CONSOLIDATED Electronics, Inc.

MONITORING THE FUTURE

Power Semiconductor Analyzer

PST 5000

USER'S GUIDE

Revision I
February 1999

WELCOME

Dear Customer:

We at CONSOLIDATED ELECTRONICS, INC. welcome you to the growing number of people who recognize the cost and time saving advantages of using "state-of-the-art" test equipment to evaluate today's sophisticated electronics components.

Keeping industry operating efficiently in today's intensely competitive world depends to a very large extent on information obtained from reliable, easy to use, test equipment.

CONSOLIDATED ELECTRONICS, INC. is dedicated to providing test equipment which minimizes expensive and time-consuming human errors. Please take a few minutes to familiarize yourself with the information contained in this manual. If you have questions or need help, please feel free to call us at **1-800-845-2908**; we'll be delighted to assist you.

Thank you for your dedication to excellence.

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SPECIFICATIONS

Electrical specifications apply for an operating temperature range of 15°F to 120°F (-10°C to 50°C), relative humidity up to 80%, and a 1 year calibration cycle.

Power Supply		
Internal NiCad Rechargeable Battery Pack		12/24Vdc
PST 5000 Operating Time (Fully Charged Batteries)		4 - 8 Hrs.
Primary Test Voltages (open circuit)		
Low Power ("LOW") & Intermediate Power ("MID") Tests		+/- 10v Max.
High Power Tests ("HIGH")		+/- 24v Max.
Primary Test Currents (short circuit)		
Low Power ("LOW") Tests		+/- 0.05A Max.
Intermediate Power ("MID") Tests		+/- 1.0A Max.
High Power ("HIGH") Tests		+/- 2.0A Max.
High Voltage Tests		
Maximum Voltage		5,000 VDC
Maximum Current		2.3 mA
Voltmeter - Peak Voltage Measurement		
Input Impedance		20 Meg
Maximum Input Voltage (peak)		1,000 V
Response Time To Rated Accuracy		2 Sec.
DC Accuracy	0 - 30v Range	Reading +/- 1 Digit
(See Note Below)	30 - 1000v Range	+/- 2% + 1 Digit
AC Peak Accuracy (50-120Hz)	0 - 30VAC Range	Reading +/- 1 Digit
	30 - 1000VAC Range	+/- 2% + 2 Digits

Note:
Caution should be exercised when interpreting low voltage readings. The PST will display the peak of any ripple voltage riding on top of a DC voltage. Therefore, caution should be exercised when reading low DC voltages with high ripple factors or noise.

Case Dimensions (H x W x L)	3.7" x 8.7" x 9" (94mm x 221mm x 228mm)
Weight	4.1 Lbs. (1.9 kg)

1. INTRODUCTION

1.1. UNPACKING YOUR INSTRUMENT

1.1.1. Checking Equipment

The shipping container should contain the equipment listed below. Please check to insure that all items are present and that they have not been damaged in shipment.

1 PST Semiconductor Tester
1 Battery Charger
3 Test leads with banana plugs on both ends
3 Insulated alligator clips with banana jack connector

If anything is missing, please call **CONSOLIDATED ELECTRONICS, INC.** immediately at **1-800-845-2908.** Please have your invoice and serial number available when making a call.

1.1.2. Checking Line Voltage

Before connecting the battery charger, check the line voltage to insure it agrees with the specifications given on the charger.

NOTE: BEFORE USING YOUR PST FOR THE FIRST TIME, READ SECTION 1.2.3.3

1.2. GETTING ACQUAINTED

This section discusses the features and types of tests that can be conducted with the PST. Actual operating procedures will be given in Chapter 2, along with some "do's and don'ts" which should improve accuracy and help avoid errors. The digital voltmeter included in the PST has features not usually found in standard digital multimeters. However, this instrument is not intended as a replacement for standard DMMs. Its primary function is for testing semiconductors and includes capabilities not normally found in dedicated testers such as diode testers, transistor testers, thyristor testers, etc. It is not designed to test passive components such as capacitors or inductors, and error messages will be generated if an attempt is made to use the "Primary Test" function to test such components. However, pass/fail tests **can** be conducted using the "High Voltage Test" function as described in Section 3-12.

1.2.1. Liquid Crystal Display (LCD)

The microprocessor controlled LCD has a wide viewing angle and is capable of displaying two rows of 16 alpha-numerical characters. Backlighting is used to provide excellent contrast regardless of ambient lighting conditions. Each row of letters is 0.180 inch high and can be read from a distance of approximately five feet. Examples of messages displayed during component tests are given in Section 4.

1.2.2. Pushbutton Switches

1.2.2.1. On/Off

When this button is depressed it latches in the "On" position and connects the internal 12v/24v battery pack to the analyzer circuit. This button should be in the "On" position approximately 30 seconds **before** the PST is connected to an external circuit or component. Pushing this button a second time turns the unit off.

NOTE: A self-test is conducted during the first 30 seconds after start-up. An external circuit connected to the unit during this period may cause the PST to interrupt its test cycle and give a "self-test error" message. Do not attempt to power up the PST while connected to a component.

1.2.2.2. Primary Test

This is a momentary switch which must be held in the depressed position while component evaluation determine the type of component, whether it is good or bad, and the gate/base location, if applicable. In devices with a gate or base, the gate/base will be turned on and off several times during the test sequence. **Up to** 24 VDC will be applied to the component, ramping to this maximum through three intermediate stages of "Low," "Middle", and "High". The maximum voltage will only be applied if the component cannot be identified at an intermediate stage.

The time required to complete the test cycle is approximately 15 seconds. Releasing the button prematurely may cause erroneous messages to be displayed. If the button is accidentally released, pushing it again will initiate another test cycle.

Note: The PST <u>cannot</u> identify the gate of a Triac with 100% accuracy.

1.2.2.3. Voltmeter

After completion of the unit self-test at start-up, the voltmeter function is automatically selected by the PST and this selection is retained until changed by pushing another button. The red and black test leads must be plugged into the "Peak Voltmeter" banana jacks when using the PST as a voltmeter. If the red test lead is connected to a positive source of DC voltage, the magnitude will be displayed on the "Peak +" line of the LCD. Reversing the test leads causes the magnitude to be displayed on the "Peak -" line. This facilitates polarity checking when polarities are unknown. If the test leads are connected to a periodic waveform, the magnitude of the positive and negative peaks will be displayed.

However, if the periodic waveform is baised in either the positive or negative direction by a DC voltage, the "Peak +" and "Peak -" values will not be equal. If the magnitude of the bias is greater than the "peak" value of the waveform, one of the peaks may not register on the LCD. Additional details about this characteristic of the PST are given in Chapter 2.

1.2.2.4. High Voltage Test

This is a momentary switch which must be maintained in the depressed position throughout the voltage and current rise as displayed on the LCD. Releasing the button while the test is in progress terminates the test and the displayed values of voltage and current are those that were present at the instant the test sequence was interrupted. However, the PST **output** voltage and current have dropped to **ZERO**. To reset the display to "0" after a sequence has been interrupted, momentarily depress the button. Press the button again to repeat the test.

The output voltage from these jacks starts at "0" and increases to the breakover voltage of the semiconductor being tested or until the button is released. Determine the breakover voltage by observing the current rise. It will ramp slowly until breakover is observed by the PST, at which point the current will rise dramatically and continue to rise to the unit's current limit. Voltage will stop at observed breakover, preventing further stress on the component.

The maximum voltage available is 5000VDC. The time required to cycle through the test sequence will depend on the magnitude of the breakover voltage. The information provided by this test is useful for evaluating a component's characteristics to determine if they have deteriorated from original specifications.

The appropriate test leads must be connected to the corresponding "High Voltage" banana jacks, and the gate/base lead disconnected, before conducting these tests.

1.2.3. Batteries

1.2.3.1. Type

Two 12v Nickel-Cadmium battery packs are installed in the PST. Each pack is composed of 10 "AA" batteries connected in series. The two packs are operated in parallel/series combinations to supply 12v and 24v to the Analyzer circuits.

1.2.3.2. Low Battery Indication

When the batteries need recharging, a capital "B" appears in the lower left corner of the display. Connecting the power supply will cause the "B" to disappear.

1.2.3.3. Charging

THE BATTERIES SHOULD BE CHARGED FOR APPROXIMATELY 12 HOURS BEFORE THE UNIT IS USED THE FIRST TIME. This is accomplished by plugging the charger into a standard 110-120v, 60Hz outlet and connecting the DC power plug to the jack in the back of the PST**. DO NOT LEAVE THE BATTERY CHARGER CONNECTED TO THE PST CONTINUOUSLY WHILE NOT IN USE.**

NiCad batteries have a *"memory effect"* and leaving them connected to the charger continuously will cause a reduction in the "use time" between charging cycles.

The time required to charge the batteries from a completely discharged condition is 8 to 10 hours maximum with the unit turned off. With the unit turned on, the charger may be left connected indefinitely. However, this results in a "trickle-charge" only, and the batteries may not be fully charged even after several hours. Turn the unit off to charge.

Normal operating time between battery charges is approximately 8 hours. After several charging cycles there may be a noticeable reduction in normal "use time" between charges. When this occurs, leave the PST turned on until the "low battery" indication appears on the display, then charge the unit for at least 12 hours. Repeating this procedure two or three times in succession should remedy the "memory effect".

