_1} + r'_{e1} \text{ and } \frac{r'_{b2}}{\beta_2} + r'_{e2} < 100 \Omega$$

Resistors $\pm 3\%$

Voltages $\pm 3\%$

Amplifier characteristics:

Gain between 17.5 and 21

Frequency response--200 cycles to 4 mc

AC Input impedance $> 25K$ (at base of T1)

AC Output impedance $< 156 \Omega$

Figure 1 One Stage of Two Stage Feedback Read Amplifier

signal to be written in each of the 13 channels can be 0, 1, L or \bar{L} , where L is the output of a Bit Pattern Generator with a cycle length of 16 bits. This results in a pattern of four different words repeated 64 times in the 256 word block. A parity circuit generates a parity valid input for the 14th (parity) channel.

(H. C. Brearley, B. Levy)

On June 1, the 32,768 word magnetic drum mechanism currently under test made a scraping or squeaking noise a few minutes after turn-on. During the month, it was audibly noisy on five out of ten days, always within the first few minutes after turn-on. It is thought that the top bearing is responsible, but this is not certain. The designer thinks the noise may be caused by the outer race of the top bearing slipping in its housing during warmup. The investigation is continuing.

Radiated signals in the computer room were measured at the place where the drum read amplifier will be located. The pickup from the core memory, paper tape reader and paper tape punch were all of the same order of magnitude, 15 millivolts peak-to-peak in a one turn loop, eight inches in diameter. The normal drum read voltage is only 50 millivolts. Shielding from the Core Memory will be provided by the previously planned doors on both the Core Memory cabinet and the Drum Memory cabinet. Shielding from the paper tape reader and punch, which are in the same cabinet with the Drum Memory, will be provided by a shield between bays 6 and 7.

(H. C. Brearley)

The Drum Memory logic drawings D1300, C1302, C1304, and C1307 were checked, particularly with respect to fanout, cable drivers, indicators, and switching amplifier thresholds. Numerous additions and changes were made. File No. 462, "Some Notes on Using Shifted Thresholds with Slow Circuits," was prepared.

The Slow Circuits schematic, D1131, was corrected, and a similar but different schematic was prepared for the Modified Slow Circuits which allow cable inputs to the switching amplifier collector node. These circuits are used as loads on the Interplay Set Up cables, specifically in the Drum Order Register.

(M. D. Freedman)

5. Interplay

During April work continued on block layout of interplay. To relieve some congestion of the chassis holding the drum channel control circuits, it was decided to move a number of cable drivers out of these units into center wall chassis.

A test unit for the interplay address list core memory was designed.

During May block layout of interplay continued and was almost finished with the exception of two areas. The first is one chassis of the drum channel control which is awaiting a decision by the shop as to the best layout. The second is some of the chassis for the interplay address list, which cannot be completed until the design of the address list core memory is fixed. An experimental chassis to test the design of this memory was built by the shop.

During June the rough drafts of the block layout for the central part of interplay and the drum channel were completed. These are now being copied into their final form with occasional modifications where a worthwhile shortening of wiring can be accomplished easily.

The transistor count for the drum channel, and the whole of the central part of Interplay, with all circuitry required for 31 channels, is 5180, not counting 2N1309 bumps.

The number which have to be installed to provide for the drum and a few other channels (maximum of six others) is about 3500. Provision for additional channels can be added in lots of six.

(C. S. Wallace)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

Sergio Ribeiro has continued his analysis of the asymmetric flipflop, investigating the conditions for triggering. A qualitative phase-plane diagram is used to show conditions during transition.

Tohru Moto-Oka has investigated the theory of a cascade amplifier consisting of a load and an arbitrary number of tunnel diodes in parallel, connected by sections of strip line, and driven by a generator. Expressions for available power gain and transducer gain have been developed.

Henry Guckel has set up a program for a series of calculations currently being run on Illiac for the emitter-follower oscillator investigation. A report will be prepared shortly. He has also carried out some tunnel diode measurements and is working on two aspects of tunnel diode circuit theory. The first is a basic investigation of directivity and the second is a small-signal theory of oscillation in which the non-linear character of the tunnel diode capacitance is taken into account.

Thomas Burnside has continued the statistical analyzer work with the design of a discriminator circuit to be used at the output of the diode circuit described last month. The discriminator uses four transistors with a high input impedance. A scheme for counting pulses in each interval has been devised.

2. Phase-Plane Analysis of Flipflops

The discussion of last month is continued. In order to simplify references, the equation numbers used below follow in sequence those of the May report.

Triggering

The effect of the trigger is to change the character of the system for the time of its duration τ_g , so that when the trigger is ON, only one stable singularity exists (node or focus).

Assume the trigger is a square wave voltage of amplitude v_g . Normalizing x with respect to i_0 and assuming $i_{s1} = i_{s2} = i_s \ll i_0$, and also $i_s \ll x$ in the range of interest, a suitable approximation for equation (6) is:

$$\ln \frac{x}{1-x} = \eta R_2 i_0 x + \eta V_0 + \eta v_g \quad (9)$$

Suppose that V_0 is such that $\eta R_2 i_0 x \frac{1}{2} + \eta V_0 = 0$, i.e., $V_0 = -\frac{i_0}{2} R_2$, and $x_0 = \frac{1}{2}$; this means that $v_0 = 0$ exactly when $i_2 = \frac{1}{2} i_0$ (in hypothetical steady state conditions) which implies a certain kind of symmetry in the flipflop behavior.

A qualitative plot of equation (9) is shown for various conditions in Figures 1a, b, c, d, e. Notice the movement of singularities for increasing values of v_g , as indicated by the arrows in Figure 1c.

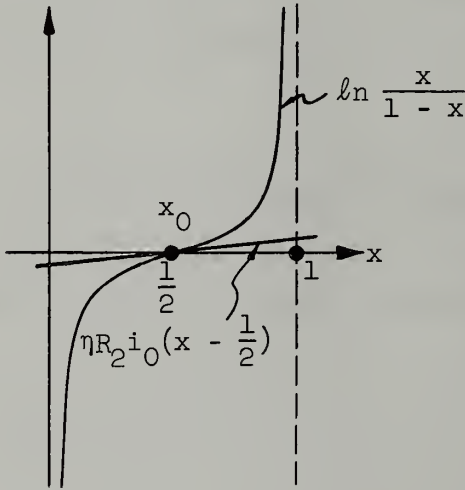


Figure 1a $i_0 < \frac{4kT}{gR_2}$

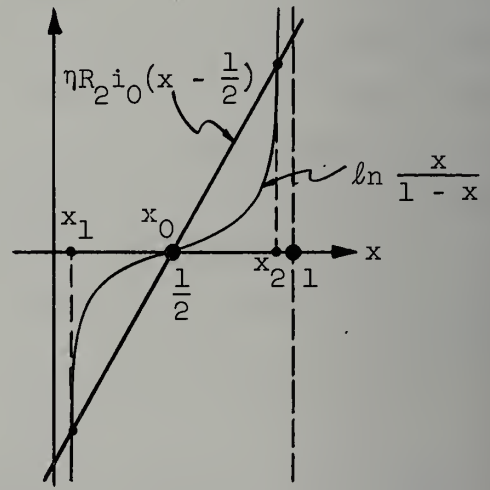


Figure 1b $i_0 > \frac{4kT}{gR_2}$

$$v_g = 0$$

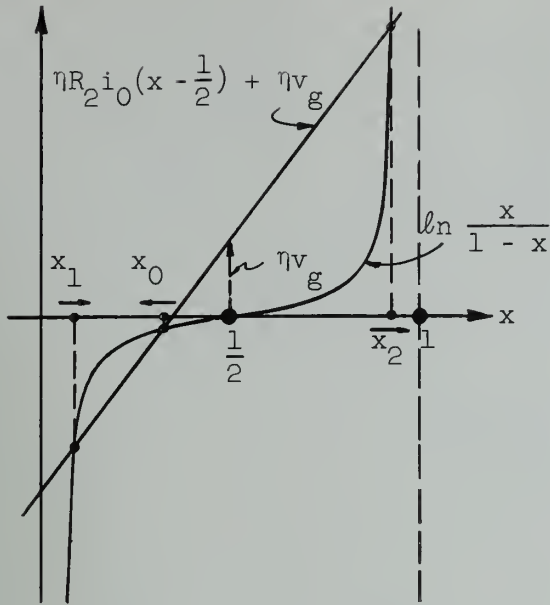


Figure 1c $i_0 > \frac{4kT}{4R_2}$

$0 < v_g < v_{g_{critical}}$ --flipflop not yet triggered.

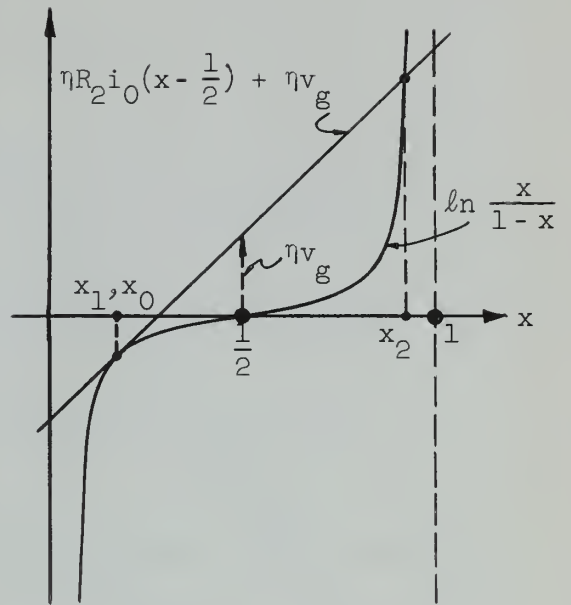


Figure 1d $i_0 > \frac{4kT}{gR_2}$

$v_g = v_{g_{critical}}$ --flipflop barely triggered; saddle point at x_0 meets stable node at x_1 .

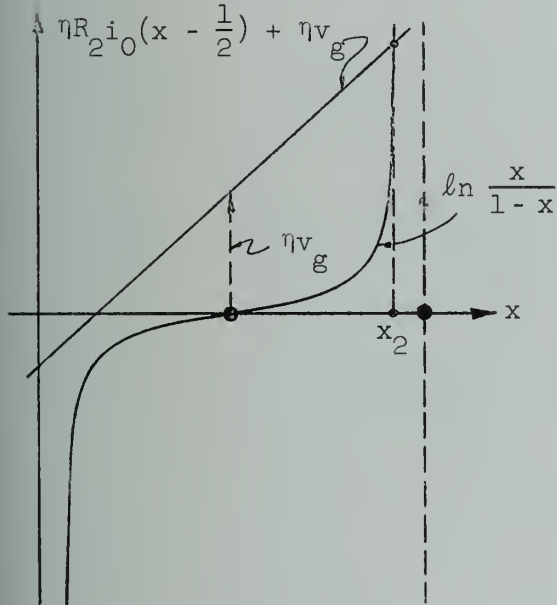


Figure 1e $i_0 > \frac{4kT}{gR_2}$

$v_g > v_{g_{critical}}$ --flipflop definitely triggered--singularities x_0 and x_1 disappear--only stable node at x_2 remains.

It is interesting to mention the values of $v_{g_{critical}}$ and approximate values for x_1 and x_2 .

It has been found that for this case, if $i_0 \gg \frac{4}{R_2 \eta} \gg i_s$

$$v_{g_{critical}} = \pm \left(R_2 \frac{i_0}{2} - \frac{1}{\eta} \ln i_0 R_2 \eta \right) \quad (10)$$

The voltage hysteresis width is

$$\Delta v_{g_{critical}} = R_2 i_0 - \frac{2}{\eta} \ln i_0 R_2 \eta \quad (11)$$

And, under the same assumptions,

$$0 < x_1 < \frac{1}{R_2 \eta i_0} ; 1 > x_2 > \left(1 - \frac{1}{R_2 \eta i_0} \right) \quad (12)$$

for $\frac{1}{R_2 \eta i_0}$ and $\left(1 - \frac{1}{R_2 \eta i_0} \right)$ are the points where the saddle-point meets the stable nodes (respectively).

To get a qualitative notion of the phase-plane portrait of this circuit, we can draw the isoclines. The isocline for $y' = 0$, shown in Figure 2, already furnishes some useful information.

Equation (4) can be rewritten in normalized form, with the usual approximations and we get:

$$y \frac{dy}{dx} = a \left\{ bx + c + \ln \frac{1-x}{x} \right\} (1-x)x - \left\{ \frac{2x-1}{(1-x)x} y^2 + ay \right\} \quad (13)$$

where y corresponds to $\frac{K_1}{i_0} y$ in equation (4)

and x corresponds to $\frac{x}{i_0}$ in equation (4).

The parameters are: $a = \frac{K_1^2}{K_2}$; $b = i_0 \eta R_2$; $c = \eta(V_0 + v_g)$. If $\frac{dy}{dx} = y'$, we get the isocline equation:

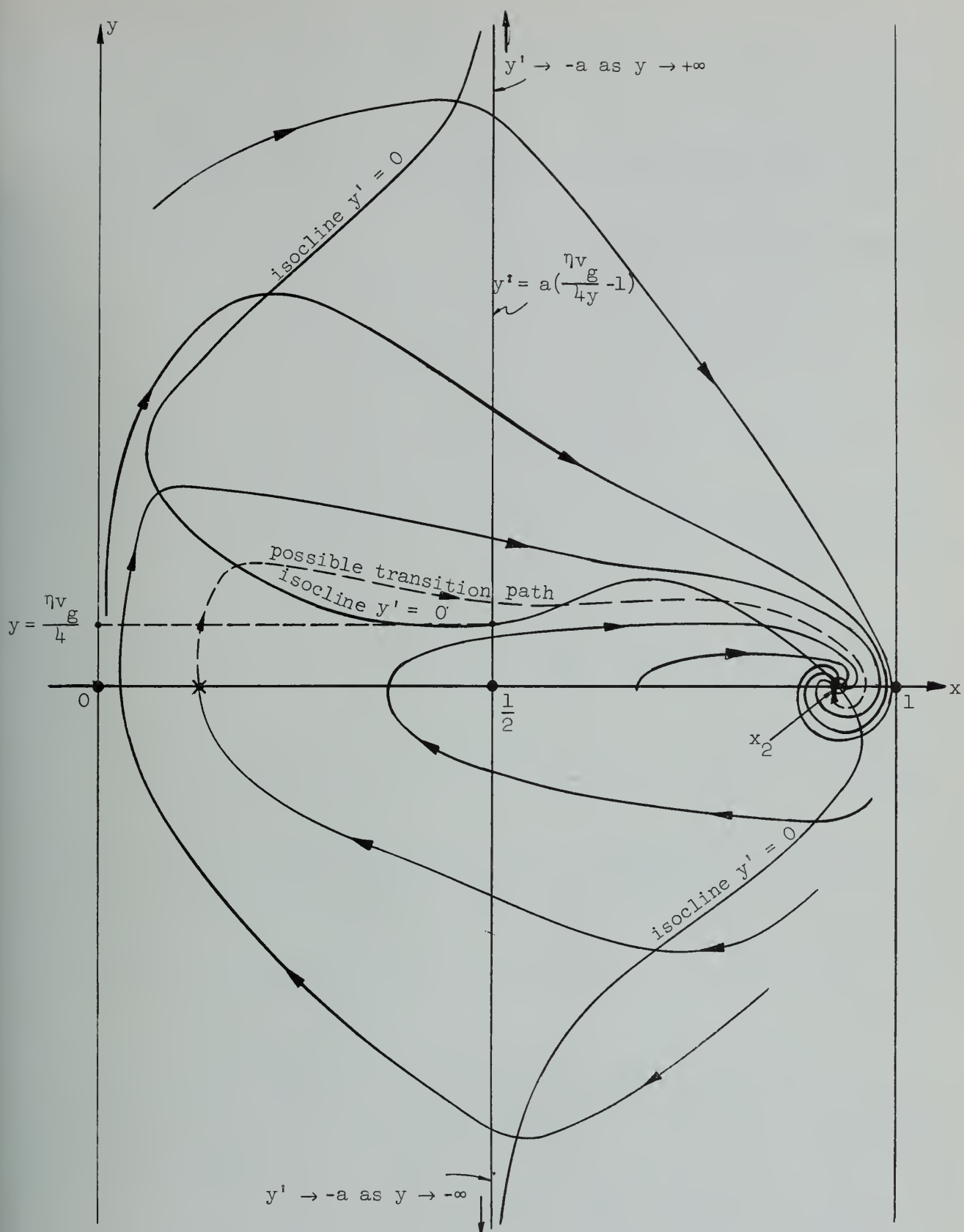


Figure 2

A Qualitative Phase-Plane Portrait of the Asymmetric Flipflop
 during Transition (for some value of $v_g > 0$)

$$\frac{y}{a} = \left\{ (1 + y') \pm \sqrt{(1 + y')^2 + \frac{4}{a} FG} \right\} x \left(-\frac{1}{2F} \right) \quad (14)$$

where $F(x) = \frac{2x - 1}{x(1 - x)} = F$ and $G(x) = \left\{ bx + c + \ln \frac{1 - x}{x} \right\} (1 - x)x = G.$

Also notice from (13) that, if $x = \frac{1}{2},$

$$y' = a \left(\frac{\eta v}{4y} - 1 \right) \quad (15)$$

We should point out that two singularities are left out when x is restricted to the interval $(0, i_0)$ in equation (6) (the normalized interval becomes $(0, 1)$). This is so because $g(x)$ and $h(x)$ have a common denominator $\psi'_2 - \psi'_1$ which can be cancelled out when x is so restricted. However, this is a factor given by:

$$\frac{1}{\psi'_2 - \psi'_1} = \eta \frac{(i_{s2} + x)(i_{s1} + i_0 - x)}{(i_0 + i_{s1} + i_{s2})}$$

which is zero at $x_3 = -i_{s2}$ and $x_4 = i_0 + i_{s1}$ thus introducing two other singularities. These singularities turn out to be stable nodes.

They have been left out of our discussion because they correspond to a peculiarity of our mathematical model, and do not exist in practice. In fact, our model assumes that base currents are always zero, and that collector currents are always equal to respective emitter currents. This is approximately valid in the interval considered, but is obviously false for negative emitter currents.

This model should be a good approximation in the range of interest $(0, i_0)$, so that the more sophisticated model would behave as though virtual nodes existed at x_3 and x_4 , i.e., their action would be felt over a representative point located in the interval $(0, 1)$, but not otherwise, so that the only true stable nodes would be those already discussed, x_1 and x_2 .

3. The Analysis of a Tunnel Diode Amplifier

The parallel or serial circuits consisting of a load and several tunnel diodes which are kept in a negative resistance region when a signal does not exist, have a characteristic similar to that of a linear amplifier. Using a strip-line circuit technique, a parallel type amplifier is shown in Figure 3, where l_i and R_i are respectively the length and the characteristic impedance of the i th section of strip line.

In this circuit, the number of tunnel diodes can be selected arbitrarily. The constant current supply must keep all tunnel diodes in negative resistance regions. The negative resistances of the tunnel diodes, the characteristic impedances of the strip line and the load resistance must have a special relation which is needed for this circuit to have the characteristic of an amplifier. Otherwise, it may work as an oscillator or a binary cell.

This cascade circuit is composed of basic circuits shown in Figure 4.

The circuit equation of this basic amplifier is as follows:

$$\begin{pmatrix} \vec{V}_2 \\ \overleftarrow{V}_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{2G_2}(G_1 + G_2 - Y)\epsilon^{-s(\tau_1 + \tau_2)} & \frac{1}{2G_2}(-G_1 + G_2 - Y)\epsilon^{s(\tau_1 - \tau_2)} \\ \frac{1}{2G_2}(-G_1 + G_2 + Y)\epsilon^{-s(\tau_1 - \tau_2)} & \frac{1}{2G_2}(G_1 + G_2 + Y)\epsilon^{s(\tau_1 + \tau_2)} \end{pmatrix} \begin{pmatrix} \vec{V}_1 \\ \overleftarrow{V}_1 \end{pmatrix}$$

where G_1 , G_2 and Y are respectively $1/R_1$, $1/R_2$, $1/Z$ and the tunnel diode equivalent impedance Z is given by $r + sL + \frac{1}{-G + sC}$, that is

$$Y = \frac{sC - G}{1 + (sL + r)(sC - G)}$$

If the terminal 1-1' is terminated by the series circuit of a signal voltage source $2E$ and a resistance R_1 , and the terminal 2-2' by a load resistance R_2 , \vec{V}_1 and \overleftarrow{V}_2 become E and 0 respectively. Therefore, the output voltage of 2-2' is as follows:

$$\vec{V}_2 = v_2 = \frac{2G_1}{G_1 + G_2} E \epsilon^{-s(\tau_1 + \tau_2)} \frac{s^2 LC - s(GL - rC) + (1 - Gr)}{s^2 LC - Cs \left\{ GL - C(r + \frac{1}{G_1 + G_2}) \right\} + \left\{ 1 - G(r + \frac{1}{G_1 + G_2}) \right\}}$$

$$\text{If } 1/G = r + 1/(G_1 + G_2)$$

$$\vec{V}_2 = \frac{2G_1}{G_1 + G_2} E \epsilon^{-s(\tau_1 + \tau_2)} \frac{(s - \alpha)(s - \beta)}{s \left\{ s - \left(\frac{G}{C} - \frac{1}{LG} \right) \right\}}$$

where $\alpha, \beta = \frac{1}{2} \left(\frac{G}{C} - \frac{r}{L} \right) \pm \sqrt{\frac{1}{4} \left(\frac{G}{C} + \frac{r}{L} \right)^2 - \frac{1}{LC}}$

Under these conditions, the basic amplifier has an infinite voltage gain at zero frequency. In this case, the backward input voltage \overleftarrow{V}_1 is given by the following equation.

$$\overleftarrow{V}_1 = - \frac{-G_1 + G_2 + Y}{G_1 + G_2 + Y} \epsilon^{-2\tau_1 s} E$$

The available power gain of this basic amplifier is given by

$$G_{av} = (\vec{V}_2 \overrightarrow{V}_2 G_2) / (\vec{V}_1 + \overleftarrow{V}_1)(\overrightarrow{V}_1 + \overleftarrow{V}_1) G_1$$

that is

$$G_{av} = \frac{G_2}{G_1} \left(\frac{2G_1}{G_1 + G_2} \right)^2 \left| \frac{(s - \alpha)(s - \beta)}{s \left\{ s - \left(\frac{G}{C} - \frac{1}{LG} \right) \right\}} \right|^2 / \left| \left\{ 1 - \frac{G_1 + G_2 + Y}{G_1 + G_2 + Y} \epsilon^{-2s\tau_1} \right\} \right|^2$$

Since the input impedance may be mismatched in tunnel diode operation, it becomes necessary to know how much of the available power has been amplified. For this purpose, we will define power gain in terms of transducer gain. The available power from the source is

$$P_{in} = E^2 G_1$$

The output power is

$$P_0 = \left(\frac{2G_1}{G_1 + G_2} \right)^2 E^2 \left| \frac{(s - \alpha)(s - \beta)}{s \left\{ s - \left(\frac{G}{C} - \frac{1}{LG} \right) \right\}} \right|^2 G_2$$

The transducer gain is

$$G_{Tr} = \frac{P_0}{P_{in}} = \frac{4G_1 G_2}{(G_1 + G_2)^2} \left| \frac{(s - \alpha)(s - \beta)}{s \left\{ s - \left(\frac{G}{C} - \frac{1}{LG} \right) \right\}} \right|^2$$

Further investigation is being done.

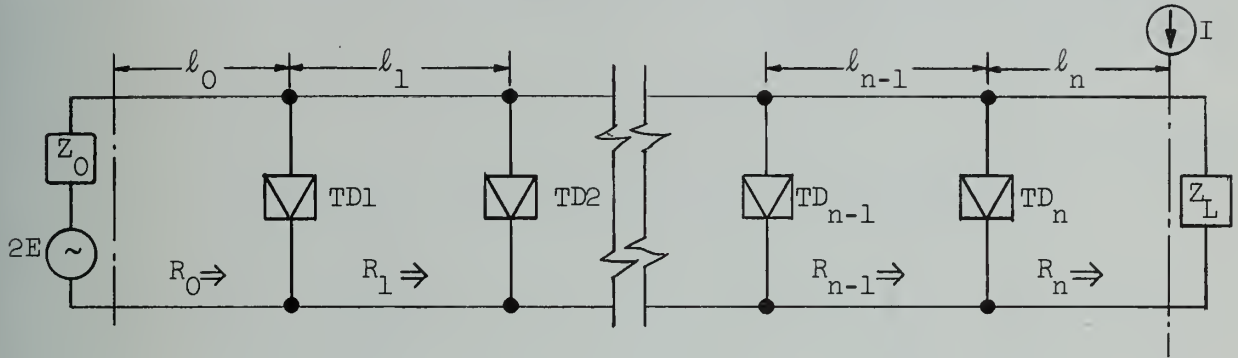


Figure 3 Parallel Type Tunnel Diode Amplifier

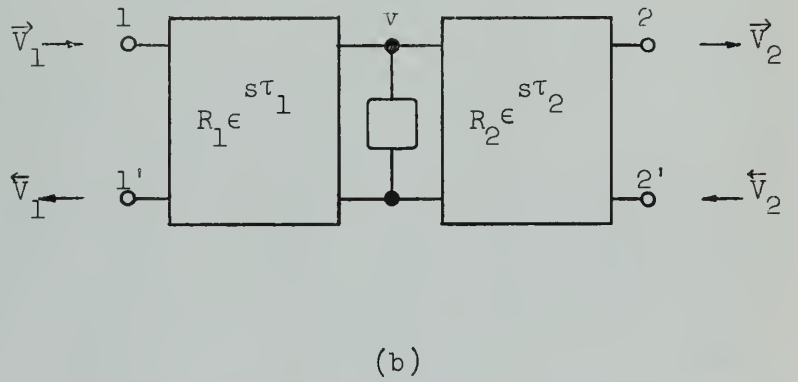
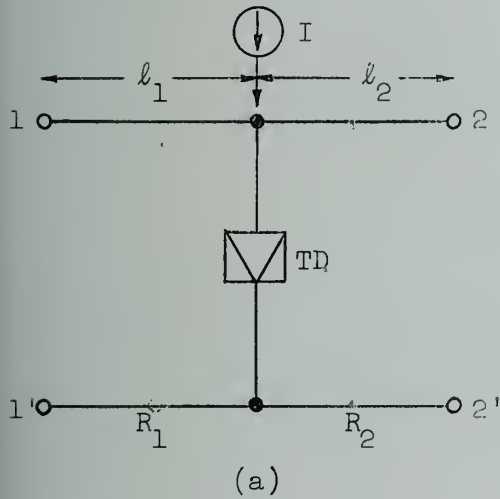


Figure 4 Basic Amplifier

4. Emitter Followers

Machine evaluation of emitter follower input impedance as a function of transistor parameters and circuit parameters is continuing and will be finished in two weeks.

5. Tunnel Diode Work

Tunnel Diode Measurements

Three types of jigs are currently being studied. These are to be used to study the negative resistance region of the diode at low frequency (60 cps) in a modified bridge circuit, and at high frequency by use of the diagraph. Special resistors are on order.

Directivity

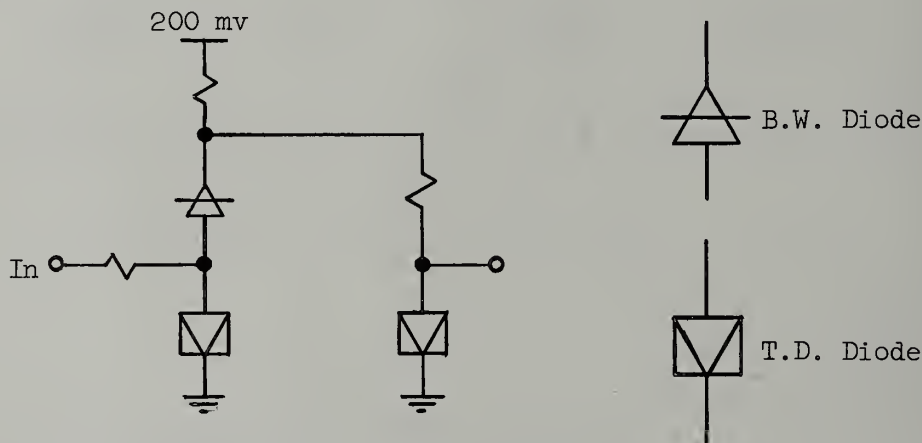


Figure 5 Directive Stage

A study of conditions for directivity resulted in the above circuit. The backward diode is about 450 mv. The circuit itself is not very useful due to its high current attenuation. However, with 1 ma tunnel diodes it may be used to achieve directivity in an amplifier.

Small Signal Oscillation Theory

The effect of the non-linear capacitor C_E associated with the tunnel diode depletion layer capacitance is being investigated. The stored energy for abrupt junction theory may be shown to be

$$E_C = 2C_0 V_D^2 \left[\frac{1}{3} \left(1 - \frac{v}{V_D} \right)^{\frac{3}{2}} - \sqrt{1 - \frac{v}{V_D}} + \frac{2}{3} \right]$$

where
$$C_E = \frac{C_0}{\sqrt{1 - \frac{v}{V_D}}}$$

V_D = diffusion potential

By using this expression and neglecting the bulk resistance and case inductance, a diode biased so that $r = R$ can be shown to have the following phase-plane equation:

$$h = \frac{L_0 C_0^2}{2} \frac{1}{\left(1 - \frac{v}{V_D} \right)} \dot{v}^2 + 2C_0 V_D^2 \left(\frac{1}{3} \left(1 - \frac{v}{V_D} \right)^{\frac{3}{2}} - \left(1 - \frac{v}{V_D} \right)^{\frac{1}{2}} + \frac{2}{3} \right)$$

h = total energy

The equivalent linear model is

$$h = \frac{1}{2} L_0 C_E^2 \dot{v}^2 + \frac{1}{2} C_E v^2$$

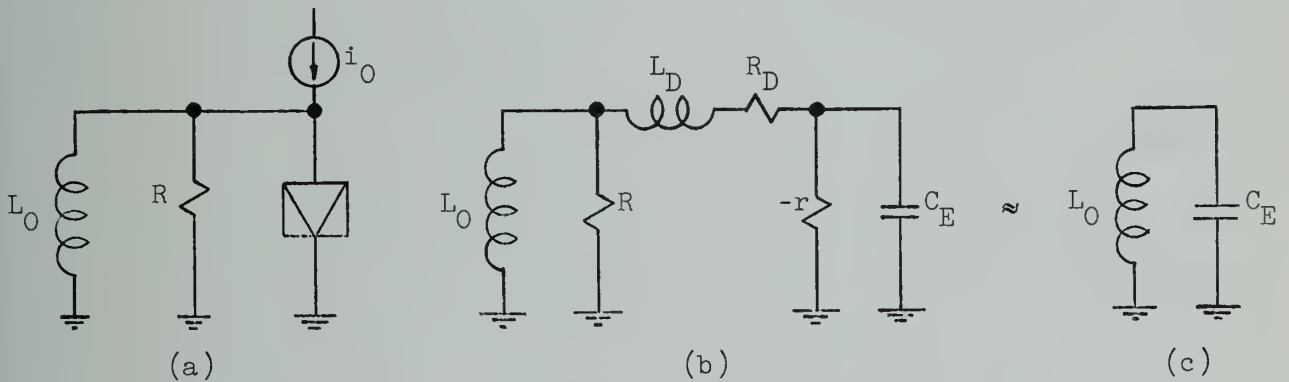


Figure 6

(a) Tunnel diode circuit;

(b) Equivalent circuit;

(c) Approximate equivalent circuit for oscillating conditions.

6. Statistical Analyzer

A discriminator circuit has been designed to sample the output of the diode circuit which will be statistically analyzed. Nine of these circuits can be used to divide the output range of the diode circuit into eight equal intervals.

If the nine discriminator circuits are connected in parallel to the experimental circuit output, the input impedance of each must be very high in order that the statistical circuit be unchanged by the analyzing circuitry. An input impedance of 100K has been established for each discriminator. Nine of the circuits in parallel would have a combined input impedance of more than 10K. This will introduce only a small error in the results because the output impedance of the statistical diode circuit is only 1K. If only one discriminator is used for economy as explained in the May progress report, the input impedance will be 100K as compared to the 1K output impedance.

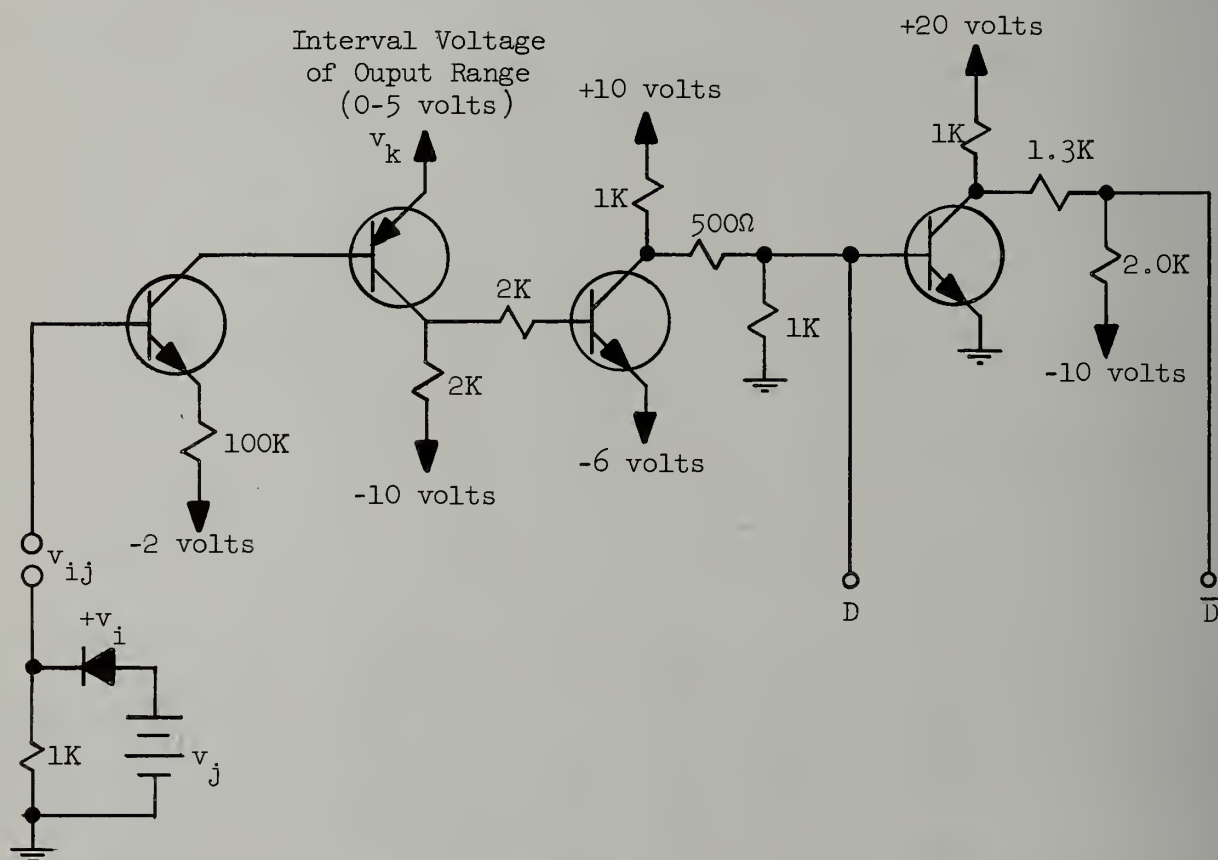


Figure 7 Discriminator Circuit

In Figure 7 above:

if $v_{ij} < v_k$ ($k = 1, 2, 3, \dots, 9$)

then $\left. \begin{array}{l} D \doteq -4 \text{ volts} \\ \overline{D} \doteq +4 \text{ volts} \end{array} \right\}$

if $v_{ij} > v_k$

then $\left. \begin{array}{l} D \doteq +4 \text{ volts} \\ \overline{D} \doteq -4 \text{ volts} \end{array} \right\}$

+4 volts is a logical 1 and -4 volts is a logical 0. A variance of only 0.1 volt at the v_{ij} input of the discriminator will cause D to switch from +4 to -4 volts. This sensitivity is great enough in this case for sampling purposes. The discriminator will be subjected to more bench tests to further check its performance at high speeds.

In Figure 8 a scheme is shown by which the output pulses can be counted in the eight intervals of the output range. Notice that counters are included to check if v_{ij} is ever outside the assumed output range.

An approximate output probability function can be found from the number of pulses totalled by each counter. For the statistical diode circuit there are 64 possible output voltage pulses. Let us assume, for example, that they were counted as indicated below.

Counter 1	-	1
Counter 2	-	3
Counter 3	-	6
Counter 4	-	12
Counter 5	-	17
Counter 6	-	15
Counter 7	-	8
Counter 8	-	2
TOTAL		<hr/> 64

The probability density function may be approximated as shown in

Figure 9.

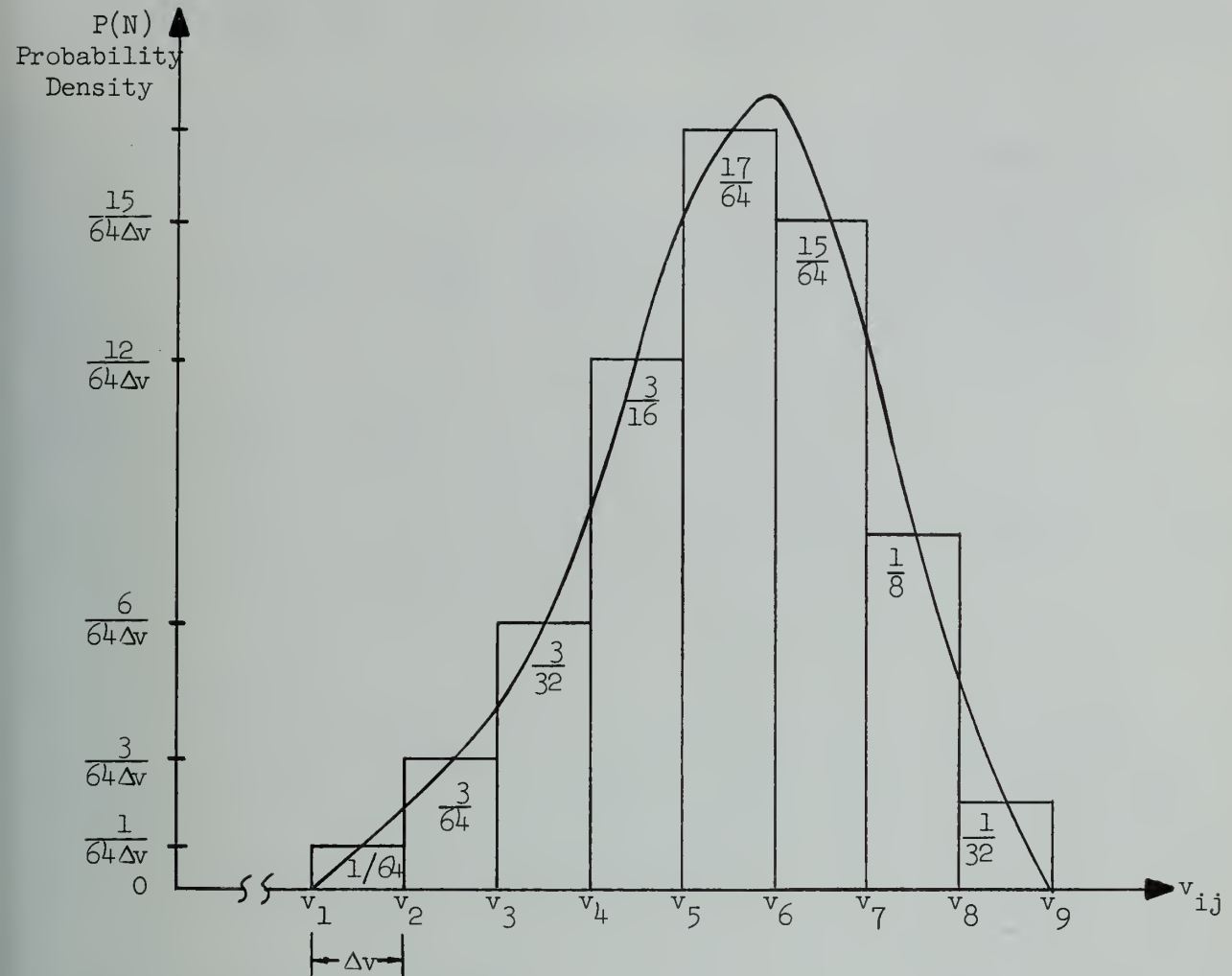


Figure 9 Approximate Probability Density of v_{ij}

A smooth curve is drawn so that the area under the curve in each interval represents the same discrete approximation.

PART III
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Pattern Recognition Report

The following report has been prepared:

R. Narasimhan, "A Linguistic Approach to Pattern Recognition,"
DCL Report No. 121

Procedures are described for the parallel processing of digitized bubble chamber negatives, alpha-numeric characters, and similar material largely characterized by line-like elements. In particular it is agreed the original digitized image can be pre-processed to an idealized line-like image. The pattern recognition unit (PRU) is then instructed to output a first primitive description of this line drawing as an abstract graph, listing pairs of nodal points (end points, junctions, corners, etc.) common to each branch in turn.

The fundamental problem then discussed is to construct an intuitively natural description of the picture from the first primitive machine-produced list above. It is necessary to link together line segments (e.g., in the bubble chamber case) common to each beam track, electron spiral, etc.--that is, to partition the graph into "phrases" commonly used by a scanner in pointing to and describing a bubble chamber event. For this purpose a grammar is introduced to manipulate the primitive graph. The procedures used have direct counterparts in the analysis schemes of contemporary structural linguistics. Several examples, worked out in detail, are given.

II. Pattern Recognition: Experimental Programming

1) Thinning

Intuitively the idea behind thinning is to "shrink" the original digitized image to a line drawing while preserving all connectivity of the original. A satisfactory axomatic definition of this process has been discovered and will be later reported in DCL Report No. 122 by B. H. McCormick.

Dr. A. H. Amon and R. K. Rice have suggested parallel processing algorithms for thinning within the PRU. R. K. Rice has programmed one of these for the PRU simulator.

2) Gap Filling

B. Mayoh spent the month programming for the PRU simulator a general purpose gap-filling routine. This work will be reported in a file note later.

III. Pattern Recognition Computer Engineering

1) Rack Modification

The integrated set of racks for the computer, under sub-contract to Northern Tool and Die, Chicago, have been modified to allow a larger number (now 54) of connections to (from) the basic module (stalactite) of that system.

2) Visual Display Console

The Amco racks of the visual display console were assembled during the month. Mechanical design of the 1,600 indicator lamp display of the contents of the 40 x 40 PRU was largely completed.

3) Air Conditioning

Installation drawings for a roof-mounted recirculating air conditioner (Trane) were prepared. An improved heat load estimate was calculated. The design now calls for a seven-ton unit with 3000 CFM of air flow. The Physical Plant is presently preparing a cost estimate.

4) Stalactite Logical Realization

Considerable simplification in the generic stalactite logical design has been made. B. H. McCormick is preparing a formal report summarizing the machine as currently envisioned.

(K. C. Smith, B. H. McCormick, L. Whyte)

III. Thesis

The following Ph.D. thesis supervised by B. H. McCormick was accepted by the thesis committee:

James L. Divilbiss, "A Pattern Recognition Computer Using All-Magnetic Logic," Department of Electrical Engineering, University of Illinois, June, 1962.

The logical design of the pattern recognition computer described therein largely follows the discussion of the earlier DCL File No. 403 by J. L. Divilbiss and B. H. McCormick. Transfluxor realization of that machine is one of the primary topics of the thesis. The experimental work on magnetic logic was performed by Dr. Divilbiss in the Coordinated Science Laboratory, University of Illinois, and was not supported by AEC funds.

(B. H. McCormick)

IV. Lectures

A series of five lectures entitled "The Logical Realization and Efficient Utilization of a Parallel Pattern Recognition Computer" were given by B. H. McCormick at the University of Michigan Summer Engineering Conference, June 18-29, 1962.

(B. H. McCormick)

ILLIAC USE AND OPERATION

Illiac Usage

During the month of June, specifications were presented for 19 new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2179. Numbers followed by T are for theses.

2179 Institute of Communications Research. American Psychological Association Information Exchange. The investigation concerns the image which psychologists have of the journals within their own profession and how these attitudes are related to certain personal variables such as divisional membership within the American Psychological Association and area of research interest. The first part of the project involved selection of a representative sample from the 20,000 membership list of the Association and the mailing of a questionnaire booklet (semantic differential) to about 600 members. The second part involves the analysis of the data in terms of mean semantic differential ratings on 20 journals, correlation and factor analyses.

2180 Agricultural Economics. Effect of Lender Policy on Farm Operations. This research problem concerns the determination of optimal additions to the present enterprise patterns of five farm situations as influenced by available resources on each and credit conditions associated with each. In addition, the optimal repayment schedule will be determined for additional borrowed funds used.

The Illiac, using a linear programming routine, can compute the optimal enterprise additions and credit use subject to the realistic farm situations and credit terms as stated by each of three types of primary lenders.

2181T Agricultural Economics. Costs and Returns on Philippine Poultry Farms. Cost functions will be fitted to data from 45 poultry farms. The standard regression routine R-14 will be used on the data from farms as they actually are operated. The farms will then have plans developed for them by the method of

linear programming and new cost functions will be fitted to estimate the decrease in cost. The standard M-15 routine will be used.

2182 Office for Research in Medical Education. Medical School Environment. A number of variables descriptive of situational determinants of medical student behavior have been obtained from a sample of 28 United States medical schools. These variables are not necessarily independent and their reduction in terms of a limited number of principal factors is important in the description and interpretation of environmental pressures in these schools.

The factor analytic routines available for Illiac represent a feasible statistical procedure for accomplishing this. The computer will be used specifically to obtain correlations and principal axis factors.

2183 Physics. Eigenvalue Problem for Molecular Vibrations. This involves the solution of $|FG - \lambda|$ for values of λ using assigned values of F and G based upon kinetic energy and potential energy using molecular structure parameters.

2184T Physical Education. Multiple Regression Analysis of Motivation and Human Fitness Data. The problem calls for the prediction of seven motor variables using ten motivation variables as the independent variables. A standard library routine, K-14 (Multiple Regression Analysis with Transformations), is appropriate for the solution of the problem.

2185 Digital Computer Laboratory. Emitter Follower Input Impedance. If the input impedance of an emitter follower has a negative real part instability may result. In order to assure stability, a damping element is inserted in series with the base. The design of such an element is possible only if the dependence of the input impedance (Z_n) on the amplification factor (α_n), the cut-off frequency (ω_n), the collector depletion layer capacitance (C_c) and the load capacity (C_e) is known.

The program is used for the evaluation of the input impedance (Z_n). The effect of the above parameters is studied by using suitable groups of data.

2186T Theoretical and Applied Mechanics. A Mechanical Analysis of Coupled Tube Sheets. A system consists of two parallel circular plates of constant

thickness, one directly above the other. The plates are coupled by a large number of tubes which pass thru them. The system is loaded by mechanical loads and subjected to temperature gradients. The problem is to investigate the stresses in and the deformation of the system.

An approximate analysis has yielded general equations for stress and deformation. Using a numerical example, we desire to compare these approximate results with the results given by the Ritz method of minimizing the total potential energy expression for the system. The Ritz method yields n linear algebraic equations in n unknowns which will be solved by machine computation.

2187 Physics. Least Square Fitting. Measurements have been carried out on the thermal properties of Helium three at low temperatures. Among the data are the pressure and temperature coordinates of the solid-liquid phase boundary. A least square fit of these data to an algebraic series:

$$P = P_{\min} + \alpha (T - T_{\min}) + B (T - T_{\min})^2 + \dots$$

is to be performed.

The availability of such an analytic form will be of great help in carrying out thermodynamic consistency checks of other thermal data (specific heats, entropies etc.), also obtained in the same experiment.

Standard library routines are to be used.

2188T Business Administration. Impediments to Interregional Mortgage Investment. The research problem involves the testing of several models set up to explain variations in out-of-state mortgage investment in the various states. The dependent variable is the out-of-state mortgage investment and various state characteristics (legal, economic, and demographic) are the independent variables. Multiple linear regression analysis is desired for the problem.

2189 Physics. μ -Mesic Atom Energies. It is desired to integrate the radial Dirac equation describing the motion of a μ -meson in the Coulomb field of a nucleus. Finite nuclear size is an appreciable effect.

The above problem has been programmed for the IBM 7090 computer at the General Motors Technical Center, Detroit, and is operating. Since the eigensolutions sought, however, are exponentially decreasing with distance, the problem of accuracy, because of the irregular, exponentially increasing solution, is troublesome. It is desired to check the code (Runge-Kuta integration scheme, floating point single precision) for an especially simple charge distribution, by doing the same calculation using the Illiac F7 integration scheme.

Mathematically; the differential equations are

$$\frac{dG}{dx} = -\frac{1}{x}G + [2-\epsilon-\mathcal{V}(x)]F$$

$$\frac{dF}{dx} = +\frac{1}{x}F + [\epsilon+\mathcal{V}(x)]G$$

where $x = \mathcal{V}/\lambda$ is the radial distance in units of the μ Compton Wavelength $\epsilon_{\mu c}^2$ is the binding energy of the 1s state. (Constants given here are those for the 1s state).

$$\begin{aligned}\mathcal{V}(x) &= -\frac{3}{2} \frac{(ze^2/\text{trc})}{(R/\lambda)} \left[1 - \frac{1}{3} \frac{x^2}{(R/\lambda)^2}\right], x < \frac{R}{\lambda} \\ &= -\frac{\alpha}{x}, x > \frac{R}{\lambda}\end{aligned}$$

is the potential of a uniform charge distribution of radius R .

2190 Economics. Sources, Composition, and Uses of Savings. The problem is one of trying to estimate by multivariate regression a dependent variable which is always non-negative, but which takes on values extremely close to zero. When normal regression analysis is applied, some values for the dependent variables are negative. To avoid this difficulty, the regression problem has been formulated as a linear programming problem with the additional constraint that the dependent variable is always non-negative. The only theoretical difference, other than that in the linear programming problem the probability of the dependent variable being negative is zero, is that the linear programming approach minimizes the absolute deviations of the residuals whereas regression analyses minimizes the squared deviations of the residuals.

2191 Theoretical and Applied Mechanics. Analysis of Multiple Rocket Launcher. The problem is a study of the dynamic effects of exiting rockets on a multiple launcher. The variation in exit angle and angular velocity are computed from a set of transmission equations of matrix form. Only standard routines are used.

2192 Bureau of Educational Research. Sampling Simulator for RHO_{MT}^2 . It is intended to use the new routine as a further tool in a research project concerned with experimental tests of a general theory of reliability.

During the last 2 semesters a Sampling Simulator Routine for this project was completed under problem number 2086(A50). This earlier routine compiles on the basis of a stratified sampling plan an n-item test which, by the same routine, is then analyzed into 4 different reliability coefficients.

The new routine is to provide an analysis of such tests into a 5th coefficient, RHO_{MT}^2 which will be regarded as a standard against which the 4 earlier coefficients can be compared so as to judge their value as approximations to the latter.

Technically, $RHO_{MT}^2 = \sum \bar{c}_i / V_M V_T$, where the numerator is the weighted average of the covariances of all test-items with the universe strata and V_T , V_M are the variances of the total test and universe score, respectively.

2193 Agricultural Economics. Planning Optimal Farms Under Various Labor Situations. This is a linear programming problem using the M29-295 library routine. The problem determines the optimal farm setups for Southern Illinois farms in Rural Area Development Counties under different labor situations.

This is part of a larger problem of determining the total supply of and demand for labor in the Rural Area Development Counties.

2194 Sociology. Two Images of the Adolescent. This research proposal grows out of the assumption that there are two images of the adolescent in American society. One is that of "American Youth", those adolescents who contribute a fresh, unsullied approach to the maintenance of traditional values and are striving to attain adulthood in a manner acceptable to adults. The other image is that of the "teenager" who is immersed in a "teenage culture" of pop records, dating, parties, bizarre fads, strong peer group loyalty, conflict with adult standards, and oriented to strongly hedonistic values.

The main problem of the research consists in showing that these two types of adolescents do, in fact, exist, and further demonstrating the demographic variables which are associated with "pro" and "anti" adult attitudes. The portion of analysis for which Illiac will be used is that of demonstrating (by means of analysis of variance) the relationship between membership in certain types of groupings (age, sex, socio-economic class, etc.) and the possession of certain types of anti-adult attitudes.

2195 Chemistry. Least Squares. The kinetics of the oxidation of formic acid by NO_2 are being studied by following the pressure as a function of time. Deuterium labelling of the formic acid gives rise to a kinetic isotope effect which is experimentally determined from a comparison of the initial rates of reaction of formic acid and deuterated formic acid. The initial rates are obtained from the slope of the pressure vs. time plot which is linear for small extents of reaction.

The Illiac will be used to calculate initial rates by a standard least squares method applied to the data points at small extents of reaction.

2196 Psychology. Social Distance. The study represents an investigation into the actions people would take with other persons of various ages, races, religions, sexes, and occupations.

2197 Psychology. Monadic and Dyadic Creativity. Various indices of creativity will be intercorrelated and the results will be analyzed with a view towards discovering the nature of the creative process in the solution of monadic and dyadic problems.

Table I shows the distribution of Illiac machine time for the month of June. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min
Scheduled Maintenance	93:58
Unscheduled Maintenance	6:21
Drum Engineering	10:38
Leapfrog	15:41
Classes	1:04
Instruction	:23
Demonstrations	1:43
Wasted	1:15
	<u>131:03</u>

Use by Departments

Agricultural Economics	34:17	(3:04)
Agronomy (00 15 65 330 38)	3:20	
Animal Science	:11	
Astronomy	16:39	(1:13)
Chemistry	52:05	(2:01)
Civil Engineering (DA-104)	2:55	
Civil Engineering	48:57	(2:24)
Coordinated Science Lab. (DA-36-039-SC56695)	49:38	
Digital Computer Lab. (US TR AEC-1018)	25:52	
Digital Computer Lab. (NONR 1834(27))	1:51	
Digital Computer Laboratory	149:23	
Economics (NSFG 7056)	2:39	
Economics	3:07	
Education	:42	
Electrical Engineering (NASA-NSG 24-59)	1:56	
Electrical Engineering (NSFG 19005)	1:08	
Electrical Engineering (NSFG 14894)	3:28	
Electrical Engineering	:15	
Finance (IHR-71)	1:20	
Geological Survey	:42	(2:14)
Inst. of Communications Res. (44-28-20-378)	5:45	
Inst. of Communications Res. (USPHM-3941)	1:58	
Institute of Communications Research	:38	
Institute for Research on Exceptional Children	:38	
Mechanical Engineering (NSFG 9725)	:36	
Mechanical Engineering	1:04	
Mining and Metallurgical Eng. (TRUS AF6770)	:16	
Mining and Metallurgical Engineering	:33	
Music	:35	
Nuclear Engineering	:33	
Office of Instructional TV (OE 7-11-107.00)	6:02	
Physics (AF49(638)661)	2:26	
Physics (NONR 1834(05)A)	1:52	
Physics (NSF 14 308)	:05	
Physics (NSFG-17428)	:29	
Physics	1:23	

Psychology (MD 2060)	:53	
Psychology (M 1774)	2:10	
Psychology (ONR 1834-36)	1:04	
Psychology (M 2509)	:17	
Psychology	102:24	(5:39)
Sociology	5:18	(:23)
State Water Survey (DA-36-039-SC75055)	12:25	
State Water Survey	29:10	
Theo. and Appl. Mech. (DA-01-021 ORD 11878)	8:04	
Theo. and Appl. Mech. (DA-11-070-508 ORD)	:22	
Theoretical and Applied Mechanics	:31	
University of Illinois Medical School	:54	
Zoology	:07	
	<u>588:57</u>	<u>(16:58)</u>
		<u>720:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure.

This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Reader	7
Punch	2
Power Supplies	1
Drum	5
Unknown	<u>1</u>
TOTAL	16

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	STOPPING LEAPFROG
6/1/62	17:28	:00	6:32	0		:00	:40	0
6/2/62	24:00	:00	:00	0		:00	:00	0
6/3/62	24:00	:00	:00	0		:00	:34	0
6/4/62	12:56	:00	11:04	0		:00	:00	0
6/5/62	20:23	:00	3:37	0	(1) 300 volt power supply bad.	:00	:23	0
6/6/62	19:26	1:04	3:30	1	(1) Reader "I" making errors. (2)	:00	:35	0
6/7/62	19:49	:27	3:44	3	Punch number 4 making errors. (3) Reader "J" making errors.	:00	:39	0
					(1) Drum failure.			
6/8/62	19:17	1:01	3:42	1		:00	:58	0
6/9/62	24:00	:00	:00	0		:00	:42	0
6/10/62	24:00	:00	:00	0		:00	:40	0
6/11/62	19:59	:00	4:01	0		:00	:19	0
6/12/62	20:31	:11	3:18	1	(1) Piece of chad in tape caused reader to read incorrectly.	:00	:28	0
6/13/62	20:06	:36	3:18	1	(1) Drum failure	:00	:52	0
6/14/62	15:58	1:56	6:06	2	(1) Drum failure. (2) Drum failure.	:00	:42	0
6/15/62	21:31	:00	2:29	0		:00	:10	0
6/16/62	23:39	:21	:00	2	(1) Reader "I" making errors. (2) Unknown.	:00	:33	0
6/17/62	23:55	:05	:00	1	(1) Reader "J" bad.	:00	:00	0
6/18/62	20:41	:05	3:14	1	(1) Reader "J" clutch bad.	:00	1:05	0
6/19/62	20:30	:00	3:30	0		:00	:51	0
6/20/62	20:24	:10	3:26	1	(1) Drum failure.	:00	:24	0
6/21/62	20:29	:00	3:31	0		:00	:21	0
6/22/62	11:36	:00	12:24	0		:00	:54	0
6/23/62	24:00	:00	:00	0		:00	:04	0
6/24/62	23:45	:00	:00	0		:15	:00	0
6/25/62	21:22	:00	2:38	0		:00	:25	0
6/26/62	20:05	:00	3:55	0		:00	:21	0
6/27/62	20:48	:00	3:12	0		:00	:44	0
6/28/62	17:38	3:07	3:15	2	(1) Brake on reader "J" bad. (2) Punch number 4 making errors.	:00	:15	0
6/29/62	20:28	:00	3:32	0		:00	:50	0
6/30/62	24:00	:00	:00	0		:00	:00	0
TOTALS	616:44	9:03	93:58	16		:15	15:05	0

International Business Machines 650 Usage

During the month of June, specifications were presented for 5 new problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 418'. Numbers followed by T are for theses.

418'T Civil Engineering. "Three Dimensional Transformation of Coordinates with Least Square Adjustment". The problem deals with the three dimensional transformation of coordinates (from photogrammetric machine coordinates into terrestrial land coordinates) based on a least square adjustment. For the purpose for which this problem is to be used, a limit of 10 points common to both systems will be observed ($10 \times 3 = 30$ observations, required = 7 observations, redundants = $30 - 7 = 23$). Only standard routines are involved in the program.

419'T Electrical Engineering. Impedance of Antenna in Plasma. The problem is to compute the complex expression

$$Z_{in} = \frac{Z_0}{jK^1} \left\{ [2 \ln \frac{L}{\rho} a - 2] + \frac{3\rho}{aL} \right\},$$

where

$$K^1 = 1 - \frac{X(1-jZ)}{(1-Z)^2 - Y^2},$$

$$K_0 = 1 - \frac{X}{1-jZ},$$

$$a = \sqrt{\frac{K^1}{K_0}},$$

for various $X, Y^2, Z, L/\rho, Z_0$.

X, Y^2, Z are the plasma parameters. X is the normalized plasma frequency, Y^2 the normalized cyclotron frequency, and Z the normalized collision frequency.

420' Civil Engineering. Stability Analysis of Cohesionless Slope. In the design of cohesionless slopes to withstand seismic forces it is necessary to correlate the interdependence of the factor of safety, the angle of friction of the material, the water level in the reservoir, and seismic acceleration.

This program is intended to furnish data over a suitable range of these parameters for the design of cohesionless slopes for earth dams.

421'T Mechanical Engineering. Heat Transfer to Fluid Sphere. Heat transfer to a single fluid sphere moving with uniform velocity in another fluid infinite in extent is studied for large values of Reynold's Number.

The solution of a differential Equation for the temperature distribution around the fluid sphere has been obtained analytically. Local and average Nusselt Numbers and heat transfer coefficient may be calculated by numerical evaluation of the resulting integral function, which depends on the parameter whose value is determined by the fluid properties of both phases and Reynolds Number.

422' Economics. Production Functions and Pricing. This is a study of the usefulness of prices in estimating aggregate production functions. The work will be done with variations of multiple regression analysis. Certain matrices will be altered in the computation in order to change the statistical properties of the results.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of May.

TABLE I'

		Hrs:Min
Scheduled Engineering		15:26
Unscheduled Engineering		6:03
Air Conditioning		6:41
Building Maintenance		3:17
Tape Test		2:09
Log Summary		:34
CDC Preparation		10:08
DCL Library		1:31
Classes		3:21
Aeronautical and Astronautical Eng.	:27	
Civil Engineering	:09	
Mathematics	:44	
Mechanical Engineering	<u>2:01</u>	
Instruction		:38
Wasted		<u>2:34</u>
		52:22

Use by Departments

		Hrs:Min
Aeronautical and Astronautical Engineering		2:06
Agricultural Economics		1:50
Agronomy		11:57
Animal Science		3:59
Astronomy		2:54
Chemistry		25:14
Civil Engineering		55:03
Economics		3:10
Education		9:33
Electrical Engineering		52:29
Graduate College		17:31
Home Economics		:49
Horticulture		:52
Mechanical Engineering		2:48
Physics		8:59
Statistical Service Unit		83:08
Bursar's Office	5:36	
Business Office	11:02	
DHIA	39:31	
Education	11:14	
Forestry	:29	
Marketing	:58	
Mechanical Engineering	:26	
Mining and Metallurgical Eng.	:04	
Psychology	2:40	
Student Counseling	<u>11:08</u>	
State Water Survey		8:25
Theoretical and Applied Mechanics		<u>11:52</u>
		<u>302:39</u>
		<u><u>355:01</u></u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 2:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 2:00 noon on Mondays.

Table II' presents a summary of errors for June.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

Air Conditioning		1
533 card read punch		7
Card jam	1	
Fails to read	3	
Fails to read correctly	2	
Fails to punch correctly	<u>1</u>	

407 accounting machine		7
Cycles when off line	1	
Fails to reset	1	
Fails to print correctly	<u>5</u>	
650 console		3
Lost bits	1	
Multiple bits	<u>2</u>	
727 tape units		4
Fails to read or write	1	
Fails to read correctly	2	
Fails to come out of a high speed rewind	<u>1</u>	
		<u> </u>
	TOTAL	22

TABLE III

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	BUILDING MAINTENANCE	AIR CONDI- TIONING	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
6/1/62	16:42		:05	:07			2	(1) 407 fails to reset after a total. Too much air gap in total print emitter 9 contact. (2) Cannot read or write on any tape unit. Bad tube in unit one.
6/4/62	8:33	3:45			:22	4:11	0	
6/5/62	16:25		:14	:15			2	(1) 407 fails to print correctly. Defective brush. (2) 407 fails to print correctly. Metal pieces found in special programming relay.
6/6/62	14:27		2:23	:10			1	(1) Lost quinary bit in position 7 of distributor. All tubes changed in circuit.
6/7/62	16:54			:07			0	
6/8/62	17:03			:07			0	
6/11/62	13:19	3:29	:10	:08			2	(1) Broken wire in 533 read clutch. Repaired. (2) 407 prints incorrectly. Loose connection causing circuit breaker to arc badly.
6/12/62	16:14		:25	:15			2	(1) Reading errors on tape unit one. (2) 407 continues to cycle when on line. Welded relay point.
6/13/62	15:54		:13	:04	:44		2	(1) Card jam in 533. Removed. (2) Reading errors in 533. Bent connectors found.

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	BUILDING MAINTENANCE	AIR CONDI- TIONING	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
6/14/62	16:52		(:50)*	:04			1	(1) Tape unit 3 does not come out of high speed rewind. Adjusted lever.
6/15/62	15:29		(1:30)* 1:28	:07			2	(1) Position 1 of distributor picking up multiple bits. Bad tube. (2) 407 prints incorrectly. Loose connection causing circuit breaker to arc badly.
6/18/62	11:05	3:45				2:30	1	(1) Air conditioning system out. Water in basement unit overheated.
6/19/62	16:54			:05			1	(1) Type wheel 21 on 407 not printing. Bad tube.
6/20/62	15:57		:35	:17			1	(1) 533 does not obey a read order. Broken wire.
6/21/62	17:05			:10			0	
6/22/62	13:57			:06	2:11		0	
6/25/62	12:21	4:27					0	
6/26/62	16:58			:05			1	(1) Column 20 on 533 does not punch using SOAP board. Bad tube.
6/27/62	16:34		:05	:12			1	(1) Tape unit 3 fails to read properly. Bad tube.
6/28/62	16:36		:20	:05			0	
6/29/62	15:46		:05	:10			3	(1) Position 5 of program register had both binary bits. (2) Feed check lights on 533 constantly. (3) Multiple bits.
TOTALS	321:05	15:26	6:03	2:34	3:17	6:41	22	

*Unscheduled engineering done on some unit but computer continued to run. Time is not included in totals.

PART VI
INSTRUCTIONAL USE OF COMPUTERS

During the month of June, specifications were presented for 1 new problem.

81 Mechanical Engineering 271. Problem 1. IBM 650. Evaluation of Gear Tooth Form Factor. The problem consists of evaluating a form factor used in the design of gear teeth. The computer will be used to provide information concerning this design factor for a number of different given (input) conditions.

The mathematical method will involve using available library routines for calculating values in an equation of the form:

$$y = \frac{t^2}{6h_p}$$

where $t = (A + B) \sin (\beta + \varphi)$

$$\beta = \sin^{-1} \frac{B}{A+B}$$

$$\varphi = C[D + \text{inv}\phi] \text{ where } \text{inv}\phi = \tan \phi - \phi$$

$$h = E + F \sin \theta$$

A, B, C, D, E, F are constants.

PART VII
7090-1401 COMPUTING SYSTEM

Problem Specification Program

The purpose of the Problem Specification Program is to generate tables containing the information concerned with Problem Specifications. These tables are used by the Monitor each time a problem is run on the 7090. The Problem Specification Program (PSP) will be run as a part of the system tape edit program; when the 1301 disk is available, PSP updating will be batched with regular problems.

PSP and its tables will follow the Monitor on the system tape. Each year's problem specification numbers will comprise a file, each month's will comprise a record. The maximum number of words used for any problem specification will be 64_{10} , 13_{10} of which will appear for all problem specifications.

PSP will read the card(s) which contain information punched from the problem specification form. A problem specification number of the form YMnnn, where Y is a digit designating the current year, M designates the current month, and nnn is the next available sequence number within the month, is generated, and it and the information on the input card(s) are assembled into a table. If the user has requested special tapes, the right to have tapes assigned to him is also noted. These tables are then written on the new system tape.

PSP punches at least two cards for each new problem specification. One of these is a duplicate of the card input and the assigned number; the other contains only the user's name and his problem specification number. (If more than one user was specified, their names will be punched 1/card on additional cards, all with the same problem specification number). If the user requested special tapes, the numbers of the tapes to be assigned to him will be punched on additional cards.

If this problem specification has a contract number, the new problem specification number will be entered in a table containing only the contract number and all of its associated problem specification numbers.

Several control cards (same format as system control cards) control the action of PSP:

\$	PRØBSPECENTER	(new one)
\$	PRØBSPECALTER	(<u>change</u> information in an existing one)
\$	PRØBSPECADD	(add information to an existing one)
\$	PRØBSPECDELETE	

\$ CØNTRACTENTER (new one)
\$ CØNTRACTALTER (change to no charge)
\$ CØNTRACTDELETE

J. Flenner
R. Flenner

Tape Labelling Procedures

In anticipation of the volume of users who will need to reserve magnetic tapes for extended periods of time, recognizing the need to automate insofar as possible the handling and keeping of records involving the use of these and other utility tapes, it has been decided to adopt a form of internal tape labelling. Procedures for implementation of such a system are here outlined.

1. A table containing information about the pool of tapes in the Laboratory shall be kept on the system tape. This table, called the Pool Table, is accessible by both PSP and the Monitor. The information contained in the Pool Table for each tape is:

- a. The tape label number. This number is of the form TKnnnn, where T is the type of tape (e. g., long regular-duty tape, short heavy-duty tape, etc.) and may also reflect some history of the tape (e. g., if a tape acquires a bad spot and two or more reels of tape are created from the original one); K is the owner of the tape reel and may be (1) "D" for DCL-owned tapes, (2) "L" for tapes leased by DCL to some individual but stored by DCL, or (3) "Ø" owned by some other individual or department and stored outside of DCL; nnnn is a serial number for the tape.
- b. Problem specification number to which this tape has been assigned (if it has been).
- c. Whether or not the Problem Specification is currently using the tape.

2. Other tables accessible by the Monitor and the Problem Specification Program (see PSP description) contain all the information pertinent to each Problem Specification number. If a user has requested his "own" tapes, these tables will contain the tape label numbers of the tapes assigned to him and the date on which each tape was last used by him.

3. Each tape used in the Laboratory shall have a label written at the beginning of the tape as the first file. The mode of the label file will be BCD and the density 556 char./inch. Information in the label will be:

- i. The 6-digit tape label number;
- ii. The density of the rest of the information on the tape, 200 char./inch, 556 char./inch or 800 char./inch.

Should there ever be a necessity to cut a bad section from the middle of a labelled tape, thus creating two tapes, the previous label will be retained for one of the tapes, and the same label, after appropriately coded changes in the tape label number, will be written on the other tape section. Persons may be able in rare cases to operate without (our) tape labels. In general, these persons would have brought tapes from outside installations to be used as data input tapes; it is expected, however, that any tapes generated here, even by these persons, shall have a tape label of our format.

4. Two control cards are available to the user for having his special tapes mounted and saved.

- i. \$\$ MØUNT

This card contains \$\$ in columns 1 and 2, the word MØUNT in columns 8-12, and pairs of parameters in the variable field. The first of each pair of parameters is the tape label number (TKnnnn); the second is the unit on which the tape is to be mounted. A comma must follow each parameter except the last.

The Monitor, upon reading this card, will check the labels of all mounted tapes to see if the requested tape has been pre-mounted. If it has not, the computer will stop after an on-line comment to the operator to hang this tape.

After completion of this job, the tape will be rewound and unloaded. The operator then places the tape in a cabinet with all other utility tapes. The Monitor also sees that the Pool Table entry for this tape indicates that this tape is not currently in use by the Problem Specification to which it is assigned, and therefore it may be used as a utility tape. It may not, however, be assigned to another Problem Specification.

- ii. \$\$ SAVEMØUNT

This card contains the word "SAVEMØUNT" in columns 8-16; in all other respects, it contains the same information as the MØUNT card.

Its function differs only in the following manner:

Upon completion of the job, after the tape indicated on the SAVEMOUNT card has been rewound and unloaded, the operator will place this tape in a cabinet containing tapes which are not used as utility tapes. The Monitor also sees that the Pool Table entry for this tape indicates that this tape is currently being used by the Problem Specification to which it is assigned. Moreover, should the operator inadvertently mount this tape as a utility, the Monitor will not allow it to be used and will print an on-line message to the effect that the tape should be removed and placed in the correct cabinet.

5. If, in spite of this ability of the user to return tapes temporarily to utility status, the utility tape supply should dwindle drastically, a program will exist which will search the Problem Specification tables and print the following information for each assigned tape:

- i. Problem Specification number;
- ii. Tape label number(s);
- iii. Date tape(s) was (were) last used.

In this way, it will be possible to ask users who are not currently using their tape to allow it to be released to utility, but assigned, status. The control card

\$ RELEASE TKnnnn

placed in a batched deck following a standard DCL Separation Card and Problem Run Card will cause the Pool Table entry for this tape to indicate that this tape is available as a utility although it is still assigned to a Problem Specification.

If the user can relinquish the tape entirely, the PRØBSPECALTER procedure may be used to relieve this tape of its assignment to the Problem Specification.

6. Other provisions are made in the case of an individual applying for a Problem Specification number, who requests that tapes be assigned to him, but who knows that these tapes will not be used for some time. If he notes this on his Problem Specification application form, the tapes will not be assigned until he requests assignment from the computer operator at some later date. Thus, tapes which might not have been available for assignment to other Problem Specifications are not tied up until the user actually needs them. The computer operator can initiate assignment of tapes at some later date by means of the \$ PRØBSPECADD card (see PSP description).

It is recognized that future experience may require more information in all the tables in this description and in the tape label itself. It is felt, however, that the above procedures are easiest to implement in the short time available and will allow growth without altering user and operator functions.

J. Flenner
B. Wulf

PART VIII
CONTROL DATA CORPORATION 1604

During the month of June specifications were presented for 1 new problem. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 20. Numbers followed by T are for theses.

20 Civil Engineering. A Study of Combined Stresses in Reinforced Concrete Beams without Web Reinforcement. The purpose of this study is to compute the stresses in the region of a crack as it propagates across a reinforced concrete beam without web reinforcement. A knowledge of these stresses will permit a rational estimate to be made of the capacity of such a beam under load.

A method has been developed by which such calculations can be made. This method involves first, the numerical integration of a differential equation by which the path of the crack may be traced from point to point as it propagates across the beam, and second the generation and solution of simultaneous equations for each of numerous points along the path so that the stresses may be computed at each of these points. A number of beams of varying properties, for which test data is available, are to be studied.

The following table shows the distribution of CDC 1604 time used by the University. That portion of the time used on Illiac simulation is also shown in Table I of Part

CDC 1604 TIME DISTRIBUTION
June, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	3:04			3:04
Astronomy	1:13			1:13
Chemistry	2:01	8:14		10:15
Civil Engineering	2:24	12:23		14:47
Electrical Engineering		2:31		2:31
Geological Survey	2:14			2:14
Physics	:	10:08		10:08
Psychology	5:39			5:39

Department	Simile	Non-Simile	Maintenance	Totals
Sociology	:23			:23
Maintenance			1:37	1:37
TOTALS	16:58	33:16	1:37	51:51

PART IX
GENERAL LABORATORY INFORMATION

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	12	2	13.0
Research Associates	9	0	9.0
Graduate Research Assistants	9	25	23.7
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>42</u>	<u>17</u>	<u>52.5</u>
TOTAL	79	46	106.2

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

UNIVERSITY OF ILLINOIS
DEC 7 1962

TECHNICAL PROGRESS REPORT

- PART I - CIRCUIT RESEARCH PROGRAM
- PART II - ILLIAC USE AND OPERATION
- PART III - IBM 650 USE AND OPERATION
- PART IV - INSTRUCTIONAL USE OF COMPUTERS
- PART V - CONTROL DATA CORPORATION 1604
- PART VI - GENERAL LABORATORY INFORMATION

July, 1962

PART I⁴
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

This month Sergio Ribeiro continues his analysis of the asymmetric flipflop. A piecewise-continuous method is used to obtain critical triggering conditions and transition times.

Tohru Moto-Oka has obtained the gain characteristic for a two-tunnel diode strip line amplifier. Under certain conditions, two peaks are found. This suggests that a larger number of tunnel diodes might be used to obtain a desirable characteristic for pulse amplification. Equations are also derived for the gain of a tunnel diode built in the form of a strip line.

Henry Guckel has completed the Illiac calculations for the report on emitter-follower oscillations. The design of a jig for tunnel diode measurements has been completed and construction awaits the arrival of resistors from Filmohm. The study of the depletion-layer capacitance is complete and its effect upon tunnel diode oscillations is reported upon below. Peripheral hybrid circuits are being designed and are under construction to allow evaluation of tunnel diode logic. The first part of these circuits, a 4×4 memory is discussed in this report.

Thomas Burnside is carrying out tests of the circuits of the statistical analyzer. Several changes have been made to improve speed of operation and a difficulty with the discrimination input impedance has been found that will require a redesign.

2. Analysis of an Asymmetric Flipflop (continued)

Quantitative Analysis

If we select as the dependent variable the voltage v_0 at the base of T_1 (see Figure 1) rather than the current i_2 at the collector of T_2 we find an equation which is somewhat easier to treat quantitatively. Under a current trigger of amplitude i' this equation is:

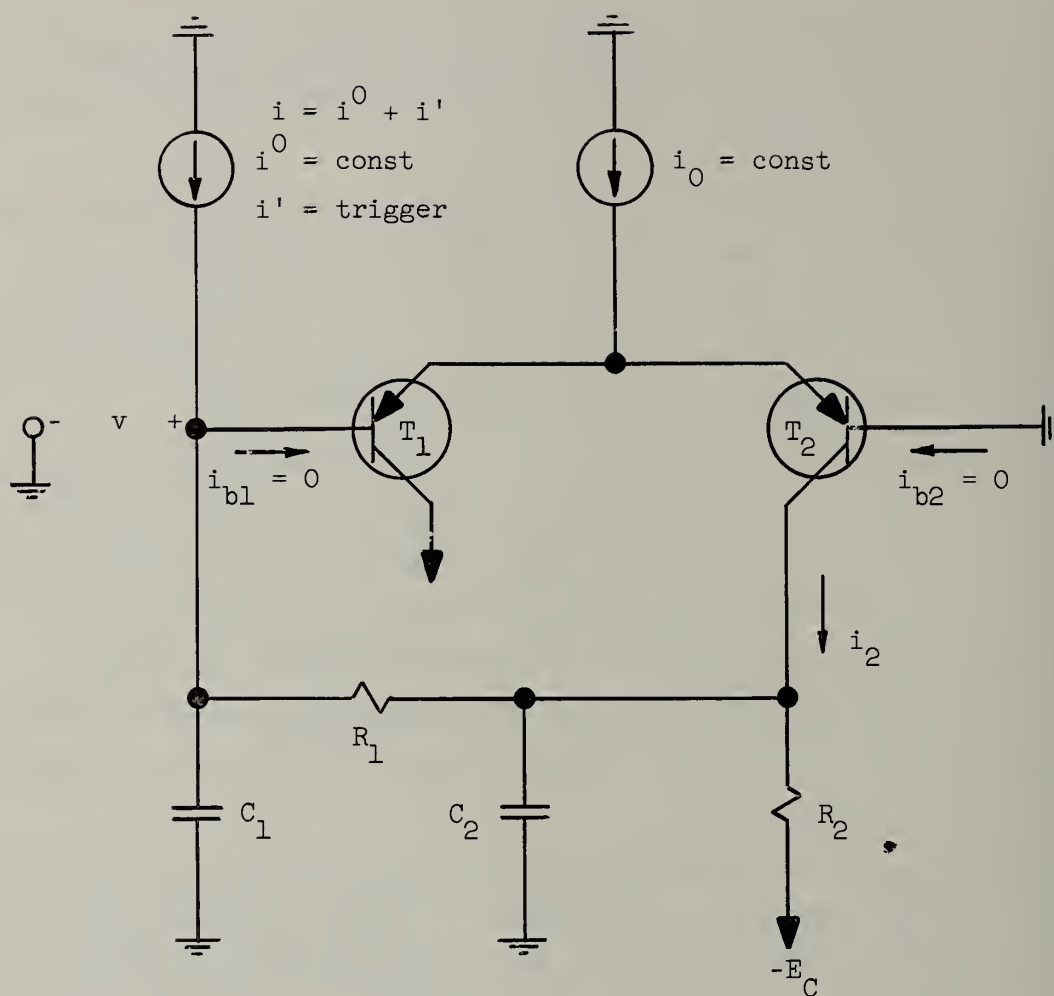


Figure 1 Asymmetric Flipflop

$$k\ddot{x} + \ell\dot{x} + x = \tanh(px) + \Gamma \quad (1)$$

where $x = 2 \frac{v}{i_0 R_2}$

(Observe: We must have $p > 1$; otherwise the circuit will not behave like a flipflop.)

$$k = R_1 R_2 C_1 C_2$$

$$\ell = R_1 C_1 + R_2 C_1 + R_2 C_2$$

$$p = \frac{q_e i_0 R_2}{4kT}$$

$$\Gamma = qv + r\dot{v}$$

$$q = 2(1 + \frac{R_1}{R_2})$$

$$f = 2R_1 C_2$$

$$\tau = \frac{i'}{i_0}$$

which can be analyzed by means of a piecewise linear approximation to the $\tanh(px)$; we work with the following equation:

$$k\ddot{x} + \ell\dot{x} + x = f(x) + \Gamma \quad (2)$$

$$f(x) = \begin{cases} -1, & x \leq -\frac{1}{p} \\ px, & -\frac{1}{p} \leq x \leq +\frac{1}{p} \\ +1, & +\frac{1}{p} \leq x \end{cases}$$

Observe that Γ takes into account the effects of the trigger.

