SURFACE
VEHICLE
STANDARD

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(R) Vehicle Electromagnetic Immunity—Electrostatic Discharge (ESD)

1.   Scope—This SAE Standard specifies the ESD test methods and procedures necessary to evaluate electronic modules intended for vehicle use. It describes test procedures for evaluating electronic modules in complete vehicles.

A procedure for verifying the simulator that is used to generate the electrostatic discharges is given in Appendix A.

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

2.   References

2.1   Applicable Publication—The following publication forms a part of this specification to the extent specified herein.

2.1.1   IEC PUBLICATION—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

IEC 61000-4-2 (2001-04)—Electromagnetic compatibility (EMC)—Part 4-2: Testing and measurement techniques—Electrostatic discharge immunity test

3.   Definitions

3.1   Electrostatic Discharge (ESD)—A transfer of electrostatic charge between bodies at different potentials occurring prior to contact or induced by an electrostatic field.

3.2   Human ESD Model for Vehicle Occupants—The capacity, voltage, and resistance that characterize a person as a source of an electrostatic charge for automobile conditions. Figures 1A and 1B define the capacitance/resistance parameters for an occupant inside and outside a vehicle.

3.3   DUT—Device under test.

3.4   ESD Simulator—An instrument that simulates the human ESD model for vehicle occupants.

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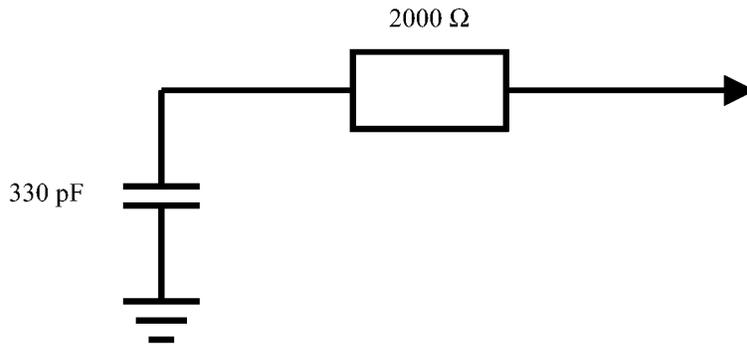**SAE WEB ADDRESS:**   **http://www.sae.org**
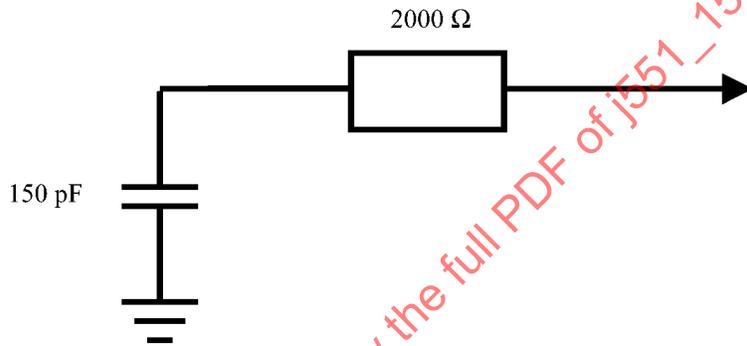
FIGURE 1A—INSIDE VEHICLE PARAMETERS

FIGURE 1B—OUTSIDE VEHICLE PARAMETERS

FIGURE 1—HUMAN BODY MODEL PARAMETERS

4. **Test Equipment**—This section describes test equipment that is applicable to all parts of this procedure, including Appendix A.

4.1 An ESD simulator that simulates the Human Body ESD model having the following characteristics shall be used:

    a.   Voltage Range—Variable from –25 to +25 kV
    b.   Capacitance—330 pF ± 10%, 150 pF ± 10% (two probes)
    c.   Resistance—2000 Ω ± 10%
    d.   Risetime

