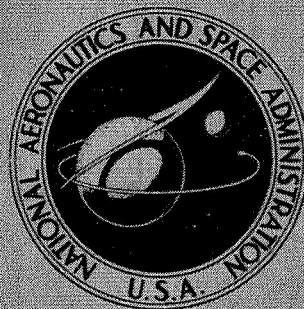


N71-31399

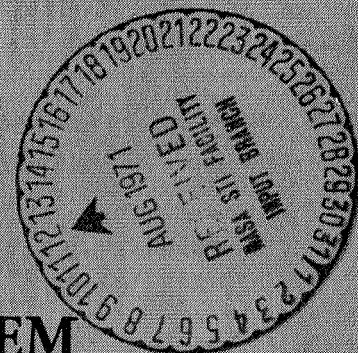
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CASE FILE
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GENERALIZED SOFTWARE SYSTEM
FOR MULTIPLE SMALL
DATA-ACQUISITION SYSTEMS

by Norman A. Landis, Jr.

Lewis Research Center

Cleveland, Ohio 44135

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GENERALIZED SOFTWARE SYSTEM FOR MULTIPLE SMALL DATA-ACQUISITION SYSTEMS

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SUMMARY

A software system has been developed for small data-acquisition systems used in life-testing applications at Lewis Research Center. These data acquisition systems provide the functions of data acquisition, limit checking, limited experiment control, data recording, and data processing.

Most of the operational characteristics of the system are controlled by parameter tables. These tables are easily modified in mnemonic form, by research personnel, via the console teletypewriter. The data analysis calculations are written in an on-line conversational interpretive language. Modifications to the processing codes can be made from the console teletype in the source language without reassembly. The result is a generalized software system which is very flexible and easily modified for new or changed applications.

INTRODUCTION

Lewis Research Center has a number of research tasks that require the life testing of electrical power generation systems for space use. The data recording requirements of life-testing experiments at Lewis historically have required around the clock and weekend staffing of both the test facility and the central recording system. Therefore, to eliminate these extra manpower requirements, three computer controlled data acquisition systems were acquired. These systems are automatic in their operation, permitting unattended operation of the experiments and the data acquisition for extended periods.

A single contract was let to provide both the hardware and software for all three systems. The functions provided by these systems are data acquisition, limit checking and limited experiment control, data recording, data processing, and ability to store a

sufficient reserve of data to analyze a machine detected experiment failure after an automatic system shutdown.

All three computers are from the same manufacturer, thus a single software monitor system can be used on all three systems. Parameter tables are entered via the typewriter to control the data selection, limit checking, and the conversion of the data into engineering units. The data, in engineering units, are then available for data analysis calculations, which are different for each application. The calculations are written in an extended version of FOCAL. FOCAL (formula calculator) is an on-line, conversational, interpretive language provided by Digital Equipment Corporation (DEC) for the PDP-8 family of computers. FOCAL was extended by Delphic Industries, Inc., to include communication abilities to the data acquisition hardware of the Lewis system. This extended version of FOCAL is called FOCAL-X.

The significant features of these systems are their flexibility of operation and the range of program modifications that can be made from the system teletype. Data acquisition, limit checking, and conversion to engineering units are controlled by table entries that can easily be made by the research people from the console teletypewriter. Changes to the problem codes can be made by modifying the FOCAL-X text via the teletypewriter, with no reassembly required. It is an easier task to train research personnel to use the extended FOCAL-X language than the assembly language of the computers. Also the system operation is simplified.

The following is a description of the software system provided for three data acquisition systems. The software was written to NASA specification by the Delphic Industries, Inc., Livermore, California, a subcontractor to VIDAR Corporation Mountainview, California, prime contractor for NASA Contract No. NAS 3-12945. Mr. Fred Strange of Delphic Industries, Inc., served as the software manager and provided most of the impetus for the method of implementation of the software systems.

SYSTEM FUNCTIONS

Each of the three real time data acquisition systems are used in unique applications (hardware and applications are described in appendix A). These applications are for finite time periods, and the systems will be used in new applications when the current ones are completed.