Equation (2) is equivalent to three linear difference equations, each one valid in a certain region:

$$\begin{aligned}
 \text{Region I:} \quad k\ddot{x} + l\dot{x} + x &= -1 + \Gamma, & x &\leq -\frac{1}{p} \\
 \text{Region II:} \quad k\ddot{x} + l\dot{x} - (p-1)x &= \Gamma, & -\frac{1}{p} &\leq x \leq +\frac{1}{p} \\
 \text{Region III:} \quad k\ddot{x} + l\dot{x} + x &= +1 + \Gamma, & +\frac{1}{p} &\leq x
 \end{aligned} \tag{3}$$

By matching initial conditions with final conditions in the border lines $x = -\frac{1}{p}$ and $x = +\frac{1}{p}$ a phase-plane analysis can be carried out.

Solutions in regions I and III are of the parabolic type converging to stable nodes located respectively at $(x,y) = (-1,0)$ and in region II they are of the hyperbolic type diverging from the saddle point at $(x,y) = (0,0)$.

Separatrices can be found and the expressions for the trajectory joining two points (known to be over the same path) are obtained, all in implicit form.

Transition times can also be found from the above equations, but since the expressions are implicit, iteration is in general necessary to compute these times.

Therefore approximations are useful, and it is possible to show that, under square wave current triggering, the path on the phase-plane can be reasonably approximated by straight line segments. From these segments, whose slopes and initial points are easily found, transition times can be calculated. In fact the times taken by x in the various regions correspond to significant times from the standpoint of the output current i_2 . For example, if x is in region I, $i_2 = 0$, so the time necessary for x to go, say, from -1 to $-\frac{1}{p}$ is a delay time; if x is in region III, $i_2 = i_0$, so i_2 builds up when x crosses region II, from $-\frac{1}{p}$ to $+\frac{1}{p}$; the time it takes to cross region II is the "active" time in the sense that the transistors are active if and only if x is inside region II; settling times can also be considered in the effects of turning trigger OFF, etc.

Thus the piecewise linear approximation of the phase-plane path during a transition furnishes not only transition times, but also an approximation to the wave form of i_2 . The latter can be fed into another differential equation and an approximation to the wave form of v_2 , the output voltage, can be obtained.

A typical trajectory of a transition under a square wave current trigger is shown in Figure 2 below, from which a broken line approximation can be obtained.

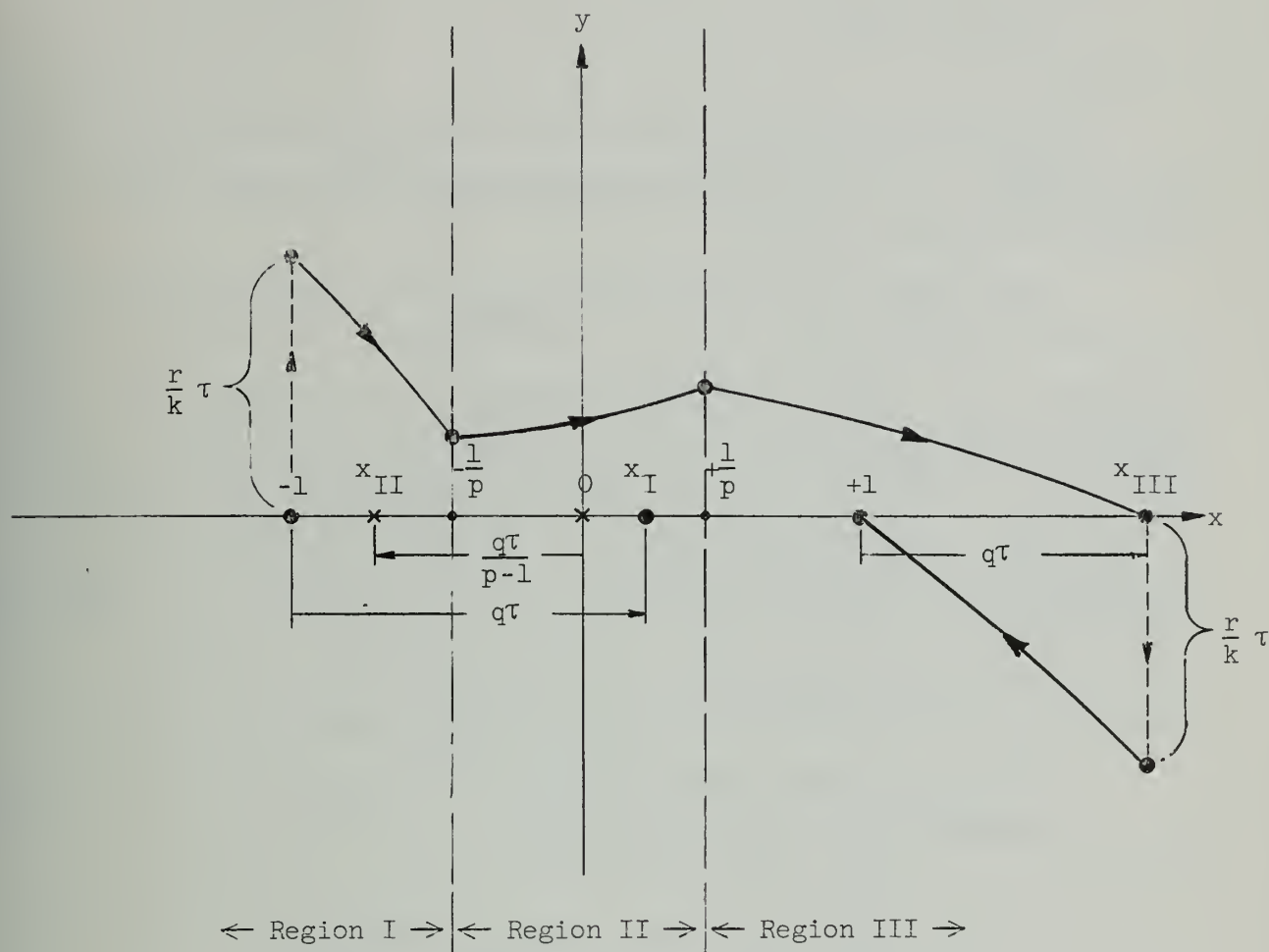


Figure 2 Typical Transition Trajectory under Square Wave Current Trigger

Observe: x_I and x_{III} : stable nodes shifted right
 x_{II} : saddle point shifted left } by positive current trigger

x_I and x_{II} are virtual singularities because they lie outside their respective regions of influence.

Notice that y suffers discontinuities when trigger is turned ON and OFF.

Given a straight line segment in the phase-plane, say $y(x) = y_a + y'x$, assuming that the points (x_a, y_a) , (x_b, y_b) are on $y(x)$, the time θ_{ab} for the representative point to move from (a) to (b) is

$$\theta_{ab} = \frac{1}{y'} \ln \frac{y_b}{y_a} \quad (4)$$

So, both from the exact solution of system (3) and from expressions like (4) applied to piecewise linear approximations to the exact solution, transition times can be found.

Also, there is a minimum value τ_{minimum} of τ under which no transition occurs, and a maximum value, τ_{maximum} , of τ may exist above which the flipflop may return to its original state upon elimination of the trigger. These are determined by the positions of P_1 and P_4 (respectively) with respect to the separatrices. A value τ_{critical} of τ may exist above which the representative point will pass through region II after the trigger is removed; this is not desirable since it causes a variation of i_2 (after removal of the trigger) which could be avoided. All these values (τ_{minimum} , τ_{maximum} and τ_{critical}) of τ are found from the phase-plane piecewise linear approximation, and also the respective conditions under which τ_{minimum} , τ_{maximum} and τ_{critical} do exist.

We will defer the lengthy analysis to a final report, but will mention here, for illustrative purposes, some results:

$$1) \text{ If } |\beta_I| > \frac{r}{qk} \text{ then } \tau_{\text{minimum}} = \frac{p-1}{pq}$$

$$2) \text{ If } \frac{r}{qk} > |\beta_I| \text{ then } \tau_{\text{minimum}} = \frac{p-1}{pq} \frac{D}{D-1}$$

$$3) \text{ If } |\beta_I| > \frac{r}{qk} \text{ there are no } \tau_{\text{critical}} \text{ or } \tau_{\text{maximum}}$$

$$4) \text{ If } \frac{r}{qk} > |\beta_I| \text{ then } \tau_{\text{maximum}} = \frac{p-1}{pq} E$$

$$\text{and } \tau_{\text{critical}} = \frac{p-1}{pq} F$$

And:

$$D = \left\{ \left(\frac{\alpha_I + \frac{\alpha_{II}}{p-1}}{\alpha_I + \frac{r}{qk}} \right)^{\alpha_I} \left(\frac{\beta_I + \frac{\beta_{II}}{p-1}}{\beta_I + \frac{r}{qk}} \right)^{-\beta_I} \right\}^{\frac{1}{\alpha_I - \beta_I}}, \quad \beta_I < \alpha_I < 0$$

(obviously $D < 0$).

$$E = -D \text{ (with } \alpha_{III}, \beta_{III} \text{ instead of } \alpha_I, \beta_I)$$

F is obtained by setting $\alpha_{II} = \beta_{II} = 0$ in expression for E.

Observe: (4) is given for the case of a fairly long trigger, i.e., assuming the representative point has practically settled at the stable-node x_{III} before the trigger is removed; approximate expressions can be found for the case of a short trigger (trigger removed before the representative point reaches the stable-node x_{III}) then we use only a bound for the trigger, in the sense that

$$\text{if } \left\{ \begin{array}{ll} \tau < \tau'_{\text{critical}} & \text{no perturbation of } i_2 \text{ occurs} \\ \tau > \tau'_{\text{critical}} & \text{perturbation of } i_2 \text{ may occur} \\ \tau < \tau'_{\text{maximum}} & \text{no switching back occurs} \\ \tau > \tau'_{\text{maximum}} & \text{switching back may occur} \end{array} \right\} \text{ after}$$

removal of trigger.

These expressions, however, depend on the piecewise linear approximation of the trajectory (so do expressions for the transition times), and therefore have a degree of arbitrariness inherent to this kind of approximation. We take the linear approximation in such a way as to furnish the maximum possible values of τ'_{critical} and τ'_{maximum} which still satisfy the inequality conditions above.

(Sergio Ribeiro)

3. Tunnel Diode Amplifier Theory

Introduction

The theory of a strip line type amplifier with two tunnel diodes was investigated. The gain of this amplifier has two peak values which occur at DC and at a frequency, ω_0 .

From these results, it appears to follow that amplifiers with many tunnel diodes will have many peaks in the gain characteristic. It also seems that optimum gain for pulse amplification would be found with an infinite number of tunnel diodes.

The gain characteristic of a strip line type tunnel diode was investigated theoretically. The design condition was obtained and it was found that it had the gain characteristic of $\frac{K}{\omega^2}$ at low frequency.

A Strip Line Type Amplifier Having Two TD's

The circuit equations of the amplifier shown in Figure 3 are as follows:

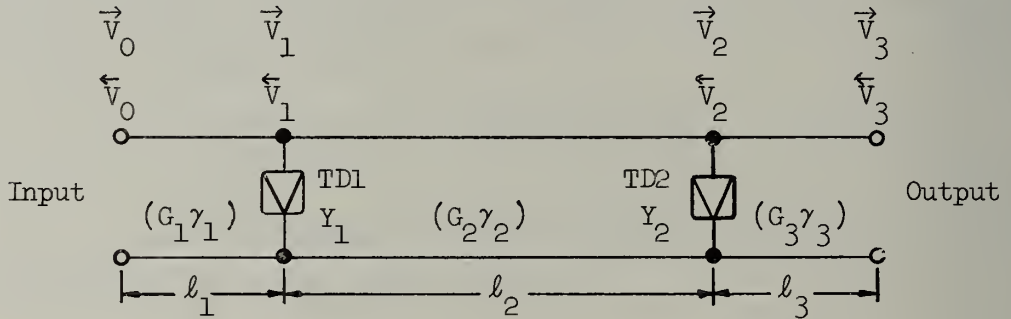


Figure 3

$$\begin{pmatrix} \vec{V}_3 e^{s\tau_3} \\ \overleftarrow{V}_3 e^{-s\tau_3} \end{pmatrix} = \begin{pmatrix} \vec{V}_2 \\ \overleftarrow{V}_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{2G_3} (G_2 + G_3 - Y_2) e^{-s\tau_2} \frac{1}{2G_3} (-G_2 + G_3 - Y_2) e^{s\tau_2} \\ \frac{1}{2G_3} (-G_2 + G_3 + Y_2) e^{-s\tau_2} \frac{1}{2G_3} (G_2 + G_3 + Y_2) e^{s\tau_2} \end{pmatrix} \begin{pmatrix} \vec{V}_1 \\ \overleftarrow{V}_1 \end{pmatrix} \quad (5)$$

$$\begin{pmatrix} \vec{V}_1 \\ \overleftarrow{V}_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{2G_2} (G_1 + G_2 - Y_1) \frac{1}{2G_2} (-G_1 + G_2 - Y_1) \\ \frac{1}{2G_2} (-G_1 + G_2 + Y_1) \frac{1}{2G_2} (G_1 + G_2 + Y_1) \end{pmatrix} \begin{pmatrix} \vec{V}_0 e^{-s\tau_1} \\ \overleftarrow{V}_0 e^{s\tau_1} \end{pmatrix} \quad (6)$$

(where $s\tau_1$, $s\tau_2$ and $s\tau_3$ are $\gamma_1\ell_1$, $\gamma_2\ell_2$ and $\gamma_3\ell_3$ respectively).

When it is assumed that the input and output terminals are terminated by resistors equal to $\frac{1}{G_1}$ and $\frac{1}{G_2}$ respectively, the voltage gain is given by the following equation.

$$G_V = \frac{\vec{V}_3}{\vec{V}_0} = \frac{4G_1G_2\epsilon^{-s(\tau_1+\tau_3)}}{(-G_2+G_3+Y_2)(-G_1+G_2-Y_1)\epsilon^{-s\tau_2} + (G_1+G_2+Y_1)(G_2+G_3+Y_2)\epsilon^{s\tau_2}} \quad (7)$$

If it is assumed that tunnel diode admittances Y_1 and Y_2 are $sC_1 - G_{T1}$ and $sC_2 - G_{T2}$ respectively, for a single frequency ω , the voltage gain becomes:

$$G_V = \frac{2G_1G_2\epsilon^{j\omega(\tau_1+\tau_3)}}{[G_2(G_1+G_3-G_{T1}-G_{T2})\cos \omega\tau_2 + \{\omega C_1(G_{T2}-G_3) + \omega C_2(G_{T1}-G_1)\} \sin \omega\tau_2] + j[\omega(C_1+C_2)G_2 \cos \omega\tau_2 + \{G_2^2 + (G_1-G_{T1})(G_3-G_{T2}) - \omega^2 C_1 C_2\} \sin \omega\tau_2]} \quad (8)$$

If we set $G_1 = G_{T1}$, $G_3 = G_{T2}$,

$$G_V = \frac{2G_1G_2\epsilon^{j\omega(\tau_1+\tau_3)}}{j[\omega(C_1+C_2)G_2 \cos \omega\tau_2 + (G_2^2 - \omega^2 C_1 C_2) \sin \omega\tau_2]} \quad (9)$$

If the condition that $\omega_0\tau_2 = \frac{\pi}{2}$, $G_2 = \omega_0\sqrt{C_1 C_2}$ is satisfied, the voltage gain becomes infinity at $\omega = 0$ and ω_0 .

Equation (9) is rewritten as follows:

$$|G_0| = \frac{\omega_T}{\omega_0} \sqrt{\frac{C_1}{C_2}} F(x), \quad F(x) = \frac{2}{kx \cos \frac{\pi}{2} x + (1-x^2) \sin \frac{\pi}{2} x} \quad (10)$$

where $x = \frac{\omega}{\omega_0}$, $R = \frac{C_1 + C_2}{\sqrt{C_1 C_2}} \geq 2$ and $\omega_T = \frac{G_{T1}}{C_1}$.

$F(x)$ is shown in Figure 4.

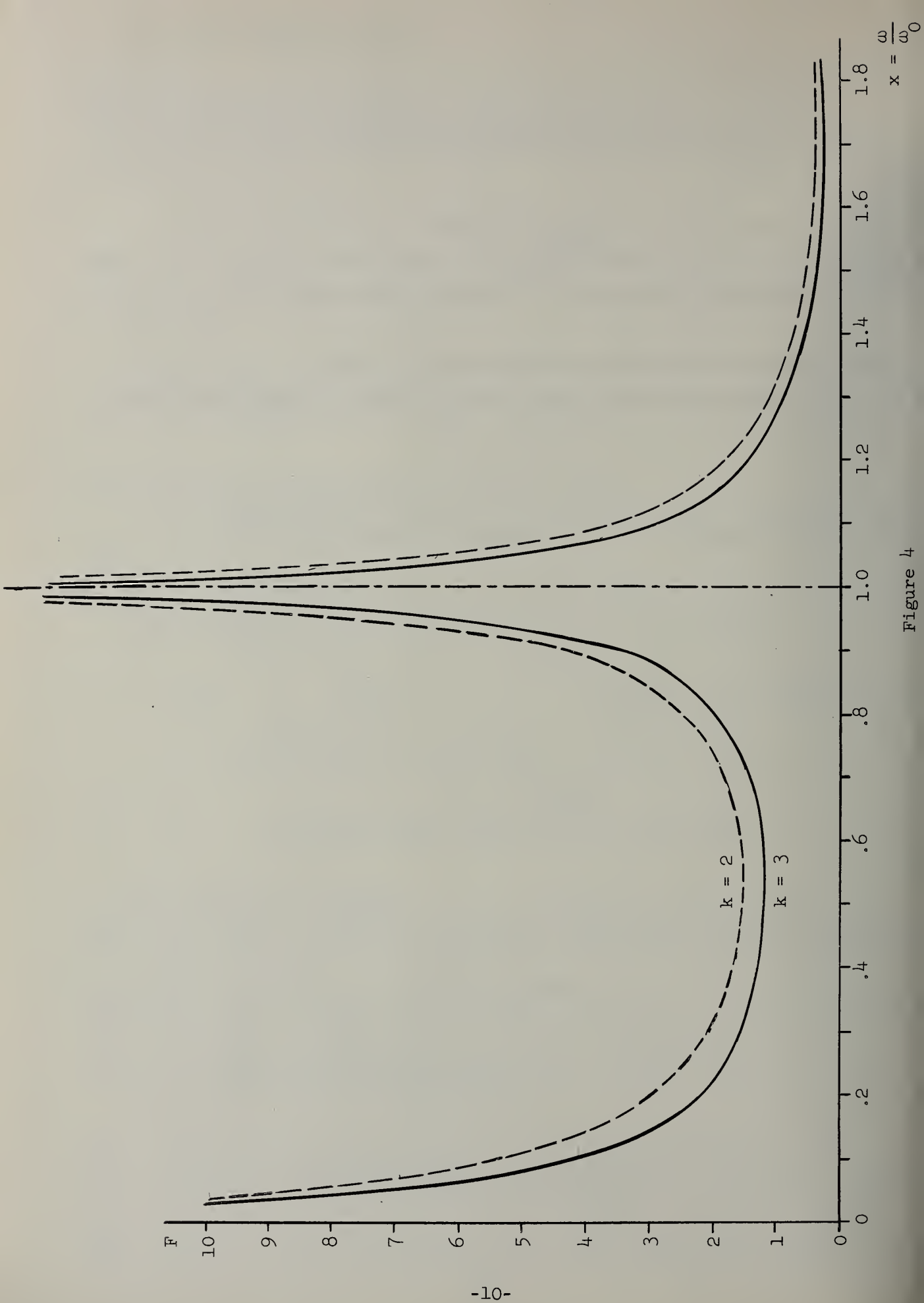
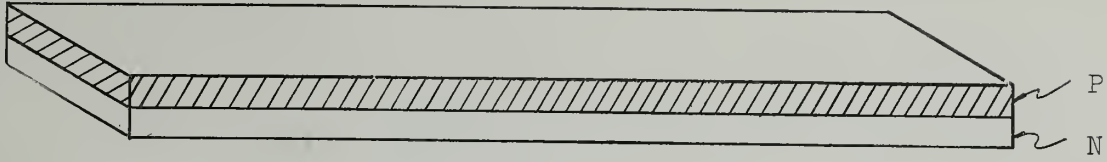
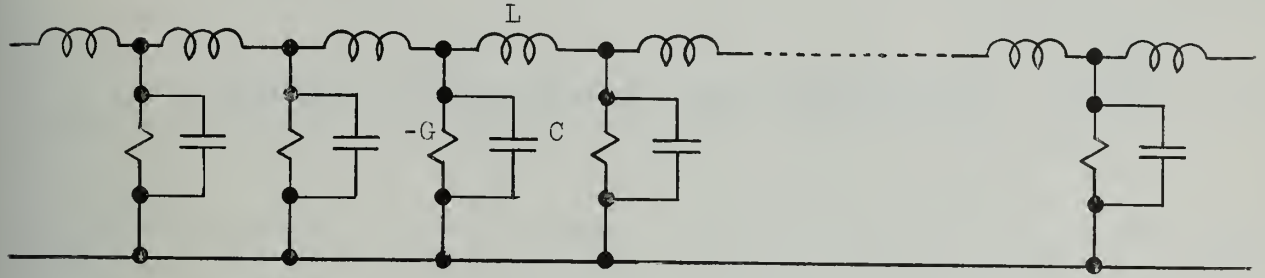


Figure 4

A Strip Line Type Tunnel Diode



(a)



(b) Equivalent Circuit

Figure 5

The characteristic equations of the strip line tunnel diode shown in Figure 5 are as follows:

$$V = A e^{-\dot{\gamma}x} + B e^{\dot{\gamma}x} \quad (11)$$

$$I = Y_0 (A e^{-\dot{\gamma}x} - B e^{\dot{\gamma}x}) \quad (12)$$

where $Y_0 = \sqrt{\frac{C}{L} (1 + j \frac{\omega_T}{\omega})}$, $\gamma = \alpha + j\beta = j\omega \sqrt{LC(1 + j \frac{\omega_T}{\omega})}$, $\omega_T = \frac{G}{C}$ and L , C , $-G$ are the inductance, capacitance, and negative conductance per unit length of the tunnel diode respectively.

If the input terminal ($x = 0$) is terminated by a series circuit of a resistance R_s and voltage source \dot{E} and the output terminal ($x = \ell$) is terminated by a resistance R_ℓ , then A and B are given by the following equation:

$$\begin{pmatrix} 1 + R_s \dot{Y}_0 & 1 - R_s \dot{Y}_0 \\ (1 - R_\ell \dot{Y}_0) e^{-\dot{\gamma}\ell} & (1 + R_\ell \dot{Y}_0) e^{\dot{\gamma}\ell} \end{pmatrix} \begin{pmatrix} A \\ B \end{pmatrix} = \begin{pmatrix} \dot{E} \\ 0 \end{pmatrix} \quad (13)$$

The voltage gain is given by

$$G_v = \frac{V_l}{E} = \frac{R_l}{R_s + R_l} \frac{1}{\cosh \dot{\gamma} l + \left(\frac{1 + R_s R_l \dot{Y}_0^2}{(R_s + R_l) \dot{Y}_0} \right) \sinh \dot{\gamma} l} \quad (14)$$

and

$$|G_v| = \frac{2R_l}{R_s + R_l} \frac{1}{\sqrt{(1 + N^2 + M^2)^2 - 4M^2}} \frac{1}{\sqrt{\cosh (2\alpha l + \varphi_1) - \cos (2\beta l - \varphi_2)}} \quad (15)$$

where

$$M + jN = \frac{1 + R_s R_l \dot{Y}_0^2}{(R_s + R_l) \dot{Y}_0}, \quad \varphi_1 = \tan^{-1} \frac{2M}{1 + M^2 + N^2} \quad \text{and} \quad \varphi_2 = \tan^{-1} \frac{2N}{M^2 + N^2 - 1}$$

For low frequency

$$\begin{aligned} G_v &= \frac{R_l}{R_s + R_l} \frac{1}{1 + \frac{1}{2} (\dot{\gamma} l)^2 + \frac{1 + R_s R_l \dot{Y}_0^2}{(R_s + R_l) \dot{Y}_0} (\dot{\gamma} l)} \\ &= \frac{R_l}{R_s + R_l} \frac{1}{\left(1 - \frac{R_s R_l}{R_s + R_l} G_l - \frac{1}{2} \omega^2 L C l^2\right) + j\omega l \left\{ \frac{L}{R_s + R_l} + \frac{R_s R_l C}{R_s + R_l} - \frac{L G_l}{2} \right\}} \quad (16) \end{aligned}$$

If $\frac{R_s R_l}{R_s + R_l} G_l = \frac{R_s R_l}{R_s + R_l} G_T = 1$, G_v at frequency zero goes to infinity.

If $Z_0 = \sqrt{\frac{L}{C}} = \frac{\sqrt{2} R_s R_l}{\sqrt{R_s^2 + R_l^2}}$ is satisfied, too, then the frequency

characteristic becomes $\frac{K}{\omega^2}$ at low frequency. If $R_s = R_l$, this condition means

that $R_s = R_l = \frac{2}{G_T} = \sqrt{\frac{L}{C}}$. Further investigation is being continued.

(Tohru Moto-Oka)

4. Tunnel Diode Oscillator Theory

Behavior of Depletion Layer Capacitance

Let

$$C_E = \frac{C_0}{\left(1 - \frac{v}{V_0}\right)^{\frac{1}{n}}} \quad V_0 = \text{diffusion potential} \quad (17)$$

then: $C = \frac{dq}{dv}$

and the energy stored on the capacitor is equal to the work done by the charging current:

$$E_c = \int e i dt = \int v dq = \int C v dv$$

$$E_c = C_0 \int_0^v \frac{v dv}{\left(1 - \frac{v}{V_0}\right)^{\frac{1}{n}}} \quad (18)$$

Let: $y = 1 - \frac{v}{V_0} \quad v = V_0(1 - y)$

$$dy = - \frac{dv}{V_0} \quad dv = - V_0 dy$$

$$E_c = - C_0 V_0^2 \int_1^r \left(y^{-\frac{1}{n}} - y^{1-\frac{1}{n}} \right) dy$$

$$= C_0 V_0^2 \left[\frac{1}{1 - \frac{1}{n}} - \frac{y^{1-\frac{1}{n}}}{1 - \frac{1}{n}} - \frac{1}{2 - \frac{1}{n}} + \frac{y^{2-\frac{1}{n}}}{2 - \frac{1}{n}} \right]$$

$$E_c = n C_0 V_0^2 \left[\frac{1 - y^{\frac{n-1}{n}}}{n-1} - \frac{1 - y^{\frac{2n-1}{n}}}{2n-1} \right] \quad (19)$$

For tunnel diodes the value $n = 2$ follows from abrupt junction theory. Hence:

$$E_c = 2C_0 V_0^2 \left[\frac{1}{3} y^{\frac{3}{2}} - y^{\frac{1}{2}} + \frac{2}{3} \right] \quad (19a)$$

$$E_c = 2C_0 V_0^2 \left[\frac{1}{3} \left(1 - \frac{v}{V_0}\right)^{\frac{3}{2}} - \left(1 - \frac{v}{V_0}\right)^{\frac{1}{2}} + \frac{2}{3} \right]$$

For a linear capacitor C_0

$$E_c = \frac{1}{2} C_0 v^2$$

so that
$$\frac{E_c}{E_{c_{\max}}} = \frac{\frac{1}{2} C_0 v^2}{\frac{1}{2} C_0 V_0^2} = \left(\frac{v}{V_0}\right)^2$$

and for the above case:

$$\frac{E_c}{E_{c_{\max}}} = 4 \left[\frac{1}{3} \left(1 - \frac{v}{V_0}\right)^{\frac{3}{2}} - \left(1 - \frac{v}{V_0}\right)^{\frac{1}{2}} + \frac{2}{3} \right]$$

Normalized plots are shown in Figure 6.

Small Signal Oscillation Theory

If the tunnel diode is linearized as in Figure 7a and the equivalent of 7b is used in region II a small signal theory can be formed which includes the non-linear effect due to C_E .

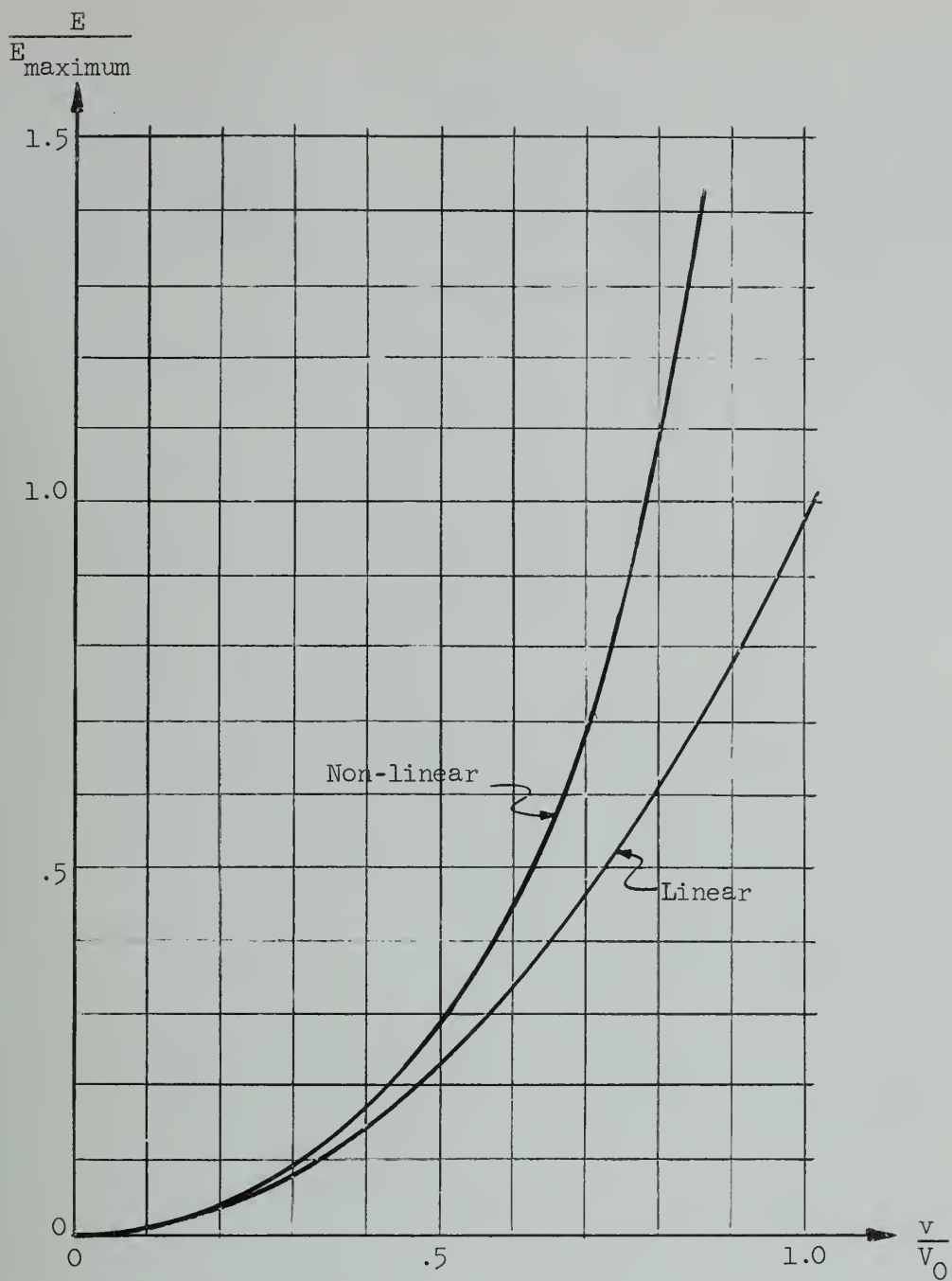


Figure 6 Effect of Non-linear C

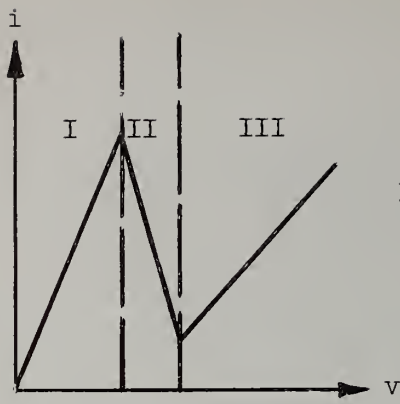


Figure 7a

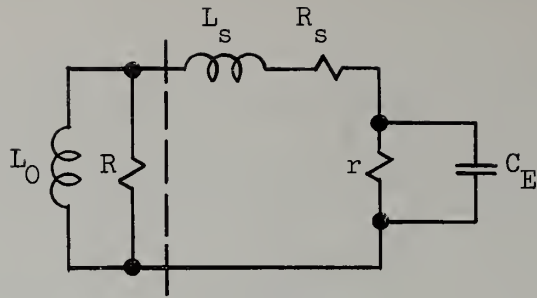


Figure 7b

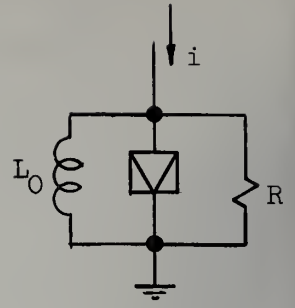


Figure 7c

If the tunnel diode series resistance and case inductance is neglected and R is chosen equal to r , dissipation does not occur. The condition corresponds therefore to a parallel tuned tank circuit. Then:

$$L_O \ddot{q} + \int \frac{dq}{c(q)} = 0 \quad (20)$$

Let the LaGrangian L be:

$$L = \frac{L_O \dot{q}^2}{2} - \iint \frac{dq}{c(q)} dq$$

$$\frac{\partial L}{\partial \dot{q}} = L_O \dot{q} \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{q}} \right) = L_O \ddot{q}$$

$$\frac{\partial L}{\partial q} = - \int \frac{dq}{c(q)}$$

Hence the Lagrangian is in the desired form. The energy integral is therefore:

$$\dot{q} \frac{\partial L}{\partial \dot{q}} - L = h \quad (21)$$

$$L_O \frac{\dot{q}^2}{2} + \iint \frac{dq}{c(q)} dq = h$$

or
$$L_O \frac{\dot{q}^2}{2} + \int v dq = h$$

This means that h is the total energy. The integral term was found in Equation (19a). Hence:

$$h = \frac{1}{2} L_0 C_0^2 \left(\frac{1}{1 - \frac{v}{V_0}} \right) \dot{v}^2 + 2C_0 V_0^2 \left[\frac{1}{3} \left(1 - \frac{v}{V_0} \right)^{\frac{3}{2}} - \left(1 - \frac{v}{V_0} \right)^{\frac{1}{2}} + \frac{2}{3} \right] \quad (22)$$

For the linear system:

$$h = \frac{1}{2} L_0 C_0^2 \dot{v}^2 + \frac{1}{2} C_0 v^2$$

This may be written more conveniently by letting

$$\left. \begin{aligned} v &= \sqrt{\frac{C_0}{2}} v \\ t' &= \frac{1}{\sqrt{L_0 C_0}} t \end{aligned} \right\} \frac{dv}{dt'} = \left(\frac{1}{2} L_0 C_0^2 \right)^{\frac{1}{2}} \frac{dv}{dt}$$

Hence $h = \dot{v}^2 + v^2$

and
$$h = \frac{1}{1 - \sqrt{\frac{2}{C_0}} \frac{v}{V_0}} \dot{v}^2 + 2C_0 V_0^2 \left[\frac{1}{3} \left(1 - \sqrt{\frac{2}{C_0}} \frac{v}{V_0} \right)^{\frac{3}{2}} - \left(1 - \sqrt{\frac{2}{C_0}} \frac{v}{V_0} \right)^{\frac{1}{2}} + \frac{2}{3} \right]$$

In order to eliminate the active element the operating point O is used as zero reference.

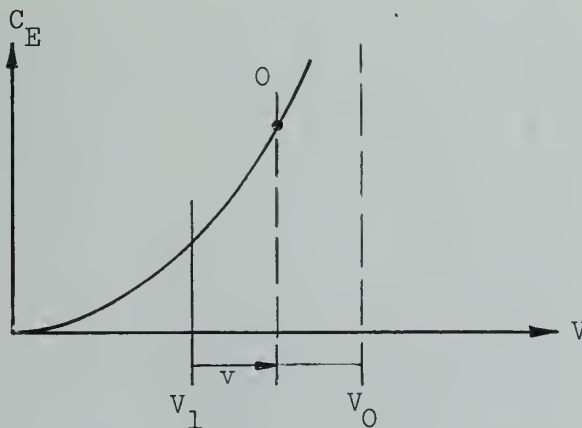


Figure 8

Hence

$$C_E = \frac{C_0}{\left(1 - \frac{v}{V_0}\right)^{\frac{1}{n}}} = \frac{C_0}{\left(1 - \frac{V_1 + v}{V_0}\right)^{\frac{1}{n}}}$$

$$E_c = \int_0^v v dq$$

$$= 2V_0 C_0 \left[(V_0 - V_1) \left(\left(1 - \frac{V_1}{V_0}\right)^{\frac{1}{2}} - \left(1 - \frac{V_1 + v}{V_0}\right)^{\frac{1}{2}} \right) - \frac{V_0}{3} \left(\left(1 - \frac{V_1}{V_0}\right)^{\frac{3}{2}} - \left(1 - \frac{V_1 + v}{V_0}\right)^{\frac{3}{2}} \right) \right]$$

This results in an energy equation:

$$h = \frac{1}{2} L_0 C_0^2 \frac{\dot{v}^2}{1 - \frac{V_1}{V_0}} + E_c$$

For the linear case the energy condition is given by

$$h = \frac{1}{2} L_0 C_0^2 \dot{v}^2 + \frac{1}{2} C_0 v^2$$

Numerical example:

$$C_0 = 11 \mu\mu+$$

$$V_0 = 650 \text{ mV}$$

$$V_1 = 92.5 \text{ mV}$$

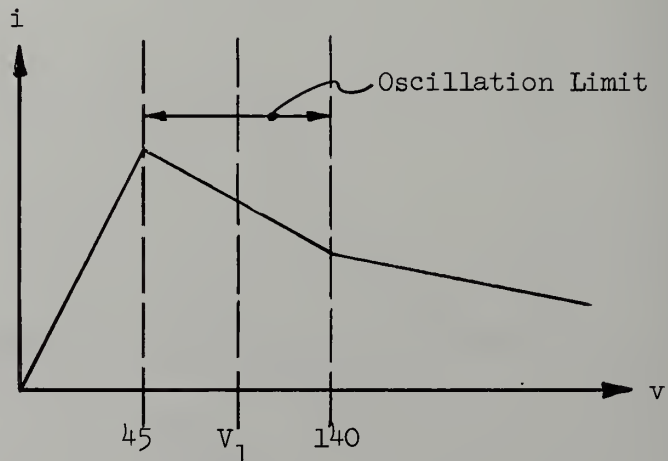


Figure 9

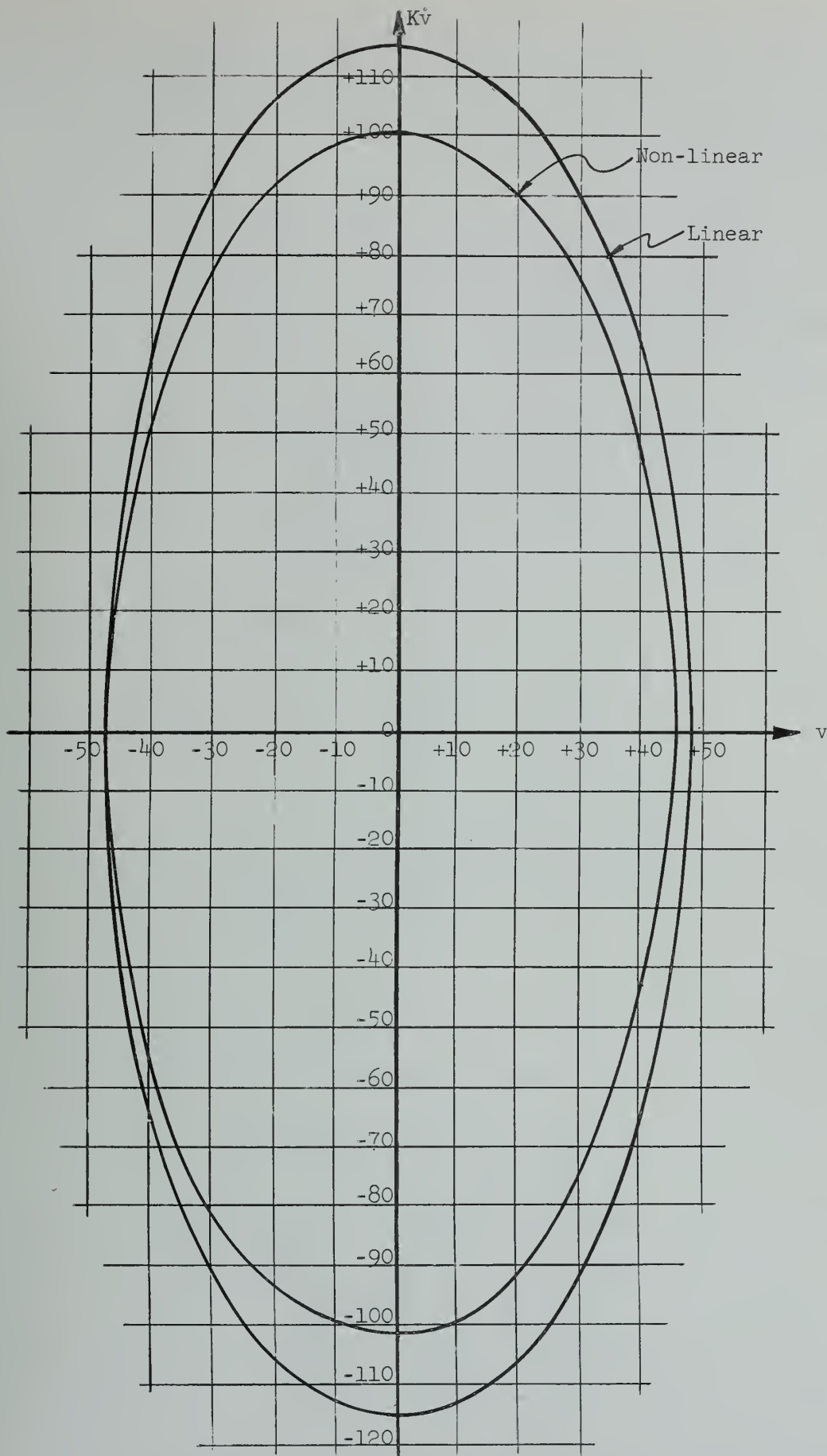


Figure 10 Small Signal Oscillations

The above data closely resemble the situation for the 5 ma germanium tunnel diode. Both linear and non-linear models were evaluated. The results depend, of course, very much on the range of voltages assumed. For small signal response the linear model is sufficient.

(Henry Guckel)

5. Tunnel Diode Hybrid Circuits

Buffer Memory

If the tunnel diode is to be used as a memory element it has to be biased to two stable points independent of signal. Two methods are available: current bias, voltage bias. The current bias method is preferred because of tolerance restrictions and power supply requirements.

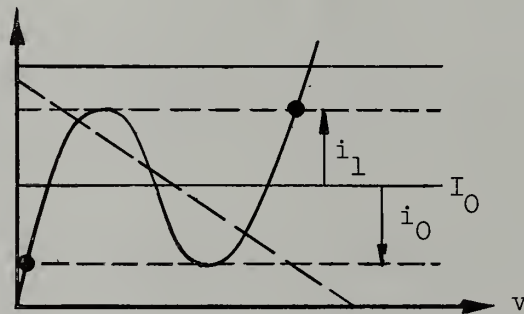


Figure 11 Bias Methods

For the current bias method the signal must be able to change the current through the diode as indicated. Again, the application of a signal in current form is preferred. These arguments resulted in the following memory cell:

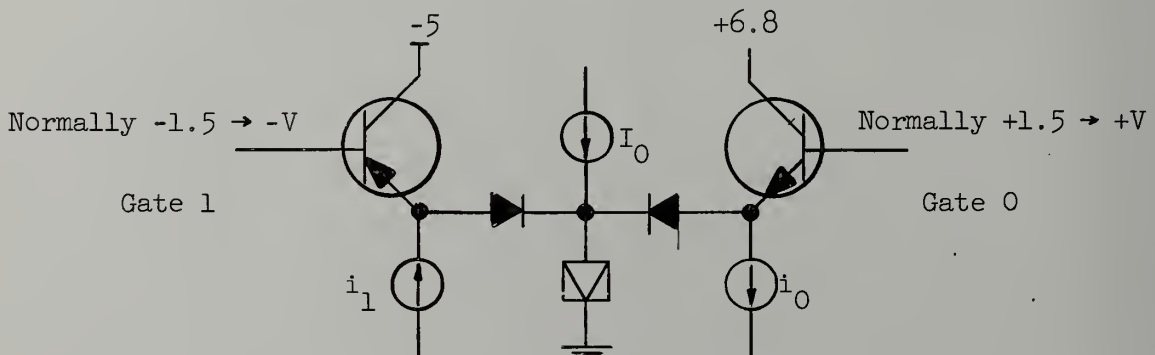
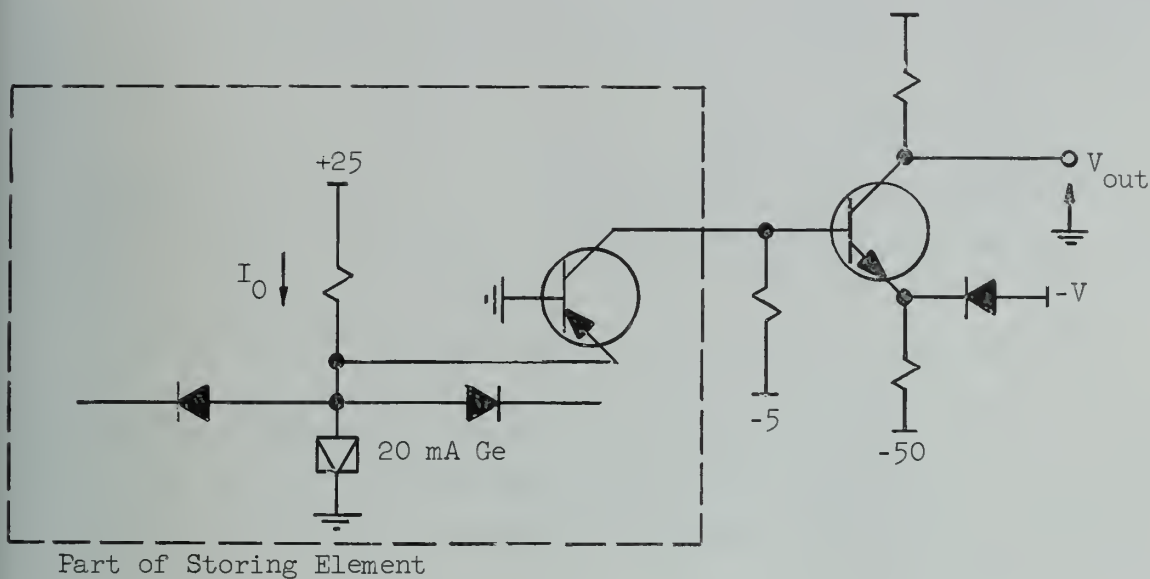


Figure 12 Memory Cell

The read-out now must involve the conversion of a tunnel diode state to transistor voltage levels. This may be accomplished as shown in Figure 10.

Figure 13



The "OR" operation is obtained at the collector of the PNP transistor. Measurement of the GF 45011, 2N250 and 2N711 for grounded base operation shows that all three may be used as shown in Figure 11.

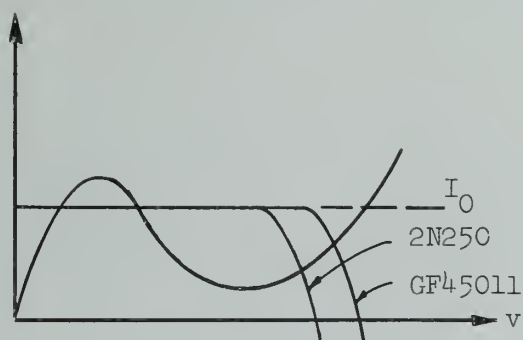


Figure 14

Read-out speed seems to be around 5 nsec. Setting speed of the storer cannot be measured. The read-in circuit is presently in the form of a difference amplifier.

(Henry Guckel)

6. Statistical Analyzer

Bench tests have been made this month on the existing statistical analyzer circuits to check their operations when connected as they may be found in the statistical analyzer. Changes will be necessary for several of the circuits in order to speed them up and obtain a proper 1 megacycle operation.

The circuits would work for an ordinary 1 megacycle computer circuit. But here we want to do DC analysis during 1 microsecond. This means that the DC level must be reached rapidly in comparison to 1 microsecond. Circuitry that ordinarily would run in a computer circuit at 10 megacycles would, in this case, just give the minimum necessary speed.

We had recommended the 2N1308 and 2N1309 for most of the circuit transistors. In order to attain the rapid rise time we need, these are being replaced in many cases by faster transistors, GF 45011's and 2N706's.

Another major barrier that must be overcome before the statistical analyzer can be built is that of synchronization. The flipflops change state very rapidly. If no delay is used in some of the shorter feedback logic loops, the "new" output of the flipflop will appear before the clock pulse disappears. This causes erroneous results. Short delay lines are being investigated to correct these synchronous problems.

The discriminating circuit (June report) gives some difficulty at high speeds. The input impedance was thought to be very high in the circuit. At high frequency, however, the collector to base impedance of the first NPN transistor becomes very small which causes the circuit to work unsatisfactorily. Investigations indicate that the discriminating circuit must be redesigned with a higher input impedance.

Tests indicate that the switching circuit (March report, Figure 3, page 13), pulse generator (April report, Figure 4, page 7) and decoding circuit (February report, Figure 6, page 11) are working satisfactorily for the statistical analyzer. Minor changes may be made to level out small ripples in the pulses.

When the circuit revising is complete, new circuit diagrams will be reported and a statistical analyzer model built.

(Thomas Burnside)

PART II

ILLIAC USE AND OPERATION

Illiac Usage

During the month of July, specifications were presented for twenty-one new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2198. Numbers followed by T are for theses.

2198 Psychology. Random Variables in Factor Analysis. The problem is to determine the influence that the inclusion of random variables with sets of variables which are presumed to be non-random has upon centroid and rotated orthogonal factor loadings.

Only library routines will be used.

2199 Mechanical Engineering. Two Phase Nozzle Calculations. The one dimensional two phase flow equations for a gas-solid suspension through a nozzle of arbitrary area distribution neglecting wall heading and wall friction are:

$$\frac{dA}{A} + \frac{du}{u} + \frac{dP}{P} = \frac{dT}{T} \quad (1)$$

$$\frac{dT}{dx} + 2u \frac{du}{dx} + m_p \frac{c_p}{c} \frac{dT_p}{dx} + 2m_p u_p \frac{du_p}{dx} = 0 \quad (2)$$

$$u_p \frac{du_p}{dx} = E (u - u_p) \quad (3)$$

$$\frac{dP}{P} + \frac{2uc}{RT} \frac{du}{dx} + \frac{2ucm_p}{RT} \frac{du_p}{dx} = 0 \quad (4)$$

$$- u_p \frac{dT_p}{dx} = B(T_p - T) \quad (5)$$

$$\frac{dA}{dx} = f(x) \quad (6)$$

$$\text{If } \frac{dA}{dx} = \left[1 - \frac{c_e}{R} (1+m_p \frac{b}{a})\right] \left[1 - \frac{c}{c_e} a^2 x^2\right]^{-\frac{c_e}{R} (1+m_p \frac{b}{a}) 778.16} \left[-2 \frac{c}{c_e} a\right] - \frac{1}{ax^2} \left(1 - \frac{c}{c_e} a^2 x^2\right)^{1-\frac{c_e}{R} (1+m_p \frac{b}{a}) 778.16} \quad (7)$$

$$\text{where } \frac{c_e}{c} = \frac{\frac{B}{a} (1-m_p \frac{c}{a}) + 2(\frac{b}{a})}{(1+m_p \frac{b^2}{a^2})(\frac{B}{a} + 2(\frac{b}{a}))} \quad (8)$$

Then $u = ax$ and $u_p = bx$. This is known as the linear case.

Where: A = Flow area, FT^2
 P = Static pressure, LB/FT^2
 u = Velocity of gas, FT/SEC
 u_p = Velocity of particles, FT/SEC
 T = Temperature of gas, $^{\circ}R$
 T_p = Temperature of particles, $^{\circ}R$
 m_p = LB of solids/ LB of gas
 c = specific heat at constant pressure, $BTU/LB^{\circ}R$
 c_p = specific heat of solid particles, $BTU/LB^{\circ}R$
 R = Gas constant, $FT \cdot LB/LB^{\circ}R$
 E = Drag parameter
 B = Convection heat transfer parameter
= Ratio of specific heats

The initial boundary conditions are:

$$\text{At } x=0, T=1, p=1, T_p=1, u=0, u_p=0 \quad (9)$$

The second set of boundary conditions is at the throat (section of minimum area) where the following equation must be satisfied:

$$\frac{\gamma RT}{2cu_c} = 1+m_p \left[\gamma \frac{u_p}{u} \frac{du_p/dx}{du/dx} - (\gamma-1) \frac{u_p}{u} \frac{du_p/dx}{du/dx} - (\gamma-1) \frac{c_p}{2c} \frac{dT_p/dx}{du/dx} \right] \quad (10)$$

The general method of solution is: select an initial value for a , use the linear solution from $x=0$ to $x=0.05$, use Runge-Kutta method for solution to throat ($x=0.45$), check second boundary condition, if second boundary condition is satisfied, proceed with Runge-Kutta method to exit plane of nozzle. If the second boundary condition is not satisfied, recalculate a for next iteration.

2200 Mechanical Engineering. Flow Field Study within Ejectors. It is intended to develop a program for the Illiac to calculate the iteration phenomenon between the given supersonic primary and the subsonic secondary streams within confined ducts. This has immediate application to the flow within ejectors.

This calculation will be carried out using the method of characteristics for the supersonic stream and one-dimensional flow relations for the subsonic stream. Besides the general flow relations which have to be obeyed, the pressure and the stream line directions have to be matched between the two streams. These calculations will essentially be followed by an iterative, step by step procedure.

2201T Physical Education. Analysis of Metabolic and Motivation Variables in Young Men. The problem involves the correlation analysis of a set of data ($n=32$) comprising tests of motor performance, oxygen utilization, and objective tests of motivation. K-8 is an appropriate means of obtaining the Pearson product moment r 's, together with the means and standard deviations of the variables concerned.

2202 Psychology. Personality Factors in Delinquency. The project is concerned with the improvement of measures of personality tendencies related to juvenile delinquency. A long questionnaire was administered to large numbers of delinquent and non-delinquent boys. Four separate factor analyses are now proposed. This will involve use of three library routines: KSL 2.40 for the calculation of phi coefficients (12 hours), KSL 1.20 for the extraction of centroid factors (3 hours), and KSL 1.80 for the analytic rotation of vectors to simple structure (1 hour).

2203T Civil Engineering. Dynamic Buckling of Spherical Shells. The dynamic buckling of spherical shells will be computed by a modified finite-difference procedure. Necessary data for this calculation includes the natural modes and frequencies of the shell.

2204 Digital Computer Laboratory. Control Study. As part of the check-out of Advanced Control for the New Illinois Computer a data recording machine has been built. This program converts this data to a useful form by substitutions, permutations, and other format changes in the data tape. A typical run might involve a matrix of observations of size $10^4 \times 100$, where an observation is a tape character representing a computer circuit output quantized as one of: too far negative voltage, negative voltage representing digital "0", voltage too near ground, positive voltage representing digital "1", or voltage too far positive voltage.

2205 Psychology. A Monte Carlo Method for Developing Fictitious Data for Trial of Methods of Factor Analysis. Procedures are being investigated for developing matrices of intercorrelations possessing some given structures in the variables and some random elements in the variables such that these correlation matrices will possess properties, when factor analysis is applied, which more nearly parallels the properties of correlation matrices obtained with real data than do concocted matrices using existing procedures and models. It is hoped to mechanize the procedure so as to produce a number of examples for study. One hope is to obtain material for critical study of the effectiveness of various methods of factor analysis.

2206T Psychology. Originality, Learning, and Problem-solving. This problem is concerned with an investigation of relationships between various measures of mental abilities, including measures of originality and creativity, and performance under both conventional and programmed learning situations. A set of predictor variables will first be factored over all subjects (both programmed and conventional learners). Factor scores will then be obtained for the four or five major ability factors extracted. These predictor factors will then be used to determine regression weights for predicting learning performance, separately for the two learning conditions. The resulting sets of regression

weights will then be compared to determine possible differential predictions for the two groups, as well as to determine the relative contributions of the various ability variables to performance under the two conditions of learning. The entire procedure will then be replicated with another sample of subjects, under both learning conditions, to determine the stability of the findings.

2207 Theoretical and Applied Mechanics. Stresses in a Rectangular Plate. The problem consists of finding stresses in a rectangular plate with a crack on one side. The plate is loaded by opposing concentrated forces in tension. The solution will be achieved by Finite Difference Methods in conjunction with the Airy Stress Function of Plane Elasticity. Illiac will be used to solve the linear algebraic simultaneous equations resulting from application of the Finite Difference Method.

2208 Civil Engineering. To Determine Accuracy of Data Reduction Techniques in regard to Earthquake Accelerogram Records. It is desired to study the accuracy involved in reading Earthquake Accelerogram Records by both visual and machine techniques. The results will be obtained in the form of Response Spectra.

This program treats a five degree of freedom structure by concentrating the mass of the system at five separate levels and by interconnecting these levels by springs which are mathematical equivalents of stiffness, and by a damping restraining force which is proportional to the velocity of the system.

The basic mathematical expression used is the classical differential equation of motion of a body, generalized in such a manner as to permit varying each parameter. The equation is integrated numerically once to obtain the velocity response to the input motion and once again to obtain displacements of the system.

The results of this program are given as maximum and minimum values of velocity, displacement, and acceleration.

2209 Geology. Classification of Sedimentary Rock Samples. Some 8 measurements, mostly of fossil densities, have been made on over 1000 rock samples taken from an oil well core. The variation of the measurements is thought to be caused largely by depth at the time of sedimentation, but other factors are also known to be present, and the dependence of the measurements on the depth

and other factors is thought to be highly non-linear, and in some cases non-monotonic. In an attempt to aid the investigation of these factors, the samples will be classified into about 10 groups by a minimum distance technique. The major part of the program will be a search by a simple iterative technique for the set of archetypes which minimizes the total intra-group variation.

2210T Psychology. Factor Analysis of Three Dimensional Matrices. This research project employs a factor analytic technique developed to deal with observations classifiable in three or more dimensions. A three-way matrix of data which has been previously analyzed employing traditional factor analytic techniques will be reanalyzed by means of this technique in order to compare the information yielded by this technique as opposed to traditional methods.

Illiac will be used to factor matrices derived from this data. The resulting factor matrices will be operated on to produce a matrix reflecting the intrinsic structure of the data.

2211T Psychology. Determination by P-Technique of Functional Unities of Depression. This study is an attempt to determine by means of p-technique factor analysis the various types of functional unities of depression. A single subject has been measured on 80 psychological and physiological variables concentrated in the area of depression over 160 test sessions. The problem now is to discover the psychological state factors existing in the data, using the programs listed above.

2212T Chemistry. Kinetic Isotope Effects. The problem is divided into two parts: to solve for molecular vibrational frequencies of isotopic molecules and their proposed activated complexes by matrix methods, and to solve for ratios of isotopic rate constants and equilibrium constants from the calculated frequencies.

2213 Nuclear Engineering. Model Calculations for Nuclear Reactor Kinetics. The kinetic behavior of a nuclear reactor system is determined by delayed neutron emitters and a reactivity feedback and can be described by a system of ordinary, non-linear differential equations of first order which are solved by F6. For programmed changes in excess reactivity a parameter study is made

with the main objective of fitting the results to experimental data which have been obtained from the TRIGA nuclear reactor of the University of Illinois.

Under problem number 2152 this code has already run successfully and has yielded valuable results. Further investigations with different driving functions are expected to give better information about the influence and true values of some parameters, which have not yet been determined with sufficient accuracy.

2214 Psychology. Three-way Factor Analysis, In-Basket Tests. This is an experimental try out of a method for factor analysis of three-way matrices of data. The present data involve scores of 230 individuals on 40 scoring categories in 3 situations. The computer will facilitate the matrix operations involved.

2215 Digital Computer Laboratory. Gapfilling in the Pattern Recognition Computer. A typical bubble chamber photograph consists of criss-crossing, thick, smudgy, broken lines. A code exists to thin this photograph into a network of lines of unit thickness. However before trying to recognize a pattern in this thinned photograph it is necessary to reduce its complexity as far as possible by using intelligent guesswork.

This code tries to connect up broken line segments into one long line, and to join stray lines to the dominant tracks, if this is feasible. The code is run using the pattern recognition computer simulator and falls into 5 stages: classification of points into start, finish, and junction points, measuring the length of each line segment in the photograph and storing it at both ends of the segment, finding the directions in which "whiskers" should be grown from the ends of line segments, growing of whiskers from the end of line segments proportional to the length of the line behind the endpoint (whiskers are not grown to their maximum permitted length if a shorter length suffices to fill the gap or join a stray line), and the removing of "whiskers" which have been grown but do not succeed in filling a gap.

2216T Psychology. Measures of Self-Evaluation. The purpose of this problem is to investigate the mutual relationship of three measures of self-evaluation (for both self perception and ideal-self perception) for pre-adolescent boys

and to determine the relationship of each of these measures to behavioral adjustment, I.Q., and academic performance. One method of scoring the self-evaluation instruments is to obtain a correlation between self rating and ideal-self rating over the several test items for each subject. These correlation scores along with other normative scores and scores for I.Q., behavioral adjustment, and academic performance will then be intercorrelated to determine the extent to which they are interrelated. Illiac will be used for obtaining both the correlation scores for individual tests and the inter-correlation of all variables in the study.

2217 Forestry. Small Woodland Owners. The Forestry Department and the National Department of Agriculture are particularly interested in discovering why small holdings of timber are not being exploited for economic gain particularly since 60% of the national resources of timber is held in this particular way.

This study is directed toward measuring over 325 pertinent variables including personality data to systematize and explore the behavior of small woodland owners. A core set of variables which are excessive in duplications and additional categories are to be factor analyzed, utilizing centroid and oblique rotation techniques. Two independent samples have been taken to test for replicability of the factor structures obtained. The additional variables will be added by Dwyer extension to yield a final analysis which included the entire repertoire of measured variables. The results will be reported at different phases to acquaint the Government and private persons with the nature of the problem that is to be solved.

2218 Economics. Bank Loan-Offer Function. This problem is designed to test the importance of certain variables in determining the allocation of bank credit. The general hypothesis is that a bank considers the total customer relationship when it allocates credit. Aspects of credit other than those which would be considered when buying securities are evaluated for their influence on credit allocation.

Initially, a series of multiple regressions will be run. Loan size will be the dependent variable with maturity, past profits on the customer's account, worth/debt of the firm, firm worth/debt, industry worth/debt,

interest rate, percentage of loan secured, number of other banks, and firm's assets as the independent variables. A multiple regression will be run using all of the variables. Then, additional multiple regressions will be run in which independent variables are successively eliminated in order to test the significance of each of the eliminated variables. Then, a new set of multiple regressions will be run with dollar years of credit as the dependent variable. All of the independent variables except maturity will be used, and the above process will be repeated.

Upon completion of the above analysis, some other estimating techniques may be investigated.

The data is drawn from a randomly selected cross-section sample of fifty customers who applied for credit during May of 1962 at a large commercial bank in Chicago.

Table I shows the distribution of Illiac machine time for the month of July. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min	
Scheduled Maintenance	57:00	
Unscheduled Maintenance	29:51	
Drum Engineering	15:52	
Leapfrog	18:16	
Library Development	1:45	
Classes	40:25	
Instruction	:25	
Demonstrations	1:45	
Wasted	:07	
	<hr/>	
		165:25

Use by Departments

Agricultural Economics	74:06	
Agronomy (00 51 65 330 38)	:52	
Astronomy	7:59	(3:40)
Bureau of Educational Research (PH-M1839)	1:19	
Chemistry (AEC 1142)	:04	
Chemistry	65:17	(2:04)
Civil Engineering	67:36	(1:27)
Coordinated Science Lab. (DA-36-039-SC56695)	59:27	
Digital Computer Lab. (09-22-55-970)	69:28	
Digital Computer Lab. (US TR AEC-1018)	6:04	
Digital Computer Laboratory	2:34	
Economics	3:26	
Electrical Engineering (NASA NSG 24-59)	4:42	

Electrical Engineering (AF 7043)	1:24	
Electrical Engineering (SC 85173)	:04	
Electrical Engineering (NSFG 19005)	3:58	
Finance (IHR 71)	:14	
Geological Survey	1:37	(:2)
Geology	:35	
Inst. for Communications Res. (44-28-20-378)	4:38	
Inst. for Communications Res. (USPHM-3941)	1:54	
Institute for Communications Research	1:51	
Institute for Research on Exceptional Children	:09	
Mathematics	14:30	
Mechanical Engineering (NSFG 9725)	:11	
Mechanical Engineering	7:16	
Mining and Metallurgical Eng. (TRUS AF 6770)	:25	
Nuclear Engineering	:33	
Office of Instructional TV (OE 7-11-107.00)	8:25	
Physical Education	:43	
Physics (AF 49(638)661)	:52	
Physics (NONR 1834(05))	:49	
Physics (NSFG-17428)	:28	
Physics	:35	
Psychology (MD 2060)	:31	
Psychology (ML774)	13:32	
Psychology (ONR-1834-36)	:24	
Psychology (ONR-46-32-66-362)	:43	
Psychology (M2509)	4:36	
Psychology (US NONR 1834(39))	1:46	
Psychology	80:12	(:2)
Sociology	9:23	
State Water Survey	20:01	
Theoretical and Applied Mech. (NOBS 72069)	:43	
Theoretical and Appl. Mech. (DA-01-021 ORD11878)	13:04	
Theoretical and Applied Mech. (DA-11-070-508ORD)	:40	
Theoretical and Applied Mechanics (ARMY ORDGL48)	:16	
Theoretical and Applied Mechanics	:53	
	<u>578:34</u>	(7:5)
	<u>744:00</u>	

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table

has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Punch	1
Reader	5
Memory	4
Drum	6
Power Supplies	4
Input-Output	1
Unknown	<u>5</u>
TOTAL	26

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/62	24:00	:00	:00	0	(1) Punch #2 failed.	:00	1:38	0
7/2/62	21:37	:10	2:13	1		:00	:24	0
7/3/62	21:02	:00	2:58	0		:00	:52	0
7/4/62	20:01	3:59	:00	1	(1) +150 v fuse in power supply blew.	:00	:32	0
7/5/62	21:30	:00	2:25	0		:05	:54	0
7/6/62	18:15	3:15	2:30	2	(1) Tube loose in socket greengate chassis 2-26. (2) Leapfrog, unknown.	:00	1:54	1
7/7/62	24:00	:00	:00	0		:00	:25	0
7/8/62	20:48	3:12	:00	2	(1) Pos. 2-27 failing memory. (2) Drum failure.	:00	:00	0
7/9/62	21:05	:05	2:50	1	(1) Unknown.	:00	:30	0
7/10/62	20:00	1:30	2:30	1	(1) Pos. 2-23 memory bad.	:00	:30	0
7/11/62	20:18	1:23	2:19	1	(1) Brake on reader "J" bad.	:00	:29	0
7/12/62	20:51	:45	2:24	1	(1) Filament voltage out of adjustment.	:00	1:02	0
7/13/62	20:30	1:00	2:30	1	(1) Reader "K" bad.	:00	:00	0
7/14/62	21:57	2:03	:00	1	(1) Failure due to marginal voltage on power supplies.	:00	:00	0
7/15/62	23:30	:30	:00	2	(1) Reader "J" bad. (2) Reader "K" bad.	:00	:21	0
7/16/62	21:07	:23	2:30	2	(1) Reader "G" bad. (2) Memory failure 2-1.	:00	:49	0
7/17/62	21:38	:34	1:48	1	(1) 300 v power supply dropped out.	:00	:12	0
7/18/62	21:33	:00	2:27	0		:00	:50	0
7/19/62	19:33	:54	3:33	2	(1) Automatic output switch on console not working properly. (2) Unknown.	:00	:55	0

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/20/62	21:37	:00	2:23	0		:00	:00	0
7/21/62	24:00	:00	:00	0		:00	:00	0
7/22/62	24:00	:00	:00	0		:00	:13	0
7/23/62	20:41	:08	3:11	1	(1) Unknown.	:00	:41	0
7/24/62	19:56	:58	3:06	1	(1) Drum failure.	:00	:19	0
7/25/62	20:46	:01	3:13	1	(1) Unknown.	:00	:40	0
7/26/62	20:42	:00	3:18	0		:00	:58	0
7/27/62	17:56	3:04	3:00	1	(1) Drum failure.	:00	1:10	0
7/28/62	19:53	4:07	:00	2	(1) Drum failure. (2) Drum failure.	:00	:00	0
7/29/62	24:02	:00	:00	0		:00	:00	0
7/30/62	18:32	1:56	3:32	1	(1) Drum failure.	:00	:32	0
7/31/62	20:12	:00	3:48	0		:00	:00	0
TOTALS	655:30	29:57	58:28	26		:05	16:50	1

PART III
INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATION

International Business Machines 650 Usage

During the month of July, specifications were presented for thirteen problems. This list does not indicate how the International Business Machines 650 was used, because large amounts of machine time may have been consumed by problems with numbers less than 423'. Numbers followed by T are for theses.

423' Mechanical Engineering. Analysis of Wind Speed and Directions on House Infiltration Rate. An analysis of covariance will be used to analyze the effects of wind speed and direction in respect to infiltration rates (air leakage measured by indoor-outdoor temperature difference). The infiltrate measures were taken on 22 tri-level houses at each level.

424'T Business Administration. Impediments to Interregional Flow of Mortgage Funds. A two-stage multiple regression analysis routine will be used to establish functional relationships between out-of-state aggregate mortgage investment and certain economic, demographic, and legal variables. Simple correlations, means, and standard deviations are obtained in the first stage. The correlation matrix is the input for the second stage. The second stage computes multiple regression coefficients with the successive addition of independent variables.

The hypothesis is that certain elements of risk, as measured by economic, demographic, and legal variables are associated with mortgage lenders' decisions as to the geographic area in which mortgage funds are placed. For example, unemployment, unfavorable mortgage investment laws, and large numbers of minority groups influence investors not to place as large amounts of mortgage funds in those states as in other states.

425' Physics. Deuteron Compton Effect. The problem consists of a measurement of the differential cross section of elastic scattering by deuterons of photons in an energy range of 180-270 Mev. The experimental measurement was performed at the University of Illinois 300 Mev betatron employing a liquid

deuterium target; spark chambers and particle detection counters are used to visually display the scattering events. The spark chamber tracks as well as an oscilloscope trace displaying the pulses from the detection counters are photographed on 35mm film. This film is read on a semi-automatic film reading device (Hydel) and information on the film is punched on IBM cards. The IBM 650 is to be used to analyze the data on the cards in order to select the Compton events from the various contributory kinds of background and to punch out the important kinematical and dynamical parameters measured and calculated from the data on the cards. The program is mostly a logical one, with most of the mathematics consisting of simple arithmetical calculations and tabulations.

426¹ Electrical Engineering. Antenna Phase Center Displacement. In the measurement of the characteristics of antennas it is proposed to construct a set of curves and tables that will allow the determination of the displacement of the phase center from the center of rotation of the antenna. To construct these working curves it is necessary to solve the equation

$$R = \sqrt{|A|^2 + B^2 - 2AB \cos \phi}$$

$$\phi = 2\pi x (1 - \cos \theta)$$

$$B = 1.1$$

for	$0 \leq A \leq 1$	in .1 steps
	$0 \leq \theta \leq 90^\circ$	in 10° steps
	$0 \leq x \leq .5$	in .01 steps

This solves for the voltage (R) which is the vector sum of the complex voltages A and B. A is the voltage (signal) received from the antenna, B is a reference signal and ϕ is a function of the displacement of the antenna.

427¹ Agronomy. Effect of Shade on Corn Yields. Two single cross corn hybrids are being tested under full sunlight and 90% shade (giving the shade for 3 or 6 weeks of time) at different stages of time in the corn plants' development. Different characters are then measured including yield of grain per plant, total plant weight, weight of 100 kernels, percentage moisture, days to silk, days to tassel, ear height etc.

Analysis of variance is then to be used to see if significant differences are present in the characters measured relative to hybrids, stage of shading, and length of shade period.

428' Agronomy. Forage Yields and Prussic Acid Content. Three Sudan Grass and three Pearl Millet varieties are being combined along with 3 ratios of the combinations. These combinations were planted with and without soybeans.

Yields will be determined as will prussic acid content of the forage. Analysis of variance will be run to determine if there are significant differences among the treatments.

429' Agriculture Engineering. Machinery Selection. This routine will solve one equation for the selection of the optimum size of farm implement as a function of 3 variables:

acreage (20-values)
price of implement (10-values)
value of crop (12-values)

The routine will print out tables for the determination of the implement best suited for the farm depending on the above three items.

430' Physics. Least Squares Mean Fit of Track. The object of the program is to check the performance of the bubble chamber track-measuring machines. The machine measures a straight line track of various angles to the horizontal. A fit of the resulting (x_i, y_i) data to a line

$$A_x + B_y + C = 0$$

is made.

The deviations

$$d_i = Ax_i + By_i + C$$

are calculated and the mean absolute and maximum deviation are found.

431' Digital Computer Laboratory. Full Wave Rectifier. This problem consists of an investigation of the effects of loading on the output of a full wave rectifier with a single reactive section filter. The forcing function is

a steady state sinusoid, for which the output voltage and the choke current are known as Fourier series. However, these series solutions are only valid for positive values of the choke current.

The first part of the problem is to find the critical load resistance such that the minimum value of the Fourier series for the choke current is zero. This will be done by iteration, with resistance as the independent variable.

The second part of the problem is to obtain tabular solutions of the voltage and current waveforms versus time, for values of resistance less than, equal to, and greater than the critical resistance. This will be done by evaluating the Fourier series, where valid. Where the series solutions are invalid, the current is zero and the voltage is a known exponential decay function.

432^o Agronomy. Determination of Number of Samples for Soil Testing. Two 40-acre fields have been sampled on a 16x16 grid yielding 256 samples per field. The following determinations have been made per sample: p^H (soil acidity), P_1 (available phosphorous), P_2 (total phosphorous) and K (potassium). A program has been written to combine varying numbers of these samples for a given field and determine the optimum number of samples needed for sampling such a field relative to each of the four different determinations (p^H , P_1 , P_2 , and K) made on each of the soil samples.

433^o Animal Science. Ovulation Rate and Embryo Survival in Swine. The purpose of the research is to study the effect of various levels of energy on the ovulation rate and embryo survival in swine and to see if a high level of energy induces greater ovulation as compared with the usual maintenance energy level and also if this high energy is beneficial to embryonic mortality.

The 650 will be used to analyze the combined data including a number of variables (ovulation sites, total and viable embryos, weight change in the gilts, time on the experiment and percentage survival).

434^o Physics. Magnetic Tape Load. This routine is to be used to load data cards on magnetic tape for the CDC 1604 computer.

435' Horticulture. Effect of Various Levels of Nitrogen and Phosphorous on Roses Grown at Three Plant Spacings. "Better Times" roses were planted at 3 spacing in the greenhouse bench. Spacings of 3, 4, and 6 plants per row across the bench were used. The spacings were assigned to these plots at random. The rose plants were grown at three nitrogen levels (60, 80, and 100 ppm N) and two levels of phosphorous (12 and 18 ppm P). Potassium and calcium were held constant. These nutrient levels were assigned at random. The treatments were replicated four times.

Rose flowers were harvested daily for 13 months. The number of flowers and their stem length were recorded for each plot as well as the number of culls.

This 3x3x2 factorial split-plot design will have analysis of variance made by quarter and by month on production and culls per square foot for each spacing at the various nutrient levels.

Production will be analyzed as to marketable 3-inch intervals of stem length. The various interactions will also be analyzed.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of July.

TABLE I'

		Hrs:Min
Scheduled Engineering		15:15
Unscheduled Engineering		17:18
Air Conditioning		:14
Tape Test		1:50
CDC Preparation		13:05
DCL Library		3:04
Log Summary		:29
Classes		5:07
Mechanical Engineering	<u>5:07</u>	
Demonstrations		3:14
Instruction		:59
Wasted		<u>2:42</u>
		63:17

Use by Departments

Agricultural Engineering	1:31
Agronomy	6:07
Chemistry	21:49
Civil Engineering	41:11
Digital Computer Laboratory	:23
Economics	6:32
Education	3:46
Electrical Engineering	33:16
Food Technology	:09
Graduate College	8:31
Graduate School of Business	1:34
Home Economics	:08

Mechanical Engineering		6:43
Mining and Metallurgical Engineering		:18
Physics		29:48
Statistical Service Unit		82:46
Bursar's Office	5:59	
Business Office	26:24	
DHIA	37:39	
Education	3:54	
Finance	4:26	
Mechanical Engineering	:44	
Student Counseling	<u>3:40</u>	
State Water Survey		4:03
Theoretical and Applied Mechanics		<u>13:19</u>
		<u>261:57</u>
		<u>325:14</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for July.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

Air Conditioning		1
Belt replaced	<u>1</u>	
533 Read Punch		4
Lost all power	1	
Reads incorrectly	1	
Punches incorrectly	1	
Read side adjusted	<u>1</u>	
407 Accounting Machine		7
Prints incorrectly	5	
Does not print at all	<u>2</u>	
650 Console and Magnetic Drum		4
Multiple and/or blank bits	2	
Drum belt	<u>2</u>	
652 and 727 Tape Control and Tape Unit		3
Fuse	2	
Reads incorrectly	<u>1</u>	

653 Floating Point, IAS, and Index Registers		2
False storage unit lights	<u>1</u>	
Core operating improperly	<u>1</u>	
655 Power Supply		3
Fuse	<u>3</u>	<u>—</u>
TOTAL		24

TABLE III

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
7/2/62	12:59	3:55			0		(1) Tape unit fails to read correctly.
7/3/62	16:51			:05	1		(1) Fuse blew in 655.
7/5/62	16:15		:50	:05	1		(1) 533 lost all power. Burned relay.
7/6/62	15:02		2:00	:05	5		(2)-(3) Fuse blew in 655. (4) 407 not printing digit 6 of word 8. Bad tube.
							(5) Accumulator and distributor picking up multiple bits. Reduced 150 v AC voltage.
7/9/62	13:00	4:10			0		
7/10/62	14:23		2:19	:13	1		(1) 407 printing position 8 of word 7 incorrectly. Bad tube.
7/11/62	17:25			:05	0		
7/12/62	17:05			:10	0		
7/13/62	16:16			:12	1		(1) 407 not printing col. 79 using the 80-80 board. Defective brush.
7/16/62	13:32	3:30			0		
7/17/62	16:47			:35	0		
7/18/62	17:13			:10	0		
7/19/62	14:19		2:26	:12	5	:14	(1) Drum belt broken. Replaced. (2) Belt on air conditioning unit replaced (3) Multiple bits when reading. Shorted brushes found in 533 read. (4) Sound made by 533 read changed. The armature was hitting the coil. (5) Fuse blew in 652.
7/20/62	11:48	3:40	:22	:05	1		(1) Fuse blew in 652.

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI- TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
7/23/62	11:47		:13	:05	2		(1) Fuse blew due to a bad drum belt. (2) 407 not printing digit 2 in word 9. Bad tube replaced.
7/24/62	11:17		:37	:05	1		(1) 533 not punching digit 6 of word 5. Bad tube replaced.
7/25/62	11:01		1:28	:06	2		(1) 407 would not print either on line or off line. Stacker stop switch stuck. (2) 407 printing and spacing incorrectly. Cables on inner gate hitting relays on rear gate.
7/26/62	12:05			:05	0		
7/27/62	12:56	(4:00)*	(3:30)*	:06	0		
7/30/62	8:43		2:54	:18	3		(1) 407 would not print on line or off line. Dirty circuit breaker. (2) False storage unit light. (3) Core not operating properly. Multiple bits, blank bits and false storage unit lights.
7/31/62	9:01		4:09		1		(1) Accumulators and index registers got blanks and multiple bits at random. Loose diode in 650.
TOTALS	289:45	15:15	17:18	2:42	24	:14	*Engineering done on some machine but the main 650 continued to operate.

PART IV
INSTRUCTIONAL USE OF COMPUTERS

During the month of July, specifications were presented for three new problems.

