Commander
US Army Missile Command
Attn: AMSMI-RD-PR-P/ROY YELL
Redstone Arsenal, AL 35898-5249

ARVIN
CALSPAN CORPORATION

FRANKLIN RESEARCH CENTER

F-P060/6119

SHORT PULSE TEST SET

November, 1990

TECHNICAL REPORT

Valley Forge Corporate Center 2600 Monroe Blvd. Norristown PA 19403 TEL 215-666-3000

F-P060/6119

SHORT PULSE TEST SET

November, 1990

Ramie H. Thompson
Joseph F. Heffron

Franklin Research Center
Division of Arvin/Calspan
1600 Monroe Boulevard
Norristown, Pennsylvania 19403

prepared for

U.S. ARMY MISSILE COMMAND
REDSTONE ARSENAL

Contract No. DAAH01-85C-1418

ACKNOWLEDGEMENTS

The development, construction, and testing of the test equipment described herein were performed by personnel of the Applied Physics Laboratory of the Franklin Research Center under the direction of Ramie H. Thompson, the laboratory manager. Laboratory personnel contributing significantly to this project were A. W. Cipkins, S. Mazzone, and G. Roatche.

The author also express his thanks to R. E. Betts, the MICOM Contracting Officer's Technical Representative for his assistance and cooperation.

Table of Contents

Section	Title	Page
1.	INTRODUCTION	1
2.	SHORT PULSE GENERATION	2
	2.1 Pulse Generating Circuitry	2
	2.2 Control Circuitry	5
3.	SHORT PULSE VOLTAGE AND CURRENT MEASUREMENT	7
4.	TEST SET OPERATION	12
	4.1 Turning on the Test Set	12
	4.2 Configuring the Pulse Generator	12
	4.3 Running "Waveform Catalyst"	13
	4.4 Preparing the Program and Digitizer to Acquire Data	13
	4.5 Mounting the EED	15
	4.6 Performing the Short Pulse Test	15
	Appendix - Component Description & Parts List	

List of Figures

Fig. No.	Title	Page
2-1	Pulse Circuit - Pin-to-Pin	3
2-2	Pulse Circuit - Pins-to-Case	4
2-3	Control Circuit	6
3-1	Waveform Catalyst Typical Display	8
3-2	Asystant Typical Display	9
3-3	PPLOT1 Typical Display	11
4-1	Waveform Catalyst Quick Reference	14
4-2	EED Mountings	16

1. INTRODUCTION

This report discusses the construction and operation of the Short Pulse Test Set that has been built for the U.S. Army Missile Command for the purpose of applying short (25 to 100 nanosecond), high voltage pulses to EEDs in both the pin-to-pin and pins-to-case mode. The test set employs the short pulse generating techniques first described in the Franklin Institute Research Laboratories (now Franklin Research Center) Report I-C3410, "Pins-to-Case Short Pulse Sensitivity Studies for the Atlas DC Switch", December 1974. This report, authored by Ramie H. Thompson, was prepared for Picatinny Arsenal under contract DAAA21-72C-0766. The test set described herein utilizes a computer controlled high speed digitizer to monitor the pulse voltage and current and provides software to process and display these data.

2. SHORT PULSE GENERATION

2.1 Pulse Generating Circuitry

The pulse generating section of the test set is shown in Figures 2-1 and 2-2. This circuit functions as follows:

1) The high voltage power supply charges the critical length of 50 ohm RG 218/U transmission line (303-XXX) through the isolating resistors R1 and R2 and the delay line (302).

2) When relay K5 is activated via the control circuit its contacts begin to close and at some point the charge on the transmission line arcs across the moving but still separated contacts. This action is roughly equivalent to a perfect switch and approximates the theoretical situation of a charged transmission line being instantaneously connected to a load.

3) The electromagnetic disturbance caused by the switching propagates from the relay contacts in both directions; through line 304 toward the insertion unit and back through line 303 toward R2. Resistor R2 is chosen to be very large in relation to the 50 ohm characteristic impedance of the transmission line so that it approximates an open circuit. The insertion unit contains a 51 ohm resistor that is connected in series with the load for pin-to-pin tests as shown in Figure 2-1, or in parallel with the load for pins-to-case tests as shown in Figure 2-2. The choice of impedance insures that the system behaves as if line 303 is open circuited at the R2 end and is terminated with 50 ohms at the relay end. This results in a theoretically rectangular voltage pulse across the input impedance of the insertion unit. The amplitude of the pulse is theoretically one-half of the value of the charging voltage and its duration is twice the one way delay time of line 303.

Several of the circuit components are contained in oil baths. The oil is actually dielectric grade silicone fluid (Dow Corning 200, 50 cs viscosity) and it serves to eliminate corona discharge and its resulting interference. The metal cans are part of the shield that has been devised to completely confine the electromagnetic noise generated by the arc at the relay contacts. The only connections between the shielded volume containing the arc and the outside volume containing the measuring instruments is through 300 feet of transmission line (302), through 300 feet of shielded Twinax cable (204), or through the T&M monitor output cables (401 & 402). Noise on the monitor output cables is a real perturbation to the measured

