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PRODUCTION MEASUREMENT OF FUZE COMPONENTS UNDER DYNAMIC STRESS.(U)
MAR 77 A J EISENBERGER, P KASZERMAN

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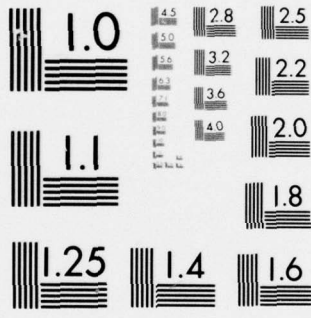
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THIRD QUARTERLY REPORT

PRODUCTION MEASUREMENT OF FUZE COMPONENTS
UNDER DYNAMIC STRESS

11 NOVEMBER 1976 - 10 FEBRUARY 1977

CONTRACT NUMBER DAAB07-76-C-0032 ✓

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U.S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
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PRODUCTION MEASUREMENT OF FUZE COMPONENTS
UNDER DYNAMIC STRESS

THIRD QUARTERLY REPORT

11 NOVEMBER 1976 - 10 FEBRUARY 1977

OBJECT OF STUDY: DEVELOPMENT OF A COMPUTER
CONTROLLED AUTOMATIC TESTER,
CAPABLE OF TESTING AND TRIM-
MING THICK FILM ADJUSTMENT
CIRCUITS AT THE RATE OF
3,000/HOUR

CONTRACT NUMBER DAAB07-76-C-0032

PREPARED BY

ARTHUR J. EISENBERGER
PHILIP KASZERMAN

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ABSTRACT

During the third quarter, the major components of the test station were built, assembled, and successfully checked out at the vendors' plants. These components consisted of the following subsystems:

- . Computer control
- . Stimulus
- . Measurement
- . Interface
- . Laser Trimmer

The first four subsystems were integrated and checked as a total system by Hewlett-Packard. The tests included a complete check of the software operating system, as well as a test of all peripheral hardware. The laser trimmer was tested on a stand-alone basis using simulated computer inputs. A simulation of the real-time amplifier test program was begun. The main-line program was coded and debugged. The design of the revised fuze oscillator and amplifier circuitry was completed, and prototype capacitors and chip resistors were fabricated and analyzed.

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1. PURPOSE

The purpose of this program is to develop a dynamic test and correction system, capable of high-speed operation, for electronic assemblies. The circuits selected for verification under this contract are the oscillator and amplifier assemblies of the M732 Fuze. The contract requires that 3,000 units of each assembly be delivered, of which 2,900 have been trimmed to meet the specifications. The required test rate is 3,000 an hour.

2. NARRATIVE AND DATA

2.1 INTRODUCTION

During the third quarter, the major components of the test station were built, assembled, and successfully checked out at the vendors' plants. The computer control, stimulus, measurement, and interface systems were tested at the Hewlett-Packard facility in Cupertino, California. These tests were witnessed by Lockheed Electronics Company, Inc. (LEC) personnel. These tests will be repeated, after delivery, at the LEC plant as the final acceptance procedure. The computer control tests consisted of individual checks on all the elements of the operating system and associated programs such as the file manager, editor, and program compilers. The hardware peripherals were tested using Fortran driver programs and checking with actual hardware measurements at each output point. The laser trimmer was checked out at the Quantrad plant in El Segundo, California. Computer commands were simulated by a test device. Beam positioning, laser optics, interface, laser status, and laser cutting ability were successfully tested.

A simulation of the real-time amplifier test program was begun, and was partially completed. A main-line routine was written and debugged. Calls to the subroutines were included, and the subroutines were identified.

All components and subassemblies necessary to fabricate oscillator and amplifier units (with two minor exceptions) have been released for prototype and/or final assembly.

2.2 FUZE REDESIGN

The progress made in releasing components during the third quarter is shown in the revised oscillator and amplifier assembly

family trees in Figures 1 and 2 (refer to Figures 1 and 2 in the Second Quarterly Report for a comparison). All components and subassemblies necessary to fabricate oscillator and amplifier units, with two minor exceptions, have been released for prototype and/or final assembly.

2.2.1 *Oscillator Chip Capacitor*

A number of capacitor chips in the preliminary design were saw-cut from the fired array on the master substrate, and mounted on aluminum adapter plates. These plates, in turn, were mounted into the testing fixture, and trimming cuts were performed on the chips at the distance anticipated within the test chamber. An .003-wide kerf in the gold film was obtained using a relay lens and the following laser settings (see Figure 3):

- . Lamp current - 22.5 amps
- . Iris - 256; Spot - .080
- . Overlap - medium (50 percent)
- . Repetition rate - 5 kilohertz
- . Trim speed - 1 inch per second; slew speed - 4 inches per second

It was necessary to incorporate a second light source within the chamber to observe the metallized pattern and locate the starting point, which does not appear to pose any mechanical or electrical problems. Computer control was simulated by introducing the final position coordinate and executing the *go to* command.

The original chip-capacitor design described in the first quarterly report was redesigned to provide four binary-valued capacitances; thus, 16 equal steps are available instead of the equal four-increment version. Two separate designs are presently being constructed, using different fringing-capacitance criteria. One criterion is based on the result of the original experimental capacitance-testing data, and the other is based on theory. Test samples will be evaluated and modified, as required, to provide

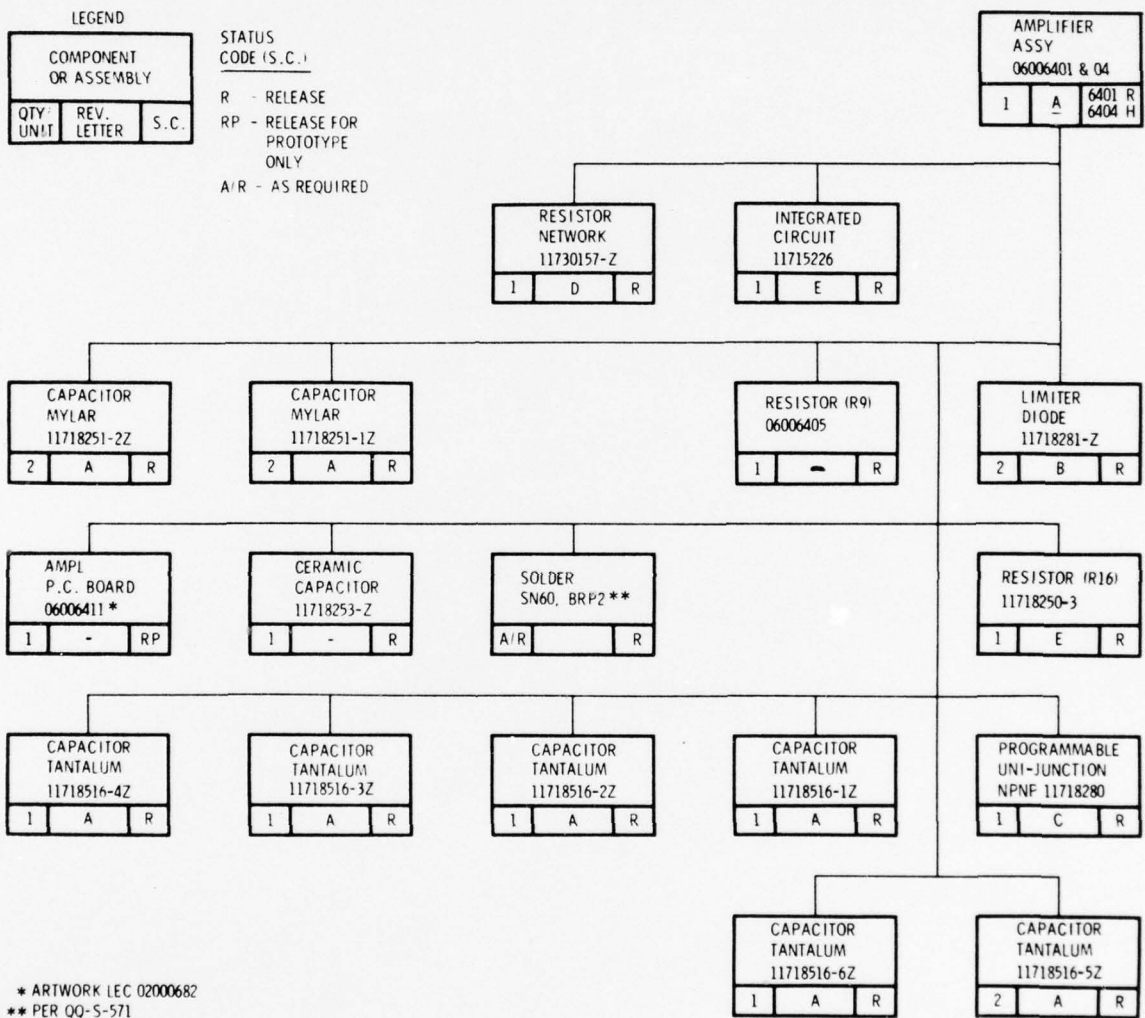


Figure 2. ECOM Amplifier Board Family Tree (Revision 2)

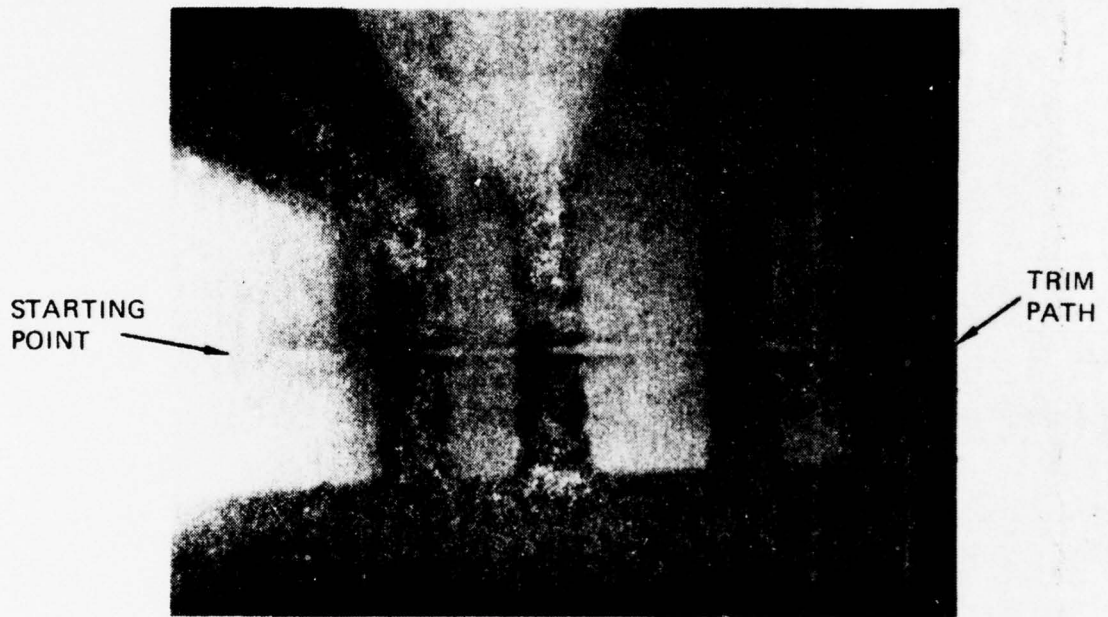


Figure 3. Capacitor Laser Trim (.003 kerf)

the needed capacitance. The starting-point locator has been centralized to reduce initial slewing time. Artwork has been completed (see Figure 4), and samples will be available during the fourth quarter.

2.2.2 *Oscillator Ribbon Wire*

A short piece of rectangular* ribbon wire is required to connect the ceramic chip capacitor to the major oscillator circuitry. Several commercial wires are readily available at LEC. Selecting a specific type will be made by the time the first prototype units are ready for assembly.

2.2.3 *Trimable Resistor (Amplifier Gain Adjustment)*

Statistical data on 1 kilohm per square thick-film resistor material (from six different vendors), subjected to two different firing cycles, was accumulated and analyzed (see Table 1). LEC's objective was to achieve multisources of material for a standard firing cycle. The distribution spread is significant in determining which material would be most predictable from trimming and reliable design standpoints. Several conclusions (see Figure 5) can be drawn at this point, as follows:

- . High resistance values can be produced by the following:
 - Using termination conductor with higher platinum content
 - Using fritless (reactively bonded) termination material
- . Vendors can be ranked as follows:
 - Cermalloy - most flexible; tightest distribution
 - Electro-Science Laboratories - Close to nominal; good distribution
 - Englehard - close to nominal; good distribution

*The length of the wire is about 0.100 inches; the width is 0.050 to 0.075 inches.

