

THERMAL TRANSIENT TEST SET
MODEL 630B SN-25

Volume I
MEASUREMENT SECTION
INSTALLATION AND OPERATION

Copyright 2005 Pasadena Scientific Industries

Pasadena Scientific LLC
1418 Gunston Rd
Bel Air, Maryland 21015

MODEL 630B - AUTO NULLING
THERMAL TRANSIENT TEST SET

Some features can be tailored to your requirements

SPECIFICATIONS

BRIDGEWIRE RESISTANCE RANGE: 0.10 to 3.50 ohms, to 10 ohms with reduced capability (see graph, Section IV).

TEST CURRENT: Current is normally set to 60% of no-fire current and can range from 10 to 2000 ma. Minimum and full scale values are set by software routines entered via the GPIB port or by keyboard entry.

CURRENT RESOLUTION: One part in 4095 of full scale value.

CURRENT ACCURACY: 2% plus 1 milliamp

GAIN: Nominal 100 (May be set to other values and read via the GPIB port or displayed on local VGA monitor.)

NULL: Precise to +/-5 millivolts at output at nominal gain, 50-microvolts at the EED (see graph)

OUTPUT NOISE: Less than 5 millivolts p-p at output at nominal gain, 50-microvolts at the EED (see graph).

BALANCE CURRENT: Minimum 10 milliamp, maximum 200 milliamp. Normally balance current is set to 10% of test current. Value is set by software routines entered via the GPIB port or locally from the keyboard.

CURRENT PULSE DURATION: 10 to 99 milliseconds. Value is set by software routines entered via the GPIB port or locally from the keyboard.

TEST START TRIGGER: Command input from user to start test. TTL level pulse, 15 millisecc minimum, via a BNC connector, a software trigger via the keyboard, or from a host computer via the GPIB port.

SYNC OUT (SWEEP START TRIGGER): TTL output, nominal 1 millisecc, via a BNC connector to trigger oscilloscope sweep prior to start of EED characteristic pulse.

INPUT POWER: 105 - 125V, 50-60Hz, 10 Amps (max).

TEMPERATURE: Operating: 15°C to +35°C
Storage : -40°C to +70°C

COOLING: Fan

DIMENSIONS: 19.00"W x 12.25"H x 22.70"D.

WEIGHT: 53 lbs (approx) net.
125 lbs (approx) shipping

@2002

A word about safety

Thermal transient testing involves the application of precise, controlled test signals to the device under test. The nondestructive aspects of the test, and the safety implied, are closely related to the magnitude of the test signals and the characteristics of the test item.

As in any test involving potentially hazardous material, an element of danger is present when an EED is subjected to an electrical test signal. In the interest of safety, it is recommended that those using the equipment described herein thoroughly familiarize themselves with the contents of this manual prior to testing hazardous devices. In addition, hazardous test items should be placed in appropriate fixtures and protective enclosures (test chamber, barrier, etc.) during the time test signals are being applied.

PASADENA SCIENTIFIC LLC

WARRANTY

Model 630 Thermal Transient Test Set is warranted against defects in materials and workmanship for one year from date of shipment. Our obligation is limited to repairing or replacing parts which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

Pasadena Scientific LLC
1418 Gunston Rd
Bel Air, Maryland 21015

TABLE OF CONTENTS

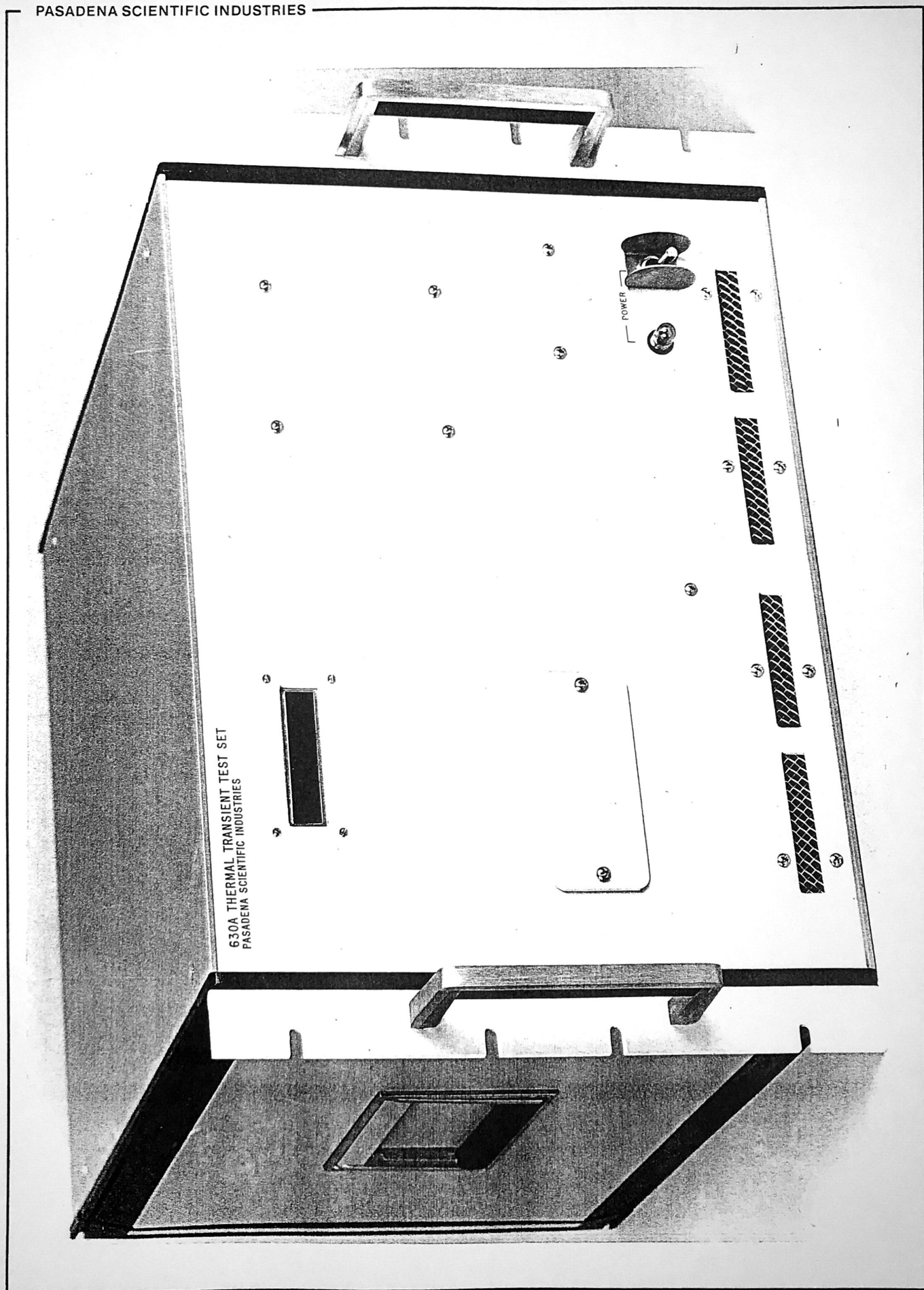
SPECIFICATIONS

SAFETY NOTICE

WARRANTY

SECTION I.	THERMAL TRANSIENT TEST	1
	Introduction; Test Concept; Test Capabilities; Basic Test Circuit.	
SECTION II.	DESCRIPTION -MODEL 630B	3
	General; Physical Description; Power Supply; Main Board; Interface Section; Data Capture and Analysis Section; Functional Description; Digital Circuits; Analog Circuits; I/O Interface; Circuit Description; Null and Test; I/O Interface.	
SECTION III.	INSTALLATION	10
	General; Test Fixtures; EED Cable; Connectors; Power Requirements; Grounds; Installation.	
SECTION IV.	OPERATING INSTRUCTIONS	20
	General; Description of Signals; Operating Procedure; Parameter Setting; Thermal Response; Local Operation; Host Operation; Offset Correction; Oscilloscope Controls; Parameter Selection; Test Current vs Load Resistance; Test Current Magnitude; Test Pulse Duration; Cable Connections; Controls and Indicators.	
SECTION V.	MAINTENANCE	29
	Component replacement; Digital Display; Switching Transients.	
APPENDIX A	"Reference Bridgewire RB101"	30
APPLICATION NOTES		
AN-2	"Thermal Transient Test Theory"	
AN-3	"Calculation of Electrothermal Parameters"	
AN-4	"Interpretation of Thermal Response Curves"	

Pasadena Scientific LLC
1418 Gunston Rd
Bel Air, Maryland 21015



SECTION I

THERMAL TRANSIENT TEST¹1.1 INTRODUCTION

The use of electroexplosive devices (EED's) in military, aerospace, and many commercial applications necessitates a high degree of reliability at a high level of confidence in each item. Commonly employed testing techniques rely heavily on destructive techniques. The thermal transient test is a nondestructive technique for inspection of the critical bridgewire-explosive interface. In essence, the test allows one to "look" inside the EED nondestructively and determine if certain failure conditions and/or abnormalities are present.

In addition to the nondestructive testing aspects, the thermal transient test offers unique and significant advantages for EED characterization. The test is particularly well-suited for quality assurance, development, and production control applications.

1.2 TEST CONCEPT

Application of a current to a hot bridgewire type EED causes the bridgewire temperature to increase. Some of this energy is dissipated from the bridgewire to surrounding explosive material. The temperature rise is accompanied by a corresponding increase in the resistance of the bridgewire material (it is important that the bridgewire material have a reasonable temperature coefficient of resistance [TCR]). By carefully controlling and limiting the amplitude and duration of the current pulse, so that no chemical change of the explosive material occurs, the EED will return to ambient temperature at the end of the pulse with no discernible permanent change. The pulse magnitude is selected to stress the bridgewire-explosive interface to the extent that its latent thermal characteristics become responsive. Pulse duration is chosen to produce thermal equilibrium at the interface. The rate at which the bridgewire changes, and the maximum value of change, are determined by the interface characteristics. The signals generated by the changes are displayed on an oscilloscope for observation and analysis.

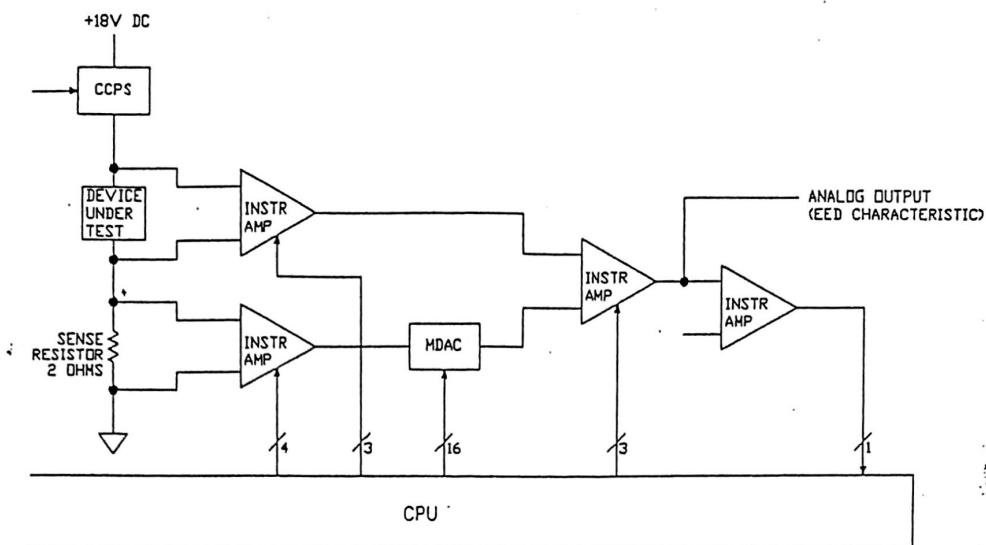
1.3 TEST CAPABILITIES

EED nondestructive test and measurement² capabilities include:

- (a) Bridgewire weld quality
- (b) Loading density
- (c) Interface air gaps
- (d) Explosive contamination
- (e) Gas inclusion along bridgewire
- (f) Thermal time constant
- (g) Thermal capacity
- (h) Bridgewire resistance
- (i) Bridgewire temperature

1.4 BASIC TEST CIRCUIT

An elementary form of the basic circuit for thermal transient testing is shown below.



