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Integrating an oscilloscope into a general purpose automatic test system

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INTEGRATING AN OSCILLOSCOPE INTO A GENERAL PURPOSE AUTOMATIC TEST SYSTEM

BY

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ABSTRACT

The General Purpose Automatic Test System was developed for the Air Force as a system to automatically test and fault isolate an electronic unit under test. The Test System is a building block concept and this paper developed the hardware and programming software necessary to integrate an oscilloscope into the system. A Tektronix Type 564 oscilloscope with a Tektronix Type 3A5 Programmable Amplifier and a Tektronix Type 3B5 Programmable Time Base was used. A prototype of the digital and analog interface between the Test System and the Tektronix System was built and demonstrated. The Oscilloscope Building Block displays waveforms only and requires manual intervention in the automatic test program to interpret the presented data.

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I. Summary

The General Purpose Automatic Test System (GPATS) was developed for the Air Force as a system to automatically test and locate a fault in an electronic unit under test. The system presents all data discretely and as a result the continuous data of complex waveforms is lost. The GPATS system has a block concept. This paper develops the software and hardware necessary to integrate a programmable oscilloscope into the general purpose test system.

The logic and interfacing circuitry required for this integration is shown schematically and is included as Figures 4, 5, and 6, pages 22, 23, and 24, which are included in Appendix A. A photograph of a functional prototype model of the interfacing hardware is included as Figure 3, page 21, Appendix A.

II. Test Philosophy

Before discussing the operation of the General Purpose Automatic Test System, it is necessary to understand the testing philosophy. The General Purpose Automatic Test System was developed for the Air Force as a system which automatically tests an electronic unit and determines whether or not the unit under test is operational. If the unit under test is not operational, the General Purpose Automatic Test System will isolate the fault in the unit to the level of a defective component (or components). The elemental unit of the testing scheme is the individual test, with a mutually exclusive pass or fail objective. These individual tests are then assembled into a test program which by proper design executes the individual tests in an order determined by the previous tests results to achieve the desired end; - pass or fault location in the unit under test.

A. Individual Test

Each test contains the following five specifications:

1. Definition of dummy loads, stimuli equipment, and measurement equipment along with the required settings of the equipment.
2. The locations on the unit under test where the loads, signals, and measurements are to be applied and taken.
3. The definition of the expected value for a pass condition.
4. The action to be taken for either the pass and fail condition.
5. The time an initiate measurement command is to be given.

B. Test Program

The test program is assigned an identity number applicable to a unique set of units under test. The identity number allows verification of the correct test program for the unit under test.

Typically each individual test checks only one component. A pass or go condition would indicate the component is within the required tolerance and the program will continue to the next individual test which would check another discrete component. A fail or no-go condition normally indicates the component tested is not within the required tolerance and the testing program will stop indicating a failure on a certain test number. The no-go on a given test number is associated with a defective component. It is assumed that, once a defective component has been isolated through a program stop, the unit under test will be removed from the test system, the defective component replaced, and the test program re-run in its entirety from the beginning. The test program is repeated from the beginning to eliminate the possibility of a repair causing a failure of another component which has already passed the test program.

Individual tests are classified as performance or diagnostic tests. The performance tests are further sub-divided into no-power and power performance test. The no-power performance tests are usually resistance readings and precede the power performance tests to isolate a short-circuit before power is applied to the unit under test. Sometimes, a performance test will check several discrete components in series or parallel operation. In this case, a pass would indicate that all of the discrete components checked are good. A failure, however, would indicate that one or more of several series or parallel components are bad and the test program must enter a diagnostic series to isolate the particular component. A test program will never enter a diagnostic series unless there has been a fault indication. Since there must be a failure to branch to a diagnostic test the series will eventually terminate in a no-go stop condition with a different component replacement requirement depending on whether the no-go stop is high, in, low, or over-range. A pass unit under test will not leave the main flow of the test program and enter a diagnostic series since it does not have a failure. For this reason the diagnostic test series is a sub-program located at the end of the main test program.

III. General Purpose Automatic Test System

The General Purpose Automatic Test System shown in Figure 1 is analogous to a manually operated electronics laboratory. They both have similar test equipment, objectives, and procedures. They differ, however, in their implementation. The advantages of an automatic test system over a manual test system include: reduction of time required to check out a unit under test; identical reproducibility of test procedures; reduced chance of error; and finally, a lower level of technical skill required of the operating personnel.

The unit under test, the interface box, the engineering tape, the operator's manual, the General Purpose Automatic Test System, and the Operator are all necessary. All but the General Purpose Automatic Test System and the Operator will be different for each unique set of units under test. The interface box is required to make the unit under test mechanically and electrically compatible with the General Purpose Automatic Test System as well as supply switching, loads, and stimuli required by the unit under test and not available in the General Purpose Automatic Test System. The engineering tape contains the instructions in machine language necessary to run the test program. In the following discussion the General Purpose Automatic Test System is described from a software and physical system perspective.