      1.   Direct Contact 0.7 to 1.0 ns (into a 2 Ω load)
      2.   Air Discharge ≤20 ns (into a 2 Ω load)

    e.   Tip—(see Figure 2)—IEC 61000-4-2 (2001-04)
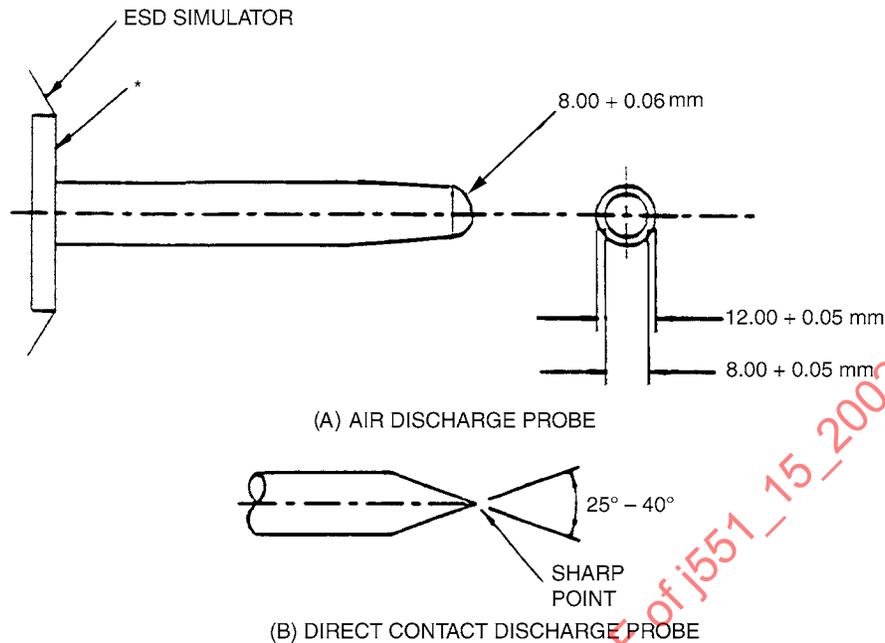
NOTE 1—The discharge switch (e.g., vacuum relay shall be mounted as close as possible to the tip of the discharge electrode.

Dimensions in millimeters

FIGURE 2—ESD SIMULATOR DISCHARGE TIP PROBES

4.1.1   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 device under test and shall not allow bleed-off prior to discharge.

4.1.2   The ESD Simulator equipment is commercially available.

4.2   The ground plane shall be a conductive metallic sheet (i.e., copper, brass, or galvanized steel) with a minimum thickness of 1.0 mm and with an area of at least 1 m^2. The ground plane shall be connected to the facility earth ground by a ground strap as short as possible. (Length less than 2 m suggested.)

4.3   **Coaxial Target**—A 50 Ω coaxial target specified by IEC 61000-4-2 (2001-04) shall be used during the ESD simulator verification of Appendix A.

4.4   **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 A.

4.5   **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 rate of 4-Gigasamples per second and a single shot bandwidth of 1 GHz. Each instrument shall have 50 Ω input impedance. The use of a Faraday shield, to separate the target from the measurement instrumentation, is highly recommended.

4.6 **Voltage Probe (Electrometer)**—The ESD simulator charging voltage shall be verified using an electrometer (input resistance 100 GΩ minimum).

5. *Test Procedure for Vehicle Tests*

5.1 Record the pertinent test vehicle information or any specific test conditions in the test report.

5.2 Prior to performing the tests, a test plan shall be generated which shall include all the interface test points and respective test levels for each interface to be tested; the vehicle modes of operation such as drive/idle, cruise; and any special instructions and changes from the standard test.

5.2.1 The discharge points, at a minimum, shall include all electrical switches and controls that can be interfaced by an occupant within the passenger compartment. Also any knobs, levers, or handles which would be actuated in the normal operation of the vehicle should be included.

5.2.2 In a standard test sequence, the vehicle's engine is to be running in drive/idle mode. If the test sequence involves tests of systems at road speeds using a dynamometer (i.e., cruise control), the speed will be defined in the test plan.

5.3 Before the application of any discharges to the vehicle, the ESD Simulator Discharge Verification procedure of Appendix A shall be performed.

