

Submitted for recognition as an American National Standard

**(R) Electromagnetic Compatibility Measurement Procedure for Vehicle
Components—Part 13—Immunity to Electrostatic Discharge**

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1. **Scope**—This SAE Standard specifies the test methods and procedures necessary to evaluate electrical components intended for automotive use to the threat of Electrostatic Discharges (ESDs). It describes test procedures for evaluating electrical components on the bench in the powered-up mode and for packaging and handling.

Functional status classifications for immunity to ESD are given in Appendix A.

Sensitivity classifications for ESD sensitive devices are given in Appendix A.

A procedure for calibrating the simulator that is used for electrostatic discharges is given in Appendix B.

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1.1 Measurement Philosophy—The familiar static charge generated and discharged when moving about inside a vehicle or exiting from a vehicle has assumed greater significance with the increase of vehicular electronic components. Tests simulating the electrostatic discharge of humans, in common use by various industries, were examined and it was determined that they were not applicable to the automotive environment. As a consequence, test tailored to the automotive environment were developed.

Tests that simulate an electrostatic discharge (ESD) into a vehicular electrical system are based on the human ESD model. The ESD model consists essentially of a capacitor formed by a person to his surroundings and discharged through a path that includes that person's resistance as well as vehicle loads. Sensitive electrical devices can be adversely affected by energy either injected or radiated from electrostatic discharges.

ESD generates collapsing radiated EM fields as a result of the rapid high-voltage charge transfer. These EMS fields are an inherent part of the discharge event and are not simulated separately.

Components can also be damaged by ESD during handling and they should therefore be evaluated for ESD sensitivity in a non-powered mode. The test procedures to evaluate the ESD sensitivity classification of components in a non-powered mode is detailed in Section 5 of this document.

2. References

2.1 Applicable Publications—The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113-1—Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft) (60 Hz to 18 GHz)

2.1.2 IEC PUBLICATION—Available from International Electrotechnical Commission, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland.

IEC 801-2 (1984 issue)
IEC 61000-4-2 (1995/01 issue)

2.1.3 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO TR 10605

3. Test Equipment—This section describes test equipment that is applicable to all parts of this document, including Appendix B.

3.1 An ESD simulator that simulates the Human Body ESD model (see Figures 1A and 1B) having the following characteristics shall be used:

- a. Voltage Range—Variable from -25 to $+25$ kV
- b. Capacitance— 330 pF $\pm 10\%$ pF, 150 pF $\pm 10\%$ (Multiple Probes)
- c. Resistance— 2000 Ω $\pm 10\%$ Ω
- d. Risetime
 1. Direct Contact— 0.7 to 1.0 ns
 2. Air Discharge ≤ 5 ns
- e. Tip—(see Figure 2)—IEC Standard 801-2