82 Mathematics 295. Problem 1. Illiac. Sexadecimal Multiplication Table. The students are asked to write their names and course number using 92 orders and then to compute and print a 15x15 matrix of two digit sexadecimal products using as multipliers the sexadecimal digits 1, 2, ..., K, S, N, J, F, L.

83 Mathematics 295. Problem 2. Illiac. Solutions of a Quadratic Equation. The solutions of a quadratic equation, $AX^2 + BX + C = 0$, may be found by using the quadratic formula:

$$X = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

We wish to design a program which will calculate a set of X_{ij} ($i = 1, 2$; $j = 1, 2..P$).

84 Mathematics 295. Problem 3. Illiac. Sine-Cosine Table. This problem is the first problem involving the calculation with fractions.

The problem is to print a table of values for $\sin \frac{\pi}{2} X$ and $\cos \frac{\pi}{2} X$ from -0.5 radians to +0.5 radians with increments of 0.1 radians. The students are expected to evaluate the following polynomial approximations:

$$\sin \frac{\pi}{2} X = C_1 X + C_3 X^3 + C_5 X^5 + C_7 X^7 + C_9 X^9$$

where $C_1 = 1.57079631847$, $C_3 = -.64596371106$, $C_5 = .07968967928$, $C_7 = -.00467376557$, and $C_9 = .00015148419$, and

$$\cos \frac{\pi}{2} X = \sin \frac{\pi}{2} (1 - |X|).$$

PART V
CONTROL DATA CORPORATION 1604

During the month of July specifications were presented for nine new problems. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 21. Numbers followed by T are for theses.

21 Nuclear Engineering. Square Well Resonance. This program calculates the "exact" solution for the resonance escape probability and collision density for a resonance absorber with arbitrary resonance width and spacing in an infinite medium.

This problem represents part 1 of a 4 part computer program planned for the IBM 7090. The time to be used now is needed to check this part of the code (each part will be checked separately) and also to obtain preliminary information necessary for the proper construction of later sections. Thus, in addition to checking several numerical calculations will be run.

The method of solution uses only standard library routines.

22 Civil Engineering. Investigation of Joint Forces in Multibeam Bridges. The problem involved is solved by writing a series of Fourier terms to describe the joint forces. Up to 21 simultaneous equations must be generated and solved. The solutions to these equations are then processed by an asymptotic procedure to get final joint forces.

23 Civil Engineering. Dynamic Spherical Stresses. The problem is to determine the stresses around a spherical cavity in an elastic medium when subjected to an incident pressure wave. The solution is found by superimposing stresses caused by outgoing waves originating at the center of the sphere, and the incoming incident stresses.

The outgoing waves are expressed in an infinite series containing spherical harmonic functions, and the incident pressure wave is expanded in an infinite series by the use of the same spherical harmonics. Satisfying known boundary conditions results in two simultaneous linear differential equations for each mode of the series.

The computer is used to solve these differential equations by an iterative method, and compute the stresses for each mode at various points on the spherical surface as a function of time.

24 Civil Engineering. Endblock (Prestressed Concrete). A finite difference method is to be used to solve $\nabla^4 F = 0$ in a rectangular region.

25 Civil Engineering. Effect of Column Capital Size and Beam Stiffness on the Deflections of Elastic Plates. The differential equation governing the relationship between applied load and the resulting deflections of medium-thick elastic plates is

$$\frac{\partial^4 w}{\partial x^4} + \frac{2\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = q/D$$

where w is the deflection normal to the plane of the plate, x and y are a set of orthogonal coordinate axes, q the intensity of uniform load, and D a measure of the stiffness of the plate.

For certain types of boundary conditions closed form solutions to the above equation may be developed. However, for the case where the plate is supported on elastic beams which in turn are connected to columns having a finite size, no closed form solutions are available. Therefore, in order to find solutions to this problem it is necessary to use the method of finite differences in conjunction with a small grid spacing. The resulting large number of simultaneous equations may be practicably solved only with the aid of a high-speed computer.

It is proposed to investigate the effects of different column sizes and different ratios of beam to slab stiffness with the aid of the 1604 computer. A program will be used which will generate simultaneous equations by applying various difference patterns to the proper points on a mathematical model of a plate. A subroutine will be used to solve the resulting matrices. The matrices will vary in size from 46 equations to 150 equations.

26 Statistical Service Unit. Subroutine Checking for IBM 7090 Programs. 1604 time is needed to check accuracy and relative timings of alternate methods for subroutines which are expected to be used repeatedly in the development

of IBM 7090 programs. Two specific applications are now programmed:

- i) Subroutine for Eigenvalues and Eigenvectors by Jacobi's method and also Given's method;
- ii) Subroutine to compute a matrix inverse by Faddeeva's method and also by Dickman's factor method.

In addition to checking the above programs using a fixed matrix for which results are known, it is desirable to further test using alternative size matrices in order to assure general applicability of the subroutines.

27 Chemistry and Chemical Engineering. Effect of Contact Angle on Bubble Growth. The study of vapor bubbles growing in supersaturated liquids has its origin in the study of a number of chemical engineering problems. Thus far, however, theoretical predictions have required a large number of assumptions, some of them questionable, in order to get a solution to the problem. At the present time it is hoped to determine the validity of the assumption that the system has spherical symmetry by comparing the results with those to be calculated for a system slightly closer to reality.

Mathematically, the problem has been reduced to the solution of two elliptic second order partial differential equations in two independent variables and two dependent variables. The coefficients are themselves variable, and involve trigonometric functions of one of the independent variables. The usual finite difference methods may be used to approximate these equations by difference equations which may be solved by an iterative technique.

28 Agriculture Engineering. Laminar Flow in Partly Filled Sewers. It is desired to determine the laminar velocity distribution in a partly filled sewer. The boundaries are defined by a unit circle and a free surface at any depth Y from the extreme bottom of the sewer. The computer is to be used to compute a rectangular network of grid points in the region described; assign initial trial values of the function describing the phenomenon to these points; then apply an iteration procedure to each point in turn until a pre-determined accuracy is obtained. The output from the computer is to consist of a record of the input quantities, (i.e., depth of flow and desired accuracy parameters), information

concerning the grid spacing and irregular grids at the boundary and the value of the function at each node. (The program anticipates a maximum of about 2000 nodes).

The basic equation describing the flow reduces to a Poisson equation. This equation is to be solved in finite-difference form for each depth of flow investigated.

29 Physics. Optical Scattering. The aim is to work out the properties of a model for the interaction between charge carriers and optical mode vibrations in polar crystals. Drift and Hall mobilities are calculated as functions of two variables (temperature and magnetic field), by solving an integro-differential transport equation. This is done by expanding the unknown function as a sum of given functions and determining the coefficients from a system of linear algebraic equations. This leads to inversion of matrices.

Mathematically, the problem is in the end reduced to inverting and multiplying several matrices. The elements of the starting matrices are functions of the independent variables, which are supposed to span the regions of experimental interest.

The 1604 would be used to evaluate the elements of the starting matrices (polynomials times tabulated Bessel functions) for the different values of the independent variables and, in each case, to perform with the matrices the operations indicated above.

CDC 1604 TIME DISTRIBUTION July, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Astronomy	3:40			3:40
Chemistry	2:04	16:06		18:10
Civil Engineering	1:27	14:07		15:34
Electrical Engineering		1:22		1:22
Geological Survey	:23			:23
Nuclear Engineering		:05		:05
Physics		15:57		15:57
Psychology	:21			:21
Statistical Service		:37		:37
Maintenance			1:43	1:43
TOTALS	7:55	48:14	1:43	57:52

PART VI
GENERAL LABORATORY INFORMATION

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full- time</u>	<u>Part- time</u>	<u>Full-time Equivalent</u>
Faculty	11	3	12.5
Research Associates	9	0	9.0
Graduate Research Assistants	18	13	24.6
Graduate Teaching Assistants	0	2	1.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>41</u>	<u>17</u>	<u>53.1</u>
TOTAL	86	35	107.2

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

Physics

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TECHNICAL PROGRESS REPORT

- PART I - CIRCUIT RESEARCH PROGRAM
- PART II - DATA REDUCTION METHODS
- PART III - ILLIAC USE AND OPERATION
- PART IV - IBM 650 USE AND OPERATION
- PART V - 7090-1401 COMPUTING SYSTEM
- PART VI - CONTROL DATA CORPORATION 1604
- PART VII - GENERAL LABORATORY INFORMATION

August, 1962

PART I
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

Sergio Ribeiro is carrying out experiments to test the assumptions of the asymmetric flipflop theory reported here over the last several months. Results so far are encouraging.

Tohru Moto-Oka investigated the large-signal behavior of the transmission line tunnel diode oscillator. Comparison is made with the small-signal theory discussed in the April progress report.

Henry Guckel has looked into the 2N711 emitter follower oscillator problem and has designed a reasonably effective suppressor. A high-frequency jig of new design has been completed. Progress in the theory of intercoupled distributive systems is particularly promising; a generalized method of transformer design for tunnel diode logic has been found.

Thomas Burnside reports on an indicator circuit to be used in the output of the statistical analyzer.

2. The Asymmetric Flipflop

Laboratory tests whose purpose is to study the errors involved in the approximations made in the solution of the (non-linear) circuit equation are under way.

Since our mathematical model, as a first approach to the problem, assumes the transistors to be instantaneous devices (with transition speed limited by the passive network), a "slow" flipflop is being tested, with physical capacitors connected in parallel with the (much smaller) parasitic input and output capacitances. This serves also to approach the mathematical model, where such capacitances are supposed fixed, when actually they are non-linear functions of stored charge.

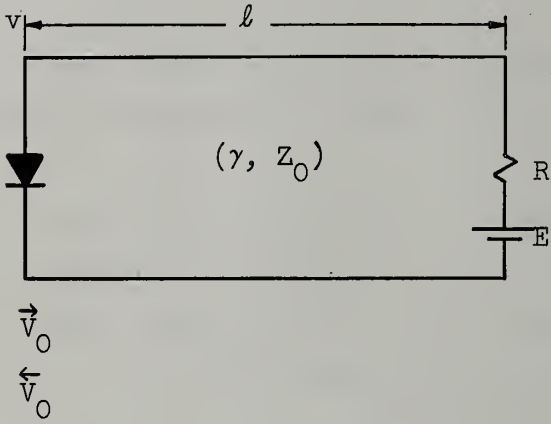
Agreement between experiment and theory has been good; experimental results so far indicate the approximations to be legitimate in any practical

circumstance. Such experimental results together with corresponding theoretical results will be presented when experiments are completed.

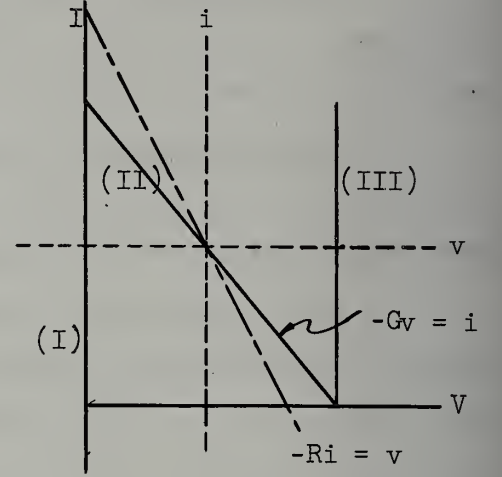
(Sergio Ribeiro)

3. A Large Signal Theory of the Transmission Line Type Tunnel Diode Oscillator

The circuit equation of the oscillator shown in Figure 1 is as follows, as mentioned in a former report.



(a)



(b)

Figure 1

$$v = \vec{V}_0 + \overleftarrow{V}_0 \quad (1)$$

$$\overleftarrow{V}_0 = \rho \epsilon^{-2st_0} \vec{V}_0 = \frac{R - Z_0}{R + Z_0} \epsilon^{-2st_0} \vec{V}_0 \quad (2)$$

$$\left. \begin{aligned} v &= -E && \text{in (I)} \\ \frac{dv}{d\tau} + (1 - GZ_0)v &= 2\overleftarrow{V}_0 && \text{in (II)} \\ v &= E && \text{in (III)} \end{aligned} \right\} \quad (3)$$

where $\tau = \frac{t}{Z_0 C}$, $t_0 = \sqrt{\mu \epsilon \ell}$ and C is the shunt capacitance of the tunnel diode.

If it is assumed that the switching time of the tunnel diode is negligible as compared to the transmission time t_0 , the following discussion is apparent. At first, it is assumed that the tunnel diode is switched from $-E$ to E at $t = 0$ and \bar{V} is V_1 for $0 \leq t < 2t_0$ where V_1 must be larger than $(GZ_0 - 1)E$. Then for $2t_0 \leq t \leq 4t_0$, $\bar{V} = \rho(E - V_1)$ and v remains at E if $(GZ_0 - 1)E + 2\rho(E - V_1) \geq 0$. For $4t_0 \leq t < 6t_0$, $\bar{V} = \rho \left\{ E - \rho(E - V_1) \right\}$ and v remains at E if $(GZ_0 - 1)E + 2\rho \left\{ E - \rho(E - V_1) \right\} \geq 0$. In general, for $2(m - 1)t_0 \leq t < 2mt_0$,

$$\bar{V} = - \sum_{n=1}^{m-1} (-\rho)^n E + (-\rho)^{m-1} V_1$$

and v remains at E if $(GZ_0 - 1)E + 2\bar{V}_0 \geq 0$.

If it is assumed that

$$-E \sum_{n=1}^{m-1} (-\rho)^n + (-\rho)^{m-1} V_1 \geq \frac{-E}{2} (GZ_0 - 1) \quad (4)$$

and
$$-E \sum_{n=1}^m (-\rho)^n + (-\rho)^m V_1 < \frac{-E}{2} (GZ_0 - 1) \quad (5)$$

the tunnel diode is switched from E to $-E$ at $t = 2mt_0$. This behavior is illustrated in Figure 2.

A steady state condition is given by

$$-V_1 = -E \sum_{n=1}^m (-\rho)^n + (-\rho)^m V_1$$

or
$$V_1 = \frac{-\rho E}{1 + \rho} \frac{1 - (-\rho)^m}{1 + (-\rho)^m} \quad (6)$$

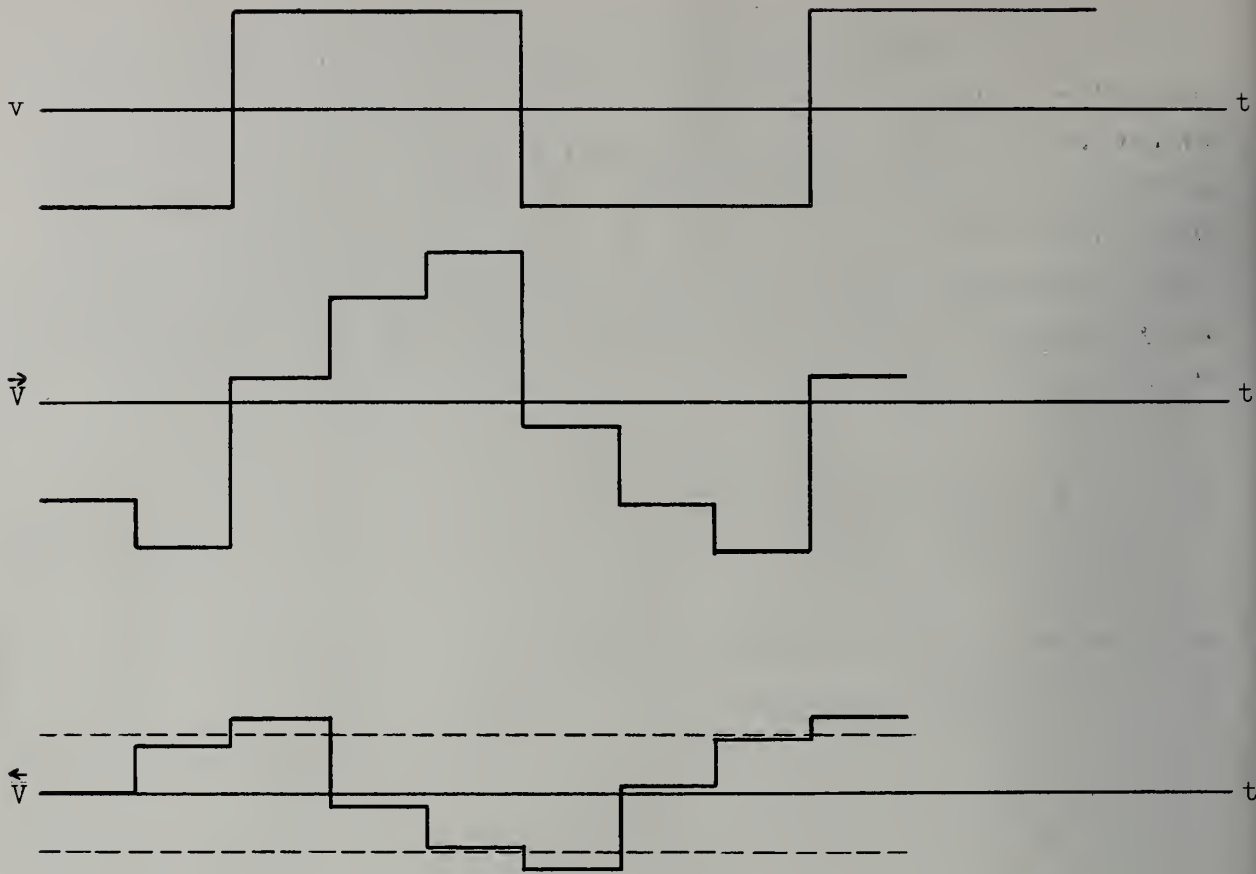


Figure 2

In order to get maximum oscillation frequency, m must be one. That is

$$\frac{-2\rho}{1-\rho} > GZ_0 - 1$$

or

$$2 > Z_0 \left(G + \frac{R}{Z_0^2} \right) \quad (7)$$

Therefore, Z_0 must be selected in the following range.

$$\frac{1}{G} < Z_0 < \frac{1 + \sqrt{1 - GR}}{G} \leq \frac{2}{G} \quad (8)$$

If \bar{V} is given by $\frac{-\rho}{1-\rho} E$, the switching time of the tunnel diode is gotten from the following equation:

$$\frac{dv}{d\tau} = av - \frac{2\rho}{1-\rho} E$$

where $a = ZG - 1$.

At $\tau = 0$, $v = -E$, then

$$v = \left\{ \frac{-2\rho}{a(1-\rho)} (\epsilon^{a\tau} - 1) - \epsilon^{a\tau} \right\} E$$

At $\tau = \tau_1$, $v = E$, then

$$a\tau_1 = \log \frac{-2\rho + a(1-\rho)}{-2\rho - a(1-\rho)} \quad (9)$$

Then the maximum oscillating frequency f_m is expected in the following range:

$$\frac{G}{4C} > \frac{a}{2 \log \frac{-2\rho + a(1-\rho)}{-2\rho - a(1-\rho)}} \frac{1}{Z_0 C} > f_m > \frac{a}{4 \log \frac{-2\rho + a(1-\rho)}{-2\rho - a(1-\rho)}} \frac{1}{Z_0 C} \quad (10)$$

As far as the small signal theory is concerned, the maximum oscillating frequency f_m is given by

$$f_m = \frac{G}{2\pi C} \frac{-2\rho}{1+\rho^2} \quad (11)$$

and this value seems to be included in the range of Eq. (10).

It is worthwhile to mention that f_m becomes $\frac{1}{2\pi} \frac{-2\rho}{1+\rho^2} \frac{G}{C}$ only under some restriction. Since $G_0 Z$ must be $\frac{1+\rho^2}{1-\rho^2}$ and at the same time $G_0 Z$ must be less than $\frac{-2\rho}{1-\rho} + 1$, it follows that $-\rho < 0.5$ is a condition that Eq. (11) is satisfied.

(T. Moto-Oka)

4. Emitter Follower Oscillations

The 2N711 series and their equivalents were investigated for emitter follower stability. Compared to the GF45011 this transistor shows a slightly larger negative real part of the input impedance and becomes unstable at a lower frequency. The spread obtained for 12 selected transistors was found to be large. A compensator was designed by selecting a different core material. However, it is quite obvious that not all transistors can be made stable. It is suggested that only the low alpha units be used for emitter followers.

The final form of the report on emitter follower stability was handed in.

5. Tunnel Diode Work

A second high frequency jig was designed for tunnel diode measurements. It was then used to obtain characteristics for all available 5 mA tunnel diodes. This data was evaluated for spreads, etc. The average negative resistance was found to be 20 ohms.

Theoretical consideration of intercoupled distributive systems was continued. It was found that a general system of n parallel conductors can be treated and that certain theorems can be established for such a system. A new matching condition for flat performance of a transformer was found. The theories are being tested experimentally in a jig. Results will be given in report form.

(H. Guckel)

6. Statistical Analyzer

An indicator light circuit has been designed to show the binary number stored in the counters when it is connected to the output of the flipflops. The indicator circuit, shown in Figure 3 has an input impedance of 100K so it will not load the flipflop. Because of the high input impedance two stages are used to amplify the current enough to light a small bulb.

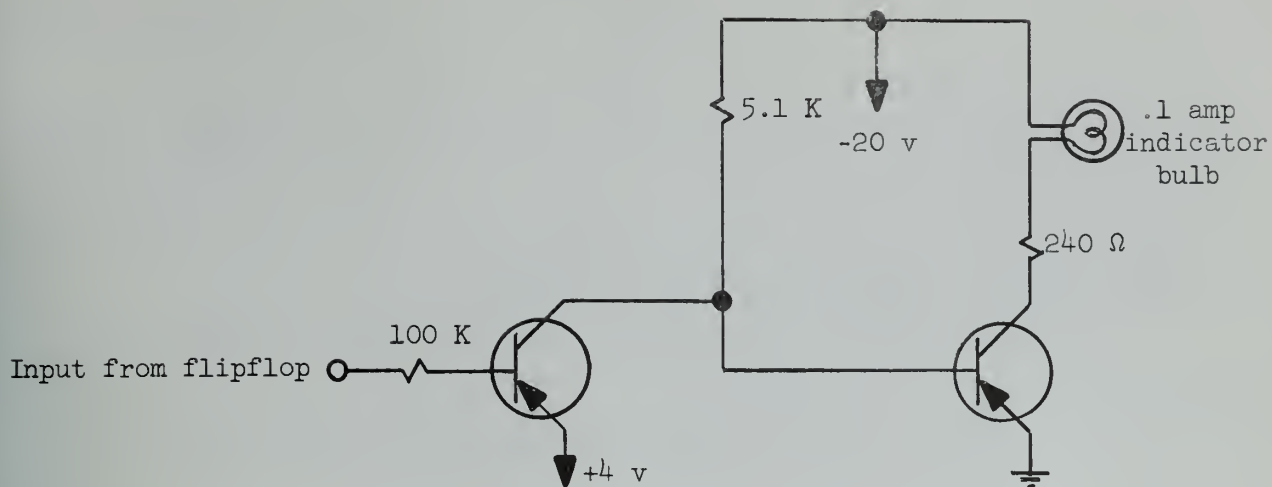


Figure 3 State Indicator Circuit for Counter

For the flipflop, a logical "1" is represented by +6 volts while a logical "0" is represented by 0 volts. When the input to the state indicator is +6 volts, the first transistor will not conduct and the second one will, causing the bulb to light and indicating a logical "1". When the input is 0 volts, the first transistor conducts but the second one does not, indicating a logical "0".

(Thomas Burnside)

PART II
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. Simulation of the Pattern Articulation Unit (PAU)

A number of analysis procedures for bubble chamber negatives were programmed for previously digitized film. These procedures all use an early version of a pattern recognition preprocessor as simulated on ILLIAC (File No. 449 by James H. Stein):

File No. 476, "The Filling of Gaps in Digitized Bubble Chamber Photographs," by Brian H. Mayoh, August 23, 1962

File No. 478, "Machine Realization of a Labelling Algorithm Suggested by R. Narasimhan," by J. H. Stein, August 24, 1962

File No. 483, "An Algorithm for the Rapid Analysis of Certain Classes of Bubble Chamber Pictures," by R. K. Rice, August 28, 1962

II. Circuitry of the Pattern Articulation Unit (PAU)

Detailed engineering specification of stalactite circuitry is reported in Report No. 127 by K. C. Smith. Experimental verification of performance of the so called bubble register is given in File No. 482 by K. C. Smith and D. Hall. File No. 473 concerns a test circuit for the development of PAU circuitry.

Report No. 127, "Design of Circuits for the Pattern Articulation Unit," by K. C. Smith, August 31, 1962

File No. 473, "A Versatile One-Shot and NAND Logic Board," by K. C. Smith, August 20, 1962

File No. 482, "Observations on the Operation of a 3-Bit Bubbling Register," by K. C. Smith and Dennis Hall, August 31, 1962

III. The Transfer Memory

The transfer memory in combination with the pyramidal readout facility, represents a versatile associative memory. A preliminary design is given in File No. 477 by S. R. Ray. File No. 469, also by Ray, has been used as the basis to subcontract a prototype core stack, currently on order.

File No. 469, "Specifications for an Experimental Magnetic Core Matrix Stack (Transfer Memory)," by S. Ray, August 7, 1962

File No. 477, "Preliminary Description of the Transfer Memory," by S. Ray, August 23, 1962

IV. Scheduling Fabrication of the PAU

The following report, issued internally only, has been prepared:

File No. 467, "Proposed Scheduling of Engineering for the Pattern Recognition Computer," by B. H. McCormick, August 1, 1962.

(B. H. McCormick)

PART III
ILLIAC USE AND OPERATION

Illiac Usage

During the month of August, specifications were presented for 8 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 2219T. Numbers followed by T are for theses.

2219T Agricultural Economics. The Influence of Merchant Credit on Farm Enterprise and Financial Organization. The objective of this research effort is to determine the effect of various lending practices of primary lenders and merchants upon the production and financial organization of a model farm situation in the cash grain area of Illinois. There exists an interrelationship between credit alternatives available to the farmer and his profit maximizing production organization. This linear programming model using the M29-295 routine is designed to determine the effect on the farm organization of varying certain parameters such as maximum loan limit on interest charges. This model makes allowance for the interrelation between primary lender and merchant and among classes of merchants as well as the interrelationship of production and financial organization.

Technological advances in agriculture along with larger operating units have increased the capital requirements. Apparent failure of the institutional lenders to meet these needs has resulted in farmers requesting more credit from merchants. This is an effort to use linear programming as a tool to examine some of the implications of these developments.

2220T Electrical Engineering. Maser Oscillation from Ion Pairs. The exchange interaction between ion pairs causes splittings in energy levels that are attractive for maser work. Isotropic exchange theory appears not to apply to pairs of Cr^{+++} ions in dark ruby. A diagonalization of the anisotropic exchange matrix will allow a comparison with spectroscopy, then a subsequent evaluation of the anisotropy, which will lead to the prediction of the matrix elements for oscillation from the eigenvectors. The Illiac can serve by diagonalizing a 16×16 matrix for various proportions of anisotropy, determining the eigenvectors of that matrix. This will allow the theoretical basis for the maser to be established.

2221T Agricultural Economics. An Institutional Beef Procurement Program. The problem is to determine a minimum cost beef procurement plan for Central Food Stores, a University of Illinois food service facility. A linear programming routine will be used to select the minimum cost program, given the requirements for the various beef item and the availability of two kinds of processing labor. Seasonal price patterns and required amounts of labor will be included in the program.

The solution will determine which beef purchase forms to buy and when to buy them, and will aid in other managerial decisions.

2222 Mechanical Engineering. Absorption-Isothermic Equations (Collision Integral). This research program is concerned with the properties of gases under ultra-high vacuum conditions. Of particular interest are the conditions which prevail very near the walls of a container. From the absorption-isothermic equations the integral for the collision of gas molecules with the wall of the container can be formulated. After suitable manipulations the gas-solid collision integral takes the form:

$$S = \sum_{\tau=1}^{\infty} \left[\frac{1}{\tau!} \frac{\tau}{(3\tau-1)} \right] \left(\frac{\epsilon^*}{RT} \right)^{\tau}$$

where T is the temperature in degrees Kelvin, ϵ^* is the kinetic energy in the collision, and R is the gas constant. The factor $\frac{\epsilon^*}{RT}$ will, of course, vary for different conditions. Values for the gas-solid collision integral for values of $\frac{\epsilon^*}{RT}$ in the range 1 to 150 will be calculated. The series is seen to converge after n terms, when n satisfies the relation $\frac{\epsilon^*}{RT} - 4 = n$. The terms will be summed until they become smaller than a predetermined value k.

2223T Theoretical and Applied Mechanics. Notched Half-Plane Problem. The problem is concerned with the determination of the stress distribution in a notched half plane loaded by two wedge forces $\pm P$. The application of the Muskhelishvili equations of the mathematical theory of elasticity in conjunction with conformal mapping leads to the following integro-differential equation:

$$\frac{t}{2(t^2-1)} \overline{N(t)} = 1/2 N^*(t) - \frac{1}{2\pi i} \int_{-1}^{+1} \frac{N^1(\delta) d\delta}{\delta - t} = \frac{P}{\pi} \frac{p}{p^2 - t^2}$$

This equation can be expressed in the form of sums by the substitution:

$$N(t) = \sum_{n=0}^{\infty} A_n t^n$$

resulting in a system of simultaneous equations for the A_n . With the help of these coefficients it will be possible to calculate the stress distribution of the notched half plane at any point.

In the above, $N(\delta) = \frac{2(\delta^2-1)}{\delta} \overline{\phi^1(\delta)}$ is the boundary value of $\overline{\phi^1(\zeta)}$ which, in turn, is a function of the complex variable ζ . $-t$ and δ are points on the real axis of the complex ζ - plane, and $\overline{N(t)}$ is the complex conjugate of $N(t)$. P is the applied force, and $p = \sqrt{1+b^2}$ where b is the distance of the point of application of the wedge forces $\pm P$ from the origin.

2224 Psychology. Personality and Blood Characteristics of Cyclothymics. The purpose of the study is to determine whether certain personality and genetically linked blood factors which have differentiated manic-depressives from normal controls will also discriminate between normal cyclothymics and normal non-cyclothymics. The goal is to discover the determinants of the psychotic disorders.

2225T Illinois State Water Survey. Calculation of Running Averages. In conjunction with a cloud physics research program, the atmospheric potential gradient at the Illinois State Water Survey, Meteorology Lab., has been recorded continuously for the past 10 months. Hourly averages of the potential gradient have been tabulated, and it is desirable to process the data with the Illiac to determine a 24 hour running average. The data will enable the initiation of a climatological record of the potential gradient for this station.

2226 Institute of Communications Research. This study is an attempt to investigate the generality of a personality differential. The study is made in the United States and Japan to make a cross-cultural comparison possible.

The measuring instrument used was the semantic differential where a total of 29 political concepts were rated against 12 descriptive scales. Data thus derived consists of a 12 x 29 matrix per subject. This data will be used as the input for K8 to investigate the correlations among the 12 scales, which is posited to represent the "semantic frame of reference" of each individual subject.

The "frame of reference" of individual subjects in two cultures will be correlated across subjects after the transposes of the original correlation matrices have been obtained. This should yield the correlations among subjects on the basis of the posited "semantic frame of reference". The subject x subject intercorrelations, then, will be factored utilizing the Thurstone's centroid factor analysis routine with fixed communalities. The factors thus obtained will be rotated by the Kaiser's Varimax rotation scheme (simple structure). Factorial similarity (viz., generality across the personality differential) among the subjects, Japanese and American, will be investigated utilizing the Wrigley-Neuhaus coefficients of factorial similarity (cosine program).

Table I shows the distribution of Illiac machine time for the month of August. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min	
Scheduled Maintenance	108:15	
Unscheduled Maintenance	23:24	
Leapfrog	10:14	
Drum Test	11:22	
Demonstrations	:31	
Instruction	:14	
Classes	34:37	
Library Development	<u>22:11</u>	
	210:48	
Use by Departments		
Agricultural Economics	68:36	(3:00)
Animal Science	:03	
Bureau of Educational Research (PHM 1839)	3:27	
Chemistry	22:11	
Civil Engineering	106:52	(1:02)
Coordinated Science Laboratory (DA 36039 SC56695)	29:10	
Digital Computer Laboratory (AT(11-1)-415)	1:04	
Digital Computer Laboratory (1834(27))	1:56	
Digital Computer Laboratory (TR AEC 1018)	26:42	
Digital Computer Laboratory (09-22-55-970)	30:49	
Economics	:59	
Education	1:17	

Electrical Engineering (NASA-NSG 24-59)	1:05	
Electrical Engineering (AF 7043)	:04	
Electrical Engineering (NSFG 19005)	:15	
Electrical Engineering (AFOSR 62-287)	2:41	
Geology (IC GRAD GEOLOGY)	:42	
Geological Survey	5:19	
Inst. for Communications Res. (44-28-20-378)	9:35	
Inst. for Communications Res. (USPHM 3941)	2:36	
Mathematics	10:43	
Mechanical Engineering (NSG 13-59)	2:00	
Mechanical Engineering (NSFG-19926)	:21	
Mechanical Engineering (AF 400-600-909)	:26	
Mechanical Engineering	4:46	
Mining and Metallurgical Engineering (AF 6770)	:18	
Nuclear Engineering	:12	
Office of Instructional TV (DE 7-11-107.00)	:09	
Physical Education	:24	
Physics (AF 49(638) 661)	:39	
Physics (NONR 1834(05))	2:47	
Physics	:03	
Psychology (NIMH-46-32-66-370)	4:59	
Psychology (46-22-66-359)	4:22	
Psychology (RESEARCH BOARD GRANT)	2:43	
Psychology (MD 2060)	:21	
Psychology (M 1774)	11:06	
Psychology (ONR 1834-36)	:32	
Psychology (M 2509)	1:42	
Psychology (US NONR 1834(39))	5:49	
Psychology	112:10	(:38)
Sociology	11:50	
State Water Survey (NSFG-17038)	:06	
State Water Survey	23:19	
Theoretical and Applied Mechanics (NOBS 72069)	:53	
Theoretical and Appl. Mech. (DA-01-021 ORD 11878)	3:00	
Theoretical and Appl. Mech. (DA-11-070-508 ORD)	2:46	
Theoretical and Appl. Mech. (ARMY ORD G148)	:45	
Theoretical and Applied Mechanics (46-22-60-356)	2:28	
Theoretical and Applied Mechanics	:38	(:28)
	<u>533:12</u>	(5:08)
		<u>744:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error

frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Arithmetic	1
Reader	6
Punch	3
Memory	3
Drum	2
Power Supplies	2
Unknown	<u>6</u>
TOTAL	23

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPT- IONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/1/62	20:00	:00	4:00	0	(1) Unknown	:00	:25	0
8/2/62	19:38	:38	3:44	1		:00	:25	0
8/3/62	15:20	:00	8:40	0		:00	1:32	0
8/4/62	24:00	:00	:00	0		:00	:28	0
8/5/62	23:46	:14	:00	1	(1) Punch #5 failed.	:00	:25	0
8/6/62	21:63	:00	7:57	0		:00	:08	0
8/7/62	20:21	:00	3:39	0		:00	:19	0
8/8/62	21:24	:00	2:36	0		:00	:32	0
8/9/62	14:12	:00	9:48	0		:00	:00	0
8/10/62	15:21	:00	8:39	0		:00	:00	0
8/11/62	24:00	:00	:00	0		:00	:00	0
8/12/62	23:40	:20	:00	2	(1) Reader error "J". (2) Reader error "J".	:00	:00	0
8/13/62	18:44	:08	5:08	1	(1) Punch jammed.	:00	:03	0
8/14/62	14:28	:00	9:32	0		:00	:00	0
8/15/62	14:31	:00	9:29	0		:00	:12	0
8/16/62	19:23	1:06	3:31	1	(1) Drum error.	:00	:00	0
8/17/62	21:40	:00	2:20	0		:00	:05	0
8/18/62	22:16	1:44	:00	2	(1) Reader "I" failed. (2) Unknown.	:00	:00	0
8/19/62	16:30	7:30	:00	5	(1) Filaments low. (2) Memory failure 20. (3) Unknown. (4) Reader. (5) Unknown.	:00	:00	0
8/20/62	15:00	5:25	3:35	2	(1) Arithmetic error. (2) Memory 2 ⁰ .	:00	:30	0
8/21/62	20:30	:00	3:30	0		:00	:15	0
8/22/62	19:29	:00	4:31	0		:00	:17	0
8/23/62	21:11	:21	2:28	2	(1) Reader "I" failed. (2) Unknown.	:00	:24	0
8/24/62	20:07	:00	3:53	0		:00	:40	0
8/25/62	23:47	:13	:00	1	(1) Reader "L" failed.	:00	:21	0
8/26/62	24:00	:00	:00	0		:00	:00	0
8/27/62	20:12	:48	3:00	1	(1) Drum failure.	:00	:08	0
8/28/62	19:29	1:20	3:11	1	(1) Unknown.	:00	:20	0
8/29/62	19:38	1:02	3:20	2	(1) Power supply failure. (2) Memory failure 2-33.	:00	:56	0
8/30/62	22:13	:42	1:05	1	(1) Punch #1 failed.	:00	:36	0
8/31/62	21:32	:00	2:28	0		:00	:23	0
TOTALS	617:25	21:31	105:04	23		:00	9:42	0

PART IV

INTERNATIONAL BUSINESS MACHINES 650 USE AND OPERATIONS

International Business Machines 650 Usage

No new problem specifications were accepted for the IBM 650 during the month of August.

The IBM 650 was physically removed from the Laboratory on Tuesday, August 21. Hence, the Digital Computer Laboratory Monthly Technical Progress Report will no longer contain a section on the IBM 650.

Table I' shows the distribution of the International Business Machines 650 machine time for the month of August.

TABLE I'

		Hrs:Min
Scheduled Engineering		5:35
Unscheduled Engineering		35:18
Tape Test		1:20
CDC Preparation		7:53
DCL Library		2:45
Log Summary		:42
Classes		3:27
Mechanical Engineering	<u>3:27</u>	
Wasted		<u>1:31</u>
		58:31

Use by Departments

Agricultural Economics	:46
Agricultural Engineering	6:07
Agricultural Extension	3:21
Agronomy	2:40
Animal Science	1:31
Chemistry	6:52
Civil Engineering	44:48
Digital Computer Laboratory	3:15
Economics	3:16
Education	:26
Electrical Engineering	47:12
Food Technology	5:25
Graduate College	11:58
Horticulture	2:06
Mechanical Engineering	1:27
Physics	7:06

Statistical Service Unit		36:24
Bureau of Community Planning	:35	
Business Office	8:05	
DHIA	24:53	
Mechanical Engineering	:45	
Student Counseling	<u>2:06</u>	
State Water Survey		2:54
Theoretical and Applied Mechanics		<u>25:01</u>
		<u>212:35</u>
		<u>271:06</u>

Error Frequency and Analysis

The International Business Machines 650 is normally on from 8:00 a.m. to 12:00 midnight. The machine is used for preventive maintenance from 8:00 a.m. to 12:00 noon on Mondays.

Table II' presents a summary of errors for June.

Table III' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

TABLE II'

407 Accounting Machine		2
Fails to space properly	1	
Fails to print correctly	<u>1</u>	
533 Card Read Punch		7
Fails to read properly	1	
Fails to read	3	
Blown fuse	1	
End of file fails to release	1	
Fails to feed correctly	<u>1</u>	
650 Console		3
Missing or multiple bits	1	
Fails to input or output	1	
Accumulator	<u>1</u>	
653 High Speed Storage, Index Registers and Floating Point		8
Storage unit errors	2	
Index register errors	2	
Blown fuse	<u>4</u>	
727 Tape Units		1
Fails to read or write	<u>1</u>	
TOTAL		21

TABLE III'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
8/1/62	12:12		2:13	:09	1	(1) Reading errors into IAS. Burnt point on circuit breaker in 533.
8/2/62	13:15		:49	:05	3	(1) Pos. 3 of program register lost quinary bit. (2) Missing bits in IAS. (3) Cannot write on tape unit.
8/3/62	10:36		2:46	:14	1	(1) Constant index register errors. Tubes replaced.
8/6/62	8:08	1:35	2:57	:10	5	(1)-(2)-(3)-(4) Blown fuse in 653. (5) Storage unit error.
8/7/62	11:56		5:17	:10	2	(1) 650 will not input or output. Bad tubes and diode replaced. (2) 407 not spacing properly. Trouble found on 8/10. Bad tube replaced.
8/8/62	11:51		2:45	:23	1	(1) Constant accumulator error light. Bad tubes replaced on 8/9.
8/9/62	15:22		2:33	:10	1	(1) 533 stops on 70 order. Reason unknown until 8/13.
8/10/62	15:10		:40	:10	2	(1) 407 not printing correctly. Bad tube replaced.
8/13/62	17:55	4:00	2:05		1	(1) 533 stops on 70 orders. Bad timing in a circuit breaker found.
8/14/62	24:00				0	
8/15/62	12:00		12:00		1	(1) Index register B will not do any order properly. Bad tube found.
8/16/62	23:30		:30		1	(1) Fuse blew on 533.
8/17/62	23:30		:30		1	(1) 533 would not release end of file to feed out cards. Adjustment made.
8/18/62	24:00				0	
8/19/62	5:17		:13		1	(1) 533 was not feeding cards properly.
TOTALS	228:42	5:35	35:18	1:31	21	

PART V
7090-1401 COMPUTING SYSTEM

IBM 1401

The IBM 1401 was delivered on Monday, August 6, 1962. Installation and adjustments were completed about 5:00 p.m. August 13, 1962. A very informal log book was kept during the month of August and the information noted here is approximate.

Scheduled Engineering	31:15
Unscheduled Engineering	12:30
Code Checking by Digital Computer Laboratory	27:52
Control Data Corporation 1604 Preparation	13:07
Listing	3:16
Statistical Service Unit	33:49
TOTAL TIME	121:49

The Statistical Service Unit started running on the IBM 1401 on August 14, 1962.

The multiply/divide feature was installed on August 23, 24 and 27. Approximately 26 hours were logged for the installation.

The scheduled engineering is mainly for the multiply/divide feature and for checking out the 800 bit density on tape. The 800 bit density was finally checked out on August 29. A transistor card had been left out at the factory.

IBM 7090

The IBM 7090 was delivered on August 30. The remainder of the month of August was spent installing and checking out the machine.

Input/Output with Conversion

The routines described here are those which are available to the user to provide conversion of data as well as input and output data transmission. These routines use the system Execution Coordination input/output routines for transmission of data.

The names of the routines with the function and calling sequence of each appear in Section 4 following. The Format Specification, described in Section 1 following, and the Input/Output List, described in Section 2 following, are common to all the routines in Section 4.

This writeup is to be regarded as preliminary. Additional information about the input/output features of the system will form the substance of subsequent publications.

1 Format Specifications

When information is read from (or punched into) a card into (or from) a computer, it is necessary to know how this information has been allocated among the available columns of the card. Similarly, whenever information is to be printed by a printer (either on-line or off-line), it is necessary to know how this information has been allocated among the columns available on the printer. A description of each allocation is called a format specification. Usually, but not always, a list of variables (see section 2, The Input-Output List) whose values are to be printed, punched or read, is associated with a format specification. (Occasionally, the information is contained entirely in the format specification, so the list may be empty).

In substance, a format specification is a string of alphanumeric characters and a restricted subset of special characters, all terminated by the (very) special character "*". All characters which may be used are mentioned explicitly in the following subsections of this section.

A format specification, in order to be used, must be stored in successive locations, therefore, it is stored in groups of six characters per location. A format specification should be stored in such a way that the first character in the specification is the left-most of the six in a location. If the specification is stored in such a way that the first character is not the left-most, then those characters to the left of it must be blanks.

When a format specification is to be written using an assembly language, e.g., SCAT, the most natural way of writing it is to use the BCI pseudo-op

The format specification may be written so that the consecutive locations are in either descending order or in ascending order. If, in the calling sequence to one of the routines in section 4, the decrement of the calling sequence word which contains the ~~F~~ORMAT parameter in the address is zero, then the conversion routine will assume that the consecutive locations containing the format specification are in ascending order. If the decrement is non-zero, the conversion routine will assume that the consecutive locations containing the format specification are in descending order.

1.1 Single Line Format Specifications

A single line format specification has the form:

$$T_1, T_2, \dots, T_n *$$

where the T_i 's are terms of the format specification, the characters ",", separate pairs of terms and are included in the format specification, and the character "*" follows the last term of the format specification and must appear in the format specification; it serves to terminate the specification.

Any term T_i may be one of the following:

- (a) a Basic Field Description (see section 1.11, Basic Field Descriptions-a Resume');;
- (b) a Multiple Basic Field Description (see section 1.3, Multiple Basic Field Descriptions);
- (c) a Scaled Field Description (see section 1.13, Scaled Field Descriptions).

1.2 Multiple Line Format Specifications

A single format specification may be made to refer to more than one line or card at the time it is used.

A multiple line format specification has the form

$$\lambda_1 / \lambda_2 / \dots / \lambda_{q-1} / \lambda_q *$$

where each λ_i may have the form of a complete single line format specification without a terminating "*" but with carriage control if required (see section 1.15.2 Carriage Control) or any λ_i may be blank or vacuous to indicate a blank line or card for output or an ignored card for input, the character "/" is used to terminate a single line format specification λ , and the character "*" is used to terminate the last single line format specification of the multiple line format specification.

1.3 Format Fields

Each format specification describes successive fields across the available columns, starting from the left. If the specification describes fewer than the total number of available columns, the remainder of the line or card will be filled in with blanks. If, at execution time, a format specification is used which describes more than the total number of available columns an error indication will be given and the problem will be terminated.

The seven types of fields which may be described in a format specification appear in the following list:

S - Field; skip or blank information
 X - Field; skip or blank information
 I - Field; integer
 F - Field; fixed point number
 E - Field; floating point number
 Ø or K - Field; octal number
 A or C - Field; BCD characters
 H - Field; Hollerith information

The terminology "fixed point number" used in connection with F-fields and "floating point number" used in connection with E-fields is rather unfortunate but is difficult to avoid. It is meant solely to provide a means of distinguishing "the form of the information which occupies an F field" from "the form of the information which occupies an E field" and throughout this section is used solely for that purpose. In both cases the internal form is floating point.

"Format Field" is a name for two concepts taken together.

First, there is the "Basic Field Description". This is an item which appears in a format specification.

Second, there is the "Field Information". This refers to the information and the form of the information which may appear on a card or a printed line in the field described by the corresponding Basic Field Description.

Both the Basic Field Description and the Field Information for each of the types of format fields are described in the following sections (sections 1.4 through 1.10).

1.4 S-Fields

1.4.1 S-Field Basic Field Description

The basic field description for an S-field has the form:

$$S_n$$

where the character "S" indicates an S-field and n is a decimal integer equal to the number of columns in the field.

1.4.2 S-Field Information

If an S-field basic field description appears in a format specification which is used for input, any information which appears in the corresponding columns will be ignored.

If an S-field is used for output the corresponding columns will be blank.

Example: The basic field description

S31

indicates that thirty-one columns are to be skipped.

1.5 X-Fields

1.5.1 X-Field Basic Field Description

The basic field description for an X-field has the form

$$nX$$

where the character "X" indicates an X-field and n is a decimal integer equal to the number of columns in the field.

1.5.2 X-Field Information

If an X-field basic field description appears in a format specification which is used for input, any information which appears in the corresponding columns will be ignored.

If an X-field is used for output the corresponding columns will be blank.

1.6 I-Fields

A number in an I-field has the form of an integer internally; i.e., if m is an integer, then its internal representation is

$$m \cdot 2^{-35}$$

1.6.1 I-Field Basic Field Description

The basic field description for an I-field has the form

In

where the character "I" indicates an I-field and n is a decimal integer equal to the number of columns in the field.

1.6.2 I-Field Information

The information in an I-field may have any of the following forms:

+m

-m

m

where m is an integer satisfying

$$0 \leq m \leq 9999999999.$$

If, as in the third form, no sign is punched, the integer will be assumed to be positive. Any possible sign must be counted in determining the field size.

If an I-field is used for input:

All blanks in the field are ignored;

If the entire field is blank, the value will be set equal to minus zero;

Leading zeros need not be punched;

Trailing zeros must be punched;

If the integer is negative the "-" sign must be punched.

If an I-field is used for output:

For positive integers, "+" signs are not printed or punched;

For negative integers, "-" signs are printed or punched;

If the integer internally contains fewer digits than provided for by the field size, it will print right justified in the field with blanks in the remainder of the field;

If the integer internally contains more digits than provided for by the field size, the least significant digits will be printed and the sign and the remainder of the most significant digits will not appear. No decimal point, ".", is printed or punched in an I-field.

1.7 F-Fields

A number in an F-field has the form of a floating point number internally.

1.7.1 F-Field Basic Field Description

The basic field description for an F-field has the form

$$F_n.k$$

where the character "F" denotes an F-field, n is a decimal integer equal to the number of columns in the field, k is a decimal integer equal to the number of digits to the right of a missing decimal point and the character "." (period) separates m and k. The integer k is always interpreted mod 10, e.g., k = 13 is equivalent to k = 3.

1.7.2 F-Field Information

If an F-field is used for input:

The information may have any one of the following forms:

$\pm m.l$	$\pm m.l E \pm e$	$\pm m l E \pm e$
$m.l$	$m.l E \pm e$	$m l E \pm e$
$\pm m l$	$\pm m.l E e$	$\pm m l E e$
$m l$	$m.l E e$	$m l E e$
	$\pm m.l \pm e$	$\pm m l \pm e$
	$m.l \pm e$	$m l \pm e$

where m is a decimal integer, l is a decimal fraction, and e is a decimal integer equal to the exponent of the power of 10 by which the number $\pm m.l$ or $\pm m l$ is to be multiplied; e may contain one or two digits, no more.

The character "E", if punched, indicates that an exponent follows;

If a sign ("+" or "-") does not appear as the left-most character, the number is assumed to be positive;

The sign which follows the character "E" is the sign of the exponent, e;

If no sign character follows "E" the exponent e will be assumed to be positive;

Notice that the "E" is necessary only if the sign of the exponent is not punched and that the sign of the exponent is not necessary only if the "E" is punched and the exponent is positive;

All blanks are ignored;

If an entire F-field is blank the value will be set equal to minus zero;

If the F-field information is in one of the forms with a decimal point ("."), this "." in the field information will override the effect of the number k in the basic field description. In that case, trailing zeros in ℓ need not be punched;

If the form of the field information is one for which the decimal point is not punched, then trailing zeros must not be omitted;

Any number of digits may be used in the field but only eight digits of accuracy are retained.

In determining the field size, n, in the basic field description the count must include any possible occurrences of the sign of the number, "+" or "-", a decimal point, ".", an "E", and an exponent sign "+" or "-" as well as the maximum number of digits in m, ℓ and e, combined.

If an F-field is used for output:

The printed or punched information will have one of the following forms:

$$\begin{array}{c} m.\ell \\ -m.\ell \\ m \\ -m \end{array}$$

where m is a decimal integer and ℓ is a decimal fraction rounded to k digits;

The character "+" is not printed, the form without sign represents a positive number;

One of the two forms m or -m will occur when k=0 (the "." is not output);

The number will be right justified in the field in all cases;

If the field size, n, is larger than required for the information, blanks will be printed or punched in the remaining columns to the left;

If the field size is smaller than required, information will be output from right to left until the field is exhausted; notice that a sign, "-", and/or a decimal point, ".", which otherwise would print or punch may be lost in this event;

In determining the field size, n , the count must include possible occurrences of the characters "-" and "." as well as the maximum total number of digits in m and ℓ .

1.8 E-Fields

A number in an E-field has the form of a floating point number internally.

1.8.1 E-Field Basic Field Description

The basic field description for an E-field has the form:

$$E_n.k$$

where the character "E" denotes an E-field, n is a decimal integer equal to the number of columns in the field, k is a decimal integer equal to the number of digits to the right of a missing decimal point and the character "." separates n and k. The integer k is always interpreted mod 10, e.g., k = 22 is equivalent to k = 2.

1.8.2 E-Field Information

If an E-field is used for input:

The information may have any one of the following forms:

$\pm m. \ell$	$\pm m. \ell E \pm e$	$\pm m \ell E \pm e$
$m. \ell$	$m. \ell E \pm e$	$m \ell E \pm e$
$\pm m \ell$	$\pm m. \cancel{\ell} E e$	$\pm m \ell E e$
$m \ell$	$m. \ell E e$	$m \ell E e$
	$\pm m. \ell \pm e$	$\pm m \ell \pm e$
	$m. \ell \pm e$	$m \ell \pm e$

where m is a decimal integer, ℓ is a decimal fraction, and e is a decimal integer equal to the exponent of the power of 10 by which the number $\pm m. \ell$ or $\pm m \ell$ is to be multiplied; e may contain one or two digits, no more.

The character "E", if punched, indicates that an exponent follows;

If a sign ("+" or "-") does not appear as the left-most character, the number is assumed to be positive;

The sign which follows the character "E" is the sign of the exponent, e;

If no sign character follows "E" the exponent e will be assumed to be positive;

Notice that "E" is necessary only if the sign of the exponent is not punched and that the sign of the exponent is not necessary only if the "E" is punched and the exponent is positive;

All blanks are ignored;

If an entire E-field is blank the value will be set equal to minus zero;

If the E-field information is in one of the forms with a decimal point ("."), this "." in the field information will override the effect of the number k in the basic field description. In that case, trailing zeros in ℓ need not be punched;

If the form of the field information is one for which the decimal point is not punched, then trailing zeros must not be omitted;

Any number of digits may be used in the field but only eight digits of accuracy are retained;

In determining the field size, n, in the basic field description, the count must include any possible occurrences of the sign of the number, "+" or "-", a decimal point, ".", an "E", and an exponent sign "+" or "-" as well as the maximum number of digits in m, ℓ and e, combined.

If an E-field is used for output:

The printed or punched information will have one of the following forms:

$$\begin{array}{ll} m. \ell \text{ b e}_1 \text{ e}_2 & m \text{ b e}_1 \text{ e}_2 \\ -m. \ell -\text{e}_1 \text{ e}_2 & m -\text{e}_1 \text{ e}_2 \\ -m. \ell \text{ b e}_1 \text{ e}_2 & -m \text{ b e}_1 \text{ e}_2 \\ -m. \ell -\text{e}_1 \text{ e}_2 & -m -\text{e}_1 \text{ e}_2 \end{array}$$

where m is a decimal integer, ℓ is a decimal fraction rounded to k digits, "b" represents a blank and e_1 and e_2 are the two digit exponent of the power of 10 by which $m. \ell$ or $-m. \ell$ is to be multiplied; e_1 is always punched or printed, even when equal to zero;

The four forms in the right hand column result when $k = 0$;

The number will be right justified in the field in all cases;

If the field size, n, is larger than required for the information, blanks will be printed or punched in the remaining columns to the left;

If the field size is smaller than required, information will be output from right to left until the field is exhausted; notice that signs, "-", and/or decimal points "." which otherwise would print or punch may be lost in this event;

In determining the field size, n, the count must include possible occurrences of the characters "-" and "." and the two exponent digits as well as the maximum total number of digits in m and ℓ .

1.9 K-Fields and ϕ -Fields

There is a one-to-one correspondence between the 36 bits internally and the bits represented by the number in a K-field or an ϕ -field. Any octal digit represents binary bits as follows:

<u>Octal</u>	<u>Binary</u>
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

1.9.1 K-Field and ϕ -Field Basic Field Description

The basic field description for a K-field has the form

$$Kn$$

where the character "K" denotes a K-field and n is a decimal integer equal to the number of columns in the field.

The basic field description for an ϕ -field has the form

$$\phi n$$

where the character ϕ denotes an ϕ -field and n is a decimal integer equal to the number of columns in the field.

1.9.2 K-Field and ϕ -Field Information

If a K-field or an ϕ -field is used for input:

The information in a K-field or an ϕ -field may have any one of the following forms:

$$+ p$$

$$- p$$

$$p$$

where p is an octal integer satisfying

$$0 \leq p \leq 777777777777;$$

The octal integer p either contains or implies a value for each of the 36 binary bits in a computer word; the left-most of these 36 bits coincides with the sign bit; the sign of the number is determined by the logical "or" of the sign; if any, and the left-most bit as given by the following list ("+" is 0, "-" is 1):

Sign Field	Left-Most Bit	Sign of Number
+	0	+
-	1	-
b	0	+
+	1	-
-	0	-
b	1	-

All blanks in the field are ignored;

If the entire K-field or ϕ -field is blank the value will be set equal to plus zero;

Leading zeros need not be punched;

Trailing zeros must be punched;

The field size must include possible occurrences of a sign character in the count.

If a K-field or an ϕ -field is used for output:

The information punched or printed will have the following form:

p

where p is an octal integer;

No sign is punched or printed; the sign of the number is indicated by whether the left-most of 12 octal digits is less than 4(+) or greater than or equal to 4(-);

The number is right justified in the field;

If the field size is larger than required for the information the remaining columns to the left are filled with blanks;

If the field size is smaller than required for the information, the information is output from right to left until the field is exhausted and the most significant part does not appear.

1.10 C-Fields and A-Fields

The Hollerith card code for each character corresponds to the internal 6-bit BCD code for the same character.

1.10.1 C-Field and A-Field Basic Field Description

The basic field description for a C-field has the form

C_n

where the character "C" denotes a C-field and n is a decimal integer equal to the number of columns in the field.

The basic field description for an A-field has the form

A_n

where the character "A" denotes an A-field and n is a decimal integer equal to the number of columns in the field.

1.10.2 C-Field and A-Field Information

The information in a C-field or an A-field has the form:

c

where c is any string of Hollerith characters available on the computer. Blanks are not ignored.

If a C-field or an A-field is used for input:

Characters are taken from the field from left to right either until six columns have been read or until the field has been exhausted, whichever occurs first;

The information is left justified internally;

If the field size, n , is less than six, the right-most $6-n$ characters are filled with blanks. If the field size n is greater than six, the right-most $n-6$ characters are lost;

If a C-field or an A-field is used for output:

Characters are output from left to right either until six have been transmitted or until the field has been exhausted, whichever comes first;

The information is left justified in the field;

If the field size, n , is greater than six, the right-most $n-6$ characters are filled in with blanks;

If the field size, n , is less than six the right-most $6-n$ characters are lost.

Examples:

- (1) If the format specification

2C3*

were used to read a card punched with

ABCDEFGHIJK

in columns 1 through 11, the two computer words involved would contain

ABCbbb

DEFbbb

- (2) If the format specification

C6*

were used to read the card of example (1), the single computer word involved would contain

ABCDEF

- (3) If the format specification

C7,C3*

were used to read the card of example (1), the two computer words involved would contain

ABCDEF

HIJbbb

1.11 H-Fields

The purpose of the H-Field is to permit the inclusion of strings of Hollerith characters directly in the format specification itself.

1.11.1 H-Field Basic Field Description

The basic field description for an H-field has the form

$$nHc$$

where the character "H" denotes an H-field, c is any string of Hollerith characters and n is a decimal integer equal to the number of characters in the string counting from the character immediately following the "H".

Although, for every other type of field, the basic field description which appears in a format specification must be separated from a following basic field description by a character ",", for the H-fields, since the number n explicitly defines the number of characters in the description, the character "," after the last character in the string c is optional.

1.11.2 H-Field Information

If an H field appears in a format specification which is used for input, the Hollerith characters which appear in the corresponding card columns will replace the characters in the string c in the format specification itself.

If an H-field is used for output, the characters of the string c will be printed or punched in the corresponding columns. The characters of the string c are not disturbed.

1.12 Basic Field Descriptions - A Resume'

The purpose of this section is merely to gather together all in one place a recapitulation of the possible seven types of basic field descriptions. They are:

Sn	(see section 1.4)
nX	(see section 1.5)
In	(see section 1.6)
Fn.k	(see section 1.7)
En.k	(see section 1.8)
Kn or ϕ n	(see section 1.9)
Cn or An	(see section 1.10)
nHc	(see section 1.11)

1.13 Multiple Basic Field Descriptions

If several consecutive fields can be described by the same basic field description, repetition may be avoided by using a Multiple Basic Field Description.

- (a) a multiple basic field description may have the form

$$iD$$

where D is any one of the basic field description forms of section 1.12, Basic Field Descriptions - A Résumé, and where i is a decimal integer equal to the number of consecutive fields with form D;

- (b) if M is a basic field description of the form

$$D$$

a multiple basic field description of the form

$$iD$$

or a scaled field description S where S may have the form of either a scaled basic field description (see section 1.14.1) or a scaled multiple basic field description (see section 1.14.2), then a multiple basic field may have the form

$$j(M_1, M_2, \dots, M_q)$$

where j is a decimal integer equal to the number of times the group of q field descriptions M_1, M_2, \dots, M_q is to be repeated and where the characters "(" and ")" delimit the group of field descriptions on the left and right respectively.

- (c) a multiple basic field description may have no other form than those given by (a) and (b) above.

Notice in particular that parenthesized groups may not be nested.

Examples:

- (1) the format specification

$$3F10.3, E18.4, 2E9.1, 3I2^*$$

is a short way of writing the format specification

$$F10.3, F10.3, F10.3, E18.4, E9.1, E9.1, I2, I2, I2^*$$

They are logically equivalent.

- (2) The format specification

$$3E10.3, 2(I2, 3F10.1), 2C5^*$$

is logically equivalent to the format specification

$$E10.3, E10.3, E10.3, I2, F10.1, F10.1, F10.1, I2, F10.1, F10.1, F10.1, C5, C5^*$$

1.14 Scaled Field Descriptions

It is possible to write an F-field or an E-field description with a scale factor which will be applied to every number to which the description is applied.

1.14.1 Scaled Basic Field Descriptions

A scale factor may be applied to a basic field description. Such a scaled basic field description may have any one of the following forms

sPD
+ sPD
- sPD

where D is either an F-field basic field description (see section 1.7.1) or an E-field basic field description (see section 1.8.1), the character "P" (for "power") denotes a scale factor and s is a decimal integer equal to the exponent of the power of 10 times which the number is to be multiplied. If the exponent is negative the sign "-" must be punched; if the exponent is positive, the sign "+" is optional.

1.14.2 Scaled Multiple Basic Field Descriptions

A scale factor may be applied to a restricted form of a multiple basic field description. Such a scaled multiple basic field description may have any one of the following forms

sPiD
+ sPiD
- sPiD

where D is either an F-field basic field description (see section 1.7.1) or an E-field basic field description (see section 1.8.1), i is a decimal integer equal to the number of consecutive fields described by D (so that

iD

above has the form of the primitive multiple basic field description of section 1.13 (a)), the character "P" denotes a scale factor and s is a decimal integer equal to the exponent of the power of 10 times which the number in each of the consecutive i fields is to be multiplied. If the exponent is negative, the sign "-" must be punched; if the exponent is positive, the sign "+" is optional.

1.14.3 Scaled F-Fields

When a scale factor is applied to an F-field the following formula is true:

$$\text{External Number} = \text{Internal Number} * 10^{\text{Scale Factor}}$$

The scaling (multiplication by $10^{\text{Scale Factor}}$) is done before the number is printed or punched on output and after the number has been read and converted on input. Notice that scaling actually changes the value of the number in an F-field.

Example:

Suppose the format specification

3F7.3*

is used and as a result the three numbers which follow are printed:

0.522b-1.567b93.671

If, instead, the format specification

-2P2F7.3,F7.3*

were used the same numbers would print as:

0.005b-0.016b93.671

1.14.4 Scaled E-Fields

When a scale factor is applied to an E-field used for output, although the number is modified the exponent is also modified so that the value is unchanged; only the form in which the number is printed is changed.

Example:

Suppose that the format specification

E18.4*

is used and as a result the number

0.9321E-03

is printed.

If the format specification

2PE18.4*

were used instead, the same number would print as

93.2100E-05

1.15 Format Specifications and Reading, Punching and Printing

With the following two exceptions specifications for reading or punching cards and printing lines are identical.

1.15.1 Available Columns

(a) Cards

Whether reading or punching, the maximum number of card columns is 80. A format specification used for cards may describe 80 columns. If more than 80 columns are described at execution time indication of an error is given and the job is terminated. It is an often useful convention that the card columns used for data be limited to 72 leaving the remaining columns for purposes of identification. Use of on-line equipment, though rare, imposes a limit of 72 columns.

(b) Printing Lines

As in the case of cards, the number of characters available for a print line depends on the equipment being used. When printing on-line 119 columns are available. Otherwise (off-line) 132 columns are available. On-line printing is to be used extremely rarely. If more than 132 columns are described at execution time, indication of an error is given and the problem is terminated.

1.15.2 Carriage Control

(a) The character destined for the first column of a card, when punching, has no special significance. It is regarded in the same light as the remaining 79 columns. It is punched in column 1 and the successive characters go to successive columns.

(b) The left-most character output for a print line is the "carriage control character." It controls the printer carriage "vertical motion," immediately before the line is printed, i.e., "controls the preprint skip." The code for the carriage control character is given by the following table:

If the left-most character is	The preprint skip is
blank	single space
0	double space
+	no space
-	triple space

1	sheet eject (skip to next page)
2	skip to next half page
4	skip to next quarter page
6	skip to next sixth page
all others	single space

This control character is specified in a format specification in addition to the 119 or 132 information positions.

In any format specification which is used to print a line, the left-most character output is detached to be used as carriage control and is not printed. The appearance of the line which is printed is as if the carriage control characters had gone to "print position zero" which is non-existent. The second character is printed in print position 1, the third in print position 2, etc.

Note that blanks count as characters.

2 The Input/Output List

It was demonstrated in section 1, Format Specifications, that the function of a format specification is to describe the format of data on an external medium, cards or print lines.

It is the function of the input/output list to describe how the data is allocated or is to be allocated among computer storage locations. The input/output list is a part of the calling sequence to any input/output conversion routine. The Store-and-Trap instruction, STR, is used to specify an item on the list so as to furnish to the conversion routine the address of the location which contains the next data word.

The STR instruction may be used to specify an entry in the I/ \emptyset list in each of the following ways with the indicated results:

(1) STR D

Such an entry in the I/ \emptyset list serves to indicate that this item in the I/ \emptyset list is contained in the single computer word at location D.

(2) STR D,X

Such an entry in the I/ \emptyset list serves to indicate that this item in the I/ \emptyset list is contained in the single computer word at the location the effective address of which is

D,X

i.e., whose address is

(D minus contents of index register X).

(3) STR D1,0,D2

Such an entry in the I/ \emptyset list serves to indicate that this item in the I/ \emptyset list is in reality a block of data contained in

D2-D1+1

consecutive storage locations.

(4) STR

or STR 0,0,0

Such an entry is used to indicate the end of an I/ \emptyset list. To be certain that all data has been transmitted a STR 0,,0 should be given before terminating the job or before changing core loads.

When a conversion subroutine reaches a point at which it needs the next item on the I/ \emptyset list, it transfers control to the location one past the location

containing the previous item, an STR, on the list, with the contents of the index registers as they were after the entry from the last item.

For the simplest type of I/Ø list that location would contain the next item on the list. For example, the following is a simple I/Ø list:

```
STR    A
STR    B1,,B2
STR    MATRIX,2
STR
```

It is not, however, required that the I/Ø list have the simple form above. Computation may be performed between items in the I/Ø list, restricted only to the extent that no I/Ø conversion routine should be entered from the I/Ø list of itself or of another conversion routine.

Therefore, if it is desired to indicate with an I/Ø list that every other location to a total of 1000 locations is to be transmitted, it is not necessary to write an I/Ø list of 1000 STR instructions. The following I/Ø list will accomplish the same thing:

```
AXT    2000,2
L      STR    DATA+2000,2
      TIX    L,2,2
      STR
```

With these facts in mind, then, let it be understood that by "I/Ø list", what is meant is a sequence of computer instructions with STR, I/Ø list items, interspersed, and terminated in time, not space, by an STR 0,,0.

3 Relationship Between the I/O List and the Format Specification

Except for Hollerith strings imbedded in the format specification itself (see section 1.11) and the S- or X-fields, each field in the specification refers to one item on the list. For this purpose, a block item on the list, such as STR A+6,,A+8 counts as several items in the format specification (in this case, A+6,A+7 and A+8). During the transmission of information, the input or output subroutine scans both the list and the specification simultaneously, correlating corresponding entries, and associating a field size, a type of conversion, etc., to each variable. If a Hollerith string is encountered in the specification, it is immediately transmitted, and it is not associated with any item on the list.

For example, given the following I/O list

```
STR   ABC
STR   XYZ,1
STR   INT
STR   K
STR
```

and suppose that it is output using the following format specification

```
1H1,F11.3,-2PE14.4,S13,3HM = I3,S9,3HJ = I3*
```

then, assuming the appropriate values for the data, the following line would be printed (at the top of the next page because of the 1H1):

```
456.010  -1612.510           M = 50           J = 17
```

As stated above a specification may not account for more than 80 columns on a card. It may happen, however, that a list calls for more information than can appear on a single card. Or perhaps only a certain part of each card is to be read. The determining factor in every case is whether or not the entire list has been accounted for. After each card is read according to the format specification, the list is consulted; if it is not yet satisfied, another card is read, and so on. It is important to realize that the specification is not necessarily scanned from the beginning when a new card is read. In fact, the specification scanner moves to the left from the end of the specification (the *) until it hits a left parenthesis not in an H field. (If there is no left parenthesis, it will move to the beginning of the specification). It then

examines the characters just to the left of this left parenthesis to see if they are a multiplicity indication (see section 1.13). The information from this left parenthesis (together with the multiplicity, if any) to the end of the specification now becomes the format specification until the list is satisfied. A similar statement may be made for printed or punched output.

Thus, if the specification which follows

$$3F10.3 \ /4(F10.3, 6HBETA = I2)*$$

is used with an I/ϕ list which contains more than 11 elements (say 19 or 27), then the first line printed (or read) would have three fixed point numbers. Subsequent lines would all be printed (or read) according to the specification

$$4(F10.3, 6HBETA = I2)*$$

until the last element of the I/ϕ list were transmitted.

As another example one might have an integer equal to a count of subsequent cards on a first data card, followed by many cards, each with six floating point numbers. The specification might then be:

$$I6/(6E10.5)*.$$

Only the first six columns would be read on the first card, and only 60 columns would be read on subsequent cards. The remaining columns are ignored and may contain any legitimate Hollerith characters.

If a specification contains a Hollerith string of the form $nHa_1a_2\dots a_n$, certain conventions are observed:

- (1) If the list is satisfied, but the next field specification is a Hollerith string, the string is transmitted anyway;
- (2) On input, i.e., reading from cards, when a Hollerith string is encountered in the specification, the information in the corresponding columns of the input card will be brought in and will replace the Hollerith string itself within the format specification. This can then be used as a specification for output. For example, this is useful for labelling a set of data and causing the label to appear on the output along with a date, etc.

Thus, a card punched as follows:

1 DATA SET NO. 3-A JULY 31, 1959 J. DOE

might be read in with a format specification

72H (72 blank spaces) *.

Later, this specification could be used to print the same information as a heading for the results. Note the "1" provided for carriage control for the printing.

WARNING: The specification S72* and 72(1H)*, while indicating 72 blank spaces, do not allow the reading in of an entire card, as indicated above, since they do not provide a storage region in the format specification of 72 characters in length into which the information on the card may be read and stored until needed.

4 Input/Output Conversion Subroutines

The routines described in this section are those which are available to the user for the purpose of performing input/output with conversion from binary to BCD and from BCD to binary according to a specified format on the external medium. Each of these routines will automatically cause to be loaded any auxiliary subroutines which it needs.

4.1 .READ

Read BCD Cards from the System Input Tape and Convert According to a Format Specification.

Calling sequence:

```
TSX    .READ,4  
STR    FØRMAT,,D  
(I/Ø List)
```

where FØRMAT is the location containing the first word of the format specification and D specifies the order in which the format specification is stored:

D = 0: The second word of the format specification is in location FØRMAT+1, the third in FØRMAT+2, etc.

D ≠ 0: The second word of the format specification is in FØRMAT-1, the third in FØRMAT-2, etc.

The format specification must not describe more than 80 columns per card. If the I/Ø list is empty the input tape will be spaced past one card image. If an end-of-file is read on the system input tape the job will be terminated unless the option to set the end-of-file return has been exercised.

4.2 .PRINT

Write BCD Line Images on the System Output Tape According to a Format Specification.

Calling sequence:

```
TSX   .PRINT,4  
STR   FØRMAT,,D  
(I/Ø List)
```

where FØRMAT is the location containing the first word of the format specification and D specifies the order in which the format specification is stored:

- D = 0: The second word of the format specification is in location FØRMAT+1, the third in FØRMAT+2, etc.
- D ≠ 0: The second word of the format specification is in location FØRMAT-1, the third in FØRMAT-2, etc.

See section 1.15.2, Carriage Control, for an explanation of the significance of the left-most character output.

4.3 .CØMNT

Write BCD Line Images on the System On-Line Printer.

Calling sequence:

```
TSX   .CØMNT
STR   FØRMAT,,D
      (I/Ø List)
```

where FØRMAT is the location containing the first word of the format specification and D specifies the order in which the format specification is stored:

D = 0: The second word of the format specification is in location FØRMAT+1, the third in FØRMAT+2, etc.

D ≠ 0: The second word of the format specification is in location FØRMAT-1, the third in FØRMAT-2, etc.

This subroutine is used only for comments to the operator and not for results or dumps. It is wise to limit a line to 120 columns, although as many as 133 will be accepted. If necessary a second line, single spaced away from the first will be printed. The image will be broken after 120 columns without regard for format. The subroutine will cause a one-sixth page skip after printing so the line will be made visible to the operator.

4.4 .PUNCH

Write BCD Card Images on the System Output Tape According to a Format Specification.

Calling sequence:

```
TSX    .PUNCH,4  
STR    FØRMAT,,D  
(I/Ø List)
```

where F~~Ø~~RMAT is the location containing the first word of the format specification and D specifies the order in which the format specification is stored:

- D = 0: The second word of the format specification is in location F~~Ø~~RMAT+1, the third in F~~Ø~~RMAT+2, etc.
- D \neq 0: The second word of the format specification is in location F~~Ø~~RMAT-1, the third in F~~Ø~~RMAT-2, etc.

The format specification must not describe more than 80 columns.

4.5 .TAPWR

Write BCD Line Images on a Specified Tape Unit According to a Format Specification.

Calling sequence:

```
TSX    .TAPWR,4
STR    UNIT
STR    FØRMAT,,D
(I/Ø List)
```

where UNIT is either a symbolic tape name or a logical tape number (consult the manual covering the use of the system for restrictions on UNIT) and where FØRMAT is the location containing the first word of the format specification and D specifies the order in which the format specification is stored:

D = 0: The second word of the format specification is in location FØRMAT+1, the ~~th~~ird in FØRMAT+2, etc.

D ≠ 0: The second word of the format specification is in location FØRMAT-1, the ~~th~~ird in FØRMAT-2, etc.

The format specification must not describe more than 133 columns per record. If the user desires to take action upon reaching the end-of-tape, then it is necessary for him to exercise the option to set the end-of-tape return.

4.6 .TAPRD

Read BCD Line Images from a Specified Tape Unit and Convert According to a Format Specification.

Calling sequence:

```
TSX    .TAPRD,4
STR    UNIT
STR    FØRMAT,,D
(I/Ø list)
```

where UNIT is either a symbolic tape name or a logical tape number (consult the manual covering the use of the system for restrictions on UNIT) and where FØRMAT is the location containing the first word of the format specifications and D specifies the order in which the format specification is stored:

D = 0: The second word of the format specification is in location FØRMAT+1, the third in FØRMAT+2, etc.

D ≠ 0: The second word of the format specification is in location FØRMAT-1, the third in FØRMAT-2, etc.

The format specification must not describe more than 133 columns per record. If the I/Ø list is empty, the tape on UNIT will be spaced past one record. If the unit specified is the system input tape, an end-of-file will result in termination of the job unless the option to set the end-of-file return has been exercised. For other tape units no action will be taken at end-of-file unless the end-of-file return has been set.

Execution Coordination Routines

The Execution Coordination (E.C.) Routines are those system subroutines, executive routines and processors which remain in the low core area, below the system origin during execution time. For safety, the user should not ØRG below 5500_{10} . It is intended that this area shall be memory protected except during the operation of the execution coordination routines themselves, during the operation of the system Supervisory and Accounting Monitor, during the operation of the system translators, and during the execution of a RELINQUISH problem. Even when not memory protected, the E. C. routines will be there initially and will be available for use unless destroyed.

The Storage Indicators, all index registers, the index register mode and the trapping mode will be preserved for the user by these routines. The accumulator and MQ registers will not be preserved and, indeed, will in some cases contain output to the user.

1 INPUT/OUTPUT ROUTINES

A large number of the execution coordination routines will be devoted to expediting input and output. These routines are not to be confused with subroutines available to the user from the library which will perform numerical conversion on the user's data. Those conversion routines (IØH, IØB routines) do indeed make use of the execution coordination input/output routines.

1.1 The following are routines whose functions are to operate on the system input and output tapes.

The system input tape is the medium onto which a user's program and data cards are transcribed by the 1401 for entry into the 7090.

The system output tape is the medium onto which are written, at execution time as well as translator processing time, all data which are to be printed or punched as a matter of course.

1.1.1 SYSRIT: Read Input Tape

The system subroutine SYSRIT is entered by a calling sequence of the following form:

TSX SYSRIT,4

TIX FWA,,EØF

Normal Return - - -

Upon return to the normal return the image of the "next card" on the input tape will be in the block beginning with the location whose address is FWA. If the card was a BCD card the image will reside in the area

FWA through FWA+13

where only the leftmost 12 bits of FWA+13 came from the card and the rightmost 24 represent 4 BCD blanks. If the card was a binary card (7 and 9 punches in col. 1), then the column binary card image will reside in the area

FWA through FWA+27

where the leftmost 24 bits of FWA+26 are the last which came from the card and the rightmost 12 bits of FWA+26 and all of FWA+27 are zeros.

Upon normal return the accumulator will contain zero if the card to be read upon the next entry to SYSRIT is BCD, or will not contain zero if the card to be read upon the next entry to SYSRIT is binary.

If EOF is zero, the job will be terminated upon the entry to SYSRIT which reads the end-of-file mark which delimits the job.

If EOF is not zero, control will be transferred to location EOF upon the entry to SYSRIT which reads the end-of-file.

The user will not be permitted to read past the end-of-file and continued entry to SYSRIT will cause looping.

1.1.2 SYSWOT: Write Output Tape

The system subroutine SYSWOT is entered by a calling sequence of the form:

TSX SYSWOT,4

TIX FWA,,L

Normal Return - - -

The BCD line image beginning in location FWA and continuing through location FWA+L-1 will be written on the system output tape. A maximum of 133 BCD characters will be used, from left to right, the first of which will be detached for carriage control.

The code for carriage control specifies the preprint skip as follows:

blank	Single Space
0	Double Space
-	Triple Space
+	Suppress Spacing
1	Sheet Eject (full page skip)
2	Skip to Next Half Page
4	Skip to Next Quarter Page
6	Skip to Next Sixth Page

All others will be replaced by blank and will result in single spacing.

1.1.3 SYSPCB: Punch Card Binary

The system subroutine SYSPCB is entered by a calling sequence of the form:

TSX SYSPCB,4

TIX FWA,,L

Normal Return - - -

The column binary card image beginning in location FWA and continuing through location FWA+L-1 will be written on the system output tape. A maximum of 960 bits (26 words and 24 bits) will be used, from left to right. The 7 and 9 bits in "column one" are not supplied by SYSPCB. If the card is to be read back in as a binary card the user must provide them in the card image.

1.1.4 SYSPCD: Punch Card Decimal

The system subroutine SYSPCD is entered by a calling sequence of the form:

TSX SYSPCD,4

TIx FWA,,L

Normal Return - - -

The BCD card image beginning in location FWA and continuing through location FWA+L-1 will be written on the system output tape. A maximum of 80 BCD characters (13 words and 12 bits) will be used.

1.1.5 SYSPPD: Print and Punch Decimal

The system subroutines SYSPPD is entered by a calling sequence of the form:

TSX SYSPPD,4

TIx FWA,,L

Normal Return - - -

The BCD image beginning in location FWA and continuing through location FWA+L-1 will be written on the system output tape. A maximum of 81 BCD characters will be used. The first, leftmost, will be detached for carriage control with the same action as that described under SYSWØT. The remaining characters will be both printed and punched starting with print wheel 1 and card column 1.

1.2 SYSCAP: Comment Attached Printer

The system subroutine SYSCAP is entered by a calling sequence of the following form:

TSX SYSCAP,4

TIX FWA,,L

Normal Return - - -

The BCD line image beginning in location FWA and continuing through location FWA+L-1 will be written on the on-line printer. A maximum of 120 BCD characters will be used. No carriage control is recognized.

1.3 The following routines may be used by the user for accessing all input-output units other than the system input and output tapes, the system master tapes, and any I/Ø units for which he does not have permission.

The calling sequence for all the following routines in section 1.3 has the form:

```
TSX SYSxxx,4
TIX EØR,,UNIT
TIX LIØCL,,ETT
TIX EØF,F,RTT
```

Normal Return - - -

The names, SYSxxx, of the subroutines appear with associated descriptions below.