2. OPERATING INSTRUCTIONS

2.1. OPERATING FUNCTIONS

2.1.1. Test Lead Connections

The type of test to be conducted determines how the test leads will be connected to the PST. To conduct the "Primary Test", connect the leads to the "A, B, C" jacks. To conduct the "High Voltage Test", or use the PST as a "Voltmeter", connect two leads to the "High Voltage" or "Peak Voltmeter" jacks. The "A, B, C" jacks are electrically isolated from the "High Voltage" jacks, therefore you can not remove one lead from the "A, B, C" set and insert it in a "High Voltage" jack without inserting a lead in the remaining "High Voltage" jack. From a strictly "functional" viewpoint, test lead polarity is unimportant except in the "High Voltage Mode". However, developing consistent habits in connecting test leads can help minimize errors. For this reason, it's recommended that standard practice be observed when connecting color coded test leads to the "High Voltage Jacks".

2.1.2. Turning the Unit On

Depressing the On/off switch turns the PST on and initiates a self evaluation test that takes approximately 30 seconds to complete. The PST automatically selects the voltage mode of operation during the self evaluation sequence and the voltmeter appears on the display when the sequence is completed.

NOTE: Do not turn the unit on while connected to a component. This may interfere with the self-test and cause an error message to display.

2.1.3. Primary Test

This test is used to determine if a semiconductor component is defective, to identify the type of component, and specify the component's terminal configuration. The gate or base is turned on and tested if applicable. Test leads may be connected to the device in any sequence without regard to polarity. The PST interrogates the semiconductor, and displays information on the LCD. When testing high power devices, the button should be continuously depressed until the test results are displayed on the LCD. This may take up to 12 seconds, depending on the type of component being tested. The information presented on the LCD display depends on the type of semiconductor being tested and several examples are given in Section 4 along with connection information and definitions of terminology. Test procedures for several types of semiconductors are described in Section 3.

2.1.4. Voltmeter

Connect the red and black test leads to the "Peak Voltmeter" + and - jacks. Connect the red alligator clip to the "high" side of the circuit and the black clip to the "low" side. The PST is an auto-ranging device and will display the peak value of a DC voltage or the positive and negative peaks of a periodic waveform. Caution must be exercised when measuring the peak to peak values of periodic waveforms. If a DC bias shifts the waveform above or below neutral, the values shown on the PST may lead to the erroneous conclusion that the waveform is unsymmetrical because the absolute value indicated for the positive peak may be considerably more (or less) than the absolute value of the negative peak. For example: if the DC bias is large enough to swamp the negative swing of the waveform, it may appear that only a DC voltage is present when actually the value shown on the PST is a DC voltage plus the positive peak of the periodic waveform.

2.1.5. High Voltage Test

This test is normally conducted after the "Primary Test' has determined that the component is "good" and has identified the type of component and lead configuration. It is used to determine the breakover point of semiconductors and can be used for other purposes, as described in other sections of this manual. If the component to be evaluated is installed in a circuit, it may be necessary to disconnect one or more of the leads to eliminate the effects of parallel circuits that may be present. After the test leads have been connected to the semiconductor device and the gate/base lead is disconnected, depress and hold the button. There will be a time delay of approximately 10 seconds from the time the button is pressed until the display begins to indicate changes in the applied voltage. When a reverse voltage is applied to a good semiconductor, breakover is indicated by a sudden change in the current displayed on the LCD. However, when low voltage diodes and some SCR gates are *forward biased,* a change in current is indicated *before* a voltage appears on the LCD. Therefore, knowledge of polarities is important in such circumstances. When the leads are not connected to a component or circuit, holding one lead in the hand may result in voltages ranging from 2 to approximately 5 volts indicated by the LCD. However, when the PST is connected to a component or circuit, holding a lead in the hand makes no difference in the reading and therefore accuracy is not affected.

2.2. TESTING COMPONENTS IN-CIRCUIT

Most components can be tested without being removed from the circuit, providing the following general guidelines are followed:

1. Disconnect components that are connected in parallel with the component to be tested, i.e. RC-network, reverse diodes, etc. Normally it is quite easy to identify any parallel connected components by checking the wiring diagram of the circuit.

2. Disconnect the gate/base if applicable. This should be done to project the gate/base drive circuit **in case the component under test has a faulty PN-junction.**

3. Connect the PST and do the "Primary Test", followed by the "High Voltage Test" if the "Primary Test" indicates a good component.

A typical example where the "in-circuit" test will drastically reduce service time is a heat sink with hockey puck SCRs mounted under pressure. Remember to test the MOVs and RC-network with the "High Voltage Test" as well.

DO NOT HESITATE TO CALL US AT 1-800-845-2908 IF YOU HAVE ANY APPLICATION QUESTIONS.

3. COMPONENT TEST PROCEDURES

3.1. TESTING SEMICONDUCTORS

The primary purpose of the PST is to determine if semiconductors have failed or are beginning to fail. The capability to determine that a component is beginning to fail **before** it fails is unique in a compact, portable, battery operated piece of test equipment. Curve tracers or other sophisticated lab equipment would be required to provide the information available from the PST. The messages programmed into the PST relate to parameters for semiconductors such as SCRs, TRIACs, general purpose and zener diodes, and bipolar and MOSFET transistors. Using this preprogrammed information the PST interrogates these devices, determines if they are good or bad, and displays information about the type of device and terminal identification. This is very useful when component identification information is not available. Other semiconductors such as JFET transistors, PUT transistors, etc., can be evaluated if the type of device and terminal identification are known. However, the test procedure is different for these devices since there is no pre-programmed information for them in the PST.

Two separate tests are required for a complete evaluation of a **good** semiconductor. The “Primary Test” button is used in the first step to determine if the component is good or band and to display the terminal configuration. The “High voltage Test” button is used in the second step to determine if degradation of the component has occurred and, if so, the extent of the degradation. If the “Primary Test” determines that the component is bad, there is no need to proceed to the “High Voltage Test”. However, if the “Primary Test” determines that the component is good, the “High voltage Test” should be conducted to determine “how good”.

3.1.1. SCR

3.1.1.1. Primary Test

Plug the test leads into jacks “A”, “B” & “C” and connect them to the SCR’s anode, cathode, and gate connections. The sequence of connections is not important; the PST interrogates the SCR and detects the position of the lead connections. The gate is turned on during the test to verify its operation. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good SCR is shown in the diagrams. If the button is pressed briefly and released, only the low power test will be conducted and defects that would be detected at higher powers may be missed.

3.1.1.2. High Voltage Test

Remove the red and black test leads from the “A”, “B” & “C” jacks and plug them into the “High Voltage” jacks with corresponding colors. On page 20, Figures 3 & 4 show the connections and test results for a good SCR. Press the button continuously and monitor the changing voltage and current. At the breakover voltage, the anode to cathode, (or cathode to anode), current increases rapidly and a corresponding reduction in the rate of voltage change will occur. At this point in the test, release the button and record the breakover voltage.

3.1.2. TRIAC

3.1.2.1. Primary Test

Plug the test leads into jacks "A", "B" & "C" and connect them to the TRIAC as shown on page 20, Figures 5 & 6. The sequence of connections is not important; the PST interrogates the TRIAC and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good TRIAC is shown in the diagrams. If the button is pressed briefly and released, only the low power test will be conducted and a false message will appear on the LCD, as shown in the diagrams. The gate of a TRIAC may not be identified on the LCD.

3.1.2.2. High Voltage Test

Remove the red and black test leads from the "A", "B" & "C" jacks and plug them into the "High Voltage" jacks with corresponding colors. On page 21, Figures 7 & 8 show the connections and test results for a good TRIAC. Press the button continuously and monitor the changing voltage and current. At the breakover voltage, the anode to cathode (or cathode to anode) current increases rapidly and a corresponding reduction in the rate of voltage change will occur. At this point in the test, release the button and record the breakover voltage.

3.1.3. NPN Bipolar Transistors

3.1.3.1. Primary Test

Plug the test leads into jacks "A", "B" & "C" and connect them to the Transistor. The sequence of connections is not important; the PST interrogates the Transistor and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good Transistor is shown in the diagrams. If the button is pressed briefly and released, only the low power test will be conducted and defects that would be detected at higher powers may be missed.

3.1.3.2. High Voltage Test

Remove the red and black test leads from the "A", "B" & "C" jacks and plug them into the "High Voltage" jacks; POLARITY IS IMPORTANT. On page 21, Figures 11 & 12 show the connections and test results for a good transistor. Press the button continuously and monitor the changing voltage. At the breakover voltage, the collector-emitter current increases rapidly and a corresponding reduction in the rate of voltage change will occur. At this point in the test, release the button and record the breakover voltage.

3.1.4. PNP Bipolar Transistors

3.1.4.1. Primary Test

Plug the test leads into jacks “A”, “B” & “C” and connect them to the Transistor as shown on page 22, Figure 13. The sequence of connections is not important; the PST interrogates the Transistor and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good Transistor is shown in the diagrams. If the button is pressed briefly and released, only the low power test will be conducted and defects that would be detected at higher powers may be missed.