Current pulses of appropriate magnitude for nulling and testing are derived from the constant-current power supply. The device under test (DUT) is in series with a precision sense resistor. Since the voltage across the sense resistor and the DUT are proportional to the current through both, the voltages are proportional to each other. One of the functions of the test set is to determine what that proportion is. Knowing the proportion and the resistance of the sense resistor allows the test set to calculate the DUT resistance and display the characteristic waveform. When a thermal test pulse is applied to the sense resistor and the DUT, the DUT resistance changes as the temperature increases, causing the proportion to change. The output signal characterizes the electrothermal condition of the bridgewire-explosive interface. Output signals are then displayed on a monitor oscilloscope or captured on a digitizing device.

Application Note AN-4 "Interpretation of Thermal Response Curves" covers representative examples of normal and abnormal curves likely to be encountered.

- 1 See Application Note AN-2 "Thermal Transient Theory"
- 2 See Application note AN-3 "Calculation of Electrothermal Parameters"

SECTION II

DESCRIPTION - MODEL 630B

2.1 GENERAL

The 630B is designed to facilitate thermal transient testing of EED's within the constant current capacity and load resistance range of the Test Set.

2.2 PHYSICAL DESCRIPTION

The Model 630B Auto Nulling Thermal Transient Test Set consists of a standard 19-inch rack mounted cabinet 22.70 inches deep by 12.25 inches high. The cabinet is light blue with dark blue trim. Front and back panels are ivory with black engraved lettering.

The test set can run as a stand-alone unit or under control of a host computer. Communication is achieved via a GPIB port on the back panel or by keyboard entry.

The front panel contains the power switch and a digital display. Power and other cable connections are on the back panel.

The cabinet houses the power supply chassis below and the measurement and analysis sections above.

The test set is shipped with AC power cord; coaxial cable assemblies; EED Cable; GPIB Cable; Assorted accessory cables; Reference Bridgewire RB101; and Installation and Operating Manuals.

The Model 630B is capable of providing 2000 milliamperes constant current pulses to an EED of 0.1 to 3.5 ohms. EEDs in the range of 3.5 to 10.0 ohms require reduced maximum current levels and have increased noise and null specifications (see graph).

2.3 Power Supply Section

The DC power supply section houses seven power supplies and provides all voltages used in the system. There are two supplies for the digital circuits, three for the analog circuits, two to power the Data Capture and Analysis section including the disk drives. A +5V DC, 10 amp supply and a dual ± 15 V DC, 200ma supply power the digital circuits. The analog supplies include a single +5V DC, 1000mA supply and a dual ± 15 V DC at 200mA. A third analog supply providing null and test current is a +24V DC supply with a 3.6 amp capacity. The two power supplies which power the Data Capture section are a ± 12 V DC, 240ma supply and a +12V DC, 5.1Amp which provides power to the disc drives.

A simplified schematic of the constant current loop is shown in Figure 2-1.

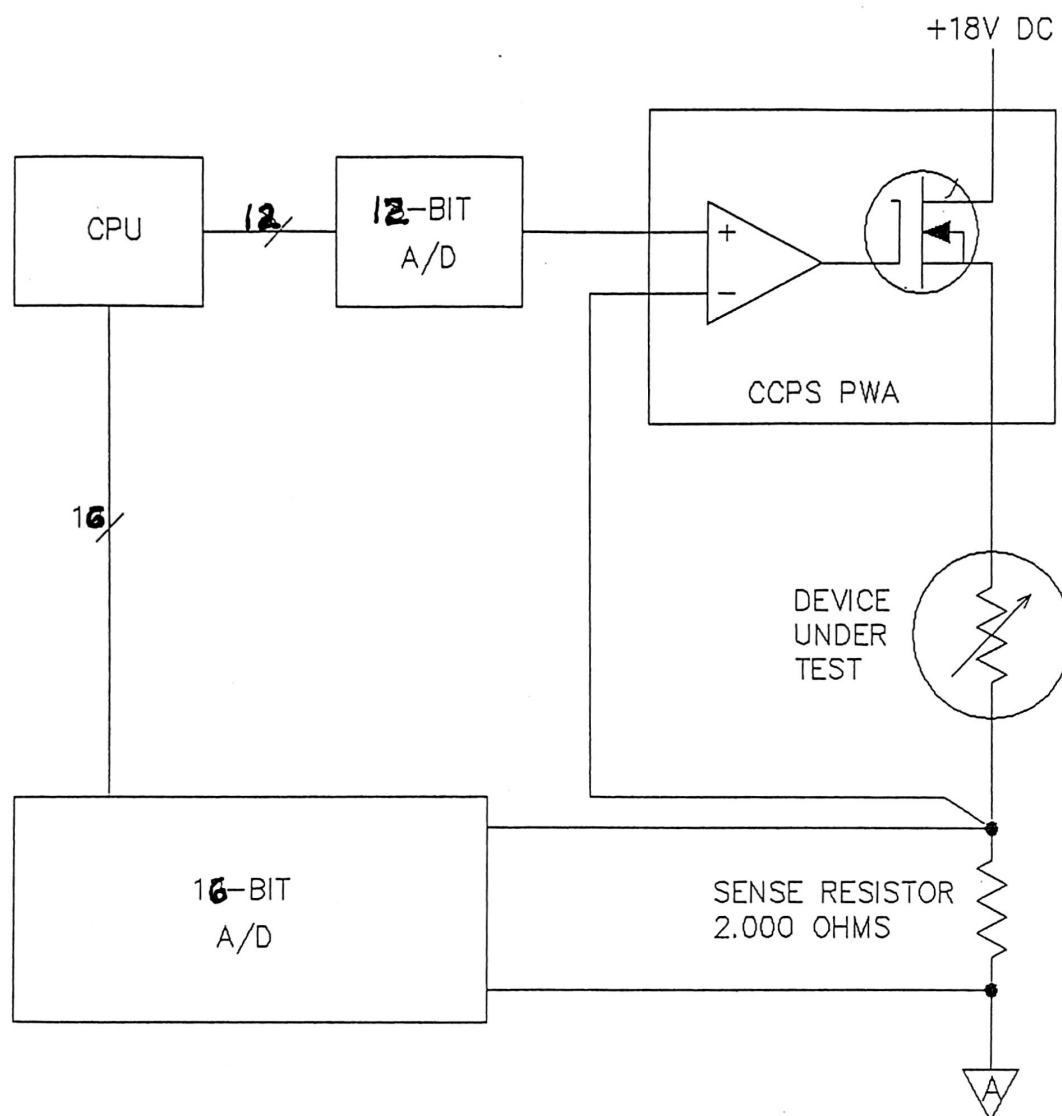


Figure 2-1. Constant Current Simplified Schematic

2.4 Main Board

The main board contains a constant current power supply, measurement circuit, interface section, and I/O section.

2.5 CPU - The CPU is mounted above the I/O section of the main board. Connection to the main board is made via 6 connectors. Communication is provided to an IBM compatible computer via a serial port. There is a 16-bit A/D converter in the CPU which monitors the internal functions of the main board.

2.6 Interface Section

An alpha-numeric display is on the front panel, which displays information on Test Set operating status. Power and other cable connections are on the back panel.

Digital data is routed into and out of the test set through BNC connectors via the I/O section of the main board and the I/O card of the Data Capture and Analysis section.

2.7 Data Capture And Analysis Section

The Data Capture and Analysis section consists of a monoboard MMX Pentium III, 233MHz CPU; a GPIB Communications board, a TTL digital I/O board; and a Model 620 Data Capture board. These four boards are on a 4-slot passive backplane which forms the base of the card cage.

Volume II of this manual describes installation and operation of the Data Capture and Analysis section of the test set.

2.8 FUNCTIONAL DESCRIPTION

The Model 630 Auto Nulling Thermal Transient Test Set is a digitally controlled measurement system designed to produce a high level analog output waveform representing the change in resistance of a bridgewire device as it heats during a DC current pulse. This waveform is available at an output BNC connector on the back panel.

When a trigger command is received, the processor establishes a coarse null using null current pulses. Then a fine null is established with a few short test current pulses. Resistance of the EED is then displayed on the front panel and made available to a connected computer via the GPIB port.

The I/O section passes control signals from the processor to the rest of the test set. These signals set op amp gains, control the nulling sequence, and set the current levels produced by the CCPS section.

In the constant current power supply (CCPS) section a digital word from the CPU sets a Digital-to-Analog Converter (DAC) to produce the null and test current levels sent to the EED. Relays in this section provide Safe-and-Arm and Current-Disable functions to protect the EED during setup and test parameter changes.

The measurement section receives voltage from the sense leads across the Electro-Explosive Device (EED) and produces a digital word at null that is proportional to the cold resistance of the EED. The output analog characteristic waveform represents the change in resistance of the EED as a result of heating during the test current pulse. Circuits in the measurement section monitor the voltage across the EED during this entire sequence and produce the EED characteristic waveform in less than one-half second. The waveform is analyzed by the Capture and Analysis System and may be viewed on the monitor. The measurement section also sends the characteristic output waveform of the EED to the output BNC connector on the back panel of the test set.

Test parameters are passed to the Model 630 via the GPIB port on the back panel of the Model 630B or by keyboard entry.

2.9 Digital Circuits

2.10 CPU Card - The CPU Card is a single board RISC processor programmed in "C" language. The test set operator does not have access to the internal software. The processor has a 16-bit A/D converter with 8 differential channels. All functions of the test set are controlled by this card including Sync signal and Test Complete output signal communication from the test set.

2.11 Interface Section - The Interface section of the main board contains devices which pass all communication from the CPU to the analog circuits. In addition, this section provides communication to the I/O circuits.

2.12 I/O Circuits - The I/O circuits of the main board pass input and output signals to and from the BNC connectors on the back panel and to the LCD display on the front panel.

2.13 Analog Circuits

2.14 Constant Current Power Supply (CCPS) - The CCPS receives a 12-bit digital word from the CPU. This word is used by a digital-to-analog converter (DAC) which commands the test current levels in the CCPS. Analog voltages from the DAC set up the null and test current levels. Safe-And-Arm and Current Disable relays are also in this circuit.

2.15 Measurement Circuit - The measurement circuit receives voltage from the sense leads across the Electro-Explosive Device (EED) and produces a digital word at null that is proportional to the cold resistance of the EED. The measurement circuit also provides the characteristic output waveshape of the EED to the output connector of the test set. The output analog characteristic waveform consists of information representing the change in resistance of the EED as a result of heating during the test current pulse.

2.16 I/O Interface

2.17 Output Circuit - Digital data is passed to BNC connectors on the back panel via the Output Circuit. These data consist of two outputs (Sync Out and Test Complete). Other inputs and outputs to and from the back panel are controlled by the Data Capture and Analysis section. Functions of and specifications for these data are given in Section IV.

2.18 Data Capture System

See Data Capture and Analysis section in Volume 2 of this manual.

2.19 CIRCUIT DESCRIPTION

A simplified block diagram of the 630B is shown in Figure 2-2. Refer to this diagram for general circuit information

2.20 Null and Test

The CPU receives information to configure the test set via the host computer or from an operator using a keyboard and monitor connected to the test set. The CPU then sends data to the control circuit. The control circuit buffers the data and sends current information to the CCPS and measurement information to the measurement circuit.

The test set is configured by input parameters to make the desired measurement. When a Command Trigger pulse is received, a short low-level current pulse is sent to the EED to determine that there is, in fact, an EED connected; and that the EED is grossly within the tolerance specified by the input parameters. Gains are set for individual stages throughout the system, and the test set then performs its null routine.