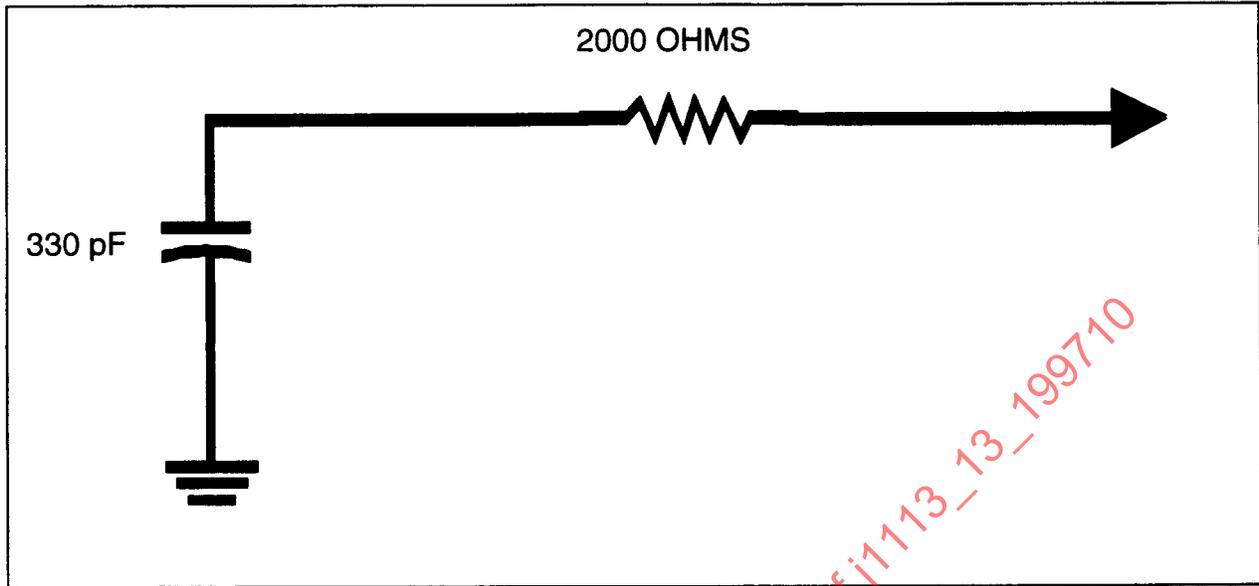


FIGURE 1A—POWERED-UP TEST SIMULATOR PARAMETERS

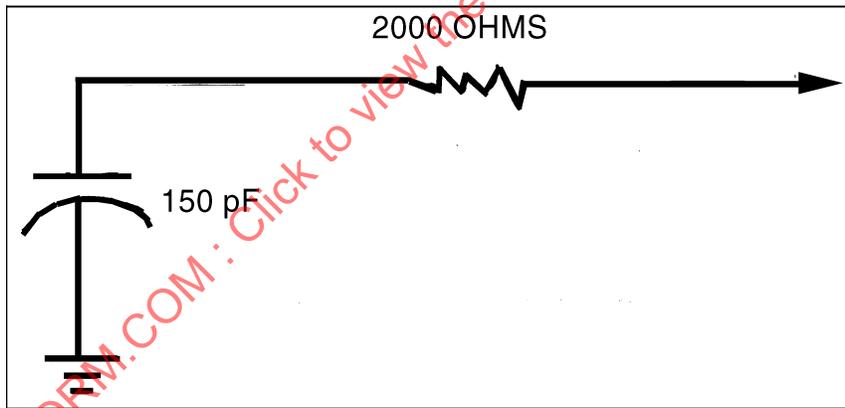


FIGURE 1B—PACKAGING AND HANDLING TEST SIMULATOR PARAMETERS

FIGURE 1—HUMAN BODY MODEL PARAMETERS

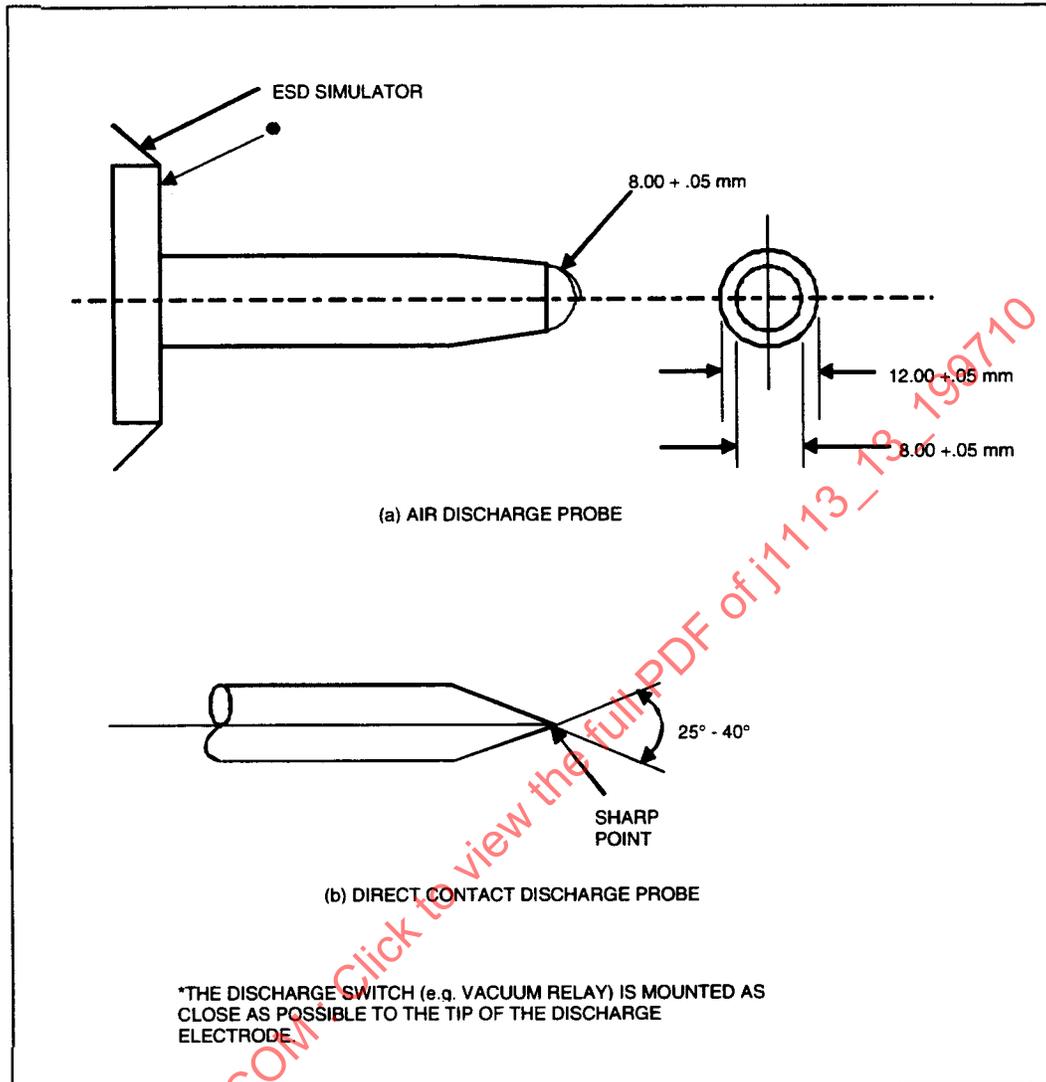


FIGURE 2—ESD SIMULATOR DISCHARGE TIP PROBES

- 3.1.1 The ESD simulator shall be designed so that the discharge capacitance is fully charged to the desired voltage before the energy can be switched to the DUT.
- 3.1.2 The construction of the ESD simulator must be such that the high voltage ground and the chassis ground are electrically isolated from each other.
- 3.1.3 The ESD Simulator is commercially available.
- 3.2 Ground Plane**—The ground plane shall be a conductive metallic sheet (i.e., copper, brass or galvanized steel)¹ as defined in J1113-1. The ground plane shall be connected to the facility earth ground by a ground strap as short and as wide as possible. The inductance of the ground strap shall be $\leq 2 \mu\text{H}$. (Length less than 2 m and at least 50 mm wide suggested.)