A. Software

Figure 2 illustrates an engineering tape. Information is presented in a hole-punched binary weighted code. Information is stored a program (seven or less frames) at a time. Frame one and two address the universal decoder of a building block. Frames three through seven

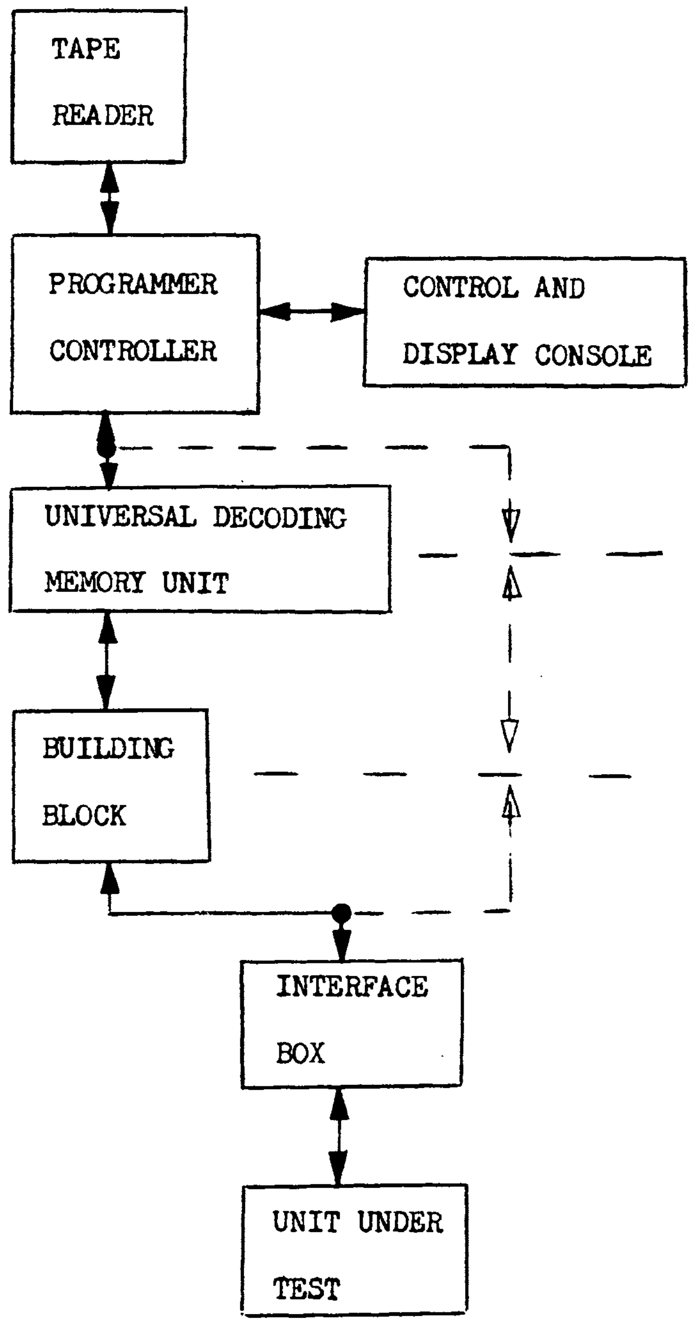

FIGURE 1. GPATS Block Diagram

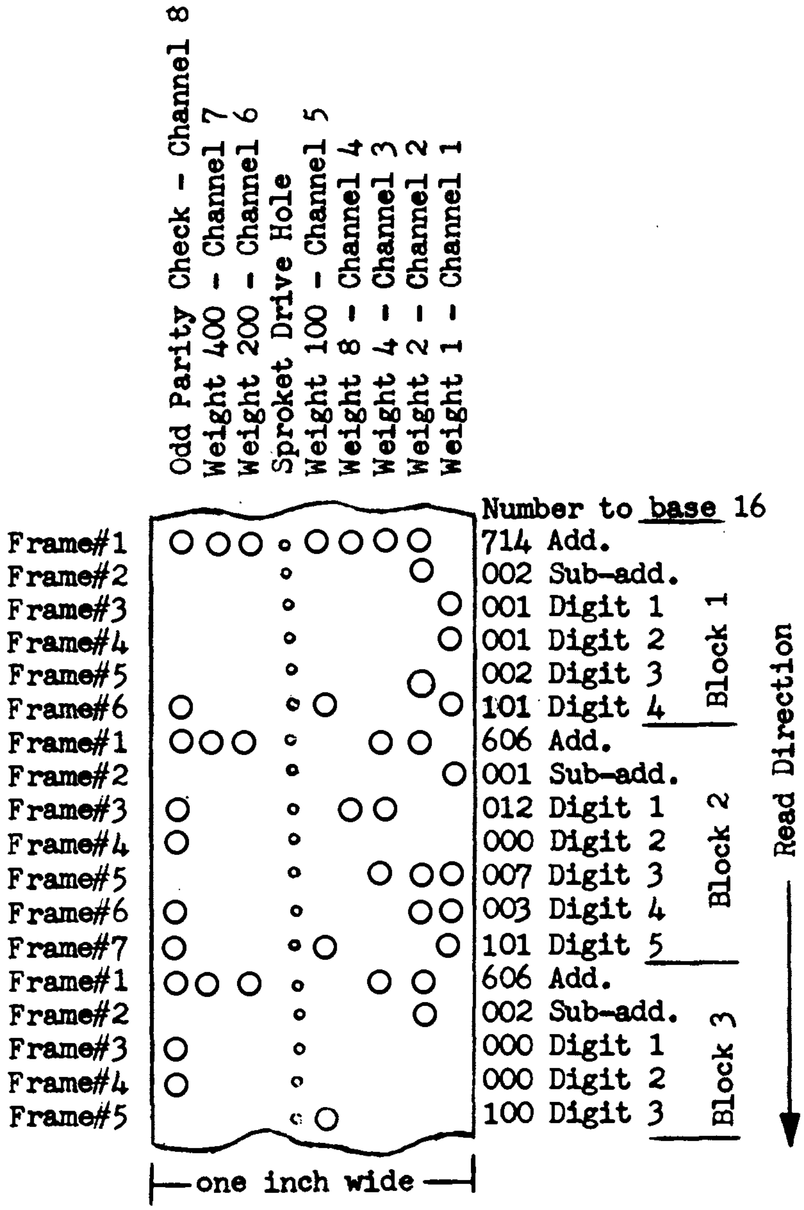

FIGURE 2. Engineering Tape - Sample Oscilloscope Program

(digits one through five) are the building block commands. Five independent commands, each one of which can be one of sixteen possibilities, are presented per program block for one decoder. If a particular building block requires more than five independent commands to fully control it, then additional universal decoders are added along with additional programming blocks to fully program the building block. Digits one through five can be programmed to any value between zero and fifteen. The meaning of a given digit value is determined by the building block software programming specification (Table 1 is an example). Since Digits one through five must be fifteen or less in value channels five, six and seven in Frames three through seven are not used and are available for control codes. For example, control code 1 (hole or 100 weight, channel 5) means that frame is the end of a program block and the next frame read will be an address.

The tape manual is the General Purpose Automatic Test System operator's handbook. The tape manual instructs the operator in any manual action required before (hook-up instructions), during (operator participation) or after (faulty component replacement) the test program. The most common operator action involved a no-go stop. This along with the appropriate test number will be indicated on the display panel. In the operator's manual the test number versus the required operator action table would direct the operator to a faulty component which must be replaced. If an operator participate is programmed for a given test number, the display panel will indicate this requirement and the operator should perform the required manual action (adjust a dial on the interface box, for example) as defined by the manual before continuing the test program.

BUILDING BLOCK # 102 - PROGRAMMABLE OSCILLOSCOPE
ADDRESS: 606

SUB-ADDRESS: 001

Digit 1: Seek Command and Sweep Rate ⚠1	0	manual mode-seek & sweep	8	sweep rate: .2 sec./div.
	1	seek amplitude & sweep	9	sweep rate: .1 sec./div.
	2	seek amplitude only	10	sweep rate: 50 ms/div.