1.3.1 SYSRUD: Read Unit Decimal

A read-select-decimal (RDS) of the specified unit is initiated, if the calling routine is permitted to access the unit.

1.3.2 SYSRUB: Read Unit Binary

A read-select-binary (RDS) of the specified unit is initiated, if the calling routine is permitted to access the unit.

1.3.3 SYSWUD: Write Unit Decimal

A write-select-decimal (WRS) of the specified unit is initiated, if the calling routine is permitted to access the unit.

1.3.4 SYSWUB: Write Unit Binary

A write-select-binary (WRS) of the specified unit is initiated, if the calling routine is permitted to access the unit.

1.3.5 The parameter UNIT is the unit specification. If it is an integer T satisfying

$$1 \leq T \leq 10$$

it will be assumed to designate a logical tape number. If it is any other number greater than zero, it will be assumed to designate a location, the address part of which contains the address of the desired unit. For tapes with both BCD and

binary addresses, the unit address may be BCD when used with a binary select, but must be BCD when used with a BCD select.

The user must get his unit assignments from the system. Use of logical tape numbers in relocatable programs will make this automatic. Absolute assembly language programs, especially those requiring units other than tapes which do not have logical numbers, may use system symbols of the form SYSyyy which will be defined at assembly time to be the system locations containing unit addresses.

The use of I/Ø units is closely tied to the permission granted on the Problem Specification and the system monitor control cards which appear in a job deck.

Definite notification of unit designations which may be used will be forthcoming. In the meantime, programming can proceed using symbolic names which can be EQU'd or SYN'd to system designations just prior to assembly.

1.3.6 The parameter LIØCL is the first Location of the Input-Output Command List, under the control of which the data channel is to operate during the execution of this select operation.

IT IS STRONGLY URGED THAT THE IØCL TRANSMIT ONLY ONE RECORD. The reason for this is that the system Bad Spot procedure must operate on that assumption, and it is the system bad spot procedure which monitors all tapes in use to be certain that their quality remains high. Transmission of erroneous information can go undetected by the system bad spot procedure if more than one record is transmitted by a single select and IØCL. Although the user may, with some difficulty, avoid this by use of the RTT exit (see below), notice of the condition of the tape escapes the system.

With these constraints in mind, it may be stated that any of the 7090 IØ channel commands may be used in the IØCL, with the two channel commands

IØCP

IØRT

providing almost total capability.

One of the commands

IØRT

IØCT

IØST

IØCD

must appear and will be assumed to terminate the IØCL.

The command IØCD may be used only if ØWNIØ or RELINQUISH permission is "on", at execution time, or by system translators not at execution time.

The non-transmitting commands of the form

IØXYN

may be used.

The command

TCH

may be used to link non-consecutive elements of the list.

1.3.7 Unless a unit is specified which may not be accessed by the user, or an improper I/Ø command list appears at LIØCL, the select will be initiated and the channel set transmitting. Return is made to Normal Return immediately, without waiting for the I/Ø process to terminate.

If the user is forced to, or desires to, wait at this point in the program for the transmission to be completed, he may/must do so by entering another system subroutine which will accomplish the delay. Description of this routine will be deferred until later. Its calling sequence will, however, be of the form

TSX SYSTØW,4

TIX ,,UNIT

Normal Return - - -

If, however, it is neither necessary nor desirable to wait for transmission, the user may allow his program to continue in parallel with the I/Ø transmission.

The returns EØR, EØF, RTT and ETT are operative whether or not the user's program is waiting.

1.3.8 EØR: End-of-Record

A normal end-of-record condition which occurs on the unit specified will cause a CPU interrupt and control will be transferred to the system trap processor.

If EØR = 0, the trap processor will return immediately to continue operation from the point of interruption. In particular, if control is in the system delay routine, control will be returned to the delay routine which will return control to the user.

If EØR ≠ 0, the trap processor will return control to the subroutine at EØR with the results of a Store-Channel instruction in the logical accumulator and the select instruction which accessed the unit in the MQ register. The contents of index register 4 will be such that return should be made to 1,4 by the EØR subroutine when it is finished to resume processing from the point of the interruption.

The EØR subroutine may set indicators which serve to describe the situation and which may be tested by other parts of the user's routine. This will allow the user to do his own I/Ø buffering.

1.3.9 EØF: End-of-File

All comments under EØF, above, apply to the EØF return, when reading.

1.3.10 ETT: End-of-Tape

When the trap processor is entered because of a normal end-of-record or end-of-file trap, the end-of-tape indicator for the channel containing the specified unit is tested. If the end-of-tape indicator is ON, the processor takes the action indicated by ETT before it looks at EØR or EØF.

If ETT = 0 the trap processor will continue on to interrogate the EØR or EØF condition.

If ETT ≠ 0 the trap processor will transfer control to ETT with the contents of MQ equal to the active select instruction of the channel causing the trap and the results of a Store-Channel instruction in the logical AC. The contents of index register 4 will be such that the ETT subroutine should return control to 1,4 when it has finished. When control is returned to the trap processor the EØR or EØF conditions will be interrogated normally.

1.3.11 F,RTT: Redundancy Check, Tapes

When, during a read or write operation on an I/Ø unit, a redundancy check occurs, the CPU is interrupted immediately and control is transferred to the system trap processor.

If both $F = 0$ and $RTT = 0$, then a backspace-record (BSR) is executed on the specified unit and reading or writing is retried ten more times. If after ten tries the operation is still unsuccessful, the job will be terminated with comments to the user and the operator regarding the bad tape or unit.

If $F = 0$ and $RTT \neq 0$, then a backspace-record (BSR) is executed on the specified unit and reading or writing is retried ten more times. If after ten tries the operation is still unsuccessful, then the user's RTT subroutine is entered with the active select instruction in MQ and the results of a Store-Channel instruction in the logical AC, and the contents of index register 4 such that the RTT subroutine should return control to 1,4 when it is finished.

If both $F \neq 0$ and $RTT \neq 0$, then the subroutine RTT is entered immediately with the active select instruction in the MQ and the results of a Store-Channel in the logical AC. The contents of index register 4 will be such that the RTT subroutine should transfer control to 1,4 when it is finished. At the time RTT received control the tape will be positioned at the end of the record in which the check occurred.

1.3.12 The foregoing descriptions of the select routines are based on the assumption that they are not providing automatic I/Ø buffering. Indeed, the facilities are provided so that a user may do his own buffering.

It is possible that eventually buffering capabilities will be added to the system. It is the present intention that this will not affect using routines written assuming the operation described above.

At the time, it is intended that a buffer assignment subroutine will have been added to the execution coordination routines. Then, if a unit has a buffer assigned to it, which is done, or not, by the user, its activity will be buffered; otherwise, the action will be that described above.

1.4 SYSTØW: Trap or Wait

The system subroutine SYSTØW is entered by a calling sequence of one of the two following forms:

```
1.4.1          TSX SYSTØW,4
                TIX ,,UNIT
                RETURN          - - -
```

where UNIT is as described in section 1.3.5, above.

If the input/output unit specified by UNIT is active, SYSTØW will dealy until the action has been terminated and checked.

```
1.4.2          CALL          TSX SYSTØW,4
                TIX TRAPX,,UNIT
                RETURN          - - -
```

where UNIT is as described in section 1.3.5, above.

If the input/output unit specified by UNIT is active, SYSTØW will return immediately to RETURN. If it is inactive SYSTØW will return immediately to TRAPX with the 2's complement of CALL in the address of the accumulator.

1.5 Non-Data Select Tape Routines

The calling sequence for all of the following routines in section 1.5 has the form:

```
                TSX SYSxxx,4  
                TIX ,,UNIT  
RETURN          - - -
```

where UNIT is as described in section 1.3.5.

1.5.1 SYSREW: Rewind tape specified by UNIT.

1.5.2 SYSBSR: Backspace record of tape specified by UNIT.

1.5.3 SYSBSF: Backspace file of tape specified by UNIT.

1.5.4 SYSWEF: Write end-of-file on tape specified by UNIT.

1.6 Tape Skipping Routines

1.6.1 SYSSKR: Skip Record or Records

Calling sequence:

```
                                TSX SYSSKR,4  
                                TIX m,,UNIT  
                                - - -  
RETURN
```

where m is an integer equal to the number of records to be skipped and UNIT is as described in section 1.3.5. An end-of-file mark is counted as a record.

Return is made to RETURN immediately; skipping proceeds concurrently with computing.

1.6.2 SYSSKF: Skip File or Files

Calling sequence:

```
                                TSX SYSSKF,4  
                                TIX m,,UNIT  
                                - - -  
RETURN
```

where m is an integer equal to the number of files to be skipped and UNIT is as described in section 1.3.5. When skipping is completed the tape will be positioned after the m-th file mark from its present position.

PART VI
CONTROL DATA CORPORATION 1604

During the month of August specifications were presented for six new problems. This list does not indicate how the CDC 1604 was used, because large amounts of machine time may have been consumed by problems with numbers less than 30. Numbers followed by T are for theses.

30 Electrical Engineering. Satellite Orbit Computation. In order to analyse existing satellite data it is necessary to know the position of the satellite. A routine written in Fortran language for the CDC 1604 has been obtained from the National Bureau of Standards. Since this routine is available and working, it is very desirable to use the 1604 for this purpose.

31 Economics. Nonlinear Models of International Growth. No solutions other than recursive ones are known to nonlinear difference equations. It is in the nature of these cases that the difference equations governing the behavior of the system will be nonlinear ones, for if both prices and quantities are variables in the system, several equations will contain money values of transactions, i.e., will contain the product of price and quantity.

For recursive solutions of nonlinear difference equations, the 1604 is well suited.

32 Physics. Feasability of a Monte Carlo Calculation of the Ground State of Liquid Helium-4. It is desired to determine the energy and two-particle correlation function of liquid Helium using the variational wave function $\psi = \exp \sum_{i < j}^N V(r_{ij})$. The expectation value of the Hamiltonian is to be minimized with respect to the function $V(r)$ to determine the "best" wave function of this form.

33 Physics. Impulse Approximation Photopion Production. In order to compare the results of a recent experiment on photopion production from He with an impulse approximation theory, it is necessary to perform numerical integrations of the theory of two types. The first is an essential averaging over internal

momenta of the nucleons in He. The second is an averaging over the physical dimensions of the counters, i.e., a counter resolution problem.

The problem resolves itself into the doing of a five-fold integral

$$I = \int d\theta_{\pi} \int d\theta_p \int d\phi_{\pi} \int d\phi_p \int dp J P d\delta/d\Omega$$

where the first four integrals are over the counter dimensions, and the last is an integral over the magnitude of an outgoing proton momentum. The impulse approximation is most naturally set up in the rest frame of the single nucleon moving in the He nucleus. The experiment, naturally, measures things in the laboratory frame. J is the Jacobian which transforms between volume elements in the two frames. P is the momentum distribution of the nucleons moving in the He nucleus. Various momentum distributions will be tried in order to fit the data. $d\delta/d\Omega$ is the photopion production cross section from nucleons at rest, and is therefore a complicated function of the laboratory coordinates.

One of the five integrations could be performed by using symmetry conditions, but the resulting four-fold integral would be enough more complicated that it is doubtful if much computing time would be saved. It is simpler, and desirable to leave it as is.

The general properties of the integrand are well known and it is estimated that sufficient accuracy can be obtained by using a five-point gaussian integration over p and a three-point gaussian scheme for each counter size integral. Each configuration of the counters therefore involves 405 calculations of the integrand. Comparison with the experimental data involves 13 counter configurations and five photon energies, so that a complete output run will involve about 26,000 calculations of the integrand.

34 Chemistry and Chemical Engineering. Atomic and Molecular Energy Eigenvalue Approximations by the Consolidated Variation-Perturbation Method. This problem is one of approximating wave functions for 2-, 4-, and 6- electron atoms, such as H_2 , Be, and LiH.

The combined variation-perturbation method used to approximate energy eigenvalues for atomic and molecular systems involves the analytical evaluation of a considerable number of single center one- and two-electron

integrals, the orthogonalization of one-electron radial functions, the evaluation of eigenvalues and eigenvectors of small symmetric matrices, the inversion and multiplication of rather large matrices. The integration procedure involves considerable looping in the evaluation of the rather complicated analytical expressions which are composed mainly of several summations over products of factorial exponential terms.

35 Chemistry. Molecular Integrals. In the calculation of approximate eigenvalues for Schrödinger's Equation for molecules certain integrals arise which must be evaluated a large number of times. There are various methods of computing these integrals. Some of the more rapid methods are least accurate. The accumulation of rounding error will be studied for various methods on the 1604. When a "best" method is selected it will be programmed in machine language for the 7090. The preliminary investigation of the methods will be done in FORTRAN.

CDC 1604 TIME DISTRIBUTION

August, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Economics	3:00			3:00
Chemistry		16:52		16:52
Civil Engineering	1:02	33:11		34:13
Economics		2:06		2:06
Electrical Engineering		:16		:16
Nuclear Engineering		:27		:27
Physics		31:49		31:49
Psychology	:38			:38
Statistical Service Unit		3:45		3:45
Theoretical and Applied Mech.	:28			:28
Maintenance			3:10	3:10
TOTALS	5:08	88:26	3:10	96:44

PART VII
GENERAL LABORATORY INFORMATION

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	11	1	11.5
Research Associates	4	5	6.5
Graduate Research Assistants	12	20	20.2
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>38</u>	<u>20</u>	<u>50.9</u>
TOTAL	72	46	96.1

The Laboratory Committee Advisory to A. H. Taub, Head, consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, J. E. Robertson, K. C. Smith, and J. N. Snyder.

Physics

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TECHNICAL PROGRESS REPORT

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September, 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research. This report covers the third quarter of 1962.

1. Construction Progress

Transistor counts for chassis wired during the third quarter of 1962 are as follows:

15 Interplay chassis	1,818
4 Spare memory chassis	248
1 Memory interlock chassis	<u>111</u>
TOTAL	2,177

The number of transistors in use in the computer or under test rose from 27,122 to 32,395 during the quarter. Seven temporary chassis, including the temporary instruction sequencing control AC₀, were removed from service during the period.

2. Computer Checkout

During July and August, the advanced control was installed and checked out, culminating in the first production problem being run on August 29, 1962. Details are given in File No. 481, "The First Production Problem on the New Illinois Computer and Its Use in the Discovery of a Logical Error," by J. N. Snyder, D. B. Gillies, R. D. Hill, and P. G. Kruger.

The month of September was devoted to the installation and checkout of that part of the Interplay Control necessary for block transfers to and from the magnetic drum. A drum simulator was used for these interplay tests.

3. Core Memory

During the first two weeks of July the memory was virtually idle while Advanced Control was being put into operation. The remainder of the month was spent in two ways: (1) AC Bootstrap (three words) was wired in (about nine hours) and (2) investigation of the cause of imperfect signals was continued. The latter item will now be considered in more detail.

The symptoms are that "0" sense signals have low amplitude and are "skewed" (displaced toward later time) relative to "1" signals. This situation is more pronounced for higher addresses (4000-7777 octal). Since the signals are bipolar, however, this situation does not necessarily result in a high error rate because the "1" signals, which are reliably strong, provide all the information required for correct operation. Hence, the small and skewed signals primarily decrease the margins on various parameters (drive currents, timing, etc.).

This problem has been very resistant to explanation. The difficulty is that nearly every object in or related to the digit lines, digit drivers, and sense amplifiers have some part in causing the small 0's. The investigation is continuing; meanwhile, minor alterations are being made to take greatest advantage of the knowledge that strong "one" signals are dependable.

By the end of September, a substantial improvement in the core memory error rate was achieved. After resoldering all loose stabistor connections, particularly in the X-Y drivers, it was possible to reduce the cycle time to 1.85 μ s. The corresponding error rate, as indicated by parity checking equipment, was about two per day for the tests and production problems which were then available. Attempts to reduce this error rate are being made.

(S. R. Ray)

4. Magnetic Drum Memory

The logic drawings of the Magnetic Drum Memory Logic (about half of the Drum electronics) have been corrected, edited into the final form, redrawn and checked. The physical placement and block layout of these circuits has been finished. It took ten chassis and 1,494 transistors as follows:

<u>Chassis</u>	<u>Number of Transistors</u>
DA5S	161
DB5S	127
DC5S	187
DA6S	188
DB6S	211
DC6S	36
DB5N	36
DB6N	24
DC5N	262
DC6N	262

After another check of the block layouts and logic drawings, the chassis can be wired.

(B. Levy)

An extensive investigation was made of the effect of write current rise time on magnetic drum performance. This information is needed to complete the design of the write amplifier. It was found that the effect of changing write current rise time was slight, with faster rise time being equivalent to a slight increase in the write current amplitude. Hence, in a region where increasing the write current amplitude will increase the read voltage, speeding up the rise time will also increase the read voltage. In a region where increasing the write current amplitude will decrease the read voltage, speeding up the rise time will also decrease the read voltage. Some of the data which illustrates this effect is plotted in Figure 1.

The effect of rise time on other characteristics was also measured. It was found that over the range of rise time from 1.5 to 0.4 μ sec:

- (1) Resolution is not a function of rise time;
- (2) Spacing loss is not a function of rise time;
- (3) Amplitude modulation is a weak function of rise time.

In one run AM decreased from 11.6 per cent at a rise time of 1.6 μ sec to 9.9 per cent at 0.4 μ sec.

It was concluded that the operating point should be at a write current of 150 to 200 ma peak-to-peak (75 to 100 ma in each half of the head winding) with a current rise time of 1.0 to 0.5 μ sec. A write voltage of 25 volts will be used.

(H. C. Brearley)

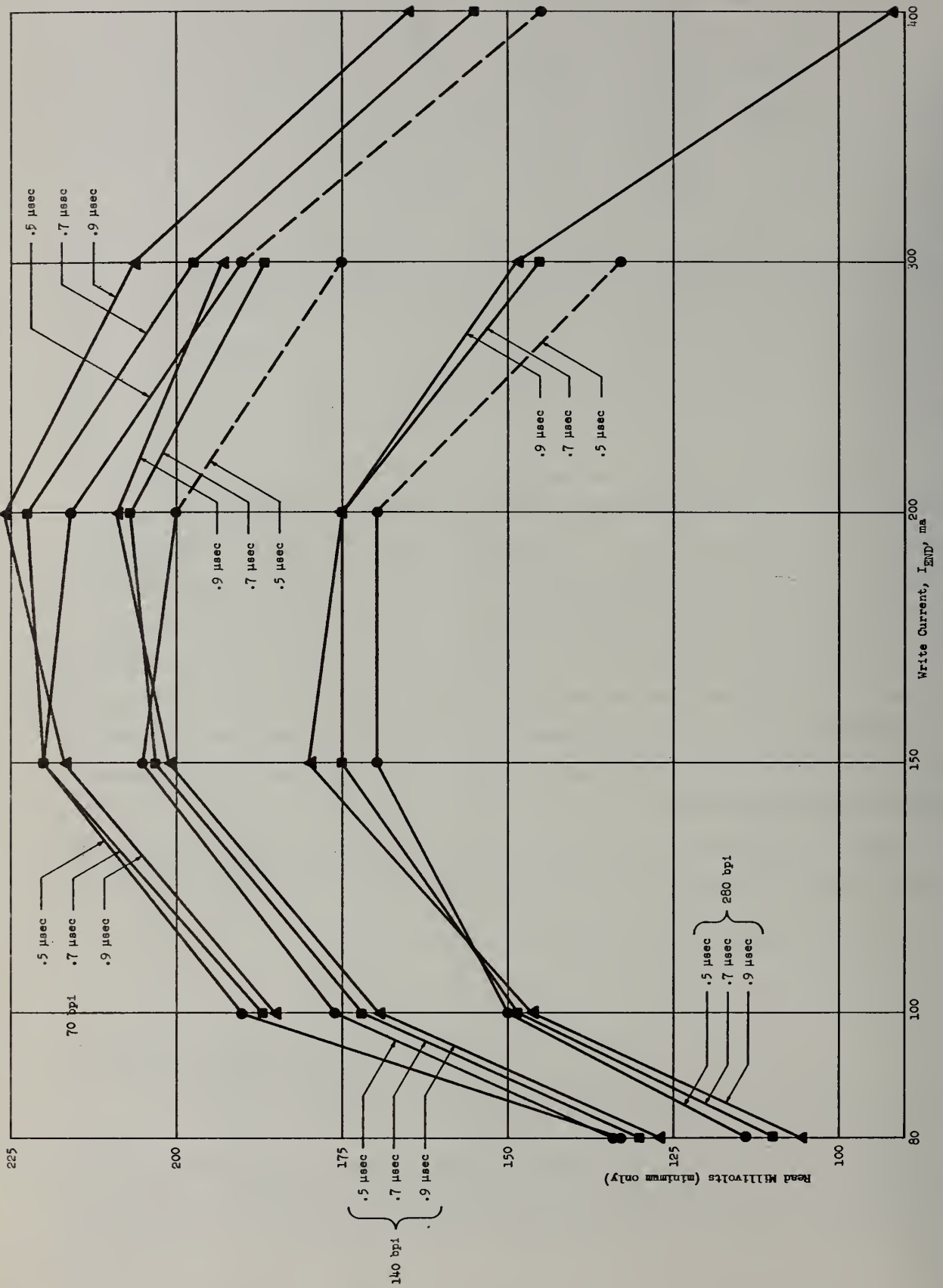


Figure 1 Read-Write Curves Showing Effect of Write Current Rise Time

Experiments were done on the matrix selection switch and the associated system. These were concerned with recovery of the system from row and column switching, and crosstalk between the selected head and others.

Selection transients consist of large spikes ($1\text{ }\mu\text{s}$, 20 v, approximately) and DC pedestals (100 to 300 mv) at the output of the selection switch. Recovery from the spikes was found to be less than $5\text{ }\mu\text{s}$. Recovery from the pedestals is entirely dependent on the low frequency response of the amplifier and the magnitude of the pedestal. However, limiting the low frequency response of the system introduces distortion in the readout wave form. Using a high pass RC filter with a time constant of around $10\text{ }\mu\text{s}$ is satisfactory from this standpoint. Recovery from a pedestal of 100 mv is then found to be around 20 to $30\text{ }\mu\text{sec}$.

Information previously written on tracks was found to be unchanged after repeated track switching. Crosstalk from unselected heads in the same row or column was found to be less than the noise level (0.2%).

Two file numbers were written, giving details of design of the read amplifier (File No. 467) and the matrix selection switch (File No. 470).

(P. V. S. Rao)

A delay circuit using commercially available delay lines and "slow circuits" components was designed and the DC Tolerance Analysis carried out. The circuit uses either fixed or variable delay lines and has several logic options to increase its usefulness.

(M. D. Freedman)

In September the second 32,768 word drum was received from Vermont Research Corporation. So far its performance has been as expected. It has not made the peculiar (bearing?) noise that the first drum sometimes makes during warmups. The runout of the second drum is better than that of the first drum giving amplitude modulations of only 2.9 to 8.3%.

(H. C. Brearley)

Slow Circuits

Experiments were performed on the D1131 Slow Circuits using 2N1309 transistors to see how long the wires between circuits could be. Severe ringing was observed in many circuits, and steady state oscillation was observed in some. The ringing amplitude increased with increasing wire length, and varied over a 2:1 range for different 2N1309's.

Experiments indicated that for a Restoring circuit driving only Restoring circuits, a lead length of three feet caused undershoots greater than 1.1 volts in only one case out of 25 when different 2N1309's were used as the driving emitter follower and as the driven switching amplifier. When Non-restoring circuits were cascaded with Restoring circuits, the data indicated that for a fanout of three to NR circuits (total fanout ≤ 6), the distance between the driving emitter follower and the NR circuits must be limited to about six inches. The output of each NR circuit can drive at most two feet of wire and even then the above criterion may be violated for some 2N1309's.

These requirements on wire length are extremely restrictive, and they apply only to "normal" D1131 Slow Circuits. For slow circuits with thresholds, no undershoot at all can be allowed, so the circuits as they stand are not useable except by careful selection of transistors and the use of very short wires.

One solution to this problem is to use an inductive resistive parasitic suppressor in the base leads of 2N1309's which are driven by long cables or any other situations in which the ringing or oscillation is excessive. The values of inductance and resistance were determined experimentally, as shown in Figure 2. The curves define a region in which the undershoot is less than 0.2 volts and the fall time is less than 100 μ sec. The contour of minimum overshoot is also shown. The final design chosen was 18 turns on a Ferramic H-CF101 core in parallel with a 430 ohm resistor.

(H. C. Brearley, M. D. Freedman)

Transistor counts indicating the extent of completion of various phases of construction of the Magnetic Drum Memory are as follows:

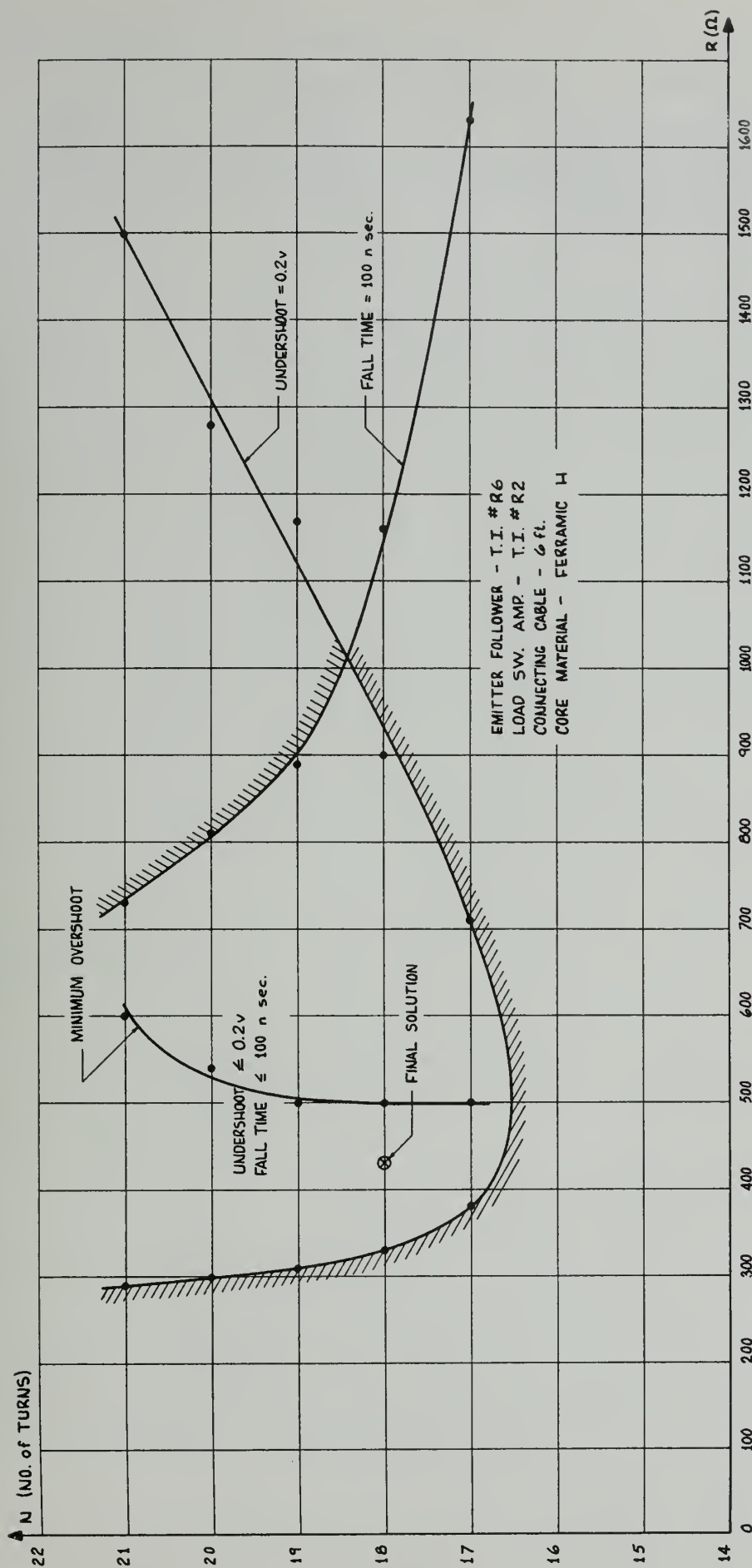


FIG. 2 - PERFORMANCE of 2N1309 RINGING SUPPRESSOR

	<u>July 31</u>	<u>September 30</u>
Total	2,500	2,500
Logical Design	1,690	1,690
Physical Placement	1,270	1,494
Block Layout	534	1,494

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

Sergio Ribeiro reports this month on experiments with flipflop circuits carried out to test the accuracy of the theory of transition times and trigger requirements. Comparison is made with theoretical values obtained by two methods, one a graphical method and the other calculation of an iterative formula.

The theory of tunnel diode amplifier, and in particular, the feasibility of obtaining useful voltage gain for cascaded stages has been studied. Analyses of single stage theory are presented by Tohru Moto-Oka and by Henry Guckel. The former contribution has been confirmed experimentally, at least so far as voltage gain is concerned. The study of intercoupling problems for distributed tunnel-diode systems is continuing. A new geometry for an intercoupled two-pair system is being built.

The statistical analyzer work by Thomas Burnside is nearing completion. Printed circuits have been designed, and an LC delay is being tried out.

2. Flipflop Circuits

Experiments

A series of experiments has been carried out with the purpose of evaluating theoretical methods for calculation of transition times and wave forms of both input and output voltages.

A small system was constructed by means of which a flipflop would be triggered in one direction by a rectangular current trigger and reset by a reset pulse (under no other requirements than sufficiency to trigger the flipflop back to its original state). The transition studied was from state 1 to state 2 (see Figure 1), since the reverse transition is its symmetric if the states are symmetric with respect to the origin and if no saturation occurs; both conditions were met by the flipflops used in these experiments.

In order to simulate the mathematical model used in the theory the flipflops were loaded with artificial input and output capacitors (C_1 and C_2 respectively; see Figure 1), so that both theoretical assumptions are met: (i) the circuit transition speed is limited by the passive network, transistors being assumed instantaneous, and (ii) input and output capacitances are constant and independent of any voltages or currents.

The following data were taken:

- | | |
|--|----------------------|
| a. Transition times vs. trigger amplitude | } for two flipflops |
| b. Minimum trigger duration vs. trigger amplitude | |
| c. Minimum trigger amplitude for arbitrarily long duration | } for four flipflops |
| d. Input and output voltages vs. time | |
| e. Derivative of input voltage vs input voltage (approximate only), i.e., phase plane portraits of the flipflops | |

Comparison of Theory and Experiment

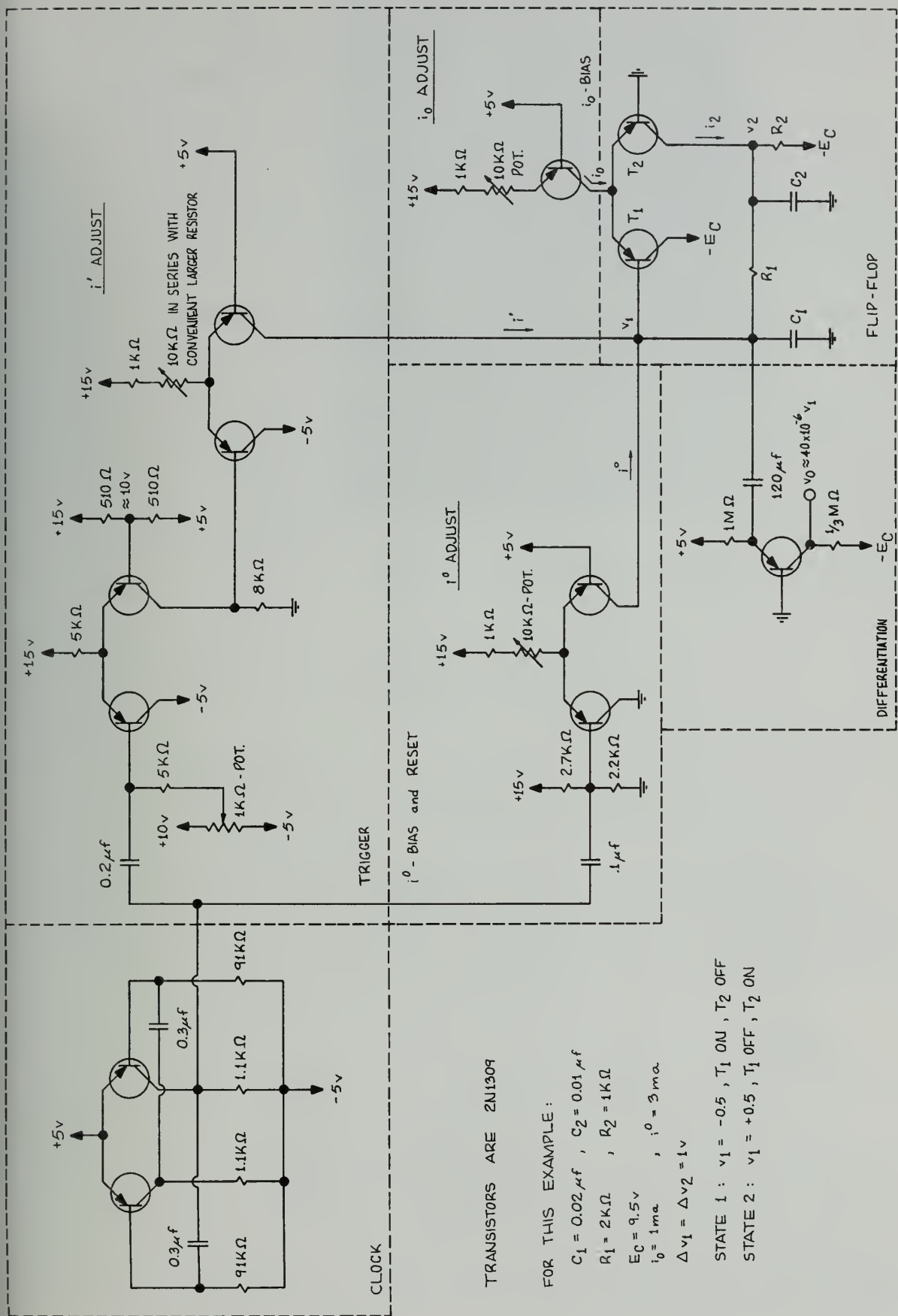
We are now in the process of comparing theoretical with experimental results. One illustrative example is presented below:

Flipflop parameters (symbols and parameters are defined in the Appendix at the end of this section):

$$(i) \begin{cases} R_1 = 2 \text{ k}\Omega; & R_2 = 1 \text{ k}\Omega \\ C_1 = 0.02 \text{ }\mu\text{f}; & C_2 = 0.01 \text{ }\mu\text{f} \end{cases}$$

$$(ii) \begin{cases} p = 10; & i_0 = 1 \text{ ma}; & i^0 = 3 \text{ ma} \\ \frac{1}{p} = 0.1; & \Delta v_1 = 1.0 \text{ v}; & \Delta v_2 = 1.0 \text{ v}; & E_c = 9.50 \text{ v} \end{cases}$$

$$(iii) \begin{cases} k = 4.00 \times 10^{-10} \text{ sec}^2; & l = 7.00 \times 10^{-5} \text{ sec} \\ q = 6.00; & r = 4.00 \times 10^5 \text{ sec} \end{cases}$$



TRANSISTORS ARE 2N1309

FOR THIS EXAMPLE:

$$C_1 = 0.02 \mu f, \quad C_2 = 0.01 \mu f$$

$$R_1 = 2k\Omega, \quad R_2 = 1k\Omega$$

$$E_C = 9.5v$$

$$i_0 = 1ma, \quad i^0 = 3ma$$

$$\Delta v_1 = \Delta v_2 = 1v$$

STATE 1 : $v_1 = -0.5$, T_1 ON, T_2 OFF

STATE 2 : $v_1 = +0.5$, T_1 OFF, T_2 ON

FIG. 1 - EXPERIMENTAL CIRCUIT (FLIP-FLOP AND TRIGGERING CIRCUIT)

$$(iv) \begin{cases} \alpha_I = \alpha_{III} = -15.50 \times 10^3 \text{ sec}^{-1}; & \alpha_{II} = +88.70 \times 10^3 \text{ sec}^{-1} \\ \beta_I = \beta_{III} = -159.0 \times 10^3 \text{ sec}^{-1}; & \beta_{II} = -264.0 \times 10^3 \text{ sec}^{-1} \end{cases}$$

$$(v) \begin{cases} \frac{r}{k} = 1.00 \times 10^5 \text{ sec}^{-1}; & q\beta_{I,III} = -9.55 \times 10^5 \text{ sec}^{-1} \end{cases}$$

$$(vi) \begin{cases} \tau_0 = 0.15 \text{ so } i'_{\min} = 0.15 \text{ ma}; & \text{test trigger: } i' = 0.3 \text{ ma so } \tau = 0.3 \end{cases}$$

Figure 2 represents a transition of such a flipflop under the above test trigger and the corresponding phase plane.

Figure 3 is a graphical approximate method to determine transition times (and wave forms). By means of guide-posts determined by the parameters a broken lines approximation to the phase plane path is determined (line a,b,c,d,e,f,g,h in this example) and then the following formula is used to determine the trajectory time between two points μ and ν connected by a straight line in the phase plane:

$$\theta_{\mu\nu} = t_\nu - t_\mu = \begin{cases} \frac{1}{y'} \ln \frac{y_\nu}{y_\mu}; & y' = \frac{dy}{dx} \neq 0 \\ \frac{x_\nu - x_\mu}{y}; & y' = 0 \end{cases} \quad (1)$$

The other method is an iteration formula which, from a given initial value of y at $x = -1$ (at $x = -1$, $y = \frac{r}{k} \tau$, theoretically) will determine values of y at the two boundaries between the three regions and the time in each region.

We define:

Delay time θ_D : time from $x = -1$ to $x = -\frac{1}{p}$

Active time θ_A : time from $x = -\frac{1}{p}$ to $x = +\frac{1}{p}$

Complementary time θ_C : time from $x = +\frac{1}{p}$ to $x = +1$

Total transition time θ_T : time from $x = -1$ to $x = +1$, i.e., $\theta_T = \theta_D + \theta_A + \theta_C$

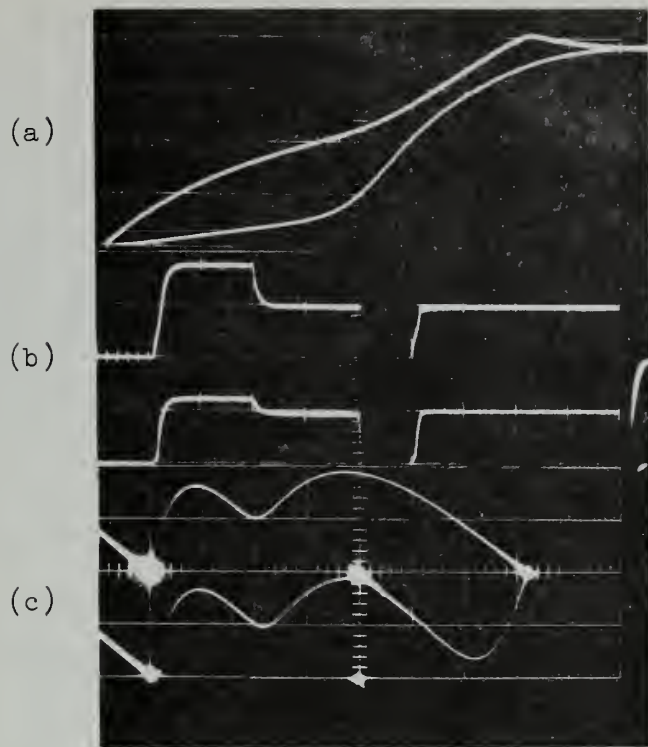


Figure 2 Flipflop Transition

a) $\left\{ \begin{array}{l} \text{Upper trace: } v_1 \text{ vs. } t \\ \text{Lower trace: } v_2 \text{ vs. } t \end{array} \right.$

b) Respectively: $\left\{ \begin{array}{c|c} v_1 \text{ vs. } t & v_1 \text{ vs. } t \\ \text{long trigger} & \text{optimum trigger} \\ \hline v_2 \text{ vs. } t & v_2 \text{ vs. } t \\ \text{long trigger} & \text{optimum trigger} \end{array} \right.$

c) $\dot{v}_1 \text{ vs. } v_1 \left\{ \begin{array}{l} \text{Upper: long trigger} \\ \text{Lower: optimum trigger} \end{array} \right.$

<u>Scales</u>	<u>Vertical</u>	<u>Horizontal</u>
(a)	0.25 v/cm	10.0 $\mu\text{sec/cm}$
(b)	1.00 v/cm	0.5 msec/cm
(c)	$12.5 \times 10^3 \frac{\text{v}}{\text{sec}}/\text{cm}$	0.25 v/cm

UNITS:
 ψ and ψ' in $(\text{msec})^{-1}$
 X is ADIMENSIONAL

POINT	X	Y
a	-1.0	30
b	-0.78	24.6
c	-0.1	14
d	-0.04	14
e	0.1	26.6
f	0.16	31.4
g	0.77	31.4
h	1	27.8
J	0.22	36.3

LINE	SLOPE	COMMENT
A	-25	$-1/R_1 C_1$
B	-15.5	α_I
C	0	
D	88.7	α_{II}
E	78	Eq (1)
F	0	
G	-15.5	α_{III}
H	-26.4	β_{II}
I	-15.9	β_I
J	-15.9	β_{III}
K	-14.1	γ_{III}

OBS.:
ORDINATE of $\psi = \tau = 30$
 $S'_- S_+ = S'_- S_+ = qT = 1.0$
 $S'_- S_0 = \frac{qT}{\beta_I} = -0.2$
 S_- and S_+ : STABLE NODES
 S_0 : SADDLE POINT
PRIME INDICATES : "SHIFTED BY TRIGGER"

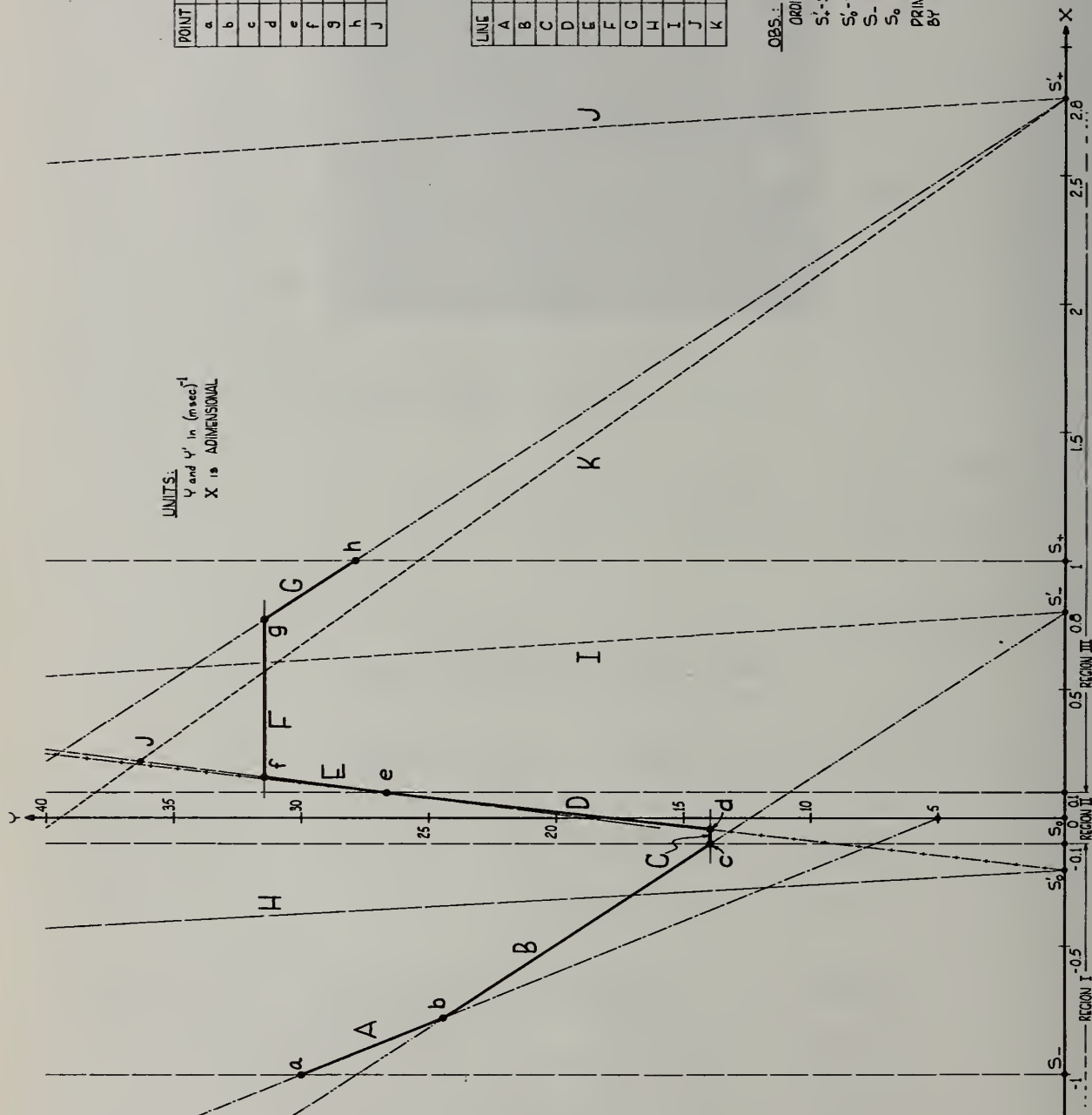


FIG. 3 ASYMMETRIC FLIP-FLOP TRANSITION

Equation 2 is the formula used for the iterative procedure. Inside a given region i of the phase plane x, y ($y = \dot{x}$), the trajectory time between two points μ and ν is given by:

$$\theta_{\mu\nu} = t_\nu - t_\mu = \frac{1}{\alpha_i} \ln \frac{(x_{\nu i} - C_i)\beta_i - y_{\nu i}}{(x_{\mu i} - C_i)\beta_i - y_{\mu i}} = \frac{1}{\beta_i} \ln \frac{(x_{\nu i} - C_i)\alpha_i - y_{\nu i}}{(x_{\mu i} - C_i)\alpha_i - y_{\mu i}} \quad (2)$$

(See Appendix at the end of this section for definitions of parameters.)

The right hand side equality furnishes $y_{\nu i}$ by iteration if $x_{\mu i}$, $y_{\mu i}$ and $x_{\nu i}$ are known; then the value of any of the two expressions is $\theta_{\mu\nu}$.

Tables 1 and 2 show the results obtained by these two methods as compared to the measurements taken for the picture in Figure 2.

TABLE I Comparison of Times

Unit: μsec

<u>Time</u>	<u>Approximate Graphical</u>	<u>Approximate Iterative</u>	<u>Measured</u>
Delay θ_D	44.23	44.75	38.0
Active θ_A	11.52	10.65	11.5
Complementary θ_C	29.73	28.48	32.0
Total θ_T	85.59	83.88	81.5

TABLE II Comparison of Key Ordinates

Unit: $(\text{msec})^{-1}$

<u>Ordinate</u>	<u>Approximate Graphical</u>	<u>Approximate Iterative</u>	<u>Measured</u>
y_a	30.0	30.00	40
y_c	14.0	15.01	15
y_e	26.6	26.97	18
y_h	27.8	27.74	28

We notice first that, even though the graphical method is a first approximation, the "exact" iterative procedure does not necessarily improve its results. From the point of view of accuracy the methods are equivalent, but the graphical procedure involves much less labor.

Then we observe that the theory tends to furnish too large values of time in the beginning of the transition ($x < 0$) and too small values of time for the end of the transition ($x > 0$), with the end result being some cancellation of these two opposite errors and consequent better accuracy in the overall transition time. This is to be expected if we remember that the division of the phase plane into three regions corresponds to approximating the characteristic of the transistor pair as in Figure 4.

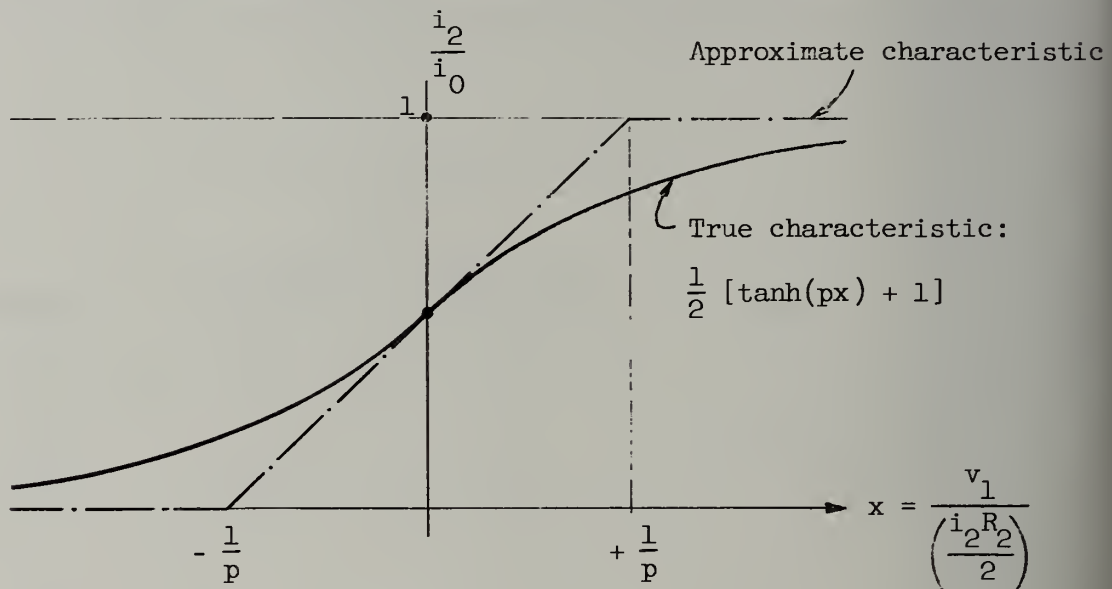


Figure 4 Approximate and "True" Transistor Pair Characteristics

It is clear that if this ideal piecewise linear transistor pair model is substituted in a flipflop instead of the real transistors the flipflop would tend to be slowed down in the first half of a transition, and speeded up in the second half.

Therefore, to improve the results, one must use either a better piecewise linear approximation to $\tanh(px)$, or a computer solution of the nonlinear equation. First, however, we should attempt to prove that indeed

the errors are caused by the piecewise linear approximation used, and this can be done by comparing computer solutions of both the approximate and the original nonlinear equations with the measured data.

(Sergio Ribeiro)

3. Tunnel Diode Amplifiers

Single-stage Tunnel-Diode Voltage Amplifier: Experimental

A one-tunnel-diode voltage amplifier, the configuration of which is shown in Figure 5, was constructed and measurements made to compare with the theory described in previous reports. (Design of a current amplifier is easier than the design of a voltage amplifier.)

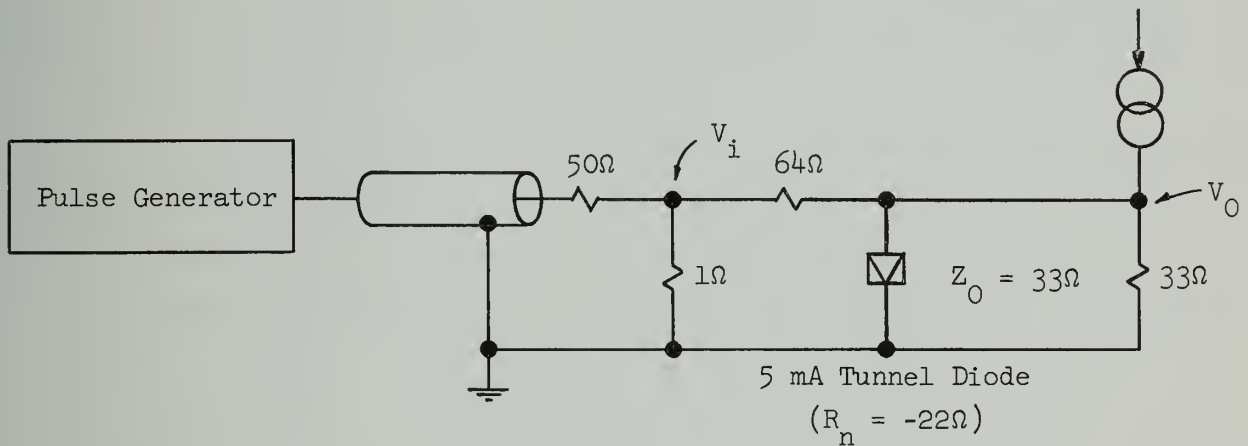


Figure 5

Agreement with the theoretical voltage gain was satisfactory. Resistances with better characteristics in the high frequency range will be needed to conform experimentally the frequency characteristic of the amplifier predicted by the theory.

Single-stage Tunnel-Diode Voltage Amplifier: DC Design Theory

The general circuit configuration of the amplifier is given by Figure 6. The necessary load resistance may be included in the tunnel-diode negative resistance or in the four-terminal network.

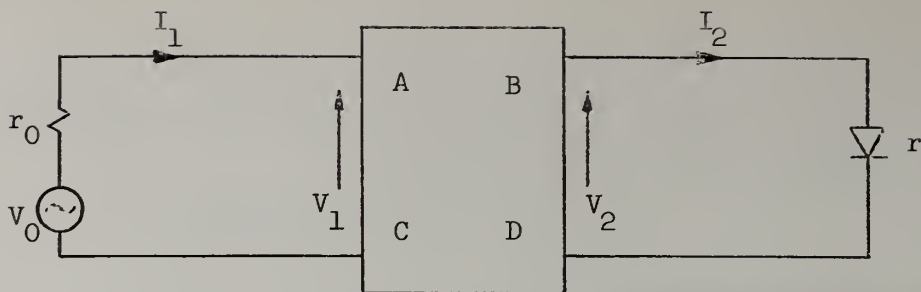


Figure 6

The circuit equations of this system are given as follows:

$$\begin{pmatrix} V_2 \\ I_2 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_1 \\ I_1 \end{pmatrix} \quad (4)$$

$$V_1 = V_0 = r_0 I_1 \quad (5)$$

$$V_2 = -r I_2 \quad (6)$$

The four-terminal network is considered to consist only of resistances. The voltage gain is given by the following equation:

$$\frac{V_2}{V_1} = G = \frac{1}{(D - C r_0) + \frac{1}{r} (B - A r_0)} \quad (7)$$

Monostable operation requires the following condition:

$$\frac{1}{r} < - \frac{D - r_0 C}{B - r_0 A} \quad (8)$$

A tunnel diode has a nonlinear negative resistance. Therefore, the voltage gain depends on the value of negative resistance; that is, on the operating voltage region. The largest output signal for which voltage gain is expected is defined by the region (V_1, V_2) as shown in Figure 7, and the average negative resistance of the tunnel diode in this region is $-R_T$. The

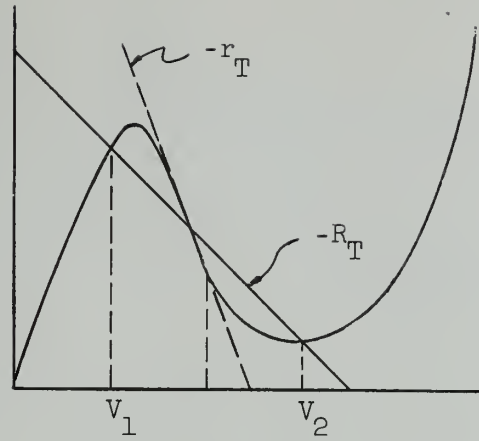


Figure 7

minimum negative resistance and load resistance have values of r_T and r_ℓ respectively. For small signal operation, the gain and the negative resistance are represented by $\frac{1}{\epsilon}$ and r_0 respectively.

From these assumptions, the coefficients of the four-terminal network are determined as follows:

$$\begin{pmatrix} \frac{r_0}{R} & -\frac{1}{R} & r_0 \\ \frac{r_0}{r} & -\frac{1}{r} & r_0 \\ \frac{r_T}{r} & -\frac{1}{r} & r_T \end{pmatrix} \begin{pmatrix} A \\ B \\ C \end{pmatrix} = \begin{pmatrix} D - 1 \\ D - \epsilon \\ -D \end{pmatrix} \quad (9)$$

$$AD - BD = 1 \quad (10)$$

$$\text{where } -\frac{1}{R} = -\frac{1}{R_T} + \frac{1}{r_\ell}, \quad -\frac{1}{r} = -\frac{1}{r_T} + \frac{1}{r_\ell}$$

$$A = -\frac{r}{r_0} D + \frac{r}{r_0} \frac{R}{R - r} - \epsilon \frac{r(r_0 R + r r_T)}{r_0(r_0 + r_T)(R - r)} \quad (11)$$

$$B = -Dr + \epsilon \frac{rr_T}{r_0 + r_T} \quad (12)$$

$$C = \frac{D}{r_0} - \frac{1}{r_0} \frac{1}{R - r} + \epsilon \frac{r}{r_0(R - r)} \quad (13)$$

$$D = \frac{r_T}{r_0 + r_T} \frac{R - \epsilon r}{R - r} - \frac{r_0}{\epsilon r} \quad (14)$$

From these equations, it is concluded that a small input impedance is necessary to get a good characteristic in large signal operation. This shows that difficulty may be expected in cascading connections for this type of amplifier.

(Tohru Moto-Oka.)

Tunnel Diode Voltage Amplifier Theory

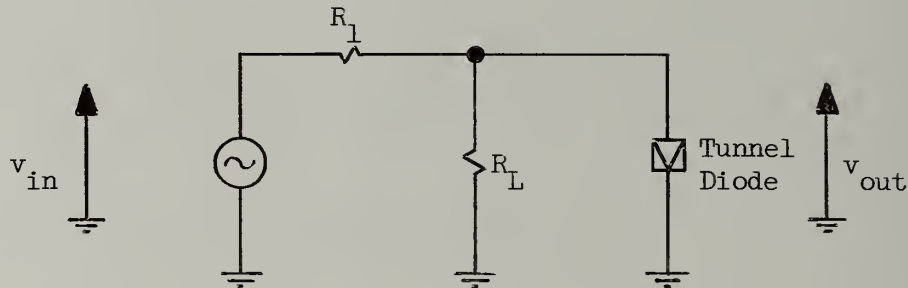


Figure 8 Voltage Amplifier

In order to study the interconnectability of voltage amplifiers and the idea of converting a small signal input to a bistable output by the use of successive amplifiers, the tunnel diode characteristic was approximated by:

$$i - i_1 = - \frac{1}{v_1^2} \frac{di}{dv} (v_A) \left[\left(\frac{v - v_A}{3} \right)^3 - v_1^2 (v - v_A) \right]$$

$$\frac{d^2 i}{dv^2} (v_A) = 0$$

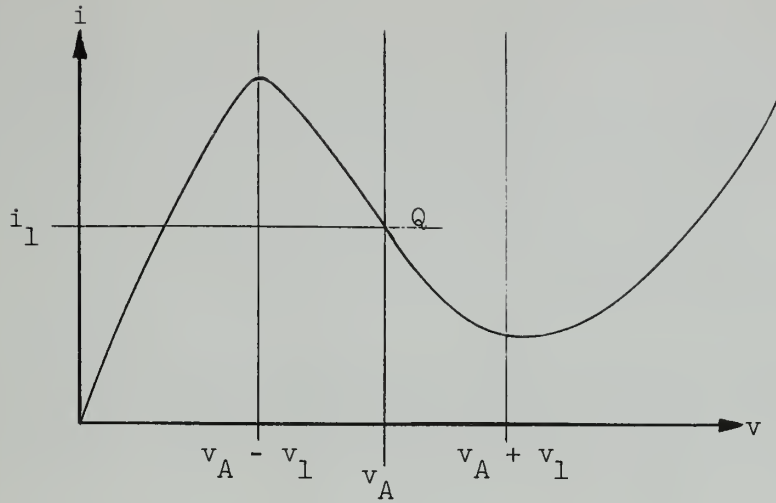


Figure 9 Second Order Approximation

so that

$$i_{AC} = - \frac{1}{v_1^2} \frac{di}{dv} (v_A) \left(\frac{v_{AC}^3}{3} - v_1^2 v_{AC} \right)$$

if

$$R \equiv - \frac{1}{\frac{di}{dv} (v_A)} , R_L = KR$$

The voltage gain is given by

$$A_v = \frac{1}{1 + \frac{R_1}{R_L} - \frac{R_1}{R} \left[1 - \frac{1}{3} \left(\frac{v}{v_1} \right)^2 \right]}$$

By considering $A_v > 1$ and the stability condition it becomes evident that

$$0 < K < \frac{3}{2}$$

$$R_1 < \frac{R}{1 - \frac{1}{K} - \frac{1}{3} \left(\frac{v}{v_1} \right)^2}$$

This yields a maximum open circuit gain of

$$A_v(0) = 3 \left(\frac{v_1}{v} \right)^2$$

It is therefore possible to design a single stage voltage amplifier. However, preliminary results of two cascaded stages are not favorable due to additional restrictions on the input impedance.

(H. Guckel)

4. Tunnel Diode Distributed Systems

Work on intercoupled distributed systems is being continued. Experiments with "four open wire" lines were performed, but yielded unsatisfactory results. This is due to the low $\frac{Z_m}{Z_0}$ ratio which can be attained while still maintaining a reasonable mechanical alignment. In order to eliminate this mechanical difficulty the following line is being considered:

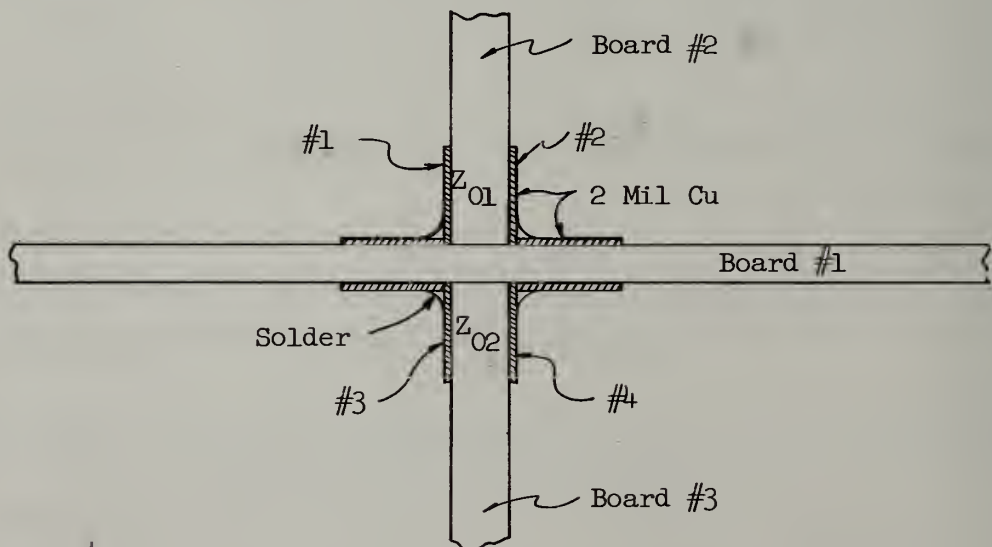


Figure 10 Intercoupled Strip Lines

Conductors #1 and #2 form the input pair, #3 and #4 the output pair. The board is high quality dielectric. Theoretical considerations indicate $\frac{Z_m}{Z_0} \geq 2$. In order to decrease this ratio the unsymmetric case ($Z_{01} \neq Z_{02}$) must be used.

(H. Guckel)

5. Statistical Analyzer

Work was continued on the circuits of the statistical analyzer. Printed circuits are being used for the final design and alterations are being studied for some of the circuits to improve performance.

A delay line is being designed for the counter to insure that the flipflops will not change states more than once during one clock pulse. An LC ladder delay line of the type shown in Figure 11 is being considered.

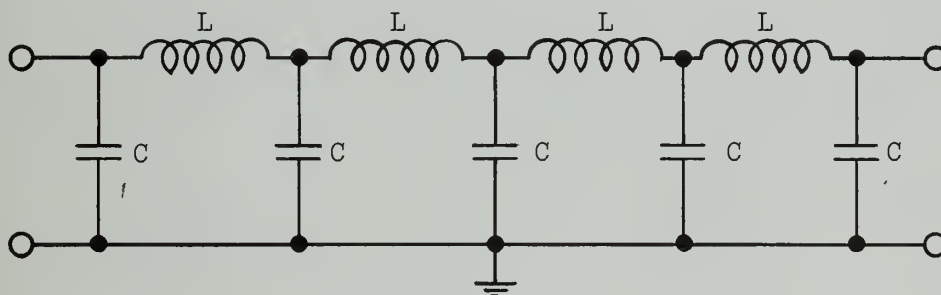


Figure 11 LC Delay Line

In general $L = C$ except for the boundaries of the line which may have other values for a better match between the line and the circuits.

The LC ladders will be placed in the counters as shown in Figure 12. The lines will delay the $F_1 \cdot F_2 \cdot F_3$ pulse by about $.4 \mu\text{sec}$, and the clock pulse will appear at the center of the $F_1 \cdot F_2 \cdot F_3$ pulse.

(Thomas Burnside)

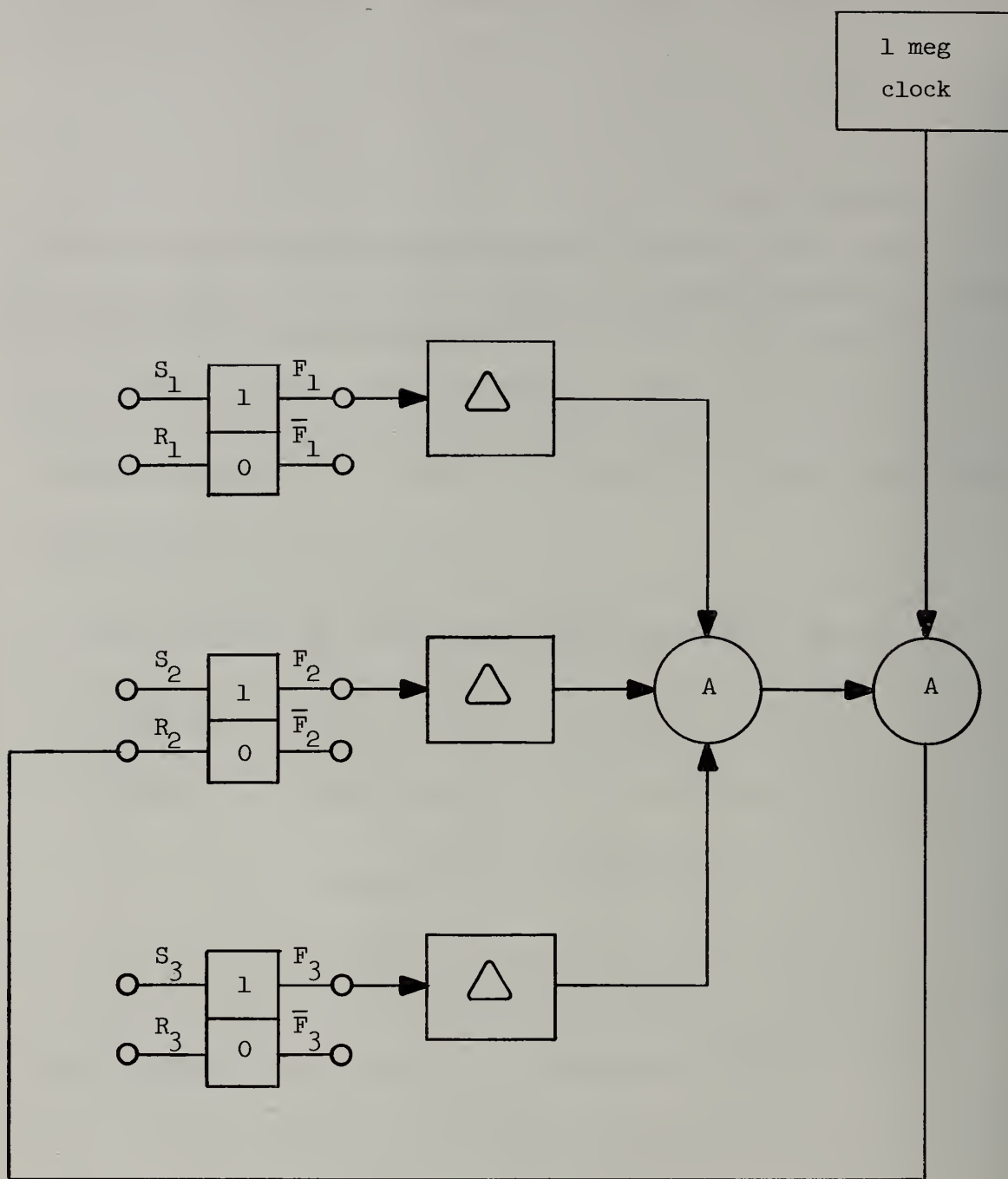


Figure 12 Delay Lines in the Modulo 8 Counter

APPENDIX TO PART II

Flipflop Circuits

The following summary has the purpose of defining parameters and condensing various previous reports.

Analysis of the asymmetrical flipflop under conditions of state symmetry yields the following differential equation, assuming rectangular current triggering:

$$k\ddot{x} + \ell\dot{x} + x = f(px) + q\tau + r\dot{t} \quad (3)$$

with

$$\left\{ \begin{array}{l} x = \frac{v_1}{\left(\frac{i_0 R_2}{2}\right)}, \quad \tau = \frac{i'}{i_0}, \quad p = \frac{1}{4} \frac{\epsilon}{kT} R_2 i_0 \\ k = R_1 R_2 C_1 C_2; \quad \ell = R_1 C_1 + R_2 C_1 + R_2 C_2; \quad q = 2 \left(1 + \frac{R_1}{R_2}\right); \quad r = 2R_1 C_2 \end{array} \right.$$

$$\left\{ \begin{array}{l} i' \text{ is the amplitude of the current trigger and} \\ v_1 \text{ is the input voltage.} \end{array} \right.$$

$$\text{and} \quad f(px) = \left\{ \begin{array}{ll} -1 & x \leq -\frac{1}{p} \\ px & -\frac{1}{p} \leq x \leq +\frac{1}{p} \\ +1 & +\frac{1}{p} \leq x \end{array} \right.$$

is an approximation to the original function (resulting from the transistor pair characteristic) $\tanh(px)$; Eq. 3 can be replaced by three linear equations each valid in one region, by dividing the plane (either y, x or x, t plane) into three regions:

$x \leq -\frac{1}{p}$, $-\frac{1}{p} \leq x \leq +\frac{1}{p}$, $+\frac{1}{p} \leq x$, which are called respectively regions I, II, and III. The solutions of such equations are exponentials of the form

$$x = A_i e^{\alpha_i t} + B_i e^{\beta_i t} + C_i, \quad i = I, II, III$$

and both x and \dot{x} must be continuous at the boundaries between two regions.

Of course the term in \dot{x} can be replaced by equivalent nonzero initial conditions, and then we will have:

$$\left\{ \begin{array}{l} \alpha_{I,III}, \beta_{I,III} = \frac{-\ell \pm \sqrt{\ell^2 - 4k}}{2k} \\ \alpha_{II}, \beta_{II} = \frac{-\ell \pm \sqrt{\ell^2 + 4k(p-1)}}{2k} \\ C_I = q\tau - 1, \quad C_{II} = -\frac{q\tau}{p-1}, \quad C_{III} = q\tau + 1 \end{array} \right.$$

where $q\tau$ is the amount of shift to the right the trigger applies to the stable nodes (in the phase plane) and $\frac{q\tau}{p-1}$ is the amount of shift to the left it applied to the saddle point.

PART III
MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Calculations

A set of programs for this project which are to be executed on the new Illinois computer were written and checked. The main program FJ-15 is an evaluation of the quantum mechanical partition function of a single particle in a one-dimensional box of length L . The main program has been coded, but has not yet been checked. It will be used to check the accuracy of the Monte Carlo scheme used to make the computation.

Routines FJ-1 through FJ-14 are subroutines most of which are concerned with the punched paper tape mode of input and output presently available with the computer.

FJ-1 and FJ-2 are respectively input and output routines for sexadecimally coded binary information.

FJ-3 through FJ-6 comprise an input routine which will accept three-letter mnemonic orders, relative and fixed decimal addresses, floating point decimal numbers, and single orders to be obeyed at the time of input.

FJ-7 calculates the exponential function e^x for $0 \leq |x| \leq 2$.

FJ-8 provides floating point decimal output.

FJ-9 calculates $\log_2(x)$ for all x in the range of the computer.

FJ-10 and FJ-11 output and input respectively decimal integers with leading zeros suppressed.

FJ-12 and FJ-13 are routines to input and output alphabetic information.

FJ-14 generates random numbers having either a uniform distribution on the interval $-\frac{1}{2}$ to $\frac{1}{2}$ or a Gaussian distribution with a mean square of $\frac{1}{2}$. Generation of a uniformly distributed number is done by the multiplicative congruence method and takes 56 usec at the present machine speed. A Gaussian number is generated from a uniformly distributed number by referring to the entry corresponding to the uniform number y in a table of $x = F^{-1}(y)$ where

$F(x)$ is the cumulative distribution function of the Gaussian distribution.
Generation of a Gaussian number takes 77 usec.

(Harry Jordan)

PART IV
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. High Resolution Oscilloscope

Conventions for programming the High Resolution Oscilloscope are described in File No. 486 by M. Shirazi. A number of engineering routines for the generation of test patterns have been prepared.

File No. 486, "Programming the High Resolution Oscilloscope," by Mostafa Shirazi, September 27, 1962.

II. Theory of Pattern Recognition

Stein completed an investigation of pyramidal encoding of bubble chamber negatives instigated in the summer of 1961.

File No. 378, "Studies on the Automatic Scanning and Measuring of Bubble Chamber Negatives III: Analysis of Bubble Chamber Negatives by Projective Encoding," by J. H. Stein, September 3, 1962.

III. Circuitry of the Pattern Articulation Unit (PAU)

The following file note was issued this month:

File No. 480, "Some Comments on Complementary Current Switching Circuitry," by K. C. Smith, September 18, 1962

IV. Power Distribution System of the PAU

Starting with the experience of the New Illinois Computer project, Smith designed the power distribution system for the pattern articulation system (PAU). Design philosophy, implementation, and test results are presented in:

File No. 474, "Power System Design for the Pattern Articulation Unit," by K. C. Smith, September 12, 1962.

At present a group of 12 modules, each rated for six amperes at system voltages of +6, -6, -12 volts, have been constructed in final circuitry, housed in a metered air flow cage and are ready to undergo final test.

(B. H. McCormick, K. C. Smith)

PART V
ILLIAC USE AND OPERATION

Illiac Usage

During the month of September, specifications were presented for seven new problems. This list does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2227T. Numbers followed by T are for theses.

2227T Chemistry. Least Square Fit of Experimental Data. Proton and fluorine relaxation times in solutions of free radicals are measured at different magnetic fields. The relation between the relaxation time T_1 and the resonance frequency of electrons w_s can be expressed in the following equation

$$\frac{1}{T_1} = A \left[\frac{1}{\tau_c} + \frac{\tau_c}{1 + w_s^2 \tau_c^2} \right] + B \left[\frac{1}{\tau_c'} + \frac{\tau_c'}{1 + w_s^2 \tau_c'^2} \right]$$

where A, B, τ_c , and τ_c' are unknown.

The Illiac program will locate the best values of these unknown numbers to fit the experimental data by least square methods.

2228 Psychology. Methodological Research in Factor Analysis. Two different, though related, problems are involved. One is an investigation of the effects on non-rotated and rotated factor loadings of the introduction of random variables in the correlational matrix.

The second problem involves the analysis of longitudinal data and the comparison of traditional factor analytic models with the more recent simplex model suggested by Louis Guttman. This last project is still in the punch card phase and will require the full gamut of routines from the computation of inter-correlations to a rotation of factors.

2229 Digital Computer Laboratory. Statistical Errors in Second Order Richardson Method. Errors will be studied from a statistical point of view in the particular iterative process

$$\vec{X}_{i+1} = 2b(A \vec{X}_i + \vec{y} - \vec{X}_{i-1}) + \vec{X}_{i-1}, \quad i = 1, 2, \dots$$

A is chosen to be the matrix resulting from the application of discreteness to the differential equation

$$\frac{d^2 y}{dt^2} = 0; \quad y(0) = a; \quad y(1) = b.$$

2230 Institute of Communications Research. Personality Differential in Person Perception. Considerable research has been carried out on the rating of personality concepts using the semantic differential procedure. Osgood and Ware have developed a form of the semantic differential for use in the measurement of personality. This instrument, the personality differential, should prove a fruitful tool for the investigation of interpersonal perception. One purpose of the present project is the investigation of the relations among several existing methods for the study of person perception, in particular the location of the personality differential within this network of methodologies. Other approaches available for the investigation of individual differences in person perception are: (1) G. A. Kelly's Repertory Test; (2) multidimensional scaling with persons as stimuli; and (3) multidimensional scaling with traits as stimuli. Each of these will be compared with the personality differential approach.

In addition to the relations among these methods an investigation is planned of the determinants or correlates of individual differences in interpersonal perception. Three types of perceiver characteristics will be studied: (1) general personality traits; (2) the perceiver's system of values; and (3) the "cognitive styles" of the perceiver.

For much of this research existing programs will be used to obtain correlations, characteristic roots and vectors, etc. New programs are being developed for obtaining cross-products and for the multidimensional scaling procedures.

2231 Psychology. Dimensional Structure of the Ego and Super Ego. This study concerns three groups of students, tested on measures of ego, super ego, and a variety of physiological and biographical measures. In each case scores will be correlated with a portion of the correlations being allocated to a factor analysis and the rest to an extension analysis.

2232 Psychology. Personality Dimension of Air Force Recruits. This research involves three groups of air force recruits. Scores on a psychological test will be correlated and the factor analysed.

2233 Psychology. Construction of an Objective Test Personality Battery. . This analysis involves the analysis of a preliminary try-out of an adult objective test factor battery. The various programs are used in order to obtain the most efficient weights for each test in the total battery.

Table I shows the distribution of Illiac machine time for the month of September. Times in parentheses are simulations on the CDC 1604.

TABLE I

	Hrs:Min
Scheduled Maintenance	54:12
Unscheduled Maintenance	15:24
Leapfrog	12:34
Drum Test	25:04
Demonstrations	:34
Library Development	<u>5:13</u>
	113:01

Use by Departments

Agricultural Economics (APPRAISAL 47 15 05 334)	:12	
Agricultural Economics	29:44	
Astronomy	2:18	
Bureau of Educational Research (PHM1839)	7:08	
Chemistry	23:07	
Civil Engineering	149:54	(:45)
Coordinated Science Lab. (DA 36 039 SC56695)	39:18	
Digital Computer Laboratory (NONR 1834(27))	14:33	
Digital Computer Laboratory	3:03	
Economics	:47	
Education	:18	
Electrical Engineering (NSFG 19005)	2:31	
Electrical Engineering (AF7043)	:51	
Geological Survey	7:07	
Geology (IC GRAD GEOLOGY)	2:07	
Inst. for Communications Res. (44 28 20 378)	32:06	
Inst. for Communications Res. (USPHM 3941)	:20	
Institute for Communications Research	17:56	(:05)
Mathematics	34:58	
Mechanical Engineering (NSFG 19926)	:19	
Mechanical Engineering (AF 400 600 909)	:30	
Mechanical Engineering	17:50	(1:25)
Mining and Metallurgical Engineering (AF 6770)	:15	

Physical Education	2:07	
Physics (NONR 1834(05))	2:20	
Physics (NSF 16721)	:09	
Psychology (MD 2060)	:40	
Psychology (ML774)	6:48	
Psychology (ONR 183436)	1:01	
Psychology (US NONR 1834(39))	2:59	
Psychology	137:22	
Sociology	3:24	
State Water Survey (NSF 17038)	:15	
State Water Survey	4:25	
Theoretical and Applied Mech. (DA 01021 ORD 11878)	:13	
Theoretical and Applied Mechanics (46-22-60-356)	1:09	
Zoology	:25	
	<u>550:29</u>	(2:15)
		<u>663:30</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure.

