GALCO INDUSTRIAL ELECTRONICS TECHTIPS
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Power Semiconductor Device Testing and Testing Limitations

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I SCR and Diode Resistance Measurements with a Volt-Ohmeter

Introduction

Many users of SCRs and diodes lack the proper equipment to make semiconductor parameter measurements. The conventional battery operated volt-ohmmeter (VOM) is sometimes used to distinguish acceptable from unacceptable devices based upon a resistance reading. A measurement of this type can lead to erroneous conclusions. The valid versus erroneous measurements are the subject of this Application Information.

VOM Measurements

The semiconductor measurements, which are generally made with a VOM involve the blocking voltage rather than the "on-state" characteristics. These DC resistance measurements are made across the anode-cathode of a SCR or diode and across the gate-cathode of a SCR since its characteristic is similar to the anode-cathode of a diode. The present Powerex diodes and SCRs have blocking voltage ratings from 100V to 4400V. The only valid SCR or diode resistance indications on a VOM are "open" and "short". The anode-cathode or gate-cathode measurement must show a short (0 resistance) in both directions (forward and reverse polarity) for a device to be considered "shorted" and infinite resistance for an "open". A diode normally shows low resistance in the forward direction and high resistance when the VOM probes are reversed. Hence, the VOM can be a check on diode polarity. The SCR normally has a high resistance across the anode-cathode in both directions. For a SCR to be open, the gate-cathode must also show open. An open failure on Powerex high power semiconductor is a rare event. Because of compression bonded encapsulation construction, the semiconductor elements are almost always under pressure, and even if damaged, the electrodes generally cannot separate.

A measured resistance value with a VOM is an erroneous semiconductor device measurement technique for segregating devices. When a resistance measurement on a semiconductor is taken with a volt-ohmmeter, the internal battery voltage, typically 1.5 or 3.0 volts, and the device's corresponding leakage current at the VOM voltage level determine the magnitude of resistance. The semiconductor also has a non-linear blocking voltage/leakage current characteristic which implies a non-linear resistance curve. Semiconductor devices are tested at the factory at rated voltage to meet the rated leakage current at the rated junction temperature. Thus, devices may have a range of resistance as shown in Figure 1 and still be within the manufacturer's rating.

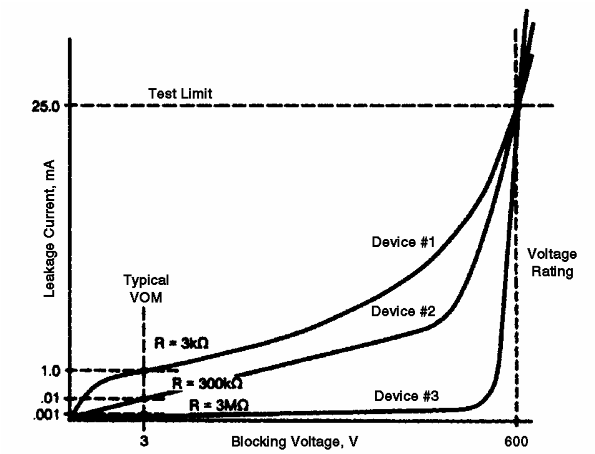

Figure 1. Representative Semiconductor Leakage Current vs. Blocking Voltage

Precautions

1. Determine if the resistance measurement is being taken across the device and not something else in the circuit. Open an anode, cathode, or gate connection if in doubt.
2. If a disc device is being measured, make sure it is under sufficient force (approximately 200 lb.) to get a reading. Otherwise, a device can appear to have high resistance in both directions because contact is not being made internally.

Summary

A volt-ohmmeter resistance measurement technique is not recommended for determining acceptable semiconductor devices. As a quick check for devices in a circuit, a VOM will allow you to determine if a device has failed catastrophically.