3.1.4.2. High Voltage Test

Remove the red and black test leads from the “A”, “B” & “C” jacks and plug them into the “High Voltage” jacks; POLARITY IS IMPORTANT. On page 22, Figures 14 & 15 show the connections and test results for a good Transistor. Press the button continuously and monitor changing voltage. At the breakover voltage, the emitter-collector current increases rapidly and a corresponding reduction in the rate of voltage change will occur. At this point in the test, release the button and record the breakover voltage.

3.1.5. N or P Channel MOSFET Transistors

3.1.5.1. Primary Test

Plug the test leads into jacks “A”, “B” & “C” and connect them to the transistor. The sequence of connections is not important; the PST interrogates the Transistor and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good Transistor is shown in the diagram. If the button is pressed briefly and released, only the low power test will be conducted and defects that would be detected at higher power levels may be missed.

3.1.5.2. High Voltage Test

Remove the red and black test leads from the “A”, “B” & “C” jacks and plug them into the “High Voltage” jacks; POLARITY IS IMPORTANT. Connect the black lead to the drain and the red lead to the source. On pages 22 & 23, Figures 17 through 20 show the connections and test results for a good Transistor. Press the button continuously and monitor the changing voltage. When the first indication of current appears on the LCD, release the button and record the breakover voltage.

Note: The gate must be grounded prior to performing the High Voltage Test!

3.1.6. General Purpose Silicon & Germanium Diodes

3.1.6.1. Primary Test

Plug two test leads into jacks “A” & “B” and connect them to the Diode as shown on page 23, Figure 21. The polarity of connections is not important. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good diode is shown in the diagrams.

3.1.6.2. High Voltage Test

Remove the red and black test leads from jacks “A” & “B” and plug them into the “High Voltage” jacks; POLARITY IS IMPORTANT. The voltage at which the current begins is the actual reverse breakdown voltage of the Diode. This voltage may be considerably higher than the value found on specification sheets because most manufacturers allow a margin of safety to compensate for production tolerances, temperature effects, etc. If the current appears on the screen first, the Diode is bad, the clip leads have been reversed, or the manufacturer has accidentally reversed the polarity marks on the diode. Caution should be exercised when working with stud mounted Diodes because some manufacturers use different conventions than others; some use the center post for the anode and others use it as the cathode. When in doubt, repeat the test with the leads reversed; this should be standard practice when the first test indicates a bad device.

3.1.7. Zener Diodes

3.1.7.1. Primary Test

Plug two test leads into jacks “A” & “B” and connect them to the Diode. The polarity of connections is not important, the PST interrogates the Diode and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good Diode is shown in the diagrams.

3.1.7.2. High Voltage Test

Remove the test leads from Jacks “A” & “B” and plug them into the “High Voltage” jacks; POLARITY IS IMPORTANT. If the Diode is good, the first voltage displayed will be the “Zener” voltage, provided the “Zener” rating is between 4 and 24 volts. If a current appears on the screen first, the Zener is bad, the Zener rating of the diode is less than 4v, or the clip leads have been reversed. Caution should be exercised when working with stud mounted Zeners because some manufacturers use different conventions than others; some use the center post for the anode and others use it as the cathode. When in doubt, repeat the test with the leads reversed; this should be standard practice when the first test indicates a bad device. They type of information displayed (not the actual values) should be similar to that shown in the diagram. Continuing to depress the button until a current value first appears will result in an erroneous "Zener Voltage" reading because the voltage will step to a higher value when the current appears; this higher voltage **is not** the "Zener Voltage". The PST displays voltages to the nearest integer and will not give readings such as 3.9, 6.2, 6.8, etc.

3.1.8. Asymmetrical AC Triggers For TRIACs

3.1.8.1. Primary Test

There is no information programmed into the PST for this type of component. Therefore, an attempt to conduct a "Primary Test" will result in a "NO CONNECTION" message as shown on page 24, Figure 27, even though a "Trigger" is connected to the test leads.

3.1.8.2. High Voltage Test

Plug the test leads into the "High Voltage" jacks and connect the alligator clips to the "Trigger" terminals. Polarity is not important. Press the button continuously and monitor the changing voltage. When the first indication of current appears on the LCD, release the button and record the "Trigger" voltage. Reverse the leads and repeat the test. The higher voltage is the reverse breakdown voltage and the lower is the "Trigger" voltage that is to trigger the TRIAC.

3.1.9. Programmable Unijunction Transistors (PUT)

3.1.9.1. Primary Test

There is not information programmed into the PST for this type of component. Therefore, an attempt to conduct a "Primary Test" will result in an "ID-IMPOSSIBLE" message, even though a "PUT" is connected to the test leads.

3.1.9.2. High Voltage Test

Plug the red and black test leads into the "High Voltage" jacks; POLARITY IS IMPORTANT. Press the button continuously and monitor the changing voltage. When the first indication of current appears on the LCD, release the button and record the reverse breakover voltage. Actual values may vary from those shown in the figures but the general relationships between them should be roughly proportional to those shown.

3.1.10. N-Channel Junction FETs (JFET)

3.1.10.1. Primary Test

There is no information programmed into the PST for this type of component. Therefore, an attempt to connect a "Primary Test" will result in a "DIODE DIODE" message. However, useful information can still be obtained from the "High Voltage Test" outlined below.

3.1.10.2. High Voltage Test

Remove the red and black test leads from the “A”, “B” & “C” jacks and plug them into the “High Voltage” jacks; POLARITY IS IMPORTANT. Connect the JFET as shown on page 25, Figures 34 & 35. Press the button continuously and monitor the changing voltage and current. Actual values may vary from those shown in the figures but the general relationships between them should be roughly proportional to those shown.

3.1.11. Gate Turn-Off Thyristor (GTO)

3.1.11.1. Primary Test

Plug the test leads into jacks “A”, “B” & “C” and connect them to the GTO as shown on page 25, Figure 36. The sequence of connections is not important; the PST interrogates the GTO and detects the position of the lead connections. Press the button continuously until the test results are displayed on the LCD (approx. 12 seconds). An example of the information displayed for a good GTO is shown in the diagram. If the button is pressed briefly and released, only the low power test will be conducted and defects that would be detected at higher powers may be missed.

3.1.11.2. High Voltage Test

Remove the red and black test leads from the “A”, “B” & “C” jacks and plug them into the “High voltage” jacks; POLARITY IS IMPORTANT. Connect the GTO as shown on page 26, Figures 37 & 38. Press the button continuously and monitor the changing voltage and current. Actual values may vary from those shown in the figures but the general relationships between them should be roughly proportional to those shown. It is recommended that the GATE and CATHODE leads be connected together during this test.

3.1.12. Metal Oxide Varistors (MOV)

3.1.12.1. Primary Test

There is no information programmed into the PST for this type of component. Therefore, and attempt to conduct a “Primary Test” will result in a “NO CONNECTION” message as shown on page 26, Figure 39. However, useful information can still be obtained from the “High Voltage Test” outlined below.

3.1.12.2. High Voltage Test

Plug the test leads into the “High Voltage” jacks and connect the alligator clips to the leads of the MOV as shown on page 26, Figure 40. Polarity is not important. Press the button continuously and monitor the changing voltage. When the first indication of current appears on the LCD, release the button and record the “clamping” voltage. Reverse the leads and repeat the test. The MOV is a bipolar device and therefore the two voltages recorded in this test are the positive and negative voltages at which transients will be "clamped".

3.2. TESTING PASSIVE COMPONENTS

The PST was not designed to replace digital multimeters and has limited capabilities for testing passive components. However, "pass/fail" tests that are useful for trouble shooting can be conducted. Therefore procedures for testing resistors, capacitors, and inductors are given below.

3.2.1. Capacitors

Plug the red and black test leads into the plus (+) and minus (-) "High Voltage" jacks. CAUTION – POLARITY IS IMPORTANT FOR THESE TESTS. Connect the positive lead to the positive terminal of the capacitor and the negative lead to the other terminal and press the "High Voltage Test" button continuously.

3.2.1.1. Disc, Film & Tantalum Capacitors

When testing values of 1uf or less, the voltage should appear on the display first. If the capacitor is good, there shouldn't be enough leakage current to register on the display and the frequency of the voltage steps generated by the PST is too low to sustain measurable current at these low capacitance values. Therefore, if current is displayed, the capacitor is probably bad. Caution must be exercised to prevent over-voltages from being applied to the capacitor, otherwise the capacitor may be permanently damaged by dielectric breakdown. This test will not detect "opens" but it will detect "shorts" and leaky components, and therefore is useful for trouble shooting. On page 27, Figures 43 & 44 show the type of information displayed.

3.2.1.2. Electrolytic Capacitors

Since leakage is a normal characteristic of this type of capacitor, current will appear on the display before or approximately the same time as voltage if the capacitance is 10uf or greater. If the capacitor is bad, the current will continue to increase without a corresponding increase in voltage, thus indicating a shorted or high leakage component. If the capacitance is 2uf or more and current is not displayed as the voltage steps to higher levels, the capacitor is very likely "open". Caution bust be exercised to prevent over-voltages from being applied to the capacitor; otherwise dielectric breakdown might occur which could permanently damage the capacitor. On page 27, Figures 45 through 47 show the type of information displayed.