This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	2
Reader	5
Punch	2
Scope	4
Power Supplies	3
Unknown	<u>3</u>
TOTAL	19

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/1/62	15:30	:00	:00	0		:00	:00	0
9/4/62	18:55	3:01	2:04	1	(1) Memory failure 2 ⁻²² .	:00	:20	0
9/5/62	22:25	:00	1:35	0		:00	:27	0
9/6/62	21:43	:00	2:17	0		:00	:35	0
9/7/62	21:42	:00	2:18	0		:00	:07	0
9/8/62	24:00	:00	:00	0		:00	:00	0
9/9/62	24:00	:00	:00	0		:00	:25	0
9/10/62	20:57	:00	3:03	0		:00	:32	0
9/11/62	22:03	1:27	:30	1	(1) Reader "J" made an error.	:00	2:34	0
9/12/62	20:06	1:24	2:30	1	(1) Memory failure 2 ⁻¹⁶ and 2 ⁻²² .	:00	:16	0
9/13/62	21:17	:16	2:27	1	(1) Punch number 1 making errors.	:00	:22	0
9/14/62	21:21	:53	1:46	1	(1) Failing on marginal voltage from power supplies.	:00	:41	0
9/15/62	23:34	:26	:00	2	(1) Reader "J" failed. (2) Unknown.	:00	:20	0
9/16/62	24:00	:00	:00	0		:00	:00	0
9/17/62	21:29	:10	2:21	1	(1) Unknown.	:00	:23	0
9/18/62	20:20	:00	3:40	0		:00	:20	0
9/19/62	18:41	1:49	3:30	1	(1) Reader "D" failed.	:00	:43	0
9/20/62	20:20	:00	3:40	0		:00	:46	0
9/21/62	21:00	3:00	:00	0		:00	:26	0
9/22/62	24:00	:00	:00	0		:00	:00	0
9/23/62	24:00	:00	:00	0		:00	:00	0
9/24/62	19:50	5:00	4:05	1	(1) Reader "B" failed.	:00	:40	0
9/25/62	21:15	5:00	2:40	1	(1) Scope failure.	:00	1:05	0
9/26/62	20:50	4:00	3:06	1	(1) Unknown	:00	:46	0

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/27/62	21:34	:00	2:26	0	(1) Scope failing. (2) Scope failing.	:00	:27	0
9/28/62	19:09	1:39	3:12	2	(1) Low filaments on Illiac. (2) Reader "B" failed.	:00	:31	0
9/29/62	21:28	2:32	:00	2	(1) Filament voltages too high. (2) Scope failing. (3) Punch "5" failed.	:00	:27	0
9/30/62	21:05	2:55	:00	3		:00	:00	1
TOTALS	596:34	16:46	50:10	19		:00	13:18	1

PART VI
CONTROL DATA CORPORATION 1604

No new problem specifications were submitted in September for the CDC 1604.

CDC 1604 TIME DISTRIBUTION
September, 1962

Department	Simile	Non-Simile	Maintenance	Totals
Agricultural Engineering		:20		:20
Chemistry		23:47		23:47
Civil Engineering	:45	20:01		20:46
Economics		:14		:14
Electrical Engineering		:43		:43
Inst. for Communications Res.	:05			:05
Mechanical Engineering	1:25			1:25
Nuclear Engineering		:29		:29
Physics		29:19		29:19
Statistical Service		:27		:27
Maintenance			1:00	1:00
TOTALS	2:15	75:20	1:00	78:35

PART VII
IBM 7090-1401 SYSTEM

During the month of September, the IBM 7090-1401 computing system was installed and physically checked out. The remainder of the month was spent in code checking the University of Illinois Executive System in order to be able to place the computer in service early in October. This executive system has been called PORTHOS. Naturally, it does not yet exist in complete and final form, nor does it yet have all of the facilities anticipated and described in earlier Monthly Technical Progress Reports. However, in order to utilize the 7090 as soon as possible for instructional and research purposes, the more important features of the final system have been implemented and placed in operation. At the present time, the MAD compiler, the FORTRAN compiler and a restricted sub-set of the SCAT assembler are operative.

During the month of September, 14 problem specifications have been submitted for the IBM 7090. Those marked by T are associated with theses.

1-29001T Civil Engineering. Shell in Elastic Medium. The problem considered consists of analyzing the response of a cylindrical elastic shell in an infinite elastic medium subjected to a plane pressure wave which envelops the shell. A cylindrically symmetric potential function represented as emanating from the center of the shell acts to produce the effects of a reflected pressure wave.

Modal equations of motion with generalized coordinates and forces are derived to describe the dynamic interaction of the shell and the medium. An additional set of integral equations insures compatibility of velocities and displacements.

The potential function is represented by Fourier series of which just the first three terms are considered.

An iterative type solution using the Beta method of integration and iteration is used to solve the problem.

2-29002 Physical Chemistry. Analytical Integrals Programs. In the calculation of approximate eigenvalues for Schrodinger's Equation certain integrals arise which must be evaluated a large number of times. There are various methods of computing these integrals. Some of the more rapid methods are least accurate. The accumulation of rounding error will be studied for various methods using the MAD compiler. When a satisfactory method is found, it will be programmed in SCAT as a subroutine to be used later.

3-29003 Electrical Engineering. Ionospheric Electron Density. This problem is used to analyze data obtained from moon reflection studies of the ionosphere. It interpolates two sets of tables to find values of $M = H \cos \theta \sec i$ for Danville, Illinois and Belmar, New Jersey, at a given instant of time. To do this, the elevation and azimuth of the moon at both places, corrected for parallox, must be known.

H = Earth Magnetic Field Strength

θ = Angle between Ray and Earth Field

i = Angle between Ray and Local Vertical

This elevation and azimuth and these corrections are determined using standard procedures from spherical trigonometry.

4-29004T Mechanical Engineering. Two Phase Nozzle Flow. The basic gas dynamic equations for two phase nozzle flow for a gas-solid suspension are:

$$A^* u^* P^* = T^*$$

$$m_s = m_p u^* / u_p^*$$

$$T^* + u^{*2} + \frac{m_p c}{c} \frac{p}{p} T_p^* + m_p u_p^{*2} = 1 + \frac{m_p c}{c} \frac{p}{p}$$

$$u_p^* \frac{du_p^*}{dx^*} = E(u^* - u_p^*)$$

$$\frac{1}{p^*} \frac{dp^*}{dx^*} + \frac{c}{RT^*} \frac{du^{*2}}{dx^*} + \frac{m_s c}{RT^*} \frac{du_p^{*2}}{dx^*} = 0$$

$$-u_p^* \frac{dT_p^*}{dx^*} = B(T_p^* - T^*)$$

where

$$B = \frac{6(Nu)_{KL} p}{c_p \int_p d^2 V_0}$$

$$E = \frac{FL}{V_0}$$

The initial boundary conditions at $x^* = 0$ are:

$$p^* = 1, \quad T^* = 1, \quad T_p^* = 1, \quad u^* = 0, \quad u_p^* = 0$$

An appropriate solution must be used for $x^* = 0$ to $x^* \approx 0.03$ because the area $(A(x))$ is infinite at $x^* = 0$. If $u^* = ax^*$ is used as an approximation then:

$$u_p = \frac{1}{2} (\sqrt{E^2 + 4Ea} - E) = bx^*$$

$$T^* = 1 - \frac{c}{ce} a^2 x^{*2}$$

where

$$\frac{ce}{c} = \frac{\frac{B}{a} (1 + m_p \frac{c}{c} \frac{p}{c}) + 2(\frac{b}{a})}{(1 + m_p \frac{b^2}{a^2}) (\frac{B}{a} + 2(\frac{b}{a}))}$$

$$p^* = (1 - \frac{c}{ce} a^2 x^{*2})^{\frac{ce}{R}} (1 + m_p \frac{b}{a})$$

$$T_p^* = T^* + \frac{2\frac{b}{a}}{(\frac{B}{a} + 2\frac{b}{a})} (\frac{c}{ce} a^2) x^{*2}$$

The second boundary condition is at the throat ($x^* \approx 0.50$) (section of minimum area) where the following condition must be met:

$$\begin{aligned} \frac{RT_c^*}{2c u_c^{*2}} &= \frac{RT_c^*}{2c a_m^2} (1 + m_p \frac{du_b^*}{du^*}) \\ &= 1 + m_p \left[\gamma \frac{du_p^*}{du^*} - (\gamma - 1) \frac{u_p^* du_p^*}{u^* du^*} - \frac{(\gamma - 1) c_p}{u^*} \frac{dJ_p^*}{du^*} \right] \end{aligned}$$

In order to meet this second boundary condition the constant a is varied in the approximate solution. Once the throat condition is met the solution is continued to $x^* = 1.0$.

The Runge-Kutta-Gill method is to be used for the solution of the equations. The time is to be used to show that the problem is feasible and to obtain sample results for a thesis proposal.

NOTATION

A	Flow Area
a	Linear Acceleration of the Gas
a_m	Velocity of Sound in the Mixture
B	Convection Heat Transfer between Solid Particles and Gas
b	Linear Acceleration of Solid Particles
c	Specific Heat at Constant Pressure of Gas

c_p	Specific Heat of Solid Particles
d	Diameter of Solid Particles
E	Drag Parameter between Solid Particles and Gas
F	Time-Lag of Fluid Solid Motion $F = \frac{18\mu}{d^2 \rho_p}$
g	Gravitational Constant
h	Thermal Conductivity of Gas
L	Length of Flow Passage
m_p	Lb. of Solid per Lb. of Gas of Inlet Mixture
m_s	Lb. of Solid per Lb. of Gas at any Location
$(Nu)_p$	Nusselt Number of Convection between Solid Particles and Gas
p	Static Pressure
R	Gas Constant
T	Static Temperature
T_p	Temperature of Solid Particles
u	Velocity of Gas
u_p	Velocity of Solid Particles
U_0	Characteristic Velocity $(= \sqrt{2g c T_u})$
x	Space Coordinate in Direction of Motion
ρ_p	Density of Solid Particles
ρ	Density of Gas
μ	Viscosity of Gas
γ	Ratio of Specific Heats of Gas

Superscript (*) indicates reduced quantities, dimensionless.

5-29005T Mining, Metallurgy and Petroleum Engineering. Hardness and the Surface Energy of Solids. It has been proposed that the hardness H of a rock material can be calculated from experimental data obtained by the method of damped oscillations. The apparatus used is a pendulum which is supported on the material to be tested by two sharp points. Thus, with a soft material the points will penetrate the sample and the pendulum will be damped more quickly than if the sample is hard. The pendulum is initially deflected to an amplitude A_0 , released and allowed to oscillate. At various times t , the amplitudes A are recorded. The values are related to hardness H as:

$$H = \frac{t}{\ln \frac{A_0}{A}} \quad (1)$$

where:

H = hardness

t = time

A = experimentally determined amplitude as a function of time

A₀ = initial deflection of pendulum

The various values of lnA and t can be plotted from which the value of H (slope) can be determined.

The equation (1) can be written in the straight line form as:

$$\ln A = -(1/H) t + \ln A_0 \quad (2)$$

If we let:

$$y_i = \ln A$$

$$m = -(1/H)$$

$$x_i = t$$

$$b = \ln A_0$$

then:

$$y_i = mx_i + b \quad (3)$$

$$x^2 = \sum_{i=1}^n [y_i - (mx_i + b)]^2 \quad (4)$$

$$\frac{\partial x^2}{\partial b} = 0 = -2 \sum_{i=1}^n [y_i - (mx_i + b)] \text{ or } \sum_{i=1}^n y_i = nb + m \sum_{i=1}^n x_i \quad (5)$$

$$\frac{\partial x^2}{\partial m} = 0 = -2 \sum_{i=1}^n x_i [y_i - (mx_i + b)] \text{ or } \sum_{i=1}^n x_i y_i = b \sum_{i=1}^n x_i + m \sum_{i=1}^n x_i^2 \quad (6)$$

Solving for m and b:

$$m = \frac{\sum y_i \cdot \sum x_i - \sum x_i y_i \cdot \sum x_i}{n \sum x_i^2 - (\sum x_i)^2} \quad (7)$$

$$b = \frac{\sum y_i \cdot \sum x_i - n \sum x_i y_i}{n \sum x_i^2 - (\sum x_i)^2}$$

This problem is an extension of IBM 650 problem number 326'T. The IBM 7090 will be used to determine the "best" linear fit by the method of least squares.

6-29006T Chemistry. X-Ray Crystal Structure of Lithium Alkyls. The research problem is the x-ray crystal structure of a lithium alkyl. The 7090 can be used for repeated lengthy calculations used in calculating the Lorentz-polarization correction factor, atomic scattering factor, two or three dimensional Fourier series summations, and finally, a reliability function. Due to the method of data collection used for obtaining reflection intensities, a Lorentz-polarization factor must be applied to raw intensity data before they can be relatively scaled. The atomic scattering factor along with Fourier series summations are used in the calculation of electron density maps.

7-29007 Ceramic Engineering. Crystal Lattice Calculations. The problem involves the calculation of the crystallographic d-spacings for the monoclinic large cell and orthorhombic large cell structures of sodium niobate. The expression for the d-spacings for monoclinic symmetry is:

$$\frac{1}{d^2} = \frac{1}{\sin^2 \beta} \left(\frac{h^2}{a_0^2} + \frac{k^2 \sin^2 \beta}{b_0^2} + \frac{l^2}{c_0^2} - \frac{2hl \cos \beta}{a_0 c_0} \right)$$

The expression for the d-spacings for orthorhombic symmetry is:

$$\frac{1}{d^2} = \frac{h^2}{a_0^2} + \frac{k^2}{b_0^2} + \frac{l^2}{c_0^2}$$

Where, for the monoclinic cell,

$$a_0 = 7.822 \text{ \AA}, b_0 = 15.524 \text{ \AA}, c_0 = 7.822 \text{ \AA}, \beta = 90^\circ 40'; \sin \beta = 0.99993,$$

$$\cos \beta = 0.01164$$

For the orthorhombic cell,

$$a_0 = 5.5682, b_0 = 15.524 \text{ \AA}, c_0 = 5.5052 \text{ \AA}.$$

The Miller indices (h, k, l) will be varied from N = 1 to N = 100 where $N = h^2 + k^2 + l^2$. The specific values of h, k, l to be used for each symmetry cover only part of this range. There are 600 calculations to be made for the monoclinic cell and 641 to be made for the orthorhombic cell.

a_0 , b_0 , and c_0 are the unit cell parameters. β is the monoclinic angle.

8-29008 Civil Engineering. Analyses of Shells in Curvilinear Coordinates. This program generates the equations of equilibrium for curved shells having fixed, simple, free, continuous, or symmetrical boundaries subjected to any loading. The shell model consists of a network of rigid bars joined at deformable elements. The generation of the equations of equilibrium at discrete points on the model results in a set of simultaneous equations which are solved by the elimination (Gauss) method. The solution, that is, the displacements, are then used to compute the axial and flexure stresses in the shell.

9-29009 Mechanical Engineering. Enthalpy of Saturated Air. Using tabular data for h versus t , the program is to relate h to t by the equation

$$h = A + Bt + Ct^2$$

for ten different ranges of t . Then the error using the equation is to be calculated based on the tabular data.

10-29010T Civil Engineering. Endblock. Rectangular plates are loaded in their plane. The stresses and strains are to be determined as a two-dimensional problem.

The stress-function method is used. The corresponding biharmonic equation is solved by applying the finite difference operator to the grid points.

Eight-hundred ninety-seven grid points are used and therefore an iterative procedure has to be employed. More cycles will be applied to parts of the region where slow convergence is expected.

11-29011 Chemistry. Calculation of Hydrolysis Rate. In a series of reaction rate studies, it is necessary to evaluate equations of the form

$$k_1 = \frac{\frac{[O]}{[S]} (k_{12} - k_3)}{\left(\frac{[S]}{[S_0]} \right) \frac{k_3 - k_{12}}{k_{12}} - 1},$$

where the k 's are rate constants and the brackets [] denote concentrations of

various reactants for a large number of values of the concentrations. The IBM 7090 will be used to calculate the concentrations and use them in the calculation of a number of values of k_1 .

12-29012T Civil Engineering. Plates. The analysis of elastic plates may be accomplished by the use of finite difference operators. To obtain acceptable accuracy using this method, a large number of simultaneous equations must be generated and solved. The number of equations required is prohibitive unless recourse may be had to a high speed digital computer.

This program will generate a matrix of linear simultaneous equations by applying finite difference operators to various points on a mathematical model of a plate. The resulting matrix will be solved and the deflections obtained will be printed. Bending moments will be obtained from the deflections and printed.

13-29016 Theoretical and Applied Mechanics. An Investigation of Some Stress Problems for Solid Propellant Rockets. Basically, the problem consists of two parts. The first part is concerned with mapping the exterior of a symmetrical star-shaped region in one complex plane into the region exterior to a unit circle in another complex plane. If z is a point in the first plane and ξ is a point in the second plane, then the following relationship is found

$$z = \omega(\xi) = \sum_{n=0}^{\infty} C_n e^{(1-np)\theta}$$

where p is the number of star points and θ is an angle connected with the unit circle. The result of this phase is the C_n and θ .

The second part uses the C_n and θ values to transform the various boundary conditions and loading conditions for the star-shaped region into the circular region and transformed back to the star-shaped region. The bulk of the work will be concerned with summing series of the type given above and also to solve systems of simultaneous equations.

14-29017T Civil Engineering. Static Analysis of Buried Structure. The determination of the stresses in an elastic perfectly plastic medium which has rectangular, reinforced openings in it is the object of the thesis. The general method being used is based on a lumped parameter system of masses and springs. Basically, the displacements of each mass is found by a systematic relaxation procedure. Then, from the displacements, the stresses are determined.

PART VIII
INSTRUCTIONAL USE OF THE IBM 7090-1401 SYSTEM

During the month of September, three problem specifications were submitted.

- I1-29013 Electrical Engineering 126. Problem 1. Calculation of Static Electric Fields. The position and strength of a large number of static charges is given. Computer calculation gives the force and electric strength vector components for any point in space. Standard routines are used.
- I2-29014 Civil Engineering 391. Problem 1. Highway Profile. Given the starting station, initial grade elevation, grade of first and second tangent, length of vertical curve, station of intersection of grades, the end station and the station increment, the program will compute and tabulate the grade elevation along a proposed highway profile consisting of two tangents and a parabolic vertical curve.
- I3-29015 Civil Engineering 391. Problem 2. Level Pool Problem. The problem is to determine the outflow hydrograph resulting from passing the design flood through the lake reservoir given the inflow hydrograph and the storage pool elevation relationship. The discharge through the sluice and over the spillway are defined by

$$Q_{\text{sluice}} = C_{s1} A_s \sqrt{2g_{3/2} H_{s1}}$$

$$Q_{\text{spillway}} = C_{sp} L_s H_{sp}$$

where

C_{s1} = sluice gate discharge coefficient

C_{sp} = spillway discharge coefficient

A_s = area of sluice

L_s = length of spillway

g = acceleration due to gravity

H_{s1} = head of sluice

H_{sp} = head of spillway

S = storage

Q_{in} = inflow

Q_{out} = Q sluice + Q spillway

The pool storage is defined by $\frac{dS}{dt} = Q_{in} - Q_{out}$ (1)

The equations are solved by iteration since both S and Q_{out} are functions of pool elevation.

IBM EQUIPMENT, SCHEDULES AND MAINTENANCE

IBM 7090

The IBM 7090 was delivered on August 30, 1962. The period between then and September 26, on which it was officially accepted, was spent in space modification, installation and checkout of the machine. During this period, the Laboratory was able to obtain 21 hours and 27 minutes of code checking time which was used in order to check out the operating system to be used on the machine.

From 8:00 a.m. September 26 through the end of the month of September, an informal log of the machine was kept.

	Hrs:Min
Scheduled Engineering	4:00
Unscheduled Engineering	2:41
Code Checking	<u>13:14</u>
TOTAL RUNNING TIME	19:55

IBM 1401

Table I shows the distribution of IBM 1401 time for the month of September.

TABLE I

	Hrs:Min
Scheduled Engineering	:52
Unscheduled Engineering	9:33
Listing	8:30
CDC Preparation	12:34
DCL Code Checking	38:59
7090 Preparation	15:55
Statistical Service Unit	64:32
Deck Reproduction	<u>:16</u>
TOTAL RUNNING TIME	151:11

Table II presents a summary of errors on the 1401 for September.
Table III gives the daily breakdown of 1401 machine time.

TABLE II

1401 Processing Unit	1
1402 Card Read Punch	5
729V Tape Units	<u>1</u>
TOTAL	7

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	
9/4/62	7:17	:52			Power shut off to connect IBM 7090.	8:09
9/5/62	8:28					8:28
9/6/62	5:17		:45	1	(1) 1402 would not read cards. Cleaned common brush and first read feed.	6:02
9/7/62	5:00					5:00
9/10/62	4:22		:15	1	(1) Constant read check lights on 1402. Due to program and not machine.	4:37
9/11/62	3:13		2:25	1	(1) 1402 keeps cycling. A gear came off. Replaced and timing adjusted.	5:38
9/12/62	2:41					2:41
9/13/62	6:02		3:54	1	(1) 1402 would not cycle. Stop key stuck.	9:56
9/14/62	8:00					8:00
9/15/62	1:00					1:00
9/17/62	6:14					6:14
9/18/62	12:31					12:31
9/19/62	6:36					6:36
9/20/62	8:50		:16	1	(1) 1402 card jam on punch side.	9:06
9/21/62	7:54					7:54
9/22/62	7:45					7:45
9/23/62	:35					:35
9/24/62	6:24					6:24
9/25/62	9:18		1:00	1	(1) Compatibility of 7090/1401 tape units doubtful. No difference found.	10:18
9/26/62	7:14					7:14
9/27/62	8:02					8:02
9/28/62	8:03		:58	1	(1) Cannot write on tape. Bad transistor card in 1401	9:01
TOTALS	140:46	:52	9:33	7		151:11

PART IX
GENERAL LABORATORY INFORMATION

Seminars

"A Study of Arithmetic Recoding with Applications to Multiplication and Division," by Dr. John O. Penhollow, Digital Computer Laboratory, University of Illinois, September 24, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full- time</u>	<u>Part- time</u>	<u>Full-time Equivalent</u>
Faculty	14	1	14.5
Visiting Faculty	0	3	1.5
Research Associates	8	0	8.0
Graduate Research Assistants	5	31	19.25
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>41</u>	<u>26</u>	<u>53.0</u>
TOTAL	75	61	103.25

The Computer Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, K. C. Smith, J. N. Snyder, and A. H. Taub.

Physics

DIGITAL COMPUTER LABORATORY
UNIVERSITY OF ILLINOIS
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TECHNICAL PROGRESS REPORT

- PART I - CIRCUIT RESEARCH PROGRAM
- PART II - MATHEMATICAL METHODS
- PART III - DATA REDUCTION METHODS
- PART IV - ILLIAC USE AND OPERATION
- PART V - 7090-1401 COMPUTING SYSTEM
- PART VI - INSTRUCTIONAL USE OF COMPUTERS
- PART VII - CONTROL DATA CORPORATION 1604
- PART VIII - GENERAL LABORATORY INFORMATION

October, 1962

PART I
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

Sergio Ribeiro continues his development of the switching theory of flipflops, considering current triggering of the symmetric flipflop, and voltage triggering for both this and the asymmetric case.

Tohru Moto-Oka has continued his design theory of tunnel-diode amplifiers, and presents several significant conclusions about a stage with input and output matched.

Henry Guckel reports briefly on the interconnection problem, and in more detail on a further extension of his approximation of the tunnel-diode curve in the active region.

Thomas Burnside reports briefly on progress in the design of circuits for the statistical analyzer.

2. Symmetric Flipflop

The symmetric flipflop can be shown to obey the same kind of equation as the asymmetric flipflop if the variables are redefined in a certain way. In fact, consider the flipflop of Figure 1.

From the approximate characteristic of a transistor pair with constant emitter current I_0 we know that:

$$\left. \begin{aligned} i_2 &= \frac{I_0}{2} \left\{ + \tanh(p'x) + 1 \right\} \\ i_1 &= \frac{I_0}{2} \left\{ - \tanh(p'x) + 1 \right\} \end{aligned} \right\} \quad (1)$$

where $x = \frac{v_{i1} - v_{i2}}{I_0 R_0}$ and $p' = 2p = \frac{qI_0 R_0}{2KT}$. (See preceeding series of reports on the asymmetric flipflop.)

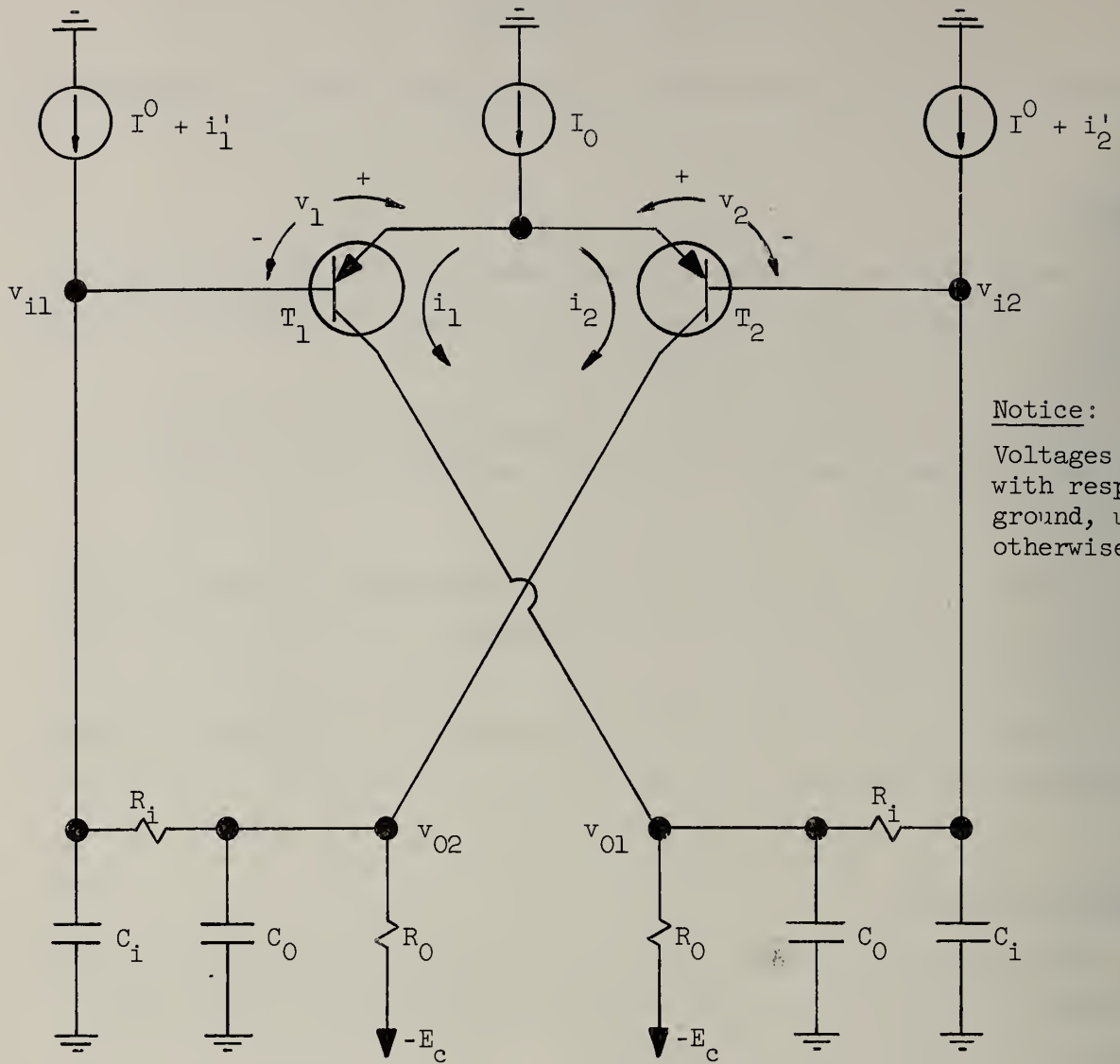


Figure 1 Symmetric Flipflop

Since the passive circuits are identical, they are described by the following equations:

$$k\ddot{x}_1 + b\dot{x}_1 + x_1 = + \tanh (p'x) + q\tau_1 + r\dot{\tau}_1 \quad (2a)$$

$$k\ddot{x}_2 + b\dot{x}_2 + x_2 = - \tanh (p'x) + q\tau_2 + r\dot{\tau}_2 \quad (2b)$$

$$\text{where } x_1 = \frac{v_{i1}}{\left(\frac{I_0 R_0}{2}\right)}, \quad x_2 = \frac{v_{i2}}{\left(\frac{I_0 R_0}{2}\right)}, \quad \tau_1 = \frac{i'_1}{I_0}, \quad \tau_2 = \frac{i'_2}{I_0}.$$

Therefore,

$$x_1 - x_2 = 2x;$$

Let $\tau_1 - \tau_2 = 2\tau;$

subtraction of (2b) from (2a) yields, after elimination of common factor 2:

$$k\dot{x} + \ell\dot{x} + x = \tanh(p'x) + q\tau + r\dot{\tau}$$

which is exactly the same equation that described the asymmetric flipflop behavior, except for the definition of x , and for the presence of p' instead of p .

We repeat the definitions of the parameters for completeness:

$$\left. \begin{aligned} k &= R_i R_o C_i C_o \\ \ell &= R_i C_i + R_o C_i + R_o C_o \\ p' &= 2p = \frac{q_e R_o I_o}{2KT} \\ q &= 2\left(1 + \frac{R_i}{R_o}\right) \\ r &= 2R_i C_o \\ x &= \frac{v_{i1} - v_{i2}}{I_o R_o} \end{aligned} \right\} \quad (3)$$

Observation: Notice the change in notation (subscripts) with respect to the analogous elements in the asymmetric flipflop case.

From Figure 2 we get the equivalent circuit shown in Figure 3, whose analysis will show that it obeys the following equation:

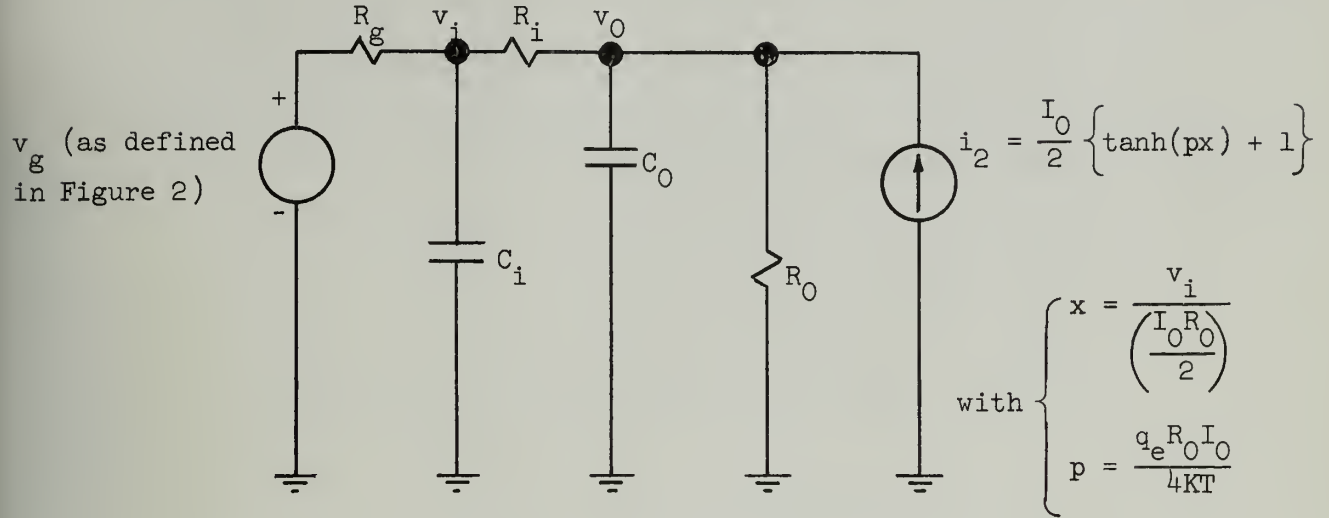


Figure 3 Equivalent Circuit to the Flipflop of Figure 2

$$k\ddot{x} + (\ell + m)\dot{x} + (1 + n)x = \tanh(px) + m\zeta + n\zeta \quad (4)$$

where

x and p as defined in Figure 3

k and ℓ as defined in Equation 3

$$m = \frac{R_i}{R_g} R_o C_o$$

$$n = \frac{R_i + R_o}{R_g}$$

$$\zeta = \frac{v_g}{\left(\frac{R_o I_o}{2} \right)}$$

(5)

This is again a similar type of equation to the one found for current triggering, except for the term independent of x and trigger, which previously

had the same coefficient as the term in $\tanh(px)$; now these two terms have different coefficients, so this equation cannot be normalized exactly as in the current triggering case.

But the treatment is the same, and, as before, if v_g is a rectangular wave voltage of duration θ , then ξ can be replaced by suitable discontinuities at time $t = 0$ and $t = \theta$, i.e., if

$$\tau = \begin{cases} 0, & t < 0 \text{ and } t > \theta \\ \xi_g, & 0 < t < \theta \end{cases}$$

Then Equation 4 is equivalent to Equation 6 below with the conditions stated:

- (a) $k\ddot{x} + \ell\dot{x} + x = \tanh(px)$, $t < 0$, $t > \theta$ whose steady state solutions are $x = \pm 1$
- (b) $k\ddot{x} + \ell\dot{x} + x = \tanh(px) + n\xi_q$, $0 < t < \theta$
- (c) Discontinuities for y :

$$\text{at } t = 0: y(0+) - y(0-) = \pm \frac{m}{k} |\xi_g + 1| \text{ where } \pm \text{ holds according to the sign of } \xi_g;$$

$$\text{Also, in general, } x(0) = \bar{+} 1$$

$$\text{at } t = \theta: y(\theta+) - y(\theta-) = \bar{+} \frac{m}{k} |\xi_g - x_\theta| \text{ with } x_\theta = x(\theta)$$

3.2 Symmetric Flipflop (Eccles-Jordan)

Proceeding in a manner analogous to the current trigger case we will get:

$$k\ddot{x} + (\ell + m)\dot{x} + (1 + n)x = \tanh(p'x) + m\xi + n\xi$$

$$\text{but } x = \frac{v_{i1} - v_{i2}}{I_0 R_0}, \quad \xi = \frac{v_{g1} - v_{g2}}{I_0 R_0}, \text{ assuming the (theoretically possible) case}$$

of two simultaneous (not necessarily symmetrical) triggering circuits v_{g1} and v_{g2} , with the same series resistance R_g . Again $p' = 2p$.

3.3 Comments

We conclude that:

- (1) The analysis of the symmetric flipflop is reducible to the asymmetric case.
- (2) The analysis of the rectangular voltage trigger with series resistance is similar (but not identical) to the rectangular current trigger case; the former has (obviously) one more parameter. However it is the same type of equation, and therefore we can obtain the results for rectangular current trigger as a limit case of rectangular voltage trigger with series resistance.

(Sergio Ribeiro)

4. Theory of Tunnel-Diode Amplifiers

A generalized method of design for a tunnel-diode amplifier is investigated. A tunnel-diode amplifier stage, which has matched input and output conditions and has a π -type of circuit configuration, is concluded to have the following characteristics:

- (1) A power gain greater than one per stage is not realizable physically.
- (2) The ratio of output and input impedances, R_O/R_i , of a voltage amplifier stage must be larger than 1 and the voltage gain is less than the square root of the ratio, $\sqrt{R_O/R_i}$.
- (3) The ratio of output and input impedances, R_O/R_i , of a current amplifier stage must be smaller than 1.
- (4) A forward voltage amplifier is usually a backward current amplifier.
- (5) Phase-inverter type voltage or current amplifier stages are also realizable.

If the input impedance, output impedances, and a voltage gain are given, it is possible to design all components easily. The details of this design method will be given in report form.

These investigations made it clear that it is very difficult to design a set of tunnel-diode logical circuits with speed-independent characteristics. It is also concluded that a hybrid circuit which is composed of an inverter type tunnel-diode voltage amplifier and a transistor-emitter follower will be a high-speed NOR circuit.

(Tohru Moto-Oka)

5. Tunnel-Diode Interconnection Systems

Theoretical studies of coupled systems are continuing. The problem of the suppression of one or more of the normal modes is being considered. An experimental intercoupled section has been assembled.

6. Tunnel-Diode Gain Characteristics

In order to facilitate the study of gain characteristics of tunnel diodes a non-symmetric approximation for $\frac{di}{dv}$ versus v was developed. This will indicate the difference in amplification for positive and negative inputs. This information is needed to consider a "return-to-zero" system.

Non-Symmetric Approximation

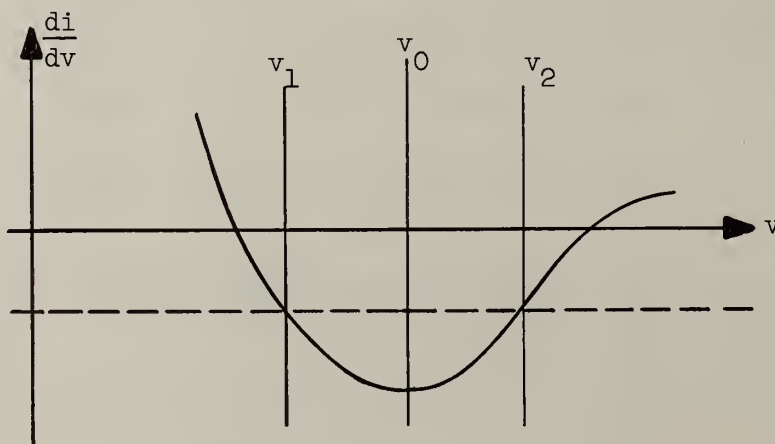


Figure 4

The shape of the $\frac{di}{dv}$ versus v curve suggests that it is possible to approximate the curve by:

$$\frac{di}{dv} = A + B(1 - e^{-\beta(v-v_0)})^2 \quad (4)$$

By inspection

$$A = \frac{di}{dv}(v_0) \quad (5)$$

In order to evaluate B and β analytically v_1 and v_2 are chosen in such a way that

$$2(v_0 - v_1) = v_2 - v_0 \quad (6)$$

$$\frac{di}{dv}(v_1) = \frac{di}{dv}(v_2)$$

Hence:

$$(1 - e^{-\beta(v_1-v_0)})^2 = (1 - e^{2\beta(v_1-v_0)})^2 \quad (7)$$

The solution

$$\beta = 0$$

is of no interest, so that

$$2 = e^{-\beta(v_1-v_0)} + e^{2\beta(v_1-v_0)} \quad (8)$$

In order to solve this let

$$e^{\beta(v_1-v_0)} = y$$

so that

$$y^3 - 2y + 1 = 0$$

$$(y^2 + y - 1)(y - 1) = 0 \quad (9)$$

The roots of Equation 6 are

$$y_1 = 1$$

$$y_{2,3} = \frac{1}{2}(-1 \pm \sqrt{5})$$

Only the positive irrational root is of interest.

$$y = \frac{1}{2}(\sqrt{5} - 1)$$

Hence

$$\beta = \frac{1}{v_1 - v_0} \ln\left(\frac{\sqrt{5} - 1}{2}\right) \quad (10)$$

and

$$\epsilon^{-\beta(v-v_0)} = \epsilon^{-\ln\left(\frac{\sqrt{5}-1}{2}\right) \frac{v-v_0}{v_1-v_0}} = \left[\left(\frac{\sqrt{5}-1}{2}\right)^{\frac{v-v_0}{v_1-v_0}} \right]^{-1}$$

The remaining constant is

$$3 = \frac{\frac{di}{dv}(v_1) - A}{(1 - \epsilon^{-\beta(v_1-v_0)})^2}$$

$$3 = \frac{\frac{di}{dv}(v_1) - \frac{di}{dv}(v_0)}{\left(1 - \frac{2}{\sqrt{5} - 1}\right)^2} \quad (11)$$

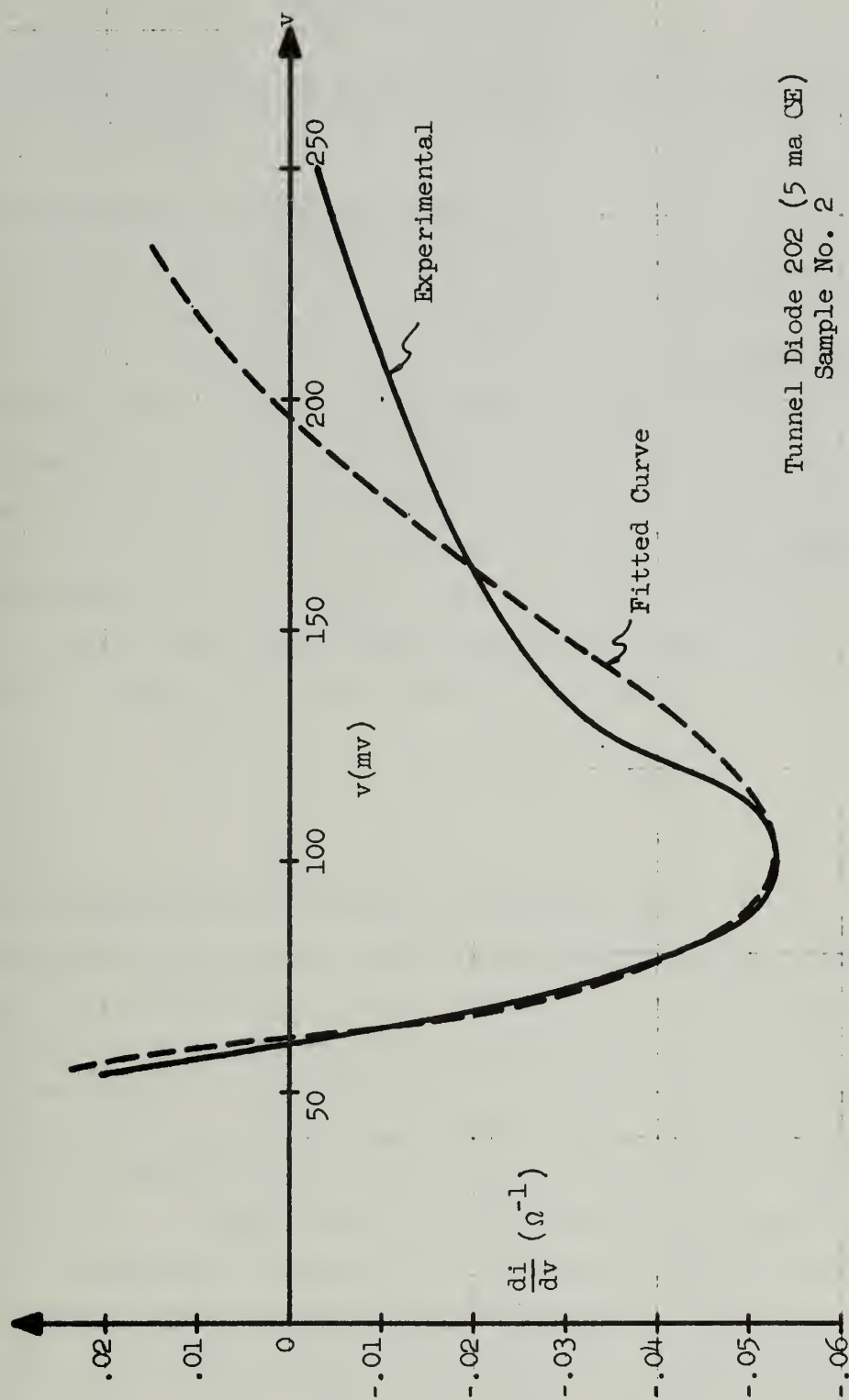


Figure 5

so that

$$\frac{di}{dv} = \frac{di}{dv}(v_0) + \left(\frac{\sqrt{5} - 1}{\sqrt{5} - 3}\right)^2 \left(\frac{di}{dv}(v_1) - \frac{di}{dv}(v_0)\right) \left(1 - \left(\frac{2}{\sqrt{5} - 1}\right)^{\frac{v-v_0}{v_1-v_0}}\right)^2 \quad (12)$$

(H. Guckel)

7. Statistical Analyzer

The circuit design of the statistical analyzer was continued. Synchronization of the counter and decoder is being investigated. Also, a circuit is being designed to produce the "start pulse" which activates the counter in the correct state.

(Thomas Burnside)

PART II
MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Calculations: Quantum Statistics

During the month of October, 1962, the Illiac II program FJ-15 to calculate the quantum mechanical partition function of a particle in a one-dimensional box was completed and checked out on the machine. Some changes were made and the most recent tests show that FJ-15 is running properly.

A number of short runs were made with FJ-15 using different values of the parameters available in order to determine the time taken by the program and the dependence of the answer on the parameters. The program FJ-16 was written to calculate the exact values of the partition function for different values of the ratio of the thermal wave length to the length of the box, and these values were compared to those obtained in the short runs done with FJ-15.

(Harry F. Jordan)

Monte Carlo Calculations: Ising Lattice Boundary Effects

Computations were made with an Illiac program called KYG1, written by N. Koppel, F. Grosshans and H. Yang. The aim of these computations is to study the effects of alternate boundary conditions on Monte Carlo calculations of the order parameters in an Ising lattice similar to those described in the paper by Ehrman, Fosdick and Handscomb (J. Math. Phys. 1, 547 (1960)). We are particularly interested in studying the effect of replacing the usual periodic boundary conditions by "statistical" boundary conditions in which the interactions at the boundary are determined by the average interactions among the spins (inside spins) which are explicitly accounted for. There are several ways to do this. The one now under study is analogous to the Bethe approximation (H. Bethe, Proc. Roy. Soc. A150, 552 (1935)). In this the coupling of a spin at the edge to its nearest neighbor on the outside (see Figure 1) is determined by assigning an orientation to the outside spin consistent with the instantaneous long-range order on the inside. Thus, when the spin at site a

(Figure 1) is being considered for flipping, a spin is assigned to its outside nearest-neighbor site b such that the probability for an up spin at b is

$\frac{N_{\uparrow}}{N_{\uparrow} + N_{\downarrow}}$ where N_{\uparrow} and N_{\downarrow} are the instantaneous numbers of up spins and down spins on the inside.

These computations are long and plans are being made to switch over to the IBM 7090.

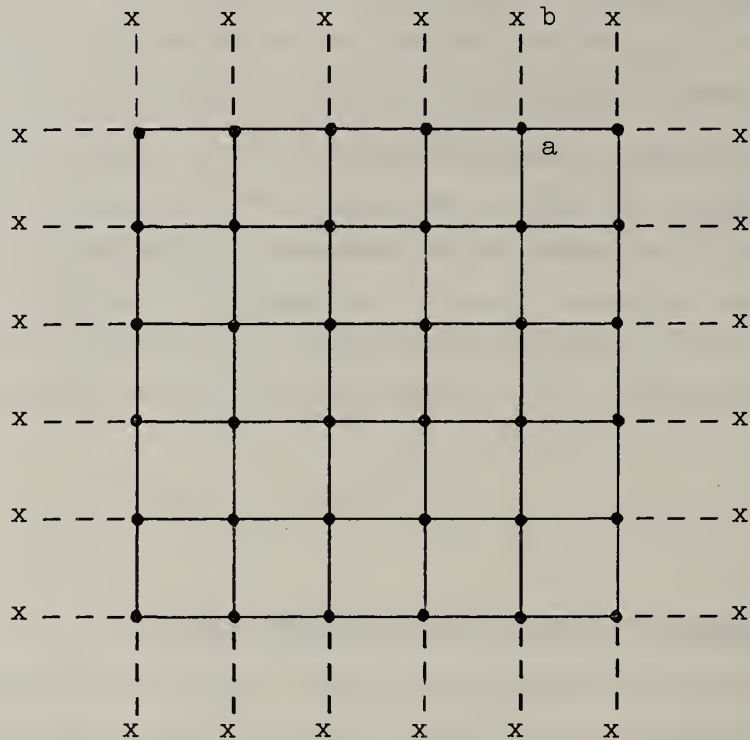


Figure 1 Inside sites marked by •, outside sites marked by x, boundary coupling of inside to outside spins marked by ---. (There are 36 inside sites here, though in our calculations there are 400.)

(L. D. Fosdick)

Switching Theory

Several new results in the theory of asynchronous circuits have been obtained. These include developments in the following areas.

1. A new and more precise formulation of the general theory of asynchronous circuits has been obtained. In this formulation, the most important property of asynchronous circuits is that the behavior of the circuit, as expressed by the set of possible state sequences through which the circuit may pass, depends only upon the present state of the circuit and not otherwise upon other states through which the circuit has previously passed. A set of state sequences satisfying this property may be regarded as "complete". In practice one may observe a sequence of states which constitutes a projection of such a complete set, since many variables affecting the state are often not observable.
2. The theory of asynchronous circuits has been tied to the classical theory of automata by a theorem showing a direct correspondence between the two. In this correspondence, for every set of tapes acceptable by a finite classical automaton, there is a corresponding projection of a complete set of state sequences. Conversely, whenever the projections of all sequences in such a complete set are finite, then that set represents the set of tapes acceptable by a finite state automaton.

(David E. Muller)

PART III
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

I. High Resolution Oscilloscope

The high resolution oscilloscopic system is being adapted for potential automatic scanning of spark chamber film on a production basis. The scanner/camera housing has been extensively modified, provided with a stand, and an improved cathode ray tube mounting arrangement devised and constructed. Modifications to attach the scope to the IBM 7090 are under study.

The following engineering test routine has been issued:

File No. 494, "Testing the High Resolution Oscilloscope without the Use of a Special Instruction Register," by
M. Shirazi

II. Theory of Pattern Recognition

The following report has been issued this month:

Report No. 126, "Decision Structures for Recognition," by
Albert H. Amon, October 1, 1962

This report discusses problems now easy for human beings but difficult for computers. A preliminary attempt is made to analyze problems of coordinating vast numbers of decisions made simultaneously and describe, if crudely, the concepts underlying complex decision-making systems. The point of view presented is that of a psychologist. The important concept of a link-forming structure, discussed therein, has proved of central importance in the design of the Pattern Articulation Unit (PAU).

III. General Introduction to the Pattern Recognition Computer

The following report has been issued this month:

Report No. 125, "The Design of the Pattern Recognition Computer, Part I: General Introduction," by B. H. McCormick,
October 1, 1962

IV. Fabrication of the Pattern Articulation Unit (PAU)

Racks for the main frame, subcontracted in part to Northern Tool and Die, Chicago, have arrived and have been installed in Room 223, Digital Computer Laboratory. Seven tons of air conditioning, generated by a roof-mounted Trane air-conditioning unit, have been provided the computer. Installation of this unit and adaptation to the computer heat funnel rack is now complete.

The power supply modules (approximately 6 amps at +6, -6, or -12 volts) have been subjected to test--in particular to check heat dissipation as a function of air flow (and incident air temperature) through the Modine cooler module. Results were considered sufficiently reassuring to initiate fabrication of 300 cooler modules in the shops of the Laboratory.

(B. H. McCormick)

PART IV
ILLIAC USE AND OPERATION

Illiacc Usage

During the month of October, specifications were presented for 8 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 2234. Numbers followed by T are for theses.

2234 Psychology. Maori Physiological Analysis. Factor analysis of physical and physiological measurements in a Maori sample will be carried out. The purpose of these procedures is to check whether endomorphy and mesomorphy can be separated in people of this race.

2235 Psychology. Italian Genetic Study. Four groups of subjects one in Boston, three in Italy are involved in this research. Scores are obtained from physiological measures and personality questionnaires. The study is an attempt to relate personality dimensions to blood-type, using standard analysis of covariance techniques.

2236 Digital Computer Laboratory. Ising Lattice, KYG1. This program is designed to calculate the long- and short- range order in a two-dimensional Ising lattice by a Monte Carlo sampling procedure. It will be used to test the effects of alternate kinds of boundary conditions and alternate sampling schemes. The method used in this calculation is similar to the one previously used in Ising lattice studies on Illiac.

2237T Electrical Engineering. Translation Program. The problem is to develop an approach to information processing in natural language which will allow, if only to a limited extent, analysis by machine at the semantic level. Illiac is typical of the size of computing system most appropriate to the beginning attempts at solution now envisaged. It is intended to test the first major section of the program, which accepts natural-language words from the teletype tape and organizes them into a vocabulary so that they may be recalled and easily recognized when input at a later time. This program section is now complete, and work is being started on the second

phase which will perform a grammatical analysis of the statements which are input to the system.

2238 Music. Computer Music Synthesis. The synthesis of a piece of music for voice and instruments with the Illiac generating the score will be carried out in line with the general method used to produce the Illiac Suite several years ago. This is based on a new set of programs that have been already code-checked and are operational except for a few specific details relating to input data.

2239T Electrical Engineering. Logic Network Simulation. It is desired to investigate the properties of some recently proposed networks of logical elements of a new type. The elementary functions proposed are believed to be of minimal complexity necessary to demonstrate the property of memory or adaptation. The Illiac presents a much less expensive approach to small networks (< 100 elements) than hardware.

2240 Psychology. Semantic Differential Analysis of Dream Symbols. The research is concerned with the analysis of semantic differential analysis of nouns representing masculine and feminine dream symbols. Undergraduate subjects were given a list of nouns representing common dream symbols, as well as the nouns, man, male, woman and female. The subjects rated 20 such nouns on 25 semantic differential scales. Five groups of subjects were included in the study, each group having the four criterion nouns and a different list of symbols.

The hypotheses being tested are that the nouns representing masculine symbols will have semantic differential profiles that are more similar to the profiles of man and male than they are to the profiles woman and female. Conversely, the profiles of nouns representing feminine symbols will resemble the profiles of the words women and female.

The mean correlation of profiles among the masculine symbols and among the feminine symbols will be higher than the mean correlation of profiles of masculine symbols with feminine symbols.

The data analysis will follow the standard pattern:

Computation of sums, means, and sigmas across subjects for each scale on each noun. This table will then be inspected for the purpose of

eliminating scales on which responses are too variable to make them useful predictors. Then computation of correlations across nouns will be made for each of the remaining scales.

2241 Psychology. Reliabilities of Minnesota Multiphasic Personality Inventory (MMPI). The principle aim of this investigation is to more definitively establish the reliabilities of a few select MMPI scales. This phase of the analysis will be concerned with only the internal consistency measures of various scales. Subsequent analyses will be undertaken but will utilize the 7090 installation; however, this step on Illiac is needed first.

Table I shows the distribution of Illiac machine time for the month of October.

TABLE I

	Hrs:Min
Scheduled Maintenance	77:51
Unscheduled Maintenance	19:37
Leapfrog	13:03
Drum Test	11:20
Scanner Engineering	7:54
Demonstrations	:22
Library Development	:50
Classes	<u>1:27</u>
	132:24
Use by Departments	
Agricultural Economics (47 15 05 334)	:41
Agricultural Economics	7:07
Agronomy	:07
Bureau of Educational Research (PHM 1839)	4:28
Chemistry	75:38
Civil Engineering	73:08
Coordinated Science Laboratory (DA 36 039 SC 56695)	52:26
Digital Computer Laboratory (NONR 1834(27))	35:33
Digital Computer Laboratory (TR AEC 1018)	2:17
Economics	:22
Electrical Engineering (NSF 46-22-25-345)	1:11
Electrical Engineering (AF 7043)	2:13
Electrical Engineering (NSFG 19005)	1:25
Geological Survey	3:30
Geology (IC GRAD GEOLOGY)	:14
Institute of Communications Research (MH06739)	10:49
Institute of Communications Research (44 28 20 378)	4:44
Institute of Communications Research	11:18
Mathematics	1:28
Mechanical Engineering (NSFG 19926)	:44
Mechanical Engineering	10:39

Mining and Metallurgical Engineering (AF 6770)	:35
Nuclear Engineering	2:48
Physics (NONR 1834(05))	:55
Physics (NSFG 17428)	:05
Physics	13:15
Psychology (MD 2060)	2:44
Psychology (ML774)	1:30
Psychology (ONR 1834 (36))	1:08
Psychology (US NONR 1834(39))	3:33
Psychology	83:11
Sociology	6:40
State Water Survey	:33
Theoretical and Applied Mechanics (DA 01 021 ORD11878)	:39
Zoology	2:18

419:56

552:20

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure.

This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Punch	2
Memory	4
Drum	5
Power	
Physical Plant Failure	1
Illiac	1
Unknown	<u>1</u>
TOTAL	14

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/1/62	20:20	:00	3:40	0	(1) Drum failure.	:00	1:18	0
10/2/62	18:01	2:27	3:32	1		:00	:33	0
10/3/62	20:31	:00	3:29	0		:00	:24	0
10/4/62	19:42	:14	4:04	2	(1) Punch #3 jammed. (2) Drum failure.	:00	:20	0
10/5/62	19:54	:00	4:15	0		:00	:35	0
10/8/62	13:54	7:36	2:30	2	(1) Drum failure. (2) Memory failure 2-37.	:00	:46	0
10/9/62	18:27	1:26	4:07	1	(1) Power failure (Physical Plant).	:00	:07	0
10/10/62	21:25	:00	2:35	0		:00	1:18	0
10/11/62	20:14	:15	2:31	1	(1) Unknown.	:00	:00	0
10/12/62	21:25	:08	2:24	2	(1) Memory failure 2-1. (2) Memory failure 2-24.	:03	:19	0
10/15/62	21:14	:00	2:46	0		:00	:33	0
10/16/62	20:50	:01	3:09	1	(1) Punch #1 failed.	:00	1:03	0
10/17/62	20:56	:00	3:04	0		:00	:45	0
10/18/62	20:08	:00	3:52	0		:00	:43	0
10/19/62	22:00	:00	2:00	0		:00	:16	0
10/22/62	19:55	:37	3:28	1	(1) Fuse blew in filament section of Illiac (power failure). (1) Drum failure.	:00	:00	0
10/23/62	18:16	3:00	2:44	1		:00	:17	0
10/24/62	20:19	:00	3:41	0		:00	:10	0
10/25/62	20:37	:00	3:23	0		:00	:28	0
10/26/62	17:36	3:25	3:10	1	(1) Drum failure.	:00	:47	0
10/29/62	20:33	:00	3:27	0		:00	:31	0
10/30/62	20:12	:00	3:48	0		:00	:19	0
10/31/62	19:36	:59	3:25	1	(1) Memory failure 2-25.	:00	1:01	0
TOTALS	456:05	20:08	76:04	14		:03	12:53	0

PART V
7090-1401 COMPUTING SYSTEM

University of Illinois 7090 Program Library

Since FORTRAN is the predominant language via which users approach the 7090, the majority of mathematical function subroutines used are those which are embedded in FORTRAN. However, being so embedded, the subroutines are difficult to alter and their properties, such as accuracy, range, etc., are difficult to assess, since complete descriptions of the mathematical methods used and the accuracies of the approximations are not provided in the standard literature supplied with the FORTRAN system. Hence, for those problems in which a user is either using assembly language or wishes to alter or completely understand the mathematical subroutines used, it is useful to provide a set of subroutines on cards which can be inserted in any program. Such a basic set of subroutines was prepared for the IBM 704 at MURA. These subroutines are being converted to the 7090 using the standard assembly language (SCAT) and complete documentation provided according to the long standing policy and custom of this Laboratory. During the month of October, the following routines were prepared and added to the University of Illinois 7090 Library.

Floating Point Square Root	B4-UOI-SQR2-3-S
Floating Point Exponential	B3-UOI-EXP1-4-S
Fixed Point Exponential, Base e	B3-UOI-EXP4-5-S
Fixed Point Exponential, Base 2	B3-UOI-EXP2-6-S
Fixed Point Exponential, Base e	B3-UOI-EXP3-7-S
Floating Point Natural Logarithm	B3-UOI-LOG1-8-S
Floating Point Sine and Cosine	B1-UOI-SIN1-9-S
Fixed Point Sine and Cosine	B1-UOI-SIN2-10-S
Floating Point Cube Root	B4-UOI-CUR2-11-S
Fixed Point Logarithm, Base e	B2-UOI-LOG3-12-S
Fixed Point Logarithm, Base 2	B3-UOI-LOG4-13-S
Fixed Point Arctangent	B1-UOI-ATN1-14-S

(D. Hutchinson)

IBM 7090 Usage

During the month of October, 58 new problem specifications were submitted for the IBM 7090.

5-29018T Chemistry. Unimolecular Decomposition. This research project is being carried out to study the process of unimolecular decomposition of a chain-type molecule. The assumptions are made that the system may be described by classical terms, Hamilton's formulation, and that the potential is a sum of modified Morse-type functions.

The equations of motion are to be integrated numerically for a wide range of initial conditions and the results are to be used to formulate high pressure rate constants for use in testing several alternate theories.

5-20002 Theoretical and Applied Mechanics. Elastically Supported Circular Plates. The problem of a circular elastic plate elastically supported at the edge is solved by means of a complex variable technique. The deflection W of the plate satisfies

$$\nabla^4 W = \frac{q}{D},$$

where q is the load intensity, and D the flexural rigidity. The general solution may be taken as $W = W_0 + W_1$, where W_0 is a particular solution, and W_1 is the solution to the biharmonic equation

$$\nabla^4 W = 0.$$

The solution W_0 is expressed as a function of the complex variable Z , and W_1 is expressed in terms of the two complex potentials $\Theta(Z), \Psi(Z)$ which are analytic functions. Substitution of W in

$$\nabla^4 W = \frac{q}{D},$$

and taking into account the boundary conditions which involve two parameters yields two differential equations in Θ, Ψ . These equations are solved by introducing series representations for Θ, Ψ . The deflection W is then given in terms of series.

The deflections of the plate with various boundary condition parameters are to be calculated.

7-20003 Agronomy. Agronomy Program Library Development. The purpose of this problem is to create a set of procedures for use in the processing of data from biological experiments.

Analysis of variance programs will be developed for the most commonly used experimental designs; these include completely randomized design, randomized complete block design, Latin square design, factorial analysis of 2, 3, or 4 factors, lattice designs, lattice square designs, rectangular lattice designs, balanced and partially balanced incomplete block designs, and combined analysis of experiments in several years.

or at several locations.

The mathematical methods involved are the standard procedures as presented in most statistics texts.

Since it is often desirable to convert or transform a research worker's original data to another form before analysis, a very flexible conversion-transformation routine will be incorporated into many of the programs. Rather thorough labeling of output is anticipated, since the output is to be utilized by research workers who, for the most part, are quite unfamiliar with digital computers and their usage.

In addition to the above, one or more programs will be developed for the estimation of parameters in non-linear biomathematical models. The first program of this type will deal with an asymptotic regression function; an iterative non-linear least squares procedure will be utilized. Standard library routines for matrix multiplication and matrix inversion will be included in the program. If the need arises, programs for other models may be developed.

18-20004T Mechanical Engineering. Temperature Field in Sphere. A partial differential equation of the parabolic type describing the transient temperature field in a spherical region $0 < r < a$, where r is the radial coordinate and A the radius of the sphere, is to be solved using explicit finite difference methods. The initial temperature throughout the region is zero, while the boundary condition at $r = A$ is a specified constant heat flux.

An analytical solution for this problem also exists. The object in using finite difference methods is to obtain information on stability and convergence of the finite difference solutions, as functions of the space and time increments used, by comparing them to the analytical solution. This information will be useful in later attacking a problem of a similar nature for which an analytical solution is not available.

Two finite difference schemes will be used, both of which give rise to explicit expressions for the temperature distribution at a given time level in terms of the temperature values for the preceding one or two time levels. Only the basic arithmetic operations arise in these expressions.

19-20005 Chemistry. Protein Crystallography. It is proposed that the IBM 7090 be used to assist in the solution of protein molecule structures using x-ray diffraction techniques. The types of operations which will be carried out on the 7090 are as follows:

- a. Processing of raw data, including application of camera and other corrections and scaling.
- b. Three-dimensional Fourier summations of the form:

$$\rho(x, y, z) = \sum_n \sum_k \sum_l (F_{nkl} e^{i\phi_{nkl}}) e^{-2\pi i (hx + ky + lz)}$$

These will be used to calculate electron density maps, Patterson vector maps, difference maps and various other convolutions.

- c. Theoretical diffraction pattern intensities from proposed molecular models, using summations over all atoms j in the molecule of the following type:

$$(F_{nkl} e^{i\phi_{nkl}}) = \sum_j f_j e^{+2\pi i (hx_j + ky_j + lz_j)}$$

These are compared with observed intensities as a measure of the quality of the model.

- d. Least squares refinement of trial atomic parameters.

Part of the programs used will be obtained from other 7090 users in SCAT or FORTRAN notation, but special purpose programs will be written here in either format. This is yet to be developed.

The majority of the time will be spent on the structure of the protein lysozyme. This is a continuation of the lysozyme work carried out during the past two years on the IBM 650.

20-20008 Physics. K-K and π - π Interactions. A π^- -p exposure was made at the Alternating Gradient Synchrotron. The bubble chamber pictures from this run are to be analyzed to study several aspects of elementary particle interactions. At the present time interest is focused primarily on K- \bar{K} and π - π interactions. The analysis of the pictures proceeds in several stages: in all but the first step most of the analysis is carried out on a computer. The steps are:

- a. The tracks for the event to be analyzed are measured in two views on a measuring machine. Coordinates of points as well as additional identification are punched on paper tape or cards.

- b. The tracks are reconstructed in space to obtain angles and momenta for each track. At this point errors on these variables are estimated, including measurement errors as well as the effects of scattering and straggling.

- c. A hypothesis is made as to the physical nature of the interactions. A least square fit of the measured variables is made imposing the constraints of conservation of energy and momenta at each step of the event (many events are really chains of linked processes). From the χ^2 of the fit one can estimate how probable the assumed interpretation is. In general several interpretations have to be tested since the interpretation

the topology of an event is rarely unique.

d. Records are produced of the results of the calculations in (b) and (c) on magnetic tape. These records will often be used for subsequent computations of quantities of physical interest, for sorting, etc.

-2009 Chemistry. Error Terms for Quadrature Formulas. Current research in Chemistry often requires numerical integrations to be carried out to high accuracy. Hence, the properties of various useful quadrature formulas must be known and are to be subjected to intensive study. It is particularly desirable to compute and tabulate the sizes of the various error terms which can occur in these formulas.

-2010T Agricultural Economics. An Institutional Beef Procurement Plan. A least-cost beef procurement program is to be computed for Central Food Stores, a University of Illinois food service facility. Given the amounts and kinds of available labor each month and the annual requirements for various beef items, the problem is solving for the least-cost combination of wholesale beef cuts and the months in which each of these cuts should be purchased.

This problem can be solved by linear programming using the LP/90 distributed SHARE. The cost-ranging and parametric programming features will be especially helpful since this is essentially a conditional price forecasting problem.

-2011 Physics. Restricted Three-Body Problem. This work involves the numerical integration of two coupled, non-linear, second-order differential equations; a first integral is known and is used in the calculations. These equations, describing the classical motion of an infinitesimal body in the gravitational fields of two other massive bodies (e.g. spaceship-earth-moon) are:

$$\ddot{\xi} - 2\dot{\eta} - \xi = -8 \left\{ \frac{(1-\mu)(\xi + 2\mu)}{\rho_1^3} + \frac{\mu(\xi - 2 + 2\mu)}{\rho_2^3} \right\}$$

$$\ddot{\eta} + 2\dot{\xi} - \eta = -8 \left\{ \frac{(1-\mu)\eta}{\rho_1^3} + \frac{\mu\eta}{\rho_2^3} \right\}$$

where:

$$\rho_1^2 \equiv (\xi + 2\mu)^2 + \eta^2 \quad \rho_2^2 \equiv (\xi - 2 + 2\mu)^2 + \eta^2$$

nd

$$(\dot{\xi})^2 + (\dot{\eta})^2 = \xi^2 + \eta^2 - K + 16 \left(\frac{1-\mu}{\rho_1} + \frac{\mu}{\rho_2} \right)$$

in the rotating (ξ, η) coordinate frame; μ is a mass ratio between the two massive bodies. The Runge-Kutta method has been used in the past for the integration process, but Adams' method of variable interval control may be more ideally suited to the work.

The general calculations involve specifying initial conditions (e.g. for $\xi, \eta, \dot{\xi}, \dot{\eta}$, and $\dot{\xi}$ for some μ) and then integrating out the associated trajectory (as a function of time t) for one or more revolutions. This is then done for many orbits by varying the initial conditions in reasonable predetermined ways. From such a series of calculations one can interpolate to find those initial conditions that give rise to periodic orbits (i.e. ones that close upon themselves after one or more revolutions). Later, the machine will be programmed to do this analysis work too (such as interpolation, curve fitting, roots of polynomial fit, etc.); the machine will then turn out only the periodic orbits.

Once these things can be done effectively and rapidly on the machine, all the general characteristics of the space and structure of the totality of periodic orbits can be studied and formulated. With such a generalized picture of the problem available the problem can be viewed in a more abstract mathematical way. At the present state of the analysis it appears that a topological-group-theoretic approach may be the key to full understanding of the physics of the problem.

24-20012T Civil Engineering. Dynamic Stresses Around a Cylindrical Opening in Elastic Medium. The purpose of this investigation is to determine the stresses in the region of a cylindrical cavity in an infinite, elastic, isotropic, homogeneous medium when the cavity is enveloped by a plane stress wave travelling in a direction perpendicular to its axis. Stresses on a cylindrical boundary are first written in Fourier series. There are two of these stresses, the radial and the shear components. Waves are then allowed to travel outward from a line source at the axis of the tunnel which cause stresses that are equal and of opposite sign to the incident wave stresses. The combination of these two waves satisfy the boundary conditions of zero stresses on the inside of the opening. In general this procedure results in two simultaneous integral equations, one from equating the shear stresses at the boundary and one from the radial stresses.

The integrals, which are of the convolution type, are written in numerical form with time divided into discrete steps. Once these functions have been found it is possible to find the stress at any point in the medium by superimposing the stresses due to the incident and diverging waves.

25-20013T Chemistry. Statistical Computation of Reaction Probabilities. Calculation will be carried out on the computer to determine statistically the transition probability for a simple chemical reaction. Using the Porter form for the potential energy of the colinear system, $A + BC$, the routine will solve the classical equations of motion for the system under a great variety of conditions.

Hamiltonian equations $\frac{\partial H}{\partial q_i} = -\dot{p}_i$, $\frac{\partial H}{\partial p_i} = \dot{q}_i$ of the system will be written

using a potential energy function of the form:

$$V(X,Y) = \gamma \left\{ [1 - \exp(-\alpha \xi)]^2 - 1 \right\}$$

where

$$\gamma = D (1 - a \sin^2 2\theta)$$

$$\alpha = \alpha_0 + (\alpha^\dagger - \alpha_0) \sin^4 2\theta$$

$$\xi = [\sqrt{2} (R_0 - S_0) - (R_0 - X_0)] \sin^4 2\theta + (R_0 - X_0) - (R_0 - X) \sec \theta \text{ and}$$

$$\theta = \text{Arctan} \frac{R - Y}{R_0 - X}$$

here X = distance between A and B, X_0 = equilibrium distance between A and B

Y = distance between B and C, Y_0 = equilibrium distance between B and C

D = Minimum potential energy

A, L = parameters variable to fit different molecules

S_0 = the value of x and y where the positive curvature along the line $X = Y$ coincides with the negative curvature along the line perpendicular to it.

26-20014 Economics. Prices, Outputs, and the Production Function. This research project is an attempt to estimate the aggregate production function paying specific attention to non-neutral technical change. Previous works in this area have assumed that technical change affects all factors of production in the same manner. This study allows, in addition to this neutral effect, a change in the bias of the function and a change in the marginal rate of substitution between factors. Throughout the study non-linear relations are permitted. The model is estimated by using two kinds of data: price relationships between factors, and physical units of input and output. The two kinds of data are integrated by using newly developed mixed statistical estimation, in which multiple regression analysis is subjected to outside constraints.

Because this problem requires ordinary regression analysis to be altered to allow the two kinds of data to be used, regression programs will not work. A simple matrix package will be used for all of the computations.

27-20015 Physics. Photoproduction Analysis. The production of neutral pi mesons by gamma rays near threshold has been observed in the University of Illinois bubble chamber. The purpose of this program is to analyze the information obtained from the bubble chamber pictures and to summarize the results. Therefore the program will use straight forward arithmetic in various sorting and plotting routines.

28-20016 Mechanical Engineering. Engine Force Analysis. This program is to perform a force analysis on a slider crank mechanism for various positions of the crank. It will be used in the Design Division of the Mechanical Engineering Department for one of its courses.

The computer will solve a series of algebraic equations for the forces and moments set up within the mechanism for several positions of the crank. Variables will be component weights and dimensions, piston offset, crank speed, cylinder pressure as a function of crank angle, and cylinder arrangement.

29-20017 Physics. Photon Scattering and π^0 Production. The cross section for elastic scattering of photons on nucleons (nucleon Compton effect) is measured in the presence of a strong background of inelastic processes, such as photo production and subsequent photon decay of π^0 - mesons. The trajectories of the recoiling nucleon and of the photon (e.g., a shower produced by it) are photographed in spark chambers. The angular correlation of both is used to discriminate inelastic events from the elastic ones, for which it is unique.

The 7090 may be used for: Calculating the kinematics of the processes, calculating the particle trajectories in a magnetic field, evaluation of experimental data which have been scanned on a semiautomatic film reading device, prediction of distributions of experimental quantities by integration over cross section and various efficiencies, and the calculation of the efficiency of photon detectors by constructing electron-photon-showers with a Monte-Carlo-program.

30-20018 Education. Programming Materials for use in Self-Instructional Devices.

The data of this research problem is the result of a study concerning the relationship of variables in the learning process, considering both variables in the learning situation and characteristics of the learner. An attempt is being made to predict responses knowing the conditions which were present in the learning situation. Nineteen mentally retarded children learned to read 25 words under various conditions. Two presentation sequences of the words were made, designated as Prompting and Confirmation

Previous research showed that Prompting promoted fast initial learning whereas Confirmation was poor in this respect, but under certain conditions confirmation promoted longer retention of the materials learned. This present study combined these two sequences in an attempt to maximize the efficiency of each sequence, prompting first for fast initial learning, then confirmation for better retention. The number of presentations of one was varied in combination with the other. This "balance" of the number of prompting and confirmation presentations is an important variable in the learning situation and of the data to be analysed.

Various mental and psychological measures were obtained on each child and the scores of these tests are considered to be important variables contributed by the learner in the learning situation. The remaining independent variables consisted of the characteristics of the experimental design other than the levels of Prompting and Confirmation and the characteristics of the words learned. (Total = 4)

Response measures (the dependent variables, total = 13) consisted of trials to reach a criterion, the errors committed and whether or not the child retained what he had learned by recall and recognition tests administered at one day, seven days and 30 days after reaching the learning criterion.

The IBM 7090 will be used for production of general least squares solutions for matrices. Crossproducts will be calculated from the row data and then a multiple regression analysis will be run on the data.

31-20021 Astronomy. Reflection Coefficients-Radio Telescope. The problem is to find the best way to connect the many antennas in the University's Radio Telescope at Danville. Specifically, this program computes the reflection coefficients at each of the antennas for a particular method of connecting the antennas.

The program will be written so that it can handle these coefficients when various procedures are used in connecting the antennas.

32-20022 Chemistry. High Resolution Structure of Lysozyme. The research involves the frequent use of the summation of Fourier series in the testing of data. For proper interpretation these results must also be displayed. Each Fourier series involves several hundred terms.

33-20023 Physics. Tunneling Integral Evaluation. This program will evaluate the following integral for specified values of the parameters x_0 and v .

$$\frac{dI}{dv} \sim \int_0^\infty \frac{e^{\sqrt{x^2 + x_0^2} + v} dx}{[e^{\sqrt{x^2 + x_0^2} + v} + 1]^2} + \int_0^\infty \frac{e^{\sqrt{x^2 + x_0^2} - v} dx}{[e^{\sqrt{x^2 + x_0^2} - v} + 1]^2}$$

$$x_0 = \frac{\epsilon_0}{KT}$$

$$v = \frac{eV}{KT}$$

If a small potential difference V is applied between two metals separated by a thin insulating film, a current will flow due to the quantum mechanical tunnel effect. For both metals in the normal state, the current-voltage characteristic is linear. If, however, one of the metals is superconducting, the I-V characteristic is non-linear, with the slope of characteristic $\frac{dI}{dv}$ being directly related to the energy gap $2\epsilon_0$ and the density of states in the superconductor.

A theoretical expression for the slope $\frac{dI}{dv}$ may be derived using the Bardeen-Cooper-Schrieffer Density of States Function for a superconductor

$$\rho(E) = \frac{|E|}{[E^2 - \epsilon_0^2]^{1/2}}$$

where E is the energy and ϵ_0 is one-half the energy gap. Such is the above expression. This may then be compared to experimental curves to determine the validity of BCS theory and the magnitude of ϵ_0 (K = Boltzmann's constant, T = abs. temperature, $-e$ = change on electron).

34-20024T Electrical Engineering. Maser Matrix Solution. The matrix to be solved is a portion of that describing the interaction of two Cr^{+++} ions in adjacent lattice sites in $\alpha - Al_2O_3$. The interaction provides the energy separations necessary for achieving submillimeter maser action. The particular, complex nature of their interaction provides the mechanism by which this end may be achieved.

35-20025 Statistical Service Unit. Statistical Library Development. The Statistical Service Unit staff is currently developing a number of statistical programs for the IBM 7090 computer. These programs include both complete programs as well as complete subroutines.

Complete programs ready for testing at this time are:

- i) Centroid Factor analysis.
- ii) Principal axis Factor analysis.
- iii) Least Squares program for analysis of variance and co-variance and multiple correlations.
- iv) Wherry-Doolittle method for multiple correlations.
- v) Auto-Correlation program for zero-order coefficients.
- ui) Product moment correlation program.

Complete subroutines ready for testing are:

- i) Matrix inversion
- ii) Eigenvalues and Eigenvectors
- iii) Matrix transposition
- iu) Matrix multiplication

36-20026T Nuclear Engineering. Neutrons in Heterogeneous Media. It is proposed to obtain exact solutions of the space and energy dependent Boltzmann equation for neutrons in heterogeneous media.

Although a vast amount of analytical and numerical work has been done in this area, exact solutions, which could be used as a guide in evaluating various approximation methods, do not exist even for simple geometries. As a first step the slowing down and transport of neutrons in a slab lattice will be investigated. Each lattice will consist of two regions of different nuclear properties. In addition to its mathematical interest, the solution of this problem will have relevant applications in reactor theory and in the evaluation of integral experiments with chain reacting assemblies.

For the purpose of this investigation the Boltzmann equation is cast in an integral form.

$$F(\vec{U}, \vec{r}) = \sum_T (U, \vec{r}) \int d\vec{r}' \left| \frac{\vec{e}}{\vec{r}} - \vec{r}' \right|^2 \sum_n \int_{u-r}^u du' S_n^*(U', \vec{r}') F(U', \vec{r}'^{-1})$$

Where:

$F(U, \vec{r})$ is the collision density of neutrons times e^U . \vec{r} is the space vector.

U is lethargy

$\zeta(\vec{r}, \vec{r}')$ is the optical path

$\sum_T (U, \vec{r})$ is the total nuclear cross section.

$S_n^*(U, \vec{r})$ is a constant times the ratio of the scattering cross section of the nth element to the total cross section.

lithergy and energy are related by: $U = +2n \left(\frac{E_0}{E} \right)$

For a slab geometry symmetry arguments and the periodicity of the lattice reduce the problem to calculating the collision density over lethergy and a finite interval on one space dimension.

The resulting difference equations are solved by utilizing an asymptotic solution at small lethergies, and calculating the space dependent collision density at increasing values of lithergy. At each lithergy the algebraic equations are coupled to the space variable. This coupling is eliminated through the use of an appropriate interpolation scheme for expressing $F(U_i, Z')$ in terms of $F(U_j, Z')$ where $i > j$. Therefore the equations are solved without iteration or matrix inversion.

2-20032 State Water Survey. Charged Particle Collisions. The interaction between spherical bodies in a moving fluid with the bodies possessing a charge with electrical field superimposed is to be investigated. The primary object of the investigation is to determine the theoretical effect of the electrical phenomenon upon the collision cross-section of the bodies. The basic mathematical formulations are: The Stokes-Oseen equations of fluid flow around a spherical body, the electric field forces on two charged spherical bodies in an electrostatic field, and the differential laws of motion of one body with respect to another to include both the dynamic-fluid and field effects.

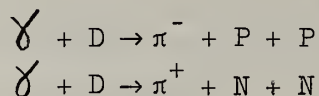
In computation the situation to be represented is that of two bodies, starting at various initial relationships, passing or colliding with one another. The relative positions of the bodies are to be calculated point by point and plotted on the CRT monitor.

3-20027 Civil Engineering. Reversed Bending of Reinforced Concrete Members. This problem concerns the properties of reinforced concrete members subjected to axial load and reversal of bending. The computer will be used to compute the theoretical relationship between load and deformation for various reinforced concrete sections and for various combinations of loading. These can then be compared to the experimental results.

9-20028 Chemistry. Quantum Energy Transfer. A quantum mechanical study of translational energy transfer processes is to be made by considering the problem of a one-dimensional harmonic oscillator interacting with a particle with translational energy, ϵ . An appropriate potential between the oscillator and the particle will be assumed, and the total wave function for the system expanded in terms of functions formed by the product of a harmonic oscillator wave function and a plane wave; i.e. $\Psi = \sum_n A_n \sigma_n \phi_n$ where σ_n is a plane wave and ϕ_n a harmonic oscillator function in state n .

The object will be to determine the values of the expansion coefficients, A_n . The integrals which arise in this connection are to be evaluated by a Simpson's rule integration in 2 dimensions. The resulting linear equations will then be solved.

