Designation: F 616M – 96

METRIC

Standard Test Method for Measuring MOSFET Drain Leakage Current [Metric][1]

This standard is issued under the fixed designation F 616M; 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 MOSFET (Note 1) drain leakage current.

NOTE 1—MOS is an acronym for metal-oxide semiconductor; FET is an acronym for field-effect transistor.

1.2 This test method is applicable to all enhancement-mode and depletion-mode MOSFETs. This test method specifies positive voltage and current, conventions specifically applicable to *n*-channel MOSFETs. The substitution of negative voltage and negative current makes the method directly applicable to *p*-channel MOSFETs.

1.3 This d-c test method is applicable for the range of drain voltages greater than 0 V but less than the drain breakdown voltage.

1.4 *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. Referenced Documents

2.1 *ASTM Standards:*

E 178 Practice for Dealing with Outlying Observations [2]

3. Terminology

3.1 *Definition:*

3.1.1 *drain leakage current of a MOSFET*—the d-c current from the drain terminal when the relationship of the gate voltage to the threshold voltage is such that the MOSFET is in the OFF state.

4. Summary of Test Method

4.1 The drain current of the MOSFET under test is measured at a specified drain voltage with the MOSFET in the OFF condition.

4.2 Before this test method can be implemented, test conditions appropriate for the MOSFET to be measured must be selected and agreed upon by the parties to the test. Conditions will vary from one MOSFET type to another and are determined in part by the intended application. The following items are not specified by this test method, and shall be agreed upon between the parties to the test.

4.2.1 Permissible range of ambient temperature.

4.2.2 Drain to source voltage V_{DS} at which the measurement is to be made.

4.2.3 Gate to source voltage V_{GS} at which the measurement is to be made. For most MOSFETs, use a gate voltage approximately 5 V different from the saturated threshold voltage, in the direction of lesser drain current.

NOTE 2—To avoid the possibility of forward biasing the gate protection diodes, the gate should not be permitted to have a potential with respect to the substrate (or source, if no substrate connection is provided) of a sign opposite that of the drain potential with respect to the substrate (or source), unless the manufacturer's specifications expressly permit such a condition.

5. Significance and Use

5.1 The drain leakage current is a basic MOSFET parameter that must be determined for the design and application of discrete MOSFETs and MOS-integrated circuits. The drain leakage current of the MOSFET is utilized in circuit design to determine performance attributes such as power dissipation, noise margin, charge storage time, amplifier effects, etc., of digital and analog circuitry.

6. Interferences

6.1 Care must be taken to prevent electrical voltage overstress damage to the gate dielectric as a result of device handling during the leakage current measurement. Under certain conditions, electrostatic discharge from the human body can result in permanent damage to the gate insulator.

6.2 Valid drain leakage current data will be obtained only if the magnitude of the drain voltage applied during the drain leakage current measurement is less than the drain-substrate junction breakdown voltage.

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[1] This test method is under the jurisdiction of ASTM Committee F-1 on Electronics and is the direct responsibility of Subcommittee F01.11 on Quality and Hardness Assurance.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

6.3 The high (positive) input of the ammeter (A1) must always be connected to the drain side of the MOSFET, regardless of the polarity of the device. Note that with such a connection, the ammeter will give negative current readings for *n*-channel MOSFET's. The reason for connecting the high input to the drain side of the MOSFET is to reduce errors in the measurement of drain current due to meter-leakage currents. Electronic ammeters are designed for low internal-leakage operation only when the high input is connected to the low-leakage, high-resistance side of the current path.

6.4 The ambient temperature must be maintained within the specified range (see 4.2.1).

6.5 The measurement method described in this test method is valid only if the MOSFET stability is sufficient to prevent changes in drain leakage current due to bias-temperature stress applied during the drain leakage current measurement.

6.6 The MOSFET threshold voltage measurements should be made under dark conditions when the MOSFET package admits enough light to increase the apparent leakage current.

6.7 Care must be taken that the manufacturer's specification limits on the MOSFET are not exceeded, even for very brief periods, or the characteristics of the MOSFET may be changed.

7. Apparatus

7.1 *Transistor Test Fixture*, to connect the MOSFET under test to the test circuit. Electrical contacts shall be clean and of good quality. Fixture and test circuit leakage current must be low. The test fixture must be shielded in order to avoid interference from electrostatic pickup. Shielded cables must be used to connect the ammeter to the drain connection.

NOTE 3—One method to determine if the leakage currents are sufficiently low is to assemble the test circuit, apply voltages (V_1 and V_2) approximately equal to the largest anticipated test voltages, and measure the resultant current (A_1). If it is less than 5 % of the anticipated leakage current, the fixture and test circuit are adequate.

7.2 Voltmeters V_1 and V_2, with (*1*) an input impedance of greater than 10 MΩ, and (*2*) capability of measuring 0 to 20 V with an accuracy of ±0.5 % of full-scale or better.

7.3 *Ammeter*, A_1, capable of measuring current in the 1 pA to 0.1 A range, inclusive, with an accuracy of ±5 % of full scale, or better (see 6.3).

NOTE 4—Vibrating-capacitor electrometers may modulate the voltage drop across their input terminals. Such modulation can change the operating conditions of the MOSFET in an uncontrolled manner and lead to invalid results.

7.4 *Voltage Sources*, VS_1 and VS_2, meeting the following specifications after warmup:

7.4.1 Drift less than ±0.15 % of the set voltage over an 8-h period,

7.4.2 Periodic and random deviation (noise and ripple) less than 0.5 % of the output voltage,

7.4.3 Output voltage adjustable from zero up to at least the maximum rated drain-to-source voltage of the MOSFET to be tested.