5.4 **Test Environment**

5.4.1 TEMPERATURE RANGE—23 °C ± 3 °C; 20 °C preferred

5.4.2 RELATIVE HUMIDITY—20 to 50%; 30% preferred

5.5 The ESD test simulator ground wire shall be electrically connected to the vehicle body inside the passenger compartment (see Figure 3). The steel seat adjustment rail or chassis is recommended.
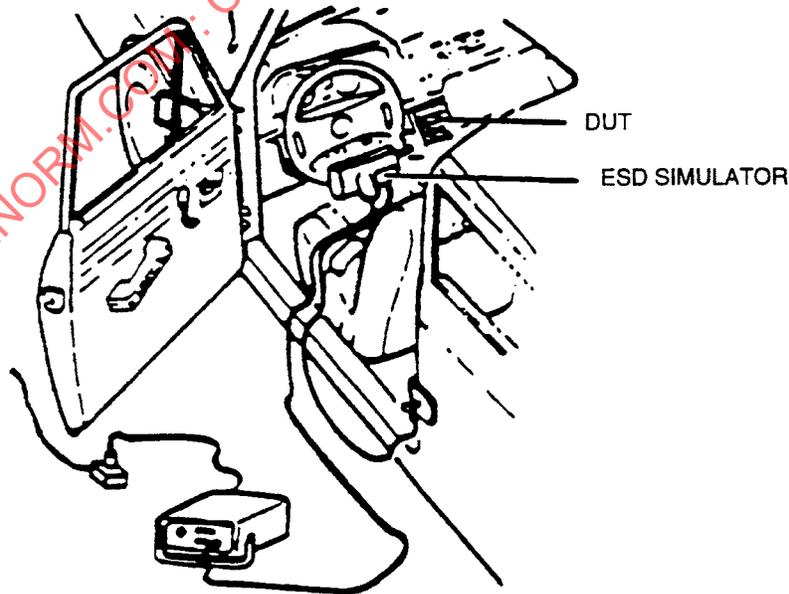

FIGURE 3—VEHICLE ESD TEST SETUP

5.6   The method of air discharge to a point in the passenger compartment shall be used to simulate the real world ESD event. With the simulator fully charged, approach the discharge point at a slow rate ≤5 mm/s until a discharge occurs.

5.7   All discharge points that can be accessed from inside the vehicle shall be tested with the 330 pF 2000 Ω probe at ±4000, ±8000, and ±15 000 V. Only those discharge points that can be conveniently accessed when standing outside the vehicle (this in effect lowers a person's capacitance) and reaching inside, such as the headlight switch or the ignition switch, shall be additionally tested with the 150 pF 2000 Ω probe at ±25 000 V. This distinction shall be at the discretion of the users.

5.8   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. Appendix B gives a summary of the test parameters.

NOTE 1—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.

NOTE 2—Multiple discharges to the same non-conductive area (e.g., radio bezel) may create a static charge where-upon subsequent full discharges are not possible (i.e., ESD simulator voltage is at similar potential as test object). For those cases, neutralize the DUT static charge between discharges (e.g., air ionizer).

5.9   Record all deviations noted from normal vehicle operation (visible, audible, failures, etc.) in the test report. Various operating systems such as heater controls, air conditioner controls, radio controls, and digital displays shall be exercised periodically during the test to demonstrate normal response.

6.   Notes

6.1   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.

PREPARED BY THE SAE EMI STANDARDS COMMITTEE

APPENDIX A

(NORMATIVE)
ELECTROSTATIC DISCHARGE SIMULATOR VERIFICATION PROCEDURE

A.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 modules and systems.

Two verification procedures each using two probes are specified. Method A.2 is to be performed at least annually and the Method A.3 is to be performed before a test or at time intervals specified by the test facility or the customer.

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

A.2.1 The test setup shall be configured in accordance with Figure A1. Figure A2 shows an equivalent schematic of the setup.

Note that a 20 dB wideband (18 GHz) attenuator may be required as shown in Figure A1 depending on the vertical sensitivity of the oscilloscope.

NOTE—The use of a full faraday cage is allowed.