One approach would be to provide a unique machine language data acquisition and reduction program for each system. This would provide a very efficient system tailored for each application. However, this type of a system would be inflexible and not easily modified for new applications or for slight variations in the current applications.

The approach chosen was to have a general purpose monitor system which was controlled by parameter tables. Although each system application was unique, a number of system functions and requirements were present in all systems. The parameter tables were organized to control these system functions.

Data Acquisition Control

The scanner selects the input data channel requested by the computer. A free and random selection pattern is permitted. The computer also commands the integrating digital voltmeter (IDVM) to select one of five amplifier gain settings, or the IDVM can be commanded to automatically select the appropriate gain setting. The automatic selection process is called autoranging. Three different integration time periods can be selected for the IDVM. Parameter lists are provided to control the data selection, integration period, and range selection of the data acquisition process.

Limit Checking and Experiment Control

Limit checking is done at two levels: checks which are made on a single channel output and checks which are made on the computed results of several channels. Some experiment control, not requiring critical time responses, is achieved by activating relay contacts which in turn initiate control actions.

Limit checks, which are functions of single channels, have been provided as a general system function. If a limit is violated, one of the following actions is permitted:

- (1) Close one of 32-relay contacts (also prints a logging message).
- (2) Print an alarm message.
- (3) Branch to a shutdown sequence.
- (4) Automatically select a new time parameter to modify the data acquisition frequency.

Data Recording

Data recording is the process of acquiring one scan of data and then punching that data on a paper tape in a standard format which is in general use at Lewis. This standard format permits the data to be processed by an existing data processing system in the computation center at Lewis.

The generalized acquisition system accepts parameters that control the frequency of the data recording and the insertion of data quality bits (code outs) in the data to be recorded.

Data Processing

In addition to the central data processing of the punched data tape, on-line data processing on the data acquisition computer is available. This on-line data processing is the process of acquiring one scan of data, converting that data to engineering units, performing the individual problem calculations, and typing the results on the teletype. Each experiment requires a unique set of problem calculations, but the conversion of the raw data into engineering units is similar in all systems. Therefore, the coefficients required to convert the various channel inputs into engineering units are entered as parameters.

Provide Data for Failure Analysis

These systems are used in life testing experiments where the test article is run until a failure occurs. The experimenter is usually interested in the cause and method of failure. A volume of data for later analysis must be recorded during the critical time following (and frequently preceding) the detection of a failure. In systems I and III data following a failure detection are obtained by the rapid recording of raw data or by the filling of internal core data storage buffers. System II provides failure analysis data before a detected failure by dynamically writing data into a storage buffer on a disk. These data are written in the buffer in a circular manner; that is, the oldest data values in the buffer are overwritten by the newest. When a failure is detected, data recording is continued until one-half of the data in the buffer have been recorded after the failure detection. This provides failure analysis data for a period of time before and after the detection of a failure. A failure analysis reference subprogram then permits these data to be processed by the on-line program or produces a punched tape for central processing.

SYSTEM ORGANIZATION

The system is organized into a basic executive system written in assembly language for the PDP-8I and three unique applications programs written in FOCAL-X. The basic executive system is common to all three systems. Interfaced to the executive system

are the special applications programs for each facility. The special applications program performs the unique set of calculations and multiple channel limit checks which are required by each facility. The basic organization of the software is nearly identical for all three systems, with the main differences found in the applications program and the hardware drivers used to drive the peripherals which are unique to each system.

The basic executive system consists of three major code modules: a system monitor, a floating point package, and the FOCAL-X system.

System Monitor

The system monitor is a master scheduling routine, controlling the flow of data through the systems, the allocation of system resources, and the use of central processor unit (CPU) time. The monitor maintains a set of software clocks which control the scheduling of limit checking, data recording, and data processing operations.

The MONITOR has a four-level internal priority structure. The highest level of priority consists of the interrupt service and hardware driver routines. These routines service such devices as the teletypewriter, paper tape readers and punches, the IDVM, and the clock. These devices generally require very prompt servicing because of heavy use or the volatility of their data. The execution times required for the service routines are short, permitting action on other interrupt requests to be deferred until completion of the current service routine. This is done by disabling interrupts during the execution of the service routine. Interrupt requests during the disabled period are remembered by the hardware and become active when interrupts are enabled at the completion of the service routine.