Note: Provisions have not been included in the PST for discharging capacitors that have been under test. Discharge the capacitors after test before handling.

3.2.2. Inductors, Coils & Transformers

Polarity is not important in these tests. Connect the alligator clips to the component being evaluated and press the “High Voltage Test” button continuously. Current should appear on the display before voltage. If the current is not indicated on the LCD, the coil is open and should be replaced.

3.3. OTHER USES

3.3.1. Continuity Checker

The PST can be used as a continuity checker but caution must be exercised to prevent the application of voltages which exceed the ratings of the components in the circuits being tested.

4. GRAPHS & LCD DISPLAY MESSAGES

4.1. INTERPRETING THE DISPLAY MESSAGES

4.1.1. General

This section provides graphic information for connecting the components to the PST, illustrations of messages presented on the LCD display, and semiconductor characteristics to aid in the interpretation of messages. For detailed information on test procedures, refer to Chapter 3.

4.1.2. Available Display Messages

There are a large number of display messages programmed into the PST. All available display messages are shown on pages 20 and 21.

4.1.3. Application Notes Explanation

The Application Notes on pages 23 through 30 show how different components should be connected to the PST, and which results to expect from good components. Below is an explanation to the column headings in the Application Notes:

FIG./DEVICE, SECTION

This column identifies the type of component corresponding to the LCD message displayed. The FIG. Number is referred to in the section(s) listed below the FIG./DEVICE nomenclature.

CHARACTERISTICS

Components characteristics given I this column relate the displayed information to the expected characteristics of a good device. This information will help give a "feel" for the test process being automatically conducted by the PST.

TEST

This column identifies the type of test for which the displayed information is applicable.

CONNECTIONS

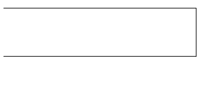
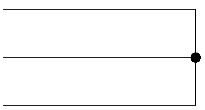
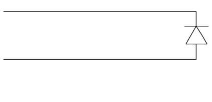
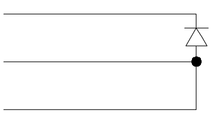
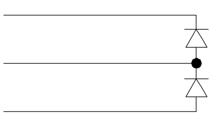
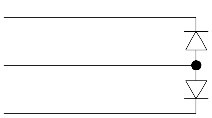
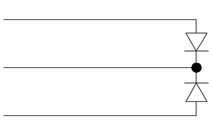
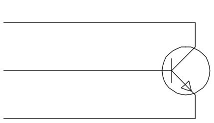
The large number of physical variations of components available makes in impractical to show specific component geometries for connection purposes. Therefore symbolic device connections are given in the "CONNECTIONS" column to aid the user in connecting the component to be tested. The connections shown for the "Primary" test are arbitrary and are not intended to imply a "correct" connection scheme.

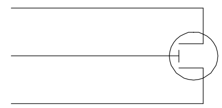
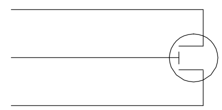
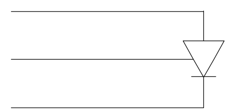
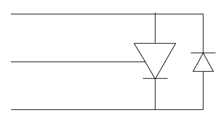
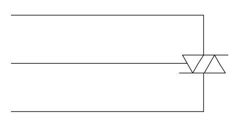
Note: The PST5000 has separate connection jacks for High Voltage testing and Voltmeter functions. The "+" and "-" signs refer to High Voltage testing.

LCD MESSAGES

When the "Primary or "High Voltage Test" button is continuously depressed, the messages automatically display in the sequence shown in the illustrations and the time between changes in messages may vary considerably, depending on the component and type of test. When this display first appears, the readings are "00" for **both** voltage and current and there is a time lag of approximately 13 seconds before changes in current begin to appear on the LCD**. Therefore, releasing the button too soon in the cycle may lead to wrong conclusions.**

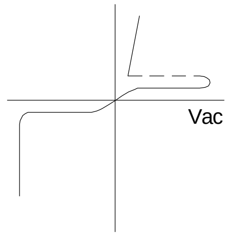
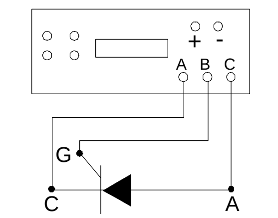
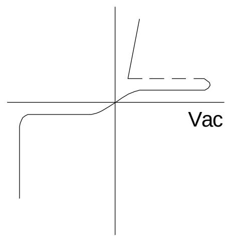
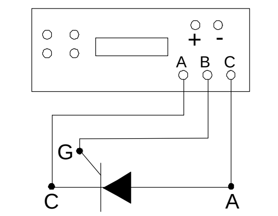
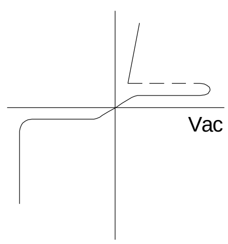
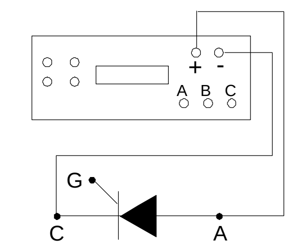
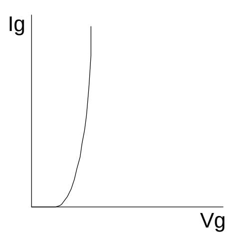
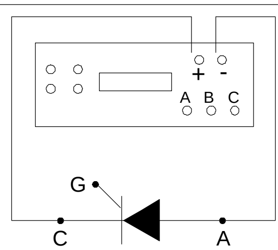
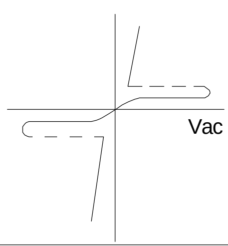
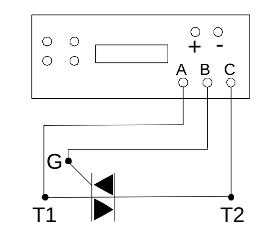
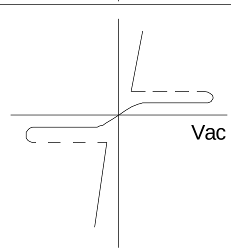
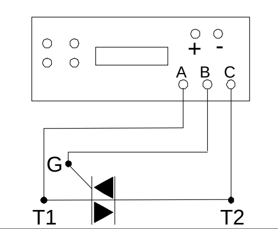
4.2. DISPLAY MESSAGES

ELECTRICAL FUNCTION	DISPLAY MESSAGE
	NO CONNECTION
	SHORT CIRCUIT OPEN CIRCUIT
	SHORT CIRCUIT SHORT CIRCUIT
	DIODE OPEN CIRCUIT
	DIODE SHORT CIRCUIT
	DIODE DIODE
	DIODE DIODE
	DIODE DIODE
	NPN FUNCTION

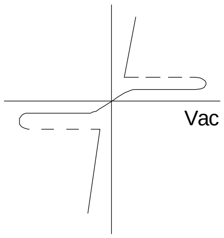
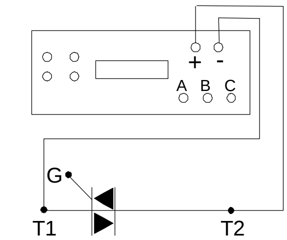
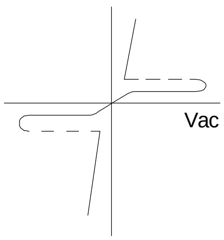
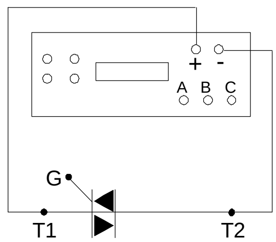
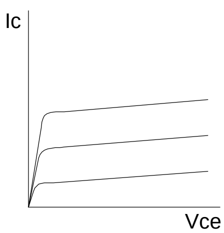
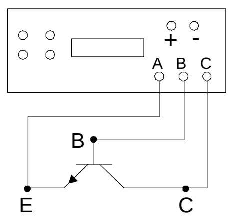
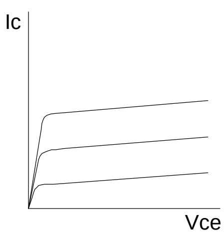
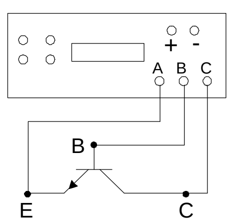
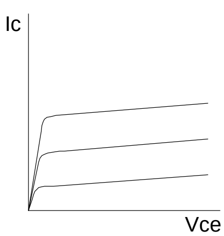
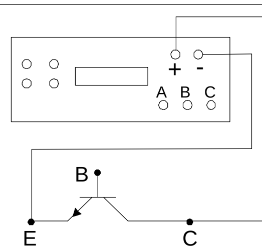
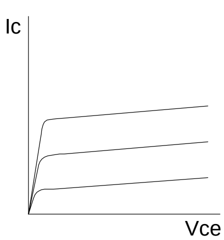
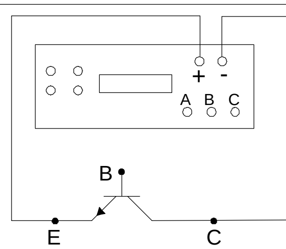
ELECTRICAL FUNCTION	DISPLAY MESSAGE
	PNP FUNCTION
	MOS P-CHANNEL ENHANCEMENT
	MOS N-CHANNEL ENHANCEMENT
	SCR GATE POS'N [ ]
	SCR/DIODE GATE POS'N [ ]
	TRIAC