Key

1 Simulator power supply   4 Oscilloscope   7 20 dB attenuator (optional)
2 ESD simulator   5 Ground strap   8 Ground plane
3 Coaxial target   6 Double shielded coaxial cable .
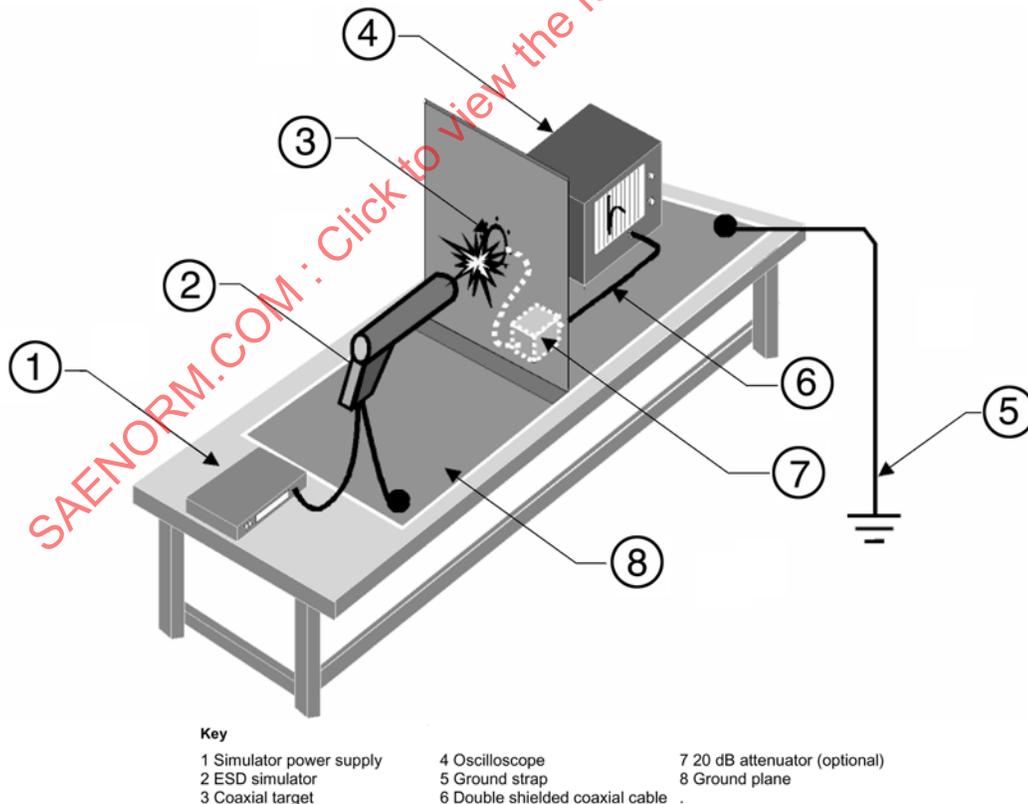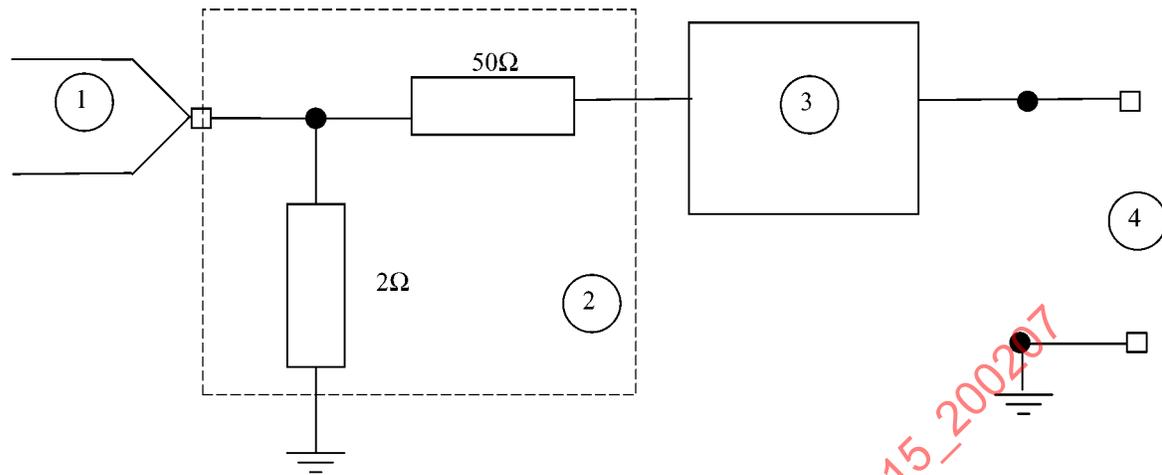
FIGURE A1—ESD SIMULATOR VERIFICATION TEST SETUP CONFIGURATION