The second highest priority level consists of relatively long sequences of machine language codes providing system services. The need for these services can originate with FOCAL-X, or they can be initiated by an interrupt. These sequences are long enough to delay the hardware devices. Therefore, routines run at this and lower priority levels are run with interrupts enabled. Examples of the second highest priority level routines are system service macrofunctions, command decoder, and system input/output buffer management.

The second lowest priority level is a FOCAL-X code sequence, which is initiated by an interrupt. The normal FOCAL-X program is suspended by an interrupt which initiates a new FOCAL-X code sequence. The suspended FOCAL-X program execution is resumed when the interrupt initiated sequence is complete. This permits FOCAL-X codes to be used in a real time sequence - interrupting the execution of another FOCAL-X sequence. Basic data acquisition and single-channel limit checks are done at this level.

The lowest priority level is the FOCAL-X background level. Problem calculations, printouts, idle, and wait loops run at this level.

Floating-Point Package (FLOAT)

The floating-point package, called FLOAT, provides the floating-point arithmetic and a variety of input/output conversions for the system. The precision of FLOAT is a 12-bit exponent and a 24-bit mantissa.

The FLOAT package has four major components:

- (1) The arithmetic interpreter
- (2) Floating-point arithmetic routines
- (3) Conversion routines
- (4) Input/output routines

The system users do not normally reference the FLOAT package directly. FLOAT is referenced internally, on a shared basis, by both the MONITOR and FOCAL-X. Requests for the use of FLOAT from the MONITOR and FOCAL-X are asynchronous and from different levels of priority. Therefore, scheduling routines, and routines to request, claim, and release the use of FLOAT are provided. Requests from the MONITOR are given priority over requests from FOCAL-X for the use of FLOAT.

The floating-point operations available in FLOAT are essentially those operations required to support the FOCAL-X language. A complete list of floating-point operations, mathematical functions, and conversions available are shown in the following tables:

FLOATING-POINT INSTRUCTIONS

Mnemonic	Operation
FADD	Floating add
FSUB	Floating subtract
FMPY	Floating multiply
FDIV	Floating divide
FGET	Load the floating accumulator
FPUT	Store the contents of the floating accumulator
FNOR	Normalize contents of floating accumulator
FPOW	Floating exponentiation
FEXT	Floating exit

FUNCTIONS

SQUARE ROOT SINE ARC TANGENT LOGARITHM FLOATING EXPONENT
--

CONVERSION ROUTINES

Instruction	Entry point	Type
FLTINT	XFPINT	Convert floating-point number to 12-bit integer
FLOAT	XFLOAT	Convert 12-bit integer to floating-point number
ASCFLT	YASCFP	Accept ASCII string, convert to floating-point number
FLTASC	YFPASC	Convert floating-point number to ASCII string
INTBCD	YINBCD	Convert 12-bit binary to 3 digit BCD
BCPFLT	YBCDFP	Convert 6-digit BCD to floating
FP2FP3	YFIF3	Convert two-word FP to three-word FP
FP3FP2	YF3F2	Convert three-word FP to two-word FP
VIDFLT	YVIDFP	Convert voltmeter output to FP

FLOAT also contains an output routine which converts a floating-point number to decimal and prints the result on the teletypewriter. The format of this output is controlled by the format control statements of FOCAL-X.

An input routine of FLOAT accepts characters from the TTY and converts them to a floating-point number. Numbers can be entered in a format with a decimal point or in an exponent format. Numbers larger than 2^{23} must be in the exponent format.

FOCAL-X

FOCAL is an on-line conversational, interpretive language provided by Digital Equipment Corporation (DEC) for the PDP-8 family of computers. The FOCAL language consists of simple English statements and standard mathematical expressions. It is designed for the solution of numerical problems. However, the FOCAL language as supplied by DEC does not have communication abilities with the data acquisition equipment. Delphic Industries, Inc., extended the FOCAL language to include communication abilities with the IDVM, the scanner, and the contact closure hardware of the Lewis systems. This extended version is called FOCAL-X.