	3	seek sweep rate only	11	sweep rate: 20 ms/div.
	4	sweep rate: 5 sec./div.	12	sweep rate: 10 ms/div.
	5	sweep rate: 2 sec./div.	13	sweep rate: 5 ms/div.
	6	sweep rate: 1 sec./div.	14	sweep rate: 2 ms/div.
	7	sweep rate: .5 sec./div.	15	sweep rate: 1 ms/div.
Digit 2: Sweep Rate (continued) ⚠2	0	manual mode-sweep rate	8	sweep rate: 2 us/div.
	1	sweep rate: .5 ms/div.	9	sweep rate: 1 us/div.
	2	sweep rate: .2 ms/div.	10	sweep rate: .5 us/div.
	3	sweep rate: .1 ms/div.	11	sweep rate: .2 us/div.
	4	sweep rate: 50 us/div.	12	sweep rate: .1 us/div.
	5	sweep rate: 20 us/div.	13	sweep rate: 50 ns/div.
	6	sweep rate: 10 us/div.	14	sweep rate: 20 ns/div.
	7	sweep rate: 5 us/div.	15	sweep rate: 10 ns/div.
Digit 3: Amplitude Deflection Factor ⚠3	0	manual mode-amplitude	8	amplitude: 2 v./div.
	1	amplitude: 10 mv/div.	9	amplitude: 5 v./div.
	2	amplitude: 20 mv/div.	10	amplitude: 10 v./div.
	3	amplitude: 50 mv/div.	11	amplitude: 20 v./div.
	4	amplitude: .1 v./div.	12	amplitude: 50 v./div.
	5	amplitude: .2 v./div.	13	not used
	6	amplitude: .5 v./div.	14	not used
	7	amplitude: 1 v./div.	15	not used
Digit 4: Input Coupling and 10x Probe Select	0	manual mode-input coup.	8	not used
	1	DC coup. w/o 10x probe	9	
	2	DC coup. with 10x probe	10	
	3	AC coup. w/o 10x probe	11	
	4	AC coup. with 10x probe	12	
	5	AC trace stab. w/o 10x	13	
	6	AC trace stab. with 10x	14	
	7	not used	15	not used
Digit 5: Trigger Function and Slope	0	manual mode:trigger	8	external DC-neg. slope
	1	internal auto-pos. slope	9	not used
	2	internal auto-neg. slope	10	
	3	internal AC-pos. slope	11	
	4	internal AC-neg. slope	12	
	5	external AC-pos. slope	13	
	6	external AC-neg. slope	14	
	7	external DC-pos. slope	15	not used

SUB-ADDRESS: 002 ⚠4

Digit 1: Trigger Level	0	manual mode: trig. level	8	increasing trigger
	1	most neg. trig. level	9	level
	2	increasing trigger	10	
	3	level	11	
	4		12	
	5		13	
	6		14	
	7	zero trig. level	15	most pos. trig. level
Digit 2: Delayed Sweep Magnifier: Magnitude and Delay ⚠5	0	manual mode: no mag.	8	x100-last six div.
	1	x10-last two div.	9	x100-last eight div.
	2	x10-last four div.	10	x100-all ten div.
	3	x10-last six div.	11	not used
	4	x10-last eight div.	12	
	5	x10-all ten div.	13	
	6	x100-last two div.	14	
	7	x100-last four div.	15	not used
Digit 3: External Horizontal Input ⚠6	0	no ext. horz. input	8	not used
	1	ext. horizontal input	9	
	2	not used	10	
	3		11	
	4		12	
	5		13	
	6		14	
	7	not used	15	not used

⚠6 Input resistance-100k ohms. Horizontal deflection factor is 5 v./div. Maximum input voltage-75 v dc plus peak ac.