40-20031T Physics. Photoproduction in deuterium. Bubble chamber films for the reactions



will be processed and analyzed.

After space reconstruction, the kinematic fitting of the vertex will be done by a least squares technique. Intermediate results will be stored on binary tapes for later analysis.

Later analysis will involve sorting and calculations of cross-sections by means of maximum likelihood methods.

41-20029 Digital Computer Laboratory. Pattern Recognition Computer Simulator
The 7090 will be used to simulate the pattern articulation unit discussed in "The Design of A Pattern Recognition Computer," Digital Computer Laboratory Report No. 122.

The simulator will be used later for research in the pattern recognition area

42-20030 Nuclear Engineering. Gamma Ray Backscattering. This problem concerns the calculation of the proportion of radiation back-scattered from a large plane surface. The basic parameters are: the height of the source above the plane, H_1 ; the height of the detector above the plane, H_2 ; the horizontal projection of the distance between the source and detector, y_d ; the energy of the gamma photons emitted by the source, E_0 . The calculation requires a knowledge of the differential albedo function, a . This is available in the form of a semi-empirical equation, dependent upon the geometry of the situation and upon the values of two empirical constants which are in turn dependent upon the reflecting material and the photon energy. A simple algebraic equation then provides the scattered dose from each incremental area, after which a summation is made. The research involves several phases: the mapping out in certain given situations of the contribution by various incremental areas, so as to determine the variation with distance and the effect of finite area size upon the results; similar exploratory sample calculations to get to understand the effect of incremental area size upon the results; several sets of runs under a variation of parameters program, in order to produce data which can be compared with experiment; a final set of tabulated data with varied parameters arranged and tabulated in a form useful for other users interested in this technology.

43-20033T Civil Engineering. Soil Structure Interaction. Basically, the problem is concerned with studying the interaction of an underground structure with the soil medium due to the passage of a blast wave. The soil is represented by a two-dimensional spring-mass system which in the elastic range can be shown to be a finite difference analog of a continuum. The model is composed of lumped masses arranged in a square grid and interconnected by a system of springs. Equations of equilibrium were derived for the lumped masses by considering the two-dimensional model to be in plane-strain.

44-20034 Sociology. Methods of Multivariate Analyses. The problem of combining analyses of variance and covariance, multiple regression, and discriminant functions into a unified theory has been solved previously. However, the methods of computation have not been solved for most efficient use.

This research will consider new methods of solving simultaneous linear equations and methods of setting up problems of the type described above, so that a single computational procedure will handle all such problems.

In many problems the original data may be desired to be combined in many ways, meaning the original data will be operated on extensively. It will be important to make error analyses of such programs and this is considered to be the second portion of this project.

45-20035 Instructional TV. Effects of Teaching by Television. For a period of three years Sociology 104-105 is to be taught by television. Students are allowed to view the lectures not only in classrooms where TV sets are provided, but in their living quarters as well, e.g. dormitory, sorority, etc. Furthermore, in some cases, the students themselves are responsible for conducting some discussion sections of the course. The questions to be answered are: What is the effect of "attending" class in places other than a classroom; are students enrolled in the course able, with special training, to lead a discussion group for that course, and how effectively?

The methods of analyses consist of multiple regression, analysis of variance and analysis of covariance. Standard routines will not be employed. All programs to be used will be written in FORTRAN. These programs will in general consist of matrix operations such as multiplication and inversion.

46-20036T Nuclear Engineering. Particle Motion in a Turbulent Field. The motion of a small spherical particle in a turbulent fluid field, in which the "relative" Reynolds number is small, is investigated for a range of possible parameters. The solutions,

which are in closed form, are restricted to the "Stokesian" regime of motion. The fundamental solution appears as the ratio of two polynomials, i.e.,

$$\frac{n^{(1)}}{n^{(2)}} = \frac{\left(\frac{\omega}{\alpha}\right)^2 + \sqrt{6} \left(\frac{\omega}{\alpha}\right)^{3/2} + 3\left(\frac{\omega}{\alpha}\right) + \sqrt{6} \left(\frac{\omega}{\alpha}\right)^{1/2} + 1}{\frac{1}{\beta} \left(\frac{\omega}{\alpha}\right)^2 + \frac{\sqrt{6}}{\beta} \left(\frac{\omega}{\alpha}\right)^{3/2} + 3\left(\frac{\omega}{\alpha}\right) + \sqrt{6} \left(\frac{\omega}{\alpha}\right)^{1/2} + 1}$$

This expression may be interpreted as the ratio of the turbulent energy of the particle to that of the fluid. The values of α (a system time characteristic) and β (a joint particle and fluid density characteristic) are determined from the system material properties, while ω (the angular frequency associated with the turbulence) varies over the full spectrum range. The asymptotic conditions for small and large values of ω are known, but the mid-range values are of interest. A sufficiently fine mesh set of results of $\frac{n^{(1)}}{n^{(2)}}$ versus $\frac{\omega}{\alpha}$ for fixed α and β is to be evaluated.

Appropriate experimental data for $F(\omega)$ (the spectral density function) is to be approximated by curve fitting techniques. An expression involving integration of $\frac{n^{(1)}}{n^{(2)}}$ and $F(\omega)$ to form the ratio

$$\frac{A_1}{A_2} = \frac{\int_0^\infty \frac{n^{(1)}}{n^{(2)}} \cdot F(\omega) d\omega}{\int_0^\infty F(\omega) d\omega}$$

is evaluated and is to be interpreted as a measure of the particle's ability to follow the fluid motion.

The ratio of the particle to fluid eddy diffusivity $\left(\frac{\epsilon_p}{\epsilon}\right)$ is formed as

$$\frac{\epsilon_p}{\epsilon} = \frac{\int_0^\infty \frac{n^{(1)}}{n^{(2)}} \cdot \frac{F(\omega) \sin \omega t}{\omega} d\omega}{\int_0^\infty \frac{F(\omega) \sin \omega t}{\omega} d\omega}$$

for which the appropriate choice of time (t) is predetermined for the specific α , β which are chosen.

A similar series of evaluations based on the relative motion between the particle and fluid are to be evaluated also. They are mathematically similar to the above equations.

Initially, five values for both α and β are to be used. Subsequent variations are expected after the first series of results are analyzed.

47-20037T Civil Engineering. Analysis of Doubly Curved Shells. The problem consists of two parts; first, the analysis of translational shells and second, the analysis of doubly curved shells bounded by characteristics.

The methods of analysis are the modified finite difference method and variational techniques such as Ritz's method and a generalized Galerkin's method.

In both these methods the governing differential equations are reduced to systems of linear algebraic equations. A computer program will be developed to generate these systems of equations and solve them. From these the displacements and stresses in the shells are determined.

48-20038 State Water Survey. Drop Inlet Spillway Study. This is a research program on drop inlet spillways to determine the best proportions for spillways which have unique hydraulic characteristics. Head loss coefficients for spillway component parts and the pressure distribution throughout the spillway must be determined. It is contemplated that this research program will extend over a period of 3 to 4 years. During this period of time, the experimental test apparatus will remain the same. Variations in geometrical proportions of the model within the same experimental design are contemplated. Observational data will be recorded for many different flow conditions.

The computer can do the arithmetic involved in the solution of a number of formulas in which observational data are inserted. These formulas will be repeated many times for different flow conditions.

49-20039 Instructional TV. Economic Forecasting. The problem involves forecasting all segments of the national economy. The primary mathematical procedures used will be the least squares method of regression and multiple correlations. Secondary techniques will involve logarithmic regression and fitting curves to parabolas.

50-20051 Office of Instructional Research. Distance Functions. The 7090 will be used to compute distance functions between a maximum of 10 variables. The input is in the form of frequency counts for each variable. The machine prints a listing of the frequency counts converted into percentages and the output matrix of distance functions. The equation being used to compute the distance function is

$$DF_{xy} = \sqrt{\sum_{i=0}^n (X_i - Y_i)^2}$$

where "i" represents the variable number and DF_{xy} is the distance function between X and Y.

51-20040 Civil Engineering. Triangulation Adjustment. In both mechanical and numerical methods of aerial triangulation, triangulated coordinates exhibit existence of systematic error. The purpose of this program is to compensate for such errors and produce adjusted coordinates.

The distribution of errors along a strip is obtained as a function of the triangulated coordinates. Redundant data requires a least squares solution for the determination of this function.

52-20041 Civil Engineering. Analytical Aerotriangulation. Analytical Aerial Triangulation is the process of reconstruction of the bundles of rays forming a block of photographs. The basic observations in this process are the planimetric coordinate of a set of points appearing in these photographs together with the ground coordinates of at least three of these points.

The solution of this problem takes two steps: construction of a mathematical model and least squares adjustment, because of the presence of redundancy.

The program will start by assuming approximate values for the unknowns in the problem (the orientation elements of the exposure stations). Linearized condition equations are then formed, from which a better approximation for the unknowns is derived employing the principle of least squares. The iteration process stops when the correction vector to the unknowns reaches a preset criterion.

53-20042T Chemical Engineering. Determining Kinetic Constants. When attempting to evaluate chemical kinetic mechanisms, it is usual to compare data with a number of proposed mechanisms. The constants of each proposed mechanism are computed by a least squares procedure, and mechanisms with zero or negative constants are discarded. The standard deviation between raw data and the remaining mechanisms when evaluated with its computed constants is calculated; the mechanisms with the smallest standard deviations are considered the most probable.

The program consists of the formulation of 35-40 functions of the raw data, the placement of these functions in specified matrix locations, the solution of the resulting simultaneous equations, and computation of standard deviations.

54-20043 Small Homes Council, Bureau of Residential Construction. One and one-half story residential roof frame. The computer is used to determine the joint moments and rotations of a 14" statically indeterminate, rigid frame for use in residential construction. The method of analysis is the solution of 28 simultaneous slope-deflection equations in matrix form.

55-20044 Agronomy. Spring Oats Breeding. This research project involves the testing of oat breeding lines and new oat varieties. This material is usually tested at 4-5 different locations throughout the state. The 7090 will usually be used to calculate variety or breeding line means and the appropriate analysis of variance so that significant differences in the material may be determined. Data analyzed will usually consist of the following characters: stand, lodging, height, maturity, yield, and test weight.

56-20045 Instructional TV. Instructional TV Attitude Study. Questionnaire data from public school and college students is being gathered on attitudes, social interaction, home behavior and school achievement surrounding the use of instructional television. Before and after change scores, group differences and variable relationships will be analyzed by analysis of variance, analysis of covariance, and correlations, and attitude dimensions of students will be sought through factor analysis.

The 7090 is needed for solution of the multivariate analyses of 20-30 variables over 600-800 subjects. Statpac programs will be used when available. Others, such as generalized analysis of variance solutions, are being written in FORTRAN.

57-20046 Animal Science. Effect of Anosmia on Reproductive Behavior. The problem seeks to determine whether rams, rendered anosmic with a topically applied anesthesia, differ from control rams in their capacity to detect and mate with estrous ewes. The method of least squares will be used to analyze the data.

58-20048 Chemistry. Diffusion Controlled Growth of Vapor Bubbles. This problem arises in connection with the study of heat transfer to boiling liquids. In particular, the point of interest is the rate at which bubbles grow under such conditions. The system under consideration may be thought of as a vapor filled cavity surrounded by supersaturated liquid. This would be the case, for instance, for bubbles growing in a soda-pop bottle after the cap has been released. The growth of such a bubble has been calculated on the assumption that the bubble is a sphere surrounded by an infinite amount of liquid, but this situation is very rarely met in practice. The present intent is to calculate the growth for one other geometric configuration, namely, a spherical bubble in an infinite and supersaturated medium, but also in contact with a plain or solid wall. The physical properties of the system are assumed known and the analysis eventually leads to a partial differential equation with suitable boundary conditions. The solution will be effected by finite difference methods, using iteration by lines.

59-20049T Agricultural Economics. Optimum Flow of Oilseed Meals. The problem is to minimize the total transportation cost of oilseed meals among a total of 20 regions. The shipments occur from 6 regions to a total of 14 regions. The 6 surplus regions which are shipping to the 14 deficit regions have given surpluses which are to be shipped and the deficit regions may receive only given quantities of the surpluses.

The problem must be run several times because the quantities of deficits and surpluses for each region must be changed to meet certain price effects which finally converge to an equilibrium.

60-20052 Agricultural Economics. Spatial Analyses of the Livestock Economy. In this problem the continental United States is partitioned into N regions. The excess demand or excess supply of livestock products for each region plus the transport cost between each pair of regions is known. Given the excess demands and supplies and transport costs the problem is one of deriving the set of geographical flows of livestock which will satisfy the demands and minimize total transport costs.

61-20055 State Water Survey. Evaporation Computations. The following equation for computing evaporation from a lake surface will be solved several thousand times:

$$E = \frac{(T_a - 212) (.1024 - .01066 \ln R) - .0001 + .025 \times \Delta e^{.88} (.37 + .0041 U)}{.025 + (T_a + 398.36)^{-2} \times 4.7988 \times 10^{10} \times e^{-7482.6 / (T_a + 398.36)}}$$

Where

E = evaporation in inches of water

T_a = air temperature in $^{\circ}\text{F}$

T_d = dew point temperature in $^{\circ}\text{F}$

R = solar radiation in langleys per day

U = wind movement in miles per day

$\Delta e = T_a - T_d$ = vapor pressure differential in inches of mercury

62-20054 Civil Engineering. Frame Analysis. This program is to be used in computing the bending moments at the ends of the members of a frame subjected to any kind of loading. It can be used, as extension, in analyzing beams, arches and in obtaining influence lines.

In vertical loading cases, this is usually done by using the slope-deflection method which requires auxiliary solutions of simultaneous linear equations in terms of the rotations of the joints, not the object of the problem. This requires that

many "exact" figures be kept when, in fact, the uncertainties involved in the assumptions and loadings do not justify more than 3.

The program is based on the simple idea of avoiding the spread of residuals, carryover moments in this case, and allows a set of simultaneous linear equations to be written in terms of the moments themselves. The system can be solved by the Gauss-Seidel procedure of successive approximations.

63-20056 Chemistry. Non-Bound State Quantum Mechanics. A method is under investigation for solving steady state scattering problems using an expansion of the wave function in a finite number of members of a complete set which spans the Hilbert space of solutions. In order to evaluate this method, it is necessary to know the solution to some degree of accuracy. The IBM 7090 will be used to obtain the solution to a few simple problems by finite difference methods. For non-bound states the solution is complex and the Schroedinger Equation must be broken up into a real and imaginary part. This may be accomplished in two ways. First we may set the solution $\Psi = U + iV$ where U and V are real and obtain two linear equations. These have the disadvantage of having oscillatory solutions. Secondly, we may set $\Psi = Re^{iS}$ where R and S are real. This leads to two non-linear equations whose solutions are slowly varying.

So the first part of the problem consists of determining which of these two methods is fastest. The last part of the problem is to find solutions to high accuracy for various simple potentials.

64-20056T Chemistry. Eddy Diffusivity Distribution. Reactant concentration distributions are to be calculated in the entry region of a tubular reactor. The reaction is assumed to occur only on the tube wall where the reactant concentration is zero. The flow through the reactor is fully developed and turbulent.

The system of interest is characterized by a high Schmidt number so that the concentration gradient is confined to a thin region near the wall. Because the region is so thin the mass balance may be written in a system of rectilinear coordinates. The basic equation appears in dimensionless form as

$$y \frac{\partial C}{\partial Z} = 0.199 \text{ Re}^{7/8} \frac{\partial}{\partial y} \left(D + \frac{\partial C}{\partial y} \right)$$

with boundary conditions

$$C (Z > 0, y = 0) = 0$$

$$C (Z, y = 5) = 1 \int_0^{\eta} \frac{e^{-\eta^3}}{.8934} dz$$

$$\eta = \frac{100}{12.1} Sc^{1/3} Re^{-0.291} y$$

and range of interest

$$y: 0 \text{ to } 5 \quad Z: 0 \text{ to } 2$$

The quantities appearing above are defined as follows:

C = reactant concentration

y = distance from tube wall

Z = distance parallel to tube wall measured from upstream end of reaction surface.

Sc = Schmidt number for reactant

Re = Reynolds number based on bulk average velocity and tube diameter.

D_+ = turbulent diffusivity

The equation is to be solved with the Reynolds number Re as a parameter varying from 10^4 to 7×10^4 . The desired results will be in the form of concentration gradients $\frac{\partial C}{\partial y}$ as a function of Z .
 $y = 0$

65-20058 Education. Eigenvalues by LR Transformations. This is a problem in numerical analysis. Using a specialized variant of the LR-transformation, it appears possible to obtain eigenvalues of real symmetric tridiagonal matrices perhaps five to ten times more rapidly than the best standard procedures (e.g. Givens-Wilkinson). This assertion is dependent upon appropriate translations of the origin. It is the purpose of this research to investigate empirically simple translations -- a problem for which elegant mathematical techniques exist, but techniques which are too time consuming. Preliminary results suggest the probability of being able to reduce markedly the computer time necessary for any eigenproblem involving real symmetric matrices.

66-20066 Statistical Service Unit. Electronic Scheduling. The purpose of this project is to investigate through simulation methods of assigning course or section request lists to a predetermined time table. Data to be used will initially consist

the file of all students registered at the University of Illinois for the Fall 1962 term and the Time Table describing the sections in which these students are enrolled.

By attempting to assign these students using computer methods, it is hoped that it will be possible to evaluate probable methods of actually replacing existing class registration procedures with a computer system. Relative speed of scheduling, methods of enrollment control, and policies toward student choice will be studies involved in the use of the 7090.

Basically the initial system will consist of three phases: (1) introduction and recoding of time table information; (2) assignment of students to time table sections; and (3) addition of title information to request and scheduled section lists. All three programs will be subject to alteration on the basis of resulting information.

In addition, several analysis programs are planned. These programs will attempt to discover conflict information, overload situations and other data related to the development of an effective computer assignment system.

Use of the IBM 7090 offers the ability to have accessible all section information and to process large volumes of student requests in relatively short amounts of time. Initial estimates are that it may be possible to assign five to twelve thousand students to requested sections per hour.

7-20059 Civil Engineering. Queuing Theory Applications, Analytical study has shown that it is feasible to forecast and measure the production of an excavator and fleet of hauling units with the use of the theory of queues. These models consist of a set of time differential difference equations which represent the states in which the production system can exist. The steady state solution to a set of these equations provides the percentage of time in which the system is expected to be in each state.

Typical steady-state equations for one such system are the following:

$$\begin{aligned} m\lambda p_0 &= \mu p_1 \\ [(m-n)\lambda + n\mu] p_n &= (m-n+1)\lambda p_{n-1} + (n+1)\mu p_{n+1} \quad 1 \leq n < c \\ [(m-n)\lambda + c\mu] p_n &= (m-n+1)\lambda p_{n-1} + c\mu p_{n+1} \quad c \leq n \leq m \end{aligned}$$

where p_i = probability of being in state i

m = number of hauling units

n = number of units in system

c = number of excavators

μ = loading time/haul unit

λ = arrival rate/haul unit

The 7090 will be used to obtain solutions to sets of such equations for various systems. It is expected that max c will be 3 and max m will be 30. Response of this model to a range of data will be studied. This response will be used to study the sensitivity of these models for use in the design of construction operations.

68-20063T Mechanical Engineering. Contact Resistance. The program is to calculate the roots of the first derivative of the Legendre function which is needed in connection with an investigation into thermal contact resistance.

The roots of $\frac{d}{d\mu} P_n(\mu) \Big|_{\mu=\mu_0} \neq 0$ is calculated by the use of an asymptotic

expansion for $P_n(\mu)$ found in Watson's treatise.

69-20064 Agronomy. Commercial Corn Testing. This research project involves the testing of commercial and breeders corn lines. This material is usually tested at 6-8 locations throughout the state. The 7090 will be used to calculate means for each entry in the test as well as an analysis of variance. This is to be carried out so that significant differences between the material being tested can be determined. Three year averages will also be calculated and significant differences determined. The data analyzed will usually consist of yield, percent moisture, percent stand and percent erect.

70-20065 Theoretical and Applied Mechanics. Dynamics Analyzer. The aim of this program is to determine the properties of a very general routine developed elsewhere for the analysis of a general class of problems pertaining to mechanical and electrical oscillations. Once these properties are determined, the routine can contribute to the research efforts in the field of applied mechanics.

71-20067 Mechanical Engineering. Cam Pressure Angle. The purpose of this investigation is to analyze the effect of various physical parameters on the pressure angle for swinging-follower cam systems. This analysis will be made for several types of follower action, involving series or trigonometric functions.

The basic equations to be used in this investigation are as follows:

$$\alpha = \arctan \left[\cot \delta - \frac{L}{C} \left(\frac{1 - \frac{d\delta}{d\theta}}{\sin \delta} \right) \right]$$

$$\delta = \delta_0 + \tau \Delta$$

$$\Delta = f(\theta),$$

where α = Pressure angle

δ = Angle between the follower arm and the line determined by the centers of rotation on the follower arm and the cam.

δ_0 = Minimum value of δ

γ = Total angle of follower-arm swing

Δ = Series or trigonometric function describing the follower motion in terms of the cam rotation

$\frac{L}{C}$ = Ratio of the follower arm length to the distance between the centers of rotation of the follower arm and the cam.

The computer will be used to determine values of pressure angle for a large number of physical configurations.

72-20069T Mechanical Engineering. Efficiency of Spur Gears. A set of parametric equations will be solved to determine the thickness of the oil film between the meshing gear teeth. The Newton-Raphson method will be used to obtain these solutions on the 7090. After the film thickness has been determined the pressure gradient will be calculated and the pressure at any point along the length of the film will be found by numerical integration (using the trapezoidal rule). In this step the constant of integration in the expression for the pressure gradient will be determined. (At some point in the divergent portion of the film both the gradient and pressure are zero.) Once the pressure gradient and pressure are known along the length of the film, the shear stresses and fluid velocities can be calculated. The pressure and shear stresses will again be integrated over the length of film to determine the torques acting on the driving and driven gears. With these torques and the corresponding angular velocities the efficiency may be calculated.

The above procedure will be used for a finite number of mesh positions during the engagement cycle.

PART VI
INSTRUCTIONAL USE OF COMPUTERS

During the month of October, specifications were presented for two new problems on Illiac.

85 Industrial Engineering 386. Problem 1. Williams Memory Routine for Linear Programming by the Simplex Method. The class problem is to solve Linear Programming Models by the Simplex Method. This can be done by using Illiac Library Routine ML5-183.

86 Industrial Engineering 283. Problem 2. Linear Programming. Each student in the class has been instructed to make up a linear programming problem and have it solved on Illiac.

The purpose of the exercise is to introduce the students to a digital computer and punched tape and to think of new applications of linear programming.

During the month of October, specifications were presented for 13 new problems on the IBM 7090.

I4-29019 Industrial Engineering 283-1. Plant Location. The program will determine the optimum location of a new piece of equipment to be placed in an established industrial layout using an appropriately selected measure of effectiveness and/or cost value.

The problem places a matrix over the existing layout and locates the existing machines on the matrix. From their location it determines the right angle distance between a particular trial location for the new machine and the existing machines. This right angle distance is multiplied by a cost C or effectiveness E factor. The sum of the cost or effectiveness to each existing machine is determined. Other possible points are specified and the C or E value calculated. The number of trial points may be specified or every point in the matrix may be calculated.

I5-20001 Chemistry 490-1. Chemistry Short Course in 7090. Write a program to read a number Y from a card with format E15.10 and print Y and X , where X is the solution of the equation

$$Y = X^2 + e^X + \sin \frac{X}{2}$$

Use the iteration method discussed in class to solve the equation.

Assume $1 < Y < 100$ and find $X > 0$

I6-20006 Electrical Engineering 329-1. Frequency Response. The program calculates the quantities:

$$\begin{array}{ll} |T(j\omega)| & \text{Magnitude Response} \\ \arg T(j\omega) & \text{Phase Response} \\ - \frac{d \arg T(j\omega)}{d\omega} & \text{Decay response} \end{array}$$

Where $T(s)$ is any ratio of polynomials in s , the laplace transform variable. This will be helpful in demonstrating properties of certain types of network functions.

I7-20007 Civil Engineering 391-1. Beam Properties. A very simple problem to compute cross sectional constants for a beam has been assigned as the first class problem-- to be done in SCAT. The mathematics involves only first and second moments of areas about an axis. Some simple address modification is required.

I8-20019 Digital Computer Laboratory 195-1. Table of Powers. Write a machine language program in SCAT to compute a table of the floating point numbers x, x^2, x^3, x^4, x^8 for $x = 0 (1) 20$.

I9-20020 Digital Computer Laboratory 295-1. Math 295 Homework Problem 1. Write a machine language program in SCAT (and check it on the 7090) to calculate a 20 by 20 multiplication table which should appear as 20 numbers per line on 20 lines, i.e.

1	2	3	4	-----	20
2	4	6	8	-----	40
3	6	9	12	-----	60

20	40	60	80	-----	400

Although it is not the best method, form these by multiplication.

You should calculate one line at a time, storing the answers in 20 consecutive storage locations, say OUTPUT through OUTPUT + 19. You should then print the line by the set of orders.

```
CALL PRINT
STR  FORMAT
STR  OUTPUT, 0, OUTPUT + 19
STR
```

[Ø is the letter 0
0 is the number 0]

where FORMAT contains the character string

1Hb,20I4* (b indicates a blank column)

and should be input in your program by

FORMAT BCI 2, 1Hb, 20I4*

The CALL pseudo operation assembles as a TSX ----, 4 so index 4 will be changed.

I10-20047 Electrical Engineering 322-1. Exponential Routine. Compute $Z = a^X$ from the truncated series

$$Z = 1 + Y + \frac{Y^2}{2!} + \frac{Y^3}{3!} + \frac{Y^4}{4!} + \frac{Y^5}{5!}$$

where $Y = X \ln a$.

A is to be read in from a card and X is to range from 0 to 2 in steps of 0.1. A table of X and Z is to be printed out.

I11-20050 Civil Engineering 391-3. Term Problem for CE 391. The term program is intended to give the student first-hand experience in developing a complete computer program from it's inception to the finished program. The following will be considered: Statement of the problem, justification of the program, method of solution, assumption and limitations, input and output data, possible extensions or incorporation in larger program, flow diagrams, listing of program, sample problem. The problems will be in the fields of structural analysis, structural design, and fluid mechanics.

I12-20053 Digital Computer Laboratory 295-2. Polynomial Evaluation. Write a floating point subroutine to evaluate a polynomial. The subroutine will be entered with a

TSX SUBRT,4

PZE A, 0, N

In order to test your subroutine on the machine, write a program that will read in 6 floating point numbers from one card in the E field format (page 1.11 of Input-Output document). They will take up to 10 columns each, so should be read with a format specification of 6E10.0*. The six numbers will be $a_0, a_1, a_2, \dots, a_5$ in that order. Then, using these coefficients, enter your subroutine 7 times to calculate

$$\sum_{n=0}^5 a_n x^n \text{ for } x = 0, 0.25, 0.5, 0.75, 1.0, 1.25 \text{ and } 1.5$$

(usually written as $x = 0 (0.25) 1.5$)

Print these numbers out to 9 places using the E specification E13.0*. The output format should also contain the a_1 . Repeat the process for another card containing new a_1 .

113-20060 Civil Engineering 315-1 Equipment Productivity. The following problem is assigned to the class, CE315: A two-wheeled tractor and scraper weighs 46,800 lb. with 66 % of the weight on the drive wheels when empty and 55 % when full. It operates over stabilized dirt roads. The payload consists of 21 cu.yd. of material weighing 120 pounds per cubic foot. The engine is rated at 240 brake horse power at 1800 rpm. The drive wheels carry 24.00 x 29-24 tires. The loading time is 1 min; dumping and turning time is 1 min; and waiting time is 1/2 min. The haul "road" has the following characteristics:

Road Section	Length	Surface	Grade
1	400	Soft clay	-1 % (loaded)
2	2200	Stabilized earth	0
3	806	Firm earth	3 % (loaded)

Determine the normal production rate for this unit. The 7090 will be programmed to solve problems in this general class. The one above is an example. This code will then be made available to students in 315 who will become program users.

114-20061 Civil Engineering 318-1. Quantity Take-Off Program. In CE 318 the quantities of concrete, steel, reinforcing steel, lumber, windows, doors, electrical conduit, machinery, etc. required for the construction of a building and/or bridge must be determined before any design of construction operations can be attempted. This quantity takeoff must be reported in terms of cost account numbers, job operations, municipal and state bid items. Job specifications must be satisfied with regard to quality of material or mechanical equipment.

This quantity take-off process is a detailed operation consisting of numerous, time-consuming arithmetic manipulations together with an information retrieval process of moderate complexity.

The 7090 will be programmed to yield a general code which can be used to obtain the quantities and bid-items, associated with a highway project that is assigned to the class. This code will then be made available to students in 318 for their use.

Il5-20062 Chemistry 490-2. Matrix Operations Problem. Write a subroutine to multiply two $N \times N$ matrices together. Write a driving program for code checking purposes which will read N , in format (I4) and two matrices in format (4F20.8), compute the product via your subroutine, print out both input matrices and their product and start over. Save all index registers used in the subroutine and do not use any index register other than 1, 2 and 4.

Il6-20068 Electrical Engineering 452-1. Magnitude Function. Beginning with a rational function $T(s)$ where s is the laplace transform variable, a simple steepest descent program is used to converge toward a desired function $|\tilde{T}(j\omega_k)|^2$ such that

$$\sum_k \left| |T(j\omega_k)|^2 - |\tilde{T}(j\omega_k)|^2 \right|^2$$

is minimized. $|\tilde{T}(j\omega_k)|^2$ is given as a discrete function of ω .

The problem will be used to demonstrate the use of digital computers in approximating a desired filter response.

During the past month, the usage of the 7090-1401 system has grown to the point where at least 400 individual runs are processed during the single eight hour shift on which the system is currently being operated. The automatic bookkeeping and logging facilities to be provided by the University of Illinois executive system are not operative, since the assembly and compiling portions of that system must take priority. Although records pertaining to the time distribution of the system exist, the processing of these records must wait until the above features of the executive system have been incorporated. These figures for the month of October will be supplied in some future monthly report.

PART VII
CONTROL DATA CORPORATION 1604

During the month of October, no new problem specifications were submitted for the CDC 1604.

CDC 1604 TIME DISTRIBUTION
October, 1962

<u>Department</u>	<u>Non-Simile</u>
Chemistry	3:16
Civil Engineering	7:45
Electrical Engineering	:29
Nuclear Engineering	:38
Physics	18:38
Statistical Service	<u>2:47</u>
TOTAL	33:33

PART VIII
GENERAL LABORATORY INFORMATION

Seminars

"Computing at Oxford University," by Professor Leslie Fox, Visiting Research Professor of Applied Mathematics at the University of Illinois, Director, Oxford University Computing Laboratory, Oxford, England, October 1, 1962

"A Class of Binary Divisions Yielding Minimally Represented Quotients," by Professor Gernot Metze, Digital Computer Laboratory, University of Illinois, October 8, 1962

"Computer Generation of Natural Language Sentences," by Professor Robert B. Lees, Department of English, University of Illinois, October 15, 1962

"Some Theorems Concerning Finite Automata," by Professor David E. Muller, Digital Computer Laboratory, University of Illinois, October 22, 1962

"A Programming Language for Picture Processing," by Dr. Rangaswamy Narasimhan, Digital Computer Laboratory, University of Illinois, October 29, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	14	1	14.5
Visiting Faculty	3	0	3.0
Research Associates	8	0	8.0
Graduate Research Assistants	7	29	22.5
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>41</u>	<u>29</u>	<u>54.75</u>
TOTAL .	80	59	109.75

The Computer Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, K. C. Smith, J. N. Snyder, and A. H. Taub.

DIGITAL COMPUTER LABORATORY
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

UNIVERSITY OF ILLINOIS

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TECHNICAL PROGRESS REPORT

- PART I - HIGH-SPEED COMPUTER PROGRAM
- PART II - CIRCUIT RESEARCH PROGRAM
- PART III - SWITCHING THEORY
- PART IV - MATHEMATICAL METHODS
- PART V - DATA REDUCTION METHODS
- PART VI - ILLIAC USE AND OPERATION
- PART VII - IBM 7090-1401 SYSTEM
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NOVEMBER, 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research. This report covers the months of October and November of 1962.

1. Construction Progress

Transistor counts for chassis wired or revised during October and November are as follows:

5 Drum Logic Chassis	711
1 Interplay Chassis	168
3 Spare Repetitive MAU Chassis	<u>563</u>
	1,442

The present status may be summarized as follows:

Transistors in use in the computer	32,395
Tested spares for maintenance use	811
Drum simulator in use for interplay tests	241
Interplay wiring not tested	200
Drum logic wiring not tested	<u>711</u>
TOTAL	34,358

2. Computer Operation and Maintenance

The first phase of speed-up of the Arithmetic Control, namely, the planned shortening of reply loops in the control, was carried out during the first three weeks of October with the following results:

<u>Operation</u>	<u>Time as Measured May 5</u>	<u>Time as Measured November 1</u>
MPY (least selector changes)	9.0	7.6
MPY (average)	11.2	8.5
MPY (most selector changes)	11.9	8.8
DIV	24.0	18.8

The above times are for cases for which normalization of operands is not required.

The second phase of speed-up of the Arithmetic Control was begun late in November and is continuing.

During the last week of October and the first three weeks of November the primary emphasis was on accelerated maintenance. Techniques included voltage tolerance tests, hammer (vibration) tests, routine inspection of signals, and current tolerance tests of individual circuits. From November 21 until November 30, the computer was operated 216.5 hours with 21 malfunctions logged, distributed as follows:

Punch errors	8
Reader errors	4
Power Supply errors	2
Memory errors	2
Faulty components or connections	3
Unknown	2

3. Present Core Memory

In October and November the following troubles were found and removed from the Core Memory:

1. Eight open, one leaky and six incorrectly-wired diodes.
2. Noise on the +65 volt power bus which was removed by distributing capacitors over the bus.
3. Two separate breaks in digit wires of Core Plane 0 (nearest the air inlet). After the second break, the core plane was heavily sprayed with Krylon and the

air path was baffled in order to reduce the motion of individual cores and the whole core "mat."

The advent of "leapfrog-type" programs led to the discovery of item (2) above. These programs have a cyclic behavior which tends to excite the +65 bus into damped low-frequency vibration.

After the above troubles were removed all available test programs except one would operate without error for periods of the order of one hour at a cycle time of 1.9 μ sec. The exception is a program of leapfrog type (OLF 11 with CRM test) which fails on one bit at 4.5 second intervals. This fault is still under investigation.

(S. R. Ray)

4. New Core Memory

Specifications for the second Core Memory have been completed.

(S. R. Ray)

5. Magnetic Drum Memory

Three tracks on drum 128 and three tracks on drum 129 were examined to see if they have the same write-read characteristic. The six heads were adjusted to give 70 millivolts output at a write current of 175 ma peak-to-peak and 280 bits per inch. Then the write current magnitude was varied, and it was found that the read voltage magnitudes track each other within 20 millivolts. The ratio of the output at 280 bits per inch to the output at 70 bits per inch was uniform at .58 to .61 for five heads, and .73 for one. The worst crosstalk observed was 2 millivolts.

It was noted that when the experimental drum electronics was turned on and off, an unwanted spike was written on the track. This was caused by races in the power supply voltages during turn-on. It will be necessary to turn on the -25 volt power (which supplies the write current) after +25 volts and -50 volts are on.

Some test equipment to be built into the Drum Memory was designed. It is a "computer simulator" in that it supplies data to the 14 write amplifiers plus the necessary commands. It consists of the (existing) Bit Pattern Generator, a new chassis containing 138 transistors, and some switches. It is described in "Drum Test Circuit," B. Levy, File No. 490, October 18, 1962.

A test panel containing lights and switches necessary to control the Drum Memory, both for on-line operation and off-line testing, was designed.

(B. Levy)

A report describing a Delay Line Circuit compatible with the "Slow" Circuits was published (File No. 493, October 31, 1962).

The problem of coupling the read signal from the output of the Head Selection Matrix to the input of the Read Amplifier was investigated further. The transformer used to convert the differential signal to a single-ended signal must have a low frequency corner frequency low enough to transmit the read signal without distortion, and high enough to recover rapidly from the voltage step that occurs when switching heads. The transformer selected was a UTC PlP-9. Its recovery from the switching step voltage was speeded up by using the network shown in Figure 1.

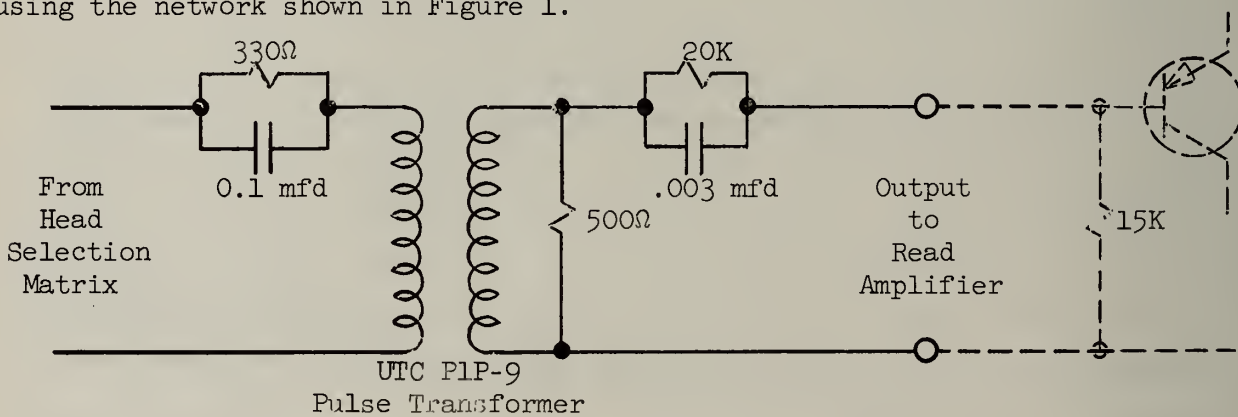


Figure 1 Coupling Network

(M. D. Freedman)

The Magnetic Drum Memory frame was installed in the computer room. Chassis frames and the ground system were mounted, and frame wiring was begun.

6. Diagnostic Programming: October

A new version of the Engineering Test Routine tape, called ETR 101, was prepared. It differs from the original ETR only in that the ASMD green switch options have been standardized. In addition, provision was made to change the test number print-out interval to one of several preselected values by means of an overwrite tape.

A "pseudo-assembler" routine (Pl-PSA-24v) was written for use in assembling octal programs. It features facilities for memory dumps of arbitrary block lengths and program-controlled insertion of O.I. or O.I.A.F. directives on the output tape, so that the output tape can be used for input via O.I. or O.I.A.F.

(R. L. Cummins)

The Duplex Memory Test was completely revised and a new print routine was included.

A Flow Gating Test featuring random delays between accesses to Flow Gating was written, code checked, and annotated.

A first version of a Print-Punch Test has been completed and is now awaiting comments from the engineers.

Memory Test II, testing memory locations "on the diagonal" according to a suggestion by Professor Gear, had originally been written using symbolic addressing. It has now been rewritten for System I format without symbolic addresses and is undergoing code checking.

(B. Whitten)

A Memory Crosstalk test has been completed. In this test, a bit pattern is loaded into a specified location. Then, all other words on the same X driver are accessed (2p times) with the digitwise complement of the test pattern. The location under test is then examined for errors. The same process is then repeated for all other words on the same Y driver (2q times). After the entire memory has been checked, the entire test is repeated with a new test pattern. The parameters p and q can be specified on tape.

At present, the error print-out format is being revised to afford a more concise print-out.

(M. Levin)

Another Memory Test is designed to determine the effects of prolonged bombardment of a particular Core Memory location with a variety of test patterns.

Several addenda to the ETR tape have been prepared to test the setting of Z and OV, and the generation of floating-point zero by store instructions.

Special timing test programs to aid in the execution and documentation of Delayed Control speed up have been written.

A Comparison Post Mortem for Octal Input has been published.

(J. Bouknight)

Several versions of an "Orbiting Leapfrog" have been written. In all cases, the distance of the move (i.e., the distance between copies) and the number of words to be moved is specified by parameters.* As in the Illiac leapfrog program, four copies of the program exist in the memory at any one time. Copy 3 is the active copy which compares copies 2 and 5 word by word and generates a new word of copy 1 if the comparison is favorable. If the comparison fails, the majority vote of copies 2, 4 and 5 is taken, the offending copy is determined, and the error information is printed if the green switch is down. Error printing is suppressed if the green switch is up. In either case, the majority vote is placed into copies 1 and 2. After all words of copies 2 and 5 have been compared, control is transferred to whatever test routines are included in OLF and old copy 2 becomes the active copy, i.e., new copy 3.

At present, a modified test "pay load" has been attached to OLF.

(G. Metze and J. Bouknight)

* OLF will move either forward or backward depending on whether the distance parameter specified is negative or positive.

7. Diagnostic Programming: November

In line with the decision to have memory sum checks on all tapes, the Pseudo-Assembler was revised to furnish a sum check automatically. A new version of ETR with sum checks was produced by this routine.

ETR tapes are now available in SQZ format which uses only two tape characters to represent a quarter word.

Work was begun on a "Phase II" version of the ETR control subroutine. The objectives of this effort are:

- a) to make the print-out of an ETR test failure more compact and more meaningful
- b) to provide "lock-in" options by which the operator can select which part of the test, print-out, etc., is to be repeated.

(R. L. Cummins)

A comprehensive Multiply-Divide Test using random operands was written and checked out. The Random Number Generator furnishes two sets of operands:

N_n normalized and rounded

N_u unnormalized and unrounded

D_n normalized and rounded

D_u unnormalized and unrounded

with the following properties:

- a) $|D_n| < |N_n|$
- b) Exponents are generated by the Fibonacci sequence

$$e_{i+2} = e_{i+1} + e_i \pmod{2^7}$$

with $e_0 = 0$, $e_1 = 1$. Exponents are in the range
 $-63 \leq e \leq 63$.

c) Fractions are generalized by using the relation

$$r_{i+1} = 5^{17} r_i \pmod{2^{44}}$$

with $r_0 = 1$. In order to remove a certain bias in the least-weighted four bits of r_{i+1} , r_{i+1} is shifted right four bits to form r'_{i+1} . This method yields a cycle of 2^{42} different positive fractions.

The Division Test examines the various cases of division requiring special treatment, i.e., the setting of OV or the generation of a zero quotient. It also tests for the cases in which the remainder is zero, either because the division is exact or because the exponent of the remainder is calculated to be ≤ -64 . The carry-borrow logic is tested by generating a quotient $Q = \frac{1}{4}$ the hard way, with an unassimilated carry in the least-weighted position of A_{most} .

The Multiply Test similarly examines the various special cases of multiplication, including the case $M = EM = 0$ which is not the legal floating-point zero and is therefore not bypassed by MPY. The test also involved a bit check via a synthetic multiplication.

(G. E. Cooper)

The Crosstalk Memory Test was modified to include a sum check and the error print-out format was made more concise.

(M. S. Levin)

Work was started on a comprehensive Normalize test program which is to be used for speed-up as well as maintenance purposes. The Punch-Reader Test is undergoing a revision. The CRM test for the Orbiting Leapfrog No. 11 is being completed.

(J. Bouknight)

Considerable effort is being spent on the re-examination of existing test programs to update and annotate the tests judged worth keeping and collect ideas for better tests.

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

Sergio Ribeiro has extended the theory of flipflop circuits to include the effects of charge storage in the base. Henry Guckel reports on experimental results of the T configuration of striplines (referred to as a "T-line") described in last month's report. Rise times appear to be faster than the 0.2 nsec limitation of the oscilloscope. Tohru Moto-Oka reports on theoretical and experimental studies of hybrid circuits using tunnel diodes and emitter followers. Thomas Burnside has completed the design of additional circuitry for the statistical analyzer.

2. Flipflop Circuits

Characteristic of the transistor pair taking into account charge storage in the base:

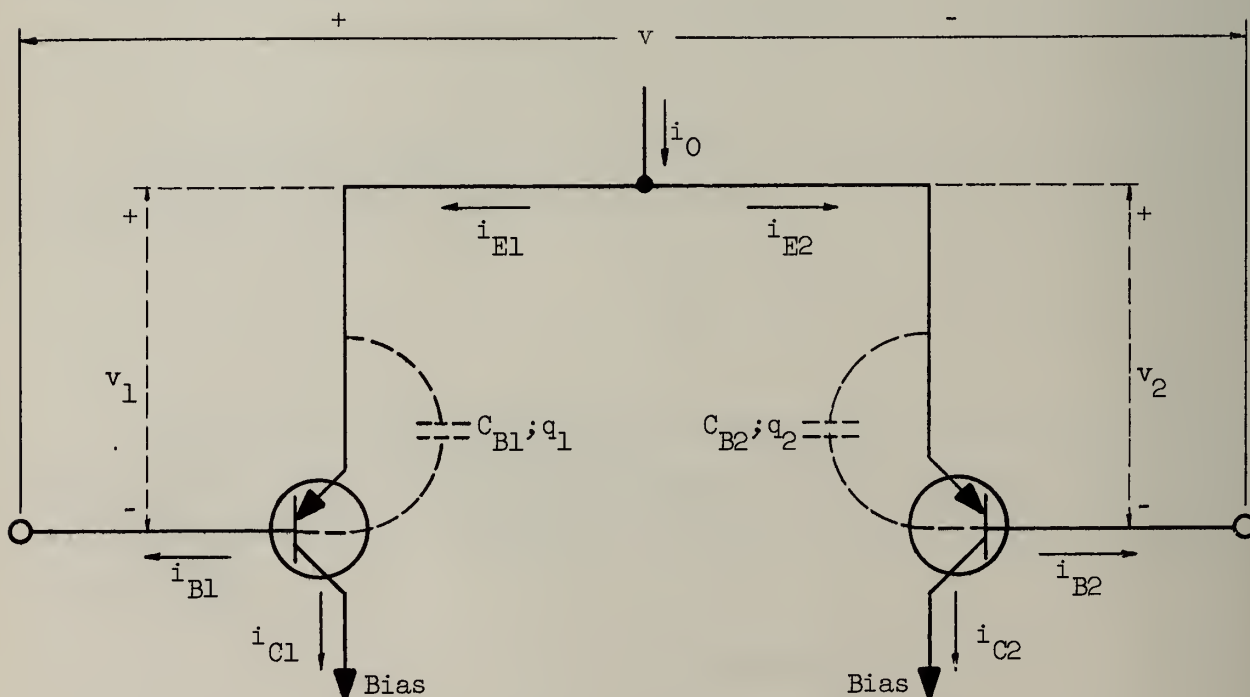


Figure 1 Transistor pair; base charge equivalent capacitors

We will neglect the junction capacitances and consider only the charge storage in the base, and we assume that this is given by an equivalent non-linear capacitor between base and emitter (see Figure 1).

$$\left. \begin{aligned} C_{B1} &= \tau_c \eta i_s e^{\eta v_1} \\ C_{B2} &= \tau_c \eta i_s e^{\eta v_2} \end{aligned} \right\} \quad (1)$$

Where τ_c is the collector time constant and $\eta = \frac{q}{kT}$, the transistors are assumed identical.

We obtain the following system of equations:

$$\left. \begin{aligned} q_1 &= C_{B1} v_1 & q_2 &= C_{B2} v_2 \\ i_{E1} &= \dot{q}_1 + i_{c1} & i_{E2} &= \dot{q}_2 + i_{c2} \\ i_{c1} &= \frac{1}{\tau_c} q_1 & i_{c2} &= \frac{1}{\tau_c} q_2 \\ i_{B1} &= \dot{q}_1 & i_{B2} &= \dot{q}_2 \\ i_{E1} + i_{E2} &= i_0 & v_2 - v_1 &= v \quad (\text{by definition of } v) \end{aligned} \right\} \quad (2)$$

If, from the system above, we develop one equation relating i_{c2} and v we get a kind of transfer equation as below:

$$\tau_c \dot{i}_{c2} + \left\{ 1 - \frac{\tau_c \eta \dot{v}}{2} (1 - \tanh \frac{\eta v}{2}) \right\} i_{c2} = \frac{i_0}{2} (1 + \tanh \frac{\eta v}{2}) \quad (3)$$

whose solution can be found, and turns out to be

$$i_{c2} = \frac{i_0}{2} (1 + \tanh \frac{\eta v}{2}) (1 + v e^{-\frac{t}{\tau_c}}); \quad v = \text{const.} \quad (4)$$

For physical considerations, $ve^{-\frac{t}{\tau_c}} = 0$, so that

$$i_{c2} = \frac{i_0}{2} (1 + \tanh \frac{\eta v}{2}) \quad (5)$$

Now i_{c1} , i_{B2} , i_{B1} can be easily found. Equation (5) implies that the transistor flipflop equation already studied in previous reports is indeed still valid when base charge storage is considered. The equation has the form

$$a\ddot{x} + b\dot{x} + cx = \tanh px + d(u + w) + e(\dot{u} + \dot{w})$$

where a , b , c , d , e , p are constant parameters, x , u , w are normalized base-to-base voltage, trigger voltage or current, and base current respectively. This same equation (with modifications in the definitions of parameters and variables by constant factors) applies to the symmetrical (Eccles-Jordan) flipflop.

The case of negligible parasitic capacitances can have a general solution presented as a quadrature formula:

$$t = t_0 + \tau_c p \int_{x_0}^x \frac{1}{\{r[\tanh(p\xi) - \xi] + 2u\} \cosh^2(p\xi)} d\xi \quad (6)$$

where r , p , τ_c are constant parameters. Under phase plane form, with $y = \dot{x}$, we get

$$y = \frac{1}{\tau_c p} \{r[\tanh(px) - x] + 2u\} \cosh^2(px) \quad (7)$$

(S. Ribeiro)

3. Tunnel-Diode Distributed Systems

The theoretical results of the distributed circuit theory were tested experimentally. A T-line with $Z_0 = \frac{44}{\sqrt{3}}$ ohms and $Z_m = \frac{1}{2} Z_0$ was designed and tested with a 1.2 ma Ge tunnel diode ($-R_{min} = 71.4$ ohms, $C = 6$ pf).

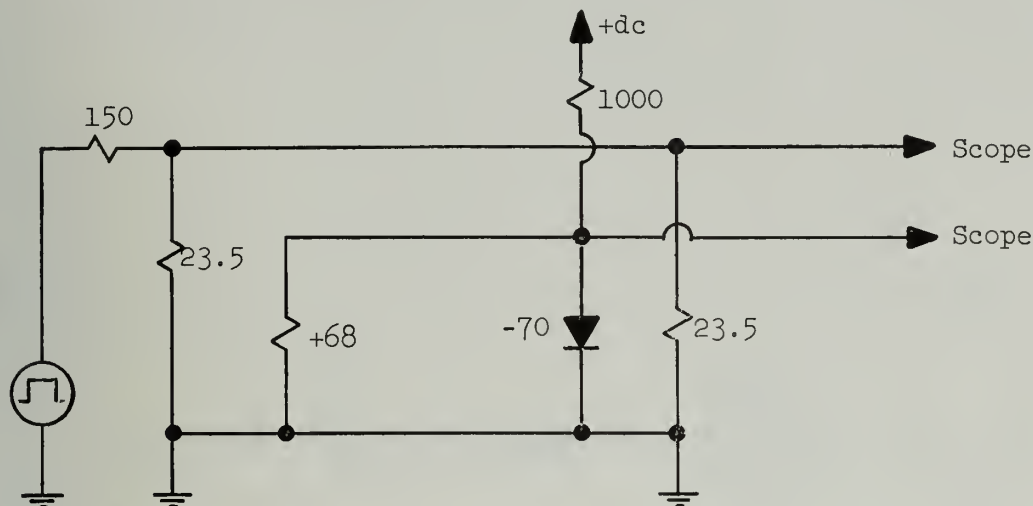


Figure 2

The scope termination (50 ohms) was used as part of the load. With an input of 50 mvolts an output of 15 mvolts was obtained. The rise time was above the scope rise time (.2 nsec). Pulses of up to 20 nsec were transmitted reasonably well. Nearly perfect response was obtained with 2 nsec pulses. This seems to indicate that the band pass of the transformer is at least

$$17 \text{ mc} < f < 1700 \text{ mc}$$

However, it is felt that this range may be doubled without too much trouble if terminations and test points are designed by microwave techniques.

Theoretical work was continued for the loss-less purely resistively matched case. Inversion is obtainable by interchanging resistor and diode location. Amplification seems to be realizable, but is subject to a stability investigation for resistor controlled terminations, i.e., a more realistic approximation for the tunnel diode.

(H. Guckel)

4. Tunnel-Diode, Emitter-Follower Circuits

A NOR circuit composed of a tunnel-diode phase-inverting voltage amplifier and a transistor emitter follower has been investigated theoretically and experimentally. An inexpensive high-speed set of logical circuits should follow from this basic NOR circuit (cf., Figure 3). The delay time per stage seems to be approximately 3 nsec, according to a preliminary basic experiment. This delay is mainly due to the emitter-follower characteristic.

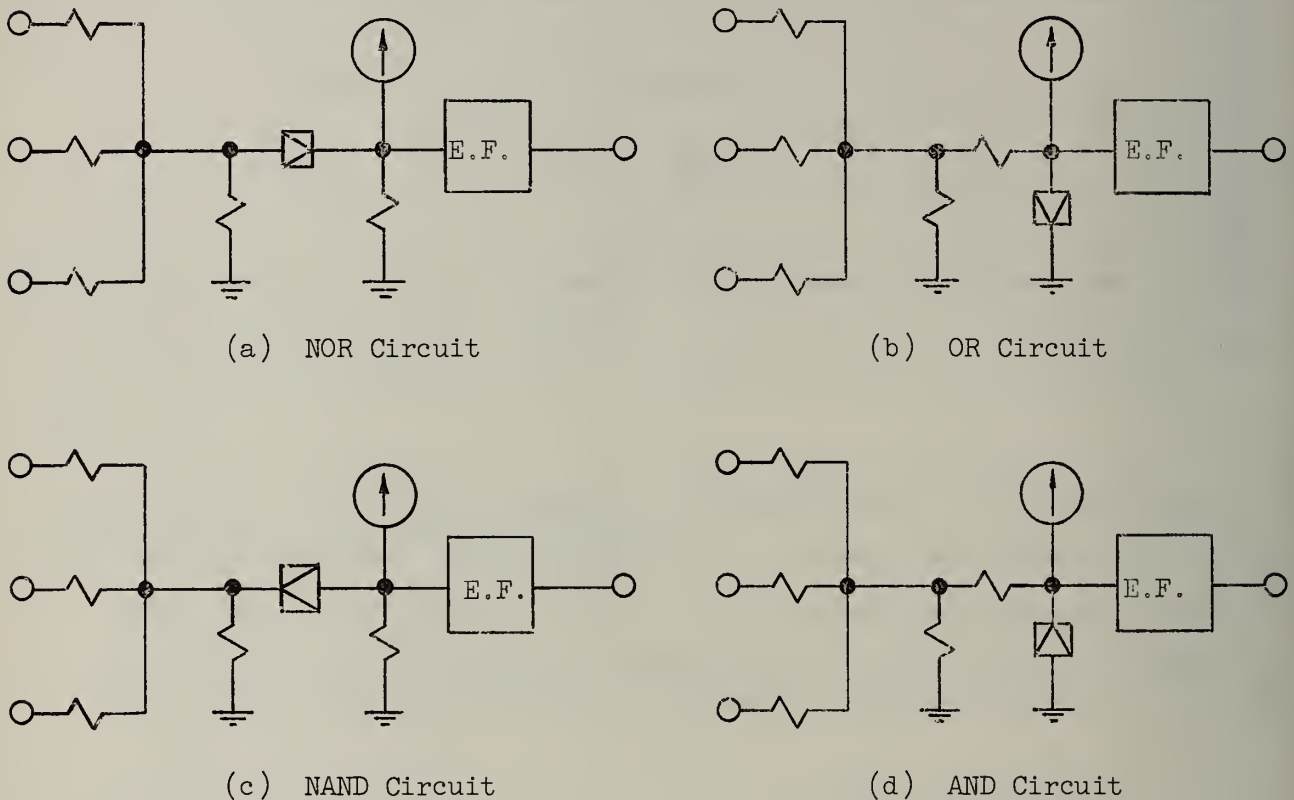


Figure 3 A Set of Hybrid Logical Circuits

The small signal operation of this NOR circuit is given by the design theory of a tunnel-diode matched amplifier which was reported in the last progress report. A non-linear characteristic for the tunnel diode must be considered in order to get the characteristic of large signal operation. One of the methods which can be used to design a NOR circuit for large signal operation is as follows (cf. Figure 4):

1. Determine operating points "a" and "b" of the tunnel diode.

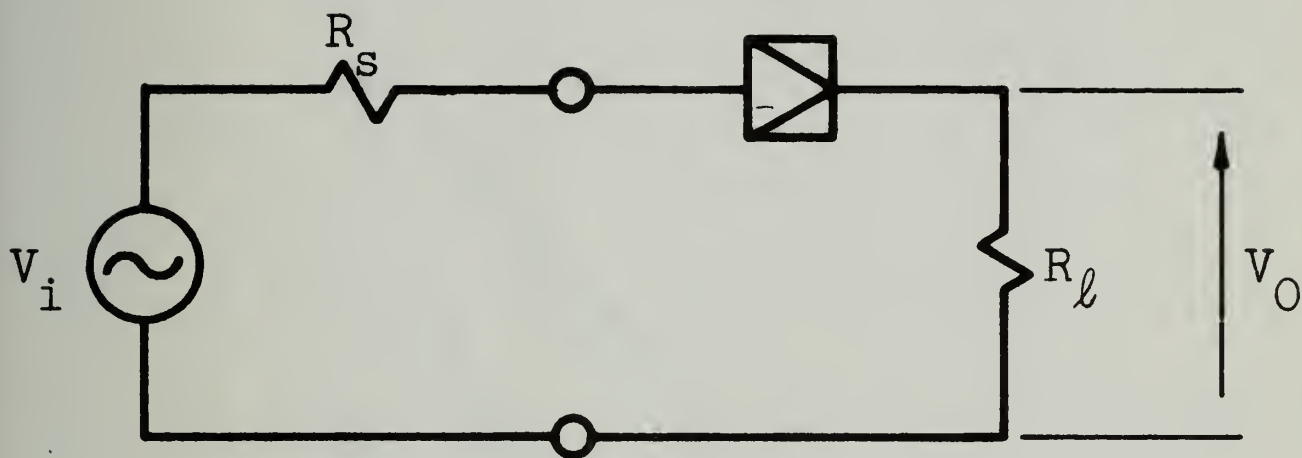


Figure 4a

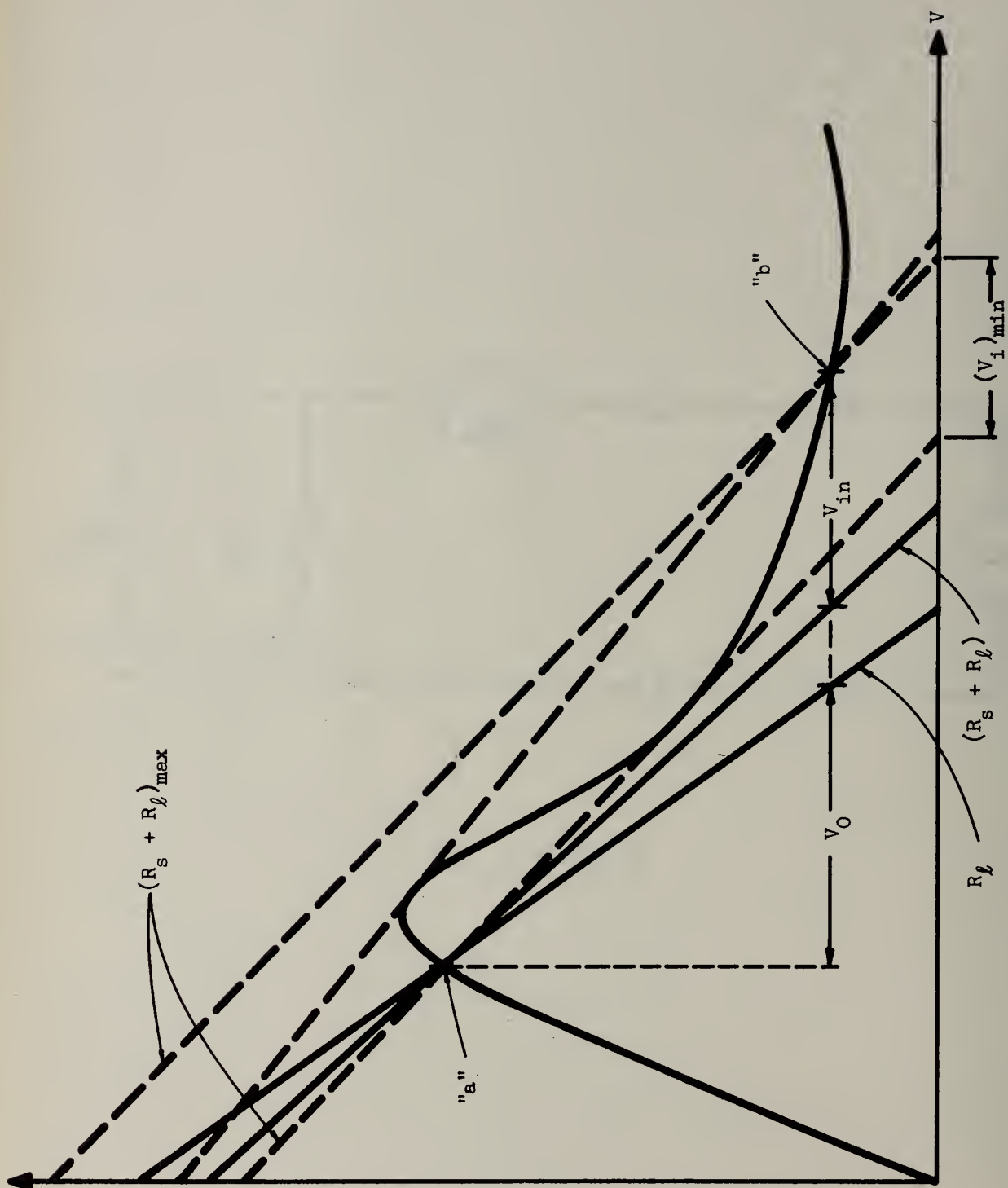


Figure 4b

2. Draw lines tangent to the tunnel diode characteristic curve through these points "a" and "b", and select whichever of the two lines has a steeper slope. This slope corresponds to the permissible maximum value of $(R_s + R_\ell)$ which gives the maximum voltage gain.
3. If R_s is given, the output voltage V_o , the input voltage V_i and the voltage gain K are functions of the load resistance only, R_ℓ , that is,

$$V_o = (I_1 - I_2)R_\ell \quad (8)$$

$$V_i = (V_2 - V_1) - (R_s + R_\ell)(I_1 - I_2) \quad (9)$$

$$K = \frac{R_\ell}{\frac{V_2 - V_1}{I_1 - I_2} - (R_\ell + R_s)} \quad (10)$$

where (V_1, I_1) and (V_2, I_2) are coordinates of points "a" and "b" respectively.

In this method, input and output impedances of the emitter follower are included in R_ℓ and R_s respectively. The maximum voltage gain is related to the minimum switching speed, i.e., the voltage gain is limited by the required switching speed. In order to determine the operating points of a tunnel diode, the following considerations are necessary. Decreasing the operating region increases the voltage gain, but stray inductances and stray capacitances may cause oscillations of the circuit if the selected operating region is too small.

A further investigation is being continued.

(T. Moto-Oka)

Statistical Analyzer

A circuit has been designed to produce the "begin pulse" shown in Figure 5, page 16, of the March, 1962, progress report. The logical design is shown below.

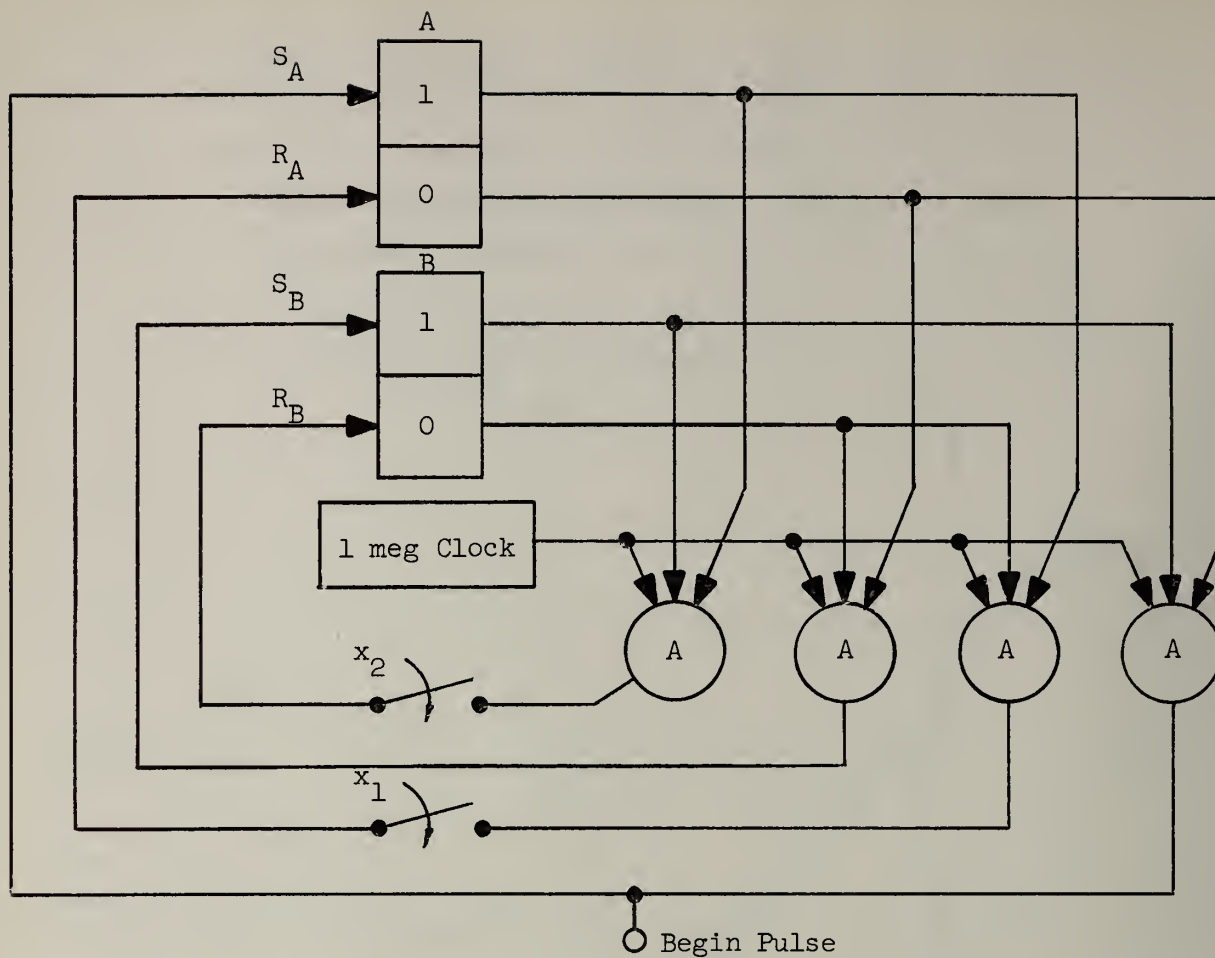


Figure 5 Logical Design of Begin-Pulse Generator

Logical functions are produced as shown in the table below:

A	B	S_A	R_A	S_B	R_B
0	0	0	0	1	0
0	1	1	0	0	0
1	0	0	1	0	0
1	1	0	0	0	1

Table I Logical Functions in the Begin-Pulse Generator

The "begin pulses" are controlled by manipulating the switches x_1 and x_2 as shown in the state versus sequence chart.

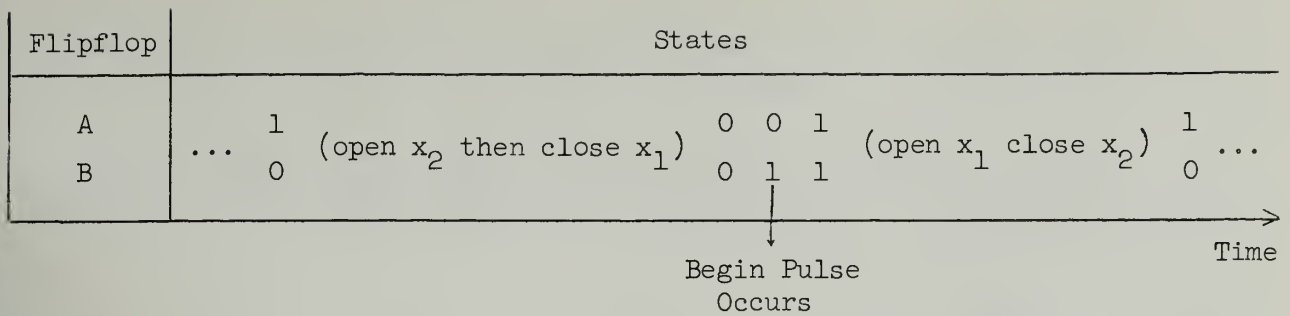
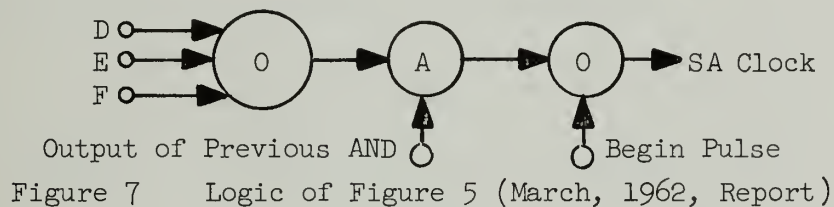


Figure 6 Sequence of Output States

The one-megacycle clock used in Figure 5 is from Figure 4, page 7, of the April, 1962, progress report. The flipflop used is found in Figure 5, page 10, of the February, 1962, progress report.

Also designed this month was the circuitry of the following part of the logic shown in Figure 5, page 16, March, 1962, progress report.



The circuit is shown in Figure 8.

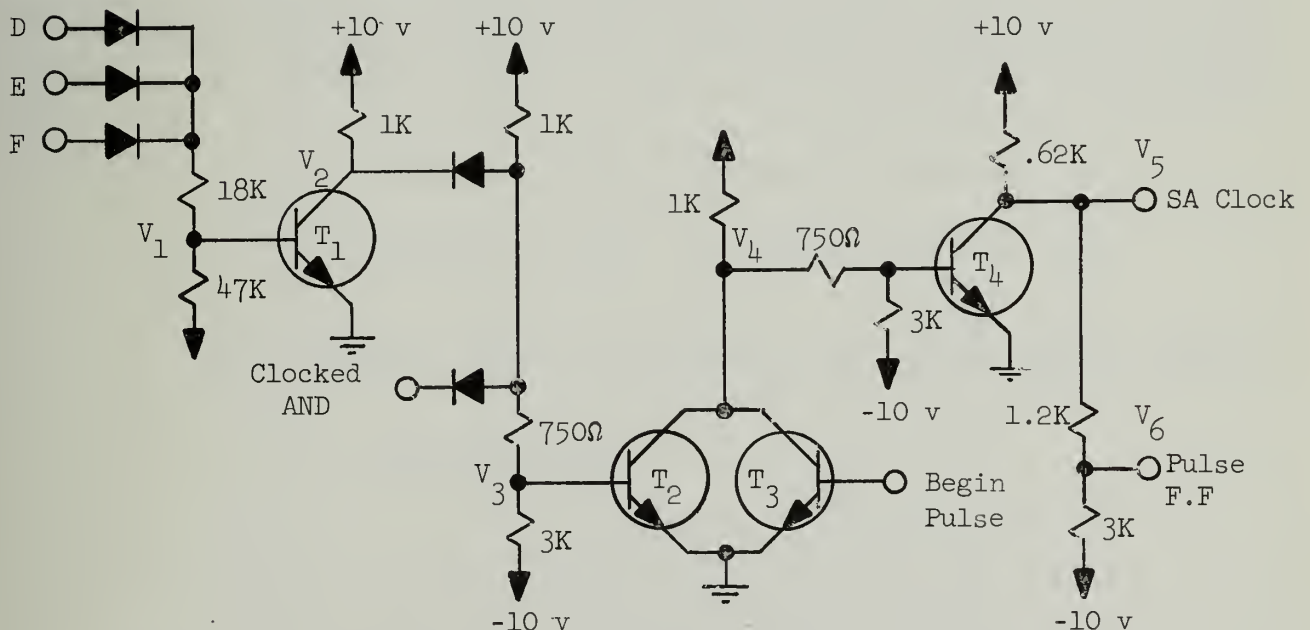


Figure 8 Circuitry to Start and Stop the Statistical Analyzer

The inputs D, E and F have logical 1 corresponding to +6 volts and logical 0 corresponding to 0 volts.

The 18 K resistor is large enough to isolate this circuit from the flipflops which drive it. An approximate equivalent circuit of the flipflop driving T_1 is shown in Figure 9.

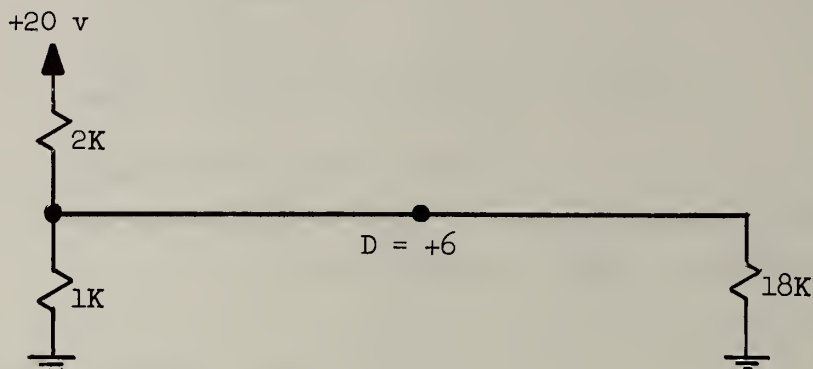


Figure 9 Approximation of Flipflop Driving Transistor T_1

Since 18 K in parallel with 1 K is .95 K, the loading on the flipflop is small.

V_1 has the following states: $V_1 = +2$ volts is a logical 1 and $V_1 = -2$ volts is a logical 0. This causes $V_2 = 6$ volts for a logical 1 and $V_2 = 0$ volts for a logical 0. T_1 is followed by a diode-AND circuit with $V_3 = +2$ or -2 volts. The two transistors T_2 and T_3 form an \overline{OR} whose output $V_4 = 6$ volts is a logical 1 and $V_4 = 0$ is a logical 0. The \overline{OR} is inverted by T_4 which has outputs at two levels:

$$V_5 = +6 \text{ volts} \rightarrow \text{logical 1} \quad V_6 = +1 \rightarrow \text{logical 1}$$

$$V_5 = 0 \text{ volts} \rightarrow \text{logical 0} \quad V_6 = -1 \rightarrow \text{logical 0}$$

V_5 will clock the second counter and V_6 will reset another flipflop.

(Thomas Burnside)

PART III
SWITCHING THEORY

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Several new results concerned with multi-dimensional spot correcting codes have been obtained. These results enable one to increase the length of known spot correcting codes indefinitely and without a great loss of efficiency. A large number of such codes have been obtained recently by use of ILLIAC. A further application allows one to form relatively efficient spot correcting codes of arbitrary spot diameter and length.

The first theorem states that under certain easily satisfied conditions the code generated by a polynomial which is the product of two polynomials corrects a set of errors which is the product of the sets of errors corrected by the codes generated by the two-factor polynomials.

To use this theorem to form spot correcting codes it is necessary to form a raster for such a product polynomial in which the polynomials representing spots to one of the factor polynomials continue to represent spots to the product polynomial. The second theorem states that this will occur if the distance function between raster points fails to decrease when passing from the factor to the product polynomial.

Methods for forming such rasters have been found and therefore they may be used to increase the length of multi-dimensional spot correcting codes.

(Clinton R. Foulk)

PART IV
MATHEMATICAL METHODS

(Supported in part by the National Science Foundation under grant G16489.)

On a Paper by Nordsieck

A report has been written concerning Nordsieck's paper, "On Numerical Integration of Ordinary Differential Equations" (Mathematics of Computation, January, 1962). The following points are discussed:

- 1) the interpretation of the predictor formula, the starting procedure and the modification of the step of the Nordsieck formulas in terms of the classical multi-step methods;
- 2) the asymptotic behavior of the errors due to the starting procedure and to the modification of the step; a "modified Nordsieck method" is proposed;
- 3) some generalizations of the Nordsieck formulas.

(Jean Descloux)

PART V
DATA REDUCTION METHODS

(Supported in part by Contract No. AT(11-1)-1018 of the Atomic Energy Commission)

Pattern Recognition: Simulator Studies

Simulator studies carried out over the past year with the help of ILLIAC I have resulted in a well-defined model for processing pictures composed of line-like elements. (For details of these studies, the model and its suitability see earlier Progress Reports and file memoranda mentioned therein.) Briefly, the model can be summarized as follows: it is assumed the input picture has been preprocessed to remove "first-order" noise. The recognition procedure then consists of two phases:

1. Labelling and Abstraction. The output of this phase is a graph consisting of labelled nodes and edges.
2. List Compilation. The output of this second phase is a set of strings (i.e., edge-strings) whose structures and interconnections constitute a description of the input picture.

Currently work is in progress to apply this scheme to the scanning of bubble chamber negatives. It is intended to realize a comprehensive program which would carry out the two phases outlined above independently for each view of a stereo-triad. The three outputs could then be fed into a higher level program for further analysis and editing. Also it is clear that because of the inherently complex nature of the bubble chamber pictures, it would be impossible (and also inadvisable) to attempt to describe them in their finest details in a single scan. Hence it is planned to organize the program so that without altering its basic structure, compilation strategies (eg., description of phase 2 above) can be prescribed to suit the fine details which are desired to be recognized.

It is proposed to implement this scheme approximately as follows: the given picture (i.e., a single bubble chamber view) will be partitioned into windows of a fixed size. Typically a picture would consist of the order of 10^3 windows. These windows would now be processed according to a TV-scan

starting with the lower left corner and proceeding to the top right corner. The two phases would be carried out alternately in each window and the set of lists, their contents and classifications would be kept continuously updated. The set of lists which result after the last window has been processed would constitute the description of the entire picture. With this method of implementation it is easily seen that the labelling and abstracting for a given window may be made to depend on the list-compilation history up to that instant and so can be optimized. This optimization capability is of very great importance since in general, because of the window size, one should expect the contribution from the majority of the windows to be nil.

The current status of the program is as follows:

- A. Labelling and Abstraction. A set of basic operations (i.e., macros) and a programming language have been formulated to implement phase 1 of the analysis. In this language, a program has been written to compute the labelled graph given a picture.

(R. Narasimhan, B. H. Mayoh, R. K. Rice)

- B. List Compilation. A general structure for the scanning program has been worked out and much of the list-processing details (i.e., basic list structures, list operations and the other necessary bookkeeping) has been standardized. The next step is to work out a first version of a flow chart for the program.

(R. Narasimhan, B. H. Mayoh)

- C. Compilation Strategies. Two major preliminary problems are the determination of a "good" window size and the specification of a "first-order" grammar for list compilation. To resolve these, systematic statistics are being computed, using two different bubble chamber pictures, of the types and frequencies of " μ -list structures" which occur within a window.

(R. Narasimhan, R. K. Rice)

D. Program Realization. A compiler for the programming language described in A above, is currently being written for IBM 7090. The input/output orders are already realized and the first set of basic operations is expected to be available in a few weeks. The compiler is being designed so that ultimately it can operate in two modes interchangeably--one simulating the programming language and the other simulating the PAU at the hardware level.

(J. Stein)

PART VI
ILLIAC USE AND OPERATION

Illiac Usage

During the month of November, two problem specifications were submitted for the Illiac. Numbers followed by a T are for theses.

2242 Institute for Research on Exceptional Children. Classification of Families as to Type of Family Organization. Both parents in 150 families ranked a list of ten domestic values in order of importance as they perceived it. The 300 sets of rank orders thus obtained constitute what are termed here the "actual" rank orders.

Through previous research, six sets of "ideal" rank orders have been established; three sets for husbands and three sets for wives. The "ideal" rank orders serve as criteria for determining type of family organization. The procedure is to compare each husband's and each wife's "actual" rank order with each of the "ideal" rank orders and to compute $\sum d^2$ as a measure of agreement between each pair of rank orders. Type of family organization is determined on the basis of the ideal rank order which is in closest agreement with the subject's actual rank order, provided that a specified minimum $\sum d^2$ value is obtained for any given comparison.

2243T Mathematics. Determinant Computation. The problem concerns the electrical parameters of smooth muscle and their analytic relations. The resistance parameter may be expressed as the ratio of two determinants times a resistance value R_m : $\frac{\Delta}{\Delta_{jj}} R_m$.