The FOCAL-X system has most of the features available in the language as described in reference 2. The MODIFY command is not available because of core space limitations. A special meaning has been assigned to any variable name which begins with the letter C.

Variable names beginning with the letter C have been used to provide communication abilities between FOCAL-X and the data acquisition equipment. When a variable name beginning with the letter C is encountered at execution time, an implicit system call is generated and immediately executed to transmit information regarding the IDVM, scanner, or relay contacts.

The internal system call is in the form:

SET B = CNNNN

where B is an internally generated FOCAL-X variable. The variable name CNNNN is handled as follows: The letter C is extracted and discarded. The NNNN portion can now be interpreted as a literal with a value from 0 to 4095 or as a simple, nonsubscripted variable name. The value of the literal or variable is then converted to a 12-bit integer and given to the system monitor for decoding. This 12-bit integer is divided into two fields: the function field and a data field. The following functions are permitted:

- (1) Transmit to FOCAL-X the value contained in the system limit check buffer for the channel number specified in the data field.
- (2) Accept from FOCAL-X a limit check control word. This word specifies the voltmeter range and integration time for limit check inputs.
- (3) Accept from FOCAL-X the number of successive limit channels desired.
- (4) Accept from FOCAL-X the starting channel address for a sequence of limit check channels. This function works with and must be preceded by items 2 and 3.
- (5) Take the variable from FOCAL-X and store it in the system data buffer at the data word address specified by the data field. This function is used primarily to return data, which has been converted into engineering units, back into the system data buffer.
- (6) Close the relay contact as specified by the number in the data field.
- (7) Transmit to FOCAL-X the value contained in the data system buffer for the channel number specified in the data field.
- (8) Accept from FOCAL-X data acquisition control word. This word specifies the voltmeter range and integration period for the data inputs.
- (9) Accept from FOCAL-X the number of sequential channels of data desired.
- (10) Accept from FOCAL-X the starting channel address for a sequence of data channels. This function works with and must be preceded by items (8) and (9).

The first four functions are used for limit checking, the last four functions are used for data recording.

The FOCAL-X text is stored internally and interpreted at run time. The FOCAL-X variable names are stored with the variables and are searched upon a variable reference. This enables the test facility research personnel to modify the processing program simply by typing changes to the FOCAL-X text at the system teletypewriter. This process is much simpler and less time consuming than reassembly. It also involves less risk. An error in reassembly could cause a system crash. An error in the FOCAL-X text would probably result in incorrect results in that area only and not interfere with other system functions.

PARAMETER TABLES

The operating characteristics of the data acquisition systems are controlled by parameter tables. These tables are constructed, edited and modified via the system input/output teletypewriters. The parameter tables can be entered from a punched paper tape via the teletypewriter reader or they can be constructed or modified via the keyboard of the teletypewriter.

The table generation phase is an off-line process. Table generation must be accomplished before system operation, or the system operation must be suspended while the table modifications are made.

The table generation codes are written in FOCAL-X, and the table entries are stored as FOCAL-X variables. The entry program is a prompting program, where the system user is given directions or controlled choices via the system teletypewriter. At a table generation session, the system gives the user a choice of which of the seven tables he wishes to construct or modify. Then he is given the following choices:

- (1) List: Prints all entries from the selected table
- (2) Delete: Removes an existing table entry
- (3) Change: Modifies an existing table entry
- (4) Input: Adds to the existing entries or makes the initial entry in the table.

When the table generation or table modification is complete, the table entries are retained as FOCAL-X variables. These variables are then referenced when the system operation is initiated or resumed. A set of teletypewriter listings from a table generation session is included at the back of the report.

The seven parameter tables currently in the system are

(1) Code-out table - This table is a list of channel numbers which will have a code-out flag included with the data when it is recorded on the punched paper tape. The code-out flag is used to indicate words of questionable quality. The punched paper tape is processed on a data processing system which is in general use in the central computer area. The code-out flags cause the central processing system to produce letter tags on the final printed results which use the tagged data values as input (ref. 1). The code-out table does

not affect the data processing performed on the data-acquisition system.