Table 1. As-Fired Resistor Values (RNOM = .695 kilohms)

Vendor	Resistor Ink	Conductor Ink	Firing Profile (See Note 1)	R Range Min Max	R AVG	36 Limits Min Max	C.V. Percent (See Note 2)	Thickness Dried Fired (mils)
Cermalloy	2300	4100	A	.585 .612	.611	.566 .656	2.45	0.8 0.35
			B	.714 .783	.745	.685 .805	2.65	0.8 0.35
			C	.616 .690	.645	.585 .705	3.10	-
			D	.480 .542	.507	.447 .567	3.94	0.9 0.4
Electro-Science Laboratories	2913	9597	A	.721 .857	.777	.693 .861	3.60	0.8 0.35
			B	.560 .649	.602	.521 .683	4.48	0.8 0.35
			C	.641 .747	.688	.598 .778	4.36	-
Engelhard	A3003	A3147 A3058 A3147 A3058 A3147 A3058	A	.631 .755	.688	.601 .775	4.20	1.0 0.7
			A	.687 .851	.773	.632 .914	6.08	.9 0.5
			B	.613 .681	.638	.578 .698	3.13	1.0 0.7
			B	.632 .722	.674	.590 .757	4.15	0.9 0.5
			C	.786 .984	.871	.736 1.006	5.55	-
			C	.939 1.11	1.001	.884 1.118	3.90	-
DuPont	4931	9770 9770 9770	A	.752 .854	.800	.722 .878	3.25	1.1 0.6
			B	.774 .881	.838	.760 .916	3.10	1.1 0.6
			C	.616 .680	.648	.588 .708	3.09	-
Thick Film Systems	850-102	3412 3709 3412 3709 3412 3709	A	.430 .480	.449	.407 .491	3.12	0.8 0.35
			A	.353 .403	.378	.333 .423	3.97	0.8 0.35
			B	.407 .470	.434	.380 .488	4.15	0.8 0.35
			B	.348 .401	.369	.330 .408	3.52	0.8 0.35
			C	.406 .457	.429	.384 .474	3.5	-
			C	.359 .435	.399	.336 .462	5.26	-
EMCA	5013-1	4249	A	.838 1.03	.958	.820 1.096	4.80	0.8 0.4
			B	.811 .967	.887	.767 1.077	4.51	0.8 0.4
			C	.830 .978	.897	.798 .966	3.67	-

NOTES:

1. A=850°C - 2 in/min (Lindberg) B=850°C - 3 in/min (Lind) C=875°C - 3 in/min (Hayes)
D=875°C - 3 in/min (Lind)
2. C.V. = Coefficient of variation, X (MEAN) ÷ σ (65 percent distribution limit)

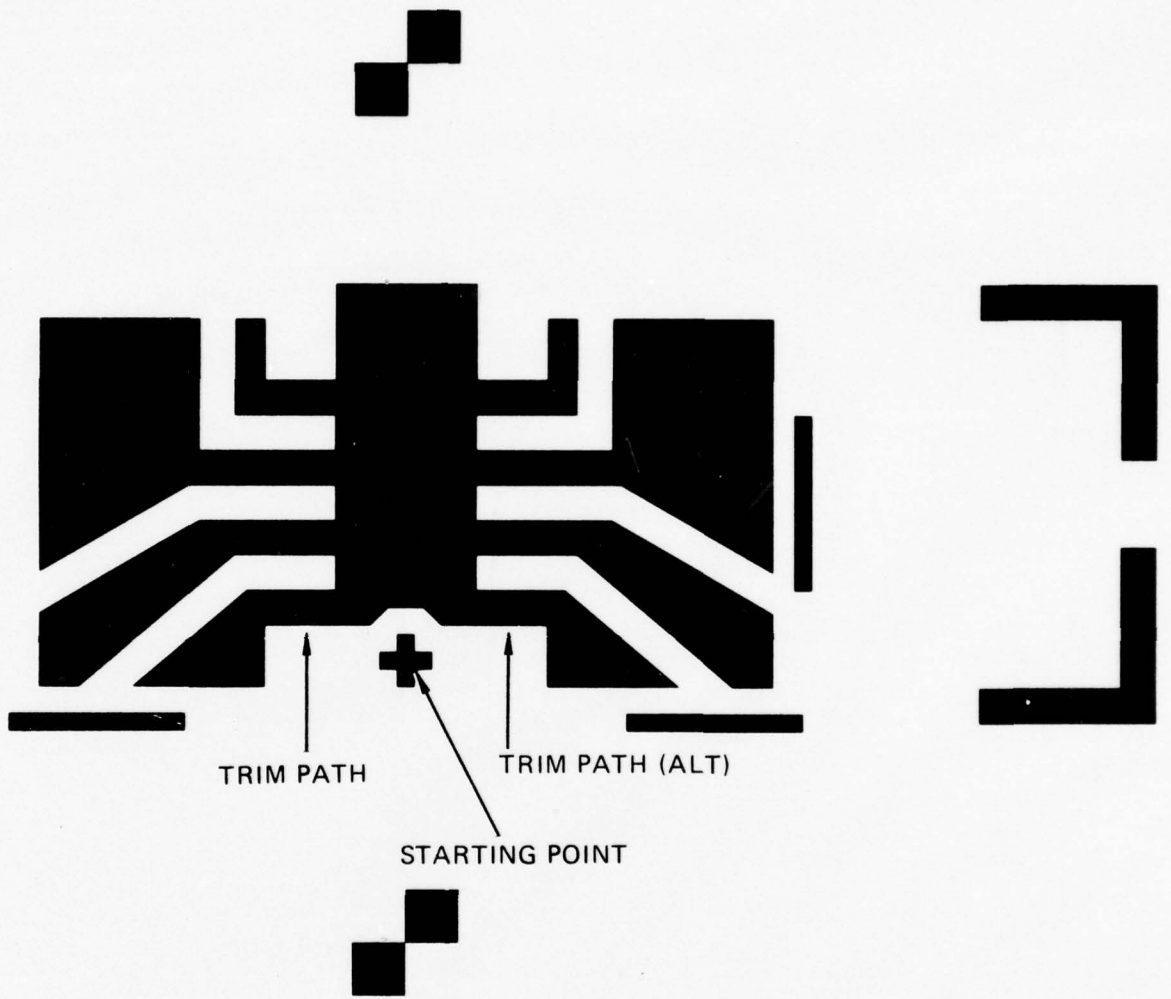


Figure 4. Trimmable Capacitor Pattern (Binary Ratio)

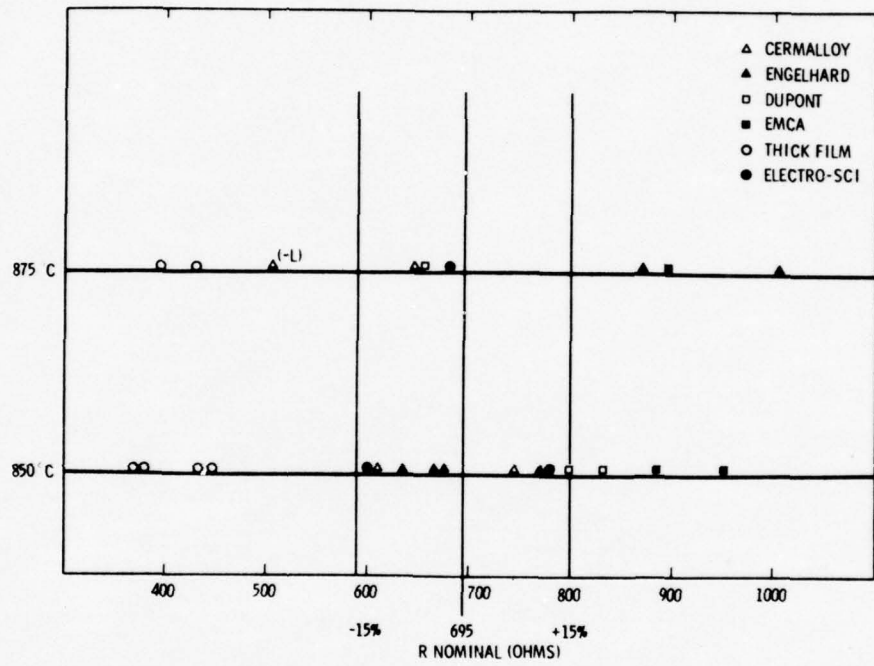


Figure 5. Resistor Chip As-Fired Mean Values

- DuPont - somewhat high; good distribution
- Thick Film Systems - very low values; good distribution
- EMCA - very high-fired values; fair distribution

2.2.4 *Laser Trimming*

A substrate array of resistor patterns were placed on the shuttle-feed mechanism, and a number of cuts were made during the check-out procedure. One resistor pattern was used to optimize the cutting parameters and simulate trimming under computer control. Figure 6 shows the back-lighted resistor plunge and shadow cuts made under computer control. Figure 7 shows the same resistor using reflected light and a third track, which did not penetrate the film because of insufficient laser power. Figure 8 depicts another resistor, which suffered surface damage because of excessive laser power and improper rep rate for a given trimming speed. The successful laser parameters used to produce a 2-mil kerf were as follows:

- . Lamp current - 18 amps
- . Iris - 225; spot - .300
- . Overlap - medium (50 percent)
- . Repetition rate - 5kHz
- . Trim speed - 0.5 inches per second
- . Slew speed - 4 inches per second

2.3 SYSTEM CHECKOUT

The test station system is a third-generation system consisting of the following major elements:

- . Computer
- . Computer-generated stimuli
- . Computer-controlled sampling system
- . Computer-controlled interface

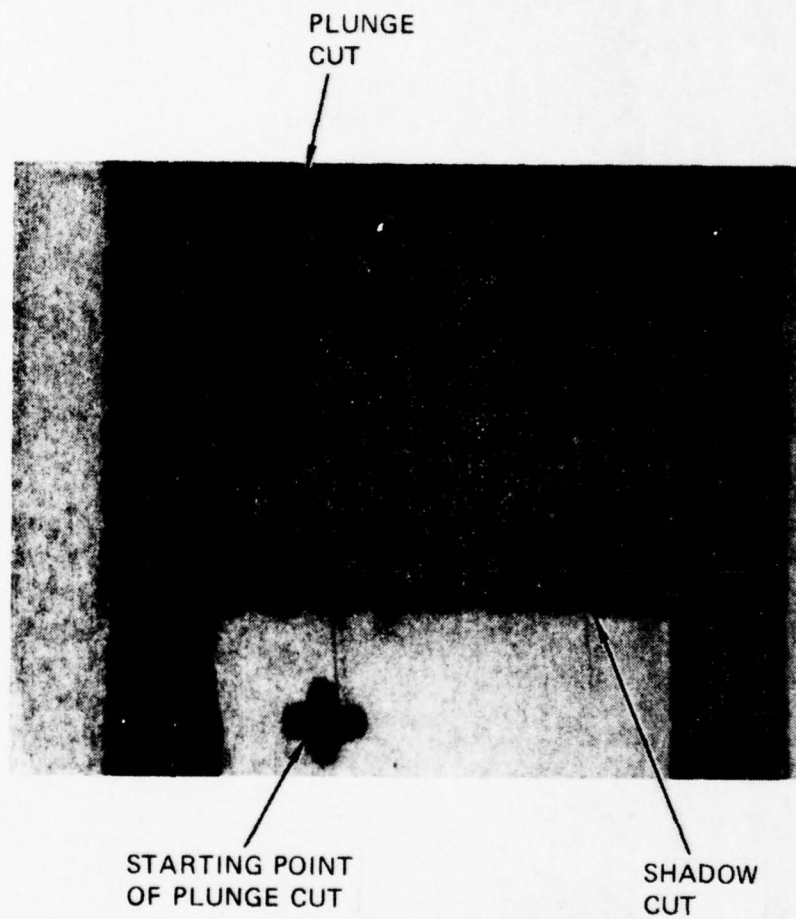


Figure 6. Back Lighted View of Resistor Cuts

SATISFACTORY THROUGH CUT
(NO SURFACE DAMAGE)

SUPERFICIAL CUT DUE
TO INSUFFICIENT LASER
POWER



STARTING
POINT

Figure 7. Top Lighted View of Resistor Cuts

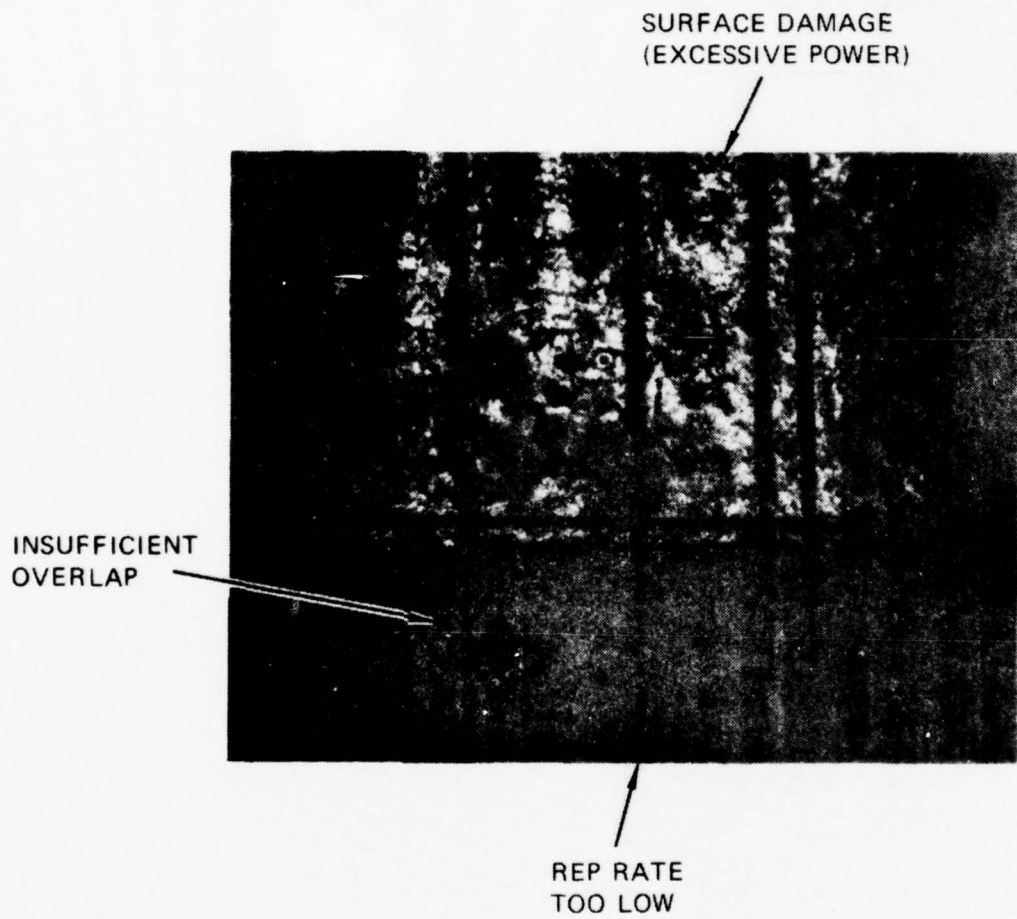


Figure 8. Unsatisfactory Laser Cuts on Thick-Film Resistor

- . Computer calculation of parameters from sampled data
- . Computer-controlled laser trimmer

By adding the laser to the third-generation test system, a real-time, computer-controlled trim capability has been realized.