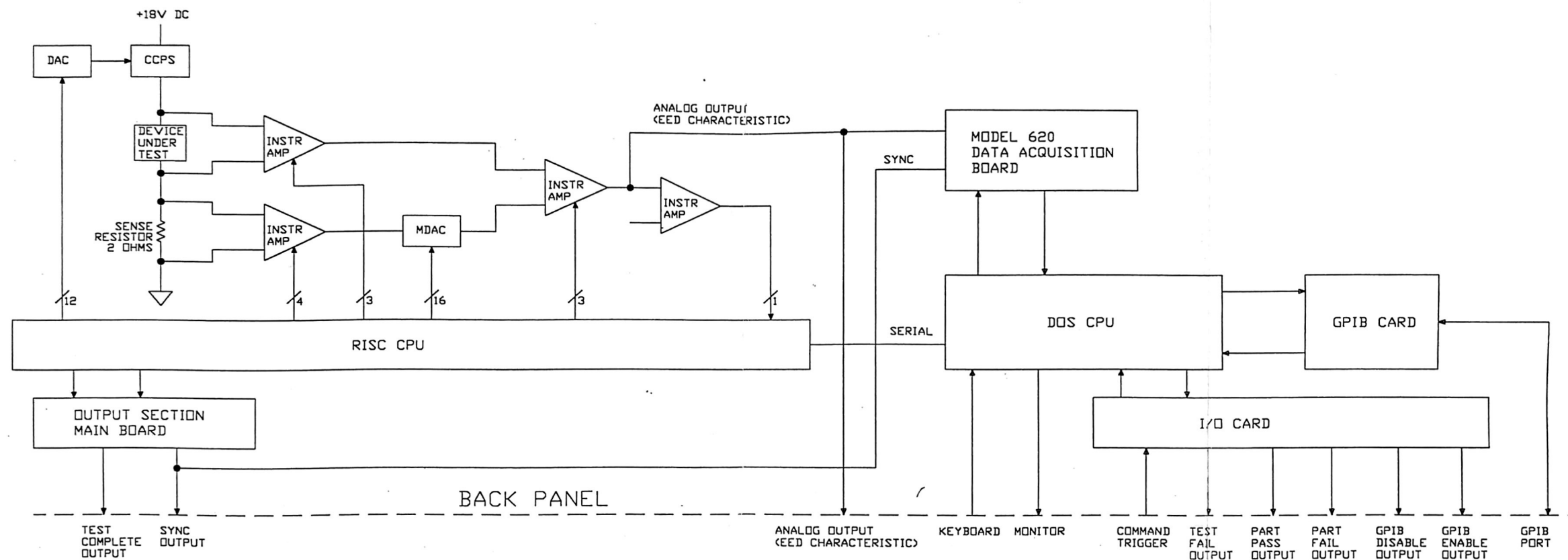


Figure 2-2. Model 630 Test Set Functional Diagram

A series of null pulses is sent to the EED. A comparison is made for each null pulse in order to find a value for the null that will cause the baseline of the characteristic output pulse to be at zero volts.

A decision is made in the CPU as to whether to leave on or turn off each bit in a 2-byte digital word. This decision is made based on information gathered by the A/D converter. The decision sequence is a binary search that begins with the MSB and ends with the LSB. The final value of this digital word is proportional to the cold resistance of the EED.

During the first 120 milliseconds of the cycle the nulling current passes through the EED. During the next 12 milliseconds no current or zero ma passes through the EED. Then the test current passes through the EED. The measurement circuit within the Model 630 monitors the voltage across the EED during this entire sequence and produces the EED characteristic waveform. This waveform is available at the output BNC connector to be viewed on an oscilloscope, or to be digitized, analyzed, and sent to a monitor attached to the test set, or a host computer.

2.20 Input/Output Interface

2.21 Test Parameter Data - Test parameters are passed to system memory using a keyboard and monitor attached to the test set or from a host computer.

2.22 Digital Data - The digital data passed to BNC connectors on the back panel via the Output Circuit are in TTL format. These data consist of two outputs (Sync Out and Test Complete). Other inputs and outputs to and from the back panel are controlled by the Data Capture and Analysis section. Functions of and specifications for these data are given in Section IV.

2.23 Analog Data - Analog data consisting of the EED Characteristic Waveform is sent to a BNC connector on the back panel from the measurement circuit. It is also displayed on a local monitor or a host computer.

SECTION III

INSTALLATION

3.1 GENERAL

The 630B is designed for bench or table top use. Optional adapters are available for rack mounting the enclosure. Installation consists of placing the instrument at a suitable operating position and making the cable interconnections to the AC power source, control device, oscilloscope or other data capture hardware, and the device under test (including user-supplied test fixtures).

3.2 TEST FIXTURES

User-fabricated test fixtures designed to accommodate the particular test components will usually improve the efficiency and safety of the test procedure.

AS A SAFETY MEASURE WE STRONGLY RECOMMEND THAT TEST ITEMS BE PLACED IN A SUITABLE TEST CHAMBER DURING TESTS. ...

User-supplied test fixtures should include provisions for electrically disconnecting the device under test from the 630B "TO EED" connector terminals and shorting, and grounding, the bridgewire leads except during the application of balancing and test currents. It should be repeated that the 630B "TO EED" connector terminals are shorted by "Safe and Arm" relay K2 of the CCPS; the short is removed during the time the null and test currents are applied.

3.3 630B EED CABLE

The test involves relatively low level and high impedance signals (on the order of a few millivolts in some cases). Electrical noise from external sources will seriously degrade the data waveforms. In order to minimize stray noise entering the system via the cable connecting the 630B and the device under test careful attention must be given the cable details.

The cable shown in Figure 3-1 is one approach. This cable has operated extremely well over distances in excess of 10 feet. Cable installations meeting these general requirements should work satisfactorily. Shields should be allowed to float at the EED end of the cable

3.4 CONNECTORS

High quality binding posts, terminals, switches, etc., are essential for low-noise test signals. Alligator clips and similar devices are to be avoided.

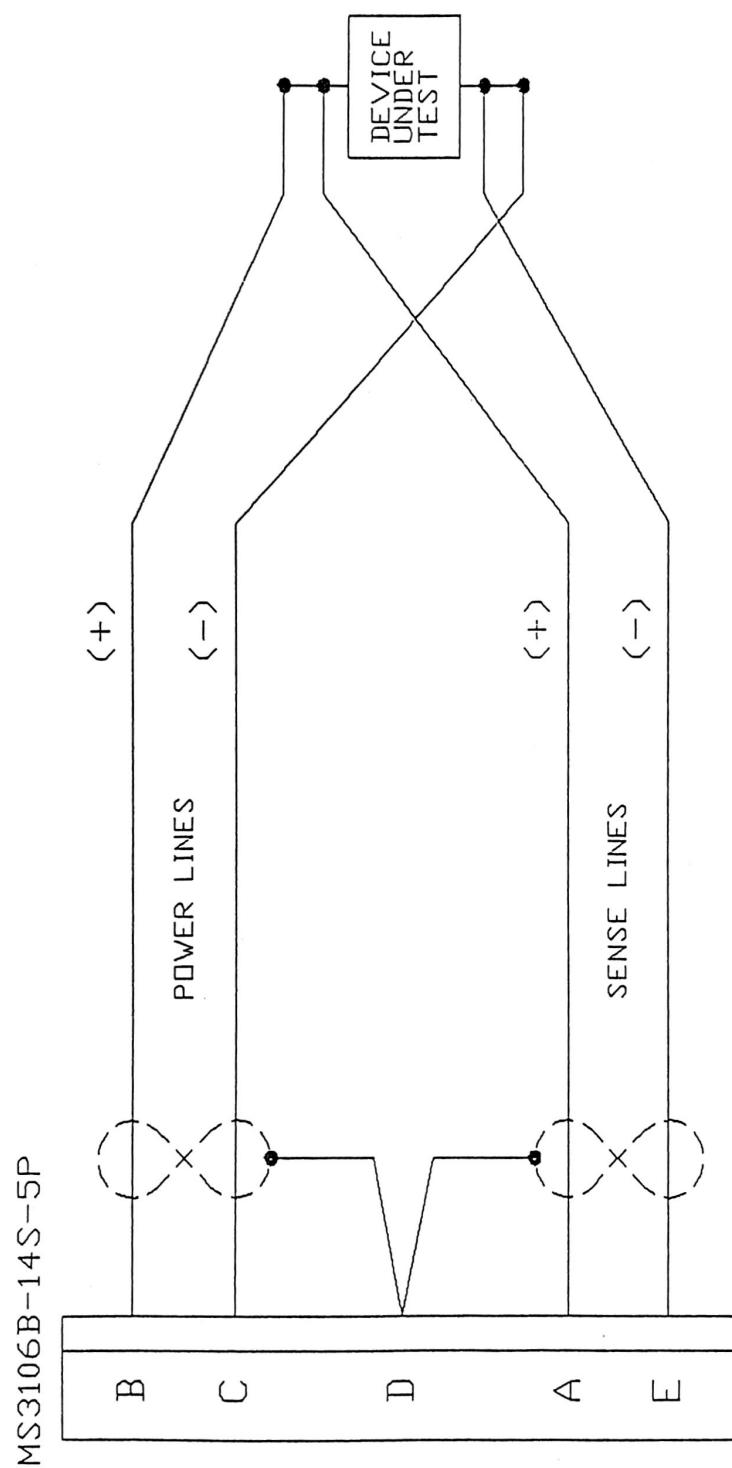


Figure 3-1. EED Cable

NOTE: Particular attention should be given the following paragraphs if clean data waveforms are to be obtained.

3.5 POWER REQUIREMENTS

The 630B is designed to operate only from an unbalanced-to-ground power source. The power line neutral (white or "identified" conductor) must be connected to the 630B neutral (unfused), and the power plug safety ground must return to ground through a different path than the power ground pin. The power requirement is 115 volts, single phase, 60 Hz, 10 Amperes.

3.6 GROUNDS

The cabinet and chassis of the 630B are electrically connected to the power plug (J1) safety ground pin.

The 630B digital circuit ground () and analog circuit ground () are connected to earth ground () at the system single point ground in the power supply. The waveform capture hardware (oscilloscope or digitizer) chassis should be tied to earth ground as close as possible to the test set.

3.7 INSTALLATION

Figure 3-2 details basic connections and startup instructions at installation for local control. Note that in local (stand-alone) operation, there is no remote data recording capability. However, there is 80Gb of data storage capability in the test set.

Figure 3-3 shows external cabling connections for local (stand-alone) operation.

Figure 3-4 details basic connections and startup instructions at installation for control by a host computer.

Figure 3-5 shows external cable connections for control by a host computer.

Figure 3-6 details basic connections and startup instructions at installation for host control when using a PLC or other production line controller.

Figure 3-7 shows external cable connections for host control when using a PLC or other production line controller.

Figure 3-8 shows the Model 630 back panel.

INSTALLATION INSTRUCTIONS

STAND-ALONE OPERATION

1. Test set may be installed in an equipment rack or it may be used alone as a piece of bench-top test equipment.
2. Make following connections to test set per Figure 3-3:
VGA Monitor to MONITOR output connector J18,
Keyboard to KEYBOARD connector J16,
AC power cord to POWER connector J1.
3. Connect AC power cord to appropriate power source.
4. The following connections are optional:
COMMAND TRIGGER INPUT J5,
EED CHARACTERISTIC OUTPUT J3 to oscilloscope vertical input,
SYNC OUTPUT J7 to oscilloscope trigger input,
PART PASS J11 and PART FAIL J12 outputs,
TEST COMPLETE J9 and TEST FAIL J10 outputs.
5. The following connections are not used:
RS-232 SERIAL PORT J4,
CAL PORT J17,
SPARE INPUTS J6 and J8,
GPIB PORT J15,
GPIB ENABLE J13 and GPIB DISABLE J14.
6. Install AC power cord and connect to appropriate power source.
7. Set power switch to ON.
8. Monitor will display main work screen.
9. See configuration instructions in Data Capture section in Volume 2 of this manual.
10. Connect device under test to TO EED connector terminals; (refer to Par. 3.3) for 630B/EED Cable details.
11. System is ready for use.