1. Aluminum ground planes are not recommended because aluminum oxide buildup causes a nonconductive layer.

- 3.3 Isolation Blocks**—Isolation blocks, if used, shall be constructed of clean, non-hygroscopic, insulating material. The blocks are to be 25 mm in height and project beyond the DUT by at least 20 mm on all sides.
- 3.4 Coaxial Target**—A coaxial target is defined by the International Electrotechnical Commission (IEC) Standard 801-2 (1984 issue) (see Figure 3). It is available commercially. The target is used during the ESD simulator verification of Appendix B. IEC 61000-4-2:1995 calls out a new target. Either target may be used, however, most international companies and organizations are now specifying the IEC 61000 target.

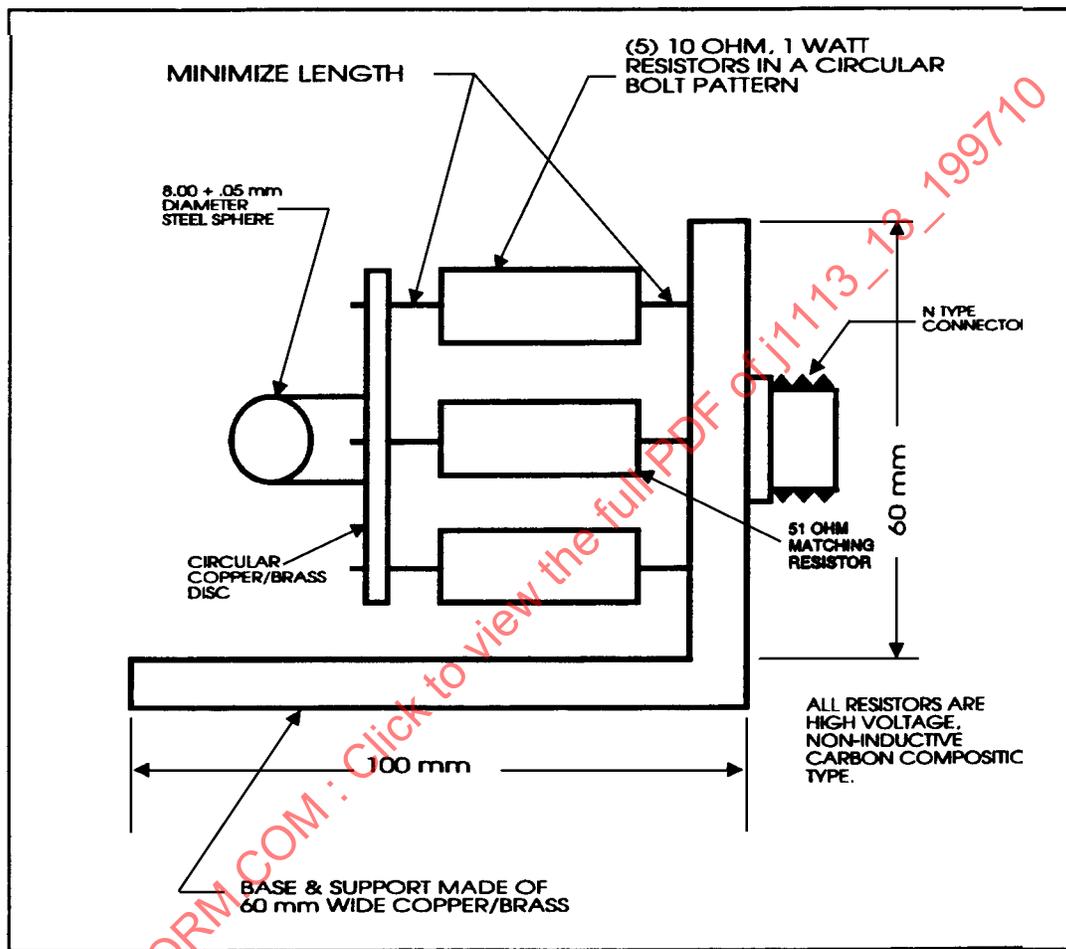


FIGURE 3—ESD COAXIAL TARGET FROM IEC STANDARD 801-2

- 3.5 20 dB Attenuator**—A 50 Ω , 20 dB wideband attenuator (bandwidth 18 GHz) may be needed at the output of the coaxial target during the simulator verification of Appendix B.
- 3.6 Measurement Instrumentation**—Verification of the risetime for the ESD simulator requires an analog measurement device with a minimum effective single shot bandwidth of 1 GHz or a digital measurement device with a minimum sampling rates of 2 Gigasamples per second and a single shot bandwidth of at least 500 MHz. Each instrument shall be 50 Ω input impedance. The use of a Faraday Shield, to separate the target from the measurement instrumentation, is highly recommended.
- 3.7 Probe**—The ESD simulator charging voltage shall be verified using an electrometer (input resistance 100 Gohm minimum).

3.8 Test Equipment used to verify the requirements of the DUT shall not be sensitive to ESD.

3.9 Static Dissipative Mat—The surface resistivity of this mat shall be between 10^7 to 10^9 Ω per square and placed on and connected to a ground plane as required by the Mat manufacturer.