During the first quarter, a conceptual system was designed (see Figure 9). During the second quarter, specific hardware was chosen and ordered. Figure 10 indicates the details of the system except for the laser trimmer. This portion of the system was checked out at the Hewlett-Packard factory in Cupertino, California. The tests consisted of separate checks on the operating system and integrated software-to-hardware tests for each peripheral device and card. The operating system, consisting of the software, disk, TTY, and high-speed paper tape reader, was exercised by first reading in diagnostic programs from the paper tape reader. The TTY was automatically checked since it was used as the system console to enter commands to the diagnostic programs, and was used by the computer as the output printer device. The disk and its setup was checked by writing and reading to it. The specific elements of the operating control system (i.e., real-time executive, file manager, and editor) were exercised by being called, and by having the operator enter commands controlled by each one. Programs written in Fortran, Algol, and Assembly language were compiled and run; these results were compared to known results.

Each peripheral was checked by either writing to it or reading from it. Each pacer was checked by setting it for a specific rate, reading a fixed number of words, and then checking the elapsed time by using the internal clock. The analog multiplexer (electronic switch) and last address detector were checked together by putting known fixed voltages on the switch points, commanding the switch to read through several cycles, and then checking the numbers against a table of known correct values. While the high-level multiplexer was checked, the A/D and sample-hold voltages were also checked since the voltages on the switch

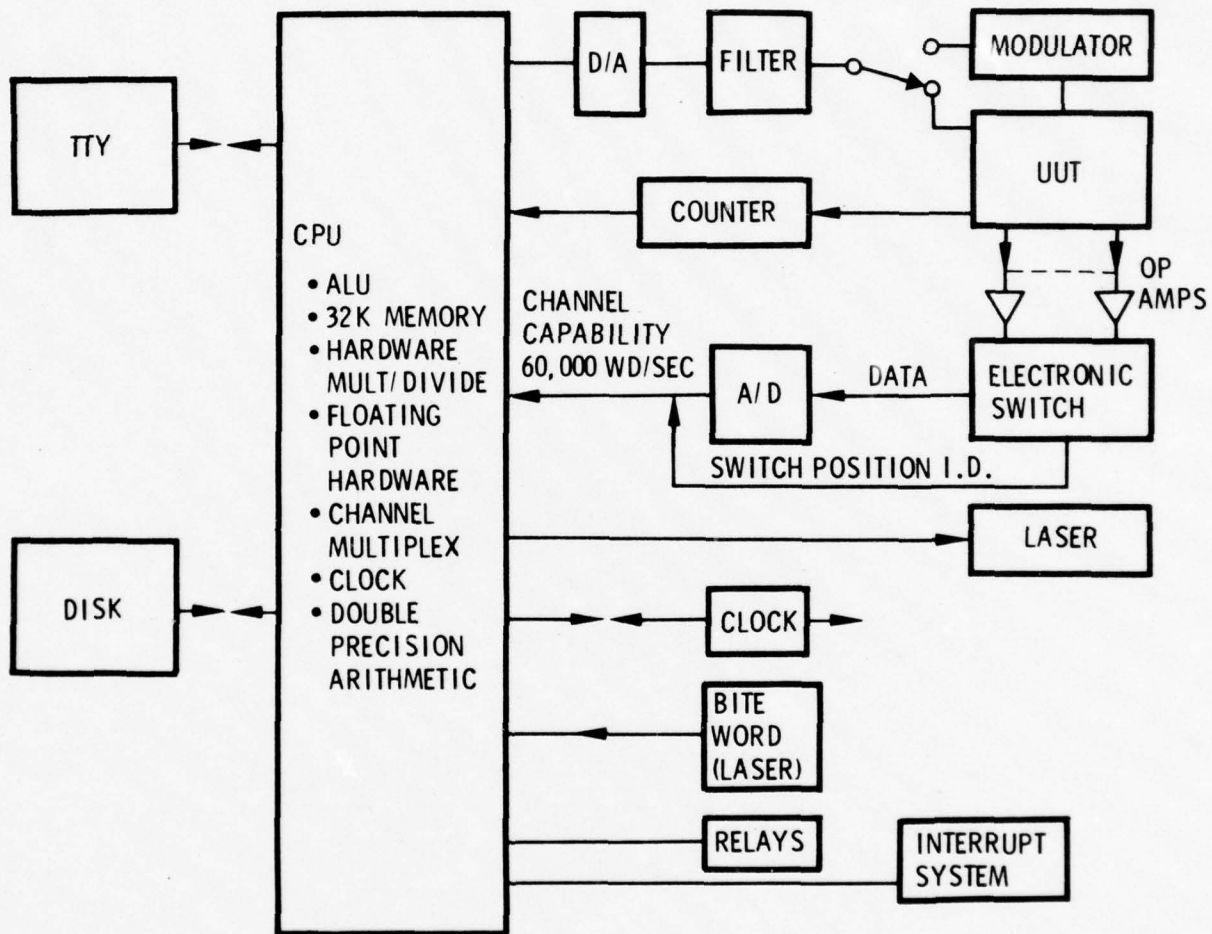


Figure 9. Test and Correction System

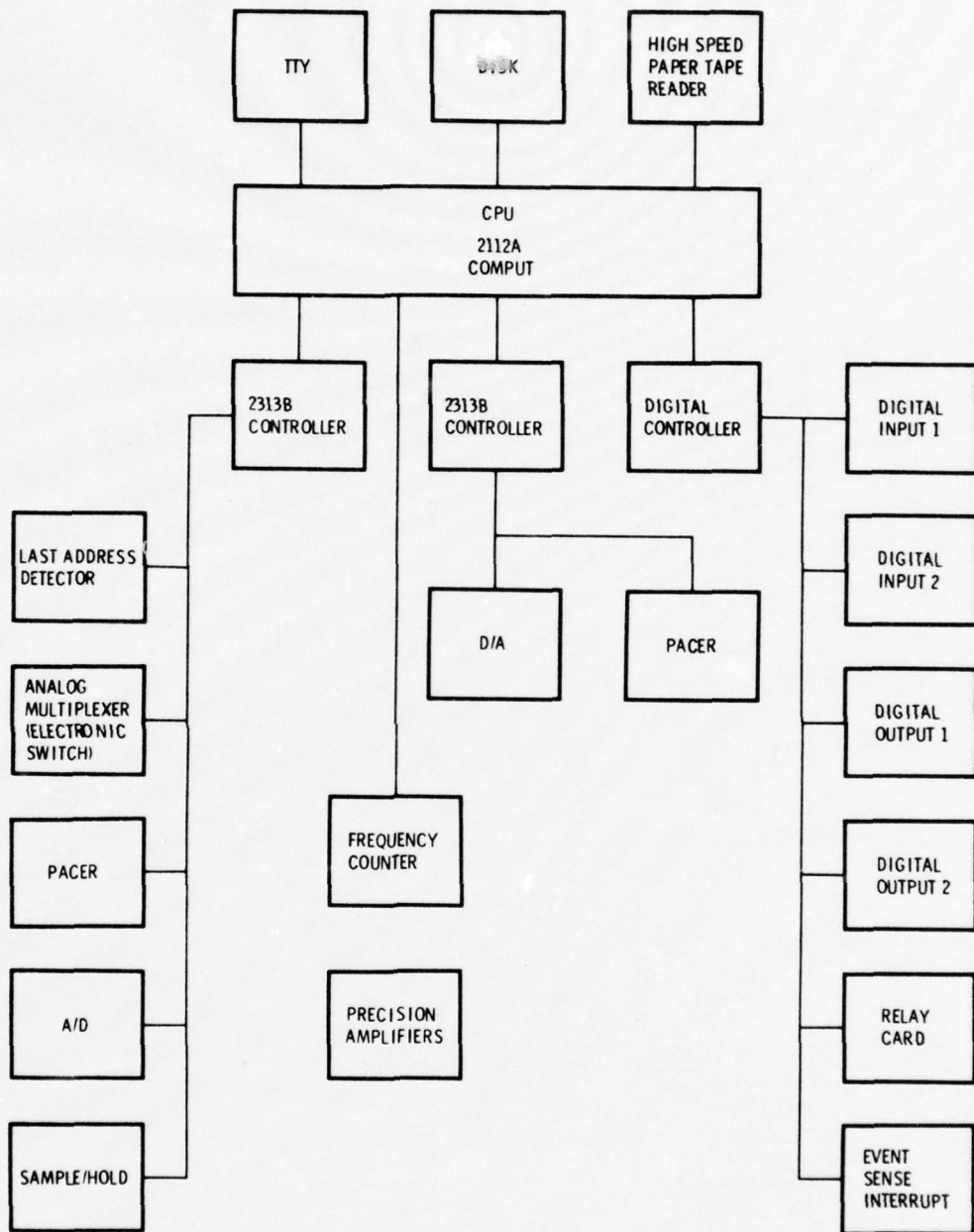


Figure 10. Computer and Computer Peripherals

had to be sampled, held, and converted to a digital number before being read by the computer. The D/A voltage was checked by outputting two different digital values from the computer and then checking (with a voltmeter) that the correct analog voltages appeared at the output of the D/A.

The cards connected to the digital controller were also tested. The digital input cards were tested by applying alternate zeros and ones to the input, reading from the card, and then comparing the card to a stored correct value. The test was repeated with alternate ones and zeros. The digital output cards were tested by successively outputting alternate zeros and ones, alternate ones and zeros, and then checking the output of the cards. The relay card was tested by commanding each relay to open and close, and then physically checking to be sure that this did take place. The event-sense interrupt was tested by energizing each of the 12 bits in succession, and checking that the computer program was indeed interrupted, and had jumped to an interrupt subroutine.

Final acceptance tests will take place at LEC during the fourth quarter.

Fuzes have been tested and the results have been checked against the model described in the Second Quarterly Report. The results of the comparison are described in Appendix A.

2.4 LASER TRIMMER CHECKOUT

The laser trimmer system was tested at the Quantrad plant in El Segundo, California. A Quantrad-supplied test procedure was used to check the laser performance, laser optics, beam positioner, interface, and laser status. The unit successfully passed all tests. The paragraphs that follow provide a description of this checkout procedure.

Laser. - Place the laser in operation, as specified in Section 2.3 of the operating manual. Remove the light shield between the

laser output mirror and the optics box, and mount Coherent Radiation Model 205 detector head in the beam path. Connect the detector head to Coherent Radiation Power Meter Model 201, turn on laser, and perform the following output power measurements:

Q-switch rf off (safety shutter held open to defeat the interlock, and no aperture in the laser) 30 watts (at 21 amps lamp current)

Q-switch as above but with .060-inch aperture 4 watts minimum (10 watts - actual)

To determine that the latter condition is indeed the TEM₀₀ mode, observe the defocused beam at the output objective position with an infrared viewer. The spot should be round with a single maximum in the center, and perform the following measurements:

Q-switch rf on, repetition rate set at 5 kilohertz:

2.5 watts output minimum

actual { 3.0 watts at 15 amps
6.5 watts at 20 amps lamp current

Laser Optics. - Set up laser-trim parameters to obtain the smallest spot size, using the aperture and spot-size controls. Trim a sample thick-film substrate using a 2-inch focal length objective, and verify that the spot size can be varied between .001 and .005 inches. Elevate the substrate with a .005-inch shim, and verify that the spot size does not change, confirming the field depth of .010 inches. Install relay lens in table top, mount sample thick-film gold sample at 6.5-inch distance below table, and perform trim. Elevate substrate with .060 shim and repeat.

Beam Positioner. - Connect the beam positioner and place it in operation according to Section 2.4 of the 1021 manual. With the control console in the manual mode, operate the joystick to the four extremes of motion. Verify that the system stops at the limits, and that the limits are 2.000 inches apart by making scribe marks on an anodized aluminum plate and measuring with a steel rule. Command the system to the center (X=2048, Y=2048),

and make a mark with the laser. Modify the command to X-1024 and then to X3072, and verify that the marks are 1.000 inches apart.

Verify slew speed by connecting an oscilloscope to TP 1 on the X axis control board and observing the voltage under manual joystick control. Measure the time for a traverse of 1 inch (eight revolutions) and divide the voltage at TP 1 by this time to calibrate the tachometer. Using this calibration number, measure the peak voltage during a slew of at least .250 inches (two turn discs placement from the end point). The slew rate should calculate to 4 inches per second. Repeated slews can be performed by commanding the system to the center and turning the mode switch to manual. The system is then displaced from the center by the joystick, and the mode switch is returned to remote. The positioner will then slew to the center, and the rate is measured by the tachometer signal. Trim rates are similarly checked by commanding the trim mode.