ELECTRICAL FUNCTION	DISPLAY MESSAGE	
?	ID IMPOSSIBLE LOAD	The impedance between A, B and/or C terminals is between 4 - 20 ohms. This message is common when testing a hockey puck SCR, without applying pressure to the component.
?	NO TEST VOLTAGE ON	Indication that there is a voltage present on one, two or all of the A, B, C terminals during Primary Test.
	[A]	Gate or Base position indication (A, B or C)
	[B]	Low Battery indication.
	SCR I_{al} = 3 mA	Indicates that the semiconductor has a **leakage current during the primary test** (low voltage). Discard component!
	Peak + 00 Peak - 00	Peak Voltmeter display.
	HIGH VOLTAGE	Start of High Voltage test.
	Voltage 1500V Current 10uA	High Voltage test.
	20000D3A20000D3A 048320000D3A	Self Test Error during start up. **Write down all digits and call Consolidated's Technical Support 1-800-845-2908.**

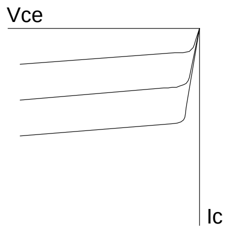
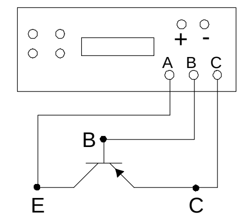
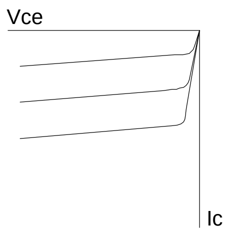
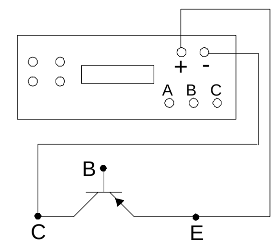
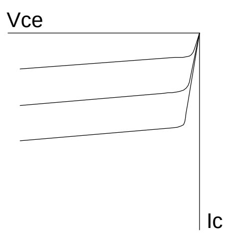
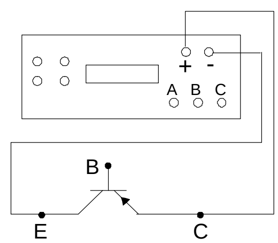
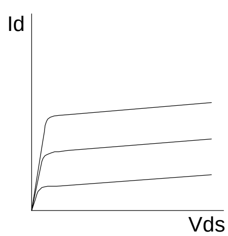
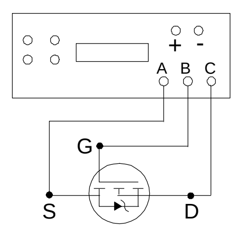
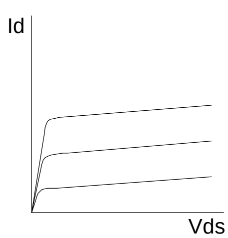
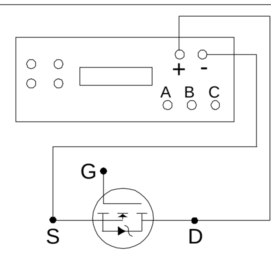
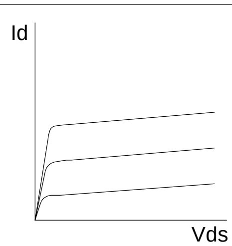
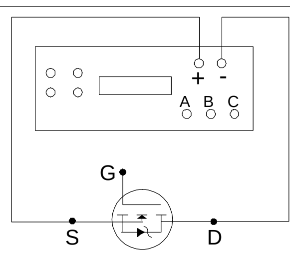
4.3. APPLICATION NOTES

FIG. DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	 SECOND
FIG. 1 SCR See Section 3.1.1.1		PRIMARY		TEST LOW	NPN FUNCTION NOTE: False message. - Button pushed momentarily
FIG. 2 SCR See Section 3.1.1.1		PRIMARY		TEST LOW MED HIGH	SCR GATE POS'n [B]
FIG. 3 SCR See Section 3.1.1.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 1150 CURRENT 20 uA
FIG. 4 SCR See Section 3.1.1.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 1200 CURRENT 50 uA
FIG. 5 TRIAC See Section 3.1.2.1		PRIMARY		TEST LOW	NPN FUNCTION NOTE: False message. - Button pushed momentarily
FIG. 6 SCR See Section 3.1.2.1		PRIMARY		TEST LOW MED HIGH	TRIAC GATE POS'n

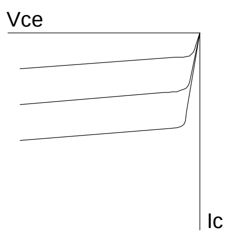
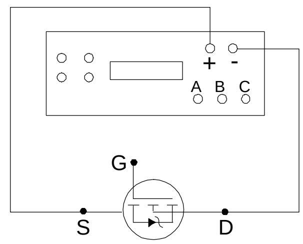
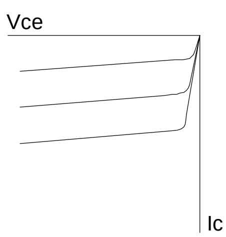
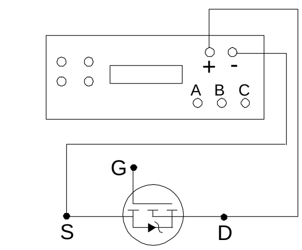
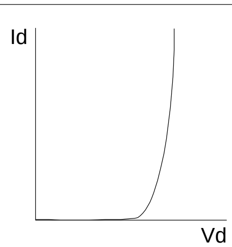
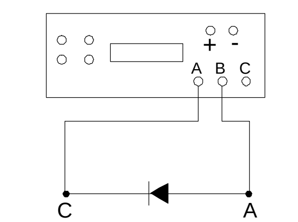
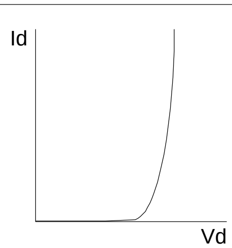
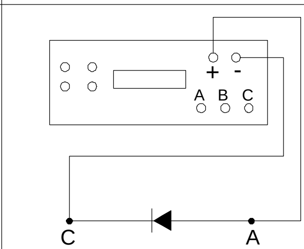
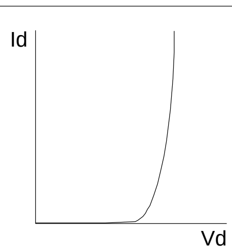
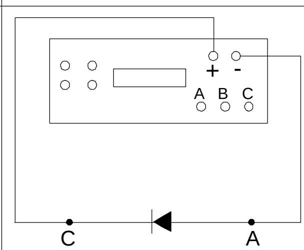
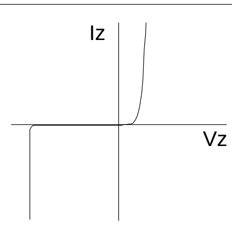
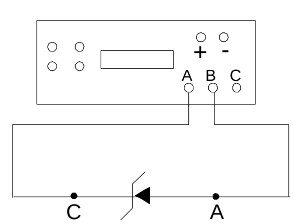
APPLICATION NOTES

FIG. DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 7 TRIAC See Section 3.1.2.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 550 V CURRENT 10 uA
FIG. 8 TRIAC See Section 3.1.2.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 808 V CURRENT 10 uA
FIG. 9 NPN TRAN See Section 3.1.3.1		PRIMARY		TEST LOW NOTE: Button pushed momentarily.	NPN TRANSISTOR [B]
FIG. 10 NPN TRAN See Section 3.1.3.1		PRIMARY		TEST LOW MID HIGH NOTE: Button pushed continuously.	NPN TRANSISTOR [B]
FIG. 11 NPN TRAN See Section 3.1.3.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 150 V CURRENT 10 uA
FIG. 12 NPN TRAN See Section 3.1.3.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 16 V CURRENT 10 uA