Key

1   ESD simulator

2   Coaxial target

3   20 dB attenuator (optional)

4   Oscilloscope input

FIGURE A2—EQUIVALENT SCHEMATIC

A.2.2 The coaxial target shall be located on and bonded to the ground plane. The target output shall be connected to the oscilloscope through a 50 Ω double-shielded high frequency cable ≤1 m long. The cable shall not be looped and shall be insulated from the ground plane.

A.2.3 The ESD simulator high voltage ground shall be directly connected to the ground plane by an insulated grounding strap less than 2 m long. For all discharge return cable lengths used, the simulator shall meet the requirements of Appendix A.

The connection of the simulator return cable to the Ground Reference plane and all bonding should be of low impedance at high frequencies. The discharge return cable of the simulator should be positioned at least 0.2 m from the DUT while the discharge is being applied. This measure is needed to reduce radiation from this cable from affecting the test results. The end of the discharge return cable connected to the simulator may be closer to the DUT.

A.2.4 The ESD simulator shall be set up and operated according to its instruction manual.

A.2.5 To verify the display voltage of the ESD simulator, first adjust the ESD simulator voltage to the desired level and polarity. Use the electrometer of 4.6 to verify the voltage setting at voltage 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 ≤±5 kV and ±10% for voltages >±5 kV to ≤±25 kV.

A.2.6 ESD Simulator Risetime Verification Procedure

A.2.6.1 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.

A.2.6.2 DIRECT CONTACT DISCHARGE VERIFICATION — SEE FIGURE 2(B)—Discharge to the target at each test level and polarity shown in Table A1 and verify the risetime and first peak current parameters specified in Table A1.

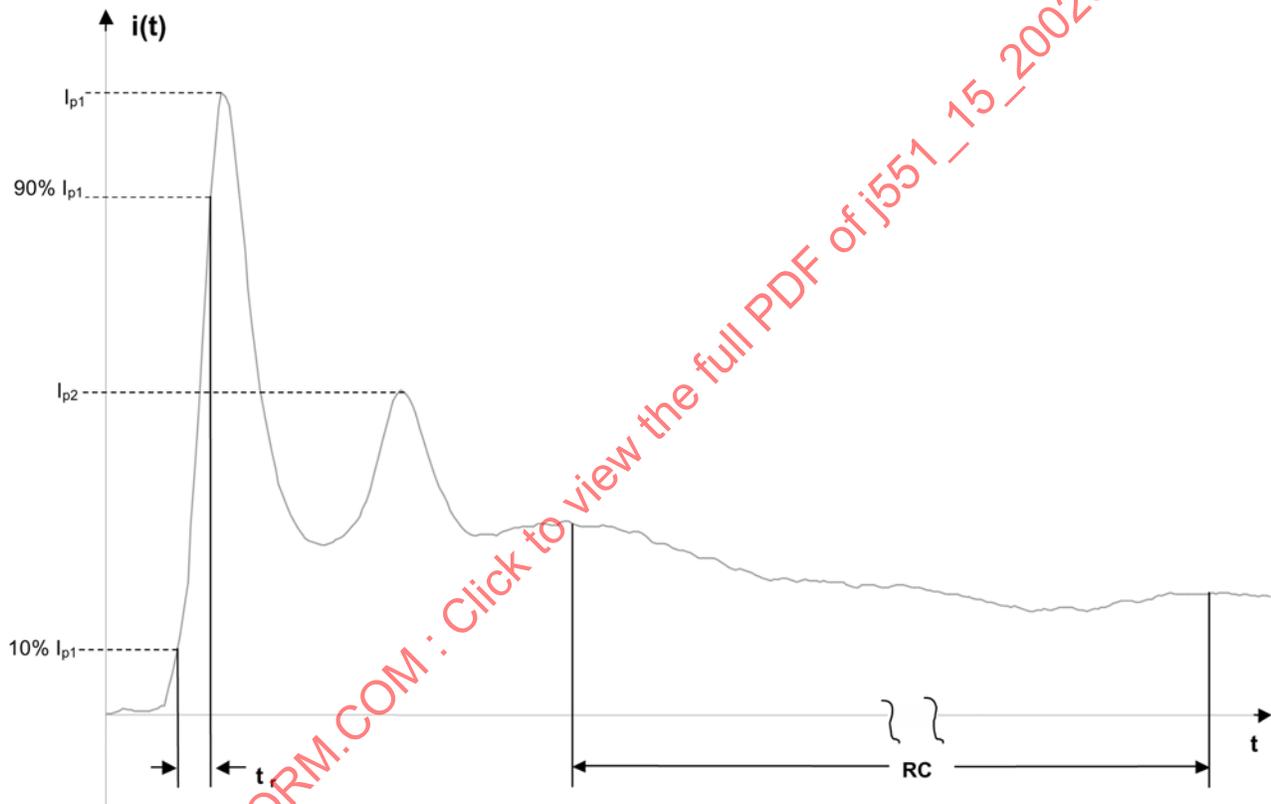Figure A3 illustrates a typical waveform shape.