7.4.4 Having an output current limit adjustment capable of limiting the output current to a value equal to the maximum rated drain current (I_{DSS}) of the MOSFET to be tested.

7.5 *Temperature-Measuring Device*, capable of measuring the temperature in the vicinity of the device under test to an accuracy of ±1°C at the temperature specified for the measurement (see 4.2.1).

8. Sampling

8.1 This test method determines the properties of a single specimen. If sampling procedures are used to select devices for test, the procedures shall be agreed upon between the parties to the test.

9. Procedure

9.1 Assemble the test circuit shown in Fig. 1 (see 6.3).

9.2 Connect the substrate terminal of the test fixture to the source electrode if a substrate electrode is provided on the MOSFET.

9.3 Turn on the apparatus and allow it to warm up at least for the period specified by the apparatus manufacturer.

9.4 Set the voltage and current controls on voltage sources VS_1 and VS_2 to zero.

9.4.1 Short-circuit the output terminals of VS_1.

9.4.2 Adjust the current limit control so that the output current of VS_1 is limited to the maximum rated drain current (I_{DSS}) rating of the MOSFET to be tested.

NOTE 5—It may be necessary to increase the voltage setting from zero slightly in order to set the current limit.

9.4.3 Reset the voltage control to zero.

9.4.4 Remove the short circuit from VS_1.

9.4.5 Repeat the procedure of 9.4.1-9.4.4 for VS_2.

9.5 Insert the MOSFET to be tested into the test fixture.

9.6 Measure and record the ambient temperature in the vicinity of the test fixture.

9.7 Adjust the voltage source VS_2 until the voltmeter V_2 indicates the specified value of V_{DS} (see 4.2.2).

9.8 Adjust the voltage source VS_1 until the voltmeter V_1 indicates the specified voltage value V_{GS} (see 4.2.3).

NOTE 6—If the specified V_{GS} is zero volts, replace the short-circuit on the output controls of VS_1 (see 9.4.1).

9.9 Record the current value, I_L, indicated by ammeter A_1. This is the drain leakage current at the specified V_{GS} and V_{DS}.

9.10 Measure and record the posttest ambient temperature in the vicinity of the test fixture.

NOTE 7—It may be necessary to allow the ammeter to settle.

10. Report

10.1 Report the following information:

10.1.1 Identification of operator,

10.1.2 Date of test,

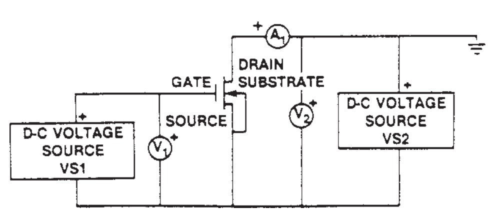

FIG. 1 Test Circuit for *n*-Channel Enhancement-Mode MOSFETs (see 1.2)

10.1.3 Device type and identification of MOSFET tested,

10.1.4 Ambient temperature, °C,

10.1.5 Measured value of drain leakage current, I_L,

10.1.6 Measured value of the gate voltage, V_{GS},

10.1.7 Measured value of the drain voltage, V_{DS}, at which the drain leakage current was measured, and

10.1.8 Calibration data for the ammeter, A_1.

11. Precision and Bias [3]

11.1 *Precision*:

11.1.1 An interlaboratory test of this test method was conducted among six laboratories starting with five transistors each of three different types. Each laboratory was to make one measurement of the drain leakage current of each transistor. One transistor became inoperative early in this test method so the data for this device were excluded from the analysis. Three other transistors were reported to be inoperative by the last laboratory to make measurements. Therefore, data from only four laboratories were available for these devices.

11.1.2 An analysis of the data showed that one laboratory reported values for leakage current that, except for data on one transistor, were much larger than those reported by the other laboratories. The T_n criterion for single samples of Practice E 178 was applied to the data from this laboratory. All but one of the reported values failed the criterion for significance at the level of 2.5 %. In fact, the values of T_n observed for all but one of these cases would occur by chance with a probability of less than 0.001. On this basis, the data from this laboratory were rejected for use in estimating the precision of this test method. Data from one transistor were rejected because the variability of leakage currents measured by the participating laboratories was more than four times larger than that for the other transistors of that type (MEM655). Data from one laboratory for three of the five transistors (Type MEM511C) failed the T_n criterion for significance at the level of 2.5 % and were rejected.

11.1.3 The analysis of the remaining data involved the calculation of the mean value and percent standard deviation of the leakage currents obtained for each transistor. An average percent standard deviation was also calculated for the transistors of a given type. The results of these calculations are summarized in Table 1.

11.2 *Bias*—The bias for this test method has not been determined since there is no suitable accepted reference material.

12. Keywords

12.1 drain leakage current; leakage current; MOSFET

[3] Supporting data are available from ASTM Headquarters. Request RR:F01-1011.

TABLE 1 Interlaboratory Test Data

Transistor Type	Range of Mean Values of Leakage Current	Range of Percent Standard Deviation	Average Percent Standard Deviation
MEM511C	23 to 108 pA	5.7 to 16.6	10.1
MEM655 [A]	40 to 99 pA	15 to 24.3	18.9
MEM711 [B]	0.62 to 44 nA	3.5 to 9.3	7.3

[A] Three transistors measured by four laboratories and one by five.
[B] Four transistors measured by five laboratories and one by four.