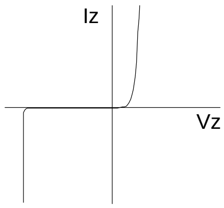
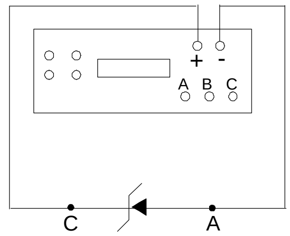
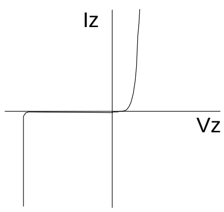
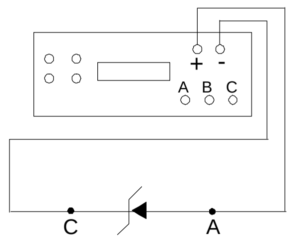
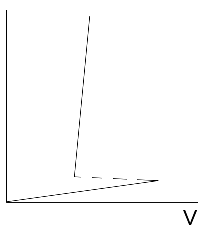
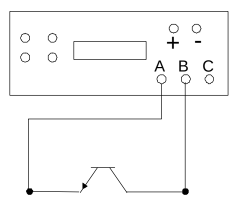
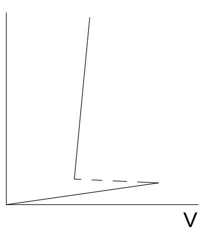
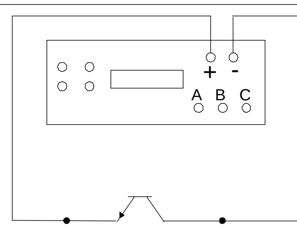
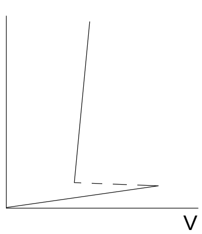
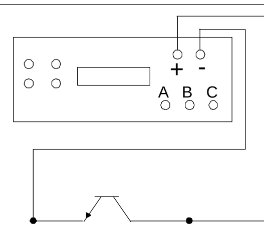
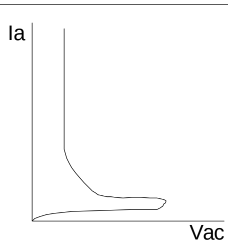
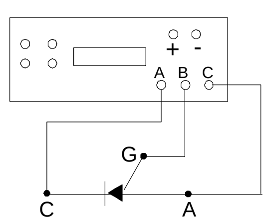
APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 13 PNP TRAN See Section 3.1.4.1		PRIMARY		TEST LOW MID HIGH	PNP TRANSISTOR [B]
FIG. 14 PNP TRAN See Section 3.1.4.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 68 V CURRENT 20 uA
FIG. 15 PNP TRAN See Section 3.1.4.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 12 V CURRENT 40 uA
FIG. 16 N MOSFET See Section 3.1.5.1		PRIMARY		TEST LOW MID HIGH	MOS N-CHANNEL ENHANC, MD [B]
FIG. 17 N MOSFET See Section 3.1.5.2		HIGH VOLTAGE		HIGH VOLTAGE NOTE: Gate must be grounded prior to starting the High	VOLTAGE 144 V CURRENT 10 uA
FIG. 18 N MOSFET See Section 3.1.5.2		HIGH VOLTAGE		HIGH VOLTAGE NOTE: Gate must be grounded prior to starting the High Voltage Test	VOLTAGE 00 V CURRENT 180 uA NOTE: This shows the forward conduction of the body

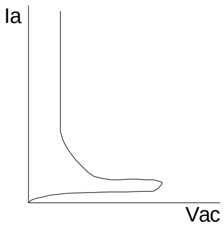
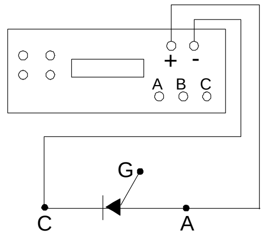
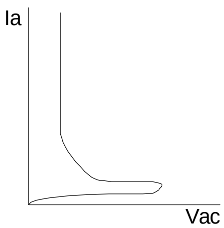
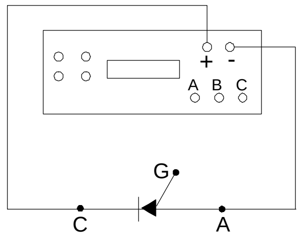
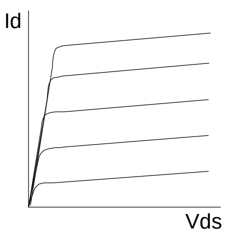
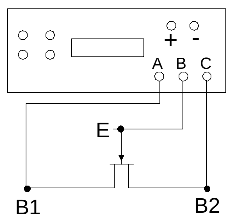
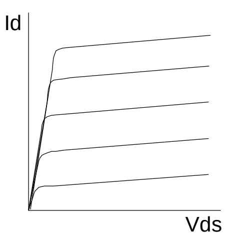
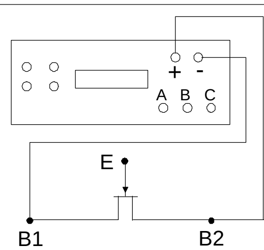
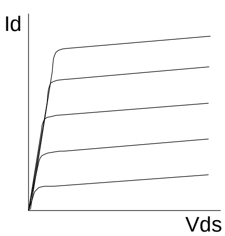
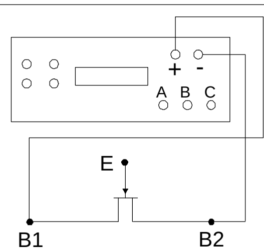
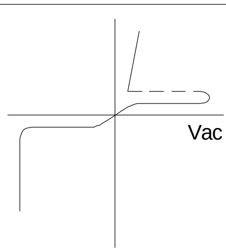
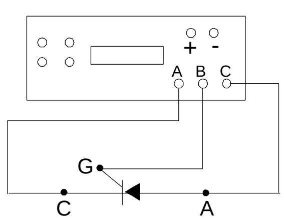
APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 19 P MOSFET See Section 3.1.5.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 44 V CURRENT 10 uA
FIG. 20 P MOSFET See Section 3.1.5.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 00 V CURRENT 180 uA NOTE: This shows the forward conduction of the body diode.
FIG. 21 DIODE See Section 3.1.6.1		PRIMARY		TEST LOW	DIODE OPEN CIRCUIT
FIG. 22 DIODE See Section 3.1.6.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 00 V CURRENT 220 uA
FIG. 23 DIODE See Section 3.1.6.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 800 V CURRENT 20 uA
FIG. 24 ZENER See Section 3.1.7.1		PRIMARY		TEST LOW	DIODE OPEN CIRCUIT NOTE: Diode across two terminals One terminal open circuit

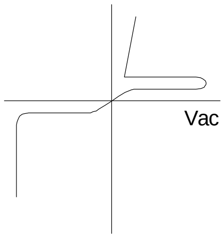
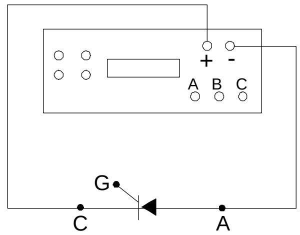
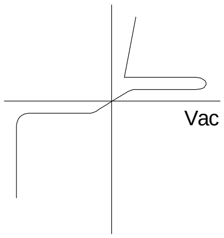
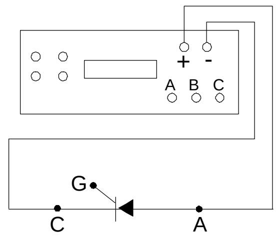
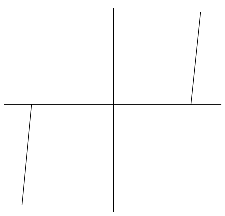
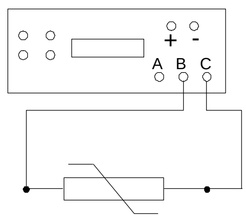
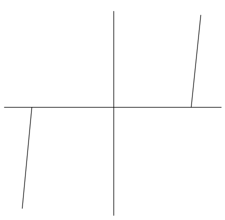
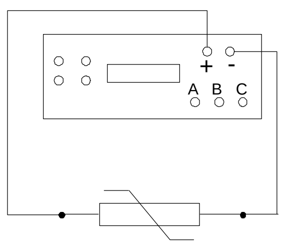
APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES	
				FIRST	SECOND
FIG. 25 ZENER See Section 3.1.7.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 12 V CURRENT 00 uA
FIG. 26 ZENER See Section 3.1.7.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 00 V CURRENT 140 uA
FIG. 27 ASYM AC TRIGGER See Section 3.1.8.1		PRIMARY		TEST LOW MID HIGH	NO CONNECTION
FIG. 28 ASYM AC TRIGGER See Section 3.1.8.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 68 V CURRENT 20 uA
FIG. 29 ASYM AC TRIGGER See Section 3.1.8.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 16 V CURRENT 10 uA
FIG. 30 PUT See Section 3.1.9.1		PRIMARY		TEST LOW NOTE: Button should not be depressed continuously.	ID-IMPOSSIBLE LOAD

APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 31 / PUT See Section 3.1.9.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 88 V CURRENT 10 uA
FIG. 32 / PUT See Section 3.1.9.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 88 V CURRENT 10 uA
FIG. 33 / N JFET See Section 3.1.10.1		PRIMARY		TEST LOW	DIODE DIODE
FIG. 34 / N JFET See Section 3.1.10.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 04 V CURRENT 180 uA
FIG. 35 / N JFET See Section 3.1.10.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 04 V CURRENT 120 uA
FIG. 36 / GTO See Section 3.1.11.1		PRIMARY		TEST LOW	NPN TRANSISTOR [B]

APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 37 / GTO See Section 3.1.11.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 1000 V CURRENT 250 uA
FIG. 38 / GTO See Section 3.1.11.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 00 V CURRENT 110 uA
FIG. 39 / MOV See Section 3.1.12.1		PRIMARY		TEST LOW MED HIGH	NO CONNECTION
FIG. 40 / MOV See Section 3.1.12.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 240 V CURRENT 00 uA