Figure 3-2. Installation Instructions - Local Control

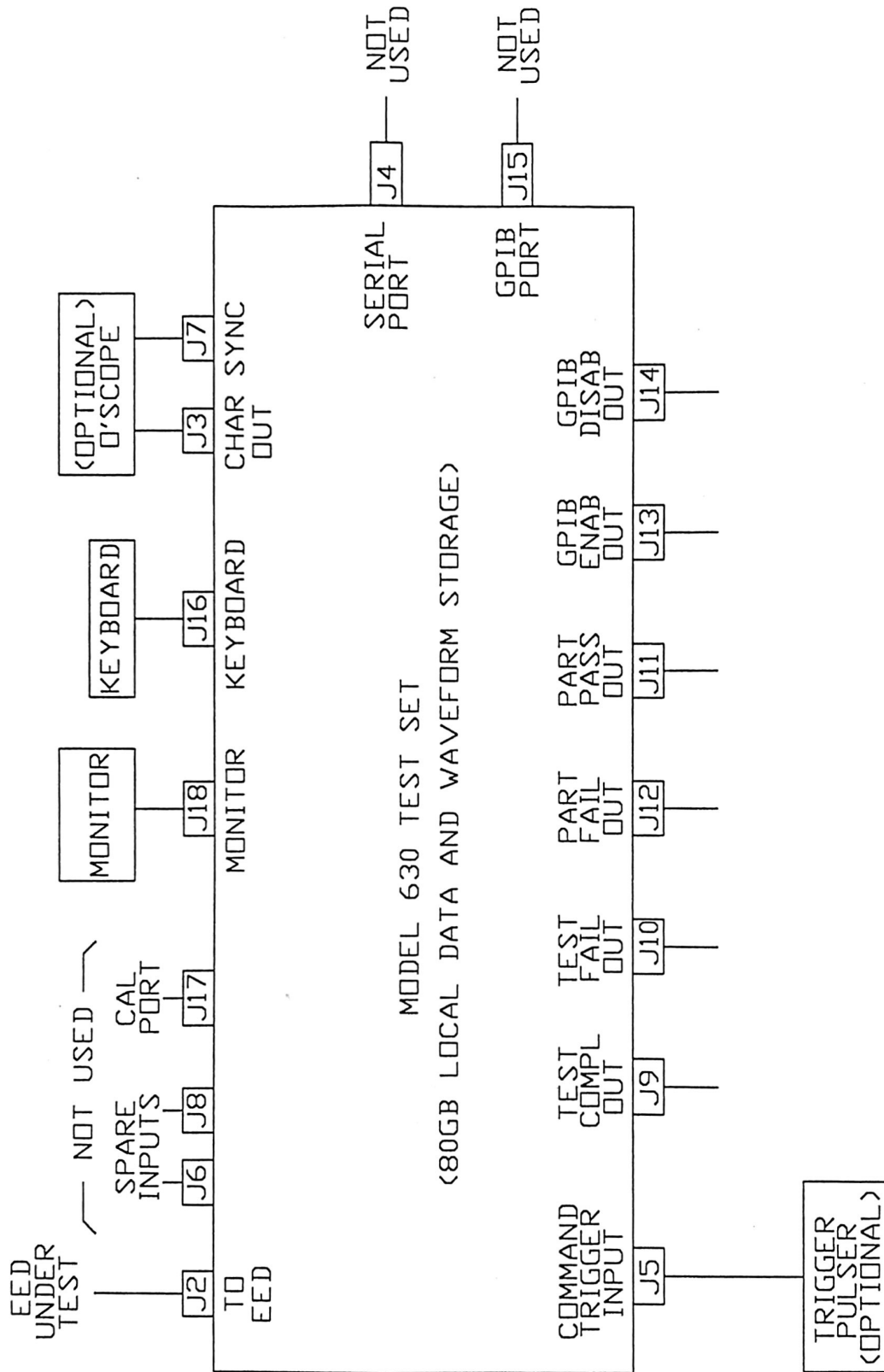


Figure 3-3. Cabling for Stand-alone Operation

INSTALLATION INSTRUCTIONS

HOST COMPUTER CONTROL

1. Test set may be installed in an equipment rack or it may be used alone as a piece of bench-top test equipment.
2. Make following connections to test set per Figure 3-5:
VGA Monitor to MONITOR output connector J18,
Keyboard to KEYBOARD connector J16,
GPIB PORT J15 to Personal Computer,
AC power cord to POWER connector J1.
3. Connect AC power cord to appropriate power source.
4. The following connections are optional:
COMMAND TRIGGER INPUT J5,
EED CHARACTERISTIC OUTPUT J3 to oscilloscope vertical input,
SYNC OUTPUT J7 to oscilloscope trigger input,
PART PASS J11 and PART FAIL J12 outputs,
TEST COMPLETE J9 and TEST FAIL J10 outputs,
GPIB ENABLE J13 and GPIB DISABLE J14.
5. The following connections are not used:
RS-232 SERIAL PORT J4,
CAL PORT J17,
SPARE INPUTS J6 and J8.
6. Install AC power cord and connect to appropriate power source.
7. Set power switch to ON.
8. Monitor will display main work screen.
9. See configuration instructions in Data Capture section in Volume 2 of this manual.
10. Connect device under test to TO EED connector terminals; (refer to Par. 3.3) for 630B/EED Cable details.
11. System is ready for use.

Figure 3-4. Installation Instructions - Host Control

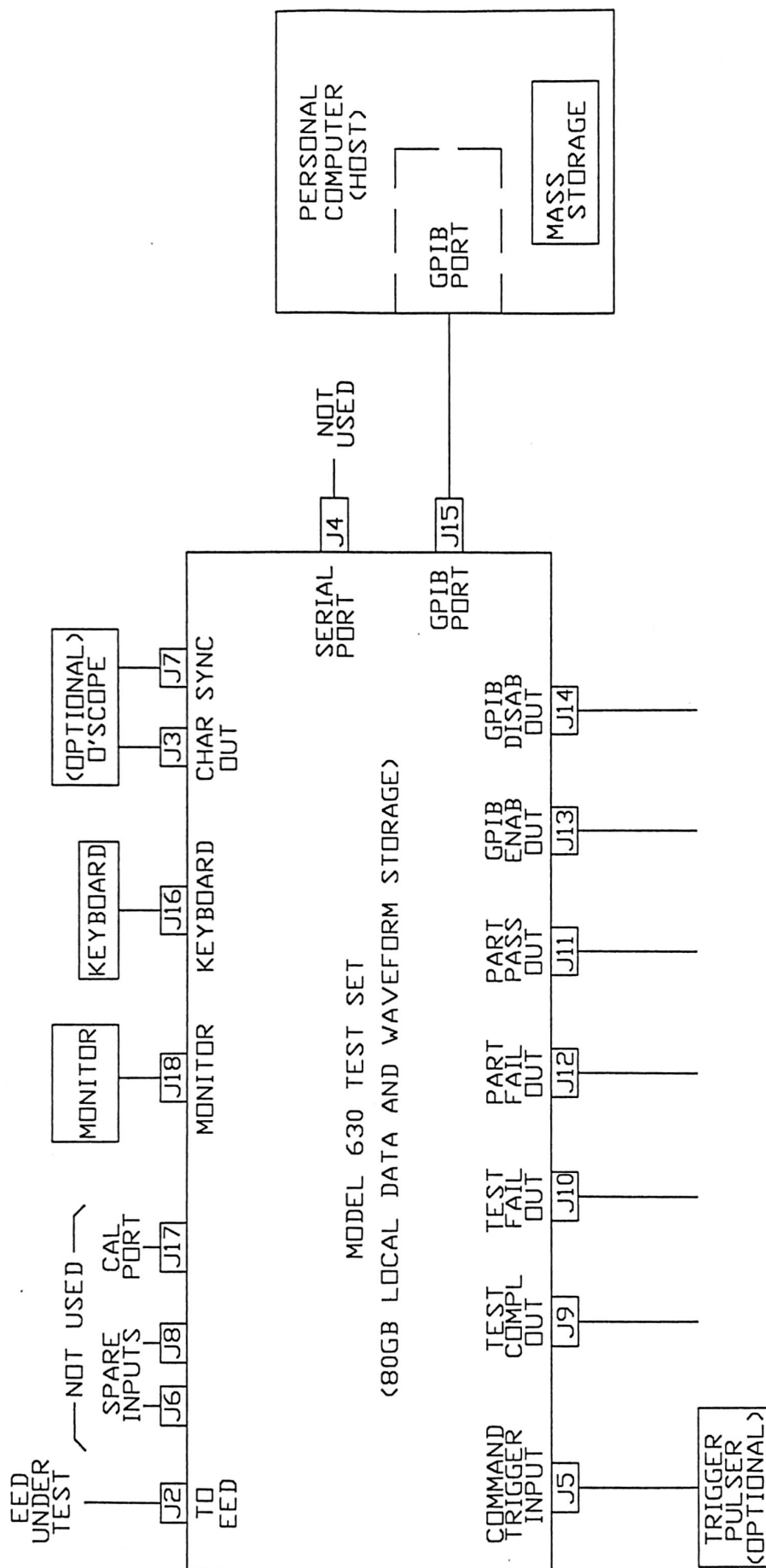


Figure 3-5. Cabling for 630 Host Operation

INSTALLATION INSTRUCTIONS

HOST COMPUTER OPERATION WITH PLC

1. Test set may be installed in an equipment rack or it may be used alone as a piece of bench-top test equipment.
2. Make following connections to test set per Figure 3-7:
VGA Monitor to MONITOR output connector J18,
Keyboard to KEYBOARD connector J16,
GPIB PORT J15 to Personal Computer,
AC power cord to POWER connector J1.
3. Connect AC power cord to appropriate power source.
4. The following connections are optional:
EED CHARACTERISTIC OUTPUT J3 to oscilloscope vertical input,
SYNC OUTPUT J7 to oscilloscope trigger input.
5. The following connections to a PLC are optional:
COMMAND TRIGGER INPUT J5,
PART PASS J11 and PART FAIL J12 outputs,
TEST COMPLETE J9 and TEST FAIL J10 outputs,
GPIB ENABLE J13 and GPIB DISABLE J14.
5. The following connections are not used:
RS-232 SERIAL PORT J4,
CAL PORT J17,
SPARE INPUTS J6 and J8.
6. Install AC power cord and connect to appropriate power source.
7. Set power switch to ON.
8. Monitor will display main work screen.
9. To set up for system control from host computer, see configuration instructions in Data Capture and Analysis section in Volume 2 of this manual.
9. See configuration instructions in Data Capture section in Volume 2 of this manual.
10. Connect device under test to TO EED connector terminals; (refer to Par. 3.3) for 630B/EED Cable details.
11. System is ready for use.