⚠5 Magnify x100 can not be used with sweep rates faster than 5 us/div. Magnify x10 must be slower than 1 us/div.

⚠4 Digit 4 and Digit 5 of Sub-address 2 are spares.

⚠3 The presence of a 10x probe display on the Amplifier Readout is programmed in Digit 4 of Sub-address 1.

⚠2 Digit 1 and Digit 2 of Sub-address 1 can not both be programmed to a value other than zero. At least one is zero.

⚠1 When "seek command" is programmed the oscilloscope automatically selects the amplitude and/or sweep rate.

NOTES:

TABLE 1: Oscilloscope Programming Specifications

B. The Physical System

The hardware of the General Purpose Automatic Test System includes: a tape reader to input the machine language software instructions; blocks which supply test stimuli and parameter measurement; a programmer controller for comparison and logic decisions; and finally, a display console to output data.

The tape reader is an eight channel light sensitive diode device. The coded information is stored seven frames or 1 block at a time and then released to the universal decoding memory unit, associated with each building block. The address and sub-address of each memory unit is unique. The same coded information is sent to every memory unit but only that memory unit with the same address and sub-address as that of the program block supplying the information will accept and store the command data. Once a memory unit is programmed to a given configuration it will retain that state until reprogrammed or reset. Once the memory unit verifies it has the correct information the memory unit outputs the commands to its associated building block.

The building blocks on the General Purpose Automatic Test System include switching units and standard electronic laboratory equipment. The switching unit allows any one piece of equipment to be connected to any given external connector. The external connector is electrically connected to the unit under test through a cable assembly and the interface box. The laboratory equipment building blocks include: stimuli equipment such as A.C. Power Supplies, D.C. Power Supplies, and Function Generators; loading equipment such as resistance loads, Syncro/Resolver Simulators, and Ratio Transformers; and finally, measurement equipment such as AC-DC-OHMS Multimeter, Waveform Analyzer, and Timer-Counter.

The program controller can be considered special purpose building blocks which store information required to operate the test program. The program controller stores: test number; alternate searchable test number (on no-go search logic)--if required; length of measurement delay for transient decay; high and low limits; basis for stop or search select; and definition of no-go logic.

The display console is the link between the operator and the General Purpose Automatic Test System. The console contains required operational switches. Information pertinent to the individual test such as test number, high and low limit, measured value, units, logic, and required operator action indication are displayed on the console. The measured information is presented as a decimal readout to eight digits.

IV. Programmable Oscilloscope

For waveform measurements the present General Purpose Automatic Test System does include a Time Interval/Frequency Meter and a Waveform Analyzer. The measured parameters are treated as discrete information to implement logical decision comparison and for test data results display. Converting the analog waveform information into digital logic is required for a fully automatic testing system requiring no manual intervention. However, in any continuous to discrete conversion information is lost. A complex modulated waveform, for example, cannot be handled by a sampling measurement technique. For a given waveform test the proper waveform is normally specified as a graph with given tolerances (amplitude, over-shoot, period, and rise time, for example). Since an oscilloscope displays continuous waveform information, the oscilloscope is an obvious choice to measure complex waveforms. Any adjustments to the oscilloscope necessary to display a waveform could be handled automatically in the test program if a programmable oscilloscope were used. The disadvantage of using even a programmable oscilloscope in a fully automatic test system is that an operator decision to interpret the displayed waveform information is required. Because of this restraint the oscilloscope would only be used for waveforms so complex that the other building blocks could not make the measurement. A further use of the oscilloscope building block would be to display in a diagnostic series what the discrete waveform analyzing building blocks failed (no-go) in the main test program. With the oscilloscope the operator would have more information about the unusual or out of tolerance waveform than discrete device data would present.

The present General Purpose Automatic Test System display console includes an eight digit decimal readout for the upper limit, lower limit, and measured value. Since the console is the interface between the operator and the test system, the programmable oscilloscope would be located adjacent to or as part of the display console. An individual test requiring the oscilloscope would, after all stimuli and load conditions have been made as well as the oscilloscope programmed and connected to the test point, activate an operator participate indication on the display console. The oscilloscope would display the measured waveform and the progress of the engineering tape would stop. The operator's manual would describe the desired waveform (sketched), tolerances, and go/no-go actions. A go action would probably be press to start and continue the tape feed. A no-go action would either specify a fault or require the operator to search the program tape to some fault isolating diagnostic test. To reduce the possibility of error, clear plastic overlays with the correct waveform and tolerance area shaded could be used in place of the manual graph. When a dual-trace programmable amplifier becomes available the second channel could be used to display a generated waveform for comparison with the measured waveform. In any case, the operator would have to conclude whether or not the displayed waveform was acceptable and pursue the course of action dictated in the manual.