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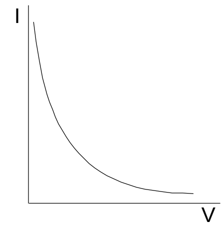
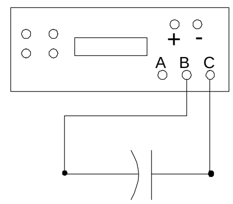
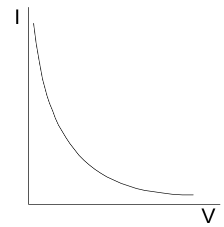
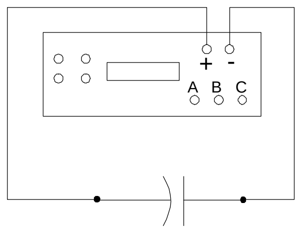
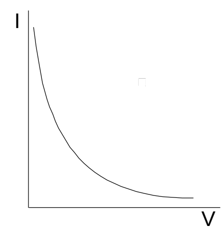
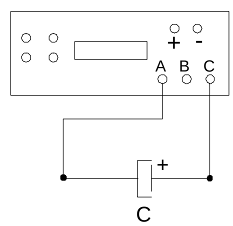
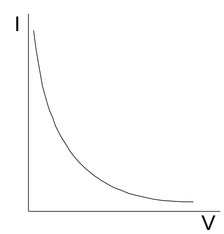
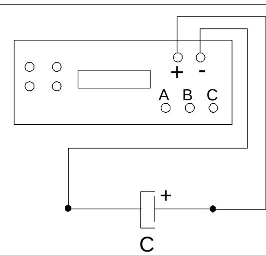
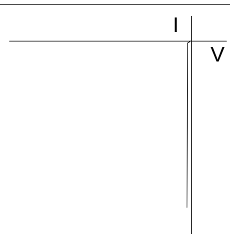
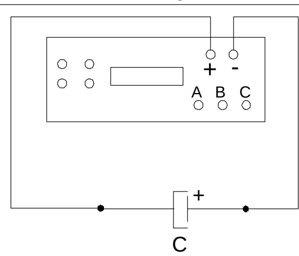
APPLICATION NOTES

FIG. / DEVICE	CHARACTERISTIC	TEST	CONNECTIONS	LCD MESSAGES FIRST	LCD MESSAGES SECOND
FIG. 43 CAPACITOR DISC/FILM See Section 3.2.1.1		PRIMARY		TEST LOW	NO CONNECTION
FIG. 44 CAPACITOR DISC/FILM See Section 3.2.1.1		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 20 V CURRENT 00 uA
FIG. 45 CAPACITOR TANTALUM See Section 3.2.1.2		PRIMARY		TEST LOW	NO CONNECTION
FIG. 46 CAPACITOR TANTALUM See Section 3.2.1.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 08 V CURRENT 60 uA
FIG. 47 CAPACITOR TANTALUM See Section 3.2.1.2		HIGH VOLTAGE		HIGH VOLTAGE	VOLTAGE 00 V CURRENT 100 uA

5. TECHNICAL DESCRIPTION

5.1. OVERVIEW

This section presents technical information about the basic principles utilized by the PST to conduct the "High Voltage Test". Since the "High voltage Test" is a very versatile tool for evaluating semiconductors, a clear understanding of the operating principles will allow the user to be innovative in the use of this instrument. The technicalities of testing SCRs will be used as an example to illustrate the PST operating principles. Even though the connections, displayed information, and testing techniques may vary with the type of semiconductor being evaluated, the technicalities of the PST operation presented herein still apply. For detailed information about test procedures and connections see Sections 3 & 4.

5.1.1. Testing SCRs

Since the maximum current used by the PST to test semiconductors at high voltages is 2.2ma, a question naturally comes to mind about the practicality of using this low current to test large junction SCRs (such as hockey pucks) which have "normal" junction leakages in the 30 to 300ma range. The first step towards answering this question is to examine SCR junction parameters to establish a basis for the technical information presented later.

5.1.1.1. SCR Junction Parameters

Since the predominant use of SCRs is in AC circuit control, most industrial SCR parameters are determined from tests using AC voltage or currents. This is implicit in the definitions of parameters such as:

V_{DRM} - The maximum **instantaneous** value of the off-stage voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all not repetitive transient voltages.

I_{DRM} - The maximum **instantaneous** value of the off-state current that results from the application of repetitive peak off-state voltage.

First impressions may lead us to expect that the maximum **instantaneous** off-state (leakage) current would occur at the peak of the applied voltage sine wave. However, a closer examination of SCR junction physics reveals that this is ***not*** the case. As we shall see, junction capacitance plays a dominant role in establishing the off-state leakage current with an **AC** voltage applied.

5.1.1.2. SCR Junction Capacitance

Junction capacitance is a function of three factors: Semiconductor permittivity (e), junction area (A), and depletion width (w). Since depletion width varies with voltage, junction capacitance (C_J) also varies.

Inspection of Figure 5.1 on page 34 shows that capacitance rapidly decreases to a relatively low, and approximately constant, value as the voltage increases. This curve represents test data taken on a commercially available SCR with a junction diameter of approximately 16mm and a V_{DRM}

rating of 1400v. It can be seen from the curve that the junction capacitance at close to zero voltage is approximately 1300pf.

Theoretically, capacitance is directly proportional to area. However, other variables such as junction geometry and semiconductor doping levels will undoubtedly cause variations in capacitance that cannot be predicted by a simple area ratio. Data shown on manufacturer's specification sheets indicate that junction capacitance could be more than 0.3µf for high power hockey-puck SCRs.

However, the purpose of this analysis is to explain the basic principles that apply to all SCRs irrespective of variations among the multitude of SCRs available. Therefore, the capacitance value used in the calculations on pages 30 through 33 is for illustrative purposes only.

5.1.1.3. AC vs DC Leakage Currents

Since capacitors pass AC and block DC currents, it should not be surprising that **tests using AC voltages will result in considerably higher "leakage" currents than would occur using a DC test voltage**.

The calculations below demonstrate that "leakage currents above 100ma can occur when AC wave forms are used for testing because of current flowing though the junction capacitance. However, it would be a mistake to assume that maximum instantaneous currents occur at the peak of the sine wave, or that they can be calculated by dividing the RMS value of the sine wave by the impedance of the junction capacitance. The calculations below show that maximum currents occur at "0 crossing" of the sine wave.

A complex relationship exists between AC "leakage" current and junction capacitance. Junction capacitance varies with voltage and is maximum when the voltage is zero. However, this capacitance decreases rapidly as the voltage increases. Examination of Figure 5.1 reveals that approximately two-thirds of the total change in junction capacitance occurs while the voltage increases from "0" to 16 volts.

Since Figure 5.1 represents data taken from an SCR with a junction area much smaller than many of the "hockey puck" units currently in use, a maximum junction capacitance of 0.3µf (at 0 volts) will be used to illustrate the principles of AC vs DC leakage currents. Assuming that the "capacitance vs voltage" graph for a unit with a maximum junction capacitance of 0.3µf has the same general shape as Figure 5.1, we can arrive at an "average capacitance of 0.219µf.

We will see that the initial instantaneous "zero crossing" current is much higher than the RMS current for the entire cycle of the sine wave because current through a capacitor is sensitive to the "rate of voltage change".

Obviously, if the applied voltage is DC or a very slowly rising voltage, current through the junction capacitance due to "rate of change" will be minimal and the true leakage current can be measured.

To illustrate this difference between the results obtained with conventional AC test methods and those obtained with the PST we will calculate transient and alternating currents flowing though the junction capacitance of an SCR, and then compare these with results obtained with the PST. The transient current will be calculated first and then the RMS value of the AC current. After these have been determined, we will compare these results with those obtained by using the PST.

Definition Of Terms:

1. E_p = The peak voltage of the sine wave = 2000v.
2. f = The frequency of the sine wave = 60Hz.
3. t = Instantaneous time in seconds.
4. T = The period of the sine wave = 16.667ms.
5. ω = Radian measure of an angle.
6. i = Instantaneous value of current.
7. i_{rms} = Root-Mean-Square (RMS) value of current.
8. de = Differential voltage.
9. dt = Differential time.
10. C = Average junction capacitance = 0.219µf.