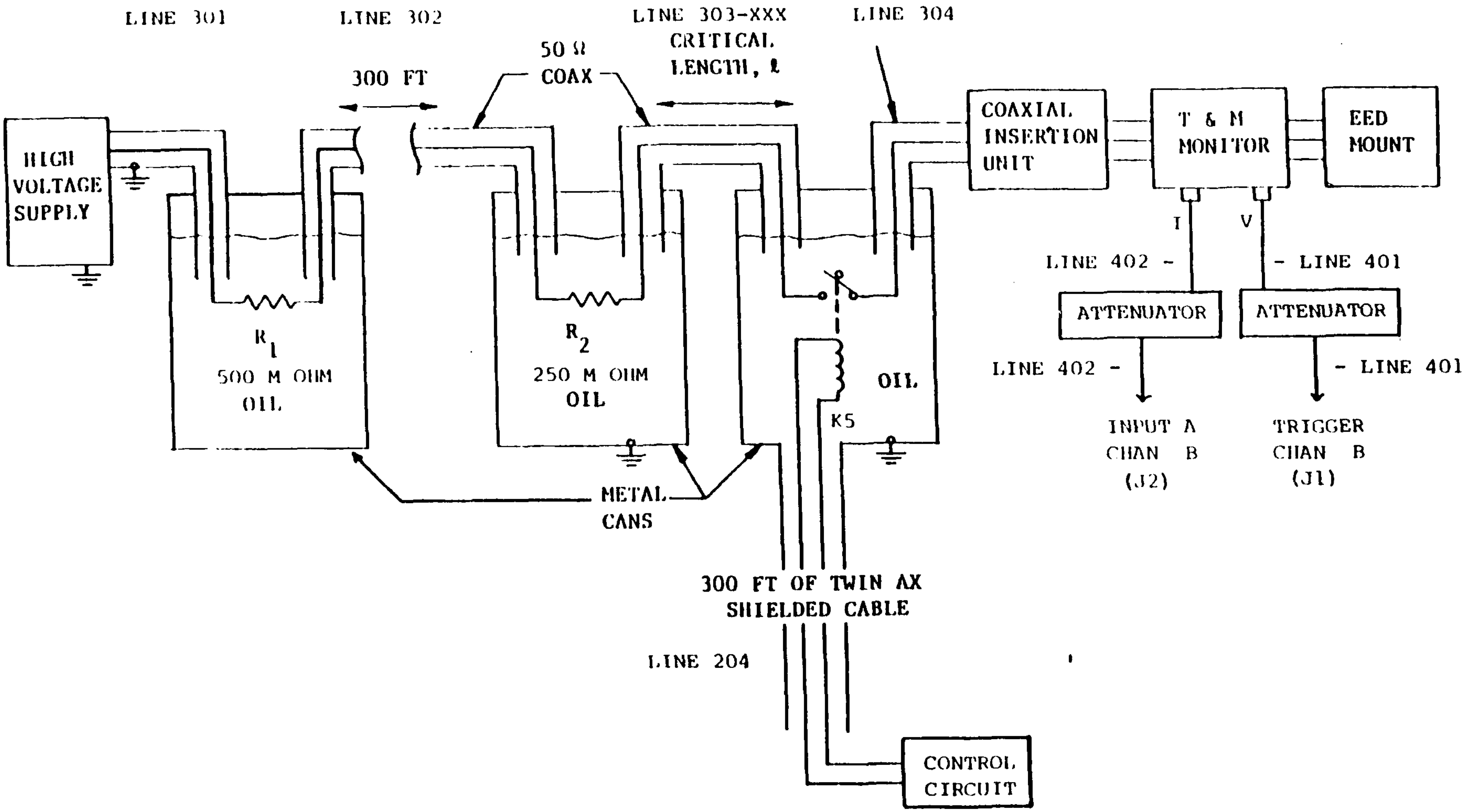

Figure 2-1 Pulse Circuit - Pin-To-Pin (Low Impedance) Configuration

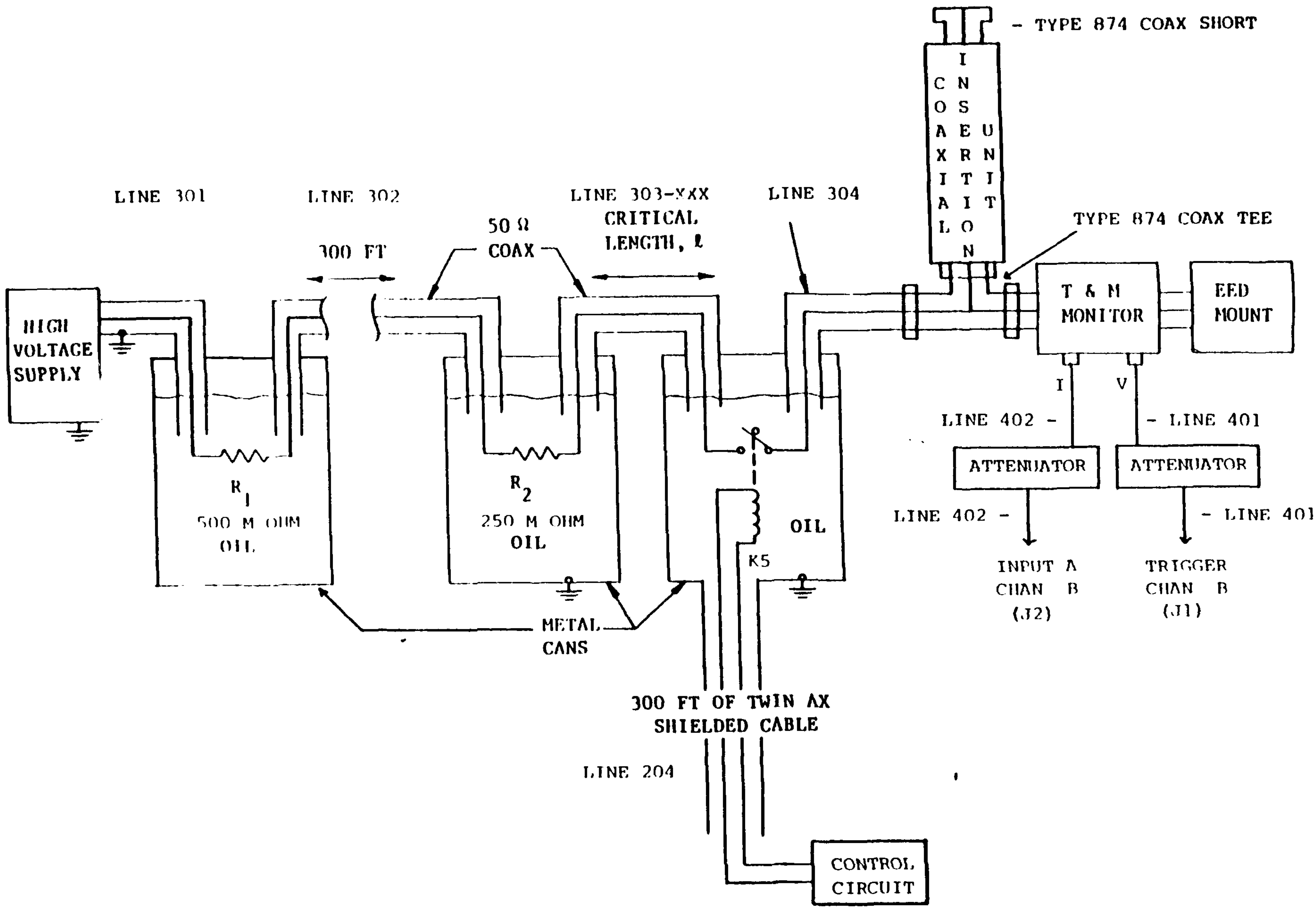

Figure 2-2 High Impedance (Pins-To-Case) Configuration

signals and it will be captured by the instrumentation as it should be. The other type of noise that would ordinarily interfere with the instrumentation - direct coupling between the arc and the instruments - is eliminated because it must propagate at least the length of line 303 or cable 204 before it can interact with the instruments. By the time this occurs the test pulse has already been captured and recorded.

The test voltage is set with the variable high voltage supply and the pulse duration is selected by changing the length of line 303. Three plug-in sections of this line are provided; 303-025 is 8 feet long, 303-050 is 16 feet long, and 303-100 is 32 feet long. They yield pulse durations of 25, 50, and 100 nanoseconds respectively.

2.2 Control Circuitry

The control circuit is shown schematically in Figure 2-3. This circuit functions to close the high voltage relay, K5, for approximately two seconds when the Pulse switch, SW2, is pressed. It also provides certain safety interlock features and panel lamps or illuminated switches that indicate the status of the system. The interlock switches SW4 and SW5 respond to opening of the console door and removal of the safety shield respectively. If the interlock has been activated switch SW3 lights and the switching circuit and the high voltage supply are disabled.