4. Test Setup and Procedure for Powered-up Component Tests

4.1 Prior to performing the test, a test plan shall be generated which shall include interface test points, component mode of operation, number of test units, and any special instructions and changes from the standard test.

4.2 Before application of any discharges to the DUT, the ESD Simulator Discharge Verification procedure of Appendix B shall be performed.

4.2.1 For this test (powered-up test), the ESD simulator shall be configured with the 330 pF capacitor probe (Figure 1A).

4.3 Test Environment

4.3.1 TEMPERATURE RANGE— $23^\circ \pm 3^\circ\text{C}$; 20°C preferred.

4.3.2 RELATIVE HUMIDITY—20 to 50%; 20% preferred.

4.4 The test setup shall be configured in accordance with Figure 4.

4.5 The ESD simulator high voltage ground shall be directly connected to the ground plane by a grounding strap.

4.6 The DUT shall be placed on the ground plane (see Figure 4). Chassis-mounted components are to be placed directly on the ground plane. Components which will be isolated from ground in normal installation shall be tested with an insulator between the components and the ground plane using the isolation blocks defined in 3.3. All voltage supply pins shall be connected to an appropriate power source (automotive battery). All other pins shall have inputs applied as necessary to put the DUT into a simulated mode of operation.

NOTE—Test equipment susceptibility to ESD may limit the ability to conduct testing using normal operational inputs; at a minimum the DUT shall be in a powered, idling mode.

4.7 Each exposed shaft, button, switch, or surface of the DUT, which will be accessible to the occupant from inside the vehicle, shall be tested at each of the voltage levels as defined in Appendix A or as specified in the test plan in accordance with the following two methods.

4.7.1 DIRECT CONTACT DISCHARGE—The ESD simulator shall be placed in direct contact with all accessible discharge points. Each discharge point shall be tested to the contact discharge voltage levels in Appendix A.

4.7.2 AIR DISCHARGE—The ESD simulator shall be placed at a minimum distance of 15 mm away from the DUT. The simulator fingertip probe shall be held perpendicular (± 15 degrees) to the discharge location. The simulator fingertip probe shall very slowly be moved towards the DUT (i.e., $\leq 5\text{mm/s}$) until a discharge is obtained. Each point shall be tested to the air discharge voltage levels in Appendix A.

NOTE—If no discharge occurs, continue moving the probe towards the DUT until the simulator discharge tip is in contact with the discharge point. If the simulator makes contact with discharge point and no discharge has occurred, discontinue testing at that voltage level and location.