(2) Data acquisition tables - This table controls the data acquisition and linkage to the calibration coefficients. An entry contains

- (a) A group of channel numbers
- (b) The gain range control
- (c) The integration period for the IDVM
- (d) The pointers to the coefficient set to be used for the conversion of these data channels into engineering units.

Figure 1 shows a teletype session of building a part of the data table. Figure 2 shows the listing of a data table. The link numbers connect the channels to the coefficient sets for conversion into engineering units. The link numbers in the range 0 to 300 reference the zero-order table. The number range 301 to 400 references the first-order tables, and 401 to 450 references the quadratic table.

(3) Zero-order constants table - This table contains the zero-order calibration constants for use in the form $Y = MX$. Figures 3 and 4 are examples of entering and listing zero-order coefficients.

(4) First-order coefficient table - This table contains the calibration coefficients required to convert the data from millivolts into engineering units. This table contains only the first-order coefficients for the form $Y = B + MX$.

(5) Quadratic-coefficient table - This table contains the quadratic coefficients for conversion of the data into engineering units. These coefficients are produced by running curve fit routines on other computers at Lewis. Higher than second-order curve fits are not used on these data acquisition systems, but the data are fitted by separating them into ranges and approximating each range with a second-degree polynomial. Figures 5 and 6 show examples of teletype listing of entering and listing a quadratic-coefficient set. The set is in the form $A2X^2 + A1X + A0$.

(6) Limit check table - This table contains the parameters that control the single-channel limit checking operations. The following items are included in this parameter list:

- (a) A channel number or a group of channel numbers
- (b) The gain range control
- (c) The integration period control
- (d) The limit for the channel or group of channels
- (e) The indication whether a limit is a high or low limit
- (f) The number of consecutive times the limit may be violated before the action is taken
- (g) The actions to be taken after the defined number of limit violations

The following actions are available:

- Print an alarm.
- Enter a system shutdown sequence.

Close one of 32 contact closures.

Select alternate timing for data recording.

Select alternate timing for limit checking.

(7) Alternate timing table - This table contains a list of alternate time period values that may be substituted for the current time periods of the system software clocks by means of the limit check control.

SYSTEM LIMITATIONS

The use of core space is critical in systems I and III. The use of space is a prime consideration, and the software system is core space optimized rather than speed optimized. Current requirements for system I require the addition of 100 input channels. The core memory will have to be expanded from 8K to 12K to handle these additional input channels and the associated increase in computational requirements. Further increase of input channels or increase of computational requirements for systems I or III would require additional memory expansion. System II has a disk and does not have memory size problems.

The present systems have a hardware clock that interrupts every 100 milliseconds. This clock drives software clocks which very adequately handle the overall system timing requirements. These software clocks schedule the data recording, data processing, and limit checking. However, the precision of the hardware clock is not sufficient to synchronously control the time samples from successive channels on the data acquisition. As a result the scanner-IDVM selection timing is controlled by the response time of the IDVM and the overhead of the computer system. The computer selects a channel address and orders the analog to digital conversion. The time of the conversion is primarily controlled by the integration period selected. The computer is interrupted, and the data value returned at the completion of the conversion. The computer then sends the next channel address. The data input rate is then a function of the integration period selected, any variation in conversion due to automatic range changes, and the computer overhead to find and send the next channel address. Since there are three integration periods available, the system is limited to three basic input rates unless the computer is programmed to serve as an additional timing control. But, this type of timing control by computer programming would require a fully devoted computer. If it were a requirement to have variable synchronous sampling rates without additional computer overhead, additional timing hardware would be required.

The software system is designed for maximum flexibility and ease of change by the user. The cost of achieving these objectives is a high system time overhead and slower execution of the problem codes. The FOCAL-X interpreter resolves the addresses of the variable names by searching for the names of the variable. Thus, the speed of exe-

cution is decreased as the number of variable names is increased. New lines of FOCAL-X text are searched for in a similar manner, with search time being increased by adding lines. The computer overhead to unpack a new entry in the data acquisition control table could be quite long and different from the time required to give the next channel address from a group within an entry. Generally, the timing requirements of the life-testing applications at Lewis have not been critical. Recording or processing requirements are rarely more frequent than once each half hour. Typical limit checking requirements are in terms of minutes. The system speed is sufficient to easily meet these time requirements. If timing requirements are critical, the control of the selection of inputs can be made directly from the FOCAL-X codes and not from the acquisition table. This technique was used in system II during the startup phase to achieve a constant sampling rate of 25 samples per second.