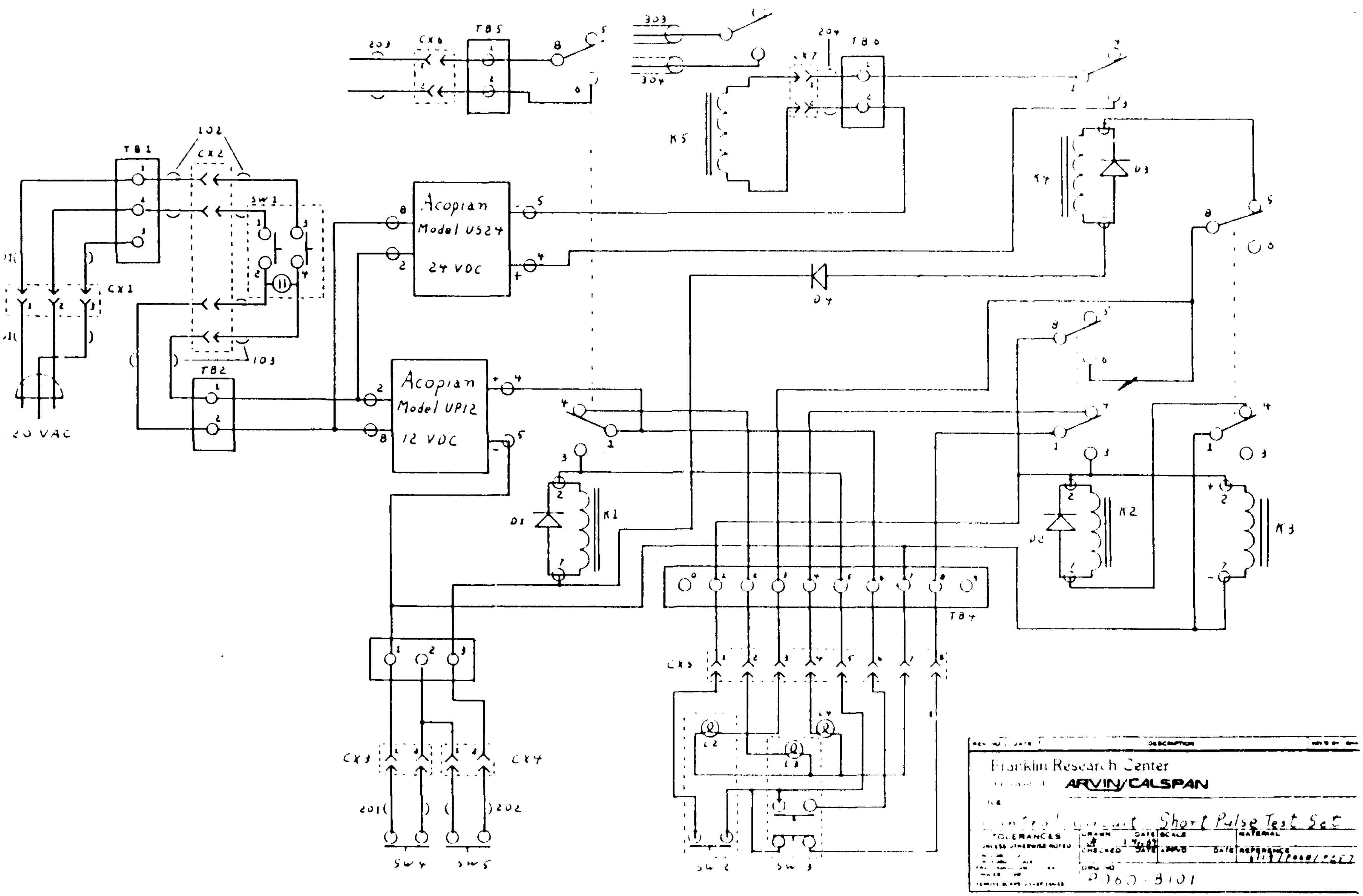

Figure 2-3 Control Circuit

3. SHORT PULSE VOLTAGE AND CURRENT MEASUREMENT

The test pulse is applied to the EED via the T&M monitor that samples both the applied voltage and current. The voltage probe has a ratio of 199:1 and the current output is the voltage across a 0.051 ohm series resistor. This series resistor is in the return side of the circuit so that in normal use the voltage across it is of reverse polarity with respect to the output of the voltage probe.

Outputs from the T&M monitor are led to separate attenuator networks that consist of a fixed attenuator followed by a variable attenuator. The variable attenuators are identical and provide 0 to 49 dB of attenuation in 1 dB steps. In the current network the fixed attenuator is 10 dB and for the voltage a 20 dB attenuator is used.

The attenuated output signals are fed to the LeCroy digitizer with current output going to channel A and the voltage to channel B. Both channels are triggered on the voltage signal. The digitizer samples these signals at a rate of 742 picoseconds per sample with a total sampling time of approximately 300 nanoseconds.

A LeCroy supplied program named "Waveform Catalyst" runs on the IBM AT339 computer and serves to configure the digitizer and display the signals that have been captured. This display shows separate traces for the voltage and current outputs in units of millivolts and nanoseconds. The traces can be expanded and cursors are provided to facilitate taking time and voltage measurements from the trace. Data displayed by "Waveform Catalyst" are the actual voltages presented to the digitizer and have not been corrected to account for the various probe factors and attenuation. These traces can be saved by dumping the screen to the printer.

Data that has been prepared by the "Waveform Catalyst" software can be further processed by a program called "Asystant". "Asystant" displays, in graphical format, the actual voltage, current, power, and energy appearing at the EED.

Figure 3-1 shows a typical display of a "Waveform Catalyst" trace. The waveforms correspond to the voltage and current resulting from the application of a 100 nanosecond pulse to a 50 ohm load. The corrected values are 5500 volts and 105 amps.

Figure 3-2 shows a typical "Asystant" display - in this instance watts delivered to a 50 ohm load during a 25 nanosecond pulse. As mentioned, this program will produce similar displays of voltage, current, or energy.