Figure 3-6. Installation Instructions - Operation with PLC

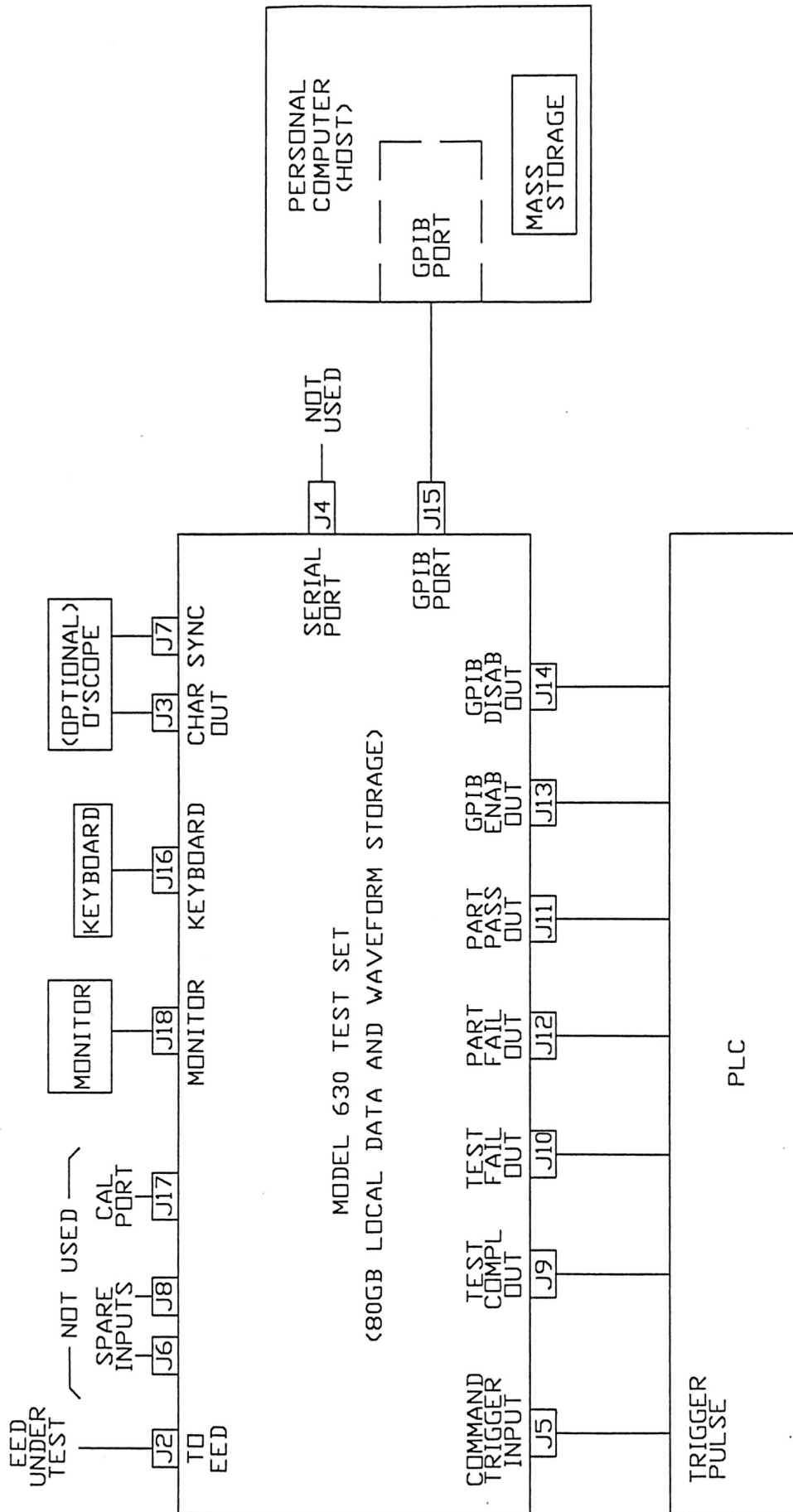


Figure 3-7. Cabling for Operation with PLC

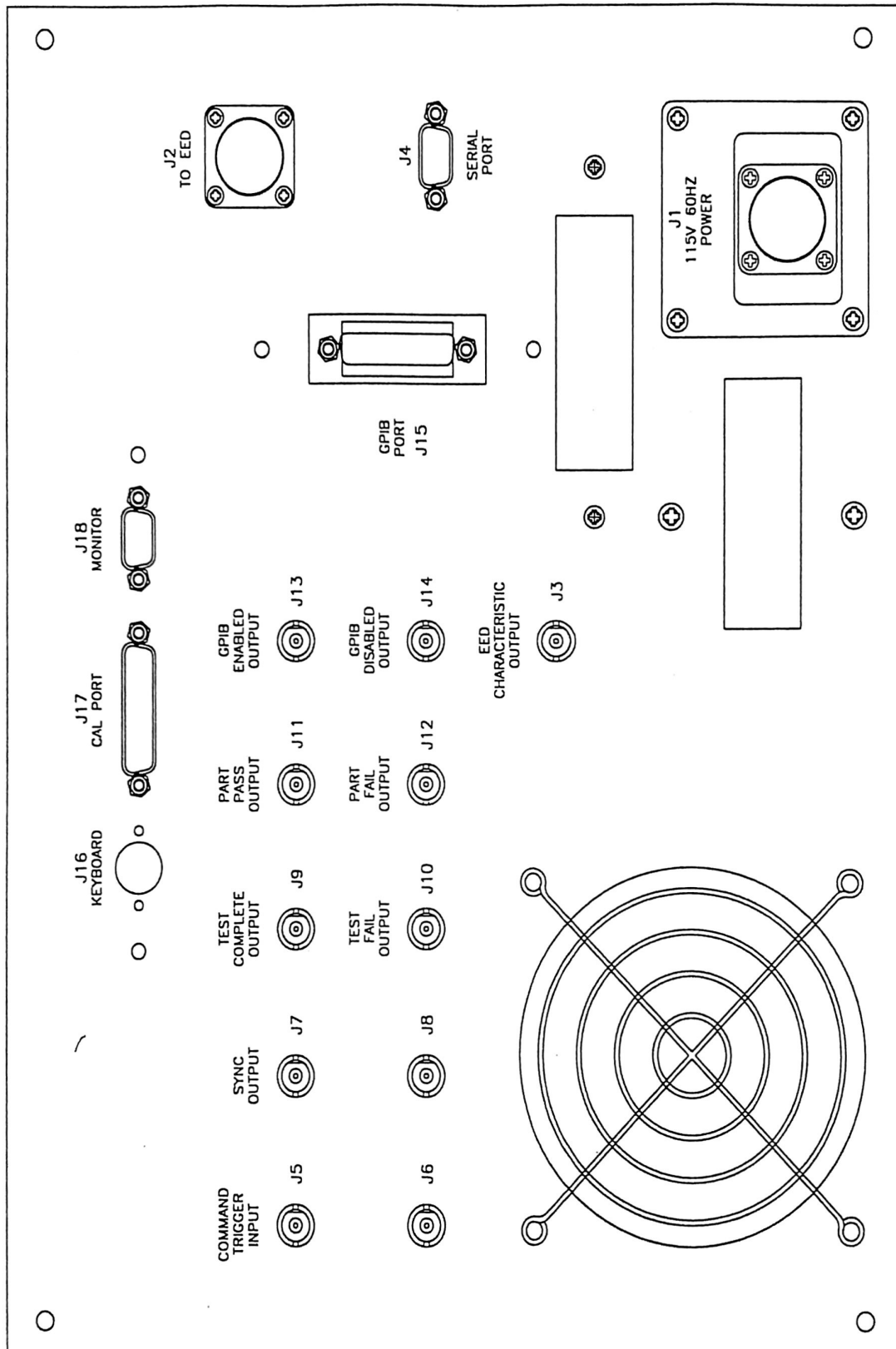


Figure 3-8. Model 630B Back Panel

SECTION IV

OPERATING INSTRUCTIONS

4.1 GENERAL

Instructions contained in this Section assume that the Test Set user is unfamiliar with the instrument and the test procedures. As the user becomes familiar with the operation of the test set and its relationship to the test, it will become apparent that some procedure details, as outlined, may be modified or deleted.

For indoctrination purposes Reference Bridgewire RB101 is used as the device under test in the examples to follow. The RB101 is a thermally responsive resistor network, whose electrothermal behavior is comparable to typical EED's. A full description of the RB101 will be found in Appendix A.

4.2 DESCRIPTION OF SIGNAL INTERFACE

INPUTS -

COMMAND TRIGGER

Positive going TTL level pulse from the user to indicate when a squib is ready for test. Minimum pulse width is 15 milliseconds. After device to be tested is in place and all wires are connected, the COMMAND TRIGGER (a logic "1") is sent to the Model 630B starting the test.

OUTPUTS -

SYNC OUT

Positive going TTL level pulse, one millisecond wide. This pulse is available to be used to start oscilloscope sweep or to open data capture window. This pulse precedes onset of the Characteristic Pulse by 5 milliseconds.

TEST COMPLETE

Positive going TTL level pulse, one millisecond wide. This pulse follows the end of the Characteristic Pulse by 5 milliseconds. Every COMMAND TRIGGER input will be followed by a TEST COMPLETE pulse output regardless of success or failure of test.

TEST FAIL

Positive going TTL level pulse, 150 milliseconds wide. This pulse follows immediately after the TEST COMPLETE pulse whenever the test set is unable to complete a test sequence. Possible causes include:

- Power line glitch
- Some types of squib anomalies
- Test set fails to find a null
- External noise interference

PART PASS OUTPUT

Positive going TTL level pulse, 66 millisecond wide. This pulse is sent when Pass/Fail analysis is enabled and the part just tested has passed all tests.

PART FAIL OUTPUT

Positive going TTL level pulse, 66 millisecond wide. This pulse is sent when Pass/Fail analysis is enabled and the part just tested has failed one or more enabled tests.

GPIB ENABLE

Positive going TTL continuous level. This signal is high when the GPIB communication link is enabled.

GPIB DISABLE

Positive going TTL continuous level. This signal is high when the GPIB communication link is disabled.

CHARACTERISTIC OUTPUT

Analog representation of the heating of the squib bridgewire during the test pulse. Width equals width of test pulse. Maximum amplitude is 12 volts but can be much lower.

NOTE: The presence of a CHARACTERISTIC pulse does not in itself indicate that a squib is good. The absence of a CHARACTERISTIC pulse does not in itself indicate that a squib is bad.

RESET INPUT - Not used

4.3 OPERATING PROCEDURE

The test procedure consists of two parts: (a) setting parameters, and (b) application of the safe-level test current pulses to the device under test and observing its thermal response on a monitor or on ancillary equipment such as an oscilloscope.

4.4 Setting Test Parameters

See configuration instructions in Data Capture section in Volume 2 of this manual.

4.5 Thermal Response

In this sequence the device under test is pulsed with controlled, safe-level current; the electrothermal response of the bridgewire/explosive interface is detected and captured or displayed on an oscilloscope for observation and analysis.

4.6 Operation Under Local Control

1. Ensure that installation is complete as detailed in Figure 3-2.
2. See operating instructions in Section IV of the Data Capture section in Volume 2 of this manual.
3. Press "T" without quotes to send Command Trigger.
4. Characteristic waveform is displayed on monitor.

4.7 Operation Under Control of a Host Computer

1. Ensure that installation is complete as detailed in Figure 3-3.
2. See operating instructions in Section IV of the Data Capture section in Volume 2 of this manual.
3. Press "T" without quotes to send Command Trigger.
4. Characteristic waveform is displayed on monitor.

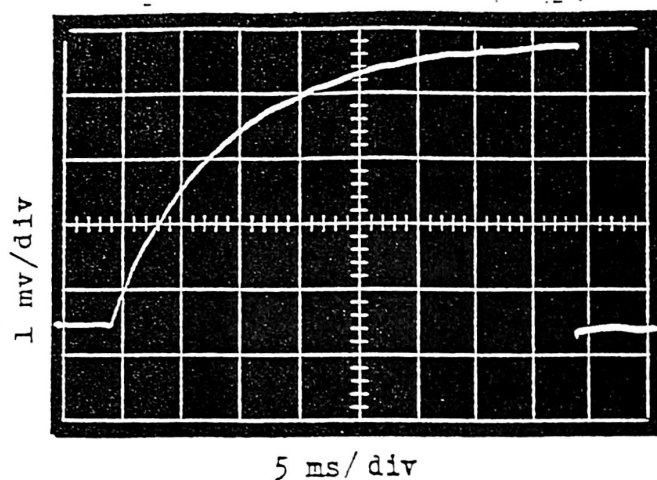
4.8 Correct or Adjust Waveform Offset

- (1) From main work screen, press "C" (without quotes).
- (2) Press "D" and then press "6".
- (3) When the message on the screen asks for an offset value, type the new value and then type "RETURN". (Start with values that represent a change of 100 to 300 in offset value)
- (4) Figure 4-1 shows the effect of offset variations in waveform presentation.

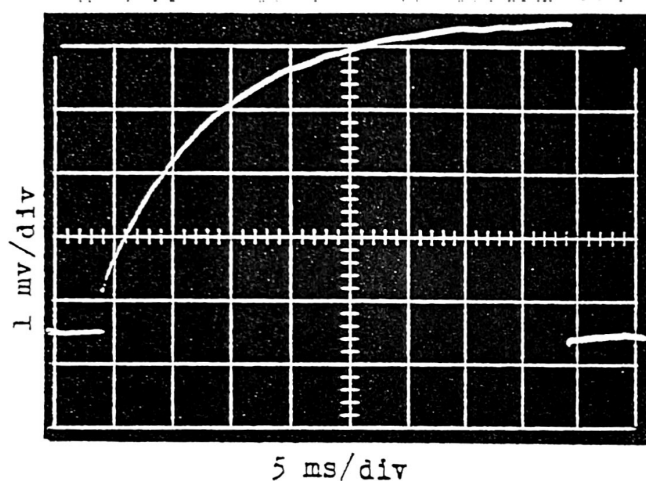
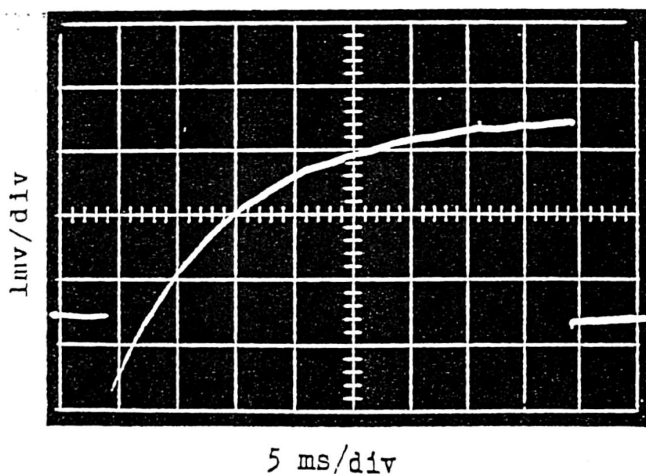
Note: For more details see configuration instructions in Section IV of Data Capture section in Volume 2 of this manual.