Interface and Digital Control. - The interface is checked by means of a simulator, supplying 25 milliamperes to the inputs on which 1's are desired, and leaving open inputs for which 0's are desired. The strobe line is supplied with a 10-microsecond pulse at the same level. The command code lines are set for either an X position, Y position, or command word. The code is put on-line, and a strobe pulse is sent. The command code can then be changed, and another word can be sent. The interface outputs are monitored by the LEDs in series with the output lines. Connections to a compatible interface or shorting plugs must be in place to use the LED indicators. Representative addresses are commanded, and the LED indicator output is observed to demonstrate that the input command is echoed in the position returned. Command codes are verified by observing that the trim speed is enabled in trim, and that the laser is controlled by the laser enabled and laser not inhibited commands.

Laser Status. - The laser status signals are verified by introducing laser faults and observing LED indicators. Temperature faults should be simulated to avoid stress on the laser.

2.5 MODULATOR DESIGN

Figure 11 shows a block diagram of the circuitry used in conjunction with oscillator load-chamber testing. The three main functions shown are a primary power source, load chamber, and modulator. Rf signals from the test oscillator are sampled by an antenna mounted in the floor of the oscillator load chamber. The sample signal is then routed to an Rf power divider, where a single sideband (ssb) modulator offsets its frequency by a computer-generated modulator signal. The offset signal frequency and duration are controlled by the computer and converted into an analog signal by a D/A converter located in the computer console. An audio filter and buffer amplifier will be provided to produce the appropriate modulation drive level for the modulator. The Rf signal is then adjusted in amplitude and reradiated into the test fuze as the stimulus for its detector.

This circuitry is also capable of amplitude modulating a constant offset-frequency return signal. In this case, the modulator drive is generated by the computer. The offset frequency, however, is locally generated. Modulating in this manner allows amplitude modulation of the return signal with an arbitrary waveform.

Three measured test parameters are required to predict oscillator *sensitivity*, the parameter to be adjusted. They are pretune operating frequency (f_o), detector voltage, and sensitivity. Operating frequency is measured by a frequency meter located in the computer console. The detector voltage and pretune sensitivity are measured at the oscillator bias circuit as a large dc

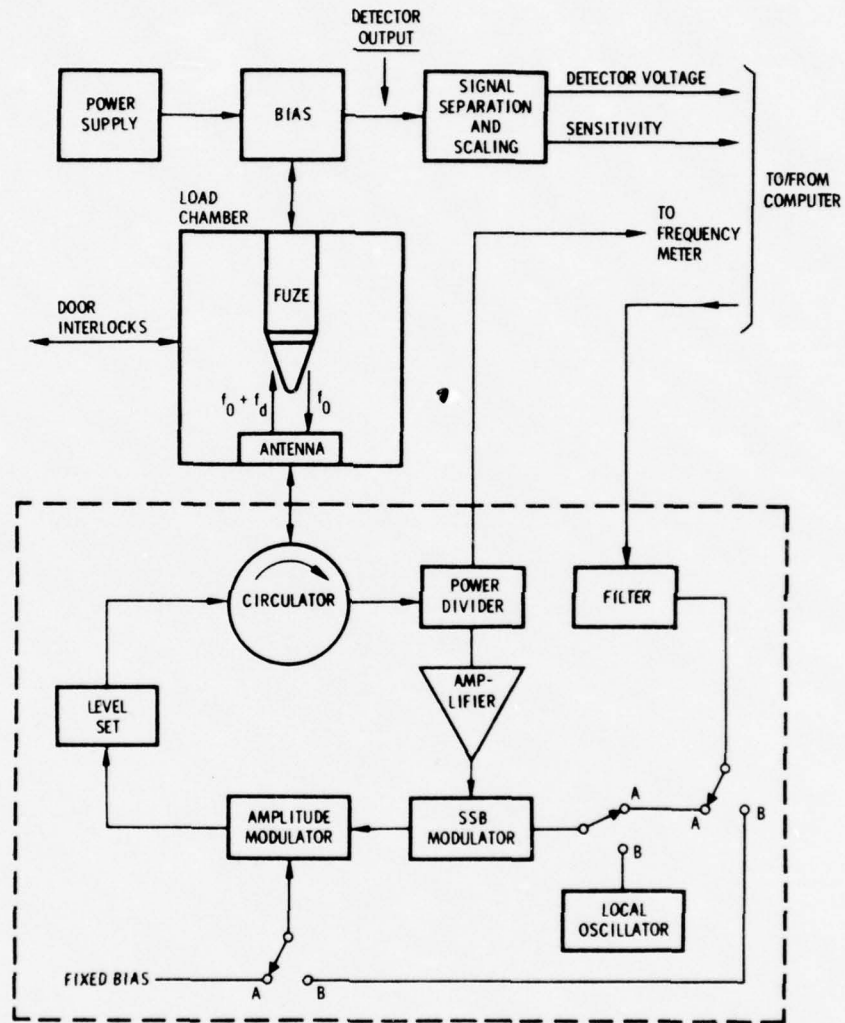


Figure 11. Modulator Block Diagram

voltage, with a low-level ac riding on top.* Detector voltage and sensitivity are measured by an A/D converter at the computer after appropriate signal separation and scaling. All three parameters must be measured accurately to properly select chip capacitors. Modulator parameters and system gain are presently being evaluated. Major components have been tentatively selected. The final choice and layout, however, will be completed during the fourth quarter.

2.6 RF CHAMBER

The rf load chamber size and its location on the laser was slightly modified. The chamber is now higher by 1.175 inches, and is equipped with an rf shield around the door, a locking handle, and a cutout (7x7 inches) in the bottom wall to accept any future variation of the rf antenna. There is also a provision to mount two additional rf loops in the upper wall of the chamber.

When the chamber door is closing, a 2-inch long guiding pin (pressed into the door and sticking out toward the chamber) will engage a proper slot in the chamber. This will prevent any possible damage to the edges of the absorbing tiles should the door become misaligned.

The closing door will also actuate two safety switches wired in series with the *Q* switch of the laser, thus providing safety interlocks on laser operation.

The chamber itself is mounted permanently to the bottom of the laser worktable; removing the chamber, while trimming the amplifier assemblies, is no longer required. This improvement is possible partly because the chamber is mounted under the laser worktable, and partly because of an optics extension (needed to

*Detector voltage levels can vary from 20 to 40 volts dc for unpotted oscillators with a small 0 to 300 millivolt rms ripple on top. This rms ripple level determines oscillator sensitivity.

obtain a 6-inch focal length), which is easily installed in, and removed from, the laser table.

It should be pointed out that the shuttle loader (a mechanism that nests and feeds the amplifier assembly during the laser trimming) must be removed from the laser table when trimming the oscillator assembly, and must be mounted again for the amplifier assembly trimming.

The design of the anechoic chamber, shown in Figures 12 and 13, is 90 percent completed. Drawings of the outer envelope of the chamber (out of aluminum), the door, and all the needed shapes of absorbing tiles that compose the inner walls of the chamber have been released for manufacturing.

The remaining drawings of the parts needed to complete the chamber are in the advanced stage of the design and detail. Long-lead purchased parts were ordered and plans for the layout of a closed area laboratory have been prepared.

2.7 SIMULATION

The simulation of the real-time amplifier test program was initiated, and the main-line routine was written and debugged. A flowchart of the program was given in the last report and is shown herein as Figure 14.

To simplify the writing and debugging, the program was divided into a main-line program and seven subroutines. Specifically, the blocks in the flowchart were converted to subroutines. A single I/O subroutine was composed of blocks 3, 4, 5, 7, 8, 9, 11, 12, 13, 17, 18, 19, 20, and 21. These blocks performed the six I/O functions described in the second report, and are summarized in Table 2. The detailed flowchart in Figure 15 shows the organization of the I/O subroutines and the portion of the main-line program that used the read-in data to calculate the parameters of the amplifier. The purpose of this particular