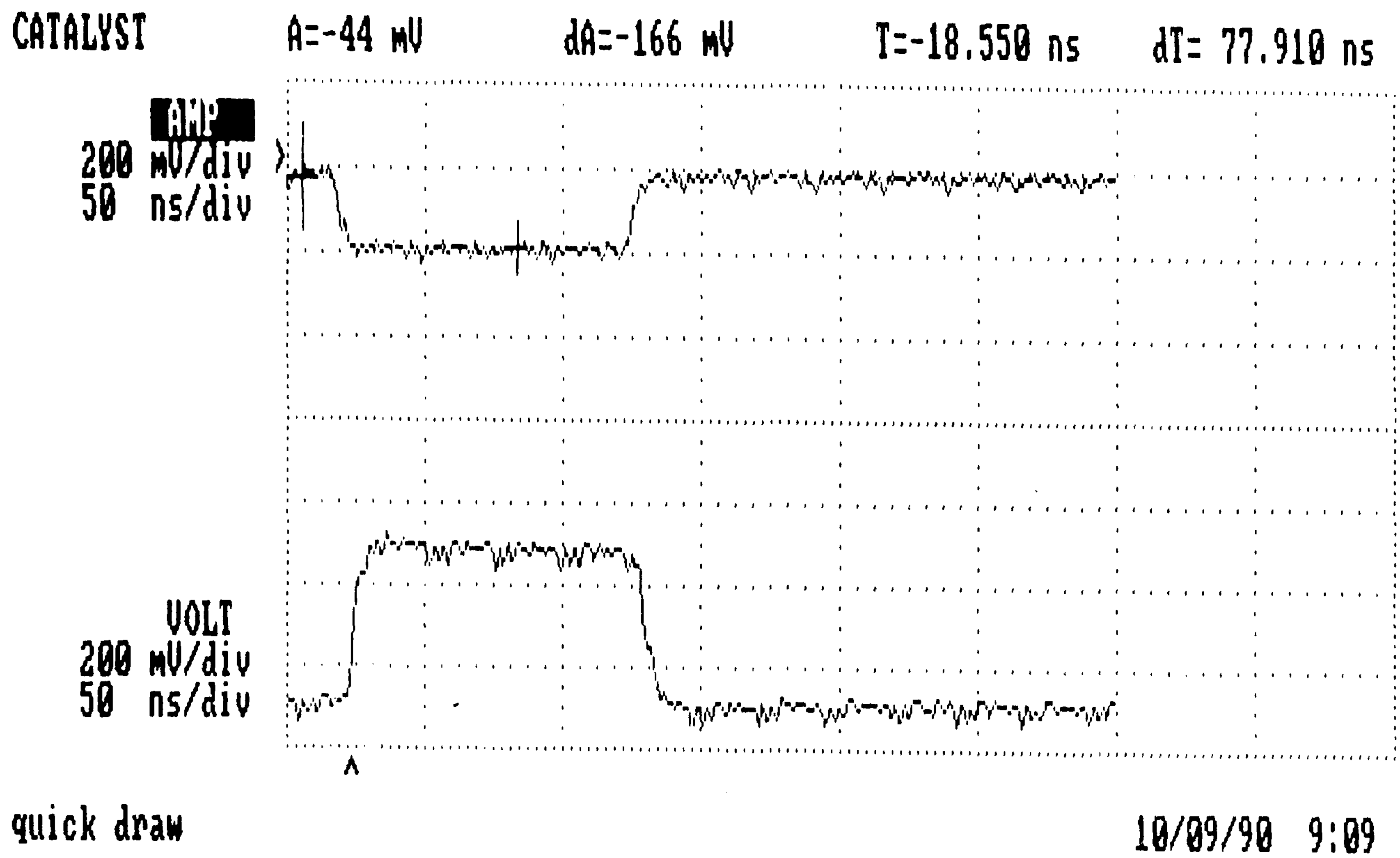

Figure 3-1 Waveform Catalyst Typical Display

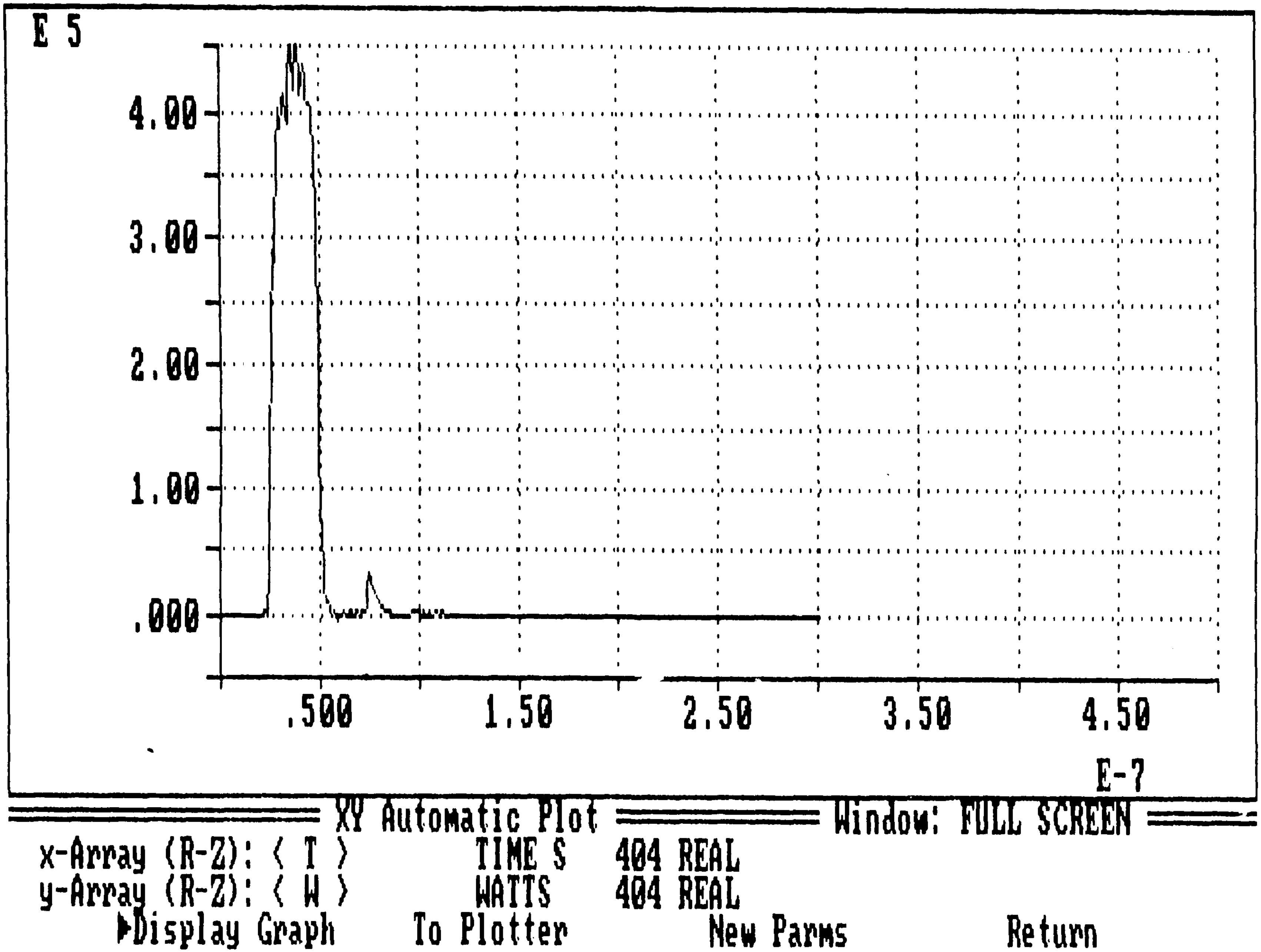

Figure 3-2 Asystant Typical Display

Although the above software packages provided adequate displays they proved somewhat inflexible especially in regard to retrieving and processing the data from a large number of tests. In addition they provided no ready means to present the data in tabular format. To overcome these difficulties FRC developed a program that works in conjunction with "Waveform Catalyst" to greatly facilitate these operations. This program is called "PPLOT1" and Figure 3-3 shows the same data as Figure 3-2 in this format. Details of using this program can be found in on the instruction file that accompanies the software.