The order of the determinants depends on the number of muscle cells involved. The Illiac may be used to evaluate the determinants, which are of a large order.

Table I shows the distribution of Illiac machine time for the month of November.

TABLE I

	Hrs:Min
Scheduled Maintenance	61:38
Unscheduled Maintenance	21:53
Leapfrog	5:23
Drum Test	7:03
Scanner Engineering	:15
Wasted	:31
Demonstrations	:15
Classes	<u>1:23</u>
	98:21

Use by Departments

Agricultural Economics (APPRAISAL 47 15 05 334)	5:14
Agricultural Economics	6:23
Bureau of Educational Research (PH-M1839)	2:32
Chemistry	32:08
Civil Engineering	99:43
Coordinated Science Laboratory (DA-36-039-SC56695)	46:09
Digital Computer Laboratory (US TR AEC-1018)	1:50
Digital Computer Laboratory (NONR 1834(27))	9:58
Digital Computer Laboratory	1:01
Electrical Engineering (AF 7043)	:39
Electrical Engineering (NSFG 19005)	:37
Electrical Engineering (NSF 25148)	2:55
Geological Survey	5:46
Geology (IC GRAD GEOLOGY)	:04
Institute of Communications Research (44-28-20-378)	2:35
Institute of Communications Research (MHO6739)	16:20
Institute of Communications Research	11:02
Inst. for Research on Exceptional Children (46-20-70-36)	:24
Mathematics	:35
Mechanical Engineering	13:15
Mining and Metallurgical Engineering (TRUS AFG6770)	:37
Nuclear Engineering	5:09
Office of Instructional TV	:35
Physics (NONR 1834(05))	3:22
Physics (NSFG-17428)	:09
Physics	2:07
Psychology (MD2060)	:06
Psychology (ONR 1834-36)	:53
Psychology (US NONR 1834(39))	2:19
Psychology	126:27
Sociology	1:39
Theoretical and Applied Mechanics (PA-01-021ORD11878)	:12
Theoretical and Applied Mechanics	:10
Water Survey	1:36
Zoology	<u>1:08</u>
	<u>405:39</u>
	<u>504:00</u>

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Memory	3
Arithmetic	2
Drum	4
Reader	1
Camera	1
Power (Low Filaments)	<u>2</u>
TOTAL	13

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	LEAPFROG
11/1/62	18:39	1:49	3:32	2	(1) Drum failure. (2) Low filaments on Illiac.	:00	:20	0
11/2/62	19:31	2:11	2:17	2	(1) Memory failure 2 ⁻²³ . (2) Reader "J" failed.	:01	:42	0
11/5/62	20:16	:00	3:44	0		:00	:40	0
11/6/62	21:28	:00	2:32	0		:00	:08	0
11/7/62	21:27	:00	2:33	0		:00	:20	0
11/8/62	20:24	:33	3:03	2	(1) Drum failure. (2) Filaments low on Illiac.	:00	1:14	0
11/9/62	19:47	1:37	2:30	1	(1) Drum failure.	:06	:00	0
11/12/62	20:30	:00	3:30	0		:00	:00	0
11/13/62	20:30	:00	3:30	0		:00	:00	0
11/14/62	21:05	:00	2:55	0		:00	:11	0
11/15/62	15:46	4:39	3:35	2	(1) Arithmetic failure. (2) Camera failure.	:00	:00	0
11/16/62	21:48	:00	1:57	0		:15	:00	0
11/19/62	20:54	:10	2:56	1	(1) Memory failure 2 ⁻¹⁸ .	:00	:34	1
11/20/62	19:14	1:05	3:41	1	(1) Memory failure 2 ⁻²⁰ .	:00	:47	1
11/21/62	13:41	7:40	2:30	1	(1) Arithmetic failure.	:09	:00	0
11/23/62	22:19	:00	1:41	0		:00	:00	0
11/26/62	17:27	3:17	3:16	1	(1) Drum failure.	:00	:45	0
11/27/62	20:54	:00	3:06	0		:00	:00	0
11/28/62	20:55	:00	3:05	0		:00	:03	0
11/29/62	21:26	:00	2:34	0		:00	:32	0
11/30/62	21:45	:00	2:10	0		:05	:00	0
TOTALS	419:46	23:01	60:37	13		:36	6:16	2

PART VII
IBM 7090-1401 SYSTEM

New IBM 7090 Codes

During the month of November, seven new routines were added to the IBM 7090 Library.

- LI-UOI-SSA1-1-BX SCAT (SHARE-Compiler-Assembler-Translator Symbolic Assembly Program for the IBM 7090). This routine constitutes the assembler portion of the University of Illinois system (PORTHOS). It is a modification of the assembly portion of the SHARE operating system (SOS). A complete description of this assembler, its language and its use is available from Mrs. Jenkins, Room 165 ERL.
(R. Flenner and Staff)
- L2-UOI-MAD1-2-RX MAD (The Michigan Algorithm Decoder). The University of Illinois system (PORTHOS) will ultimately have several compiling systems available. At the present time MAD and FORTRAN are operating. MAD originated at the University of Michigan and is an extremely rapid compiler particularly suitable for educational purposes. A complete description of the routine, its language and its use is available from Mrs. Jenkins, Room 165 ERL.
(R. Flenner and Staff)
- J5-UOI-SCP3-15-S General Alphanumeric Cathode Ray Display. This routine treats the face of the cathode ray tube in a fashion similar to a sheet of paper in a typewriter. General messages with complete format control can be displayed. The routine was originally prepared for the IBM 704 at MURA by L. D. Fosdick.
(D. Hutchinson)

C3-UOI-FAC1-16-S

Floating Point Factorial.

D2-UOI-RKY1-17-S

Fixed Point Runge-Kutta.

These two routines were originally prepared for the MURA IBM 704.

(D. Hutchinson)

M2-UOI-CNV1-18-S

Fixed Point Binary Fraction to BCD Conversion. This routine will convert a fixed point binary fraction in the accumulator into a list of BCD coded characters suitable for printing.

(D. Hutchinson)

D2-UOI-RKY3-20-S

Floating Point Runge-Kutta.

C3-UOI-CEI1-21-S

Complete Elliptic Integrals, Fixed Point.

B4-UOI-SQR1-22-S

Fixed Point Square Root.

These routines were originally prepared for the MURA IBM 704.

(D. Hutchinson)

During the month of November, 65 problem specifications were submitted for the IBM 7090.

73-2N005T Mechanical Engineering. Momentum and Energy Integral Equations. Momentum and energy integral equations of a compressible, two-dimensional flow are solved by assuming a fourth degree polynomial for the velocity profile and another fourth degree polynomial for the temperature profile. Substitution of these polynomials in the integral equation results in two non-linear first-order differential equations. Solution of these differential equations simultaneously gives the velocity and the temperature boundary layer thickness as a function of x , the distance along the direction of flow. Then the equations will be solved via the method of Runge-Kutta for simultaneous differential equations.

74-2N001T Physics. Ground State of Liquid Helium. It is desired to calculate the energy and two-particle correlation function of liquid Helium-4 using a variational wave function of the form

$$\psi(r_1 \dots r_N) = \prod_{i < j}^N \phi(r_i - r_j)$$

where r_i is the position vector of the i^{th} particle and the functional form of ϕ is to be varied to minimize the expectation value of the energy. It is necessary to evaluate integrals of the form

$$\bar{F} = \int d^3r_1 \dots d^3r_N \sum_{i < j}^N F(\vec{r}_i - \vec{r}_j) \psi^2(\vec{r}_1 \dots \vec{r}_N)$$

with N typically the order of 100. A Monte Carlo technique for evaluating such integrals in order to determine the properties of the classical N -particle system will be used. Essentially, the technique is to set up a Markov Chain which has $\psi^2(\vec{r}_1 \dots \vec{r}_N)$ as its equilibrium distribution function and to sample this distribution function by a Monte Carlo solution of the Markov Chain. A high-speed computer is necessary for this Monte Carlo solution.

75-2N003 Digital Computer Laboratory. Experiments on a Variable Step Length Integration Method. Theoretical calculations have shown in the variable step length method for solving ordinary differential equations that the errors involved in the

predictor formula, in the starting procedure and in the procedure for modifying the length of step are one order less than the corrector formula. Modified formulae have been established. The purposes of this problem are to show the differences between the original and the modified methods for simple differential equations and to establish diagrams of the size of the extraneous roots as a function of the step, in the different Adams methods.

76-2N006 Physics. K-Meson Nuclear Scattering. This is the rewrite for the IBM 7090 of the program for K-Meson events, No. 366' (A146), which was partly run on the IBM 650. This problem must now be continued on the IBM 7090.

The essence of this problem is to calculate the elastic differential cross section for K^- mesons in nuclear emulsion. It is estimated that some 4000 single (nuclear) scatters will be found and for each event, the space angle between the incident and outgoing K^- meson must be calculated from the projected angle and the "in" and "out" dip angles found. Further, a projected angle probability factor which weighs each event according to its probability of being detected is required. Such quantities as the momentum transfer delivered to the scattered nucleus, the energy of the incident K^- meson at the point of scatter, etc. must also be calculated.

77-2N007 Physics. Proton Polarization. An experiment currently in progress at the University of Illinois cyclotron is designed to measure the polarization of protons scattered from various elements. Although the raw data collected in such an experiment are rather simple, the determination of the polarization from them requires long and tedious algebraic manipulations which must be performed at each value of incident proton energy and observation angle involved in the experiment. To accomplish these calculations experimenters have in the past neglected numerous terms in the polarization formulae; it is desired in this experiment to include these terms and thereby achieve greater accuracy than has been possible in previous polarization measurements.

The IBM 7090 computer is thus an ideal tool for analyzing the data from the polarization experiment now being carried out. Furthermore, the computer will be able to determine by actual calculation which terms in the polarization formulae may be omitted without significant loss of accuracy. Neither of these two tasks can be accomplished efficiently without the aid of the computer.

No unusual mathematical methods are necessary in the polarization calculations, and only standard library routines are involved.

78-2N008 General Engineering. Study of Radon Content. This program will calculate the radon content of a given sample and its associated error from measurements and elapsed time readings taken during the experiment.

The program will include one subroutine which will cause the time entries to be converted to time in minutes since January 1, 1962. Also, one function subroutine will be used to calculate a correction factor for the counting of long decay chains.

79-2N009 Physics. KN Dispersion Relations. A theoretical analysis of the K^+ meson nucleon data will be made with particular reference to the exchange of two π -mesons. The K^+ nucleon differential cross-section data will be fitted at the various centre of mass momenta, q , by the following formula

$$\frac{d\sigma}{d\Omega}(\theta) = \left| \frac{\sin\delta e^{i\delta}}{q} + C(\theta) + \frac{1}{\pi} \int_{t_1}^{t_2} \frac{\text{Im}A(q, \theta, t')}{t' - t} dt' - \frac{1}{2} \int_{-1}^1 d(\cos\theta) \frac{1}{\pi} x \right|^2$$

$$\left| \int_{t_1}^{t_2} \frac{\text{Im}A(q, \theta, t')}{t' - t} dt' \right|^2$$

where θ is the centre of mass KN scattering angle

δ is the K^+ proton S-wave phase shift, whose energy dependence will be described by two parameters

C is the K^+ proton coulomb scattering amplitude

$\text{Im}A$ is related to the product of the amplitudes for the processes $K + \bar{K} \rightarrow \pi + \pi$ and $\pi + \pi \rightarrow N + \bar{N}$. The latter amplitude can be readily calculated from previous work on π -N scattering. The amplitude for the process $K + \bar{K} \rightarrow \pi + \pi$ may be computed from the known information about the $\pi\pi$ system and by assuming that the dominant contribution to the $K\pi$ interaction comes from the $K\pi$ resonant state, the K^* isobar. The procedure involves a further two parameters.

The above equation may be used to compute $d\sigma/d\Omega$ in terms of the four parameters whose values will be determined by performing a χ^2 - fit to the available data.

80-2N026 Psychology. Three Way Factor Analysis. This is an experimental test of a method for factor analysis of three way matrices of data. The computer will be used to carry out the various operations involved.

81-2NO27 Physics. Calculations of Kinetic Equations. For evaluation of annealing kinetics, integrals of the following forms have to be evaluated.

$$I = \int_{E_{\min}}^{E_{\max}} \prod_{i=1}^{n-1} \frac{1}{1 + B^* t_i p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} \left\{ \frac{1}{1 + B^* t'_n p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} - \frac{1}{1 + B^* t''_n p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} \right\} dE$$

$$I^* = \int_{E_{\min}}^{E_{\max}} \prod_{i=1}^{n-1} \frac{1}{1 + B^* t_i p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} \left\{ \frac{1}{1 + B^* t'_n p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} - \frac{1}{1 + B^* t''_n p_0(E) \exp\left(\frac{-E}{k\gamma_n}\right)} \right\} dE$$

Where

$$E_{\max} \text{ is defined by } 0.99 = \frac{1}{1 + B^* t''_n p_0(E) \exp\left(\frac{-E_{\max}}{k\gamma'_n}\right)}$$

$$E_{\min} \text{ is defined by } 0.01 = \frac{1}{1 + B^* t'_n p_0(E) \exp\left(\frac{-E_{\min}}{k\gamma_n}\right)}$$

Here B^* , k are constants t = time, γ = temperature, E = energy. To one temperature a set of increasing time parameters is given. t_i is the last one of the set belonging to γ_i . $p_0(E)$ is the value of interest as connected to \bar{E} . $p(t)$ are the experimentally obtained data.

$$p_0(\bar{E}) = \frac{p(t''_n) - p(t'_n)}{I}, \quad \bar{E} = \frac{p(t''_n) - p(t'_n)}{I^*}$$

Since $p_0(\bar{E})$ enters into the integral itself, an approximation is calculated using $p_0(\bar{E})$ from the previous calculation. This approximation is fed back and used for a second approximation, and this procedure is repeated. The third approximation is assumed to be good enough. Then the machine proceeds to the next time parameter.

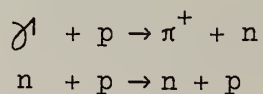
82-2N015 Mathematics. Poisson Sequential Probability Ratio Test. This program computes the power function, $B(V) = (\text{probability of crossing the upper boundary})$ and $N(V)$, the expected sample size, for the Sequential Probability Ratio Test (SPRT) as a function of the Poisson parameter V . Let X be a random variable with a Poisson distribution and parameter V , i.e., $P(X=n) = \frac{V^n e^{-V}}{n!}$. The SPRT for V large versus V small is as follows: Take a pair of parallel lines with positive slope in the plane. Now take successive observations on X . Move to the right one unit for each observation and move up n units where $X = n$. If the upper boundary is crossed, decide X large. If the lower boundary is crossed, decide X small. If neither boundary is crossed, continue sampling.

83-2N016 Agronomy. Wheat Breeding Research. This research project involves the testing of wheat breeding lines and new wheat varieties. This material is tested at 4-5 different locations throughout the state. The 7090 will be used to calculate means and analysis of variance so that significant differences in the material may be determined. Data analyzed will usually consist of the following: stand, lodging, height, test weight and yield.

84-2N017T Animal Science. Interrelationships Within Pork Carcass. A total of eight individual projects are involved which encompass a total of 106 variables, some of which are independent variables for which constants need to be fitted prior to ascertaining partial regression coefficients among the dependent variables remaining. In addition, multiple correlations between independent variables and dependent variables and multiple regression equations will be derived.

85-2N018T Agricultural Economics. Production Function for Holstein Cows. A paraboloid production surface with a constant term and all terms up to and including 2nd degree is to be tested. There are two basic independent variables and one dependent variable. R^2 corrected; standard errors of coefficients; comparison of actual and predicted values of dependent variable will all be computed.

86-2N028 Digital Computer Laboratory. Monte Carlo Study of Pion Events. This is a Monte Carlo calculation of the reaction



taking place in a 14" bubble chamber to determine the relative theoretical distribution of events.

87-2N029 Digital Computer Laboratory. Range-Energy Relations. A calculation of Range Energy and Range Momentum relations for elementary particles in matter by the Bethe-Black theory will be carried out. New experimental data will be used to fix the origin of the curves.

88-2N019 Psychology. Group and Organizational Factors Influencing Creativity. This program is being conducted to determine group and organizational factors influencing creativity. The research program has been in operation since 1960, and has concerned leadership behavior and group composition factors which affect productivity on a variety of tasks. Up to this point group problem solving problems as well as tasks requiring new solutions or new products have been used.

89-2N020 Psychology. Interpersonal Perception and Personality Assessment. Research will be carried out on psychological correlates of interpersonal perception scores, assumed similarity to others, and perceptions of co-workers.

The variables to be investigated have played an important part in the departmental research program during the last 10 years. A factor analytic study and extensive subscale analyses are expected to yield clarification about the meaning of the above mentioned variables. The interpersonal perception scores have been particularly important in the prediction of performances by military and student task groups, as well as investigations of cross-cultural and problem solving teams. The research will involve factor analysis, as well as analysis of variance programming.

90-2N021T Civil Engineering. Minimum Weight of Plastically Designed Frames. A method is sought for the determination of the minimum weight of plastically designed steel building frames. This involves the solution of real structures composed of existing structural shapes. The effects of both flexural and column action will be considered.

Algebra and matrix algebra will be used in the solution of this problem.

Initially, programs will be written for various problem types to provide solutions which will satisfy equilibrium, mechanism and yield criteria by modifications to the moment balance method. The solutions will be studied with the objective of determining the factors which are of primary importance in determining minimum weight designs. When these factors and their range of significance has been determined, design procedures will be formulated for more direct solutions. These procedures will be checked by comparison of their solutions with complete trial solutions run on the computer.

91-2N022 Agronomy. Weed Control Research. The effect of various chemicals on different crops is being studied. Similar experiments will be carried out at various locations and all results analyzed. The analysis will consist of means and analysis of variance. The analysis of variance will be used to determine if significant differences exist between the means.

92-2N023 Agronomy. Corn Oil Research. This research project involves the testing of corn hybrids. The 7090 will be used to calculate means and analysis of variance so that significant differences may be determined between hybrids. Data analyzed will usually consist of the following: per cent oil, yield, bushels/acre, per cent stand, kernel size, per cent erect, per cent diseased.

93-2N024 Agronomy. Horizontal Inflow and Outflow Finite Case. Numerical solution of the parabolic partial differential flow equations with linear boundary conditions using finite difference methods will be undertaken. This leads to a set of linear equations with a tridiagonal matrix. A typical matrix size is about 100 x 100. The linear system will be solved by a single recursive process, an adaptation of Gauss' elimination technique to tridiagonal matrices.

94-2N025 Psychology. Test Scoring by Keys. Given a set of L items with which N subjects agreed or disagreed (1 or 0), the problem is to combine subsets of the items into "scales" by reference to a predetermined pattern of responding, given by test "keys" (M), in such a manner that all subjects receive scores on the scales of interest. Input data for N subjects consists of L columns (one for each item) punched 1 or 0. Test "keys" are similarly prepared with a 1 or 0 in each column to be scored and some other entry (e.g., "8") in columns to be ignored. Each of the N subjects is compared on L items with the test "key" and the number of agreements tallied.

The program to be employed will be an extensive revision of the FORTRAN program developed for the UCLA 7090. The major adaptations will be those permitting a more flexible specification of the number of "keys" to be scored and an output format which permits entry into an intercorrelation routine. The second phase of the present problem will involve the computation of means, standard deviations and intercorrelations among subsets of variables scored by the preceding analysis.

95-2NO30 Nuclear Engineering. Reactor Kinetics. This work is a study of fast (20 sec. or less) reactor startup required for nuclear rocket propulsion. The code used, AIREK-II, was developed at Atomics International and is designed to solve the standard reactor kinetics equations with respect to time. The mathematical methods used are standard numerical techniques. The code can handle up to 25 delayed neutron groups and 25 other linear feedback equations.

96-2NO31T Chemistry. Equilibrium Constants. The purpose of this program is to calculate formation constants of the type $K_n = \frac{[ML_n]}{[ML_{n-1}][L]}$ where L is the complexing species ligand and M is the central metal-ion which is being complexed. Brackets indicate concentration.

The experimental data taken for this consists of a pH reading, the volume of base added, V_b , and the knowledge of how much initial metal-ion and ligand-acid are in solution. The equations used in this program are as follows:

$$pHC = pH + \Delta \quad = \text{corrected pH } (\Delta \text{ is an activity correction})$$

$$[H^+] = C^{[\ln(10)]pHC} \quad = \text{hydrogen ion activity}$$

$$[Me_4N] = N_b V_b / (V_s + V_b) \quad = \text{base concentration}$$

$$[M] = N_M V_M / (V_s + V_b) \quad = \text{metal ion concentration}$$

$$[OH] = K_w / [H^+] \quad = \text{base ionized from solution}$$

$$[H] = N_H V_H / (V_s + V_b) \quad = \text{concentration of ionized acid in solution initially}$$

$$[HL] = N_L \cdot V_L / (V_s + V_b) - [Me_4N] + [H^+] - K_w / [H^+] + [H] \quad = \text{effective concentration of ligand-acid}$$

$$[L] = K_D \cdot [HL] / [H^+] \quad = \text{effective concentration of ligand}$$

$$\bar{n} = \left\{ [Me_4N] + [H^+] - [L^-] \right\} / [M] = \text{"complex" formation function}$$

$$J_n = (n - \bar{n})[L]^n$$

$$\bar{n} = \sum_{n=1}^N J_n \beta_n, N = \text{maximum number of ligands which can be complexed to a metal ion.}$$

$$K_n = \beta_n / \beta_{n-1}$$

$$\overline{\log K_n} = \frac{\sum_{i=1}^n \log K_{n,i}}{n}$$

$$\sigma^2 = \text{var}(\log K_n) = \frac{\sum_{i=1}^n (\log K_{n,i})^2}{n} - (\overline{\log K_n})^2$$

$$\sigma = \text{std. dev.} = (\text{var}(\log K_n))^{1/2}$$

$$\text{confidence limits} = P_{95\%} \sigma / \sqrt{n-1}$$

The program searches through the \bar{n} values and picks those which fall into the regions 0.3-0.7, 1.3-1.7, 2.3-2.7, 3.3-3.7, 4.3-4.7 and 5.3-5.7. The individual points are then used as statistics of the experiment and all combinations of linear equations which are possible - by using one point in each region - are solved for K_i . The sample mean is then taken as the mean of the $\log K_i$ values which result. The simultaneous linear equations are solved using the library SLINEQ subroutine.

This program has been written to take cases of $N = 1, 2, 3, 4, 5$, or 6 . The applicability is obvious to all homogeneous solution problems of this type. Only minor revisions in the preliminary calculations are necessary to make this program quite general for a number of specific conditions.

Symbol definitions are as follows (when not already defined above):

- N_b = Molarity of base added
- V_s = Total volume of solution to be titrated
- N_M = Molarity of the metal ion
- V_M = Volume of the metal ion of molarity N_M used
- N_H = Molarity of strong acid
- V_H = Volume of strong acid of molarity N_H used
- N_L = Molarity of ligand acid solution
- V_L = Volume of ligand-acid solution of molarity N_L used
- K_W = ion product of water = $[H^+][OH^-]$
- K_D = dissociation constant for the acid HL

97-2N032 Physics. SMP Track End Point Location. In the development of a new bubble-chamber analysis system, the SMP system, the measurement of end points on tracks has turned out to be a slow operation compared with the measurements of tracks and fiducials. A new scheme for measuring the end point of a track has been invented that involved measuring the coordinates of all the bubbles in the vicinity (within 3mm) of the track end and deducing by a computer program which bubble is the last one in the track. The present problem consists not of production, but of testing various programs for accomplishing this goal using data obtained on the SMP prototype at the University of California. When a satisfactory program is developed, it will be incorporated as a subroutine in the master program for the SMP data analysis system.

8-2NO33T Chemistry. X-ray Structure of Nidulin. The molecular structure of two organic molecules, nidulin and a fescue alkaloid, will be solved using x-ray methods. The 7090 will be used to do a three dimensional diagonalized least squares refinement on the atomic positions, temperature factors and scale constant for nidulin. Also, Fourier map of the crystal will be calculated using the refined atom positions and the original intensity data.

The 7090 will also be used for data reduction (Lorentz-polarization correction) of scaled x-ray intensities for the fescue alkaloid, to calculate a three dimensional Patterson function

$$P_{uvw} = \sum_{hkl} |F_{hkl}|^2 e^{2\pi i (\frac{xh}{a} + \frac{yk}{b} + \frac{zl}{c})}$$

where

$$|F(hkl)|_{\text{raw}} = \sqrt{I_{hkl}} \text{ and } I_{hkl} \text{ is the intensity for reflection Miller indices}$$

hkl)., to calculate Fourier maps using phases obtained from the Patterson map and original intensities; and finally to do a three dimensional least squares refinement of the atom positions.

9-2NO34T Physics. Meson-Nucleon Interactions. Recently obtained theoretical scattering amplitudes for experimentally unobservable π meson scattering will be applied to other processes, such as meson production and meson-nucleon scattering, whose theoretical calculation requires a knowledge of the meson-meson interaction. Some numerical integrations will be required and a non-linear least squares fit of the meson-nucleon scattering angular distribution to a theoretical form for the angular distribution will be made. Other similar computations may be required.

The numerical integrations should be straightforward ones, although some may involve principal value integrals. The least squares fit will require the determination of the parameters $\delta_L, L = 0, 1, \dots, L$, given the experimental values of the differential cross section $\frac{d\sigma}{d\Omega}(\theta)$, from an expression of the form

$$\frac{d\sigma}{d\Omega}(\theta) = \left| \sum_{L=0}^L F(E) e^{i\delta_L} \sin \delta_L P_L(\cos\theta) + g(E, \theta) \right|^2$$

where $P_L(\cos\theta)$ is the Legendre polynomial of order L , $F(E)$ is a function of the energy at which the experiment is performed, and $g(E, \theta)$ is a function of energy and angle which is predicted via a knowledge of the above-mentioned meson-meson interaction.

100-2N035T Civil Engineering. Dynamic Response of Shells. The dynamic response of spherical shells to transient pressure pulses will be computed. The equations of motion for the shell will be solved by a modal superposition procedure. The responses of the individual modes are to be computed by a modified Galerkin method in which approximate displacement functions are substituted into the equations of motion, and a series of unknown coefficients determined to satisfy certain boundary conditions and to minimize the shell energy.

These coefficients are computed by numerical integration for each time increment of the input transient pressure pulse.

Output will be in terms of arrays specifying the time-wise variation of the shell displacements for integral multiples of the integration time interval.

101-2N036T Theoretical and Applied Mechanics. Stresses in a Spherical Ring. The solution of this problem is given in terms of infinite series of spherical harmonics. The computer computes the coefficients according to explicit formulae. The resulting series expressions, after being truncated, are evaluated by the computer. A subroutine has been written to evaluate any integral order of Legendre polynomial for this program.

102-2N039 Chemistry. Methods Study-Parabolic Differential Equations. Very little is known theoretically about difference method solutions of systems of parabolic partial differential equations. Since such systems frequently arise in physical problems, it would be of great interest to determine how some standard difference schemes might best be generalized to include the terms coupling the differential equations. It is planned to use the 7090 in a combined theoretical-experimental investigation of this problem.

103-2N047 Electrical Engineering. Differential Equations. The Far-Field pattern of two mutually coupled rectangular apertures is very complicated. It is a complex-function consisting of many high order partial derivatives of functions like $A(\theta, \phi)$, $B(\theta, \phi)$. In general, A, B have the form $\sin \frac{[\text{Trig.Fun}(\theta, \phi)]}{f(\theta, \phi)}$, $\sin \frac{[\text{Trig.fun}(\theta, \phi)]}{\text{trig.f}(\theta, \phi)}$. For more than 2000 sets of given conditions, it is impossible to find a complete solution by normal calculations. However, by a series-expansion technique, it is possible to express the final solution in terms of many different power series. The 7090 computer is expected to calculate all of these series under given conditions, and evaluate the total solutions. Some of the series

are of the form

$$\sum_N (-1)^N \frac{(\beta \sin \phi)^{2(N-1)}}{(2N-1)!}, \quad \sum_N (-1)^N \frac{2N \cdot \beta^{2N} \cdot (\sin \phi)^{2(N-1)} (2N \cos^2 \phi - 1)}{(2N+1)!}$$

$$\sum_N (-1)^N F(\phi) \cdot P(N) \cdot Q(\theta) \frac{B^{2N} (\sin \phi)^{2(N-2)}}{(2N+1)!}$$

104-2N048 Digital Computer Laboratory. Study of Boundary Conditions on the Ising Lattice. The aim of these computations is to study the effects of the boundary conditions on Monte Carlo calculations of the order parameters in the Ising Lattice. The research will stress studying the effect of replacing the usual periodic boundary conditions by self-consistent statistical boundary conditions, in which the interactions at the boundary are determined by the average interactions among a subset of the spins considered in detail. There are several ways to do this and the one under study here is analogous to the Bethe approximation on the Ising Lattice.

105-2N049 Chemistry. Rotational Eigenvalues. The research involved is microwave spectroscopy in which pure rotation spectra of light gaseous molecules is observed. The particular aspect of this research is the observation of small nuclear, intramolecular, and intermolecular perturbations on the pure rotational spectra. These small perturbations can be measured and used to gain information on the structure of molecules and the nature of the chemical bonding involved.

In order to gain physical significance from the observed spectra long and tedious calculations are necessary, and indeed sometimes impossible.

A program has been written which will set up the Hamiltonian matrix describing the rotation motion in a convenient basis. In addition, the dipole moment matrix is set up on the same basis. These two matrices are then transformed to the basis in which the Hamiltonian is diagonal to give the energy levels and relative intensities of the transitions. Further aspects of the program will enable a calculation of the molecular Stark effect and other perturbations such as the nuclear quadrupole interaction.

106-2N050T Electrical Engineering. Periodic Slot Array. It is required to plot $k_0 L$ versus $\beta_0 L$ from:

$$\sum_{n=-\infty}^{\infty} \frac{\sin \beta_n \frac{d}{n^2}}{\beta_n \frac{d}{n^2}} \left\{ 2 \left[\frac{7}{\sqrt{\beta_n^2 - 7k_o^2}} + \frac{1}{\sqrt{\beta_n^2 - k_o^2}} \right] \left[\frac{\sin 2k_o L}{2k_o L} - \cos^2 k_o L \right] \right. \\ \left. - \left[\frac{7}{\sqrt{\beta_n^2 - 3k_o^2}} + \frac{1}{\sqrt{\beta_n^2 + 3k_o^2}} \right] \frac{\sin 2k_o L}{2k_o L} + 3 \left[\frac{1}{\sqrt{\beta_n^2 - 3k_o^2}} - \frac{1}{\sqrt{\beta_n^2 + 3k_o^2}} \right] \right\} = 0$$

where $\beta_n = \beta_o + \frac{2n\pi}{a}$

and L, d, a are known quantities. Only one of two terms of the Summation are important. In general β_o will be complex.

107-2N051 Physics. Nuclear Reaction Kinematics. A number of kinematical relationships must be computed before the execution of almost every experiment performed with the University of Illinois Cyclotron. These calculations include energies of reaction particles (in both laboratory and center-of-mass systems) and conversion of angles and cross sections from the laboratory to the center-of-mass system. Although they involve only algebraic and trigonometric relationships, the kinematical calculations are long enough to require several hours of computation with a desk calculator for each reaction studied. The IBM 7090 will make possible a more efficient and accurate calculation.

108-2N052 Agronomy. Research with Sudangrass. This research project involves testing new Sudangrass hybrids for their possible use as a forage crop in Illinois. These new hybrids are higher yielding and have lower prussic acid content. The new hybrids are tested with present varieties with mean yields and analysis of variances calculated. The analysis of variance is used to determine significant differences among varieties and hybrids. Yield data will be collected for 3-4 cuttings. Data collected will be yield in tons/acre and purssic acid content.

109-2N053 Mens Residence Halls Association, Rocket Club. Ramjet Calculations. The purpose of this project is to design and theoretically test a ram-jet engine to be used as the propulsion unit for a high altitude research vehicle. The design phase consists of solving several equations of thermodynamic flow using the desired operational altitude, velocity, and thrust as parameters. As a result internal dimensions of the engine can be calculated. These dimensions will be determined for several sets of parameter values and the most desirable designs will be selected for further study under the second phase.

The second phase will subject each of the selected designs to an exhaustive theoretical investigation. This investigation consists of the computation of internal operating pressures and temperatures over a range of altitudes from 1000 feet to 64000 feet incremented by 1000 feet and velocities from Mach 1.0 to Mach 3.0 incremented by Mach 0.1. The twelve significant pressures and temperatures will be plotted against altitude for each of the twenty velocities.

110-2N056 Chemistry. Unimolecular Reactions. The problem consists of solving the classical Hamilton equations of motion for a triatomic molecule and in determining the reaction times for a variety of initial conditions of chemical interest. The method involves the use of the Runge-Kutta-Gill method for integrating those equations.

111-2N057 Chemistry. Diffusion Kinetics. The problem consists of solving a system of partial differential equations of the type

$$\frac{\partial c_i(r,t)}{\partial t} = D_i \Delta^2 c_i - k_i c_i - \sum_{j=1}^m k_{ij} c_i c_j + \sum_{a=1}^n k_{ai} c_a + \sum_{b,d=1}^n \left(1 - \frac{1}{2} \delta_{bd}\right) k_{b_i d_i} c_b c_d \quad i = 1, 2, \dots, n$$

which are assumed to describe the space-time history of clusters of chemically reactive species produced by the action of ionizing radiation on matter. Here, the c_i are concentrations, D_i are diffusivities, and k_{ij} are reactivities.

First, for a simplified system of this type, several methods of integration will be attempted, including implicit discretizations, to determine the most efficient one. This method will then be used for preparing a general program.

112-2N060T Civil Engineering. Dynamic Soil Arching. The problem of soil-structure interaction is being studied for the purpose of determining the distribution of pressure and soil particle velocity when a buried structure is loaded to failure by a time-dependent pressure applied at the ground surface.

By considering the soil to be a granular media with an angle of internal friction ϕ , and with the classical Coulomb-Mohr failure condition, the problem may be formulated in two-dimensional plane strain in terms of the five variables σ_x , σ_y , σ_{xy} , u_x and u_y which are the stress and velocity components in the xy-plane.

The partial differential equations governing the system are of the hyperbolic type and possess two families of real characteristics.

The solution is obtained by transforming the problem to the characteristic plane and integrating the resulting equations along the characteristics. The integration must be performed numerically by using a method of finite differences.

113-2NO61 Business Administration. Study of Middlemen. It is desired to determine the number of middlemen and intermediate levels of middlemen in an abstracted market structure. The key variables in the system are the numbers of sellers, buyers, and middlemen, the size of the rebate granted by middlemen and the costs of intermediate transactions.

The nature of the problem is such that a computer is needed to iterate the number of middlemen and levels by the systematic manipulation of a series of profit equations.

114-2NO65 Chemistry. Approximation of Atomic and Molecular Energy Eigenvalues by the Variation Perturbation Method. This problem is one of approximating wave functions for 2-, 4-, and 6 - electron systems such as H_2 , Be, and LiH.

The combined variation-perturbation method used to approximate energy eigenvalues for these atomic and molecular systems involves the analytical evaluation of a considerable number of single center one- and two-electron integrals, the orthogonalization of one-electron radial functions, the evaluation of eigenvalues and eigenvectors of small symmetric matrices, the inversion and multiplication of rather large matrices. The integration procedure involves considerable looping in the evaluation of the complicated analytical expressions which are composed mainly of summations of products of factorial and exponential terms.

115-2NO66T Mechanical Engineering. Tooth Deformation in Gear Lubrication. Three functions of x (position on the tooth) are to be calculated and integrated. One of the limits of integration is to be found by trying intelligently guessed values. The integrations are performed by using the trapezoidal rule. This integration yields the rigid body pressure distribution, P_r , which in turn permits the calculation of the film thickness correction, H . A pressure correction, P can be obtained from the known relation between P and H and then an improved pressure distribution is given by $p = P_r + P$. This procedure can be repeated by replacing the value of P_r by p until p approaches 0 or ceases to change.

116-2N062T Chemistry. Analysis of Nuclear Magnetic Resonance. The number of lines in a high resolution nuclear magnetic resonance (NMR) spectrum and their frequencies and intensities depend upon the number of magnetic nuclei per molecule in the sample, the symmetry of the molecule and upon certain physical parameters known as the chemical shifts, $\Delta\nu(i)$, and coupling constants, $J(ij)$, of the magnetic nuclei. These parameters are related intimately to the electronic and geometric structure of the molecule and provide a means of investigating molecular structure.

The basic problem of concern here is to extract the $\Delta\nu(i)$ and $J(ij)$ from the observed spectrum, which is often too complex or distorted by second-order perturbation effects to permit ready analysis by hand. Even when the analysis is simple enough for hand solution, ambiguities remain concerning relative signs of the $J(ij)$. Hitherto, complex spectra usually have been analyzed in a partially "automated" way. Trial values of the $\Delta\nu(i)$ and $J(ij)$ are used as computer input. Matrix elements are calculated and introduced into an eigenvalue, eigenvector subroutine which computes the energy levels and the transition frequencies and intensities. After print out, these are compared manually with the observed spectrum, and the trial values are modified. Iteration continues until an acceptable fit is obtained.

Recently, double resonance (DR) experimental techniques have been developed which enable one to determine which lines in an NMR spectrum arise from transitions having an energy level in common with the transitions responsible for each line. The DR(L) results can be represented as an $L \times L$ array of binary bits, where L is an index number designating the line in the spectrum. From the number of magnetic nuclei in a molecule, and the symmetry of a molecule, the transitions $T(k)$ can be written as differences in pairs of energy levels, i.e., $T(k) = E(m) - E(n)$ and a DR(T) array can be constructed. Comparison and manipulation of the DR(L) and DR(T) arrays leads to a set of identities $L(p) = T(k) = E(m) - E(n)$. The E 's are expressible as functions of the $\Delta\nu(i)$'s and $J(ij)$'s, so with numerical input for the line frequencies, $L(p)$, there results a set of L equations in the (overdetermined) unknown $\Delta\nu(i)$'s and $J(ij)$'s, which can now be solved analytically. Finally, the latter (average values) are used to compute $T(k)$ and also the sum of $[L(p) - L(k)]^2$, which is a measure of how well the observed frequencies are fitted.

The problem is to develop programs to carry out the analyses described in the preceding paragraph, and to apply them to observed spectra.

117-2N063T Agricultural Economics. Merchant Credit in Agriculture. The increasing commercialization of farming, accompanied by greater use of purchased inputs, is generating increased interest in means of adequately financing agriculture. This research project investigates the role of merchant credit in agriculture. It is designed to

determine the effect of using merchant credit on farm enterprise organization, farm income, and farm financial organization.

Earlier research has been concerned with the effect of lending policies of commercial banks and production credit associations upon farm income and organization. A linear programming model, using the LP/90 operating system, will be used to determine the effect of merchant credit upon farm organization. The computing facilities of the IBM 7090 will permit handling the interrelationships among primary lenders and merchants and their effect upon farm organization.

This linear programming model will yield an enterprise organization that maximizes farm income with the given constraints. The optimal solution provides information regarding the sources, amounts, and timing of borrowing and repaying of borrowed funds as well as use of owned funds. This model will also yield values of the primary lender loan discount factor, interest rate differential, and lender limits which are critical and result in a changed farm organization.

118-2N064T Agricultural Economics. Supply Response and Adjustments for Hog and Beef Cattle Production. The objectives of this research problem are to estimate farm resource use and supply response of hogs and beef in representative farm situations and to determine the production situations and the areas in which a specified output of hogs and beef cattle would or could be produced most efficiently under various projected levels of demand, prices, and at a given level of technology representing that which is known but not yet generally adopted. Hog and beef supply response will be estimated by programming optimal organizations for representative farms in Illinois. The standard library routine LP/90 will be used for this problem. The coefficient matrix will be approximately 65 x 89.

119-2N068T Electrical Engineering. Energy Storage in Shock Waves. The problem consists of investigating the nature and time of occurrence of thermal equilibrium behind strong shock waves in molecular nitrogen. The equations relating the number densities of the various electronic, molecular, atomic and ionic species existing at a given equilibrium temperature can be derived from statistical mechanical considerations. These equations contain temperature as the independent variable and are functionally quite complex. It is necessary to solve these equations in tabular and graphic form in order to compare the theory with experimental data over a very wide range of temperatures (500°K - 20,000 °K). The 7090 will be used to obtain both graphical and tabulated solutions to the theoretical equations.

120-2N069T Electrical Engineering. Instability of Liquid Surfaces. A study of the instability of liquid surfaces under the influence of electrical stresses is planned. Since the boundaries of the surfaces concerned are not coordinate surfaces, the computer will be used to solve Laplace's Equation in the given regions. Also, some of the equations concerned are non-linear and the computer will be used to obtain numerical solutions of them in particular cases.

121-2N070T Civil Engineering. Soil-Structure Interaction. The purpose of this research will be to study the interaction of an underground structure with the surrounding soil medium when subjected to dynamic loads produced by the passage of a blast wave on the surface. The soil will be represented by a two-dimensional spring-mass system which in the elastic range can be shown to be a finite difference analog of a continuum. In addition, the representation of the soil by a spring-dashpot-mass two-dimensional viscoelastic system will be studied.

The structure to be studied will be represented by a solid or elastic structure insulated from the soil medium by another elastic or viscoelastic medium as described above but with distinct physical properties.

Equations of equilibrium derived by considering the model to be in a state of plane-strain will be used. The subsequent equations of motion will then be solved using numerical integration.

122-2N071 Naval Science. Cottontail Age-Lens Weight Relationship. The purpose of this program is to evaluate the relationship between age and lens weight for the cottontail rabbit. The least squares method of analysis is to be used. Results will yield an aging technique vital to population analysis, an important aspect of wildlife ecological investigations.

123-2N072T Theoretical and Applied Mechanics. Deformation of a Gear Tooth Type Protrusion. The classical elasticity problem for a gear tooth protruding from a half plane is solved by Cauchy integration along the half plane. The IBM 7090 is used to obtain a plot of the conformal transformation of the gear tooth to the unit circle. The IBM 7090 is also used to solve a resulting set of linear equations with complex coefficients. Further computations include stresses and displacements induced by a uniformly distributed pressure over a finite portion of the gear tooth.

124-2N073 Digital Computer Laboratory. Beam Track Follower. The present program is designed to initiate and follow bubble-chamber beam tracks from Hough-Powell Flying Spot Digitizer data. A program option permits the tracks to be initiated either by parameter card input or by actual computation at a histogram of beam tracks within the program. Future modifications of the present program will permit the following and analysis of non-beam track data.

125-2N074 Agricultural Economics. Minimum Resources for Agriculture. The central objective of this research is to determine the long-run "least-cost" organization of production on grain and hog farms needed to obtain specified levels of earnings for labor and management of farm operators. The least-cost organizations will be found by standard linear programming procedures. Solutions will be obtained for five income levels and two levels of technology for each of the two basic farm types, grain farms and hog farms.

LP/90 will handle problems of the type contemplated. The coefficient matrices are approximately 20 x 40.

126-2N-75T Psychology. Correlation Matrix for Maternal Instincts in Rats. A correlation matrix is to be run between various measures of maternal behavior of albino rats for their first pregnancy. The measures include pup retrieving time, nursing latency and time, measures of nesting retrieval and quality of nest, etc. The correlations will allow a simple cluster analysis to be done. These clusters, if found, will help identify unitary factors in the maternal complex. Items having low (zero) intercorrelations will identify relatively independent aspects of the maternal complex. Standard library routines will be used to obtain the material.

127-2N077 Chemistry. Magnetic Resonance Data Analysis. Under Illiac Problem No. 2227T, an attempt was made to analyze some experimental data on magnetic resonance relaxation times. A standard least-squares technique was used. Because of the unusual functional forms (involving exponentials and rational functions) to which it was desired to fit the data, convergence was slow and erratic. It therefore is desirable to develop for the IBM 7090 a program capable of handling this sort of data efficiently. It is planned to use a combination of gradient and random methods to minimize the sum of the squares of the deviations of the experimental points from the theoretical curve.

128-2N078 Physics. Accelerator Beam Studies. The purpose of these computations is to explore beam transport systems for the zero Gradient Synchrotron being built at Argonne. The program will use matrix methods to propagate rays through the systems of magnets and electrostatic separators. The matrices are two by two matrices and the program is very similar to one in use at Argonne and Northwestern University. In the future randomly selected rays and the CRT output to facilitate visualization of the computations may be used.

129-2N079T Civil Engineering. Processing of Field Data. The computer is used to process raw field data from electronic measurements and to provide tabulations and plots of the variables. The raw data representing displacement, velocity, or strain is to be multiplied by the calibration constants for the particular gage. The resulting values of displacement, etc., will be tabulated and plotted versus times.

130-2N080T Chemical Engineering. Non Uniform Flow. One method of investigating the nature of turbulence in a flow field near a solid surface is to measure the rate of transfer of mass from the field to a circular area element of the solid surface. The instantaneous rate of transfer may be expressed as a sum of a time average and a fluctuating component. If the area element is not small compared to the scale of the flow disturbances the mean square value of the fluctuating component of the transfer rate obtained from measurements will be less than the true local mean square value due to averaging over the electrode surface. The objective of this problem is to compute a correction factor for this effect.

131-2N081T Civil Engineering. Multivariate Analysis. It has been stated in past work that vehicular speeds are a function of various travel conditions present in and adjacent to a traffic stream. Thus, various types and levels of travel features produce different average spot speeds. In traffic engineering work, it would be of great benefit to be able to estimate the spot speed at a particular location without having to sample the speeds at that location. In order to make this estimate, a mathematical model is needed which will predict the average speed.

By using the data taken from various sites throughout the State of Illinois, it is proposed that two mathematical models will be developed by performing correlation analysis and multiple linear regression on the independent

variables and by performing factor analysis on the independent variables, and then performing multiple linear regression on the resulting factors.

The 7090 computer would be used for the correlation analysis, the factor analysis, and the multiple linear regression.

132-2N082 Industrial Engineering. Linear Programming.

Given $A X = b$

Where

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & & a_{mn} \end{bmatrix}$$

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} \quad b = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}$$

Minimize $F = cX$

Where $F = \text{scaler}$

$$c = (c_1, c_2, \dots, c_n)$$

The general approach to the problem is to augment A with an $m \times m$ identity matrix and x with an $l \times m$ column vector (Y), i.e.,

$$(A|I) \left(\frac{X}{Y} \right) = b$$

Consider B to be the initial matrix of those vectors which become the optimal solution.

Let these vectors be the 1st m of A .

$$(B|\bar{A}|I) \left(\frac{X}{Y} \right) = b \quad \bar{A} = m + 1 \rightarrow n \text{ vectors of } A.$$

$$B^{-1} (B|\bar{A}|I) \left(\frac{X}{Y} \right) = B^{-1} b$$

$$(I|B^{-1}\bar{A}|B^{-1}) \left(\frac{X}{Y} \right) = B^{-1} b$$

$$I X = B^{-1} b$$

or

$$X_0 = B^{-1} b$$

where X_0 is the desired solution to minimize F .

Initially B is taken as I and by an iterative process the vectors of B are changed until the optimal solution of F is achieved.

133-2N083T Agricultural Engineering. Velocity Distribution in Partly Filled Sewers. It is desired to determine the laminar velocity distribution in a sewer or agricultural drain tile line flowing partly full. The boundaries are defined by a unit diameter circle and a free surface at a depth Y from the extreme bottom of the sewer. The computer is to be used to compute a rectangular network of grid points in the region described; assign initial trial values of the function describing the phenomenon to these points; then apply an iteration procedure to each point in turn, until a pre-determined accuracy of the function is obtained. The output from the computer is to consist of a record of the input quantities, (i.e., depth of flow and desired accuracy parameters), information concerning the grid spacing and irregular grids of the boundary and the value of the function of each node.

134-2N084T Electrical Engineering. Resonant Modes in Plasmas. This program will be used to find the resonances in a circular cylindrical coaxial resonator. The center conductor of the resonator consists of a plasma. An external magnetic field is applied along the axis of the conductor. The resonances are determined by the solution of the following characteristic equation

$$\frac{AG'(DE)}{DG(DE)} + \frac{\sqrt{A} J_1(\sqrt{AE})}{J_0(\sqrt{AE})} = \frac{BG'(DE)}{DG(DE)} + \frac{\sqrt{B} J_1(\sqrt{BE})}{J_0(\sqrt{BE})}$$

$$\frac{A(A-C) F'(DE)}{DF(DE)} + \frac{\sqrt{A} (A-C)(1-M^2) J_1(\sqrt{AE})}{J_0(\sqrt{AE})} = \frac{(B-C) F'(DE)}{DF(DE)} + \frac{\sqrt{B} (B-C)(1-M^2) J_1(\sqrt{BE})}{J_0(\sqrt{BE})}$$

Where $\frac{G'(DE)}{DG(DE)} = f_1(K_1, K_0, I_1, I_0)$ where the I 's, J 's, and K 's are Bessel functions and modified Bessel functions.

And $\frac{F'(DE)}{DF(DE)} = f_2(K_1, K_0, I_1, I_0)$

E , A , D , B , and V are quantities obtained from the plasma parameters and resonator dimensions through analytic formulas. The above characteristic will be solved by incrementing E until a solution is passed, then the interval containing the solution will be linearly chopped until the solution is found.

135-2N085 Music. Composition of Music. Since the production of the first ILLIAC Suite for String Quartet, extensive analysis of existent styles and techniques of music composition has been performed using statistical techniques programmed for ILLIAC. In order to test both the limitations and the degree of comprehensiveness of these analytical techniques, the data thus obtained will be used to produce a second suite for digital computer, in this case the IBM 7090.

In addition, the computer will be used to simulate certain other, nonstatistically defined methods of composition such as 12-tone techniques and "total organization". Finally, other original methods of composition will be explored, methods specifically conceived to exploit choice operations the nature and complexity of which inherently require the use of a digital computer to obtain results within a reasonable period of time. Thus, the feasibility of using a digital computer directly as an aid to composers who conceive but otherwise have no practicable means of achieving highly complex and novel musical structures will be examined.

136-2N086T Psychology. Study of Job Satisfaction. The purpose of the proposed research is to study the possibility that job satisfaction is qualitatively different from job dissatisfaction, taking into consideration the degree of pressure for production imposed on the worker. In addition, the possibility that pressure for production is a significant variable in the determination of the relationship between job satisfaction and job productivity will be examined. The data for this study will be approximately 1500 sets of answers to a job attitude questionnaire.

The statistical procedure will be a principal axis factor analysis (and varimax or other rotation) of the data in order to identify the underlying dimensions of significance of differences between means, and other related statistical methods to determine whether the relationships among the answers to individual items, or groups of items, support or oppose the hypotheses.

137-2N087 Mechanical Engineering. Infiltration into Homes. The nature of this problem is to seek a solution to the relationship between the major factors contributing to air infiltration into homes. Wind temperature data are to be correlated with infiltration rates up to and including quadratic terms involving wind and temperature.

Table I-1401 shows the distribution of IBM 1401 time during the month of November.

TABLE I-1401

Scheduled Engineering	:45
Unscheduled Engineering	14:08
Listing	7:33
CDC Preparation	2:26
DCL Code Checking	7:22
7090 Preparation	215:44
Statistical Service Unit	85:58
Deck Reproduction	:02
Tape Labeling	2:46
Waste	31:35
Idle	<u>38:04</u>
TOTAL RUNNING TIME	406:23

Information on running time, wastage, scheduled engineering, unscheduled engineering and machine errors for the IBM 1401 is given for each day of the month of November in Table III-1401. The errors and their sources are summarized in Table II-1401.

TABLE II-1401

1401 Processing Unit	0
1402 Card Read Punch	8
1403 Printer	5
729V Tape Units	<u>1</u>
	14

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	UNSCHEDULED ENGINEERING	IDLE	WASTED	ERRORS	
11/1/62	11:57				1:28	2	(1) Punch light will not go out. Dirty contact on a die found. (2) Punch stop indicator would not go off. Power turned off, then on again.
11/2/62	12:50		1:30	1:15	2:20		
11/3/62	5:00			:	:41	1	(1) Recurring reader checks. Dirty read brushes found.
11/5/62	16:04				:30	1	(1) Printer spacing incorrectly. Torn carriage control tape found.
11/6/62	15:30		:50	:11		1	(1) Excessive reader stops. Unknown.
11/7/62	16:16		:30		:30	2	(1) Numerous print errors and synchronization checks. Unknown. (2) Current leakage from chassis on 1403, probably due to static electricity.
11/8/62	14:19		:30	:19	1:05		
11/9/62	17:16					1	(1) Punch light comes on and will not go off.
11/10/62	3:55		2:13	5:55	1:20		
11/12/62	16:35			4:10	2:10		
11/13/62	15:45			:40	3:13		
11/14/62	19:59			1:58	5:15		
11/15/62	9:36					2	(1) 1403 print chain broken. Replaced. (2) Tape unit A did not properly come out of a high speed rewind.
11/16/62	4:44		3:01	5:21	:20		
11/17/62	:50			3:23	:55	2	(1) Printer spacing incorrectly. Torn carriage control tape. (2) Paper ejecting improperly. Worn brush mak- ing contact with carriage tape.
11/19/62	14:37				:34		
11/20/62	20:03	:45	2:37	:41			
11/21/62	18:14		1:07	:59		1	(1) Reader check light comes on and will not go off.
11/23/62	11:38			6:11	:35		
11/26/62	15:55			4:33	2:24		
11/27/62	18:46		:15	:14	3:40		
11/28/62	12:21			1:20		1	(1) Punch light comes on and will not go off.
11/29/62	17:40		1:35	:10	2:35		
11/30/62	14:25				:20	1	(1) Punch light comes on and will not go off.

Table I-7090 (October) shows the distribution of IBM 7090 time during the month of October. Runs outside of the monitor system and runs which destroyed the system or the storage clock reading are not included.

TABLE I-7090 (October)

<u>Use by Department</u>	Number of Runs	Time
Agricultural Economics	1	:04
Agronomy	15	:06
Animal Science	3	:10
Astronomy	4	:12
Ceramic Engineering	2	:01
Chemistry	82	1:02
Civil Engineering	62	3:15
Digital Computer Laboratory	523	14:46
Economics	6	:08
Education	13	:37
Electrical Engineering	28	:08
Instructional TV	25	:52
Mechanical Engineering	65	1:26
Nuclear Engineering	22	:14
Office of Instructional Research	3	:07
Physics	46	2:52
State Water Survey	13	:05
Statistical Service Unit	19	:28
Theoretical and Applied Mechanics	<u>31</u>	<u>:38</u>
TOTAL	963	27:11
<u>Class Use</u>		
Chemistry	54	:51
Civil Engineering	284	2:31
Digital Computer Laboratory	513	2:20
Electrical Engineering	35	:17
Industrial Engineering	<u>23</u>	<u>:13</u>
TOTAL	909	6:12
TOTAL CLASSES AND PRODUCTION	1,872	33:23

Table II-7090 (October) summarizes the information on maintenance time spent on the IBM 7090 and its associated equipment during the month of October.

TABLE II-7090 (October)

Scheduled Engineering	42:57
Unscheduled Engineering	27:57
Unscheduled Engineering on a Unit Off Line	8:00
Air Conditioning Changes and Power Installation	<u>6:55</u>
TOTAL	85:49

Table I-7090 (November) shows the distribution of IBM 7090 time during the month of November. Runs outside of the monitor system and runs which destroyed the system or the storage clock reading are not included.

TABLE I-7090 (November)

<u>Use by Department</u>	Number of Runs	Time
Agricultural Economics	1	:10
Agricultural Engineering	1	:00
Agronomy	56	:36
Animal Science	6	:22
Business Administration	4	:01
Chemical Engineering	11	:11
Chemistry	182	4:36
Civil Engineering	197	11:02
Digital Computer Laboratory	537	20:05
Economics	23	:47
Education	23	:57
Electrical Engineering	25	:10
General Engineering	6	:07
Instructional TV	79	3:02
Mechanical Engineering	114	1:54
Men's Residence Halls	3	:02
Mining, Metallurgy and Petroleum Engineering	10	:06
Nuclear Engineering	41	:43
Office of Instructional Research	20	:43
Physics	249	6:45
Psychology	1	:00
State Water Survey	42	:17
Statistical Service Unit	114	3:23
Theoretical and Applied Mechanics	42	:45
TOTAL	1,787	56:50
 <u>Class Use</u>		
Chemistry	53	:28
Civil Engineering	323	4:10
Digital Computer Laboratory	3,210	19:26
Electrical Engineering	368	3:45
Industrial Engineering	41	:37
Mechanical Engineering	10	:07
Instruction	8	:04
TOTAL	4,013	28:37
TOTAL CLASSES AND PRODUCTION	5,800	85:27

Table II-7090 (November) summarizes the information on maintenance time spent on the IBM 7090 and its associated equipment during the month of November.

TABLE II-7090 (November)

Scheduled Engineering	24:40
Unscheduled Engineering	61:35
Unscheduled Engineering on a Unit Off Line	<u>8:00</u>
TOTAL	94:15

PART VIII

INSTRUCTIONAL USE OF THE IBM 7090-1401 SYSTEM

During the month of November, nineteen problem specifications were submitted.

17-2N004 Mechanical Engineering 260. Problem 1. Using tabular data for h versus t , the program is to relate h to t by the equation $h = A + Bt + Ct^2$ for ten different ranges of t . Then the error using the equation is to be calculated based on the tabular data.

18-2N002 Digital Computer Laboratory 195. Problem 2. Three numbers are to be read from a data card to be provided in class. These three numbers are in order, the coefficients A, B, C in the equation $Ax^2 + Bx + C = 0$.

The program is then to solve this equation for the two roots (call them ROOT1 and ROOT2) and print the five numbers $A, B, C, \text{ROOT1}, \text{ROOT2}$ on a single line. The last executed statement of your program should be CALL ERROR.

19-2N010 Electrical Engineering 323. Problem 1. Given a rational function $T(s)$, it is desired to find $|T(jw)|^2$, $\arg T(jw)$, $-\frac{d}{dw} \arg T(jw)$ for $w = w_k$ $k = 1, 2, \dots, m$.

20-2N011 Electrical Engineering 324. Problem 2. Assume $T(s)$, a rational function in terms of the complex variable s , has all zeros and poles on the negative real axis. It is desired to find a $T(s)$ so that

$$\sum [|T(jw)|^2 - |T_s(jw)|^2]^2 \quad w > w_\ell$$

is minimized, where $|T_s(jw_k)|^2$ is given ($k = 1, 2, \dots, m$). The steepest descent method is used, with the zeros and poles of $T(s)$ as variables.

Such a network function is useful in the approximation problem of network synthesis.

21-2N012 Electrical Engineering 452. Problem 2. Given an electrical network N (consisting of elements e_i) with input and output ports, a transfer function $T(s)$ from input to output may be defined, where s is the Laplace Transform variable.

$$\text{Then } T(s) = \frac{a_1(s) + (e_i) a_2(s)}{a_1(s) + (e_i) b_2(s)}$$

i.e., $T(s)$ is a bilinear function of energy e_o .

A sensitivity function

$$S_{e_i}(w) = \frac{\partial |T(jw)|^2}{\partial e_i} \times \frac{e_i}{|T(jw)|^2}$$

and a "multi-dimensional" sensitivity function

$$S_e(w) = \sum_i S_{e_i}(w)$$

are defined.

The computer will be used to calculate $S_e(w)|_{w=w_k}$ ($k = 1, 2, 3, \dots, n$) for a given $T(s)$ written out explicitly in terms of e_i .

22-2N013 Industrial Engineering 453. Problem 1. The absolute error is a function of the elemental proportion $P(\%)$ and the number of cycles used to calculate P is given by

$$\text{ABS.ERR.} = \alpha \sqrt{(1-P) P/\text{CYCLES}}$$

95 % confidence

P will be varied from .01 \rightarrow 1.00 (44 different P 's)

Cycles will be varied from 100 \rightarrow 15000 (80 different cycles)

This will yield an n, m matrix of absolute errors ($n = 44, m = 80$)

With each given P_i (for a defined no. of cycles) there is an absolute error given by

$$P_i, i = 1, 2, 3, \dots, n \text{ such that } \sum_{i=1}^n P_i = 1$$

For a given combination of P_i 's the lowest number of cycles that yield $\sum_{i=1}^n (\text{abs error}) \leq 5\%$ is to be found.

23-2N014 Electrical Engineering 322. Problem 2. Compute the magnitude of T in db relative to the value at $\Omega = 0$, and the phase angle in degrees as a function of the radian frequency ' Ω '. T is a network function having three finite poles and no finite zeros. Ω is to be stepped from 0 to 5 in steps of 0.1. Each set of data will consist of three cards with the real part of the pole location punched in columns 1 thru 20, and the imaginary part in columns 21 thru 40. The number of sets of data will be specified on a separate card in the first 20 columns and is to be read in before the first set of data. For this problem, your program must end on a CALL SYSTEM statement, NOT a READ statement.

24-2N037 Electrical Engineering 329. Problem 3. Given a rational function $T(S)$, a ratio of even/odd or odd/even polynomials in S with zeros and poles interlaced along the imaginary axis, it is desired to expand $T(S)$ in the form

$$T(S) = \alpha_1 S + \frac{1}{\alpha_2 S + \frac{1}{\alpha_3 S + \dots}}$$

Such an expansion is useful in the design of filter networks but requires the accuracy of the digital computer to insure accuracy in the α 's. This characteristic of the expansion occurs because of the subtraction of large but nearly equal numbers.

25-2N038 Electrical Engineering 416. Problem 67. A convolution integral will be evaluated in order to familiarize the students with numerical techniques applied to network analysis. The choice of numerical methods and algorithms to be used will be left to the student.

26-2N040 Chemistry 490. Problem 3. Write a FORTRAN function subprogram to compute $F(X)$ where $F(X)$ is the inverse of the function $X = Y^2 + e^Y + \sin Y/2$ (i.e., $Y = F(X)$) $1 \leq X \leq 100$. Indicate an error if X is not in the proper range. Write a FORTRAN driver to check the function subprogram.

27-2N041 Electrical Engineering 416. Problem 77. The signal flow graph of a twin T network is to be entered into the machine as a connection matrix. The computer is to calculate the gain as a function of frequency. The answer is in the form of a curve of gain versus frequency.

28-2N042 Electrical Engineering 416. Problem 66. A convolution integral is to be evaluated numerically. The mathematical method is left up to the student. The estimated error is part of the answer required.

29-2N043 Electrical Engineering 416. Problem 74. A desired frequency response curve is given to the students. The program is to use the simplest approximation technique (corner plots) to arrive at a rational function which approximates the given curve. The actual curve and deviation from specification are required.

30-2N044 Electrical Engineering 416. Problem T2. The Laplace Transform of a function is given as a curve $\text{Re}F(w)$ versus w . The problem is to calculate, numerically, the time function $f(t)$.

31-2N045 Electrical Engineering 426. Problem T1. A time function $f(t)$ is given as a curve. The students are asked to produce the curves of real and imaginary parts of the Fourier Transform of $f(t)$.

32-2N046 Electrical Engineering 331. Problem 1. This project will study the design of filter chokes and various methods of testing them to determine their various characteristics. The computer will be used to design these chokes and also to analytically determine what their characteristics are.

Design of a filter choke involves a general cut and try method of solution where many iterations of the procedure may be necessary before a satisfactory solution is obtained. The analysis of the characteristics of the designed choke employs means of determining various transcendental functions and procedures for integration of some of the variables.

33-2N058 Digital Computer Laboratory 195. Problem 3. The Maclaurin series for a function $f(x)$ is given by:

$$f(x) = f(0) + f'(0) x/1! + f''(0) x^2/2! + \dots + f^{(n)}(0) x^n/n! + \dots$$

where the superscripts denote differentiation.

This series for the sine function is

$$\sin x = x - x^3/3! + x^5/5! - x^7/7! + \dots$$

where x is given in radians (2π radians = 360 degrees).

Write and run a FORTRAN program, using the DO statement where possible which will evaluate $\sin x$ for $x = \pi/4$, $-\pi/8$, and $\pi/10$ varying the number of terms from 1 term to 10 terms.

In addition, calculate the sines using the SIN function statement. Print lines giving:

number of terms, $\sin(\pi/10)$, $\sin(-\pi/8)$, $\sin(\pi/4)$

for each of the computations from the one term approximation to the 10 term approximation. Follow these 10 lines with the SIN function computations, properly lined up, which may be accomplished with a format:

1Hb, 110, 3E20.8

for the term computations, followed by:

1Hb, E30.8, 2E20.8

for the function computation.

34-2N059 Chemistry 421. Problem 1. The field of spectrophotometric determinations of elemental concentrations requires the preparation and use of emulsion calibration curves. It is desired to increase the accuracy and precision of data obtained from film or plate emulsions to such a degree that the major source of error in the method will be those defects inherent in the emulsion itself, rather than in the subsequent processing of the data, which leads to these curves.

At present, two algebraic steps are required to obtain these curves when using the "two step filter" method. The first step requires the use of manually plotted data and the second step involves data read from this first plot, resulting in an emulsion calibration curve.

The proposal is, then, to obtain the equations describing each of these curves, so that errors inherent in data plotting and interpolation will thereby be reduced in an extent proportional to the agreement between the initial data and the generated curve equations.

35-2N076 Digital Computer Laboratory 295. Problem 3. In the key punch room are copies of a deck of approximately 90 cards, each containing the following information:

Columns 1-6	Columns 10-69	70-80
Student ID ##	Student name	blank

this information can be read into the machine by placing the deck behind your program after a \$DATA card. The first part of this program is to "edit" the data, card by card, and write on logical tape 2 one 66 character (11 word) record for each card. This record should contain

6 characters	ID number
66 characters	Student name

This means that the three blanks originally in columns 7-9 of the card must be removed. In addition, some of the cards are "mispunched" in that the student name starts several characters after column 10. These names should be left justified so that they start in the same position as the others. To do this, you have to examine the beginning of the student name for blank character (blank = 111000 in binary) and for each one you see, shift the 60 character name field 6 bits to the left, inserting a blank BCD character at the right. These are to be written on Tape 2.

Part 2 of the program is to sort the entries into order determined by the numerical order of the I/D numbers and print the name and numbers.

PART IX
CONTROL DATA CORPORATION 1604

During the month of November, no new problem specifications were submitted for the CDC 1604.

CDC 1604 TIME DISTRIBUTION
November, 1962

<u>Department</u>	<u>Non-Simile</u>
Agricultural Engineering	2:12
Chemistry	2:39
Civil Engineering	5:01
Electrical Engineering	:14
Physics	<u>2:55</u>
TOTAL	11:01

PART X

GENERAL LABORATORY INFORMATION

Colloquiums

"University of Illinois IBM 7090-1401 Executive System Now and in the Future," by Mr. Ross Flenner, Digital Computer Laboratory, University of Illinois, November 5, 1962

"Computations with Prime Numbers," by Professor Paul T. Bateman, Department of Mathematics, University of Illinois, November 12, 1962

"The Syntax-Controlled Processor for Certain Formal Languages," by Dr. Manfred Paul, Visiting Research Associate from the University of Mainz, Mainz, Germany, and Dr. Hans Wiehle, Visiting Research Associate from Technische Hochschule, Munich, Germany, November 26, 1962

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	14	1	14.5
Visiting Faculty	3	0	3.0
Research Associates	7	0	7.0
Graduate Research Assistants	6	30	23.0
Administrative and Clerical	7	0	7.0
Other Nonacademic Personnel	<u>43</u>	<u>30</u>	<u>55.0</u>
TOTAL	80	61	109.5

The Computer Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, K. C. Smith, J. N. Snyder, and A. H. Taub.

Physics

DIGITAL COMPUTER LABORATORY
UNIVERSITY OF ILLINOIS
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TECHNICAL PROGRESS REPORT

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- PART II - CIRCUIT RESEARCH PROGRAM
- PART III - SWITCHING THEORY
- PART IV - MATHEMATICAL METHODS
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- PART VI - IBM 7090-1401 SYSTEM
- PART VII - INSTRUCTIONAL USE OF THE IBM 7090-1401 SYSTEM
- PART VIII - GENERAL LABORATORY INFORMATION

DECEMBER 1962

PART I
HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Construction Progress

Transistor counts for chassis wired during December are as follows:

7 Drum Logic Chassis	1,055
1 Interplay Chassis	<u>169</u>
TOTAL	1,224

All drawings for drum, interplay and core are presently up-to-date.

2. Component Testing

During December approximately 4,000 transistors and 5,000 diodes have been acceptance tested. The pedigreeing of transistors within the machine is continuing. Detailed records presently exist for about 8,000 transistors in use in high-speed circuits. Tests recently made on a repetitive S chassis which has logged 4,700 hours show no measurable deterioration in use. However, of the 98 2N711A and 47 1S166 involved, two 2N711A were destroyed during measurement, due to an elusive quirk of the test gear.

(B. Doden)

3. Computer Maintenance

The inspection of marginal operation of individual circuits has continued. A very successful technique--the use of a "current probe"--has evolved. By means of a large resistance fed by the +25 or -50 volt supplies

the sensitivity of a particular node of a circuit to more or less current can be established with a minimum of circuit loading effects. The circuit can be arranged to signal its own dynamic failure, when the probe is applied, by virtue of the failure of some particular test routine of which the circuit operation is a critical part.

By this means several defective collector-bump diodes of restoring circuits have been detected.

In addition a combination of fast and slow diodes in F-elements has been demonstrated to cause loss of information in F-elements during gating. This has been cured by an additional test of diode recovery time and the replacement of several dozen slow diodes within the MAU.

The "current probe" technique has also demonstrated in flow gating an unexpected saturation delay by driver transistors to which a small additional load current was applied. Since the normal load on these drivers is extremely bit-pattern dependent, it is expected that this effect may have caused several fleeting faults attributed to flow gating in the past. Several dozen transistors showing this behavior have been replaced.

(B. Doden, R. Kingsley, H. Lopeman,
K. C. Smith)

4. Delayed Control Speed-up

The following control steps or sequences in Delayed Control were modified in order to improve speed of operation:

- a) Multiply
- b) Decode
- c) B sequence (affects CAD, CSB, AND, NOT, LOR, BLS, CAT, CST)
- d) Normalize
- e) Detect Zero and Correct Overflow

In addition, work on the Store sequence was begun.

Improvements were, in approximate figures:

- a) 2.2 μ sec for Multiply
- b) .15 μ sec for Decode (for orders which begin with Normalize)

- c) .5 μ sec for CAD-type orders, and .8 μ sec for logical connectives
- d) .2 μ sec per step in Normalize
- e) .22 μ sec in Detect Zero and Correct Overflow

In the process of speed-up, particularly of the Multiply sequence, a number of marginally-operating circuits were found as a by-product.

The modifications simply consist of the removal of selected reply signals in order to reduce the period a given control step is on, as well as reduce the dead time between sequential steps. The procedure found most efficient is to exercise the control step with a simple program to obtain time measurement with an oscilloscope; then after modification, to apply exhaustive test programs. The actual safety margin (i.e., additional speed-up which could occur before failures would begin) was measured in some cases by temporarily connective an external "overpowering" circuit to the control step by means of a variable delay line. This circuit allows reducing the period for which a step is active, independently of reply signals. In other cases, simple programs which were believed to exercise the longest data paths were written to permit measuring safety margin with an oscilloscope.

The following are operation times indicative of the present state of the machine:

Add (no normalization)	2.5 microseconds
Average multiply	6.6 microseconds
Divide	18.8 microseconds
Memory Cycle	1.8 microseconds

(M. Faiman, R. R. Shively)

5. Present Core Memory

The core memory completed an eight-hour error-free run of the most difficult test program (OLF 11) on December 22. This test, performed at 1.8 μ sec cycle time, constitutes the "acceptance test" for the memory.

The main power transformer in one of the -25-volt power supplies shorted during the month.

(S. R. Ray)

6. New Core Memory

Requests for bids for the second core memory were sent out early in the month. Bids were received on December 28 and are presently being evaluated.

(S. R. Ray)

7. Diagnostic Programming

A "New Computer Programs List" was compiled and distributed, along with a revised index of EST and ETR routines, as part of a continuing effort to make information on current test routines and engineering (maintenance) programs available to all interested staff members. An attempt will be made to re-issue such lists whenever warranted by the accumulation of new routines or changes in old ones.

Written descriptions of two programs were distributed during December: P1-XTT-37v, Crosstalk Test, by M. Levin; and P1-FGT-38v, Flow-Gating Test, by B. Whitten.

A short program (SAMPLER) was written and code checked. This program is to be used with ETR to obtain sample error printouts for those tests in ETR which make use of the print routine in ETR Control.

A new control routine, ETR CON, was written and partially code checked. This control has the following features:

- a) Under normal, unattended operation, only the serial numbers of failed tests will be punched out.
- b) When failures occur during attended operation, the operator may elect to obtain a full punching of failure data.
- c) The operator may elect to repeat indefinitely any test that fails, either before or after obtaining failure data.
- d) After repeating a test a number of times, the data from the initial failure may be recovered if needed.

e) The new control is compatible with current ETR tests.

(R. L. Cummins)

8. Interplay-IBM 1401 Channel

The logic for the 1401 channel is nearly completed. The logic associated with block transfers is finished, but the method of exchanging control and status information between the 1401 and the main frame (NIC) is not firmly established. The logic is predominantly NOR logic and the Interplay Channel Control has been changed into NOR logic.*

A family of circuits suitable for printed circuit boards has been designed. Prototypes of most of these printed circuit boards have been made and are currently being tested. A set of symbols for these circuits has been generated and will be promulgated in the near future.

Voltage regulators for the 1401 channel power supplies are being tested. As long as a 5-volt difference is maintained between the unregulated input and the regulated output, regulation is very good. Some additional filtering appears necessary to suppress transients.

(R. Willard, Y. T. Yen)

9. Interplay-Control and Drum Channel

Block layout for all of interplay except the interplay channel controls has been completed and is either in layout or construction.

A test program for the drum channel has run successfully for over two months as a part of ETR.

(B. Briley, S. Krabbe)

* A File Number will appear shortly.

10. Programming Group

A temporary paper-tape operating system is now available for the new computer. It is described in File No. 498. Work has begun on the assembler for a card operating system to be available in June. A provisional description is given in File No. 496. This work has been planned and programming and checking out of the program has begun and should be complete by mid-March at which time it will be incorporated into an operating system.

(C. W. Gear)

11. Operations

From December 1 to December 31 the computer has operated a total of 647 hours with 44 malfunctions logged exclusive of core parity error indications. These are distributed as follows:

Punch	11
Reader	3
Power Supply	10
Faulty Components	15
Air Conditioning	1
Unknown	4

Parity error indications were prevalent early in the month; a total of 30 were logged. The level of maintenance on the reader and punch has been increased. An overhaul of the power supply system has shown a plethora of bad joints, missing jumpers and marginal components.

(W. Huffman)

PART II
CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary

The investigation of flipflop switching theory carried out by Sergio Ribeiro is essentially completed. Tohru Moto-Oka reports on two hybrid counter circuits using tunnel diodes and emitter followers. Henry Guckel has completed the current series of experiments on tunnel diodes and intercoupled lines, and will prepare a report to be submitted for publication in the near future. Thomas Burnside has worked out some circuit revisions and added features for the statistical analyzer.

2. Flipflop Switching Theory

We have completed the first part of our program.

The main results and techniques for the analysis and design of flip-flops taking into account switching times and waveforms have been completed.

A unified presentation is being worked at and experiments will be carried out with the two-fold purpose of checking the theory and analyzing into inherent sources of error, such as idealization of characteristics (mathematical model versus physical circuit) and approximate treatment of the differential equations.

A final report is being prepared and should be completed soon.

(Sergio Ribeiro)

3. Tunnel-Diode Circuit Theory

The investigations of hybrid circuits are continuing and will be published in report form in the near future. A binary counter composed of hybrid circuits was built; the circuit configuration is shown in Figure 1. It

the circuit of Figure 1 has three emitter followers. Circuit operating speeds are determined mainly by the delay time of emitter followers included in the loop. These circuit configurations can also be used as shift registers.

(Tohru Moto-Oka)

4. Tunnel-Diode Interconnected Systems

Continuation in the work on intercoupled lines resulted in the completion of experiments for all previously discussed cases. Some stability problems were experienced; however, these do not seem too severe. These experiments conclude the verification of the theory.

Theoretical work resulted in the solution of the stability conditions for a single diode termination at the sending end of the secondary line. Since this case includes inverting voltage amplifiers as well as power amplifiers, it is believed that this information is sufficient to publish preliminary results. The stability restriction for the case offers no series restriction for practical cases.

Several sources of diodes were investigated. Since the diodes are to be used in the negative resistance region it was found necessary to improve the measurement technique, which is now used to measure this region. Evaluation of samples ordered from different vendors is in progress.

(H. Guckel)

5. Statistical Analyzer

A delay has been introduced into the counters to insure that the flipflops will not change states more than once during one clock pulse. Two successive NOT circuits on the output of the decoder (February, 1962 progress report, Figure 6, page 11) provide sufficient delay. The revised decoding circuit with delay is shown below in Figure 3.

Counters will be used to record the number of pulses occurring in any output interval (see June, 1962 progress report, Figure 8, page 24). The logic for these counters is shown in Figure 4.

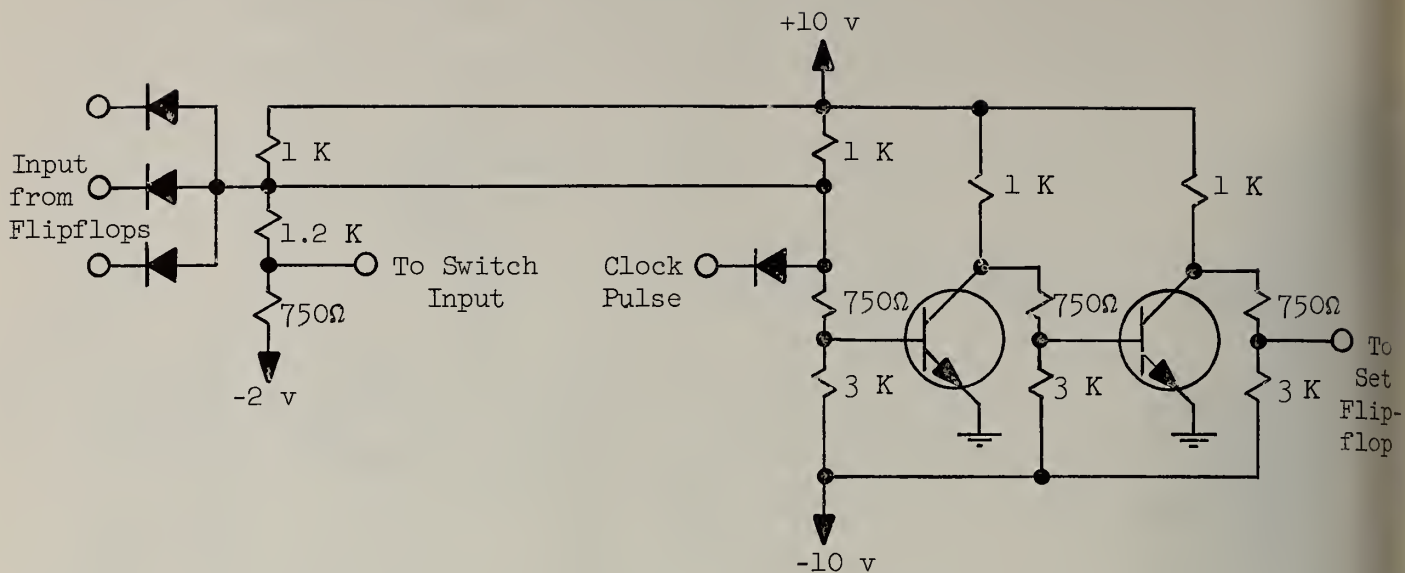


Figure 3 Revised Decoding Circuit with Delay

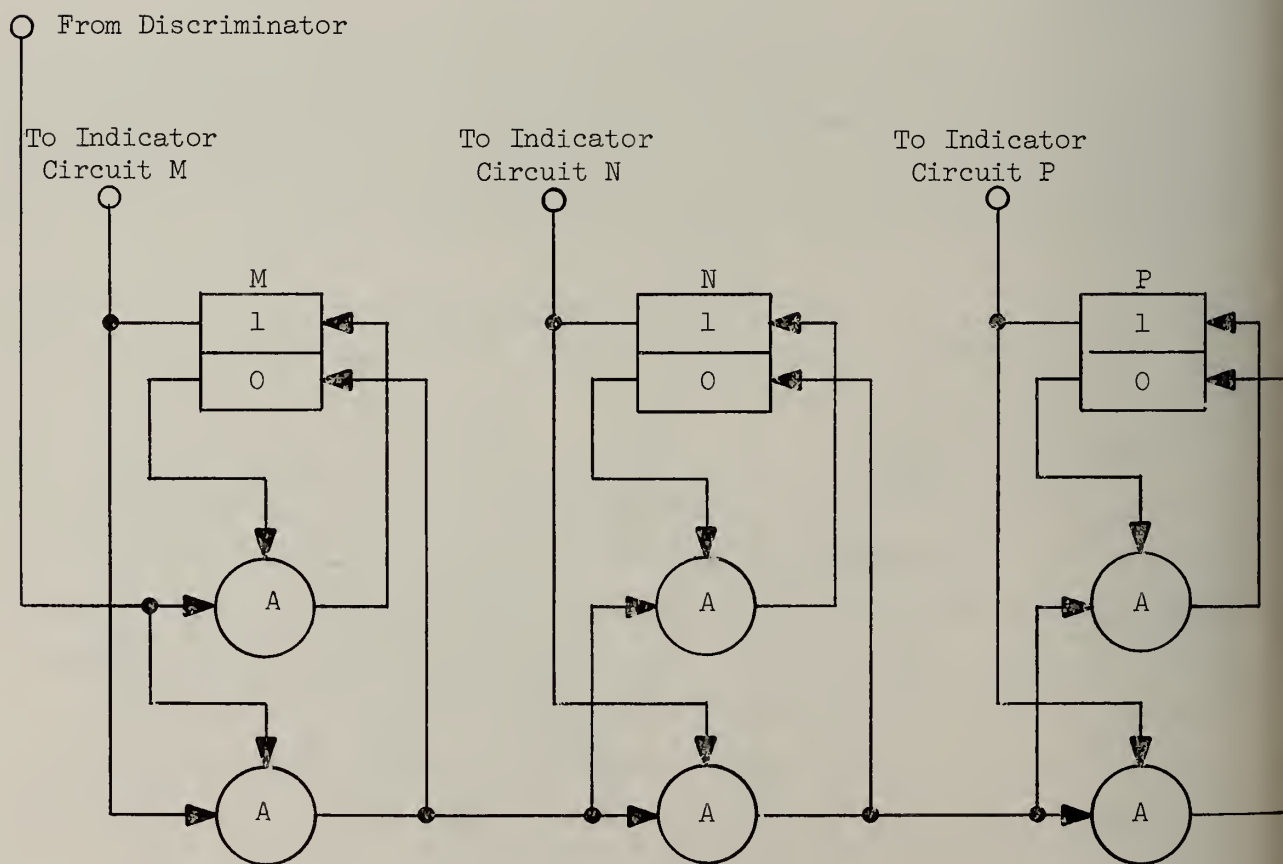


Figure 4 Output Counters

The number of flipflops to be used in a particular counter depends on the number of pulses which one estimates will occur in the corresponding interval. The initial state of each flipflop will be "0." As pulses from the discriminator circuit are counted, the flipflops change state as tabulated in Table 1.

mth Pulse	Flipflop State		
	P	N	M
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Table 1 Tabulated States of Output Counter

Each flipflop of the counter is connected to the light indicator circuit shown in the August, 1962 progress report, Figure 3, page 7.