- (5) Follow menu instructions to send new test parameters to test set.

Note: The operator is not required to stop testing while changing parameters. The test set will continue to operate as long as it receives COMMAND TRIGGER pulses. When new data is received, the test set will pause, set the new values, and resume testing using the new values. However, the test set does not have to be receiving COMMAND TRIGGER pulses in order to change test parameters.



(A) Balanced bridge

(B) Unbalanced bridge
(Positive unbalance)(C) Unbalanced bridge
(Negative unbalance)

Device Under Test : Reference Bridgewire RB101
 Vertical (Bridge output) : 1 millivolt/division
 Horizontal (Sweep) : 5 milliseconds/division

Figure 4-1. Waveforms Showing Offset Variations
 (Balanced and Unbalanced Conditions)

4.9 Oscilloscope Controls

The following will serve as a general guide for setting the optional user-supplied oscilloscope controls. An oscilloscope can be used at any time but may be most helpful during the initial test setup.

- (a) Trigger: External "+"
- (b) Sweep Rate: 10 milliseconds/centimeter
- (c) Vertical sensitivity: Generally, the 1 volt/centimeter setting is used; however, settings of 0.5V/cm or 2V/cm may produce more readable waveforms.

A single channel analog scope is adequate for general purpose work

4.10 PARAMETER SELECTION

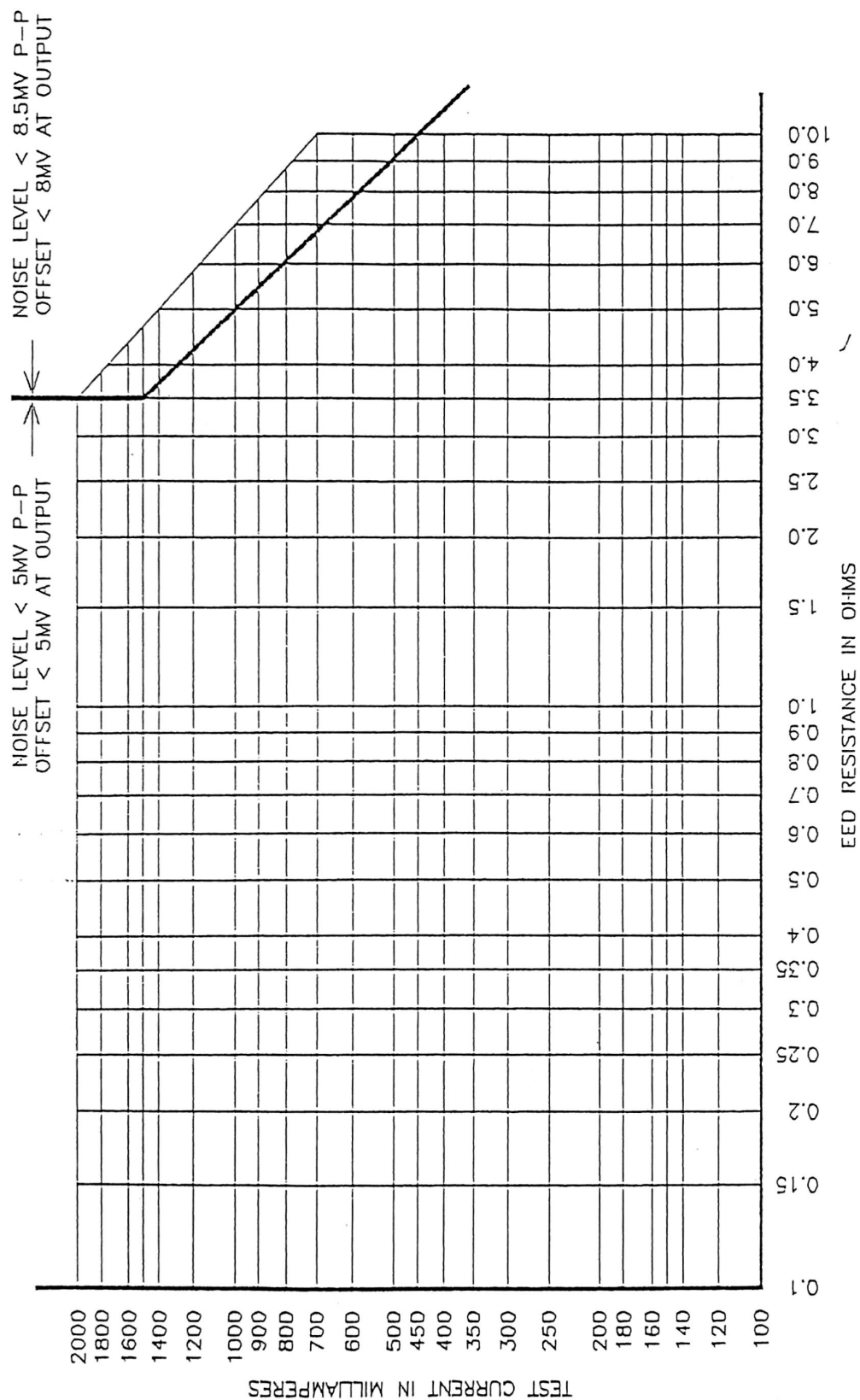
4.11 Test Current/Load Resistance

The 630B is capable of providing 2,000 milliamperes (maximum) constant current test pulses to a load of 0.10 to 3.5 ohms. Loads in the range of 3.5 to 10.0 ohms require reduced maximum test current levels to ensure reliable constant current operation. The constant current operating range is related to the load resistance. The relationship between test current and EED resistance is shown in Figure 4-2. It is essential that operation occur in the area under the curve.

4.12 Selection of Test Current Level

The nondestructive aspects of the thermal transient test, and the safety implied, are related to the magnitude of the test current. Since bridgewire temperature is a function of bridgewire current, limiting the current to a safe level is of utmost importance. Obviously, the bridgewire temperature must be held to a value less than the ignition temperature of the explosive mixture. In practice, it is customary to limit the temperature rise at the bridgewire-explosive interface to a maximum of 100°C above ambient during the thermal transient test. Either of two approaches may be used in holding the temperature to a safe level.

If the DC no-fire current value of a given design has been established (functional destructive testing), one approach is to limit the thermal transient test current to approximately 60% of the DC no-fire current.



MODEL 610A THERMAL TRANSIENT TEST SET OPERATING RANGE

Figure 4-5. Test Current vs EED Resistance

Another approach may be used if the DC no-fire current level has not been established. This method involves calculating bridgewire temperature based on the signal developed across the bridgewire when the bridgewire is pulsed with a known current, and the Temperature Coefficient of Resistivity of the bridgewire material is also known. (See Application Note 3 "Calculation of Electrothermal Parameters"). In this instance the test current level is limited to a value resulting in a temperature rise of 100°C, maximum.

The thermal transient test concept requires that the bridgewire material have a 'reasonable' Temperature Coefficient of Resistivity (TCR), and that the TCR be known in order to generate a useful signal. Bridgewire materials having TCR's greater than about 50 parts per million/°C generally yield satisfactory signals at acceptable bridgewire temperatures. TCR's much less than 50 ppm/°C probably will require dangerously high bridgewire temperatures (above the 100°C figure) in order to generate a meaningful response.

4.13 Selection of Test Pulse Duration

Test current is generally applied to the device-under-test for a period of time sufficient for the bridgewire-explosive interface to reach thermal equilibrium. This usually requires several time constants. (Refer to Application Note 3 for Time Constant calculation). The 630B series Thermal Transient Test Sets are capable of generating current pulses of less than 10 milliseconds to 99 milliseconds. Time constants of aerospace and military devices are typically in the range of 3 to 20 milliseconds, with low energy devices under 3 milliseconds. If the current pulse is too short (terminated before thermal equilibrium is reached) valuable thermal information may be missed since thermally induced abnormalities (bridgewire movement, air gaps, etc.) usually occur late in the thermal response cycle.

4.14 CABLE CONNECTIONS

1. 115V 60HZ POWER Connector - Three-pin connector (J1) for AC power cord.

2. EED Connector - The device under test is connected to the 630B Test Set through the EED cable at the "TO EED" connector (J2) on the back panel. Both cable shields must be electrically insulated from each other and from ground. The EED terminals are normally shorted by relay (K202) on the CCPS board as a safety measure. The short circuit is removed when either the null or test current circuit is activated.

3. EED CHARACTERISTIC OUT Connector - BNC type coaxial connector (J3), on the rear panel connects to an oscilloscope or other capture hardware by means of BNC coaxial cable assembly.

4. RS-232 Connector - D-subminiature connector J4 is not used in the Model 630 series test sets.

5. COMMAND TRIGGER INPUT Connector - BNC type coaxial connector (J5) on the rear panel provides a means for applying the Command Trigger to the test set.

6. SPARE INPUT Connectors - BNC type coaxial connectors (J6) and (J8) are not used.

7. TEST COMPLETE OUTPUT Connector - BNC type coaxial connector (J9) on the rear panel provides access to the Test Complete pulse.

8. SYNC OUTPUT Connector - BNC type coaxial connector (J7) on the rear panel connects the 630B to the trigger input of an oscilloscope or other capture hardware by means of a BNC coaxial cable assembly.

9. TEST FAIL OUTPUT Connector - BNC type coaxial connector (J10) on the rear panel provides access to the Test Fail pulse.

10. PART FAIL OUTPUT Connector - BNC type coaxial connector (J12) on the rear panel provides access to the Part Fail Output signal.

11. PART PASS OUTPUT Connector - BNC type coaxial connector (J11) on the rear panel provides access to the Part Pass Output signal.

12. GPIB ENABLE Connector - BNC type coaxial connector (J13) on the rear panel provides assess to the GPIB enabled signal.

13. GPIB DISABLE Connector - BNC type coaxial connector (J14) on the rear panel provides assess to the GPIB disabled signal.

14. GPIB PORT Connector - D type connector (J15) provides GPIB communication with a host computer.

15. CAL PORT Connector - DB-25 connector (J17) is used for calibration functions. It will support some parallel printers.

16. MONITOR Connector - D-type VGA connector (J18) connects a display monitor to system.

17. KEYBOARD Connector - 5-pin DIN connector (J16) connects a keyboard to system.

4.15 CONTROLS AND INDICATORS

1. AC Power Switch - Switch (S1) on the front panel is a circuit breaker switch and controls the application of AC input power to the test set.

2. Indicator Lamp - Lamp assembly (DS1) on the front panel indicates that power is applied to the test set.

3. Alpha-Numeric Display - Digital display (M1) on the front panel displays operating status information.

4. Fuse - Fuse (F1) in the CCPS circuit provides overload protection of DC constant current power to the EED.

SECTION V

MAINTENANCE

5.1 Replacement of Components - There are no user replaceable parts in the Model 630 test Set.

5.2 Digital Display 4M1 - Normally the digital display shows the resistance value of the EED just measured. It also displays messages describing events in the functional operation of the test set.

5.3 Switching Transients - Under certain operating conditions (relatively high test current and/or high inductance in the EED leads) spikes may be observed at the start and at the end of the heating curve. This is a normal condition caused by a combination of factors, e.g. - reactance of the bridge components (especially if ferrite beads are used as part of the EED assembly) and a long EED cable which has inductance of its own.

Neither spike has any measurable effect on the test data or to the device under test. The transient due to inductance in the EED should be considered part of the characteristic of that EED. These transients are shown in retouched photograph of Figure 5-1.

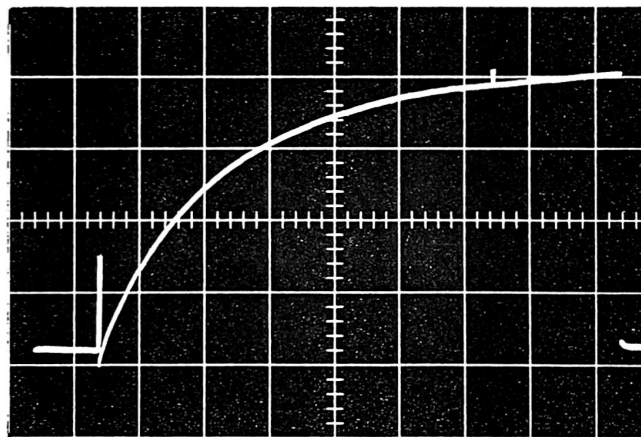


Figure 5-1. Photo of Waveform with Ferrite Bead Spikes.