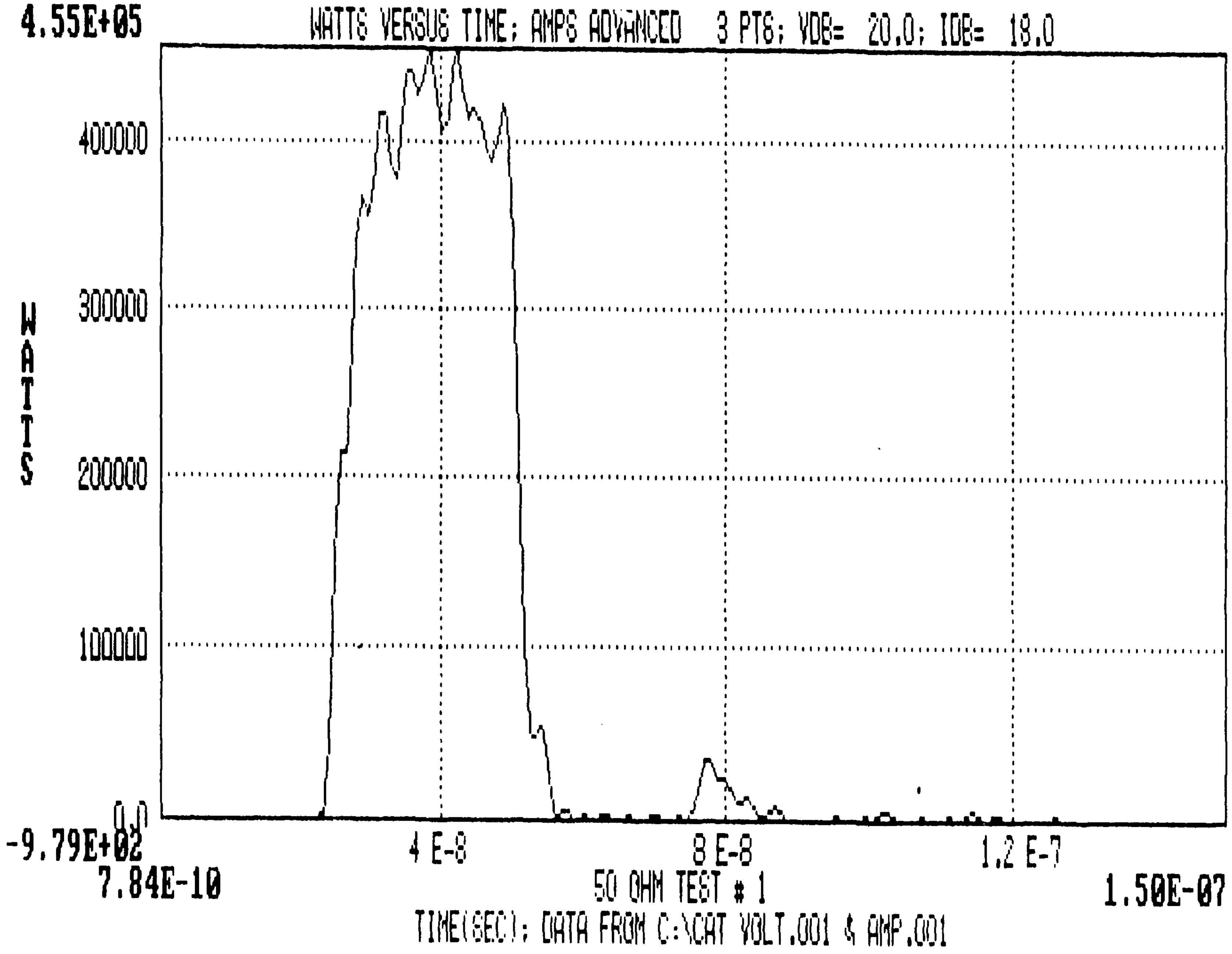

Figure 3-3 PPLOT Typical Display

4. TEST SET OPERATION

Note that some of the operations described in the following sections require that work be performed inside the rack cabinet and that high voltage cables be disconnected. Although the interlock will disable the high voltage power supply it may require a short time for the charged cables to discharge. It is recommended that the voltage control on the high voltage supply be turned all the way down and the remaining charge monitored on the voltmeter before shutting off the supply or opening the cabinet. See the power supply instruction manual for further details.

The same procedure should be followed before removing the safety shield and loading an EED into the test mount.

4.1 Turning On The Test Set

The test set requires a power source of 110/120 VAC, 25 amps. Each major component, the high voltage supply, the control circuit, the digitizer, and the computer/printer can be turned on separately in no particular order. Note, however, that although the high voltage supply will indicate that it is on it will not function unless the control circuit is operating and the interlock reset.

4.2 Configuring the Pulse Generator

There are two steps necessary to set up the pulse generator. First, it is necessary to insert the correct section of cable to provide the desired pulse duration. As mentioned previously, there are three lengths of line 303 available and each is marked with the pulse duration in nanoseconds. These cables plug into the metal oil bath cans and are retained by compression type fittings. It is necessary to remove the top of the rack cabinet to change cables. When a cable is removed from the oil bath the ends will be wet with the silicone dielectric fluid, and, although this fluid is rated nonhazardous, it is slippery and care should be taken to prevent dripping it in or around the test set. The cables may be reversed end-for-end and when installed the compression nuts should only be hand tightened.