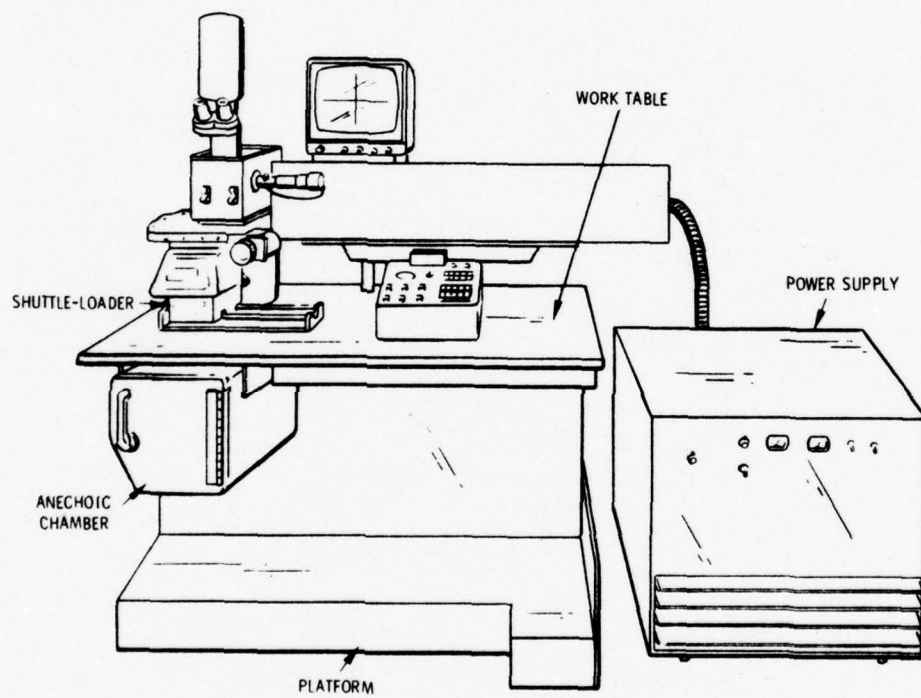


Figure 12. Laser - Trimmer Subsystem

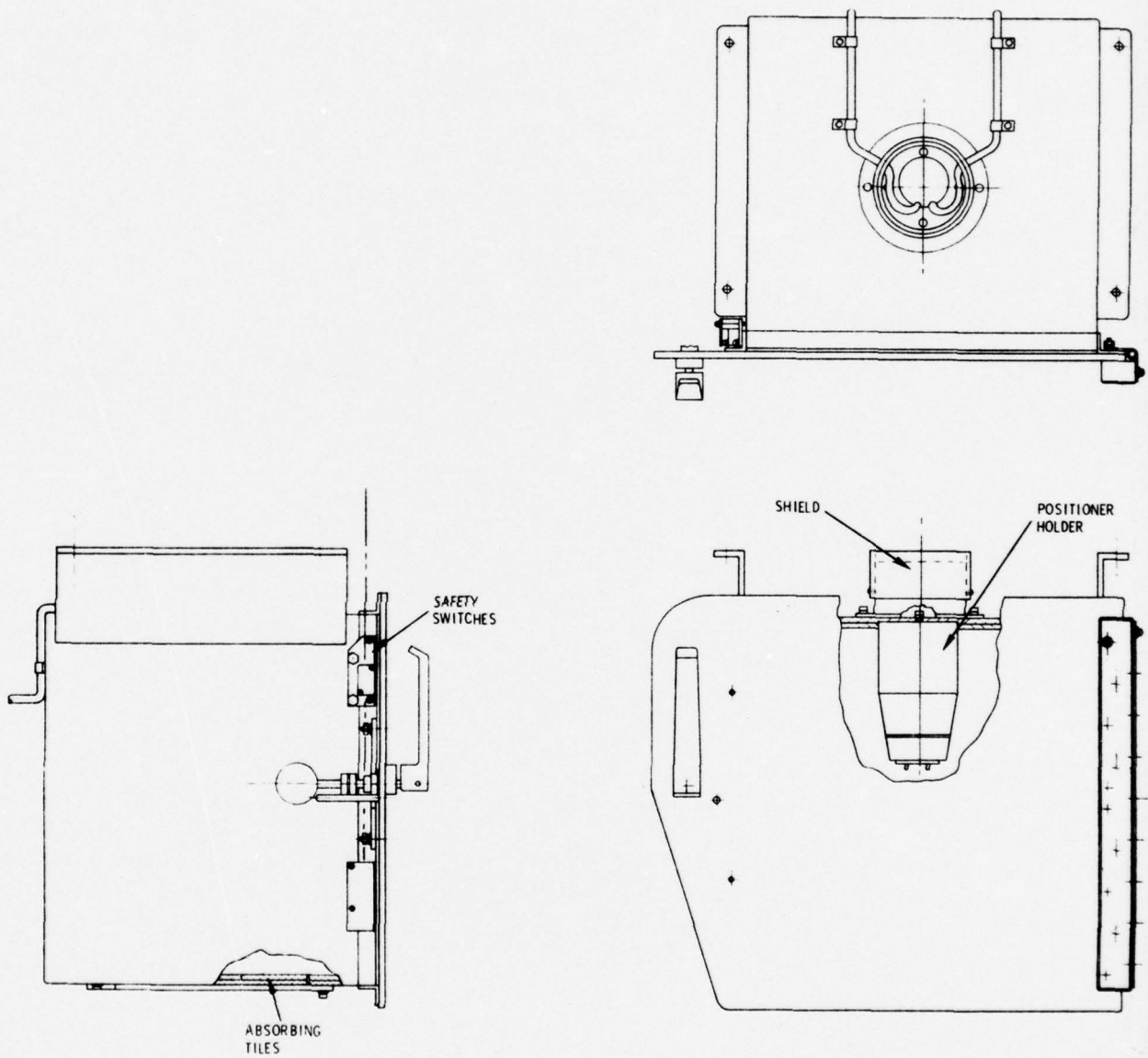


Figure 13. Rf Chamber

AMPLIFIER TEST PROGRAM

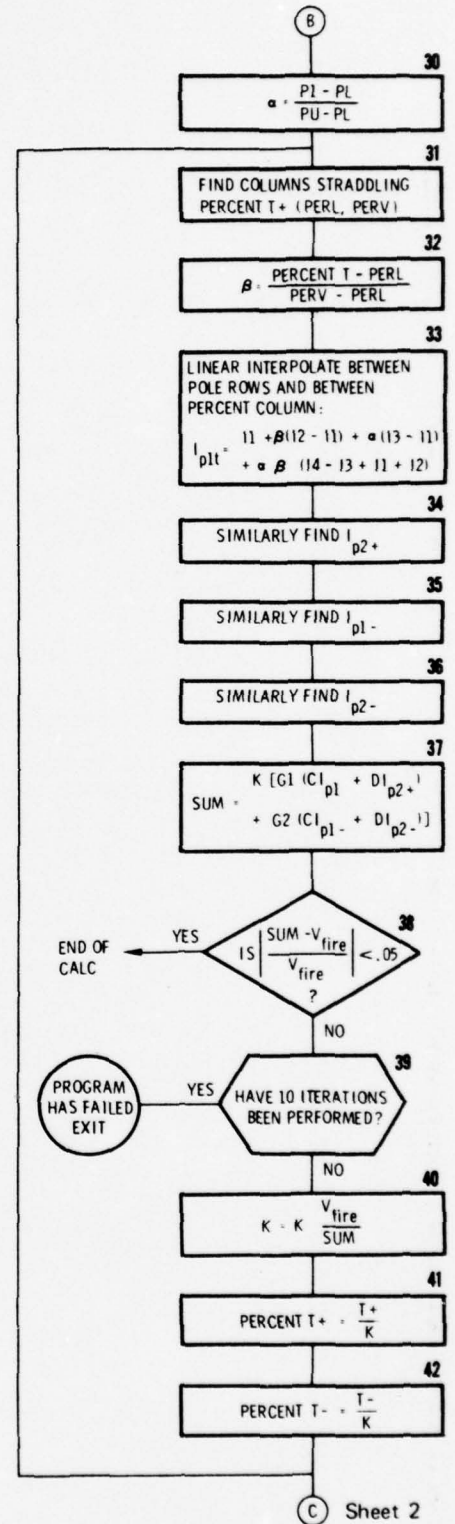
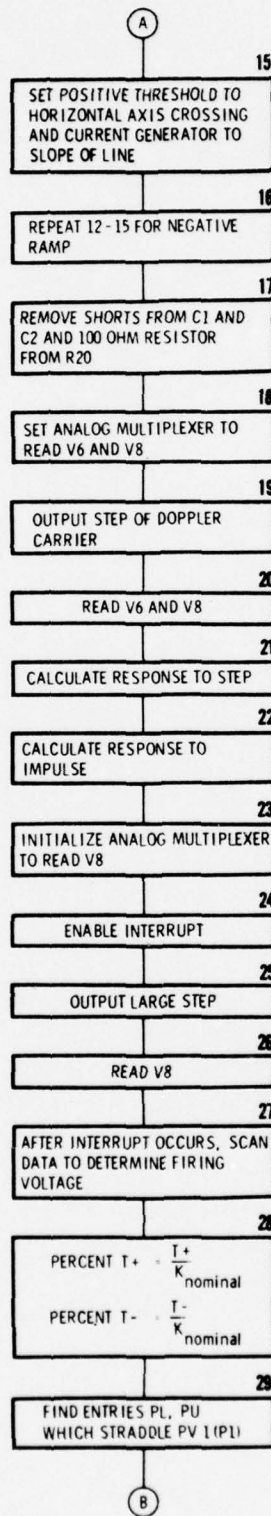
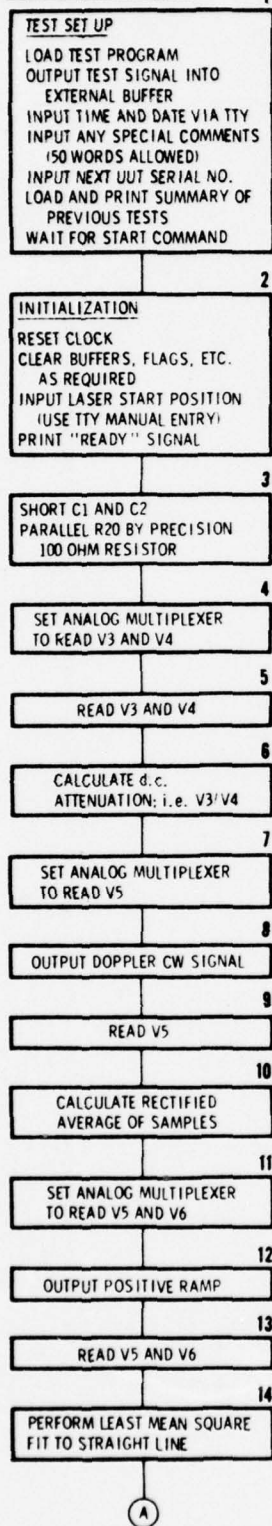


Figure 14. Amplifier Test Program (Sheet 1)

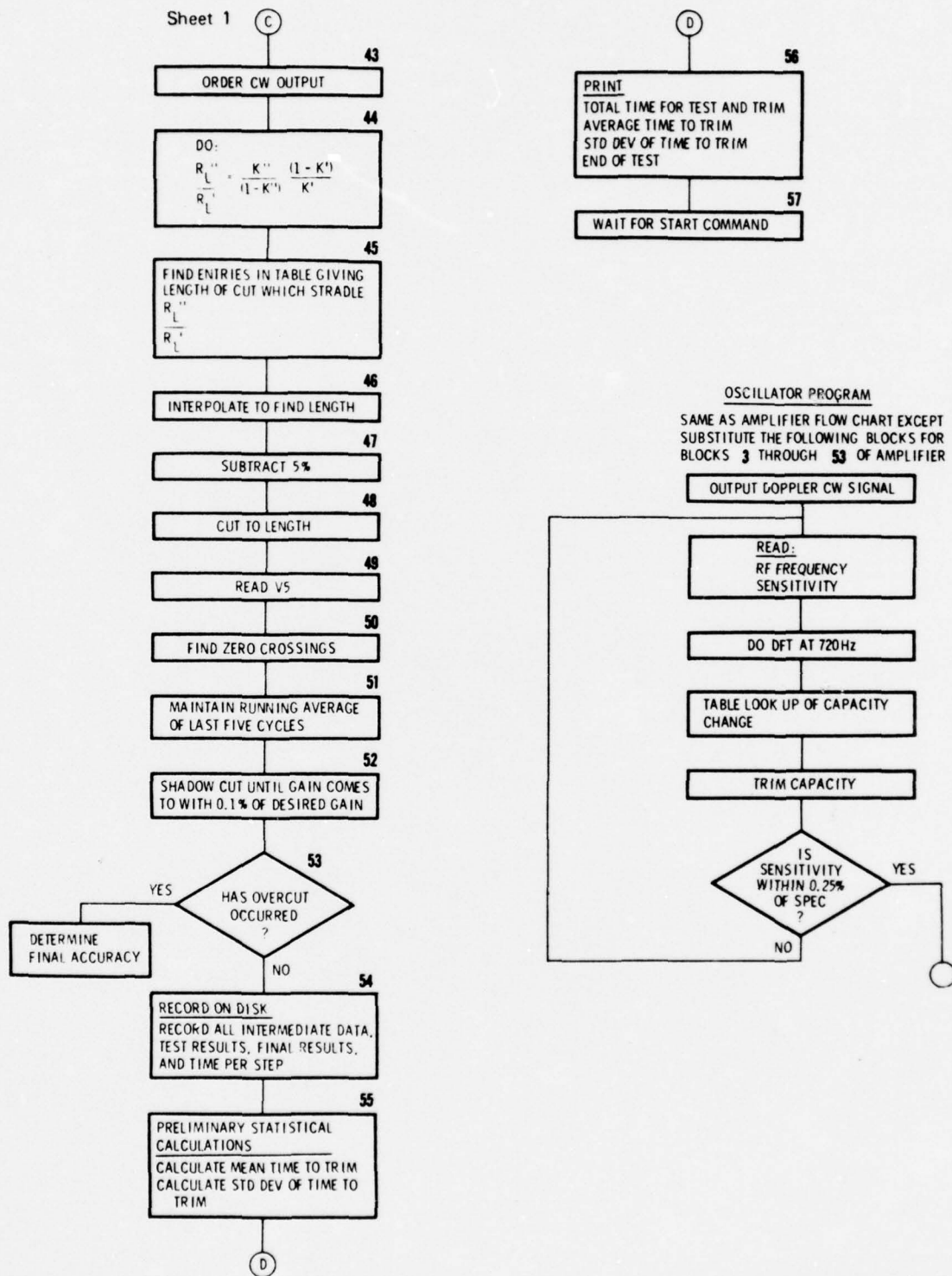


Figure 14. Amplifier Test Program (Sheet 2)

Table 2. Measured Amplifier Characteristics

Measurement Objectives	Hardware Conditions	Input Signal	Measured Voltages	Calculations
Dc attenuation of divider	Short C1,C2; parallel R20 by a small resistance	None	V3, V4	Divider attenuation
Gain to point 5	Short C1,C2; parallel R20 by a small resistance	CW	V5	Rectified average of ac
Positive and negative threshold and current generator	Short C1,C2; parallel R20 by a small resistance	Delayed positive and negative ramps at V6	V5, V6	Least mean square fit to line to give thresholds and current generators
Filter step response	Remove short from C1, C2, and small R from across	Step of carrier	V8	Preliminary calculation of step input to filter A, p1, p2 of u(t), and C and D of h(t)
SCR firing voltage	Remove short from C1, C2, and small R from across R20	Increase carrier step sign to maximum	V8	Spike determination at SCR gate

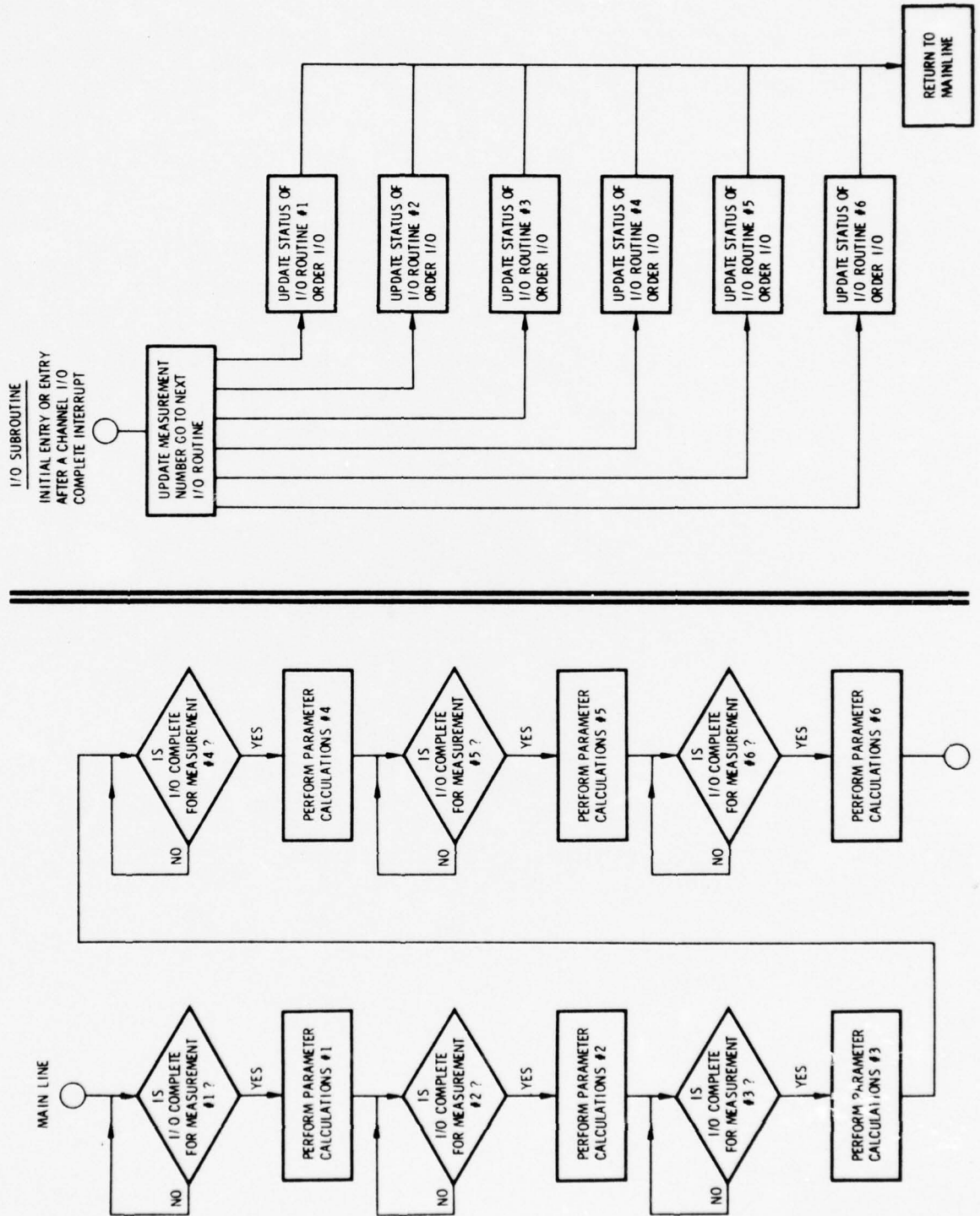


Figure 15. Measurement Flow Chart

organization was to allow continuous I/O in parallel with the calculation of the amplifier parameters. The I/O subroutine was initially entered from the main line. A measurement identification (ID) was set, and the first I/O was initiated. The program returned to the main line, while the I/O continued in parallel. When the first I/O was completed, a channel interrupt brought the program back to the I/O subroutine. It incremented the measurement ID, initiated the next I/O, and returned to the main-line program. The main-line program then checked the measurement ID and if the I/O was complete for a given measurement, the appropriate parameter calculation was performed. The I/O and main-line routine continued in parallel until the I/O required for all parameter calculations was completed.