A Tektronix Model 564 Oscilloscope[1] with a Type 3A5 Automatic/Programmable Amplifier[2] and a Type 3B5 Automatic/Programmable Time-Base[3] was chosen as the oscilloscope building block to integrate into the General Purpose Automatic Test System. The Tektronix system was chosen since it has a standard wide range display capacity within an allowable three to five percent accuracy plus several unique features which make it readily adaptable to an automatic test system. The single trace amplifier and time base can be externally programmed, operated fully automatically, or manually controlled. The units are externally programmable by a digital and analog system. The system can be operated fully automatically through a manual or external digital programmed "seek" command. Upon receipt of the "seek" command the oscilloscope automatically selects an optimum deflection factor and sweep rate to display the applied waveform. Both the amplifier and the time base have a readout facility which displays the oscilloscope setting information - deflection factor, sweep time, input coupling, presence of 10X probe, "uncal" or "not triggered" or magnified sweep indication. This readout feature supplies the operator with the correct oscilloscope setting information. The sweep speed and sensitivity setting can be different than the manual dial position when operating in the "seek" or external program mode. Any function than can be manually controlled on the amplifier or time-base generator can also be externally programmed. The Model 564 Oscilloscope was chosen because it is a memory scope which can display transient and time delay data. The memory function, however, is manually controlled and not externally programmable.

V. Oscilloscope Building Block

To accomplish the task of physically integrating a programmable oscilloscope into the General Purpose Automatic Test System requires the knowledge of the system design constraint specifications. The General Purpose Automatic functions are digital. However, they do not operate at the same logic levels. Also, some of the oscilloscope functions require a programmable analog current. Thus a logic converter is required to adapt the oscilloscope into the test system. Specifications necessary to design a logic converter include: general building block requirements, Universal Decoding Memory Unit outputs to the building block, programmable oscilloscope inputs, and the resulting logic converter requirements.

A. Building Block Requirements

A building block may require more than one Universal Decoder. A Universal Decoder is capable of storing five frames of information which can be one of sixteen events. Seemingly, this would allow 80 programmable events (16 events/frame X 5 frames) per decoder which should be sufficient for the most complex piece of equipment. However, only one independent set of events can be programmed per digit if programming control of all sets of events is to be maintained. Hence, it is common to have a building block which requires two decoders (6-10 independent sets of events) while many of the sixteen events are not used since there are not sixteen events in every set of events. Table 1 is an example of decoder digit utilization for the Oscilloscope Building Block.

A building block must be capable of being reset after initial application of power. Resetting of the Oscilloscope Building Block is defined as returning the oscilloscope from the external program mode to the manual mode. The building block must follow combinational double rail digital logic supplied by the Universal Decoder from the building block. A logic 1 pulse is supplied to the Universal Decoder from the building block when the programmed data has been accepted. Accessible test points on the building block are required to fault isolate the building block on a General Purpose Automatic Test System self-test.

The building block must conform to a standard set of military manufacturing specifications. In addition, printed circuit cards and racks should be used, solid state devices preferred, a circuit breaker power on switch with indicator required, and an elapsed time meter to indicate standby and operating time is necessary.

B. Universal Decoder Output

The Universal Decoding Memory Unit is a sequential input flip-flop storage device with a combinational level binary coded line output to the building block. The decoder output is five digits of four bits each (8, 4, 2, 1). Logic 1 is a + 10 to 15 volt source, while Logic 0 is a 0 to 1 volt sink. A pulse is defined as Logic 1 for a duration of 15-30 microseconds with a rise time less than or equal to 2 microseconds.

Both rails of the double rail logic are at Logic 0 with a no-output line at Logic 1 until the decoder is programmed and check functions are completed. The decoder then furnishes a data ready pulse followed by the 20 bit (4 bits/digit X 5 digits) program logic (D.C. level in parallel) to the building block. The sequence is repeated when the decoder is reprogrammed.

C. Oscilloscope Inputs[1, 2, &3]

The Tektronix Model 564 Oscilloscope is powered by a 115V, 50-400 Hz A.C. Power Supply. The 3A5 Amplifier and 3B5 Time Base each have a 37 pin external connector through which the programming information is supplied. Depending on the function, the oscilloscope is programmed either by a 0-500 micro-ampere analog current or combinational digital logic. Logic 0 for the scope is a -12 volt sink while Logic 1 is a ground (0 volt) source. Diode isolation on the scope inputs is required when one scope function is activated by more than one programming event.

D. Logic Converter Requirements

The obvious constraint on the logic converter is the outputs of the decoder in relation to the input requirements of the oscilloscope. Digital inputs to the oscilloscope are obtained by decoding the 4 line per digit decoder binary code and converting to a gnd/-12 volt digital logic system. The digital to analog conversion required for some scope functions is obtained by using an operational amplifier as a weighted summer to control the bias on a transistor. A unijunction one shot supplies the required data-accept-feedback pulse. Finally, the converter powers the oscilloscope from a general purpose automatic test system power source.

VI. Programming Example

Table 1 relates the oscilloscope software programming specification to the binary weighted code required by the General Purpose Automatic Test System. Each building block has an arbitrary, but unique, address. The sub-address identifies the Universal Decoding Memory Unit of the building block. It has been pointed out that more than one decoder may be required for a building block. The five digits following the sub-address contain the information required to program the building block.

Building Block Number 102 (606 to the base 16) was chosen as the Oscilloscope Building Block. The Oscilloscope Building Block requires two decoders (Sub Address 1 and 2) to completely program it. Digits 4 and 5 of Sub Address 2 are not required for programming and are spare digits for future programming additions or could be used for a self testing program. The engineering tape of Figure 1 programs the oscilloscope building block. The first programming block identifies an individual test number (1121). The next two programming blocks address the oscilloscope. In this illustration the scope is programmed for a 10ms/div. sweep rate, IV/div. amplitude deflection, AC coupled without 10X probe, auto internal trigger on positive slope, manual control of trigger level, no delayed sweep magnification, and no external horizontal input.