APPENDIX A

REFERENCE BRIDGEWIRE RB101

Reference Bridgewire RB101 is a thermally responsive resistor for use in checking the operation and performance of Series 610A Thermal Transient Test Sets. It also finds use as a training aid during 610A indoctrination and familiarization. In effect, the RB101 is a simulated bridgewire whose electrothermal response to test signals is similar to that of an operational bridgewire.

Components of the device include a #112 standard incandescent lamp in a two resistor network, shown below. Cold resistance (R°) is in the range of 2.15 to 2.35 ohms. Maximum test current (I_{max}) is approximately 600 milliamperes. The device plugs into the 610A EED cable.

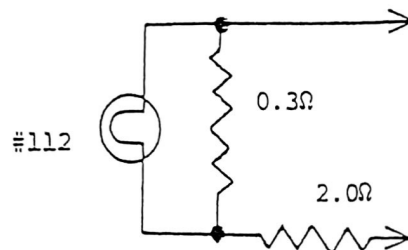
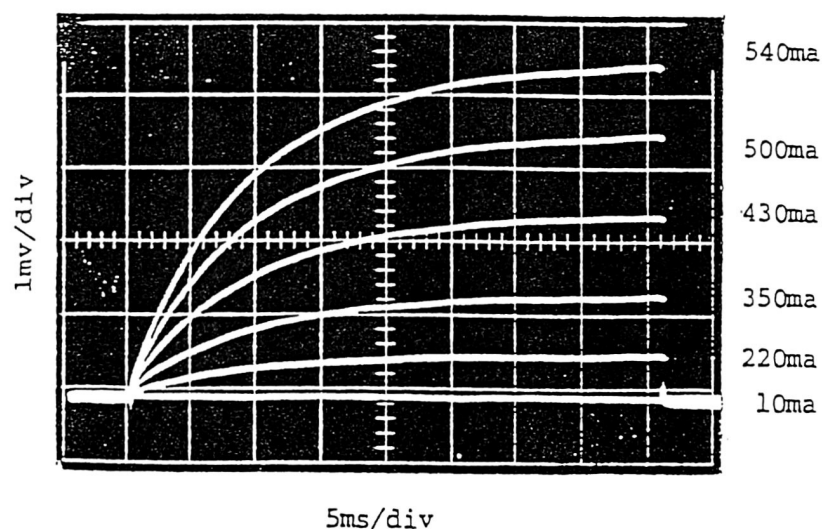


Figure A-1. Reference Bridgewire RB101

Figure A-2 is a multiple exposure photograph of typical Reference Bridgewire RB101 thermal response curves at several test current levels.* Amplitude and slope of the curves of a particular RB101 may vary from the examples because of lamp filament material TCR and manufacturing tolerances.



* Curves of different RB101 units may vary (i.e., slope, amplitude, etc.) because of lamp filament TCR differences.

Figure A-2. RB-101 Thermal Response Curves

!!! WARNING !!!

OBSERVE APPROPRIATE SAFETY PRACTICES
WHILE PERFORMING THESE TESTS

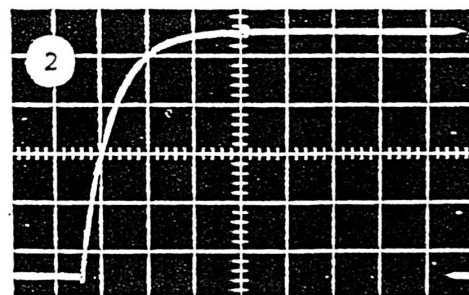
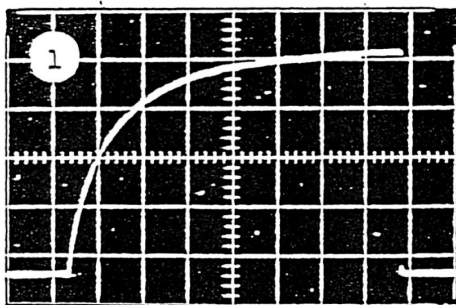
INTERPRETATION OF THERMAL RESPONSE CURVES

Introduction - Thermal response curves generated by the thermal transient test graphically describe the electrothermal character of the bridgewire-explosive interface under examination. The normal heating curve can be seriously degraded by interface faults; such as, defective bridgewire welds, bridgewire movement, incorrect compaction pressure, and other interface irregularities.

With proper interpretation of thermal response curves, the test is capable of providing a great deal of inspection information and acceptance/rejection criteria of the interface. Each fault category generates a distinctive "signature", making curve interpretation and fault determination a reliable and fairly routine procedure.

This Application Note includes representative typical examples of normal and abnormal thermal response curves likely to be encountered[†]. The causes underlying the various abnormalities are discussed.

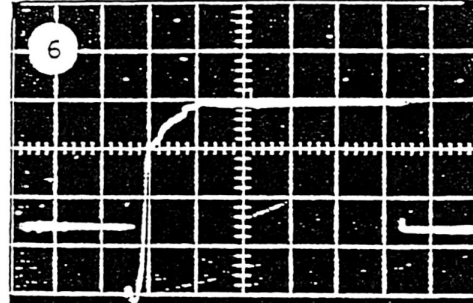
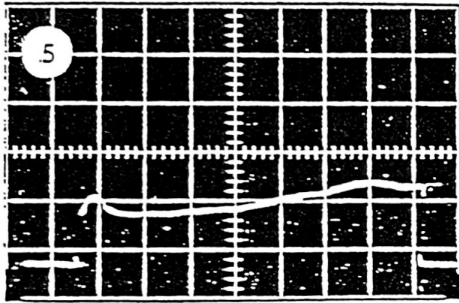
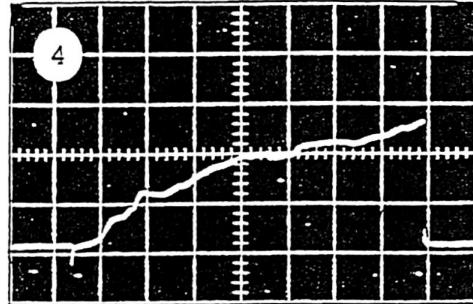
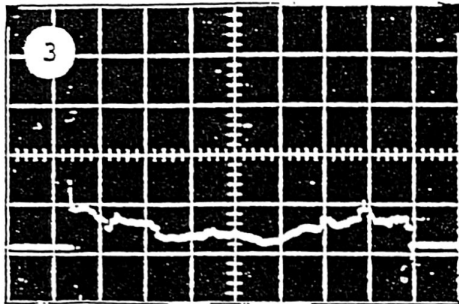
Normal Curves - Each EED, when properly fabricated, will generate a thermal response curve whose specific shape is controlled by the thermal capacity and thermal resistance inherent in the design of the EED. A normal heating curve is always smooth and continuous. In addition, normality of the heating curve will depend on its relation to other curves generated by EEDs of the same design in the test population.



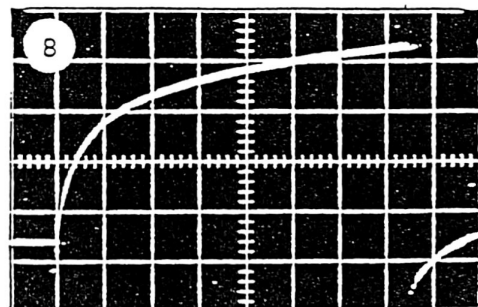
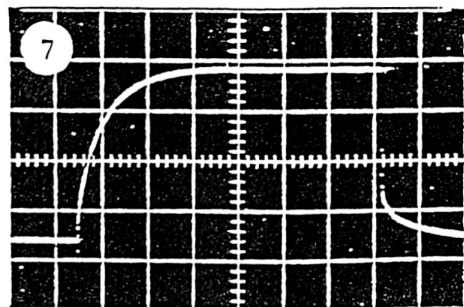
Figures 1 and 2, above, illustrate curves generated by EEDs of two different designs. Each curve is smooth and continuous. In addition, each is assumed to be within acceptable limits relative to other curves in their respective test populations. In summary, both curves appear normal in every respect.

[†] Example curves made with Model 605A Thermal Transient Test Set

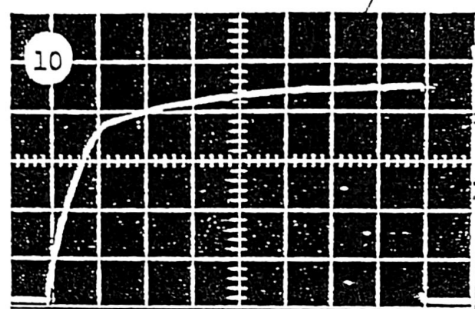
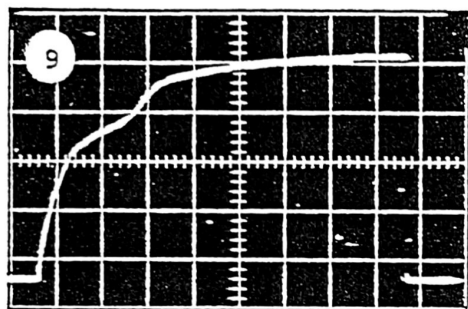
Bridgewire Welds - Defective mechanical fusing of bridgewire and posts, coupled with oxides and semiconductor products at the weld joint, combine to form a defective weld. The unstable mechanical and electrical character of defective welds generate a wide variety of erratic responses. Typical responses are shown in Figures 3 - 6, below. Abnormal welds generally manifest themselves early in the heating cycle (at the onset of the test current pulse).



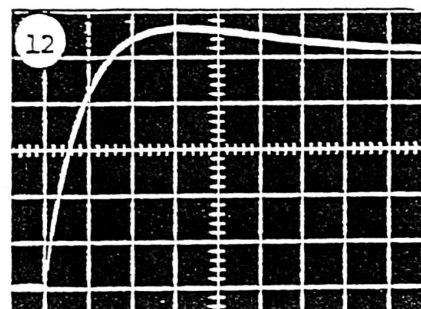
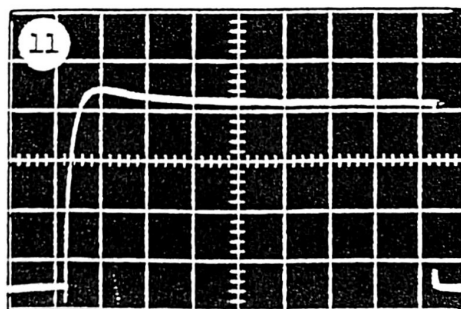
A bridgewire welded to each of two terminals creates a thermocouple junction at each weld. Bridgewire temperature changes generate thermal EMF signals across each weld. If the welds are equal, the two opposing EMF's cancel, with no discernable effect on the heating curve. However, if the welds are different, unequal EMF's generate a residual signal at the termination of the heating cycle as the bridgewire cools to ambient temperature. The decaying residual may be either positive (Figure 7) or, negative (Figure 8). A residual signal may be an abnormality to the extent that it is a possible indicator of a latent weld defect.



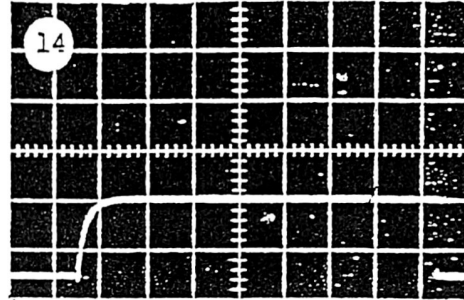
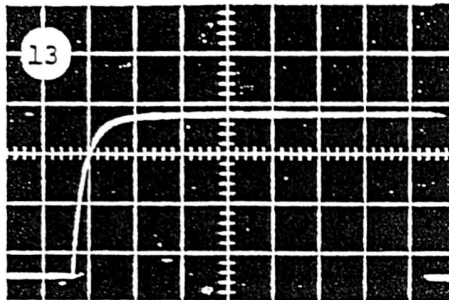
Bridgewire Movement - An air gap between the bridgewire and explosive material may permit bridgewire movement as the bridgewire expands and buckles, when heated. As the bridgewire moves, contact is made with the explosive material causing a change of rate of bridgewire temperature increase, creating a knee in the heating curve. Another potential cause of bridgewire movement is insufficient loading pressure. Bridgewire movement is minimized as the loading pressure is increased. Either air gaps, or insufficient compaction pressure may lead to bridgewire burnout before ignition is reached. Curves reflecting bridgewire movement are shown in Figures 9 & 10. Abnormalities related to bridgewire movement are thermally-induced, and occur well into the heating cycle; as indicated in the examples.