A circuit has been developed to start the statistical analyzer switching circuits and stop them after the 64th pulse. This circuit was reported in the November progress report. It allowed all possible combinations of the eight voltage sources and the eight diodes to occur. A similar circuit must be provided for the output counters so they will look at the statistical circuit 64 and only 64 times. This similar circuit produces the Delayed One-Megacycle Clock Pulse of Figure 8, page 24 of the June, 1962 progress report. The logic is shown in Figure 5. The circuit is shown in Figure 6.

In Figures 5 and 6, $V_2 = D \vee E \vee F$, where D, E and F are flipflops in the logic of the statistical analyzer. We see that the begin pulse causes the output counters to look at the initial state of the statistical circuit. When the circuit returns to its initial state, $A = 0$, $B = 0$, $C = 0$, $D = 0$, $E = 0$, and $F = 0$; the output counters receive no more pulses.

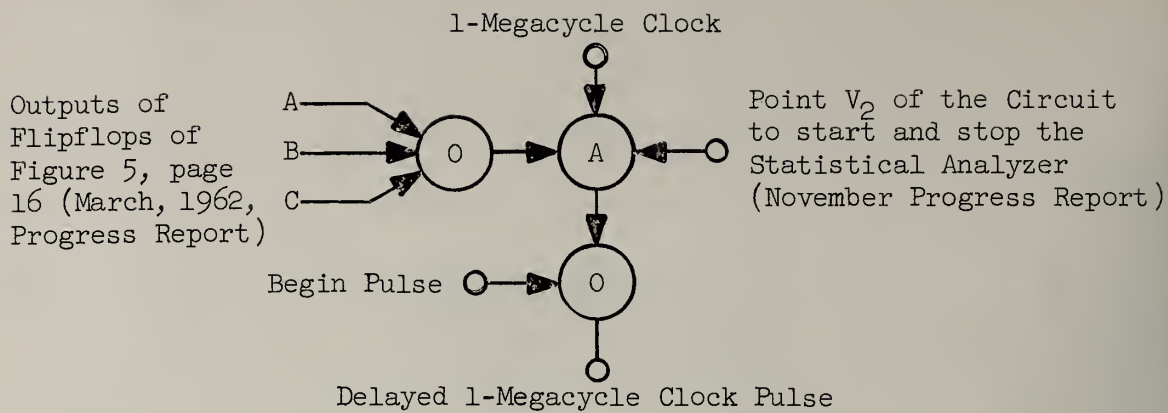


Figure 5 Logic to Start and Stop the Output Counters

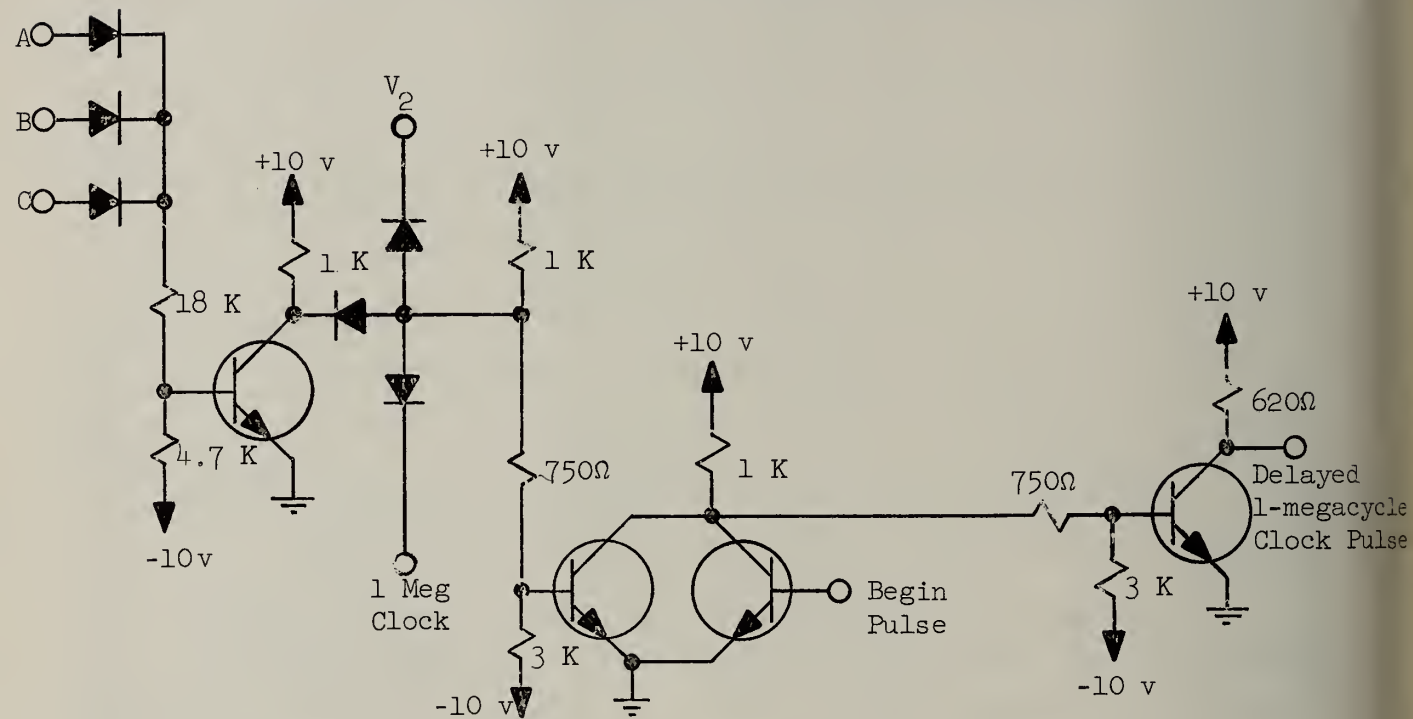


Figure 6 Circuit to Start and Stop the Output Counters

(Thomas Burnside)

PART III
SWITCHING THEORY

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

I.

Consider an element which has a threshold and oscillates for a voltage over the threshold.

Hitherto, a logic circuit system has been constructed by associating with the binary codes 1 and 0 a voltage V and 0 or a current I and 0 or oscillating signals whose phases differ by 180° from each other, i.e., parametron, etc.

In File No. 501, asynchronous logic circuit systems by using other correspondence between binary codes and oscillation signals are discussed as generally as possible. Hereafter we call such systems "Dynamic Asynchronous Logic Circuit (DALC) System."

It is proposed for convenience sake to describe such logic circuit systems by using three-valued complex Boolean algebra. Therefore, the three-valued complex Boolean algebra is also discussed (see File No. 501).

II.

The paper, "Microwave Logic Circuits Using Esaki Diodes," has been submitted to the 1963 International Solid-State Circuits Conference. In this paper, a Dynamic Asynchronous Logic Circuit, in which the oscillatory and non-oscillatory states of an Esaki diode represent the binary levels of a microwave logic system is described.

III.

The calculation of the maximum number of the most efficient error-detecting and correcting codes was attempted by use of Boolean algebra. Some theorems were obtained.

The problem of determining the greatest possible number of combinations such that any two are separated by a Hamming distance equal to or greater than p can be formulated mathematically as follows.

Here, let each code be composed of n binary digit signals. Consider the matrix

$$\begin{array}{cccc} x_{11}, & x_{12}, & \dots, & x_{1n} \\ x_{21}, & x_{22}, & \dots, & x_{2n} \\ . & & & \\ . & & & \\ . & & & \\ x_{m1}, & x_{m2}, & \dots, & x_{mn} \end{array} \quad (1)$$

where, of course each x_{ij} is 0 or 1 and a code is represented by $x_{i1}x_{i2}\dots x_{in}$.

Then our problem is to evaluate the maximum value of m which satisfies

$$|x_{i1} - x_{j1}| + |x_{i2} - x_{j2}| + \dots + |x_{in} - x_{jn}| \geq p \quad (2)$$

for any i, j ($1 \leq i, j \leq m$).

Here Boolean algebra is introduced into the analysis.

Theorem 1

Letting the proposition which is expressed by (2) be designated by F_{ij} ,

$$F_{ij} \equiv \bigvee_n^p (x_{ij}^{r_1} \cdot x_{ij}^{r_2} \dots x_{ij}^{r_p})$$

hold, where

$$X_{ij}^k \equiv (x_{ik} \oplus x'_{jk}), \quad 1 \leq k \leq n, n \geq p \geq 1$$

and the symbols \vee , \cdot , $'$, \oplus are respectively logical sum, logical product, negation, exclusive-or.

Now, (2) is valid for arbitrary integers i, j , which satisfy $i \neq j$, $1 \leq i, j \leq m$. Hence, the following formula holds:

$$\begin{aligned} & F_{12} \cdot F_{13} \cdots F_{1m} \\ & \cdot F_{23} \cdots F_{2m} \\ & \cdot \\ & \cdot \\ & F_{(m-1)m} = 1 \\ & \equiv A_m \end{aligned} \tag{3}$$

(and this formula is designated by A_m). Therefore, our aim is to obtain the largest m which satisfies

$$A_m = 1. \tag{4}$$

Namely, let the largest value of m which satisfies A_m be written m_0 . Then for arbitrary integer m which satisfies $m_0 < m$, A_m becomes identically 0. That is,

$$A_m \equiv 0 \quad \text{when} \quad m > m_0 \tag{5}$$

and

$$A_m \neq 0 \quad \text{when} \quad m \leq m_0. \tag{6}$$

Therefore, there exists a minimum value of m which satisfies $A_m \equiv 0$.

Now the following theorem holds.

Theorem 2

When

$$F = \bigvee_n^p x_{r1} x_{r2} \dots x_{rp}$$

and

$$x_1 + x_2 + \dots + x_n = \alpha_0 + \alpha_1^2 + \alpha_2^2 + \dots \geq p$$

are given,

$$F = \alpha_0 \vee \alpha_1 \vee \alpha_2 \vee \dots \quad \text{for } p = 1$$

$$F = \alpha_1 \vee \alpha_2 \vee \alpha_3 \vee \dots \quad \text{for } p = 2$$

$$F = \alpha_0 \alpha_1 \vee \alpha_2 \vee \alpha_3 \vee \dots \quad \text{for } p = 3$$

$$F = \alpha_2 \vee \alpha_3 \vee \alpha_4 \vee \dots \quad \text{for } p = 4$$

$$F = \alpha_0 \alpha_2 \vee \alpha_2 \vee \alpha_3 \vee \dots \quad \text{for } p = 5$$

$$F = \alpha_1 \alpha_2 \vee \alpha_3 \vee \alpha_4 \vee \dots \quad \text{for } p = 6$$

$$F = \alpha_0 \alpha_1 \alpha_2 \vee \alpha_3 \vee \alpha_4 \vee \dots \quad \text{for } p = 7$$

⋮

hold.

Proof

For example, in the case of $p = 1$,

$$\begin{aligned}
F &= (\alpha'_0 \alpha'_1 \alpha'_2 \dots)' \\
&= \alpha_0 \vee \alpha_1 \vee \alpha_2 \vee \dots
\end{aligned}$$

In the case of $p = 2$,

$$\begin{aligned}
F &= \{(\alpha'_0 \alpha'_1 \alpha'_2 \dots) \vee (\alpha_0 \alpha'_1 \alpha'_2 \dots)\}' \\
&= (\alpha_1 \alpha_2 \dots)' \\
&= \alpha_1 \vee \alpha_2 \vee \dots
\end{aligned}$$

In the case of $p = 5$,

$$\begin{aligned}
F &= \{(\alpha'_0 \alpha'_1 \alpha'_2 \dots) \vee (\alpha_0 \alpha'_1 \alpha'_2 \dots) \vee (\alpha'_0 \alpha_1 \alpha'_2 \alpha'_3 \dots) \vee (\alpha_0 \alpha_1 \alpha'_2 \alpha'_3) \vee (\alpha'_0 \alpha'_1 \alpha_2 \alpha'_3 \alpha'_4 \dots)\}' \\
&= \{(\alpha'_0 \alpha'_1 \alpha'_2 \vee \alpha_0 \alpha'_1 \alpha'_2 \vee \alpha'_0 \alpha_1 \alpha'_2 \vee \alpha_0 \alpha_1 \alpha'_2 \vee \alpha'_0 \alpha'_1 \alpha_2) \alpha'_3 \alpha'_4 \dots\}' \\
&= \{(\alpha'_0 \alpha'_1 \vee \alpha'_2) \alpha'_3 \alpha'_4 \dots\}' \\
&= (\alpha_0 \vee \alpha_1) \alpha_2 \vee \alpha_3 \vee \alpha_4 \vee \dots \\
&= \alpha_0 \alpha_2 \vee \alpha_1 \alpha_2 \vee \alpha_3 \vee \alpha_4 \vee \dots
\end{aligned}$$

The others can be proved similarly.

Theorem 3

When

$$x_1 + x_2 + \dots + x_3 = \alpha_0 + \alpha_1^2 + \alpha_2^2 + \dots$$

is given,

$$\alpha_i = \sum_n^i (x_1, x_2, \dots, x_n)$$

where the symbol $\sum_n^p (x_1, x_2, \dots, x_n)$ means the exclusive-or operation of all the possible combinations of the logical product which is constructed from p elements out of x_1, x_2, \dots, x_n , i.e., for example, in the case of $n = 3, p = 2$,

$$\sum_3^2 (x_1, x_2, x_3) = x_1x_2 \oplus x_2x_3 \oplus x_3x_1$$

Proof

See No. 580 Research Report of Electrotechnical Laboratory (Japanese Government).

Theorem 4

When

$$n \geq 2^{r_1} + 2^{r_2} + \dots + 2^{r_k}$$

and

$$0 \leq r_1 < r_2 < \dots < r_k$$

are given, the following relation

$$2^{r_1+2^{r_2+\dots+2^{r_k}}} = \left(\sum_n^{r_1} \right) \cdot \left(\sum_n^{r_2} \right) \dots \left(\sum_n^{r_k} \right)$$

holds, where each r_i is an integer.

Theorem 5

When $n < 2^{r_1} + 2^{r_2} + \dots + 2^{r_k}$ and $n \geq 2^{r_i}$ for any i ($1 \leq i \leq k$) is given

$$\left(\sum_n^{r_1} \right) \cdot \left(\sum_n^{r_2} \right) \dots \left(\sum_n^{r_k} \right) \equiv 0$$

holds, where each r_i is an integer and $0 \leq r_1 \leq r_2 < \dots < r_k$.

Proof of Theorems 3, 4, 5

See No. 580 Research Report of Electrotechnical Laboratory (Japanese Government) by Y. Komamiya.

Now let $\alpha_0, \alpha_1, \alpha_2, \dots; \beta_0, \beta_1, \beta_2, \dots$ be given by

$$0 \leq x_1 + x_2 + \dots + x_n = \alpha_0 + \alpha_1 2 + \alpha_2 2^2 + \dots + \alpha_r 2^r \leq n \quad (7)$$

and

$$0 \leq x_1 + x_2 + \dots + x_{n-1} = \beta_0 + \beta_1 2 + \beta_r 2^r + \dots + \beta_r 2^r \leq n-1 \quad (8)$$

Then, the following theorem can be easily obtained from Theorems 3, 4, 5.

Theorem 5

$$\alpha_0 = x_n \oplus \beta_0$$

$$\alpha_1 = x_n \beta_0 \oplus \beta_1$$

$$\alpha_2 = x_n \beta_0 \beta_1 \oplus \beta_2$$

$$\alpha_3 = x_n \beta_0 \beta_1 \beta_2 \oplus \beta_3$$

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$$\alpha_r = x_n \beta_0 \beta_1 \beta_2 \dots \beta_{r-1} \oplus \beta_r$$

In general, the following theorem holds.

Theorem 6

$$\begin{aligned} & (a_0 \oplus a_1) \vee (a_0 a_1 \oplus a_2) \vee (a_0 a_1 a_2 \oplus a_3) \vee \dots \vee (a_0 a_1 \dots a_{r-1} \oplus a_r) \\ & = (a_0 \vee a_1 \vee a_2 \vee \dots \vee a_r)(a'_0 \vee a'_1 \vee a'_2 \vee \dots \vee a'_r) \end{aligned}$$

Proof

In the case of $r = 1$, the theorem holds clearly, i.e.,

$$(a_0 \oplus a_1) = (a_0 \vee a_1)(a'_0 \vee a'_1).$$

Assume that the theorem holds in r . Then consider the theorem in $(r+1)$, i.e.,

$$\begin{aligned} & (a_0 \oplus a_1) \vee (a_0 a_1 \oplus a_2) \vee \dots \vee (a_0 a_1 \dots a_{r-1} \oplus a_r) \vee (a_0 a_1 \dots a_r \oplus a_{r+1}) \\ & = (a_0 \vee a_1 \vee \dots \vee a_r)(a'_0 \vee a'_1 \vee \dots \vee a'_r) \vee (a_0 a_1 \dots a_r \oplus a_{r+1}) \\ & = (a_0 \vee a_1 \vee \dots \vee a_r)(a'_0 \vee a'_1 \vee \dots \vee a'_r) \vee a_0 a_1 \dots a_r a'_{r+1} \vee (a'_0 \vee a'_1 \vee \dots \vee a'_r) a_{r+1} \\ & = (a_0 \vee a_1 \vee \dots \vee a_r \vee a_{r+1})(a'_0 \vee a'_1 \vee \dots \vee a'_r) \vee a_0 a_1 \dots a_r a'_{r+1} \\ & = (a_0 \vee a_1 \vee \dots \vee a_r \vee a_{r+1})(a'_0 \vee a'_1 \vee \dots \vee a'_r) \vee a_0 a_1 \dots a_r \\ & \quad (a_0 \vee a_1 \vee \dots \vee a_r \vee a_{r+1}) a'_{r+1} \\ & = (a_0 \vee a_1 \vee \dots \vee a_r \vee a_{r+1})(a'_0 \vee a'_1 \vee \dots \vee a'_r \vee a_0 a_1 \dots a_r a'_{r+1}) \\ & = (a_0 \vee a_1 \vee \dots \vee a_r \vee a_{r+1})(a'_0 \vee a'_1 \vee \dots \vee a'_r \vee a'_{r+1}) \end{aligned}$$

Therefore the theorem has been proved by mathematical induction.

From Eqs. (7), (8) and Theorems 5, 6, the following relation can be obtained.

$$\alpha_0 \alpha_1 \vee \alpha_2 \vee \alpha_3 \vee \dots \vee \alpha_r$$

$$\begin{aligned}
&= (x_n \oplus \beta_0)(x_n \beta_0 \oplus \beta_1) \vee (x_n \beta_0 \beta_1 \oplus \beta_2) \vee (x_n \beta_0 \beta_1 \beta_2 \oplus \beta_3) \vee \dots \vee (x_n \beta_0 \beta_1 \dots \beta_{r-1} \oplus \beta_r) \\
&= (x_n \oplus \beta_0) \beta_1 \vee (x_n \beta_0 \beta_1 \vee \beta_2 \vee \beta_3 \vee \dots \vee \beta_r)(x'_n \vee \beta'_0 \vee \beta'_1 \vee \beta'_2 \vee \beta'_3 \vee \dots \vee \beta'_r) \\
&= (x_n \beta'_0 \beta_1 \vee x'_n \beta_0 \beta_1 \vee x_n \beta_0 \beta_1 \vee \beta_2 \vee \beta_3 \vee \dots \vee \beta_r)(x_n \beta'_0 \beta_1 \vee x'_n \beta_0 \beta_1 \vee x'_n \vee \beta'_0 \\
&\quad \vee \beta'_1 \vee \beta'_2 \vee \beta'_3 \vee \dots \vee \beta'_r) \\
&= (x_n \beta_1 \vee \beta_0 \beta_1 \vee \beta_2 \vee \beta_3 \vee \dots \vee \beta_r)(x'_n \vee \beta'_0 \vee \beta'_1 \vee \beta'_2 \vee \beta'_3 \vee \dots \vee \beta'_r)
\end{aligned} \tag{9}$$

As shown in Eqs. (7), (8), $\beta_0 \beta_1 \dots \beta_r \equiv 0$ holds, because even if $\alpha_0 = \alpha_1 = \dots = \alpha_r = 1$, $\beta_0 = 0$ holds. Therefore in general $\beta_0 \beta_1 \dots \beta_r \equiv 0$ holds. Therefore Eq. (9) becomes

$$\alpha_0 \alpha_1 \vee \alpha_2 \vee \alpha_3 \vee \dots \vee \alpha_r = (x_n \vee \beta_0) \beta_1 \vee \beta_2 \vee \beta_3 \vee \dots \vee \beta_{r-1}. \tag{10}$$

Now, in Theorem 1, let

$$x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^n \equiv \alpha_0^{ij} + \alpha_1^{ij2} + \alpha_2^{ij2^2} + \dots + \alpha_r^{ij2^r}, \tag{11}$$

and

$$x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^{n-1} \equiv \beta_0^{ij} + \beta_1^{ij2} + \beta_2^{ij2^2} + \dots + \beta_r^{ij2^r}. \tag{12}$$

After this, the symbols α_s^{ij} , β_s^{ij} are written as α_s and the suffix is deleted for conciseness.

From Theorems 1, 2 and Eqs. (10), (11), (12), when $n = 2^r$, $p = 3$,

$$\alpha_0 \alpha_1 \vee \alpha_2 \vee \alpha_3 \vee \dots = (x_{ij}^n \vee \beta_0) \beta_1 \vee \beta_2 \vee \dots \vee \beta_{r-1} \tag{13}$$

can be obtained, where $\beta_r \equiv 0$.

Now in general, the following relation holds, i.e.,

$$\begin{aligned}
 & \{(x_n \vee \beta_0)\beta_1 \vee \beta_2 \vee \beta_3 \vee \dots \vee \beta_r\} \{(x'_n \vee \beta'_0)\beta'_1 \vee \beta'_2 \vee \dots \vee \beta'_r\} \\
 &= \{(x_n \oplus \beta_0)(x_n \oplus \beta_1) \vee (x_n \oplus \beta_2) \vee (x_n \oplus \beta_3) \vee \dots \vee (x_n \oplus \beta_r)\} \\
 &\quad \cdot \{(x_n = \beta_1) \vee (x_n = \beta_2) \vee \dots \vee (x_n = \beta_r)\}
 \end{aligned} \tag{14}$$

where $r \geq 2$ (if $r = 1$, both sides are 0).

Proof

$$\begin{aligned}
 \text{The left-hand side of (14)} &= \{(x_n \vee \beta_0)\beta_1 \vee \beta_2 \vee \dots \vee \beta_r\} \{(x'_n \vee \beta'_0)\beta'_1 \vee \beta'_2 \vee \dots \vee \beta'_r\} \\
 &= [(x'_n \beta'_0 \vee \beta'_1) \beta'_2 \beta'_3 \dots \beta'_r \vee (x_n \beta_0 \vee \beta_1) \beta_2 \beta_3 \dots \beta_r]' \\
 &= [x'_n \beta'_0 \beta'_2 \beta'_3 \dots \beta'_r \vee \beta'_1 \beta'_2 \beta'_3 \dots \beta'_r \vee x_n \beta_0 \beta_2 \beta_3 \dots \beta_r \vee \beta_1 \beta_2 \beta_3 \dots \beta_r]' \\
 &= [(x_n \oplus \beta_0)'(x_n \oplus \beta_2)' \dots (x_n \oplus \beta_r)' \vee x_n \beta'_1 \beta'_2 \dots \beta'_r \vee x'_n \beta'_1 \beta'_2 \dots \beta'_r \\
 &\quad \vee x_n \beta_1 \beta_2 \dots \beta_r \vee x'_n \beta_1 \beta_2 \dots \beta_r] \\
 &= [(x_n = \beta_0)(x_n = \beta_2) \dots (x_n = \beta_r) \vee (x_n \oplus \beta_1)(x_n \oplus \beta_2) \dots (x_n \oplus \beta_r) \\
 &\quad \vee (x_n = \beta_1)(x_n = \beta_2) \dots (x_n = \beta_r)]'
 \end{aligned}$$

$$\begin{aligned}
 \text{The right-hand side of (14)} &= \{(x_n \oplus \beta_0)(x_n \oplus \beta_1) \vee (x_n \oplus \beta_2) \vee (x_n \oplus \beta_3) \vee \dots \\
 &\quad \vee (x_n \oplus \beta_r)\} \cdot \{(x_n = \beta_1) \vee (x_n = \beta_2) \vee \dots \vee (x_n = \beta_r)\} \\
 &= [\{ (x_n = \beta_0) \vee (x_n = \beta_1) \} (x_n = \beta_2)(x_n = \beta_3) \dots (x_n = \beta_r) \\
 &\quad \vee (x_n \oplus \beta_1)(x_n \oplus \beta_2) \dots (x_n \oplus \beta_r)]'
 \end{aligned}$$

$$= [(x_n = \beta_0)(x_n = \beta_2)(x_n = \beta_3) \dots (x_n = \beta_r) \vee (x_n = \beta_1)(x_n = \beta_2) \dots (x_n = \beta_r) \\ \vee (x_n \oplus \beta_1)(x_n \oplus \beta_2) \dots (x_n \oplus \beta_r)]'$$

= the left-hand side of (14).

The following relation can be obtained in general from (14).

$$\begin{aligned} & \{(x_{ij}^n \vee \beta_0)\beta_1 \vee \beta_2 \vee \dots \vee \beta_{r-1}\}\{(x_{ij}^{n'} \vee \beta_0')\beta_1' \vee \beta_2' \vee \dots \vee \beta_{r-1}'\} \\ &= \{(x_{ij}^n \oplus \beta_0)(x_{ij}^n \oplus \beta_1) \vee (x_{ij}^n \oplus \beta_2) \vee \dots \vee (x_{ij}^n \oplus \beta_{r-1})\} \quad (15) \\ & \cdot \{(x_{ij}^n = \beta_1) \vee (x_{ij}^n = \beta_2) \vee \dots \vee (x_{ij}^n = \beta_{r-1})\} \end{aligned}$$

where $r \geq 3$.

When $n = 2^r$, $n - 1 = 2^{r-1} + 2^{r-2} + \dots + 2 + 1$ holds. Accordingly, from (12),

$$(n-1) - (x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^{n-1}) = (2^{r-1} + 2^{r-2} + \dots + 2 + 1) - (\beta_0 + \beta_1 2 + \dots + \beta_{r-1} 2^{r-1})$$

can be obtained. Therefore

$$(x_{ij}^1)' + (x_{ij}^2)' + \dots + (x_{ij}^{n-1})' = \beta_0' + \beta_1' 2 + \dots + \beta_{r-1}' 2^{r-1} \quad (16)$$

holds. Therefore

$$[\{(x_{ij}^n)' \vee \beta_0'\}\beta_1' \vee \beta_2' \vee \dots \vee \beta_{r-1}'] = \{(x_{ij}^1)' + (x_{ij}^2)' + \dots + (x_{ij}^{n-1})' + (x_{ij}^n)' \geq 3\}$$

holds. Here

$$\{(x_{ij}^1)' + (x_{ij}^2)' + \dots + (x_{ij}^{n-1})' + (x_{ij}^n)' \geq 3\} = \{(x_{ij}^1) + \dots + (x_{ij}^n) \leq 2^r - 3\} \quad (17)$$

holds where $r \geq 3$.

Therefore

$$\begin{aligned}
 & \{(x_{ij}^n \vee \beta_0)\beta_1 \vee \beta_2 \vee \dots \vee \beta_{r-1}\}[(x_{ij}^n)' \vee \beta_0']\beta_1' \vee \beta_2' \vee \dots \vee \beta_{r-1}' \\
 &= (x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^n \geq 3)(x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^n \leq (2^r - 3)) \quad (18) \\
 &= \{3 \leq x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^n \leq (2^r - 3)\}
 \end{aligned}$$

holds where $r \geq 3$.

On the other hand, consider, in (12),

$$(x_{ij}^1 \oplus x_{ij}^n) + (x_{ij}^2 \oplus x_{ij}^n) + \dots + (x_{ij}^{n-1} \oplus x_{ij}^n) \quad (19)$$

where $n = 2^r$. Then,

$$\begin{aligned}
 (19) &= x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^{n-1} + (2^r - 1)x_{ij}^n - 2(2^r - 1)x_{ij}^n(x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^{n-1}) \\
 &= \beta_0 + \beta_1 2 + \beta_2 2^2 + \dots + \beta_{r-1} 2^{r-1} + (2^r - 1)x_{ij}^n - 2(2^r - 1)x_{ij}^n(\beta_0 + \beta_1 2 + \dots \\
 &\quad + \beta_{r-1} 2^{r-1}) \\
 &= (\beta_0 + x_{ij}^n - 2\beta_0 x_{ij}^n) + (\beta_1 + x_{ij}^n - 2\beta_1 x_{ij}^n)2 + \dots + (\beta_{r-1} + x_{ij}^n - 2\beta_{r-1} x_{ij}^n)2^{r-1} \\
 &= (\beta_0 \oplus x_{ij}^n) + (\beta_1 \oplus x_{ij}^n)2 + \dots + (\beta_{r-1} \oplus x_{ij}^n)2^{r-1} \quad (20)
 \end{aligned}$$

can be obtained.

Therefore

$$\begin{aligned}
 & (x_{ij}^1 \oplus x_{ij}^n) + (x_{ij}^2 \oplus x_{ij}^n) + \dots + (x_{ij}^{n-1} \oplus x_{ij}^n) \\
 &= (\beta_0 \oplus x_{ij}^n) + (\beta_1 \oplus x_{ij}^n)2 + \dots + (\beta_{r-1} \oplus x_{ij}^n)2^{r-1} \quad (20')
 \end{aligned}$$

holds. Therefore

$$\begin{aligned} & \{(X_{ij}^n \oplus \beta_0)(X_{ij}^n \oplus \beta_1) \vee (X_{ij}^n \oplus \beta_2) \vee \dots \vee (X_{ij}^n \oplus \beta_{r-1})\} \\ & = \{(X_{ij}^1 \oplus X_{ij}^n) + (X_{ij}^2 \oplus X_{ij}^n) + \dots + (X_{ij}^{n-1} \oplus X_{ij}^n) \geq 3\} \end{aligned} \quad (21)$$

can be obtained from (20').

As $n = 2^r$, $r \geq 3$,

$$\begin{aligned} & (X_{ij}^1 = X_{ij}^n) + (X_{ij}^2 = X_{ij}^n) + \dots + (X_{ij}^{n-1} = X_{ij}^n) \\ & = (\beta_0 = X_{ij}^n) + (\beta_1 = X_{ij}^n)2 + \dots + (\beta_{r-1} = X_{ij}^n)2^{r-1} \end{aligned} \quad (22)$$

can be obtained from (20'). Therefore

$$\begin{aligned} & \{(X_{ij}^n = \beta_1) \vee (X_{ij}^n = \beta_2) \vee \dots \vee (X_{ij}^n = \beta_{r-1})\} \\ & = [\{(X_{ij}^1 = X_{ij}^n) + (X_{ij}^2 = X_{ij}^n) + \dots + (X_{ij}^{n-1} = X_{ij}^n) \geq 2\} \end{aligned} \quad (23)$$

can be obtained from (22).

Here

$$\begin{aligned} & \{(X_{ij}^1 = X_{ij}^n) + (X_{ij}^2 = X_{ij}^n) + \dots + (X_{ij}^{n-1} = X_{ij}^n) \geq 2\} \\ & = [(n-1) - \{(X_{ij}^1 = X_{ij}^n) + \dots + (X_{ij}^{n-1} = X_{ij}^n)\}] \leq 2^r - 1 - 2 \\ & = \{(X_{ij}^1 \oplus X_{ij}^n) + (X_{ij}^2 \oplus X_{ij}^n) + \dots + (X_{ij}^{n-1} \oplus X_{ij}^n) \leq 2^r - 3\} \end{aligned} \quad (24)$$

holds. Therefore, from (21) and (24),

$$\{(x_{ij}^n \oplus \beta_0)(x_{ij}^n \oplus \beta_1) \vee (x_{ij}^n \oplus \beta_2) \vee \dots \vee (x_{ij}^n \oplus \beta_{r-1})$$

$$\cdot \{(x_{ij}^n = \beta_1) \vee (x_{ij}^n = \beta_2) \vee \dots \vee (x_{ij}^n = \beta_{r-1})\} \quad (25)$$

$$= \{3 \leq (x_{ij}^1 \oplus x_{ij}^n) + \dots + (x_{ij}^{n-1} \oplus x_{ij}^n) \leq 2^r - 3\}$$

can be obtained, where $r \geq 3$.

Therefore, from Eqs. (15), (18), (25),

$$\{3 \leq x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^n \leq 2^r - 3\}$$

(26)

$$= \{3 \leq (x_{ij}^1 \oplus x_{ij}^n) + (x_{ij}^2 \oplus x_{ij}^n) + \dots + (x_{ij}^{n-1} \oplus x_{ij}^n) \leq 2^r - 3\}$$

can be obtained, where $n = 2^r$, $r \geq 3$.

As the following relation

$$\begin{aligned} x_{ij}^k \oplus x_{ij}^n &= (x_{ik} \oplus x_{jk}) \oplus (x_{in} \oplus x_{jn}) \\ &= (x_{ik} \oplus x_{in}) \oplus (x_{jk} \oplus x_{jn}) \end{aligned}$$

holds, considering the matrix (1) and (27),

$$\begin{pmatrix} x_{11} \oplus x_{1n}, & x_{12} \oplus x_{1n}, & \dots, & x_{1n-1} \oplus x_{1n} \\ x_{21} \oplus x_{2n}, & x_{22} \oplus x_{2n}, & \dots, & x_{2n-1} \oplus x_{2n} \\ \vdots & & & \\ x_{m1} \oplus x_{mn}, & x_{m2} \oplus x_{mn}, & \dots, & x_{m(n-1)} \oplus x_{mn} \end{pmatrix} \quad (27)$$

Eq. (26) means that the maximum number of n digit codes whose distances are $3 \leq \text{distance} \leq 2^r - 1$ is equal to the maximum number of $(n - 1)$ digit codes whose distances are $3 \leq \text{distance} \leq 2^r - 1$, where $n = 2^r$, $r \geq 3$.

Ex. $n = 8, p = 3.$

$$\{3 \leq x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^8 \leq 5\} = \{3 \leq (x_{ij}^1 \oplus x_{ij}^8) + (x_{ij}^2 \oplus x_{ij}^8) + \dots + (x_{ij}^n \oplus x_{ij}^8) \leq 5\}$$

(Yasuo Komamiya)

PART IV
MATHEMATICAL METHODS

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

Monte Carlo Calculations: Quantum Statistics

Work on the program FJ-17 continued. This is a program designed to calculate ξ , a two-particle, three-dimensional conditional Wiener integral of the functional F where

$$F = \exp\left\{-\beta \int_0^1 V(x(\tau)) d\tau\right\}$$

and V is a potential function of the form

$$V = \alpha \left[\frac{1}{r^{12}} - \frac{1}{r^6} \right],$$

x is the generalized (six-dimensional) position coordinate, r is the distance between the particles, and α and β are constants. This quantity ξ arises in an approximation of the partition function for liquid helium (S. G. Brush, Proc. Roy. Soc. 242A, 544 (1957)) and it is also closely related to the second virial coefficient for the above potential function.

(Lloyd D. Fosdick, Harry Jordan)

PART V
ILLIAC USE AND OPERATION

The Illiac was officially removed from service at the end of the month of December. The last day for submitting production work to Illiac was December 22. In order to complete the work which had been submitted by that time, it was necessary to operate Illiac for several days at the beginning of January. This time is included in the log information for the month of December which follows.

Illiac Usage

During the month of January, specifications were presented for two problems. This does not indicate how the Illiac was used, because large amounts of machine time may have been consumed by problems with numbers less than 2244.

2244 Digital Computer Laboratory. Computer-Motion Picture Techniques. The solutions to a problem in dynamics can often be best displayed by a motion picture in which successive frames show the solutions at successive instants of time. A number of such films have been produced on Illiac in the last few years, and several of them are to be collected together in one demonstration film.

The purpose of the present program is to prepare two additional films in which functions of two space variables and time are represented by contours of constant value.

2245 Digital Computer Laboratory. Polynomial Approximation for Logarithm Coefficients. Starting with a polynomial approximation to the logarithm, the above program will be used to reduce the degree of polynomial and keep the same accuracy. This new polynomial will be used in a logarithm subroutine for the new Illinois computer.

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 a.m. and 10:30 a.m. Since the periods between 7:00 a.m. and 10:30 a.m., together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 and 7:00 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7:00 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table III, and a summary is given in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in Table III. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

TABLE II

Reader	8
Memory	7
Drum	8
Unknown	<u>4</u>
TOTAL	27

Table I shows the distribution of Illiac machine time for the month of December.

TABLE I

	Hrs:Min
Scheduled Maintenance	69:04
Unscheduled Maintenance	21:46
Leapfrog	5:28
Drum Engineering	7:44
Wasted	<u>:13</u>
	104:15

Use by Departments

Agricultural Economics (APPRAISAL 47 15 05 334)	:13
Agricultural Economics	2:29
Agronomy	2:06
Bureau of Educational Research (PH-M1839)	10:24
Chemistry	56:00
Civil Engineering	158:08
Coordinated Science Laboratory (DA-36-039-SC56695)	50:36
Digital Computer Laboratory	15:08
Electrical Engineering (AF 7043)	3:00
Electrical Engineering (NSFG 19005)	:10
Electrical Engineering (NSF 25148)	7:14
Electrical Engineering (NASA-NSG 24-59)	:10
Geological Survey	11:35
Geology (IC GRAD GEOLOGY)	:07
Institute for Communications Research (MH 06739)	20:06
Institute for Communications Research	12:30
Mechanical Engineering	55:45
Mining and Metallurgical Engineering (TRUS AF6770)	:58
Mining and Metallurgical Engineering	:47
Nuclear Engineering	:08
Office of Instructional TV	:22
Physics (NONR 1834(05))	7:46
Physics (NSFG 17428)	:03
Psychology (M 1774)	:46
Psychology (US NONR 1834 (39))	:23
Psychology	136:11
State Water Survey	7:05
Theoretical and Applied Mechanics (NOBS 72069)	:40
Theoretical and Applied Mech. (DA-01-021 ORD11878)	:11
Theoretical and Applied Mechanics	<u>:03</u>
	<u>361:04</u>
	<u>465:19</u>

TABLE III

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG STOPPING LEAPFROG	FAILURES STOPPING LEAPFROG
12/3/62	20:10	:42	3:08	1	(1) Unknown.	:00	:17	0
12/4/62	20:20	:12	3:28	1	(1) Memory position 2 ⁻¹⁴ .	:00	:37	0
12/5/62	20:39	:00	3:21	0		:00	:10	0
12/6/62	20:39	:04	3:17	1	(1) Reader "J" failed.	:00	:00	0
12/7/62	20:24	1:19	2:15	2	(1) Drum failure. (2) Drum failure.	:02	:11	0
12/10/62	20:04	:00	3:56	0		:00	:06	0
12/11/62	14:13	6:13	3:34	3	(1) Drum failure. (2) Reader D failed. (3) Drum failure.	:00	:09	0
12/12/62	21:20	:00	2:40	0		:00	:21	0
12/13/62	19:35	:35	3:50	1	(1) Memory failure many locations.	:00	:00	0
12/14/62	21:06	:14	2:40	1	(1) Reader "I" failed.	:00	:00	0
12/15/62	24:00	:00	:00	0		:00	:10	0
12/16/62	23:50	:10	:00	1	(1) Unknown.	:00	:11	0
12/17/62	19:56	1:19	2:45	1	(1) Memory position 2 ⁻²³ , 2 ⁻²⁴ .	:00	:00	0
12/18/62	18:00	2:28	3:32	1	(1) Drum failure.	:00	:00	0
12/19/62	19:39	1:04	3:17	2	(1) Unknown, (2) Drum failure.	:00	:00	0
12/20/62	20:30	:15	3:15	1	(1) Reader "J" failed.	:00	:10	0
12/21/62	19:43	1:47	2:30	1	(1) Drum failure.	:00	:20	0
12/22/62	23:52	:08	:00	1	(1) Reader voltage low.	:00	:10	1
12/23/62	23:35	:25	:00	1	(1) Reader "J" failed.	:00	:20	0
12/24/62	4:00	:00	:00	0		:00	:08	0
12/26/62	21:16	:00	2:44	0	(1) Memory location 2 ⁻²² .	:00	:19	0
12/27/62	18:05	2:20	3:35	1	(1) Drum shut down for repairs.	:00	:56	0
12/28/62	20:52	:30	2:38	1	(1) Reader "J" failed. (2) Unknown.	:00	:00	0
12/29/62	23:00	1:00	:00	2		:00	:00	0
12/30/62	24:00	:00	:00	0		:00	:11	0
12/31/62	6:49	:00	2:11	0		:00	:20	0
1/2/63	20:30	:00	3:30	0		:00	:09	0
1/3/63	20:10	:38	3:12	2	(1) Reader "D" failed. (2) Memory position 2 ⁻³⁸ .	:00	:17	0
1/4/63	20:55	1:03	2:02	2	(1) Memory position 2 ⁻²⁶ . (2) Memory position 2 ⁻³¹ .	:00	:00	0
1/7/63	2:54	:00	1:25	0		:00	:00	0
TOTALS	574:06	22:26	68:45	27		:02	5:32	1

PART VI
IBM 7090-1401 SYSTEM

(Supported in Part by the National Science Foundation under Grant No. NSF-GP-700)

A National Science Foundation grant plus a substantial contribution by the University made it possible to purchase the IBM 7090-1401 System during the month of December.

During the month of December, two new routines were added to the IBM 7090 Library.

J5-UØI-SCPl-23-S General Axes and Point Plotter. This is a general program which will plot axes, labels and sets of points on the output oscilloscope. By means of parameters, the axes can be arbitrarily positioned and subdivided. Either fixed point or floating point numbers will be accepted. The routine also offers a mode of operation in which a given set of data will be automatically scaled and provided with the proper set of axes.

(D. Hutchinson)

B4-UØI-SQR3-24-S Fixed Point Square Root. This routine will extract the square root of a double precision non-negative fixed point fraction with an error less than 2^{-35} .

(D. Hutchinson, S. Wolfe)

During the month of December 40 problem specifications were submitted for the IBM 7090.

138-2D001 Electrical Engineering. Least-Square Method for Sum of Three Exponentials. In order to gain some insight into the nature of leukemia, experimenters inject a radioactive tracer into the blood stream of a person and subsequently measure the activity in the blood at different time intervals. The question arises as to what kind of information can be obtained from this experimental data. To this end theoretical work has been undertaken and, to a reasonable degree of accuracy, the problem has been reduced to that of solving a system of simultaneous differential equations of first order. The activity as a function of time can then be obtained explicitly and in general it will be a function involving the sum of decaying exponential functions of time, the coefficients depending on the exponents (time constants). The time constants and in turn the coefficients may be obtained by applying the least-square method to the experimental data.

139-2D002 Physics. Neutronics Codes. As part of their work in the course, the students in this course should acquire familiarity with existing codes used in reactor analysis in major government or industrial laboratories. The class is split into 5 groups, and each of these groups will attempt to make one of the standard neutron transport theory or reactor kinetics code operational on the University of Illinois IBM 7090 computer.

The problems which will be investigated with the aid of these codes are calculation of average neutron cross sections, solution of the Boltzmann equation for reactor criticality, solution of the multigroup diffusion equations, and problems in non-linear reactor dynamics.

140-2N088 Mining, Metallurgy and Petroleum Engineering. Roof Slab on Elastic Pillars. The object of the program is to calculate the deflections, and the maximum and minimum moments at points in an elastic mine roof slab supported by elastic pillars and other elastic supports. Uniform loading of the slab is approximated by point loading over a square grid, and the method of difference equations is used.

The program first solves a system of simultaneous equations to obtain deflections of each point on the grid. Then these deflections are used to calculate moments.

141-2D005T Animal Science. Relationships Between Physical Measures and Lean Yield in Beef Carcasses. Within currently accepted categories for value of beef carcasses, preliminary work has indicated dramatic differences in lean yield. Inasmuch as lean yield is accepted as one of the paramount criteria in value establishment, the Department of Animal Science has embarked on a program of data collection aimed at defining these variations. Physical measurements which are easily and inexpensively determined have been employed and regression analyses of the data should reveal relationships which exist between the measurements and lean yields. Success in this venture should lead to more accurate and meaningful market designations and should also provide essential guide lines for breeding and selection for improvement in the way of proportionate lean yields in beef carcasses.

142-2D006T Civil Engineering. Analysis of Hydrographs. The object of the program is to carry out an analysis of hydrographs using Laplace transforms. The Laplace transforms of the rainfall data and of the runoff flow data will be formed by numerical integration. The Laplace transform of instantaneous unit hydrograph will be computed from the rainfall and runoff transforms and will then be further analysed if necessary.

143-2D007 State Geological Survey. Gravity Survey of Northeastern Illinois. The problem is basically the reduction of gravity data obtained from a field survey of North-eastern Illinois.

The observed data includes county code, station number, observer, station coordinates, station elevation, and observed gravity for each field location.

Data manipulations involve the attainment of the theoretical gravity, free air and Bouguer anomalies associated with each station, and further, a gravity residual and the second derivative of the vertical component of gravity at each station.

144-2D015T Electrical Engineering. Many-valued Logics. In investigating the properties of many-valued logics, it is necessary to make numerical computations involving a great many operations. In evaluating relative logical strength, or the generating sequences for partitioning more than 1000 terms are required. The principal unit operations required, however, are no more complex than finding factorials, differentiating polynomials, grouping terms, etc.

145-2D012T Physiology. Voluntary Dehydration. The problem is to try and define some of the physiological parameters that show a relationship to voluntary dehydration in man. Voluntary dehydration is, essentially, the lag in voluntary rehydration following dehydration. Since this phenomenon has never been previously studied from this point of view, the first step in the solution is to determine which factors of bodily function to measure. Thus data from 100 male subjects will be factor analyzed to determine which of them correlates closely with voluntary water intake. The 7090 can perform the principal axis factor analysis required.

Additional data is now being collected and it will be analyzed using multivariate analytical techniques, probably a four way analysis of variance.

146-2D014T Veterinary Anatomy and Histology. I_{131} Uptake in Normal and Thyroidectomized Pigs. Two groups of twenty-four pigs were studied to determine the effect of surgical thyroidectomy. Male and female pigs of mixed and miniature breeds were used.

All pigs were weighed and given a pre-treatment I_{131} uptake test. Half of the pigs in each group were thyroidectomized, and the excized tissue was weighed. At 36 days, all pigs were again weighed, and an in vitro test for thyroid activity was performed. At 64 days all pigs were weighed again and I_{131} uptake determined. The pigs were then killed, and thyroid tissue was removed from all animals and weighed (normal thyroid glands from unoperated animals, and accessory thyroid tissue from thyroidectomized animals.) The basic differences in treatment between the two groups were that group 2 was started on experiment about 3 months after group 1 and at 36 days after initiation of the experiment, group 2 was given I_{131} to determine thyroid uptake. In all other respects, each group was treated similarly.

Standard library routines will be used in the analysis. The method of least squares will be used.

147-2D010 Physics. Nuclear Data Analysis. The primary object of this research is the analysis of experimental cross sections for neutron and proton induced reactions. The aim is to fit the experimental data in terms of the Wigner Multilevel-Multichannel Model.

The first set of trial problems will deal with low-energy neutron reactions in order to account for the Doppler Broadening. In general, appropriate least square fit subroutines will be heavily involved. Some of these routines will involve expansion in orthonormal sets (Spherical harmonics, Bessel functions, Hermite polynomials) for which appropriate subroutines will be developed.

As far as the neutron data analysis is concerned, large amounts of experimental data from Brookhaven National Laboratory and from Oak Ridge have been obtained.

148-2D016 State Water Survey. Drop Size Distributions. Basically this problem consists of determining the drop size-frequency distribution from individual measurements of the rain drops. From this frequency table the rainfall rate, the radar reflectivity, the liquid water content, and the radar attenuation cross section are obtained by a matrix multiplication. The drop size which divides the total liquid water content in half (median volume diameter) is computed.

The frequency distributions are then classified as to type (monatonic, unimodal, bimodal, or non-conformist) and measures of the mode (if it exists) and the width of the distributions are obtained.

Later the variables of rainfall rate, radar reflectivity, liquid water content will be correlated with one another for various weather conditions in the hope of improving the accuracy of radar in measuring precipitation.

149-2D018T Civil Engineering. Inelastic Frame Stability. This problem is one of finding the collapse load for rectangular steel frames loaded into the inelastic range.

The solution consists of first developing a table of Moment-Thrust-Curvature relationships for the particular members of which the frame is composed, and then, using this table, finding the maximum load to which the frame may be subjected, by successive numerical iterations to convergence, before a state of unstable equilibrium results.

Only one library subroutine will be employed: floating point square root.

All the mathematical expressions involved are relatively simple, algebraic equations, but a great deal of logical programming is required.

As a state of neutral equilibrium is approached, and as portions of the frame become inelastic, convergence will be slower for successive load increments. This will result in a large number (probably 30-50 maximum) of cycles for some increments on short stiff frames. It may require 15 to 20 such increments to the loading before a final, so-called "critical", load is obtained. There will be in the neighborhood of 120 such "critical" loads to be calculated.

150-2D019 Mechanical Engineering. Gear Design and Appraisal. A program for the IBM 7090 will be developed that will design and appraise a pair of involute spur gears based on the three criteria: strength, scoring, and wear. It will consist mainly of computations defining these criteria in terms of tooth geometry. An initial tooth geometry will then be modified in an iterative manner until the desired criteria are satisfied with certain prescribed optimum limits for both gears of a meshing pair operating under given power input conditions.

At present it is anticipated that only available library routines will be needed.

151-2D020 Electrical Engineering. Sensitivity Calculation. Given an electrical network N composed of elements e_i which may vary within certain tolerances, it is desired to compute the sensitivity of certain network functions to changes in the elements. In particular, a sensitivity function

$$S^z = dz$$

where $z(s, e_1, e_2, e_3 \dots e_n)$ is a network function in terms of the Laplace Transform variable S , is calculated for imaginary values of s ($s=jw$), using finite difference approximation to the differentials. Many networks will be compared on this basis.

152-2D021 Agronomy. The Transient Phase of Two Dimensional Flow. A parabolic partial differential equation with nonlinear boundary conditions is to be treated. Using finite difference methods the approximate solution of this differential equation is reducible to "almost" tridiagonal form:

$$\begin{bmatrix} A_0 & -B_0 & C_0 \\ & A_1 & -B_1 & C_1 \\ & & \dots & \dots & \dots \\ & & & A_{n-2} & -B_{n-2} & C_{n-2} \\ & & & & A_{n-1} & -B_{n-1} \end{bmatrix} \begin{bmatrix} T_0 \\ T_1 \\ \vdots \\ \vdots \\ T_{n-1} \end{bmatrix} = \begin{bmatrix} -H_0 & -F(T_0) \\ -H_1 \\ \vdots \\ \vdots \\ -H_{n-1} \end{bmatrix},$$

where the expression $F = F(T_0)$ in the 1st row of the right hand column matrix H is an exponential type function of T_0 , the 1st component of the vector T .

The system will be solved by making a first guess at T_0 based on given boundary conditions, and then using successive iterations. Thus the system is treated in a linear manner. A special algorithm, derived from the Gaussian elimination technique, will be used to solve the resulting tridiagonal linear

system. During the integration of a new point or vector value T, the convergence of the integrative process will be monitored. In the event of unsatisfactory convergence progress, this process will be terminated as specified by an input quantity. A typical matrix size will be between 25 x 25 and 100 x 100. In a typical run, between 50 to 150 values of the vector T will be integrated.

153-2D022T Theoretical and Applied Mechanics. Stresses in Plane, Multiply Connected Regions. The problem to be dealt with is that of finding stress distributions in plane, multiply connected regions by means of the complex variable method. A general solution of a plane elasticity problem may be written in terms of two functions of a complex variable which are analytic in the region in question. The second of these functions may be replaced by relating it to the first function defined in the region across the boundary. The problem of finding this first function is then reduced to a singular integral equation for which the solution is known to be the sum of a Cauchy integral over each of the bounding contours plus an unknown function which is analytic in the region and continuous across the boundary. The form of this unknown function is taken to be a Laurent series about a point outside the region. If the region is multiply connected, the second function is replaced by the first defined in the region across each of the bounding contours. This results in an independent expression for the second function for each contour. The coefficients in the Laurent series are determined by requiring that these expressions be identical and that the second function be analytic in the original region. This results in an infinite set of linear algebraic equations for these coefficients. Truncating the series at an arbitrary number of terms, a finite set of linear algebraic equations is obtained. These linear algebraic equations will be generated by the machine and then solved for the various physical parameters.

154-2D023T Theoretical and Applied Mechanics. Elastic Plastic Analysis of Tapered Beams Subjected to Point Loads. This research problem is the elastic-plastic analysis of tapered beams subjected to point loads. It will be assumed that the elastic-plastic boundary will propagate inward from the boundary of the beam by closely following the family of iso-octahedral shear stress curves. This family of curves will be found by solving a fourth order algebraic equation of the form

$$Ar^4 - Br^2 - Cr - D = 0$$

where A, B, C, and D are constants determined by the material properties and dimensions of the beam. The problem will involve sweeping across the beam and obtaining a sufficient number of roots of the equation above to be able to plot the family of curves desired.

155-2D025 Physics. Counts versus Channel. This program will divide each of 200 numbers representing radiation counts by each of 200 corresponding numbers representing associated background. Each radiation count number has a channel number for identification and each corresponding background number also has a channel number. A plot of radiation counts, divided by background, versus channel numbers will then be made by the computer, and channel numbers, as well as the result of the division will be printed out. Since several experiments will be run, each plot and each set of printed results will be identified.

156-2D026 Psychology. Parental Attitudes and Behaviors. This investigation is concerned with the study of parental attitudes and behaviors and their relationships with child personality structure. Inquiry is being made by questionnaires constructed by the principal investigator. Present planned analysis is by correlational and factor analytic techniques which will be effected by the 7090 installation through programs available from the Statistical Services Research Division.

157-2D027 Psychology. Stability of Individual Differences. This study is an investigation of stability of individual differences in physiological aspects of human development. Relative stability will be indicated by Pearson-Product-Moment correlation coefficients. The 7090 will be utilized in determining these coefficients. A special program is being written for this investigation by the Statistical Services Research Unit since there is some missing data in the study and it is not desirable to delete an entire subject just because he was not available for testing on one occasion.

158-2D028T Mining, Metallurgy and Petroleum Engineering. Specific Heat. Measurements of low temperature specific heat for alloys of transition elements have been carried out. All mathematical methods are standard. Measured sets of pressure and resistance data are processed to calculate the specific heat. The specific heat and temperature data are fitted to a five-term power expansion.

159-2D029 Electrical Engineering. Satellite Orbital Computation. The

determination of electron content and the study of irregularities in the ionosphere by the use of satellites requires that the position of the satellite be known. In addition, it is desirable to know the ground velocity of shadow made by a blob between the satellite and the earth at specified positions. Fortran programs for computations of this nature have been obtained from the National Bureau of Standards. These programs use standard orbital elements in the computation, and should run on the 7090 here with minor modifications.

160-2D030T Psychology. Guilt, Religion, and Personal Ethics. The problem is part of a factor analytic procedure, most of which has already been done on Illiac. Its purpose is to partition the total variance of the several factors into components attributable to the several groups of subjects which make up the total sample of subjects. This is to be accomplished by means of a series of matrix multiplications and subtractions performed on the varimax rotated factor matrix. A special program for this purpose has been written.

161-2D031T Veterinary Medical Science. Serological Study of Vibrio Fetus. The study of the seological relationships of vibrio fetus was undertaken to aid the determination of a suitable protection program in the sheep industry. This work was preliminary in nature, and was a study of the antigen-antibody relationship of strains of vibrio fetus and related strains of vibrio as found when antisera produced in rabbits were tested against whole cell formalinized antigens and 2 hour boiled antigens.

The use of the IBM 7090 may aid in the analysis of the data obtained when agglutination tests were run between strains isolated from different animal sources. The relationships found in this work have been reduced to the yes, no, plus, minus form and as such can be prepared for the computer in such a manner that a code number will be assigned each related pair or group of strains.

162-2D032T Chemistry. Spin Analysis in Nuclear Reactions. The purpose of this project is to calculate cross sections for the production of nuclei in various possible spin states for photonuclear reactions that proceed by a compound nucleus mechanism. These calculated cross sections are to be compared with experimental data to serve as a check on the validity of the compound nucleus reaction mechanism. These reactions proceed in several steps. The first step is the absorption of a photon by a target nucleus to produce an excited compound nucleus.

The compound nucleus then emits one or more particles to eventually produce a product nucleus of interest. The intermediate and final nuclei in these steps can generally have any one of several possible values of nuclear spin. The calculation follows this spin distribution throughout the course of the reaction. In any one step, the production of a nucleus of a given spin can result from transitions involving several possible changes in orbital angular momentum starting from any one of several different initial spin states. The calculation of the probability for producing a given final spin state thus involves summing the transition probabilities over several possible values of orbital angular momentum change and over several different initial spin states. The calculation of the final spin distribution involves recycling of the summing operation for the several possible final spins. The process must be repeated for each step in the reaction, and thus the use of a high speed computer is required. The calculation for different target nuclei is accomplished by simply inserting a new set of transition probabilities into the program.

163-2D033T Electrical Engineering. Plain Language Analysis. This is the second phase of a project aimed at a limited semantic analysis of plain language statements. The objective of this phase is an automatic compilation of syntactic rules, under the guidance but not strict control, of the programmer. This is a non-numerical information problem, and the program structure will be best described as an associative memory system. Nonetheless the numerical nature of the information within the computing system will be utilized whenever possible to simplify relations among the non numerical entities upon which the program operates. It is not intended that the program be realized by an interpretation of any of the Information Processing Languages, and the numerically-oriented library routines seem for the most part inapplicable.

164-2D034 Share No. 1212 Analysis of Variance or Covariance. A Share routine for statistical analysis is to be investigated as a potentially useful tool.

165-2D036 Physics. Breit-Wigner Fit. This program will fit a Breit-Wigner curve to experimental points. A graph of counts per second versus velocity is obtained. A subprogram using the method of least squares will be used to fit the data to the best curve.

166-2D037T Psychology. Reduction of Shrinkage. The hypothesis to be tested is that shrinkage in multiple regression can be reduced by using fewer predictors. The 7090 will be used to compute the regression equation for each of the experimental methods, as well as for the standard method (using all predictors). After cross-validation, the shrinkage for each method will be compared.

In addition, the 7090 will be used in computing or choosing the predictors to be used in the experimental methods.

Method A: use only the major principal components as predictors.

Method B: use only those predictors which have a significant zero-order correlation with the criterion.

Method C: after computing the standard regression equation and multiple correlation, eliminate that predictor which adds the least. If this yields a non-significant decrease in multiple correlation, eliminate the next predictor which adds the least. Continue until elimination of a predictor yields a significant decrease in multiple correlation. Then that predictor and the remaining predictors are used as the Method B predictors.

A secondary hypothesis is that reduction in shrinkage, if found, will increase as the size of the sample decreases. This will be tested by doing the above with samples of several sizes.

167-2D039 Agronomy. Forage Evaluation. This project involves the testing of forages (red clover, alfalfa, etc.). This material is tested at 4-6 different locations throughout the state. Usually the 7090 will be used to calculate means and analysis of variance so that significant differences in the material may be determined. Data analyzed will usually consist of the following characters: yield (tons/acre), percent dry matter, number of plants per plot, and disease ratings per plot.

168-2D040 Mechanical Engineering. Film Boiling Heat Transfer. Film boiling heat transfer is to be investigated. It is necessary to integrate two non-linear ordinary differential equations in order to obtain the velocity and temperature profiles in the boundary layer. Since the initial values are known, the IBM 7090 will be utilized to generate tables of the values of the velocity and temperature profiles. The Runge-Kutta library routine will be used to integrate the differential equations.

169-2D041 Psychology. Second Order Study of the Personality Factor Questionnaire. The data consists of correlations between scale scores of the 16 Personality Factor questionnaire. Previous research has found two to seven factors underlying the correlations, of which only the first two have been widely replicated. The present data, being based on a larger and more adequate population, is being factor analyzed in an effort to determine the number of factors, the exact loadings of the tests on the factors, and the correlations of the factors in order to determine the possibility of higher order factors.

The 7090 will be used for the computational aspects involved in finding a psychologically meaningful position for the principle axes factors on the basis of visual judgement of simple structure.

170-2D042T Agricultural Economics. Chicago Milk Supply. Research is directed toward exploration of the determinants of the supply of milk in the Chicago milk market with particular emphasis on estimating the relations between milk prices and supplies of milk offered by producers now in the market and by potential extrants. The IBM 7090 can aid in calculating the regression relationships and supply estimates over price differentiated area segments of the market supply area. A linear regression program will be used to calculate desired estimates from the collected basic data.

171-2D043 Physics. Reactor Kinetics. The time behaviour of neutron flux, median temperature and precursor densities are determined from the following system of ordinary differential equations:

$$\frac{dn}{dt}(t) = \frac{n}{\mathcal{L}}(t) \left[k(t, T_s) (1 - \beta) - 1 \right] - \sum \lambda_i C_i \quad i = 1, 2 \dots 6$$

$$\frac{dC_i}{dt}(t) = \frac{n}{\mathcal{L}}(t) k(t, T_s) \beta_i - \lambda_i C_i(t) \quad s = 1, 2$$

$$\frac{dT_s}{dt}(t) = A(s) (n(t) - n_o) - g(s) T(t) \quad \begin{array}{l} k = \text{driving function with} \\ \text{feed back} \\ \mathcal{L}, A(s) \text{ and } \lambda_i \text{ are constants} \end{array}$$

This problem in reactor kinetics thus requires the solution of an initial value problem. The characteristic difficulties of these otherwise routine initial

value problems are the occurrence of non-linear terms in the equations and the wide range of variation of the dependent variables. For example, the flux may vary by a factor 10^9 during one second.

It is therefore necessary to use either extremely small integration steps and thus to use computer time inefficiently, or to develop specialized routines for the integration of the reactor kinetics equations. Hence variable step-length integration procedures will be developed.

172-2D044T Civil Engineering. Intercommunity Traffic Models. The objective of this study is to develop intercommunity traffic estimation models. The basic statistical technique to be used in synthesizing the models is multiple correlation analysis. However, it will first be necessary to employ factor analysis in order to formulate conceptual elements of the models as well as to provide corroboration for previously formulated theoretical hypotheses governing the regional traffic interrelationships.

Data employed is that obtained from a 1958 Champaign-Urbana origin-destination study and involves 147 communities in East Central Illinois.

173-2D045 Psychology. Objective Test Personality Factors. The purposes of this research problem are to investigate certain personality dimensions in terms of nature-motive ratios, age trends, and criterion correlates and to intensify and improve measurement of these quantities. The methods used will be factor analysis [product-moment correlations, principal axis factors, rotation of such factors, etc. using standard matrix procedures (e.g. multiplication, inversion)], and discriminant function analysis.

174-2D046 Psychology. Validation of the Factorial Structure of Questionnaire Measurement. The purpose of this research is to examine the practical and factorial validities of the 16 P. F. scales and other questionnaire measures of personality. The relationship of such measures to a series of criteria will be examined. The methods of analysis will involve factor analysis, analysis of variance and multiple regression.

175-2D047 Psychology. The Measurement and Identification of Psychological States. Certain psychological states (α moods) have been identified by forms

of factor analysis known as P-technique and Incremental R-technique. The purpose of this study is to intensify research on those states already tentatively identified, and, in conjunction with traditional bivariate experimental design, examine their relationship to various criteria.

The methods of analysis will involve factor analysis, analysis of covariance and multiple regression.

176-2D048 Psychology. Motivation and School Performance. This problem is concerned with predicting school performance using a variety of tests of ability, personality, motivation and interest. Also of importance are developing and improving measures of motivation, interest, and conflict.

177-2D050 Agronomy. Forage Production and Management. This project involves the testing of forage production and management practices at several locations throughout the state. The IBM 7090 will be used to calculate means and analyses of variance so that differences between various production and management practices may be statistically evaluated.

Data to be analyzed includes the following: yield of hay in tons per acre, per cent dry matter, per cent composition (grass versus legume), and occasional qualitative observations.

PART VII

INSTRUCTIONAL USE OF THE IBM 7090-1401 SYSTEM

During the month of December, ten problem specifications were submitted.

I36-2D003 Digital Computer Laboratory 195. Problem 4. Interpolation and Table Look-Up. A computation is being considered in which a large number of values of $\text{TAN } x$ are required for x in the range 0 to 75° . If each tangent is to be evaluated directly by using library subroutines, a considerable fraction of the total problem execution time will be in the use of these routines. As an alternative it is proposed that only a limited number of values of $\text{TAN } x$ need be evaluated to form a table from which other values may be interpolated. Write a test program which should provide an indication of the accuracy to be expected in this procedure:

- 1) By the use of available FORTRAN subroutines generate a table of 15 values of the function $\text{TAN } x$ for x ranging from 0 through 1.4 radians in steps of 0.1 radian. Store these values in 15 identifiable memory locations--do not print them.
- 2) By means of a table look-up and linear interpolation procedure use this table to determine approximations, $\text{TABTAN } x$, to the true $\text{TAN } x$ for 15 values of x ranging from 5° through 75° in 5° increments. For each of these angles calculate the value of $\text{TAN } x$ from library routines.

I37-2D004 Agricultural Economics 441. Problem 1. Agricultural Economics 441 Term Problems. Agricultural Economics 441 has an enrollment of 10 students. Each of these students is asked to submit a term problem demonstrating their ability to use some of the statistical techniques taught. Some, but not all, of these students will wish to do regression problems. Most of these students will subsequently undertake research involving the use of the 7090 computer. It is therefore appropriate that they become familiar with the way to use these facilities. The problems submitted will deal with a variety of subjects in Agricultural Marketing, Farm Records analysis, and Farm Family Accounts.

It is expected that these problems will all be regression problems, and will all use a standard regression routine.

I38-2D009 Electrical Engineering 126. Problem 2. Investigation of the Evaluation of $\text{Sin } \theta$ by use of Series. This problem is to determine the

number of terms of the series for $\sin \theta$ which will evaluate the function within a certain error for various values of θ . Standard routines will be used.

I39-2D011 Aeronautical and Astronautical Engineering 211. Problem 1.

Pressure Coefficient. An explicit formula is used to calculate the pressure coefficient at each of a number of points in the flow about a circular cylinder with circulation.

I40-2D013 Electrical Engineering 451. Problem 1. Approximation of Magnitude Functions. A magnitude function $|T_s(j\omega)|^2$ is to be approximated by a rational

function $T(s) = \frac{p(s)}{q(s)}$ of the student's own choice. The coefficients of p and q are perturbed and then changed to reduce the mean-square error. The method of steepest descents is used.

I41-2D017 Digital Computer Laboratory 195. Problem 5. Newton's Method of Finding Roots. Using Newton's method write a FORTRAN program to determine the smallest positive root of the equation:

$$\tan x = cx$$

to five decimal places, with $c = 1.01$, $c = 2$, and $c = 30$.

Print the value of c , the initial guess for the root, the corresponding root, and the number of iterations required on separate lines for each value of c .

Provide an exit which prints

"NO CONVERGENCE"

if the number of iterations exceeds 25 (this should not actually occur if your guess is reasonable).

I42-2D024 Civil Engineering 391. Problem 3. Design of A Continuous Beam.

The assigned problem is one which is to compute the influence line for moments in a two span continuous beam. Once these influence lines are determined, the maximum moment in the beam can be computed from the applied loads. The width and depth of the beam is then determined from this maximum moment.

The program will be compiled as a main program and one subroutine in order to illustrate use of subroutines and to facilitate code checking.

I43-2D035 Civil Engineering 318. Problem 1. Critical Path Method.

The purpose of this specification is to investigate the Share Library Code entitled "Critical Path Programming." If suitable for production the code will be used by students in CE 318 and CE 316. If not suitable for production, instructors in these classes will use it as a demonstration code.

I44-2D038 Digital Computer Laboratory 195. Problem 6. Solution of Linear Equations. A set of linear equations

$$\sum_{j=1}^n A_{ij} X_j = A_{i, n+1} \quad i = 1, 2, 3, \dots, n$$

is to be solved by the Gauss triangularization method followed by back-substitution in order to get the X_i . n will be less than 50.

The data deck supplied in class will consist of a single card giving n in an I2 field in columns 1 and 2 followed by cards each having seven F10.0 fields in columns 1-70 containing the matrix

$$\begin{array}{cccccc} A_{11} & A_{12} & A_{13} & \dots & A_{1n} & A_{1, n+1} \\ A_{21} & A_{22} & A_{23} & \dots & A_{2n} & A_{2, n+1} \\ \vdots & & & & & \\ A_{n1} & A_{n2} & A_{n3} & & A_{nn} & A_{n, n+1} \end{array}$$

Each row will be on a successive set of cards, 7 elements to a card, so that the last card of each row may not be full. For example, if $n = 18$, $A_{1,1}$ to $A_{1,7}$ will be on one card, $A_{1,8}$ to $A_{1,14}$ on the next, $A_{1,15}$ to $A_{1,19}$ on the next, $A_{2,1}$ to $A_{2,7}$ on the next, etc. Finally, the deck will end up with $A_{18,15}$ to $A_{18,19}$ on the last for a total of $3 \times 18 = 54$ cards for the matrix.

The answers are to be printed 6 to a line using E19.8 fields, i.e.

$$\begin{array}{cccccc} X_1 & X_2 & X_3 & X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 & X_{10} & X_{11} & X_{12} \end{array}$$

etc.

I45-2D049 Mechanical Engineering 341. Problem 3. Deflection of Beams.

The problem consists in using the standard formula for deflection and a simple iteration method to find the maximum deflection of a given beam.

Information on the utilization and reliability of the IBM 1401 and IBM 7090 for the month of December, 1962 is given in the tables below.

TABLE I - IBM 1401
Total Time Distribution

Scheduled Engineering	4:05
Unscheduled Engineering	1:32
Air Conditioning	34:05
Tape Dump	3:02
Tape Labeling	1:13
Listings	5:57
Deck Reproductions	:12
7090 Preparation	235:27
CDC Preparation	:05
7090-1401 System Code Checking	4:20
Illiac II Code Checking	1:37
Statistical Service Unit	58:27
Wasted	6:00
Idle	43:36
TOTAL	399:38

TABLE II - IBM 1401
Sources of Error

Air Conditioning	3
1403 Printer	2
729 V Tape Units	2
TOTAL	<u>7</u>

TABLE III

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	UNSCHEDULED ENGINEERING	AIR CONDI- TIONING	IDLE	WASTED	TOTAL TIME	FAILURES	IBM 1401 DAILY TIME DISTRIBUTION
12/1/62	2:36				7:09		9:45	1	(1) Tape flies off the idler when coming out of high speed rewind.
12/3/62	19:40					:15	19:55		
12/4/62	18:52				1:05		20:32		
12/5/62	20:28	1:35			3:02	:30	24:00		
12/6/62	18:04				3:17		21:21		
12/7/62	15:06				1:09		16:15		
12/8/62	4:54				6:56		11:50		
12/10/62	18:05				2:10		20:15	1	(1) 1403 print chain and ribbon stopped and would not restart.
12/11/62	18:27		1:30				19:57	1	(1) 1403 print chain and ribbon will not engage.
12/12/62	20:33					2:10	22:43		
12/13/62	16:40			5:00	2:25		19:05		
12/14/62	10:45				:20		16:05	1	(1) Bearing was burned out on outside fan motor of air conditioning unit.
12/15/62	6:48				1:35		8:23		
12/17/62	19:05				:20	2:40	22:05		
12/18/62	22:58		:02		:40		23:40	1	(1) Tape unit A will not rewind. Caused by blown fuse and broken mercury relay.
12/19/62	20:15				2:20	:25	23:00		
12/20/62	10:51	2:30		:52	:40		14:53	1	(1) Temperature too high. Air conditioning off.
12/21/62	13:42			1:50	:40		16:12	1	(1) Failure in outside air conditioning for motor.
12/22/62	1:15				:30		1:45		
12/24/62	2:10				1:15		3:25		
12/26/62	10:30				6:00		16:30		
12/27/62				16:00			16:00		
12/28/62	8:44			6:50	:34		16:08		General maintenance on the entire air conditioning system.
12/31/62	10:52			3:33	1:29		15:54		
TOTALS	311:20	4:05	1:32	34:05	43:36	6:00	399:38		

TABLE I - IBM 7090

Total Time Distribution

Scheduled Engineering	19:38
Unscheduled Engineering	14:15
Air Conditioning	33:28
System Maintenance	6:56
Classes*	49:51
System Production*	76:16
Out of System Production*	12:34
Idle	<u>118:03</u>
 TOTAL	 331:01

*See Table II for further breakdown of these items.

TABLE II - IBM 7090

Departmental Time Distribution

	Classes	System Production	Out of System Production	Total
Aeronautical and Astronautical Eng.	:03			:03
Agricultural Economics	:31		4:59	5:30
Agricultural Engineering		:26		:26
Agronomy		1:08		1:08
Animal Science		:05		:05
Astronomy		:13		:13
Chemistry and Chemical Engineering	:07	6:34		6:41
Civil Engineering	5:32	23:22		28:54
Digital Computer Laboratory	29:51	12:48	7:35	50:14
Economics		:27		:27
Education		:21		:21
Electrical Engineering	10:55	:56		11:51
General Engineering		:12		:12
Graduate School of Business Adm.		:16		:16
Industrial Engineering	:52	:08		1:00
Instructional Television		1:49		1:49
Mechanical Engineering	:21	2:28		2:49
Mining, Metallurgy and Petroleum Eng.		:11		:11
Men's Residence Hall Assn. Rocket Club		:19		:19
Music		:30		:30
Nuclear Engineering		1:01		1:01
Office of Instructional Research		:10		:10
Physics	1:39	14:59		16:38
Physiology		:02		:02
Psychology		:41		:41
State Geological Survey		:04		:04
State Water Survey		1:04		1:04
Statistical Service Unit		2:59		2:59
Theoretical and Applied Mechanics		2:59		2:59
Veterinary Anatomy and Histology		:04		:04
TOTALS	<u>49:51</u>	<u>76:16</u>	<u>12:34</u>	<u>138:41</u>

TABLE III - IBM 7090

Sources of Error

Air Conditioning	2
729 VI Tape Units	4
Cathode Ray Equipment	6
Channel B	1
7618 Power Control	<u>1</u>
TOTAL ERRORS	14

TABLE IV

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	UNSCHEDULED ENGINEERING	IDLE	AIR CONDI- TIONING	TOTAL TIME	ERRORS	IBM 7090 DAILY TIME DISTRIBUTION
12/1/62	:35	1:00	2:30	4:47		5:22	1	(1) Tape units on channel B
12/3/62	7:11			5:53		16:34		would not read or write. Bad
12/4/62	7:32	:30		8:18		16:20		transistor card in channel B.
12/5/62	6:50	2:00	1:00	6:09		15:59	1	(1) Tape unit AS off line
12/6/62	10:17	1:30		3:58		15:45	1	for checking.
12/7/62	8:34	:45		6:39		15:58	2	(1) Tape unit BT has bad
12/8/62	1:05							capstan motor. Replaced.
12/10/62	8:14	1:30		10:45		11:50		(1) Tape unit AS put back
12/11/62	8:34	1:30		6:33		16:17		on line. (2) Tape unit AS
12/12/62	9:12	2:05		5:27		15:31		missed two end-of-file or
12/13/62	9:33	:50		4:43		16:00		tape marks. Random errors.
12/14/62	6:08	2:10	1:31	5:42		16:05	1	(1) CRT off line for checking.
				1:48	4:30	16:07	2	(1) Bearing burned out on
12/15/62	4:22		:11					outside fan motors of air
12/17/62	8:50	:25	2:30	4:22		8:55	1	conditioning unit. (2) CRT
				4:12		15:57	1	checked on line.
12/18/62	9:52	1:00		5:00		15:52		(1) Power on core went off.
12/19/62	9:53	1:00		5:09		16:02	1	(1) CRT tested on line with
12/20/62	4:10		4:08	5:09	:05	13:32		no success.
12/21/62	7:35	:18		5:33	2:34	16:00	1	(1) CRT put back on line.
12/24/62	1:32	1:00		1:11		3:43		(1) CRT malfunctioning and
12/26/62	4:58	1:05		7:25		15:53		causing errors on IBM 7090.
12/27/62			2:25		16:00	16:00		(1) Air conditioning failure.
12/28/62	6:17			3:03	6:34	15:54		
12/31/62	4:25	1:00		6:15	3:45	15:25	1	(1) CRT off line from 8:00
								a.m. until 3:30 p.m. Not
								able to keep "ready status".
								Stability circuit not work-
								ing.
TOTALS	145:39	19:38	14:15	118:01	33:28	331:01	14	

PART VIII
GENERAL LABORATORY INFORMATION

Colloquia

"Computer Studies of Energy Sharing and Ergodicty for Non-Linear Oscillator Systems," by Professor Joseph Ford, Georgia Institute of Technology, Atlanta, Georgia, December 3, 1962.

"On the Solution of an Information-Retrieval Problem," by Dr. Burnett H. Sams, Data Systems Center, Radio Corporation of America, Bethesda, Maryland, December 17, 1962.

Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	14	1	14.5
Visiting Faculty	3	0	3.0
Research Associates	7	1	7.5
Graduate Research Assistants	5	30	20.5
Administrative and Clerical	8	0	8.0
Other Nonacademic Personnel	<u>42</u>	<u>37</u>	<u>57.0</u>
TOTAL	79	69	110.5

The Computer Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, C. W. Gear, D. B. Gillies, B. H. McCormick, G. A. Metze, D. E. Muller, T. A. Murrell, J. R. Pasta, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, K. C. Smith, J. N. Snyder, and A. H. Taub.

Drafting

The following is an account of the General Drafting Room output for the month of December:

D-size drawings	13
C-size drawings	1
B-size drawings	0
Odd-size drawings	12
Change Orders	37
Report work	40

(K. C. Law)

The following is an account of the Pattern Recognition Drafting Section output for December:

Mechanical: Large	2
Mechanical: Medium	1
Printed circuits designed	6
Printed circuits artwork	4
Change Orders	0
Logics	0
Circuits	0

(J. K. Burrell)

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