The illustration is not a complete individual test, since no stimuli has been applied to the unit under test, nor has the output test waveform been applied to the scope. A waveform can be inputed to the scope in one of several ways. If a probe were required the operator could manually probe the test point on the unit under test. If coax were required a coax cable could be connected from the scope to the interface box of the unit under test. A coax relay "logic tree" within the interface box would automatically switch the input of the scope to the desired test points when the coax relay coils are powered by the General Purpose Automatic Test System. Finally, if open test leads can be used the Oscilloscope Building Block could be wired to an automatic Switching Building Block which exists in the test system. The Switching Building Block can be programmed to connect any unit under test point to any building block input. In any case, once the scope settings were programmed, the waveform input applied to the scope, and the required stimuli applied to the unit under test, an Operator Participate and Program Hold would initiate, stopping the test in progress. The operator would view the scope displayed waveform and take the appropriate action required by the operator's manual.

VII. APPENDIX A

PROTOTYPE OF OSCILLOSCOPE LOGIC INTERFACE

The body of the paper was written as a proposal for the software and hardware necessary to integrate an oscilloscope building block into the General Purpose Automatic Test System.

McDonnell Douglas Corporation made a grant to build a prototype of the logic interface. Tektronix loaned a Type 3A5 Amplifier and a Type 3B5 Time Base. During the week of October 26, 1969, the oscilloscope building block was successfully debugged and demonstrated to the Air Force at Hill Air Force Base, Ogden, Utah.

Appendix A includes a schematic of the interface between the test system and the oscilloscope, and a picture of the functional prototype hardware.

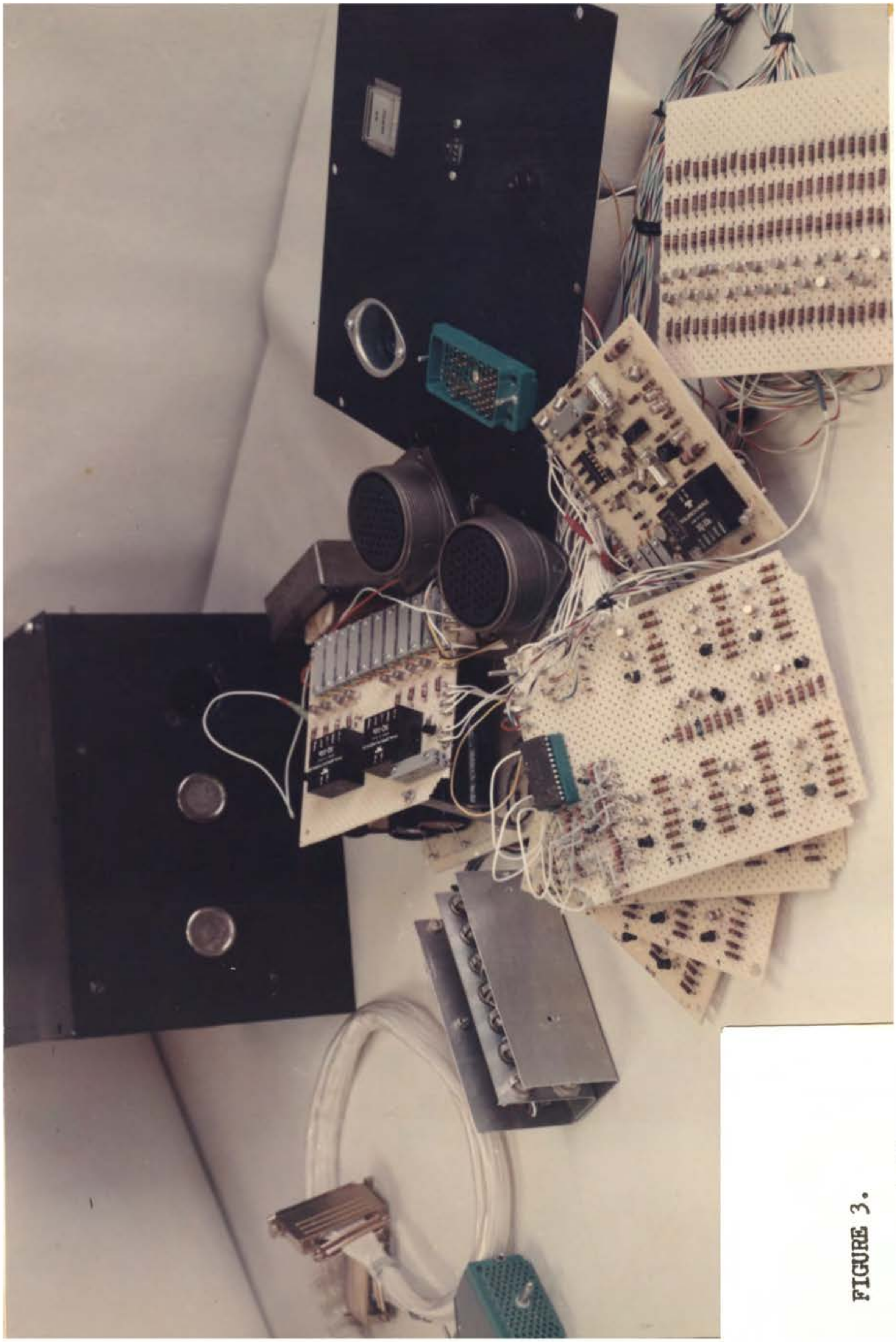

FIGURE 3.