II Testing Limitations of the Consolidated Electronics, Inc. PST2000 & PST5000

Some numbers of our customers who have used the Consolidated Electronics, Inc., www.con-elec.com, PST2000 and PST5000 analyzer to test power semiconductors have concluded (based on the PST2000 and PST5000 test results) that certain power semiconductor devices are out of spec and therefore defective. In most cases such conclusions were incorrect, and were caused by limitations or operating principles of the PST2000 and PST5000. These situations have been cause for confusion. This is not to say that there is anything wrong with the PST2000 or PST5000. In all such cases it is just a situation of understanding the instrument's limitations and operating principles. This is important to avoid an erroneous conclusion that the semiconductors are "bad", based on the characteristics of the PST2000 and PST5000, when, in fact, the devices are good.

The major limitation of the PST2000 and PST5000 is that in the high voltage test mode, the maximum current output is 2.3ma. In this test the voltage and resulting leakage current are used to evaluate device blocking voltage capability. Once this limit of 2.3ma is reached, the tester will no longer increase voltage output. If the 2.3ma limit is reached before the device rated blocking voltage is achieved, most customers conclude the device is below spec on blocking voltage. A high percentage of power semiconductor devices have maximum leakage current ratings well above 2.3ma (ratings up to 100ma or higher may be common). Therefore, in many cases a good device is assumed to be "bad" based on the test results.

Another area of concern is that the tester will continue to increase applied voltage to a device under test as long as the test button is depressed and the 2.3ma limit has not been reached. It is therefore possible to impose a higher voltage on the device than it is rated for, which may damage or destroy the device.

III Testing Limitations of the Sencore LC102 and SCR250 (Auto-Z)

There are testing limitations of the Sencore, www.sencore.com LC102 and the SCR test accessory the SCR250 (Auto-Z) with regard to power semiconductor testing. These limitations need to be understood in order to avoid an erroneous conclusion that certain power semiconductors are "bad", based on the characteristics of the LC102/SCR250, when, in fact, the devices are good. In the Sencore Tech Tips publication number 140, it states that during a leakage test that a thyristor is defective if the leakage is over 10 microamps (0.000,01 amps). A high percentage of power semiconductor devices have maximum leakage current ratings well above

10 microamps (ratings up to 100ma or higher may be common), 10,000 times over what the Sencore Auto-Z's documentation states to be acceptable. This may mislead one to unknowingly discard a perfectly good device.

Another limitation of the Auto-Z is that it has a maximum test voltage of 1,000V. Maximum Vdrm on power semiconductors exceeding 1,000 volts are not uncommon. The Auto-Z is not capable of testing leakage at the rated Vdrm on these devices. It is possible that you may falsely determine that a device is good because you have less than 10 microamps of leakage at 1,000 volts, when in fact, the device may exceed the rated leakage at rated Vdrm and be defective. This may mislead one to unknowingly conclude that a bad device is good.

This test is only acceptable for devices with a maximum Vdrm of 1,000 volts and a maximum Idrm @ Vdrm of 10μA specification. Tests on devices with higher ratings should be considered invalid.

IV Testing with a Huntron Tracker

Component Testing routinely requires various test equipment and test methods. Accuracy, results and interpretations from these tests will vary with test equipment and the experience level of the technician performing the tests.

The Huntron Tracker, www.huntron.com, is a useful troubleshooting instrument, but as with any other test instrument, it has limitations. The Huntron Tracker provides dynamic testing of components with a visual signature, indicating a pass, fail or degraded condition. Although this unit provides dynamic testing capabilities it is limited to low current and low voltages. The Huntron Tracker 1000 has selectable voltage ranges. These ranges limit the voltage and current available for testing.

Range	Vp	Vrms	mArms
High	60	42.43	0.6
Medium	20	14.14	0.6
Low	10	7.07	135

These values make it an ideal instrument for testing small discrete components and integrated circuits that operate within these available parameters.

The visual pass, fail or degraded signature is an efficient way to determine the quality of components. However, it requires the technician to compare the visual signature of the component under test with the signature of a known good component. Over time the technician can become proficient enough that he may memorize the visual signatures of common components.