The following calculations were assigned to subroutines:

- . Least mean square fit to detector data to obtain threshold and current generators
- . Discrete Fourier Transform to calculate amplitude
- . Step response of filter
- . Impulse response of filter
- . Convolution integral
- . Required length of cut for given change in gain

The main-line routine has been coded and debugged except for blocks 1, 2, 54, and 55. The first subroutine listed above (i.e., least mean square fit calculation) has also been coded, debugged, and checked out with the main-line routine.

The other subroutines have been defined within the program. Nominal values for the variables have been entered; thus, the main program can be checked out using the subroutine calls.

It is expected that most of the code for the simulation will be used for the actual real-time program. The I/O driver routines, however, will have to be written specifically for the Hewlett-Packard computer. Appendix B and C contain listings of the program and printouts of the results of an actual run.

3. CONCLUSIONS

The objectives of the third quarter were successfully met, as follows:

- . The major test station subsystems were built, assembled, and successfully tested.
- . 50 percent of the fuze components were received.
- . A simulation of the main-line routine of the amplifier test program was written and debugged.
- . Fuze redesign was completed.

4. PROGRAM FOR NEXT QUARTER

During the next reporting period, the following activities are planned:

- . Integrate the complete system.
- . Initiate coding of the real-time program on the test system.
- . Continue fuze-prototype fabrication.
- . Continue simulation effort.

5. PERSONNEL

During this reporting period, the following personnel worked on this program for the number of hours indicated.

<u>Name</u>	<u>Program Function</u>	<u>Hours</u>
A.J. Eisenberger	Program Manager	208
P. Kaszerman	System Engineer	248
R.F. De Mattos	Tester RF and Fuze	182
H.J. Curnan	Laser Trimmer and Fuze Microcircuits	56
G.L. Freed	Digital Components	117
U.Z. Escolli	Mechanical Design	168
A.H. Owens	Mechanical Design	24
R. Blau	Computer Modeling	44
-	Draftsmen, Machinists, Technical Publications, etc.	499

APPENDIX A
OSCILLATOR MODEL

During the third quarter, progress has occurred in two areas. First, some refinements have been incorporated in the model itself. Second, comparisons of experimental and calculated values of sensitivities have been made on a considerably larger number of oscillators.

The chief refinement in the model was that the effect of the walls of the test chamber were accounted for by representing it as a fixed phasor that alters loop impedance. Thus, for example, \tilde{X} and R in Equation (11) of Appendix A of the second report, are replaced by:

$$\tilde{X} + X_x \text{ and}$$

$$R + R_x,$$

where:

$$P_x = R_x + jX_x \text{ is the fixed phasor.}$$

Numerically, it is necessary to evaluate P_x by means of calibration transistors (i.e., empirically, since the algorithm has too many unknowns vis-a-vis the number of equations to accomplish this in any other way). The value of P_x that is found is quite large, about 50 ohms in magnitude. This result is perhaps not too surprising when it is recalled that the walls of the test chamber, which are far from being perfectly absorbing, surround the antenna on all six sides.

Using a value of:

$$P_x = 40 - 20j \text{ ohms,}$$

a comparison of theory versus experiment was made based on 24 oscillators (see Table A-1 for the results). *Condition 1* in Table A-1 refers to measurements or calculations with no capacitive pads attached; *Condition 3* means that the large parallel pad alone has been connected; and *Condition 4* means both parallel pads are in the circuit (it is planned in the very near future to extend these results to all combinations of parallel and series pads).

Except for SN9 and SN23, all of the calculated results are within approximately ± 15 percent of the measured values. In general, the scatter in the calculated values is not difficult to understand: in the model, values of the circuit constants are fixed, whereas the actual values must vary from oscillator to oscillator. The implication is, therefore, that if data on the error of the original calculation were fed back into the computer, these individual variations could be corrected for. In other words, if the scatter in measured versus calculated results is indeed due to individual differences in oscillator circuit values, then a process of iterative corrections should produce rapid convergence. It is planned to test this hypothesis in the near future. It is also planned to extend the tests of the model to 100 additional transistors for which data exist on several combinations of series and parallel pads.

Table A-1. Theory vs Experiment Based on 24 Oscillators

<u>SN</u>	<u>Condition</u>		<u>Sensitivity</u>		<u>Error</u>
	<u>Input</u>	<u>Output</u>	<u>Measured</u>	<u>Calculated</u>	
1	1	4	0.174	0.164	0.010
1	4	1	0.125	0.137	0.012
2	1	4	0.198	0.198	0.000
2	4	1	0.124	0.138	0.014
3	1	4	0.156	0.143	0.013
3	4	1	0.076	0.090	0.014
4	1	4	0.158	0.154	0.004
4	4	1	0.096	0.099	0.003
5	1	4	0.155	0.140	0.015
5	4	1	0.105	0.112	0.007
6	1	4	0.147	0.141	0.006
6	4	1	0.070	0.080	0.010
7	1	4	0.145	0.141	0.004
7	4	1	0.077	0.077	0.000
8	1	4	0.148	0.132	0.016
8	4	1	0.086	0.100	0.014
9	1	3	0.167	0.141	0.026
9	3	1	0.110	0.134	0.024
10	1	4	0.167	0.154	0.013
10	4	1	0.098	0.112	0.014
11	1	4	0.163	0.178	0.015
11	4	1	0.103	0.109	0.006
12	1	4	0.131	0.119	0.012
12	4	1	0.064	0.064	0.000
13	1	4	0.158	0.158	0.000
13	4	1	0.107	0.097	0.010
14	1	4	0.180	0.168	0.012
14	4	1	0.113	0.131	0.018
15	1	4	0.179	0.172	0.007
15	4	1	0.137	0.140	0.003
16	1	4	0.171	0.173	0.002
16	4	1	0.125	0.110	0.015
17	1	4	0.129	0.138	0.009
17	4	1	0.055	0.056	0.001
18	1	4	0.149	0.134	0.015
18	4	1	0.100	0.113	0.013
19	1	4	0.180	0.168	0.012
19	4	1	0.118	0.125	0.007
20	1	4	0.164	0.151	0.013
20	4	1	0.093	0.102	0.009
21	1	4	0.161	0.175	0.014
21	4	1	0.087	0.092	0.005
22	1	4	0.172	0.176	0.004
22	4	1	0.115	0.118	0.003
23	1	3	0.155	0.122	0.033
23	3	1	0.093	0.120	0.027
24	1	3	0.152	0.157	0.005
24	3	1	0.120	-0.329	0.449

APPENDIX B

LISTING OF SIMULATION OF MAIN-LINE REAL-TIME
AMPLIFIER TEST PROGRAM

```

800 C SIMULATION OF REAL TIME APLIFIER TEST PROGRAM
900 C
1000 C MEASUREMENT ID
1100 C
1200 C ID NAME
1300 C -- ----
1400 C 1 DC ATTEN
1500 C 2 RECTIFIED AVERAGE
1600 C 3 POSITIVE THRESH AND CUR. GEN
1700 C 4 NEGATIVE THRESH AND CUR. GEN.
1800 C 5 STEP RESPONSE
1900 C 6 SCR FIRING VOLTAGE
2000 C
2100 C
2200 C
2300 C
2400 C
2500 C DATA DEFINITIONS
2600 C
2700 C COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(10)
2800 C COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
2900 C COMMON M1,M2,M3,M4,M5,M6
3000 C
3100 C COMMON IMAX, G,STP,A,R,C,D,P1,P2,FIRE
3200 C COMMON CUT,TIM
3300 C
3400 C
3500 C
3600 C WRITE(9,600)
3700 C 600 FGMAT(1X,
3800 C 1 /" MEASUREMNT ID"
3900 C 1// " ID NAME"
4000 C 1/" -- ----"
4100 C 1/" 1 DC ATTEN"
4200 C 1/" 2 RECTIFIED AVERAGE"
4300 C 1/" 3 POSITIVE THRESH AND CUR. GEN"
4400 C 1/" 4 NEGATIVE THRESH AND CUR. GEN."
4500 C 1/" 5 STEP RESPONSE"
4600 C 1/" 6 SCR FIRING VOLTAGE",////////)
4700 C
4800 C
4900 C
5000 C INITIALIZATION AND DATA GENERATION FOR SIMULATION PROGRAM
5100 C
5200 C GNGM=5.
5300 C
5400 C POLE SCALING FACTORS
5500 C SP1=1
5600 C SP2=1.
5700 C NNP1=5

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```

5800      NNP2=5
5900      DELP1=5.
6000      DELP2=5.
6100      MP1=3
6200      MP2=3
6300      C
6400      KOUNTF=10000
6500      C
6600      M1=2
6700      M2=2
6800      M3=2
6900      M4=2
7000      M5=2
7100      M6=2
7200      C
7300      C MEAS.1
7400      C
7500      DTA1(1)=5.
7600      DTA1(2)=1.
7700      C
7800      WRITE(9,601)(DTA1(I),I=1,2)
7900      601  FORMAT(1X,"DC ATTENUATION"/1X,2F10.2//)
8000      C
8100      C MEAS2
8200      C
8300      DO 10 I=1,99,2
8400      10  DTA2(I)=10.
8500      DO 11 I=2,100,2
8600      11  DTA2(I)=-10.
8700      WRITE (9,602)(DTA2(I),I=1,10)
8800      602  FORMAT(///1X,"DATA FOR POINT 5 VOLT"/1X,20(6F10.2/1X),4F10.2)
8900      C
9000      C
9100      C MEAS3
9200      C
9300      DO 12 I=1,999,2
9400      12  DTA3(I)=I
9500      DO 13 I=2,1000,2
9600      13  DTA3(I)=10*I-100
9700      C
9800      WRITE(9,603)(DTA3(I),I=1,18)
9900      603  FORMAT(///1X,"POSITIVE RAMP DATA"/1X,40(6F10.2/1X))
10000     C
10100     C MEAS4
10200     C
10300     DO 15 I=1,999,2
10400     15  DTA4(I)=-I
10500     DO 16 I=2,1000,2
10600     16  DTA4(I)= 10*I-100
10700     C
10800     WRITE(9,604)(DTA4(I),I=1,18)
10900     604  FORMAT(///1X,"NEGATIVE RAMP DATA"/1X,40(6F10.2/1X))
11000     C
11100     C MEAS5
11200     C
11300     DO 20 I=1,100
11400     20  DTA5(I)=I
11500     C
11600     WRITE(9,605)(DTA5(I),I=1,12)
11700     605  FORMAT(///1X,"STEP RESPONSE"/1X,20(6F10.2/1X)/)

```

```

11800 C
11900 C MEAS6
12000 C
12100 DO 21 I=1,1000
12200 21 DTA6(I)=I
12300 C
12400 WRITE(9,606)(DTA6(I),I=1,12)
12500 606 FORMAT(///1X,"FIRE VOLTAGE DATA"/1X,20(6F10.2/1X)/)
12600 C
12700 C TABLE OF CONVOLUTION INTEGRALSS
12800 C
12900 DO 25 I=1,30
13000 DO 25 J=1,11
13100 25 CON(I,J)=I-J+100
13200 C
13300 WRITE(9,607)
13400 607 FORMAT(///1X,"TABLE OF CONVOLUTION INTEGRALS")
13500 DO 10050 I=1,5
13600 WRITE(9,610)(CON(I,J),J=1,11)
13700 10050 CONTINUE
13800 610 FORMAT(1X,11F6.0)
13900 C
14000 C SET TIME TO ZERO
14100 C
14200 TIM=0.
14300 C
14400 C
14500 C SET BREAKPOINT TEST VALUE
14600 C
14700 BKPT=1).
14800 C
14900 C
15000 C
15100 C
15200 C
15300 C MAIN LINE PROGRAM
15400 C
15500 C
15600 C CALCULATION OF AMPLIFIER PARAMETERS FROM THE MEASUREMENTS
15700 C
15800 C
15900 C CALC1. DC ATTENUATION
16000 C
16100 1100 CONTINUE
16200 IF(M1-2)1103,1110,1100
16300 C V3=DTA1(1)
16400 C V4=DTA2(2)
16500 1110 DCATT=DTA1(2)/DTA1(1)
16600 C
16700 WRITE(9,501)DCATT
16800 501 FORMAT(///1X,"DC ATT =" FIG.2)
16900 C
17000 C CALC2. GAIN TO PT. 5. AC TO RECTIFIED AVERAGE
17100 C
17200 C
17300 1200 CONTINUE
17400 IF(M2-2)1203,1210,1200
17500 1210 G=0.
17600 DO 1220 I=1,100
17700 1220 G=G + WRS(DTA2(I))