CONCLUDING REMARKS

The software system has been used on the three applications at Lewis as an effective data acquisition and control system on life-testing experiments.

The operating characteristics of the systems are controlled by parameter lists, which have been successfully generated by the people operating the experiment. The rules for modifying the parameter tables are the same for all three systems on the current applications and will be the same for future applications.

Modifications to the FOCAL-X applications program require some knowledge in addition to that required to modify the tables. The research personnel have been successful in making minor program modifications as required. A totally new applications program in FOCAL was written by one of the research facility personnel. The process of making modifications to the FOCAL program is considerably less effort operationally than the process of reassembly of assembly language codes. The lines of FOCAL text to be modified are simply retyped on the input/output teletypewriter and check listings are made of the modified portions only. This requires significantly less time than the loading of the assembler, reading the source tapes, punching the object tapes, and punching and printing the assembly listing. Also, the system user is protected from himself in modifying the FOCAL text. An incorrect modification to the FOCAL text would usually result in an incorrect result in on-line calculations, but would not interfere with the limit checking or data recording. An error in modifying the assembly language coding could result in a total system crash.

Program preparation beyond changes to the parameter lists and FOCAL-X text, is not a convenient task on the small acquisition computers. The input medium is limited to punched paper tape. Printer output must be done off-line or on-line on slow-speed teletypewriters. The two systems without a disk and a high speed punch must pro-

duce object tapes, and frequently intermediate tapes, on slow-speed teletypewriter punches.

The life-testing applications require the full time use of the computer in the acquisition system. This makes the scheduling of program preparation time impractical except during experiment downtime. A solution to this problem is to provide language translation programs for the small computers in the central computing facility. Communication between the small computer and the central computer would be by telephone lines and communications modems.

The flexibility and user protection features built into the system have resulted in a speed penalty. The execution speed of the FOCAL is directly affected by the number of FOCAL variables and lines of text. This reduced speed required some effort to time optimize system II to meet the system's timing requirements for the startup phase. The system speeds are sufficient to meet the timing requirements of the life-testing phase of the applications.

These data acquisition systems provide two methods of processing the raw data: It can be processed on-line by the acquisition machine, or it can be punched onto a data tape and later processed by the central computation center. The on-line processing provides computed results directly in the control room of the experiment. These results are provided in sufficient time to permit the person conducting the experiment to make judgments about operating the experiment. These on-line calculations can also be used to evaluate the quality of the recorded data. In some cases, the on-line calculations are all that are required. However, the punched data tapes are produced to provide a record of the experiment. These tapes would need to be processed if there was a mistake in the on-line program or if a new analysis method was to be applied to the data. The data tapes are also frequently processed in addition to the on-line processing even when the on-line results are correct. This is done to use plotting facilities of the central system, provide greater precision to some computational approximations, or to use more complex analysis programs whose computing requirements exceed the capability of the acquisition machine.

This software system provides for data recording, data processing, limit checking, and limited experiment control in three life-testing applications. The systems often run for several days unattended. A significant number of the operating characters of the system are controlled by parameter lists, which can be modified via the system teletypewriter. In addition, the processing program is easily modified at the symbolic level from the system teletype without reassembly.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 14, 1971,
129-04.

APPENDIX - HARDWARE CONFIGURATIONS AND SYSTEM APPLICATIONS

This software system operates on three different hardware configurations. The systems shall be used in new applications when the current applications are completed.