Next, it is necessary to connect the insertion unit in the correct position as shown in Figures 2-1 and 2-2. The insertion unit is marked as to input and output and the input end is always closest to line 304. Because its connectors are not symmetrical, it is difficult to install this unit backwards. The short must be attached to the output end of the insertion unit for pins-to-case testing.

4.3 Running "Waveform Catalyst"

The AT339 computer must be connected to the LeCroy digitizer via the GPIB cable and the digitizer must be turned on prior to calling "Waveform Catalyst". When turned on the computer configures itself and waits with the prompt "strike any key...". Striking a key automatically calls "Waveform Catalyst". If the computer is displaying the DOS PROMPT, C:\> then "Waveform Catalyst" is called by entering <CAT>.

"Waveform Catalyst" initializes the digitizer and pauses displaying the graph format, a short option menu, and the message, "USE STORE.DEF". If the read option, <R>, is selected and filename STORE.DEF entered, and then the Go option, <G>, the test data will be saved for subsequent processing by "Asystant". To reject this option press <space> to exit this menu.

Pressing the function key F1 causes "Waveform Catalyst" to display a help screen of various program operations and options that are also described in the program manual and shown on the Quick Reference Card. For convenience, this card is reproduced here as Figure 4-1.

4.4 Preparing the Program and the Digitizer to Acquire Data

When "Waveform Catalyst" is first called it performs a DC calibration of the digitizer. After a warm up period of at least five minutes a full calibration should be done. This is accomplished by pressing Key F8 then selecting Full <F>. The calibration requires several minutes and when complete the digitizer may not accept the SINGLE TRIGGER command. If this occurs use MANUAL TRIGGER followed by SINGLE TRIGGER. Observe the TRIGGER ARMED lights on the digitizer to confirm that the trigger is actually armed. All data is taken with the single trigger option.

At this point it is useful to use the INSERT TEXT, <I>, command to display a name or test number along with the data traces. The inserted text will overwrite the line showing "USE STORE.DEF" and should be long enough or padded with spaces to completely replace the previously displayed text.

4.5 Mounting the EED

The test set is provided with a mounting fixture to accept small, wire lead, EEDs. Figure 4-2 shows this fixture with an EED mounted for pin-to-pin testing. Also shown is an EED configured for pins-to-case testing that has been inserted into the holder. The holder can be fitted with various size bushings to accommodate different diameter EEDs. A set screw locks the bushing in place in the holder. Projections on the holder engage tabs on the locking plate to retain this assembly in the mount. For pin-to-pin testing one lead of the EED is folded back along the case as shown. The bushing is slotted to accept the lead in this position. For pins-to-case tests the leads are twisted together as illustrated. The mounting sequence is as follows:

1) An EED with the leads properly prepared is inserted into the bushing. A set screw holds the EED in place. In the pin-to-pin configuration this set screw also bears on the folded lead.

2) The EED lead(s) are carefully inserted into the slotted center conductor of the fixture. The projections on the holder and the tabs on the locking plate should be kept slightly out of alignment of this time.

3) With the base of the holder fully against the front of the locking plate the holder is rotated to bring the projections into engagement with the tabs. A special wrench is provided for this purpose.

4) The set screw in the center conductor is tightened to clamp the lead(s) in place. This is done through a hole in the side of the face plate. Do not over tighten this screw.

5) Screw the safety shield onto the mounting fixture. The shield must be all the way on or the interlock will not reset.

In some pins-to-case tests it may be necessary to coat the base of the EED and the end of the center conductor with silicone grease to prevent voltage breakdown at this point.

4.6 Performing the Short Pulse Test

The pulse generator must be properly configured, the digitizer prepared via "Waveform Catalyst", and the EED mounted as discussed in the preceding sections. Before applying the test pulse it is necessary to set the attenuators so the voltage and current will be displayed correctly. It will require some experience for the operator to predict how a given EED will respond and usually some preliminary testing is needed to establish the correct settings. A few general guidelines follow.