```

```

17800 C
17900 C RESCALE G
18000 C
18100 G=G/1000.
18200 C
18300 WRITE(9,502)G
18400 502 FORMAT(///1X,"GAIN TO PT.5=",F10.2)
18500 C
18600 C
18700 C CALCULATION 3. POSITIVE THRESH AND CURRENT GEN
18800 C
18900 C USE RAMP DATA; V5 AND V6
19000 C
19100 1300 CONTINUE
19200 IF(M3-2)1300,1310,1300
19300 C FIND COUNT AT WHICH V6 IS PAST THE BREAK POINT IN CURVE
19400 C
19500 1310 DO 1315 I=2,1000,2
19600 KOUNT=I
19700 IF (DTA3(I)-BKPT0)1315,1320,1320
19800 1315 CONTINUE
19900 1320 CONTINUE
20000 C
20100 C
20200 C
20300 C SORT EVERY 50TH VALUE OF V5 & V6 BUT AVERAGE ADJACENT
20400 C VALUES OF V660.
20500 C
20600 I=0
20700 DO 1330 K=KOUNT,1000,50
20800 I=I+1
20900 V5(I)= DTA3(K-1)
21000 V6(I)=(DTA3(K)+DTA3(K-2))/2.
21100 1330 CONTINUE
21200 C
21300 WRITE(9,503)(V5(I),I=1,20)
21400 WRITE(9,504)(V6(I),I=1,20)
21500 503 FORMAT(///1X,"V5"/1X,15(5F10.2/1X))
21600 504 FORMAT(///1X,"V6"/1X,15(5F10.2/1X))
21700 C
21800 C FIND UPPER LIMIT ON NUMBER OF VALUS OF V5 (SAME NUMBER FOR V6)
21900 C
22000 NUMB=(1000-KOUNT0)/50
22100 WRITE(9,505)NUMB
22200 505 FORMAT(///1X,"POS NUM=" I5)
22300 C
22400 C CALL SUBROUTINE TO OBTAIN LEAST MEAN SQUARE FIT TO LINE
22500 C
22600 CALL LMSF(NUMB,TP,GP)
22700 C
22800 WRITE(9,506)TP,GP
22900 506 FORMAT(///1X,"THRESH=",F10.2/1X,"GAIN=",F10.2)
23000 C
23100 C
23200 C CALCULATION 4. NEGATIVE THRESH. AND CURRENT GEN.
23300 C
23400 C USE RAMP DATA . V5 AND V6
23500 C
23600 1400 CONTINUE
23700 IF(M4-2)1400,1405,1400

```

```

23800 C
23900 C
24000 C FIND COUNT AT WHICH V6 IS PAST THE BREAKPOINT
24100 C
24200 1405 DO 1410 I=2,1000,2
24300 KOUNT=I
24400 IF(DTA4(I)-BKPT)1410,1420,1420
24500 1410 CONTINUE
24600 C
24700 1420 CONTINUE
24800 C
24900 C
25000 C
25100 C SORT EVERY 50TH READING OF V5 & V6; AVERAGE
25200 C ADJACENT VALUES OF V6
25300 C
25400 I=0
25500 DO 1430 K=KOUNT,1000,50
25600 I=I+1
25700 V5(I)=DTA4(K-1)
25800 V6(I)=(DTA4(K)+DTA4(K-2))/2.
25900 1430 CONTINUE
26000 C
26100 WRITE(9,503)(V5(I),I=1,20)
26200 WRITE(9,504)(V6(I),I=1,20)
26300 C
26400 C FIND NUMBER OF VALUES
26500 NUMB=(1000-KOUNT)/50
26600 C
26700 WRITE(9,510)NUMB
26800 510 FORMAT(///1X,"NEG NUM=" I5)
26900 C CALL LEAST MEAN SQUARE FIT TO A STRAINGT LINE
27000 C
27100 CALL LMSF(NUMB,TN,GN)
27200 C
27300 WRITE(9,506)TN,GN
27400 C
27500 C
27600 C
27700 C CALCULATION 5. STEP AND IMPULSE RESPONSE
27800 C
27900 C
28000 1500 CONTINUE
28100 IF (M5-2)1500,1510,1500
28200 C CALCULATE STEP HEIGHT
28300 C
28400 1510 CONTINUE
28500 CALL DCSTP
28600 WRITE(9,520) STP
28700 520 FORMAT(///1X,"STP HEIGHT=" ,F10.2)
28800 C
28900 C CALCULATE FILTER RESPONSE TO STEP
29000 C
29100 CALL STEP
29200 WRITE(9,521)A,P1,P2
29300 521 FORMAT(///1X,"M=" ,F10.2/1X,"P1=" ,F10.2/1X,"P2=" ,F10.2)
29400 C
29500 C CALCULATE IMPULSE RESPONSE
29600 C
29700 CALL IMPULS

```

```

29800      C
29900      WRITE(9,522)C,D
30000      522      FORMAT(///1X,"C=",F10.2/1X,"D="F10.2)
30100      C
30200      C
30300      C
30400      C   CALCULATION 6. CALCULATE SCR FIRING VOLTAGE
30500      C
30600      C
30700      1600      CONTINUE
30800      IF(M6-2) 1600,1610,1600
30900      1610      CONTINUE
31000      CALL SFIRE
31100      C
31200      WRITE(9,525)FIRE
31300      525      FORMAT(///1X,"FIRE VOLTAGE=",F10.2)
31400      C
31500      C
31600      C
31700      C
31800      C   RESET AMPLIFIER BY DISCHARGING CONDENSORS
31900      C
32000      C   SHORT C1
32100      C   SHORT C2
32200      C
32300      C UNSHORT C1
32400      C UNSHORT C2
32500      C
32600      C
32700      C
32800      C
32900      C
33000      C   CALCULATE GAIN REQUIRED TO MEET HOB
33100      C
33200      C
33300      C   FIND POLE POSITIONS AND INTERPOLATION FACTORS FOR
33400      C   USE IN LOOKING UP CONVOLUTION INTEGRALS
33500      C
33600      C POLE1
33700      C SCALE POLE VALUE
33800      P1=P1*SP1
33900      IP1=IP1
34000      IP1=IP1/NNP1
34100      PL1=IP1*NNP1
34200      ALPH1=(P1-PL1)/DELP1
34300      C FIND POSITION IN TABLE
34400      NP1=IP1-MP1
34500      C
34600      WRITE(9,530)ALPH1,NP1
34700      530      FORMAT(///1X,"ALPH1=",F10.2/1X,"P1 POSITION IN TABLE=",F10.2)
34800      C
34900      C REPEAT FOR P2
35000      C
35100      P2=P2*SP2
35200      IP2=IP2
35300      IP2=IP2/NNP2
35400      PL2=IP2*NNP2
35500      ALPH2=(P2-PL2)/DELP2
35600      NP2=IP2-MP2
35700      C

```

```

35800 C
35900 WRITE(9,531)ALPH2, NP2
36000 531 FORMAT(///1X, "ALPH2=" ,F10.2/1X, "P2 POSITION IN TABLE=" ,F10.2)
36100 C
36200 C
36300 C
36400 C
36500 C
36600 C
36700 C ITERATIVE LOOP TO FIND REQUIRED GAIN
36800 C
36900 C INITIALIZE
37000 C
37100 GCALC=GNDM
37200 KOUNT=0
37300 C
37400 C START OF LOOP
37500 C
37600 2050 CONTINUE
37700 KOUNT =KOUNT +1
37800 WRITE(9,540)KOUNT
37900 540 FORMAT(///1X, "LOOP COUNT = ",I5)
38000 C
38100 WRITE (9,546) GCALC
38200 546 FORMAT(///1X, "CALCULATED GAIN = ",F10.2)
38300 C
38400 C FIND THRESHOLD POSITIONS AND INTERPOLATION FACTORS
38500 C
38600 C POSITIVE THRESHOLD
38700 C
38800 PTP=TP/GCALC*100
38900 ITP=PTP
39000 ITP=ITP/10
39100 TPL=ITP*10
39200 BETP=(PTP-TPL)/10.
39300 NPT=ITP*1
39400 C
39500 C
39600 WRITE(9,541)BETP,NPT
39700 541 FORMAT(///1X, "BETA POSITIVE=" ,F10.2/1X, "THRESH POSITION=" ,F10.2)
39800 C
39900 C
40000 C
40100 C NEGATIVE THRESHOLD
40200 C
40300 PTN=TN/GCALC*100
40400 ITN=PTN
40500 ITN=ITN/10
40600 TNL=ITN*10
40700 BETN=(PTN-TNL)/10.
40800 NNT=ITN*1
40900 C
41000 C
41100 C
41200 WRITE(9,542)BETN,NNT
41300 542 FORMAT(///1X, "BETA NEG=" ,F10.2/1X, "THRESH POSITION=" ,F10.2)
41400 C
41500 C
41600 C
41700 C CALCULATE THE FOUR PORTIONS OF THE CONVOLUTION INTEGRAL