System I is currently used for life testing fuel cells. It consists of the following components:

- (1) PDP-8/I computer with 8K of core memory
- (2) ASR Model 35 teletypewriter with paper tape punch and reader
- (3) Real time clock
- (4) Integrating digital voltmeter
- (5) 100-Channel low-level scanner
- (6) System coupler
- (7) High-speed paper tape reader

System II is currently used for life testing Brayton cycle system components. The hardware configuration of system II is

- (1) PDP-8/I computer with 12K of core memory
- (2) ASR Model 35 teletypewriter with paper tape punch and reader
- (3) Real time clock
- (4) Integrating digital voltmeter
- (5) 200-Channel low-level scanner
- (6) System coupler
- (7) Disk file with 524K 12-bit words
- (8) High-speed paper tape reader
- (9) High-speed paper tape punch
- (10) Model 35 AT (printer only) teletypewriter

System III is currently being used for life testing Brayton cycle electrical components. The hardware configuration of system III is

- (1) PDP-8/I computer with 12K of core memory
- (2) ASR Model 35 teletypewriter with paper tape punch and reader
- (3) Real time clock
- (4) Integrating digital voltmeter
- (5) 300-Channel low-level scanner
- (6) System coupler
- (7) Fluke true RMS meter
- (8) Special wattmeter
- (9) Modified scanner to provide voltage and current inputs simultaneously to the wattmeter
- (10) High-speed paper tape reader

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2. Anon.: Focal Programming Manual. Digital Equipment Corporation, Maynard Mass., Aug. 1968.

:G

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TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*;D I
INPUT LINE*;CH 125 126 AUTO 16MS 1
INPUT LINE*;CH 127 128 10MV 16MS 301
INPUT LINE*;CH 129 129 AUTO 16MS 2
INPUT LINE*;CH 130 130 AUTO 16MS 3
INPUT LINE*;CH 131 133 10MV 16MS 301
INPUT LINE*;CH 134 134 AUTO 16MS 4
INPUT LINE*;CH 135 135 AUTO 16MS 5
INPUT LINE*;CH 136 136 AUTO 16MS 4
INPUT LINE*;CH 137 137 AUTO 16MS 5
INPUT LINE*;CH 138 138 AUTO 16MS 2
INPUT LINE*;CH 139 139 AUTO 16MS 3
INPUT LINE*;CH 140 142 10MV 16MS 301
INPUT LINE*;CH 143 143 AUTO 16MS 4
INPUT LINE*;CH 144 144 AUTO Q?
:CH 144 144 AUTO 16MS 5
INPUT LINE*;CH 145 145 AUTO 16MS 4
INPUT LINE*;CH 146 146 AUTO 16MS 5
INPUT LINE*;CH 147 147 AUTO 16MS 2
INPUT LINE*;CH 148 148 AUTO 16MS 3
INPUT LINE*;CH 149 151 10MV 16MS 301
INPUT LINE*;CH 152 152 AUTO 16MS 4
INPUT LINE*;CH 153 153 AUTO 16MS 5
INPUT LINE*;CH 154 154 AUTO 16MS 4
INPUT LINE*;CH 155 155 AUTO 16MS 5
INPUT LINE*;CH 156 156 AUTO 16MS 2
INPUT LINE*;CH 157 157 AUTO 16MS 3
INPUT LINE*;CH 158 160 16M?
:CH 158 160 10MV 16MS 301
INPUT LINE*;CH 161 161 AUTO 16MS 4
INPUT LINE*;CH 162 162 AUTO 16MS 5
INPUT LINE*;CH 163 163 AUTO 16MS 4
INPUT LINE*;CH 164 164 AUTO 16MS 5
INPUT LINE*;CH 165 165 AUTO 16MS 2
INPUT LINE*;CH 166 166 AUTO 16MS 3
INPUT LINE*;CH 167 169 10MV 16MS 301
INPUT LINE*;CH 170 170 AUTO 16MS 4
INPUT LINE*;CH 171 171 AUTO 16MS 5
INPUT LINE*;CH 172 172 AUTO 16MS 4
INPUT LINE*;CH 173 173 AUTO 16MS 5
INPUT LINE*;CH 174 174 AUTO 16MS 6
INPUT LINE*;CH 175 175 AUTO 16MS 3
INPUT LINE*;CH 176 178 10MV 16MS 301
INPUT LINE*;CH 179 179 AUTO 16MS 4
INPUT LINE*;CH 180 180 AUTO 16MS 5
INPUT LINE*;CH 181 181 AUTO 16MS 4
INPUT LINE*;CH 182 182 AUTO 16MS 5
INPUT LINE*?01.00 @ 25.43
*
```

Figure 1. - Teletype listing of a table building session. The lines with a ? are ignored and repeated on the next line. The final line is terminated with an escape character.

;G

TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*;D L

LIMITS*;1 -1
ENTRY CH-CH RANGE PERIOD LINK
1 125 126 AUTO 16MS 1
2 127 128 10MV 16MS 301
3 129 129 AUTO 16MS 2
4 130 130 AUTO 16MS 3
5 131 133 10MV 16MS 301
6 134 134 AUTO 16MS 4
7 135 135 AUTO 16MS 5
8 136 136 AUTO 16MS 4
9 137 137 AUTO 16MS 5
10 138 138 AUTO 16MS 2
11 139 139 AUTO 16MS 3
12 140 142 10MV 16MS 301
13 143 143 AUTO 16MS 4
14 144 144 AUTO 16MS 5
15 145 145 AUTO 16MS 4
16 146 146 AUTO 16MS 5
17 147 147 AUTO 16MS 2
18 148 148 AUTO 16MS 3
19 149 151 10MV 16MS 301
20 152 152 AUTO 16MS 4
21 153 153 AUTO 16MS 5
22 154 154 AUTO 16MS 4
23 155 155 AUTO 16MS 5
24 156 156 AUTO 16MS 2
25 157 157 AUTO 16MS 3
26 158 160 10MV 16MS 301
27 161 161 AUTO 16MS 4
28 162 162 AUTO 16MS 5
29 163 163 AUTO 16MS 4
30 164 164 AUTO 16MS 5
31 165 165 AUTO 16MS 2
32 166 166 AUTO 16MS 3
33 167 169 10MV 16MS 301
34 170 170 AUTO 16MS 4
35 171 171 AUTO 16MS 5
36 172 172 AUTO 16MS 4
37 173 173 AUTO 16MS 5
38 174 174 AUTO 16MS 6
39 175 175 AUTO 16MS 3
40 176 178 10MV 16MS 301
41 179 179 AUTO 16MS 4
42 180 180 AUTO 16MS 5
43 181 181 AUTO 16MS 4
44 182 182 AUTO 16MS 5
2 GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*

Figure 2. - A teletype listing of a data table. The limits 1 - 1 ask for the complete table to be listed.