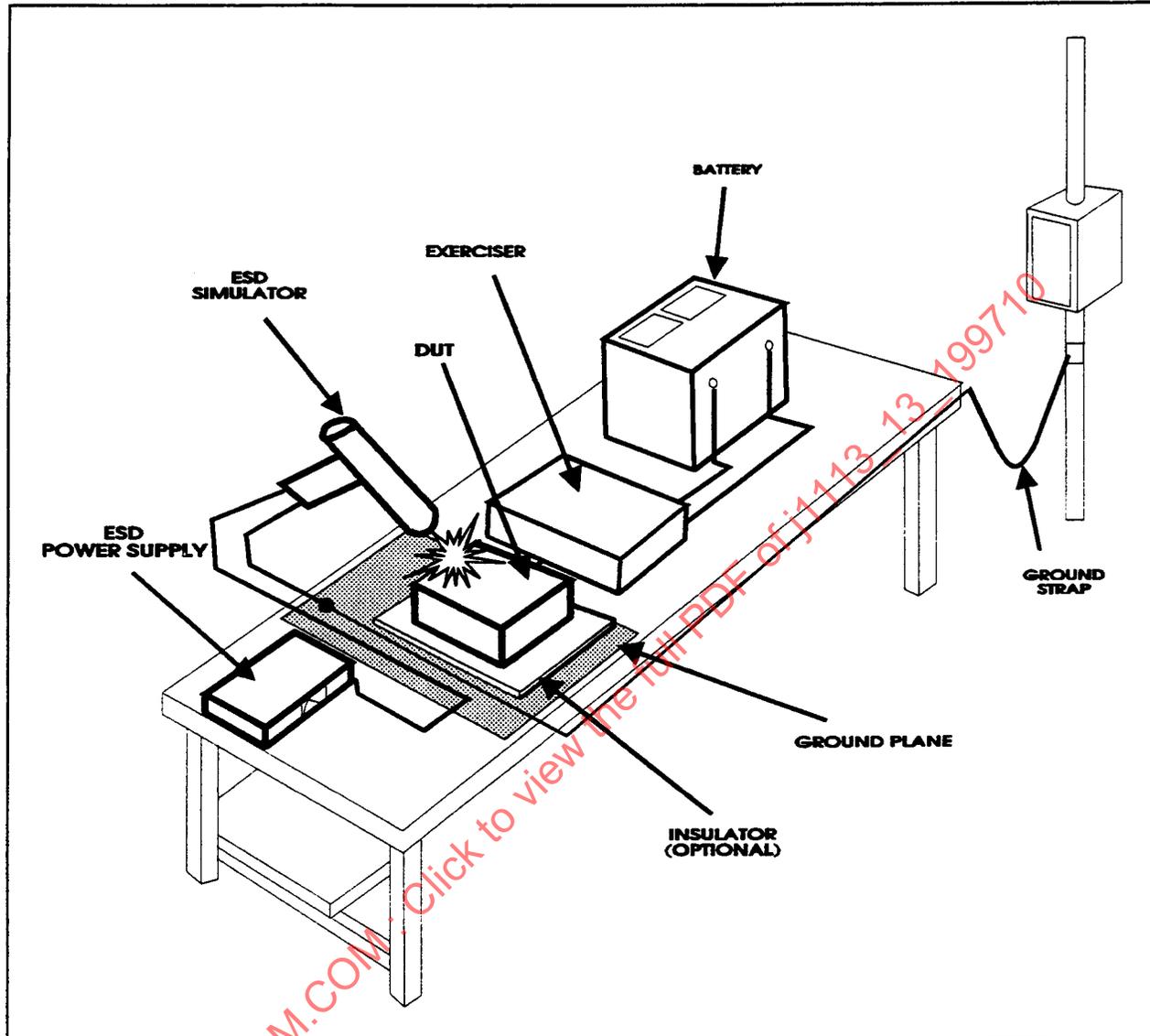


FIGURE 4—TEST SETUP FOR POWERED-UP COMPONENT TEST

- 4.8** Each discharge point shall be subjected to a minimum of three positive polarity and three negative polarity discharges at each voltage level. The time duration between discharges shall be a minimum of 5 s.

NOTE—At each voltage level, all discharge points of a device may be tested first at a single polarity and then tested with the alternate polarity.

- 4.9** During and after each series of three discharges, the DUT shall meet all applicable performance requirements.
- 4.10** Record all deviations noted (visible, audible, failures, etc.) on a data sheet such as the example Data Sheet 1 (see Section 5)

DATA SHEET 1

ELECTROSTATIC DISCHARGE TEST RECORD FOR COMPONENTS

COMPONENT DESCRIPTION _____ TEST NO. _____

PART NO. _____ PAGE _____ OF _____

COMPONENT FUNCTIONS _____

TEMPERATURE _____ RELATIVE HUMIDITY _____

SPECIAL TEST CONDITIONS _____

TEST FACILITY _____

REQUESTED BY _____ PHONE _____

TESTED BY _____ DATE _____

DISCHARGE POINT	VOLTAGE/POLARITY	PERFORMANCE DEVIATION

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FIGURE 5—DATA SHEET 1—ELECTROSTATIC DISCHARGE TEST RECORD FOR COMPONENTS

5. Test Setup and Procedure for Packaging and Handling Sensitivity Classification Test (Un-powered Test)

- 5.1** Prior to performing the test, generate a test plan including interface test points, DUT mode of operation, number of modules to be tested, and any special instructions and changes from the standard test.
- 5.2** Before applying any discharges to the DUT, perform the ESD simulator discharge verification procedures in Appendix B.
- 5.3** The test setup shall be configured according to Figure 6.