The equation for instantaneous current through a capacitor can be expressed as:

$$i = C\ (de/dt) \qquad (1)$$

The equation for a sine wave voltage is: (see Figure 5.2)

$$e = E_p[\sin(\omega \times t)] \qquad (2)$$

And de/dt can be obtained by differentiating Equation (2) with respect to time, giving:

$$de/dt = \omega\, E_p\ [\cos(\omega \times t)] \qquad (3)$$

At “zero crossing the rate of change of voltage with respect to time is maximum. Therefore, if we set t=0 in Equation (3), remembering that cos(0) =1, Equation (3) reduces to:

$$de/dt = \omega\, E_p \qquad (4)$$

Substituting Equation (4) into Equation (1) gives:

$$i = C\ \omega\, E_p \qquad (5)$$

Substituting numbers for the variables gives the instantaneous current at “0” crossing:

$$i = 165\ \text{ma} \qquad (6)$$

The next step is to calculate the RMS value for the complete sine wave. The general equation for calculating the RMS value of a periodic wave form will be given first and then substitutions made for the situation under consideration. The general equations is:

$$i =\ 1/T\ {}_0{}^T\ [f(t)]^2\ dt \qquad (7)$$

Substituting Equation (3) into Equation (1) gives:

$$i = C\omega E_p[\cos(\omega t)] \qquad (8)$$

Substituting Equation (8) for f(t) in Equation (7) gives:

$$i_{rms} = \quad 1/T \ {}_0{}^T \ [C\omega E_p(\cos(wt))]^2 \qquad (9)$$

Since "dt" is not the complete differential, the form of the equation will have to be changed. To accomplish this we substitute the identity:

$$[\cos(wt)]^2 = ½[1+\cos(2\omega t)] \qquad (10)$$

into the term under the integral. This gives:

$$i_{rms} = \quad 1/T \ {}_0{}^T \ [C\omega E_p(\cos(wt))]^2 \qquad (11)$$

Next we take the constants outside the integral and separate terms under the integral:

$$i_{rms} = \quad [(C\omega E_p)^2 /2T] \ [{}_0{}^T dt + {}_0{}^T \cos(2\omega t)dt] \qquad (12)$$

The term under the second integral still doesn't have a complete differential, but we can easily supply this by multiplying it by 1 (2w /2w). Then we have:

$$i_{rms} = \quad [(C\omega E_p)^2 /2T] \ [{}_0{}^T dt+(1/2\omega) \ {}_0{}^T \cos(2\omega t)](2\omega)dt] \qquad (13)$$

Integrating this with respect to time gives:

$$i_{rms} = \quad [(C\omega E_p)^2 /2T] \ [t+(1/2\omega)\sin(2\omega t)] \ {}_0{}^T \qquad (14)$$

Applying the limits of integration and removing the radical sign gives us the final form of the equation:

$$i_{rms} = 0.7071(C\omega E_p) \qquad (15)$$

Remembering that ω = 2pif and substituting the numbers given earlier in this section gives us the final answer:

$$i_{rms} = 117 \text{ mA} \qquad (16)$$

The instantaneous current in this example is approximately 41% greater than the RMS current for a complete cycle. Since current is the rate of change of charge with respect to time (dq/dt), it is logical that the instantaneous current at maximum de/dt would be high compared to the full cycle RMS value. Thus the junction capacitance receives most of its charge during the first few micro-seconds after "zero crossing" of the wave form. A clear understanding of these principles will help understand the basic operation of the PST described below.

Some manufacturers report RMS leakage currents as high as 300ma for "Hockey puck" types of devices. This simply means that the junction capacitance is much higher than the value used in this illustration.

5.2. TESTING SEMICONDUCTOR LEAKAGE WITH THE PST

The key to understanding why leakage currents are much lower using the PST Semiconductor Analyzer than those obtained with standard industry test procedures can be seen by examining Figure 5.3 and comparing it with the information presented in the previous section.

The following is a detailed description of the "High Voltage Test" performed by the PST:

When the "High Voltage Test" button is initially pressed, the output voltage at the "High voltage" jacks increases from "0" to "16" volts in approximately 20ns (as shown in Figure 5.3). this gives a de/dt value of 800 million volts per second, which is approximately 1000 times greater than the de/dt calculated for the sine wave defined in Equation (4). This means that the junction capacitance is charged very rapidly at the same time its value is rapidly decreasing, as shown in Figure 5.1.
The 16v level is maintained for approximately 8.5 seconds, which allows plenty of time for the transient current to die out before DC leakage current measurements are made, even when testing semiconductors with large junction capacitances.

At the end of the 8.5 seconds, leakage is sampled and displayed if the value is more than 10µa. This is a true DC leakage with no AC or de/dt current flowing. This value will usually be in the low micro-ampere range for a good device.

Continuing to press the button causes the output voltage to gradually rise towards the breakover voltage of the semiconductor, as shown at points "C" and "D" in Figure 5.3. The de/dt of this rising voltage is so low that very little junction capacitance "charging current" flows and the displayed current is, for all practical purposes, a true DC "leakage" current.

A few simple calculations will help illustrate the point.

In Figure 5.1 it can be seen that junction capacitance decreases from 1300pf at "0" volts to 550pf at 16v. In other words, the capacitance at 16v is only 42% of the "0" volt capacitance. Furthermore, the capacitance at rated voltage is only 23% of the capacitance at "0" volts.

Using these percentages and assuming an approximately proportional relationship exists between the junction capacitance of different size devices, we can calculate the junction capacitances at corresponding voltage levels for the 0.3µf device analyzed above.

Using these assumptions, we determine the capacitance at 16v to be 0.126µf and at 2000v it would be 0.05µf. Referring to Figure 5.3, we see that the voltage begins to rise again at point "B". The rate of rise for the first 2 seconds after point "B" is approximately 14v/sec. And the average capacitance would be approximately 0.103µf.

Therefore the instantaneous current flowing though the junction capacitance would be 1.5µa and would not be enough to show on the display. The rate of voltage increase during the next 2 seconds is approximately 28v/sec. And the junction capacitance during this period would be 0.09µf. The instantaneous current through the junction capacitance during this period would 2.5µa, which still would not show on the display.

It can bee seen from Figure 5.3 that de/dt increases as the output voltage increases and is approximately 232v/sec. At 2000v. However, junction capacitance decreases as voltage increases and would be approximately 0.057µf at 2000v. Thus, the instantaneous current flow due to de/dt considerations would be approximately 13µa at 2000v. DC leakage currents at the junction breakover voltage are usually several hundred microamps and 13µa would not be a significant factor in determining the breakover voltage.

Therefore, testing semiconductors with DC voltages gives a much better indication of their condition than using AC voltages which mask the true junction leakage because of AC currents flowing though the junction.

Obviously the larger (and more expensive) semiconductors are the ones most susceptible to misleading test results when AC voltages are used to evaluate their condition.

Consequently, the PST Power Semiconductor Analyzer from Consolidated Electronics, Inc. is a valuable tool for evaluating semiconductors of many types, but especially large and expensive SCRs, DIODES, TRANSISTORS, TRIACs, GTOs, etc.

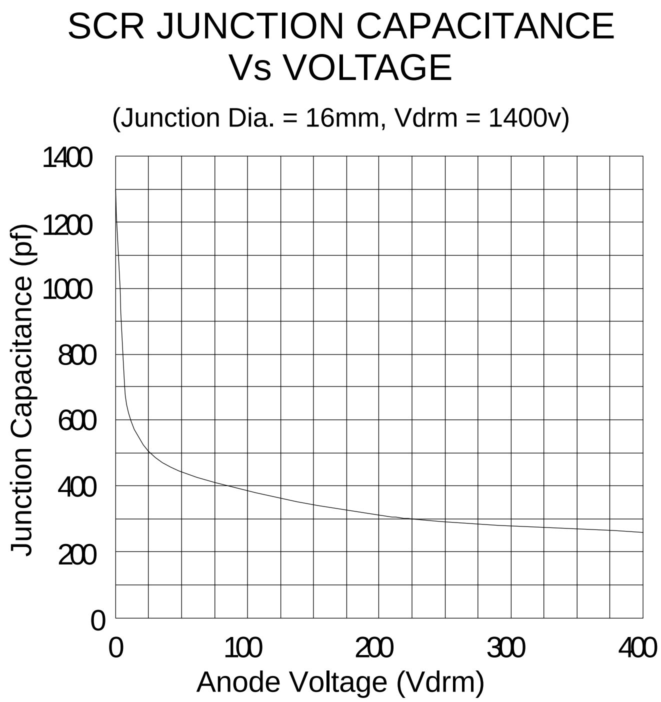


Fig. 5.1

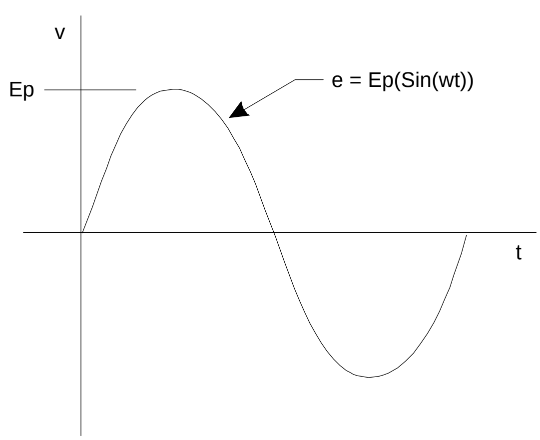


Fig. 5.2

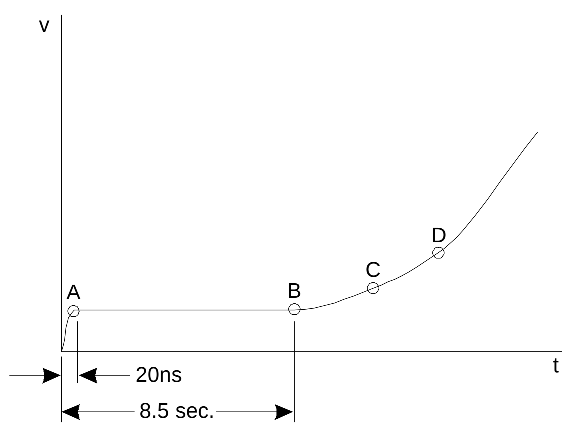


Fig. 5.3