```
?01.00 @ 25.01
*:G
```

```
TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*:K I
INPUT LINE*:833333
INPUT LINE*:200
INPUT LINE*:1
INPUT LINE*:100
INPUT LINE*:10000
INPUT LINE*:2000
INPUT LINE*:?01.00 @ 26.13
*
```

Figure 3. - Teletype listing of building the zero-order coefficient table.

```
:G
```

```
TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*:K L

LIMITS*:1 -1
ZERO ORDER COEFFICIENT TABLE

ENTRY VALUE
1 833331.00
2 200.000
3 1.000
4 100.000
5 10000.000
6 2000.000
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*?01.00 @ 25.01
*
```

Figure 4. - Teletype listing of the zero-order coefficient table.

*G

```
TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*;Q I
SET AND DELIMS*;301 3
DELIM*;5.821
A0,A1,A2*;491.199 46.7-1.0
DELIM*;9.52498
A0,A1,A2*;485.799 45.9-0.7
DELIM*;13.203
A0,A1,A2*;461.699 48.4-0.7

GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*
```

Figure 5. - Teletype listing of entering a quadratic coefficient set.

?01.00 @ 25.01
*G

```
TABLE GENERATOR
GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*;Q L

LIMITS*;1 -1
SECOND ORDER COEFFICIENT TABLE

ENTRY
  1      SET # 301
      DELIM      A0      A1      A2
      5.82100    491.19700  46.70000  1.00000
      9.52496    485.79800  45.90000  0.70000
      13.20300   461.69800  48.40000  0.70000

GIVE TABLE (C,D,F,K,L,Q,T); FUNCTION (C,D,I,L)*
```

Figure 6. - Teletype listing of a quadratic coefficient set.

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