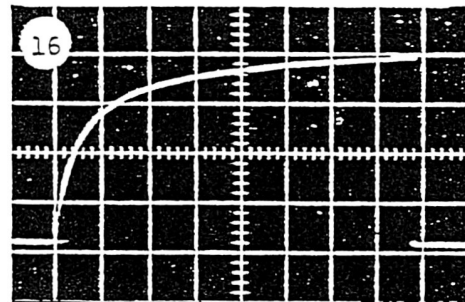
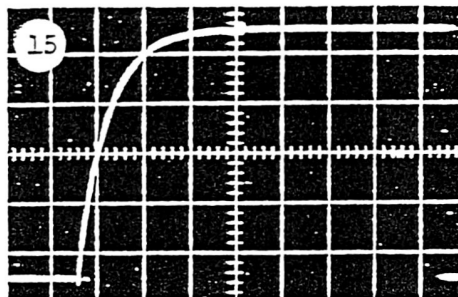
Phase Change - Acetone, MEK, and similar binder solvents, entrapped in explosive mixes can sink appreciable bridgewire heat as they undergo phase change (from liquid to gaseous state) at around 125°C, or so. The cooling effect of residual solvent is indicated in Figure 11, and Figure 12. Cooling starts immediately following the peak of the curves; as the curves begin to fall off. The implications of entrapped solvents are not generally appreciated; however, the condition may seriously affect control of EED sensitivity. It should be noted that the transient test is capable of detecting residual solvents in fully assembled units, as well as partially completed units.



Loading Abnormality - The response of a bridged header without explosive is shown in Figure 13. A device of the same design, with explosive and tested at the same current level, is shown in Figure 14. Neither response is abnormal, as such. The intent is to illustrate the difference due to the absence of explosive. Absence of explosive must be defined as an abnormality in a population of assembled units.



Thermal Stabilization - Temperature rise of the interface tends to stabilize near the end of the primary response. A component with explosive pressed in intimate contact with the bridgewire will display little temperature rise, as in Figure 15. An assembly with lesser compaction will exhibit greater rise, shown in Figure 16. Whether a given rise is abnormal or not depends on its relation to other units of the same design in the test population.



Conclusions - The curves described in the preceding pages are typical, basic, and represent those most likely to cause functional problems. Not all possible faults have been covered. One should be alert to the possibility of multiple faults in a single test item. Items exhibiting abnormal responses should be viewed with suspicion and culled out. A knowledge of fault mechanisms and curve interpretation should lead to improved product reliability, and reduced development and production costs.

=0=

Application Note 3

March 1979

Rev: 9-79

CALCULATION OF ELECTROTHERMAL PARAMETERS

The thermal transient test provides quantitative data for calculation of interface thermal parameters, i.e., thermal conductance, thermal time constant, thermal capacitance, and bridge-wire temperature rise. Data for the mathematical calculations are obtained from the test apparatus (605A Thermal Transient Test Set and associated oscilloscope). Bridgewire material temperature coefficient of resistivity (TCR), α , is obtained from handbook tables, manufacturer's data, or by experimental methods

The thermal parameters are calculated from the expressions below, where:

- ΔV_m = maximum voltage change at bridgewire terminals
- θ = temperature rise of bridgewire
- I = test current
- R_o = cold resistance (ohms) of bridgewire
- α = temperature coefficient of resistivity of bridgewire
- γ = thermal conductance
- S = initial slope of heating curve (at $t = 0$).
- C_p = thermal capacitance
- τ = thermal time constant
- $t_{1/2}$ = time at $1/2 \Delta V_m$ value

Temperature rise θ , above ambient, at the interface is expressed in $^{\circ}\text{C}$, and is determined by the definition

$$\theta = \frac{\Delta V_m}{IR_o \alpha} \quad (1)$$

Thermal conductance γ at the interface is expressed in watts/ $^{\circ}\text{C}$, and is determined by the definition

$$\gamma = \frac{\alpha R_o I^2}{\Delta V_m} \quad (2)$$

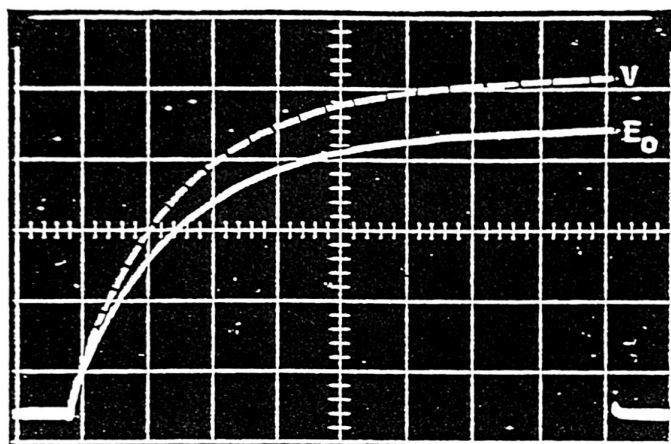
Thermal capacitance C_p is expressed in watt-seconds/ $^{\circ}\text{C}$ is determined by

$$C_p = \frac{\alpha R_o I^2}{S} \quad \text{or} \quad C_p = \gamma \tau \quad (3)$$

Thermal time constant τ is expressed in seconds and is determined by the definition

$$\tau = \frac{t_{1/2}}{0.69} \quad (4)$$

Voltage Correction - Measurement of voltage present at the bridge output terminals during application of test current pulses is basic to the resolution of bridgewire temperature (θ) and thermal conductance (γ). The voltage is measured by observing the amplitude of the thermal response curve on the calibrated oscilloscope CRT. The observed voltage will differ from the true voltage because of bridge signal-loss and nonlinearity. This difference is shown in the photograph below. The observed (uncorrected) curve is identified by the solid line " E_o " trace. The true (corrected) voltage curve is indicated by the dashed trace " V ".



The magnitude of the correction is related to the ratio of the load resistance (R_L) and the bridge fixed-arm resistance (R_b). It should be noted that R_b is a 10 ohm resistor used in all Model 605 Test Sets. Load resistance R_L is determined by the Test Set resistance measurement. R_L values will be in the 0.10 to 10.50 ohm range. Corrected voltage " V " is determined by:

$$V = E_o + \left(E_o \cdot \frac{R_L}{R_b} \right)$$

Example: E_o is observed as 4 millivolts; load resistance R_L has been determined to be 2 ohms; R_b is a constant 10 ohms. Solving for corrected voltage V :

$$V = 4 + \left(4 \cdot \frac{2}{10} \right) = 4 + (0.8) = 4.8 \text{ millivolts}$$

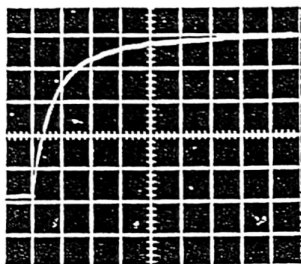
=0=

Application Note 2
March 1979

THERMAL TRANSIENT TEST THEORY

The Thermal Transient Test is a nondestructive means for characterizing the bridgewire-explosive interface of an electro-explosive device (EED). The test is based on the application of a current waveform to the device under test (DUT), and the examination of the signal developed across the bridgewire terminals. The response to the current pulse is a rise in bridgewire temperature and an increase in bridgewire ohmic resistance (ΔR). If the bridgewire cold resistance (R_0) and the bridgewire material temperature coefficient of resistivity (TCR), α , are known, the signal can be related to the bridgewire temperature rise such as in resistance thermometry.

The adjacent figure illustrates a typical electrothermal response of an EED under test as may be displayed on an oscilloscope in conjunction with a Pasadena Scientific Industries' Model 605A Thermal Transient Test Set. The horizontal axis is a time base from left to right. Vertical deflection represents the voltage developed across the bridgewire terminals. The specific shape of the analog is controlled by the bridgewire-explosive interface parameters, which are, thermal capacitance and thermal resistance. The initial slope of the curve is determined by thermal capacitance. The final amplitude by thermal resistance. The simple exponential curve can be seriously degraded by abnormalities at the interface[†].



Test theory assumes that the interface electrothermal response, generated by the current waveform, is an exponential. On this basis, Rosenthal¹ derived equations to calculate the electrothermal parameters. Actually, testing of loaded units shows the analog to deviate from a true exponential. However, Rosenthal's equations are used since the primary object of the test is to compare units rather than obtain absolute values.

Treating the bridgewire-explosive interface as a lumped thermal system, we find the differential equation describing the temperature rise (θ) to be:

$$C_p \frac{d\theta}{dt} + \gamma\theta = P(t) \quad (1)$$

[†] See AN-4, "Interpretation of Thermal Response Curves"

Equivalent heat capacity (C_p) is given in W-s/°C (or J/°C). Simple heat loss is represented by the linear thermal conductance term in W/°C. The reciprocal of thermal conductance is thermal resistance, which describes the temperature rise in °C/W dissipation. Power input $P(t)$ as a function of time controls the thermal behavior of the system, and if we select a simple $P(t)$ waveform, a recognizable and interpretable response results. The constant current (I) drive resulting in a power

$$P(t) = I^2 R_o (1 + \alpha \theta) \quad (2)$$

provides a proper, convenient, and easily generated waveform. As the temperature rises, the $\alpha \theta I^2 R_o$ component corresponds to thermal feedback; regenerative for a positive α .

The solution for (1) is

$$\theta(t) = \frac{I^2 R_o \left[1 - \exp \left(- \frac{\gamma' t}{C_p} \right) \right]}{\gamma'} \quad (3)$$

The modified heat loss factor due to feedback is

$$\gamma' = \gamma - I^2 R_o \alpha \quad (4)$$

An apparent time constant is defined as

$$\tau' = \frac{C_p}{\gamma'} \quad (5)$$

This time constant is responsive to the current or power wave form, whereas

$$\tau = \frac{C_p}{\gamma} \quad (5a)$$

is intrinsic to the device alone.

The signal, available as a voltage drop $V(t)$ across the bridgewire, is obtained from $V(t) = IR(t)$, where

$R(t) = R_o [1 + \alpha \theta(t)]$. This results in

$$V(t) = IR_o \left\{ 1 + \frac{\alpha I^2 R_o}{\gamma'} \left[1 - \exp \left(- \frac{\gamma' t}{C_p} \right) \right] \right\} \quad (6)$$

It is apparent that the voltage appearing across the bridgewire is a step replica of the current waveform with an exponential rise superimposed as shown in the Figure below. The slope of the exponential portion of the heating curve at $t = 0$ is

$$\frac{dV(t)}{dt} = \frac{\alpha I^3 R_0^2}{C_p} \quad (7)$$

and can be used to establish C_p/α , a device parameter. Note that the useful signal amplitude is $\alpha I^3 R_0^2/\gamma$ and that it varies with the cube of the current.

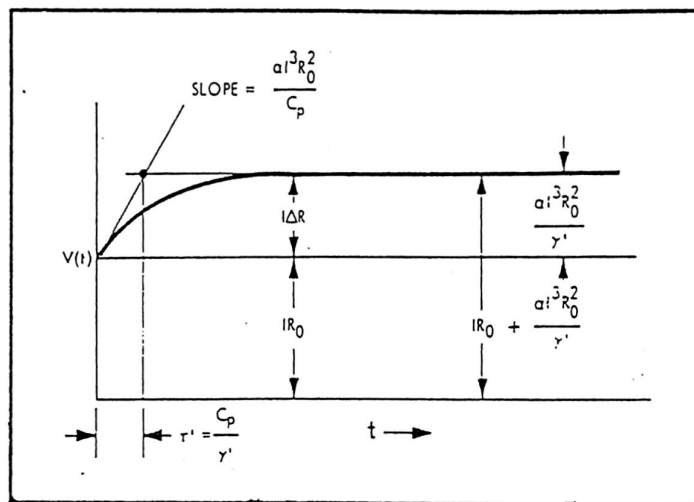


Fig. AN2-1 - Voltage drop across bridgewire

=0=

- [1] L. A. Rosenthal, "Electrothermal Equations for Electro-explosive Devices", NAVORD Report 6684, U.S. Navy Ordnance Laboratory, Silver Spring, MD, 15 August 1959.