```

```

41800 C
41900 CALL INTGRL(NP1,NPT,ALPH1,BETP,C1P)
42000 CALL INTGRL(NP2,NPT,ALPH2,BETP,C2P)
42100 CALL INTGRL(NP1,NNT,ALPH1,BETN,C1N)
42200 CALL INTGRL(NP2,NNT,ALPH2,BETN,C2N)
42300 C
42400 SUM1=GP*(Q*C1P+D*C2P)
42500 SUM2=GN*(C*C1N+D*C2N)
42600 SUM=GCALC*(SUM1+SUM2)
42700 WRITE(9,545) C1P,C2P,C1N,C2N,SUM
42800 545 FORMAT(///1X,"INTEGRALS"/1X"POLE 1,POS THRESH=",F10.2/1X,
42900 1" POLE 2, POS THRESH=",F10.2
43000 2/1X,"POLE 1,NEG THRESH=",F10.2/1X,
43100 3 "POLE 2,NEG THRESH =",F10.2//1X,"SUM = ",F10.2)
43200 TEMP=(SUM-FIRE)/FIRE
43300 TEMP=ARS(TEMP)
43400 IF(TEMP-0.0005)2000,2000,2100
43500 2100 IF(KOUNT-10)2110,9999,9999
43600 C CONTINUE ITERATIONS
43700 C
43800 2110 GCALC=GCALC*(FIRE/SUM)
43900 GO TO 2050
44000 C
44100 C
44200 C
44300 C
44400 C SUCCESSFUL EXIT FROM LOOP
44500 C
44600 2000 CONTINUE
44700 C
44800 WRITE(9,710)
44900 710 FORMAT(///1X,"SUCCESSFUL CALC OF GAIN")
45000 C
45100 C
45200 C
45300 C
45400 C CALCULATE RESISTOR TRIM
45500 C
45600 C  $RS/R=(KS/(1-KS))*(K/(4-K))$ 
45700 C  $RS/R=(GCALC/G)*(1-H)/(1-GCALC*H/G)$ 
45800 C
45900 TEMP=GCALC/G
46000 PCHNG=TEMP*(1.-DCATT)
46100 PCHNG=PCHNG/(1.-TEMP*DCATT)
46200 C
46300 C
46400 WRITE(9,550)TEMP,PCHNG
46500 550 FORMAT(///1X,"RATIO OF CALC GAIN TO ACTUAL GAIN = ",F10.2
46600 1 /1X, "RATIO OF FINAL TRIM R VALUE TO PRESENT VALUE = ",F10.2)
46700 C
46800 C
46900 CALL LNPTH(PCHNG)
47000 C
47100 C
47200 C
47300 C
47400 C
47500 C
47600 WRITE(9,560)CUT
47700 560 FORMAT(///1X,"LENGTH OF CUT=",F10.2)

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47800 C
47900 C
48000 C
48100 C CUT TO LENGTH GIVEN BY SUBROUTINE
48200 C IDLE TILL CUT IS COMPLETE
48300 C
48400 C
48500 C FINAL TRIM. MONITOR GAIN DURING TRIM
48600 C
48700 C OUTPUT CW
48800 C ORDER READ OF V5
48900 C
49000 C KCUNTR= WORD COUNT FROM CHANNEL I/O.NUMBER OF WORDS
49100 C ALREADY READ IN
49200 C
49300 C
49400 C ACCUMULATE THE SUM OF THE FIRST 20 WORDS
49500 C
49600 C
49700 C
49800 C
49900 C
50000 C
50100 C
50200 C
50300 C
50400 C
50500 C
50600 C
50700 C
50800 C
50900 C KTEMP = 1
51000 C SUM=0.
51100 C DO 2640 I=1,20
51200 2630 CONTINUE
51300 C IF (KCUNTR-KTEMP)2630,2635,2635
51400 2635 SUM=SUM+ABS(DTA2(I))
51500 C KTEMP=KTEMP+1
51600 2640 CONTINUE
51700 C
51800 C
51900 C
52000 C ORDER CUT
52100 C
52200 C MONITOR GAIN
52300 C
52400 C DO 2650 I=21,1000
52500 2600 CONTINUE
52600 C IF (KCUNTR-KTEMP)2600,2610,2610
52700 2610 KTEMP=KTEMP+1
52800 C SUM = SUM -ABS(DTA2(I-20))+ABS(DTA2(I))
52900 C IF(SUM-GCALC)2650,2660,2660
53000 2650 CONTINUE
53100 C PROGRAM HAS FAILED TO ACHIEVE REQUIRED GAIN WITHIN
53200 C THE READ TIME LIMITS
53300 C
53400 C GO TO 999
53500 C
53600 C PROGRAM HAS SUCCEEDED IN TRIMMING AMP TO TOREQUIRED HOR
53700 C

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53800      C
53900      2660      GO TO 10000
54000      C
54100      C
54200      C
54300      C
54400      C
54500      C
54600      C
54700      C
54800      C
54900      C
55000      C
55100      10000      CONTINUE
55200              WRITE (9,1)
55300      1      FORMAT(///1X,"PROGRAM HAS SUCCEEDED IN ACHIEVING"
55400              1 "REQUIRED HOB")
55500              GO TO 10001
55600      C
55700      C
55800      999      CONTINUE
55900              WRITE(9,998)
56000      998      FORMAT(///1X,"PROGRAM HAS FAILED TO ACHIEVE THE REQUIRED"
56100              1 " GAIN WITHIN THE REAC TIME LIMITS")
56200              GO TO 10001
56300      C
56400      C
56500      C
56600      9999      CONTINUE
56700              WRITE(9,9998)
56800      9998      FORMAT(///1X,"HOB GAIN CALCULATIONS FAILED TO CONVERGE"
56900              1 "IN TEN ITERATIONS")
57000              GO TO 10001
57100      C
57200      C
57300      C
57400      C
57500      10001      CONTINUE
57600      C
57700              WRITE (9,570)
57800      570      FORMAT(///1X,"PROGRAM HAS RUN TO COMPLETION")
57900      C
58000              LOCK 6
58100              STOP
58200              END
58300      C
58400      C
58500      C
58600      C
58700      C
58800      C
58900      C
59000      C
59100      C
59200      C
59300      C
59400      C
59500      C
59600      C
59700      C

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59800 C
59900 C
60000 C
60100 C SUBROUTINES
60200 C
60300 C SUBROUTINE LMSF(NUMB,T,GAIN)
60400 C LEAST MEAN SQUARE FIT TO A STRAIGHT LINE
60500 C
60600 C
60700 C DATA DEFINITIONS
60800 C
60900 C COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
61000 C COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
61100 C COMMON M1,M2,M3,M4,M5,M6
61200 C
61300 C COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
61400 C COMMON CUT,TIM
61500 C
61600 C
61700 C
61800 C A12=0.
61810 C A22=0.
61820 C B1=0.
61830 C B2=0.
61840 C
61845 C N=NUMB
61850 C DO 12 I=1,N
61860 C A12=A12+V5(I)
61870 C A22=A22+V5(I)*V5(I)
61880 C B1=B1+V6(I)
61890 C B2=B2+V5(I)*V6(I)
61900 12 CONTINUE
61910 C
61920 C A11=NUMB
61930 C
61940 C
61950 C
61960 C F=A11*A22-A12*A12
61970 C TEMP=A22*B1-A12*B2
61980 C TEMP=TEMP/F
61990 C GAIN=A12*B1-A11*B2
62000 C GAIN=-GAIN/F
62010 C T=-TEMP/GAIN
62020 C
62030 C
62040 C GAIN=ABS(GAIN)
62050 C T=ABS(T)
62060 C
62070 C
62080 C
62090 C
62100 C
62110 C RESCALE GAIN AND THRESHOLD
62120 C
62130 C GAIN=GAIN/13.
62140 C T=T*0.15
62150 C
62160 C
62170 C
62180 C

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62190 C
62200 C
62300 RETURN
62400 END
62500 C
62600 C
62700 C
62800 C
62900 C
63000 SUBROUTINE DCSTP
63100 C CALCULATE HEIGHT OF STEP
63200 C
63300 C
63400 C DATA DEFINITIONS
63500 C
63600 COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
63700 COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
63800 COMMON M1,M2,M3,M4,M5,M6
63900 C
64000 COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
64100 COMMON CUT,TIM
64200 C
64300 C
64400 C
64500 STP=13.
64600 C
64700 RETURN
64800 END
64900 C
65000 C
65100 C
65200 C
65300 SUBROUTINE STEP
65400 C CALCULATE STEP RESPONSE
65500 C
65600 C
65700 C DATA DEFINITIONS
65800 C
65900 COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
66000 COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
66100 COMMON M1,M2,M3,M4,M5,M6
66200 C
66300 COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
66400 COMMON CUT,TIM
66500 C
66600 C
66700 C
66800 A=5
66900 P1=22.5
67000 P2=32.5
67100 C
67200 RETURN
67300 END
67400 C
67500 C
67600 C
67700 SUBROUTINE IMPULS
67800 C CALCULATE IMPULSE RESPONSE
67900 C
68000 C

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68100 C DATA DEFINITIONS
68200 C
68300 C     COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
68400 C     COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
68500 C     COMMON M1,M2,M3,M4,M5,M6
68600 C
68700 C     COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
68800 C     COMMON CUT,TIM
68900 C
69000 C
69100 C
69200 C     C=2.
69300 C     D=2.
69400 C
69500 C
69600 C     RETURN
69700 C     END
69800 C
69900 C
70000 C
70100 C
70200 C
70300 C     SUBROUTINE SFIRE
70400 C     CALCULATE FIRE VOLTAGE OF SCR
70500 C
70600 C
70700 C DATA DEFINITIONS
70800 C
70900 C     COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
71000 C     COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
71100 C     COMMON M1,M2,M3,M4,M5,M6
71200 C
71300 C     COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
71400 C     COMMON CLT,TIM
71500 C
71600 C
71700 C
71800 C     FIRE=8000.
71900 C
72000 C
72100 C     RETURN
72200 C     END
72300 C
72400 C
72500 C
72600 C     SUBROUTINE INTGRL(I,J,ALPH,BET,CI)
72700 C
72800 C
72900 C DATA DEFINITIONS
73000 C
73100 C     COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(100)
73200 C     COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
73300 C     COMMON M1,M2,M3,M4,M5,M6
73400 C
73500 C     COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
73600 C     COMMON CUT,TIM
73700 C
73800 C
73900 C
74000 C FIND INTEGRAL BY INTERPOLATION OF TABLE VALUES

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74100 C
74200 C
74300 C   CI=CCN(I,J)
74400 C   I +RET*(CON(I,J+1)-CON(I,J))+ALPH*(CON(I+1,J)-CON(I,J))
74500 C   I +ALPH*RET*(CON(I+1,J+1)-CON(I+1,J)-CON(I,J+1)+CON(I,J))
74600 C
74700 C   RETURN
74800 C   END
74900 C
75000 C
75100 C
75200 C
75300 C
75400 C   SUBROUTINE LNGTH(PCHNG)
75500 C
75600 C
75700 C   DATA DEFINITIONS
75800 C
75900 C   COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(10)
76000 C   COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
76100 C   COMMON M1,M2,M3,M4,M5,M6
76200 C
76300 C   COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
76400 C   COMMON CUT,TIM
76500 C
76600 C
76700 C
76800 C   CUT=17.
76900 C
77000 C
77100 C   RETURN
77200 C   END
77300 C
77400 C
77500 C
77600 C
77700 C
77800 C   SUBROUTINE CLK
77900 C   RECORD TIME AND EVENT
78000 C
78100 C
78200 C
78300 C   DATA DEFINITIONS
78400 C
78500 C   COMMON DTA1(100),DTA2(1000),DTA3(1000),DTA4(1000),DTA5(10)
78600 C   COMMON DTA6(1000),V5(100),V6(100),CON(30,11)
78700 C   COMMON M1,M2,M3,M4,M5,M6
78800 C
78900 C   COMMON IMAX, G,STP,A,B,C,D,P1,P2,FIRE
79000 C   COMMON CUT,TIM
79100 C
79200 C
79300 C
79400 C   RETURN
79500 C   END
79600 C
79700 C
79800 C
79900 C
80000 C

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APPENDIX C

PRINTOUTS USING SIMULATION OF REAL-TIME AMPLIFIER TEST PROGRAM AND SIMULATED AMPLIFIER DATA

ID	NAME
--	---
1	DC ATTEN
2	RECTIFIED AVERAGE
3	POSITIVE THRESH AND CUR. GEN
4	NEGATIVE THRESH AND CUR. GEN.
5	STEP RESPONSE
6	SCR FIRING VOLTAGE

DC ATTENUATION
5.00 1.00

DATA FOR POINT 5 VOLT
10.00 -10.00 10.00 -10.00 10.00 -10.00
10.00 -10.00 10.00 -10.00

POSITIVE RAMP DATA
1.00 -80.00 3.00 -60.00 5.00 -40.00
7.00 -20.00 8.00 0.00 11.00 20.00
13.00 40.00 15.00 60.00 17.00 80.00

NEGATIVE RAMP DATA
-1.00 -80.00 -3.00 -60.00 -5.00 -40.00
-7.00 -20.00 -9.00 0.00 -11.00 20.00
-13.00 40.00 -15.00 60.00 -17.00 80.00

STEP RESPONSE
1.00 2.00 3.00 4.00 5.00 6.00
7.00 8.00 9.00 10.00 11.00 12.00

FIRE VOLTAGE DATA
1.00 2.00 3.00 4.00 5.00 6.00
7.00 8.00 9.00 10.00 11.00 12.00

TABLE OF CONVOLUTION INTEGRALS

100.	99.	98.	97.	96.	95.	94.	93.	92.	91.	90.
101.	100.	99.	98.	97.	96.	95.	94.	93.	92.	91.
102.	101.	100.	99.	98.	97.	96.	95.	94.	93.	92.
103.	102.	101.	100.	99.	98.	97.	96.	95.	94.	93.
104.	103.	102.	101.	100.	99.	98.	97.	96.	95.	94.

DC ATT = 0.20

GAIN TO PT.5= 1.00

V5

11.00	81.00	111.00	161.00	211.00
261.00	311.00	361.00	411.00	461.00
511.00	561.00	611.00	661.00	711.00
761.00	811.00	861.00	911.00	961.00

V6

10.00	510.00	1010.00	1510.00	2010.00
2510.00	3010.00	3510.00	4010.00	4510.00
5010.00	5510.00	6010.00	6510.00	7010.00
7510.00	8010.00	8510.00	9010.00	9510.00

POS NUM= 19

THRESH= 1.50

GAIN= 1.00

V5

-11.00	-61.00	-111.00	-161.00	-211.00
-261.00	-311.00	-361.00	-411.00	-461.00
-511.00	-561.00	-611.00	-661.00	-711.00
-761.00	-811.00	-861.00	-911.00	-961.00

V6

10.00	510.00	1010.00	1510.00	2010.00
2510.00	3010.00	3510.00	4010.00	4510.00
5010.00	5510.00	6010.00	6510.00	7010.00
7510.00	8010.00	8510.00	9010.00	9510.00

NEG NUM= 19

THRESP= 1.50
GAIN= 1.00

STP HEIGHT= 10.00

A= 5.00
P1= 22.50
P2= 32.50

C= 2.00
D= 2.00

FIRE VOLTAGE= 8000.00

ALPH1= 0.50
P1 POSITION IN TABLE= 1.00

ALPH2= 0.50
P2 POSITION IN TABLE= 3.00

LOOP COUNT = 1

CALCULATED GAIN = 5.00

BETA POSITIVE= 1.00
THRESH POSITION= 3.00

BETA NEG= 1.00
THRESH POSITION= 3.00

INTEGRALS
POLE 1, POS THRESH= 97.50
POLE 2, POS THRESH= 99.50
POLE 1, NEG THRESH= 97.50

POLE 2, NEG THRESH = 99.50

SUM = 3940.00

LOOP COUNT = 2

CALCULATED GAIN = 10.15

BETA POSITIVE= 0.48
THRESH POSITION= 2.00

BETA NEG= 0.48
THRESH POSITION= 2.00

INTEGRALS

POLE 1, POS THRESH= 99.02
POLE 2, POS THRESH= 101.02
POLE 1, NEG THRESH= 99.02
POLE 2, NEG THRESH = 101.02

SUM = 8123.65

LOOP COUNT = 3

CALCULATED GAIN = 10.00

BETA POSITIVE= 0.50
THRESH POSITION= 2.00

BETA NEG= 0.50
THRESH POSITION= 2.00

INTEGRALS

POLE 1, POS THRESH= 99.00
POLE 2, POS THRESH= 101.00
POLE 1, NEG THRESH= 99.00
POLE 2, NEG THRESH = 101.00

SUM = 7998.17

SUCCESSFUL CALC OF GAIN

RATIO OF CALC GAIN TO ACTUAL GAIN = 10.00
RATIO OF FINAL TRIM R VALUE TO PRESENT VALUE = -8.00

LENGTH OF CUT= 17.00

PROGRAM HAS SUCCEEDED IN ACHIEVING REQUIRED HOR

PROGRAM HAS RUN TO COMPLETION

UNCLASSIFIED

9 Quarterly progress rept. no. 3,
11 Nov 76 - 10 Feb 77.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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