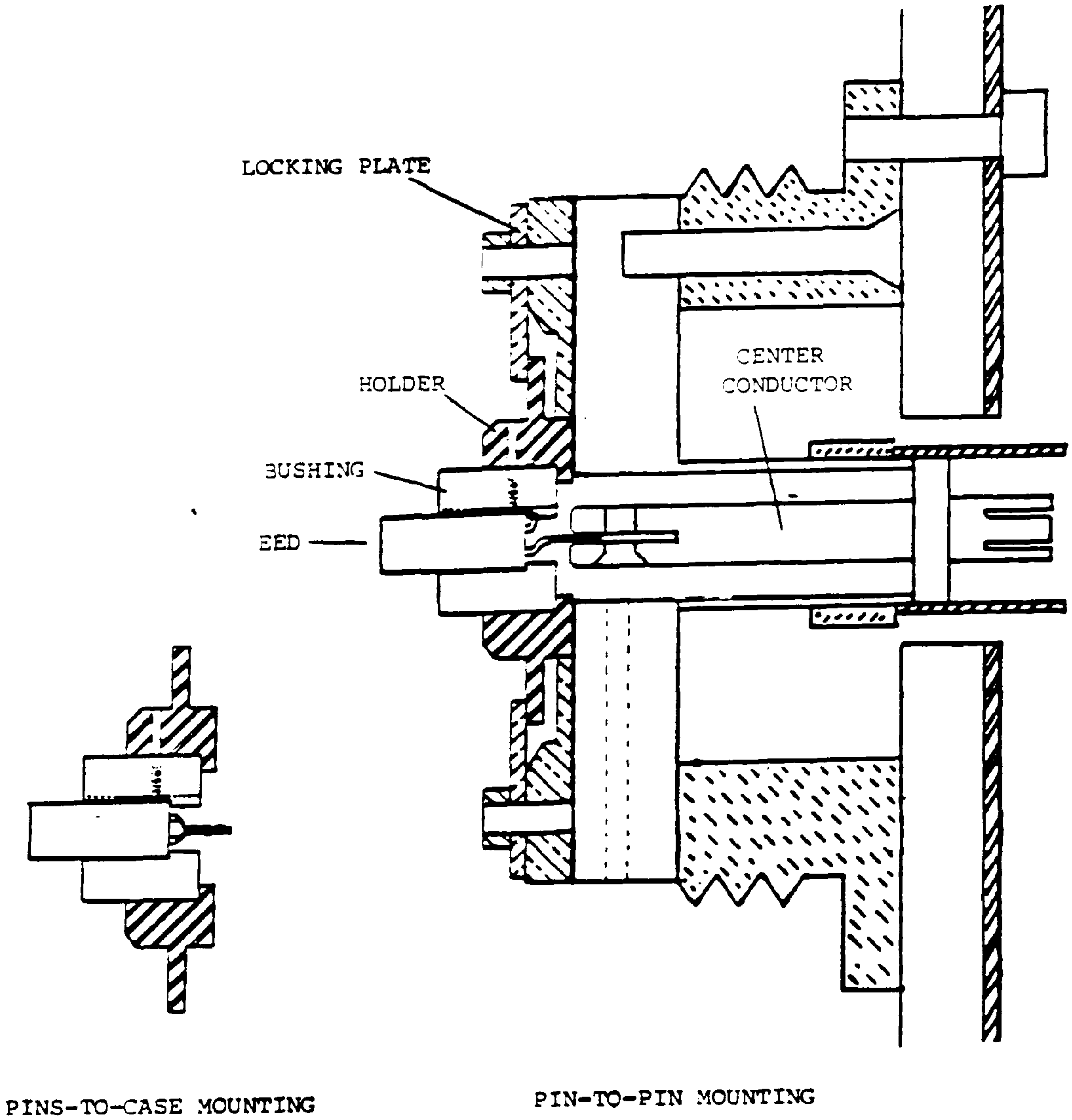

Figure 4-2 EED Mountings

1) Pin-to-Pin Voltage - With an input voltage of 50 kV only about 500 V can be expected across the one ohm load. However, because of the inductance of the EED, short voltage spikes much higher than this are observed. Attenuator dial settings of about 15 dB have been used successfully.

2) Pin-to-Pin Current - With 50 kV input the current will be approximately 500 amps and requires a attenuator dial setting of about 30 dB.

3) Pins-to-Case Voltage - At 50 kV input about 25 kV appears across the EED if breakdown does not occur. This requires a dial setting of about 35 dB.

4) Pins-to-Case Current - If breakdown does not occur current is minimal and setting of 10 to 15 dB may suffice, but if breakdown takes place current will be much higher. Currents as high as 900 amps have been observed. This required a setting of 45 dB.

5) It is possible to offset the baseline of the trace from zero and thus make more efficient use of the digitizer's +/- 0.250 volt range. How effective this will be depends on the shape of the observed signal. Some traces will show both positive and negative excursions.

When the attenuators have been adjusted the digitizer should be set for single trigger and then the voltage raised to the desired level. Allow about 30 seconds after setting the voltage level for the cables to charge. Pressing the PULSE button applies the pulse to the EED. The PULSE button should light briefly the digitizer should trigger and the new traces should be displayed on the computer monitor.

The data can now be processed and/or saved by one of the available methods.

APPENDIX

COMPONENT DESCRIPTION & PARTS LIST

PARTS LIST

Control Circuit

Part Number	Description
CX1	Connector, Hubbel 7593 / 7594
CX2	Connector, Cinch S304CCTK / P304CCTL
CX3	Connector, Cinch S302CCTK / P302CCTL
CX4	Connector, Cinch S302CCTK / P302CCTL
CX5	Connector, Cinch S308CCTK / P308CCTL
CX6	Connector, Hubbel 7464V / 7465V
CX7	Connector, Cinch S302CCTK / P302CCTL
D1/D4	Diode 1N4001
K1	Relay, Potter & Brumfield KRP11DG-12
K2	Relay, Potter & Brumfield KRP11DG-12
K3	Relay, Potter & Brumfield CKD-38-20010
K4	Relay, Potter & Brumfield KRP11DG-12
K5	Relay, Kilovac H-25
SW1	Switch, Microswitch AML32LBK7AD
SW2	Switch, Microswitch PWH4533FG
SW3	Switch, Microswitch PWH2534FG
SW4	Switch, Microswitch 914CE1-3
SW5	Switch, Microswitch 914CE19-3

Pulse Generator

R1	Resistor, Victoreen MOX 4-13 500 Mohm
R2	Two Of Above In Parallel
Coupling	Type 874-T 50 ohm Tee
Termination	Type 874-WN Short Circuit
Insertion Unit	Type 874-X 50 ohm
Line 302	Cable, Times Microwave Type RG 218/U 50 ohm
Line 303	"
Line 304	"
Cable 204	Cable, Belden Type 9463 78 ohm Twinaxial