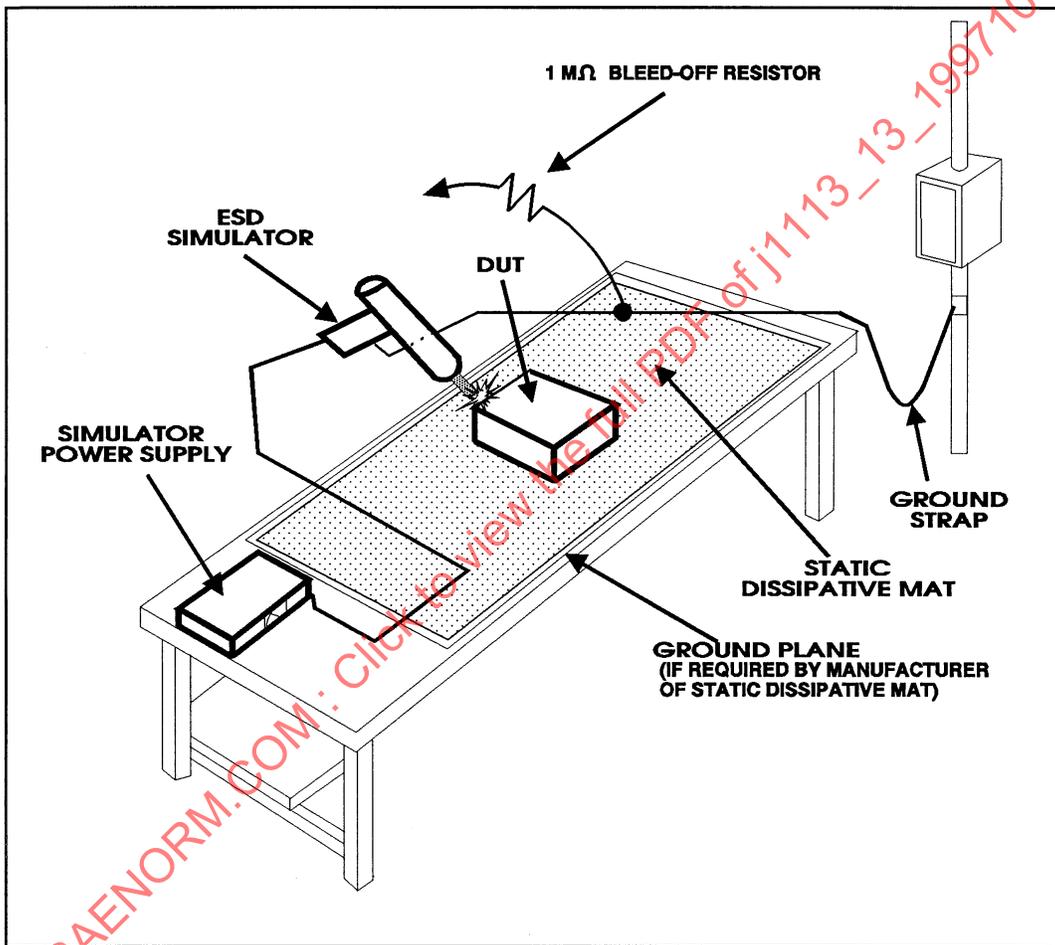


FIGURE 6—TEST SETUP FOR PACKAGING AND HANDLING CLASSIFICATION TEST

- 5.3.1** For this test, the ESD Simulator shall be configured with the 150 pF capacitor probe shown in Figure 1B.
- 5.4** Connect the ESD simulator high voltage ground directly to the ground plane (if used) or to the earth ground, by a grounding strap as described in 3.2.
- 5.5** DUTs shall be step stressed according to the test sequence shown in Table 1.

- 5.6 The DUT must pass a full functional test prior to any application of ESD.

NOTE—The test is to be performed on the DUT (checking for rise time, current leakage, etc.) and not on individual parts or components of the DUT.

- 5.7 Place the DUT on a static dissipative mat as described in 3.9 to bleed-off any accumulated charge of the DUT housing.
- 5.8 Remove the DUT power source.

TABLE 1—ESD TEST SEQUENCE AND VOLTAGE LEVELS

Test Sequence	Type of Discharge	Test Voltage Level	Minimum number of discharges at each polarity
1	Contact Discharge	±4 kV	3
2	Contact Discharge	±6 kV	3
3	Air Discharge	±8 kV	3
4	Contact Discharge	±8 kV	3
5	Air Discharge	±15 kV	3
6	Air Discharge	±25 kV	3

- 5.9 Apply the ESD at, but not limited to, each connector pin, case, button, switch display, case screw, and case opening of the DUT that is accessible during handling. For this procedure, recessed connector pins are considered accessible during handling.

- 5.9.1 Use a wire with gage 14 AWG to 20 AWG to access recessed connector pins. The wire shall be solid core (not stranded) and ≤25 mm long.

NOTE—Modules that have recessed pins in metallized grounded connector bodies where the pins are not easily accessible (e.g., with a finger) need not to be tested.

- 5.9.2 A connector with closely-spaced pins may result in a crowding of the lead wires. This makes it difficult to discharge to the intended wire. If this occurs, use multiple connectors with reduced number of lead wires in each. Evaluate each connector configuration separately.

- 5.10 **Direct Contact Discharge**—Place the ESD simulator in direct contact with all selected discharge points and test at the direct contact discharge voltages specified in Table 1. After each discharge to the DUT, residual charge remaining on the DUT shall be dissipated by briefly connecting a 1 MΩ resistor (see Figure 6) in the following sequence, (1) between the discharge location and earth ground, and (2) between the ground point of the DUT and earth ground.

- 5.10.1 A minimum of six discharges shall be applied to each test point at each voltage level, three with a positive polarity and three with a negative polarity.

- 5.11 **Air Discharge**—Test each discharge point at the air discharge voltages specified in Table 1 using the air discharge probe. Place the ESD simulator a minimum of 15 mm away from the DUT. Place the simulator air discharge probe perpendicular (±15 degrees) to the discharge location. Move it very slowly, i.e., 5 mm/s or less, toward the DUT until a single discharge is obtained. After each discharge to the DUT, residual charge remaining on the DUT shall be drained by briefly connecting a 1 MΩ resistor (see Figure 6) in the following sequence, (1) between the discharge location and earth ground, and (2) between the ground point of the DUT and earth ground.

5.11.1 A minimum of six discharges shall be applied to each test point at each voltage level, three with a positive polarity and three with a negative polarity.

5.11.2 If no discharge occurs, continue moving the probe towards the DUT until the simulator discharge probe contacts the discharge point. If still no discharge occurs, discontinue testing at that voltage level and location.

5.12 When testing inaccessible points (non-connector), slowly move the probe tip close enough to generate a discharge.

NOTE—Points shall be considered inaccessible when the ESD simulator probe cannot touch them directly.

5.13 After discharging to all the points of the DUT at one of the specified positive and negative voltage levels, the DUT shall meet all applicable functional tests. (After each positive and negative voltage level).

5.14 Record deviations on a data sheet such as the example Data Sheet 1 (see Figure 5).

5.15 Use Section A.2 to determine the ESD sensitivity classification.

NOTE—It is recommended that all DUT's survive ± 4 kV direct contact discharge, otherwise, they may be difficult to protect against ESD damage due to handling.

5.16 All CONTAINERS of ESD Sensitive (ESDS) devices and some ESDS devices themselves shall be clearly marked with a standard ESD warning label.

6. **Test Severity Levels**

6.1 A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113-1, Appendix A. Please review it prior to using the suggested Test Severity Levels presented in Appendix A.