Photograph Of Oscilloscope Logic Interface

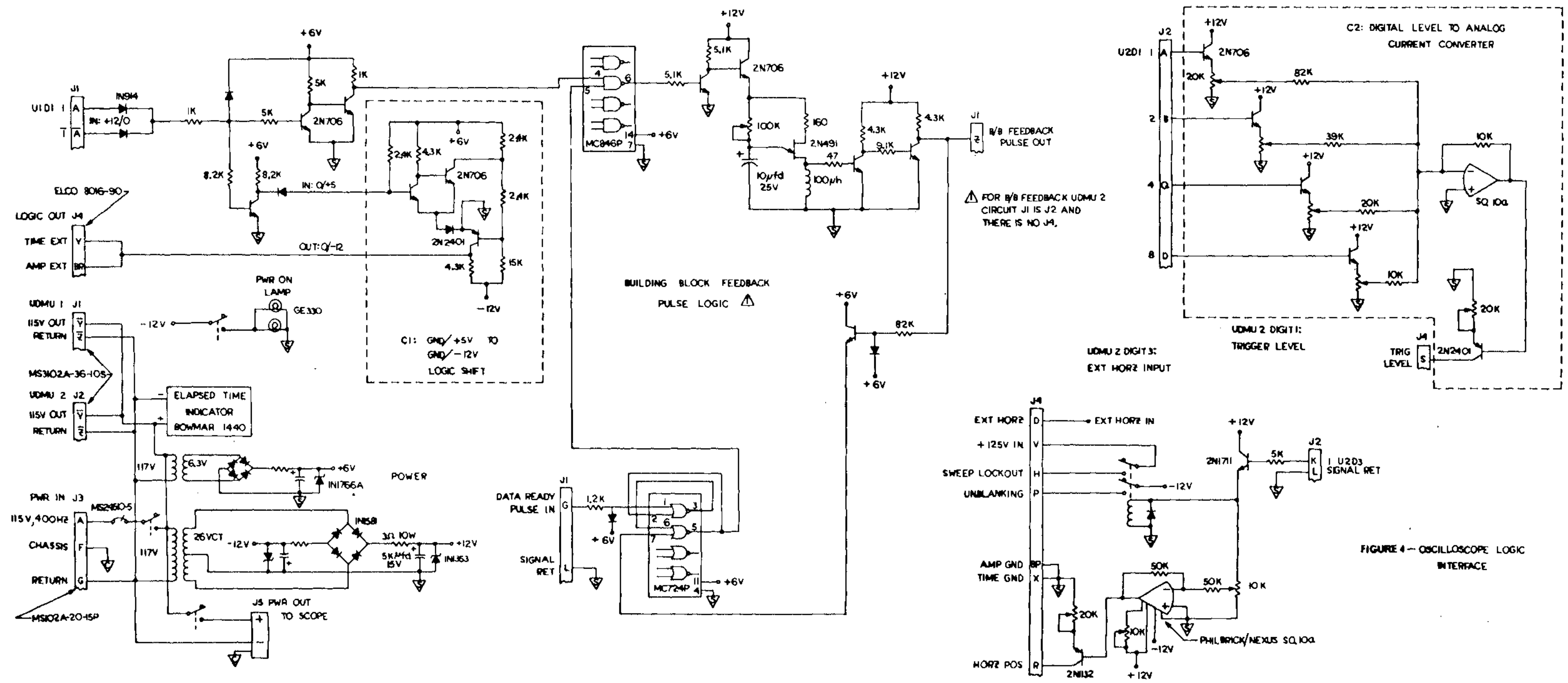

FIGURE 4 - Oscilloscope Logic Interface

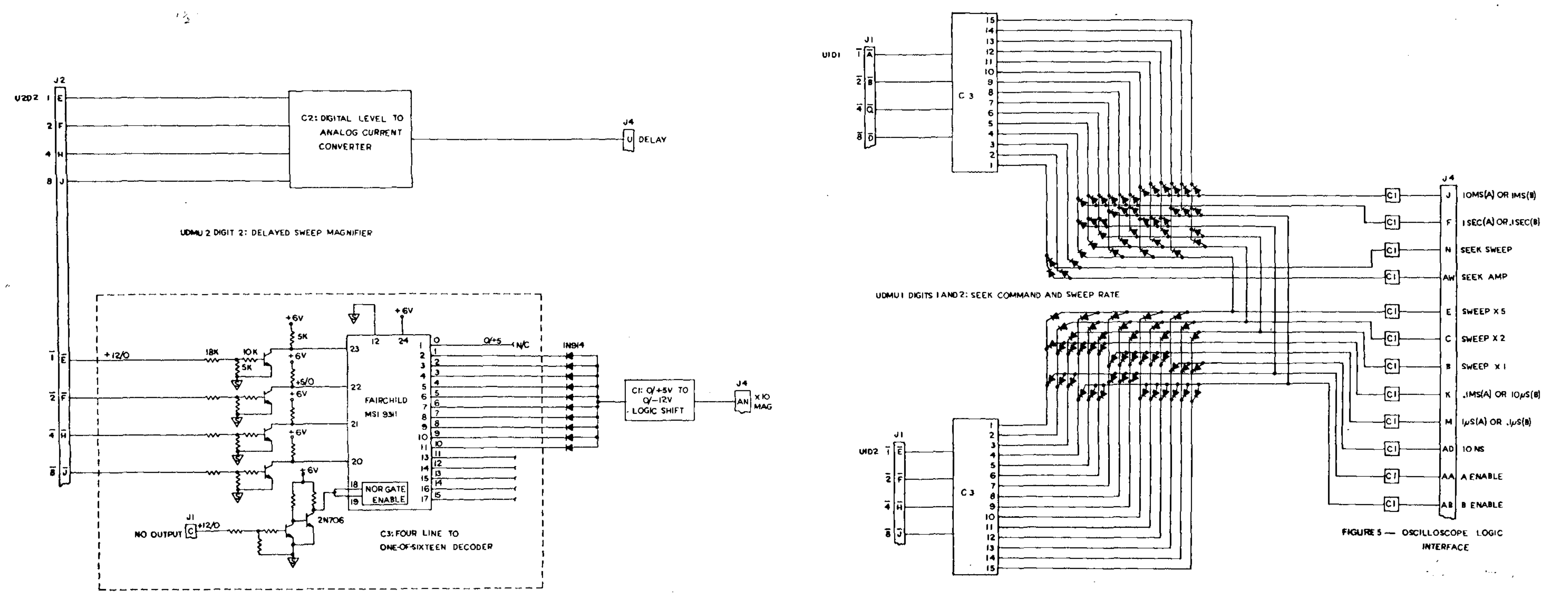

FIGURE 5 - Oscilloscope Logic Interface

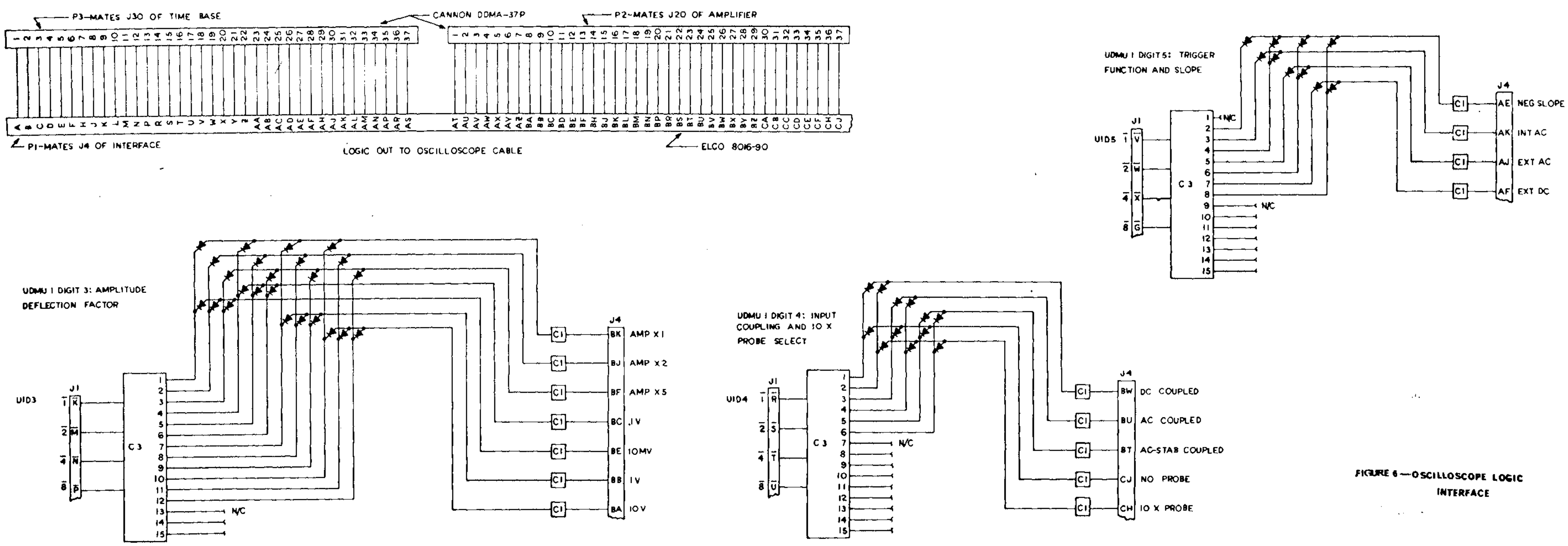

FIGURE 6 - Oscilloscope Logic Interface

VIII. BIBLIOGRAPHY

1. Instruction Manual - Type 564 Oscilloscope, c 1963 by Tektronix, Inc., Beaverton, Oregon.

2. Instruction Manual - Type 3A5 Automatic/Programmable Amplifier, c 1965 by Tektronix, Inc., Beaverton, Oregon.

3. Instruction Manual - Type 3B5 Automatic/Programmable Time Base, c 1966 by Tektronix, Inc., Beaverton, Oregon.

IX. VITA

William Charles Bauer was born on December 8, 1944, in St. Louis, Missouri. He received his primary and secondary education in Ferguson, Missouri. He received his college education from University of Missouri - Rolla. He received a Bachelor of Science Degree in Electrical Engineering from the University of Missouri - Rolla, in Rolla, Missouri, in May, 1967.

He has been employed by the McDonnell Douglas Corporation in St. Louis, Missouri, since June 1967. He is currently a design engineer in the Radar Electronics Laboratory of the Aircraft Division.

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