Standard Test Method for Measuring Transistor and Diode Leakage Currents [Metric][1]

This standard is issued under the fixed designation F 769M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of leakage currents of transistors and diodes. These procedures are intended for the measurement of currents in the range from 10^{-11} to 10^{-3} A.

1.2 This test method may be used with either a virtual-ground current meter or a resistance-shunt current meter.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions:*

2.1.1 *resistance-shunt meter*—a meter that determines current by measuring the voltage generated across shunt resistors by the current.

2.1.2 *virtual-ground meter*—a meter employing feedback to the amplifier in such a way as to make the meter input appear to be at ground potential.

3. Summary of Test Method

3.1 A junction whose leakage is to be determined is reverse-biased with a power supply. A current meter is placed in series with the junction and the appropriate range is selected on the meter. The current is read directly from the meter readout.

4. Significance and Use

4.1 Knowledge of diode and transistor leakage currents is very important to the circuit designer. Proper transistor biasing depends on accurate leakage current data. In addition, these currents are of special interest to the radiation effects community because leakage current is affected by total dose.

5. Interferences

5.1 Noise generated by thermal agitation in the various resistances in the test circuit sets an ultimate limit of instrument resolution. The noise current generated in a current meter shunt resistor is proportional to the inverse square root of the resistance, so a high shunt resistance value is desirable.

5.2 Other sources of noise are a–c signals propagating through the power supply or imposed on the test leads. A meter with a high a–c rejection ratio and with high common mode rejection ratio will be less sensitive to such forms of noise. A shielded test fixture may be required for proper measurement of low currents.

5.3 All components associated with very high resistance circuitry should be mechanically rigid. Movement of a coaxial cable can produce piezoelectric and triboelectric effects in the cable which result in voltages across the current meter inputs.

5.4 When working with a high resistance source, all leakage paths must be high in comparison to the circuit resistance. Phenolic or rubber insulation, for example, may have a resistance of only $10^{9}\Omega$, causing large errors in measurements with circuit resistances of greater than $10^{8}\Omega$.

5.5 Circuits employing a feedback picoammeter can have measurement errors which result from offset current, offset voltage, drift, and time constants in the amplifier. Amplifier time constants are of particular importance whenever the annealing rate of an irradiated device approaches the sampling rate of the current meter.

5.6 The voltage drop across a resistance-shunt type ammeter for a given current varies with the range selected. Therefore, a range which gives maximum meter resolution will also introduce maximum voltage drop error. An excellent way of determining the input resistance of an ammeter is by direct measurement using a transistor curve tracer. A range should be selected which has

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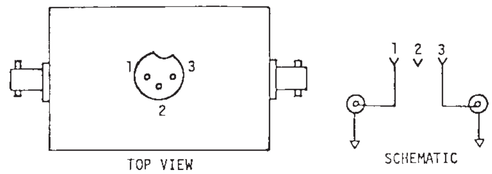

FIG. 1 Unshielded Test Fixture

an associated resistance less than 1 % of the equivalent resistance (bias voltage/leakage current) of the test device.

5.7 Care must be taken to keep the test device and test fixture free from contamination such as dust, dirt, solder flux, oil films, fingerprints, and water vapor. It is therefore important to perform this measurement in a clean, dry environment. If open-socket measurements yield a current value greater than 1 % of the test device leakage current, the socket should be cleaned. Methyl alcohol will dissolve most common dirt without chemically attacking the insulation. Test devices should be cleaned prior to measurement and cotton gloves or some other form of protective covering should be used to prevent subsequent contamination.

5.8 Transparent or translucent package types admit light which may generate significant photocurrents in semiconductors. Therefore, leakage current measurements must be made under dark conditions for devices with these packages.

5.9 The reverse saturation, or leakage, current of a *p-n* junction device is dependent upon temperature. A good estimate of the effect of varying the temperature upon leakage current is that the current approximately doubles for every 10°C rise in temperature.

6. Apparatus

6.1 *D-C Power Supply*, regulated, with floating output.

6.2 *Electrometer*, or current meter with accuracy of 6 % or better for a reading of 1×10^{-11} A.

6.3 *Test Fixture*, similar to Fig. 1 or Fig. 2. The fixture shown in Fig. 1 may be used when shielding is not necessary (error in current measurement resulting from ambient a-c noise << measured value). When shielding is necessary, a fixture similar to that of Fig. 2 is required.

6.4 *Coaxial Cables*.

6.5 *Digital Voltmeter* with 1 % accuracy.

6.6 Temperature sensor capable of measuring ambient temperature in the immediate vicinity of the device under test to within ±0.5°C.

7. Calibration

7.1 Adjust power supply to the voltage to be used in biasing the junction. Measure voltage with voltmeter.

7.2 Select a resistor such that $R = V_{BIAS}/ I_{LEAK(EXPECTED)}$.

7.3 Place the resistor in the socket and measure the current. Verify that the current is within $I_{LEAK(EXPECTED)} \pm$ (Resistor Tolerance + Voltmeter Accuracy + Electrometer or Current Meter Accuracy).