7. **Notes**

7.1 **Marginal Indicia**—The change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

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APPENDIX A

TEST SEVERITY LEVELS

NOTE—Please review SAE J1113-1, Appendix A, prior to the use of this Appendix.

A.1 The test levels shown in Figure A1 are the recommended Performance Objective for the powered-up component test of Section 4.

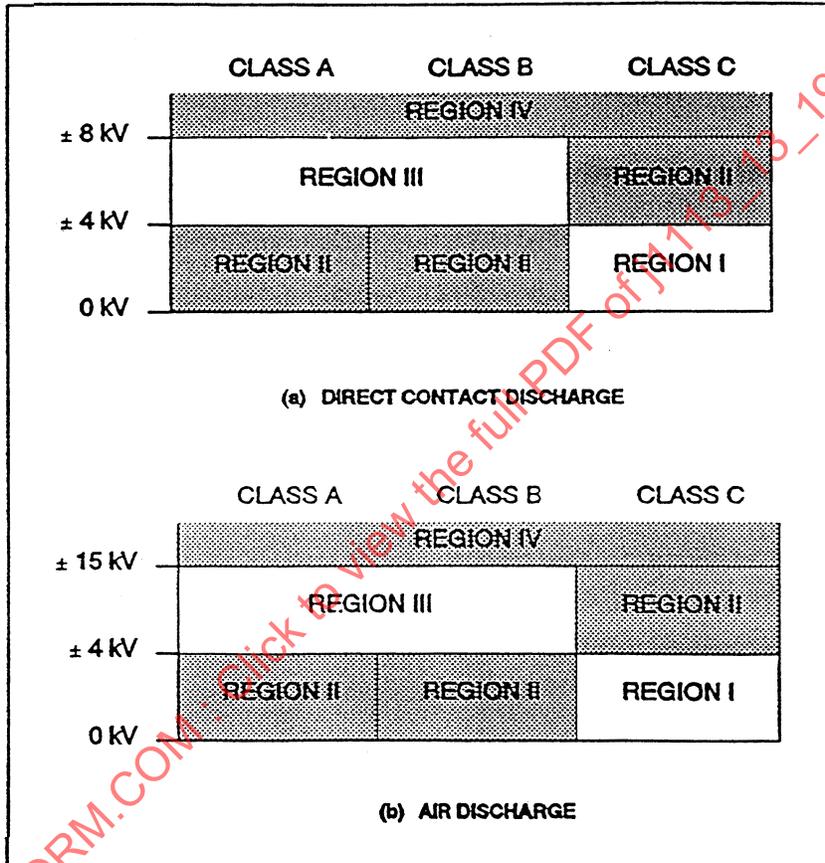


FIGURE A1—SUGGESTED TEST SEVERITY LEVELS

A.2 Figure A2 provides ESD Sensitivity Classification for the Packaging and Handling Sensitivity Classification test of Section 5.

ESD VOLTAGE (\pm kV)	TEST MODE	CLASSIFICATION
$0 < V \leq 4^*$	CONTACT DISCHARGE	EXTREMELY SENSITIVE
* MINIMUM RECOMMENDED PASSING LIMIT = ± 4 kV		
$4 < V \leq 6$	CONTACT DISCHARGE	HIGHLY SENSITIVE
$4 < V \leq 8$	AIR DISCHARGE	
$6 < V \leq 8$	CONTACT DISCHARGE	MODERATELY SENSITIVE
$8 < V \leq 15$	AIR DISCHARGE	
$15 < V \leq 25$	AIR DISCHARGE	SLIGHTLY SENSITIVE
$V > 25$	NOT TESTED	NOT SENSITIVE

FIGURE A2—ESD SENSITIVE COMPONENT CLASSIFICATION RECOMMENDATIONS

APPENDIX B

ELECTROSTATIC DISCHARGE SIMULATOR VERIFICATION PROCEDURE

B.1 Scope and Field of Application—This Appendix defines a test method for verifying the operation of an ESD simulator that is used for testing automotive electronic components and systems.

Two verification procedures are specified. Method B.2 is to be performed at least annually and method B.3 is to be performed daily.

B.2 ESD Simulator Full Verification Setup and Procedure—Shall be performed at least annually and more frequently with heavy usage.

B.2.1 The test setup shall be configured according to Figure B1. Figure B2 shows an equivalent schematic of the setup. Note that a 20 dB wideband attenuator may be required as shown in Figure B1 depending on the vertical sensitivity of the oscilloscope.