The Huntron Tracker may be used to troubleshoot circuit boards and electronic assemblies. But the current and voltage limitations still hold true. In circuit testing lends itself to the presence of parallel current paths, visual signatures may become misleading. The technician may have to remove the component under test to get a qualified visual signature. Ultimately, as with many troubleshooting tools, is most useful in identifying suspect devices. Additional testing may be required to positively determine if a device is good or not.

Furthermore, devices produced by different manufacturers are likely to produce different signatures. This does not necessarily indicate a failed device.

V IGBT Handling Precautions

Since IGBT gates are insulated from any other conducting region, care should be taken to prevent static build up, which could possibly damage gate oxides. IGBT modules are shipped from the factory with conductive foam contacting the gate and emitter control terminals. Never touch the gate terminals during assembly and keep the conducting foam or copper grounding straps in place until permanent connections are made to the gate and emitter control terminals. Always ground parts touching gate terminals during installation. In general, standard ESD precautions applicable to MOSFETs should be followed.

Other handling precautions that should be observed are:

1. Use a grounded work station with grounded floors and grounded wrist straps when handling devices.

2. Use a 100Ω resistor in series with the gate when performing curve tracer tests.

3. Never install devices into systems with power connected to the system.

4. Use soldering irons with grounded tips when soldering to gate terminals.

VI IGBT Testing

Most manufacturers IGBT devices are 100% tested before shipping and guaranteed to meet the published parametric data. We generally do not recommend re-testing by the customer because of the potential of damaging the device. If it is necessary to assess the electrical characteristics of the IGBT the following tests can be performed:

General Requirements:

(1) Always use static (ESD) safe handling procedures. Replace the conductive gate-emitter foam after testing.
(2) Never apply connector to emitter voltages greater than the IGBT's V_{CES} rating. Never apply gate to emitter voltages greater than the IGBT's V_{GES} rating. When using a curve tracer, ramp the voltage up and back down for each test.
(3) Never apply a voltage greater than 20V to the collector-emitter with the gate terminal open.
(4) Avoid thermal shock. Never put a cold device on a preheated hotplate. The temperature should not increase more than 10°C/min.

Digital multi-meter (DMM) test procedure:

(1) Equipment Requirement – DMM with diode check mode and battery voltage less than 20V. (Typical units using 9V battery are OK).
(2) Collector-Emitter Junction test:
- With the module out of circuit remove the conductive foam and short the gate to emitter.
- With DMM in diode check mode, the collector to emitter should give a normal diode reading with positive on the emitter and negative on the collector.
- The DMM should read open or infinite with positive on the collector and negative on the emitter. Damaged IGBTs may test as shorted in both positive and negative directions, open in both directions, or resistive in both directions.

(3) Gate Oxide test: With the DMM in resistance mode the resistance from gate to collector and gate to emitter should read infinite on a good device. A damaged device may be shorted or have resistive leakage from gate to collector and/or emitter.

Curve Tracer test procedure (Tests #1 & #2 require a high power curve tracer like Tektronix 371A):

(1) Measure $V_{CE(sat)}$ with $I_C=I_{C(rated)}$, T_j=25C, V_{GE}=15V
(2) Measure V_F (free wheel diode) with $I_E = I_{E(rated)}$, T_j=25C, V_{GE}=0 (shorted)
(3) Measure I_{CES} with $V_{CE}=V_{CES}$, T_j=25C, V_{GE}=0 (shorted)
(4) Measure $V_{GE(th)}$ with V_{CE}=10V, $I_C=I_{C(rated)}$/10,000

Reference & Credits:

I. Balenovich, J.D., "SCR and Diode Resistance Measurements with a Volt Ohmmeter," Westinghouse Tech Tip 5-5. Youngwood, PA: Westinghouse Electric Corp., Semiconductor Division, 1975.

Powerex Rectifier and Thyristor Applications and Technical Data Book, First Edition, August 1993. Copyright 1993 by Powerex, Inc. www.powerex.com

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III. Neil K LeJeune, BSEE Westcode Semiconductors, Inc. Long Beach, CA. www.westcode.com

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VI. Eric Motto, Powerex, Inc.