FIGURE A3—TYPICAL OUTPUT WAVEFORM OF THE ESD SIMULATOR

A.2.6.3 AIR DISCHARGE VERIFICATION (PERFORMED AT ±15 KV ONLY) — SEE FIGURE 2(A)—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 at 5 mm/s or less until a single discharge occurs. Only single event discharge waveforms are acceptable. Figure A3 illustrates a typical waveform shape.

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

A.2.6.3.1 Record the waveform shape and parameters on Data Sheet 2 (see Figure A4.)

A.2.6.3.2 Verify that the air discharge risetime at each polarity is ≤20 ns.

TABLE A1—DIRECT DISCHARGE VERIFICATION PARAMETERS

Level	Indicated Voltage	First Peak Current		Risetime With Discharge Switch
			+2.25 A	
1	2 (kV) ± 10%	7.5 A	−0 A	0.7 to 1 ns
			+4.5 A	
2	4 (kV) ± 10%	15.0 A	−A 0	0.7 to 1 ns
			+6.75 A	
3	6 (kV) ± 10%	22.5 A	−0 A	0.7 to 1 ns
			+9.0 A	
4	8 (kV) ± 10%	30.0 A	−0 A	0.7 to 1 ns

A.2.6.4 Acceptable ESD waveforms must be repeatable a minimum of six times in 10 attempts for both direct contact discharge and air discharge.

A.2.7 ESD Simulator RC Time Constant Verification Procedure

A.2.7.1 Configure the horizontal time base and vertical amplifier level of the oscilloscope to show the complete ESD waveform. Set the horizontal sweep to single event trigger.

A.2.7.2 RC time constant verification of the ESD simulator is performed at ±15 kV (air discharge) only.

A.2.7.3 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 at 5 mm/s or less until a single discharge occurs. Only single event discharge waveforms are acceptable. Figure A3 illustrates a typical waveform shape.

A.2.7.4 Record the waveform shape and parameters on Data Sheet 2 (see Figure A4.)

A.2.7.5 Determine the RC time constant from the discharge curve starting after the second peak and/or ringing and ending when the waveform has decayed 63%.

NOTE—In determining the RC time constant, where there is no second current peak (lp 2) or when there is ringing in the measured waveform, calculate the RC time constant after the leading edge and/or ringing (where the waveform is stable).

A.2.7.6 Verify that the RC time constant value is 600 ns ± 130 ns, for the 330 pF probe, and 300 ns ± 60 ns for the 150 pF probe.

A.2.7.7 Acceptable ESD waveforms are those that are repeatable a minimum of six times in 10 attempts.

A.3 ESD Simulator Voltage Verification Procedure

A.3.1 Perform the ESD simulator Voltage verification before performing an ESD test or at the time intervals specified by the test facility or the customer.

A.3.2 To verify the display voltage of the ESD simulator, first adjust the ESD simulator voltage to the desired level and polarity. Use the electrometer of 4.6 to verify the voltage setting at voltage 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 ≤±5 kV and ±10% for voltages >±5 kV to ≤±25 kV.