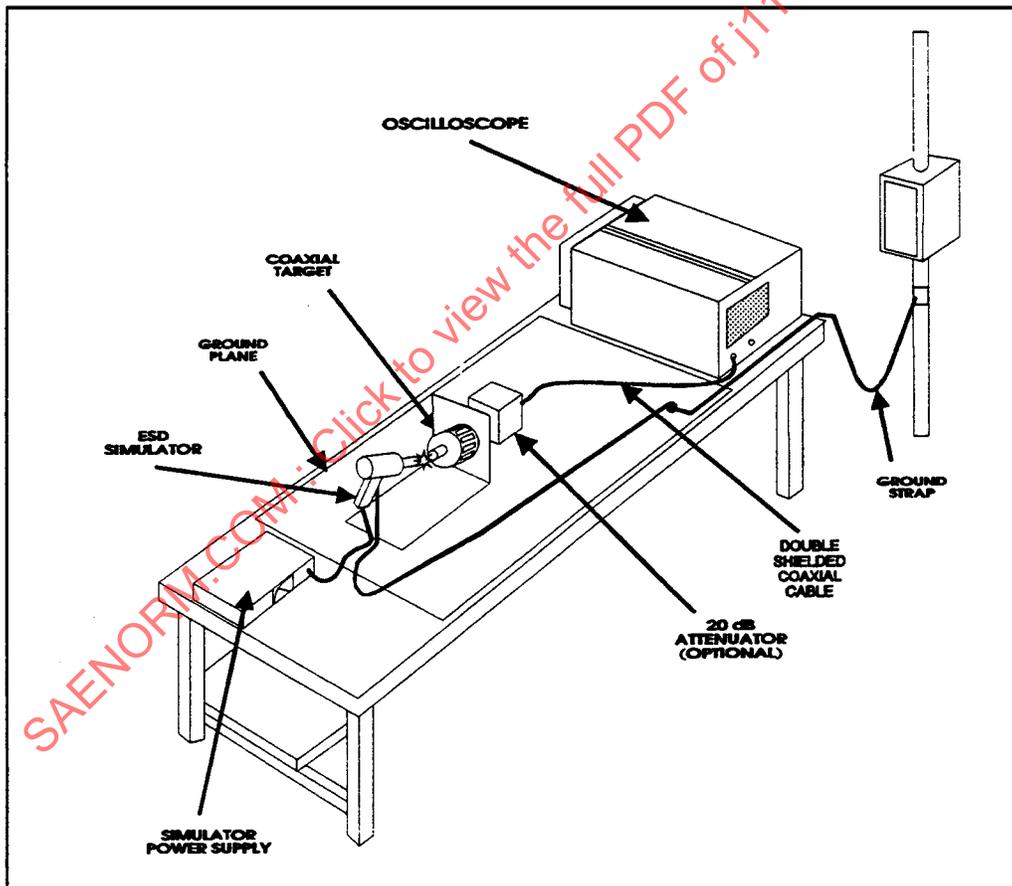


FIGURE B1—ESD SIMULATOR VERIFICATION TEST SETUP CONFIGURATION

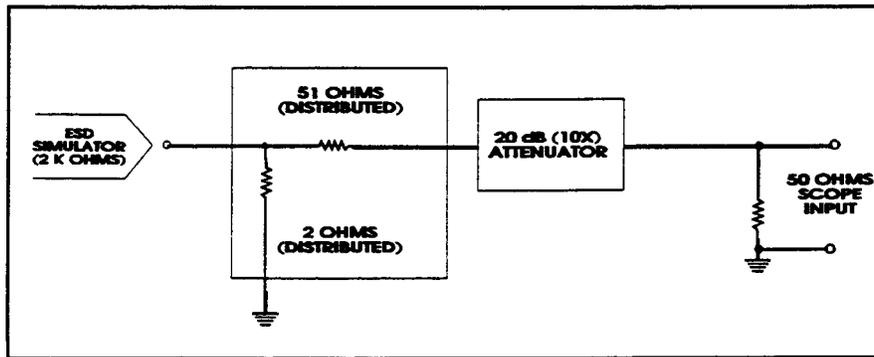


FIGURE B2—EQUIVALENT SCHEMATIC

- B.2.2** The coaxial target shall be located on and bonded to the center of the ground plane. The target output shall be connected to the oscilloscope through a 50 Ω double-shielded, high-frequency, cable with length ≤ 1 m. The cable shall not be looped and shall be insulated from the ground plane.
- B.2.3** The ESD simulator high-voltage ground shall be directly connected to the ground plane by a grounding strap with length ≤ 2 m and inductance ≤ 2 μ H. The ESD simulator shall be set up and operated according to its instruction manual.
- B.2.4** To calibrate the display voltage of the ESD simulator, first adjust the ESD simulator voltage to the desired level and polarity. Next, verify the voltage setting at levels of ± 2 kV, ± 4 kV, ± 6 kV, ± 8 kV, ± 15 kV, and ± 25 kV. The electrometer reading shall be within ± 500 V for voltages $\leq \pm 5$ kV and $\pm 10\%$ for voltages $> \pm 5$ kV to $\leq \pm 25$ kV.
- B.2.5 ESD Simulator Risetime Procedure**
- B.2.5.1** The horizontal time base and vertical amplifier level of the oscilloscope shall be configured in order to view the risetime of the ESD waveform. The horizontal sweep shall be set to single event trigger.
- B.2.5.2** DIRECT CONTACT DISCHARGE VERIFICATION (SEE FIGURE 2)—Discharge to the target at each test level and polarity shown in Table B1 and verify the risetime and first peak current parameters specified in Table B1. Figure B3 illustrates a typical waveform shape.
- B.2.5.3** AIR DISCHARGE VERIFICATION (SEE FIGURE 2)—The ESD simulator shall be placed a minimum distance of 15 mm from the coaxial target. The ESD simulator, with air discharge probe attached, shall be held perpendicular (± 15 degrees) to the target. From this position the simulator air discharge probe shall be slowly moved towards the target (≤ 5 mm/s) until a single discharge occurs. Only single event discharge waveforms are acceptable. Test voltages for air discharge risetimes are at ± 15 kV only. Figure B3 illustrates a typical waveform shape.

NOTE—The slow approach method specified above minimizes multiple discharges, discharges at lower voltage levels, and ringing in measurement equipment.