7.4 Remove resistor from socket and measure the current. Verify that the open-socket current is less than 1 % of the expected leakage current value for currents in the range from 10^{-10} to 10^{-3} A and less than 6 % for currents in the range 10^{-11} A.

8. Procedure

8.1 Turn power supply and current meter on. Allow warm-up period recommended by manufacturers of instruments.

8.2 Connect power supply and current meter to test fixture.

8.3 Adjust the power supply to the specified voltage. This voltage may be determined from either the manufacturer's specification sheets or examination of device characteristics using a curve tracer.

8.4 Place the test device in the socket and allow it to reach thermal equilibrium. Read leakage current directly from the current meter. Record leakage current and ambient temperature. See Fig. 3 and Fig. 4 for typical diode test circuits.

9. Report

9.1 Report the following information:

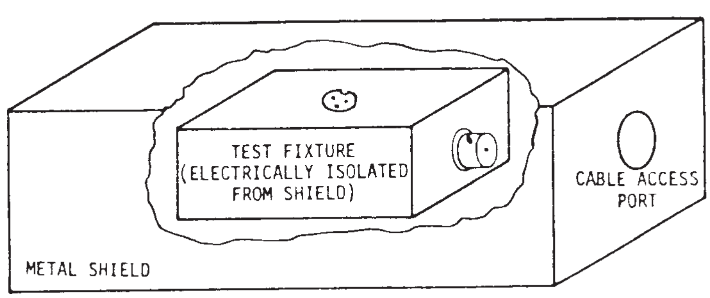

FIG. 2 Shielded Test Fixture

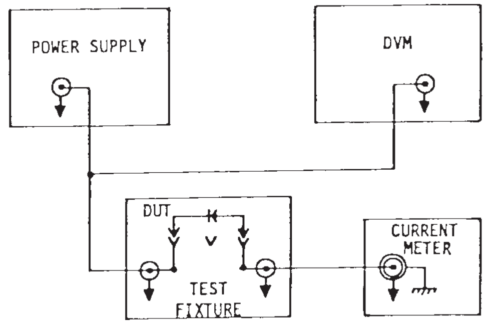

FIG. 3 Typical Test Circuit (Unshielded) for Diodes

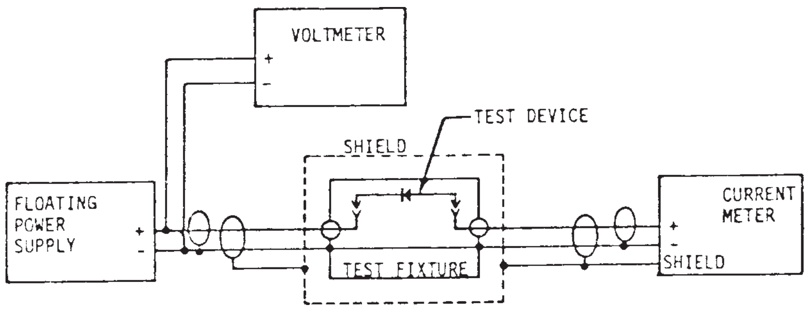

FIG. 4 Typical Test Circuit (Shielded) for Diodes

9.1.1 Part number of each test device,
9.1.2 Reverse bias used,
9.1.3 Leakage current for each device, and
9.1.4 Ambient temperature at time of measurement.

10. Precision and Bias

10.1 Three groups of devices, each with two sets of seven test devices, were used in an interlaboratory experiment. Three device types (1N58A, 1N457, and 2N3819) were selected to explore the interlaboratory precision of the test method at three levels of current: micro-, nano-, and pico-amperes.

10.2 Five laboratories were involved in the experiment; one served as the reference laboratory. Each of the four participating laboratories tested one set of devices in each of the device groups. The reference laboratory measured the leakage current for all six device sets at three temperatures to establish the temperature coefficient for each device. This was used to compare the leakage current reported by each participating laboratory for its ambient temperature with the leakage current the reference laboratory would have measured at that temperature.

10.3 The measure used to compare the measurement results was the percentage difference in the leakage currents measured by the reference and the participating laboratory for each test device.

10.4 An analysis of the results of the interlaboratory experiment showed that the reproducibility of the test method was approximately 5 % and that there was a bias of approximately 8 %. The results indicate that the precision and bias of the test method is limited by the accuracy and the control of the temperature of the devices during the test. This conclusion is based on the sensitivity of the device leakage current to temperature and the procedure used by the laboratories to measure and control the device temperature. The devices used in the experiment showed a leakage current sensitivity of approximately 5 % per °C.

11. Keywords

11.1 diode; junction leakage; leakage current; radiation testing; total radiation dose; transistor