RESISTANCE OF ELECTRONIC DEVICES TO ELECTROSTATIC DISCHARGES

Supervisor: **Mazzarino M.** - P.P.& I. - Testing Benches & Tracks - telephone +39. 011.00.75578

Manager: **G. Nicocia** - P.P.& I. - Testing Benches & Tracks - E.M.C. - telephone +39.011.00.75321

1 PURPOSE

Defining equipment and methods to verify at the bench and on vehicle the resistance of electronic devices to electrostatic discharges.
The simulated discharge model is the HBM (Human Body Model) one.

2 SUBJECT

The present standard is valid for electronic devices installed on 12-V and 24-V vehicles equipped with internal combustion engines with “Otto” or “Diesel” cycles.

3 GENERAL TEST CONDITIONS

3.1 In general

The tests must be carried out on electronic devices that have already passed the functional checks recalled in IVECO STD. 18-2252 and in the specific Specifications.

The following standard takes into account discharges generated by an electrostatically-charged operator that touches or skims the accessible metallic parts of the component during usual operations.

3.2 Test environment

- Temperature: 23 ± 5 °C
- Relative humidity: 30 - 60 %
- Atmospheric pressure: 860 - 1060 mbar

Edition	Date	Description of modifications	Group
1	24.04.1992		PEL
3	01.12.1993	Point 7.2 added, points 7.3, 7.4 and Table IV modified.	
4	28.08.1999	Modified: points 2; 4.1; 4.3.1; 4.3.2; 5.2; 7.1 - 7.6 and Fig.1. Figures 11 and 12 added.	
5	15.06.2001	Revised with respect to previous edition, points 4.1.3, 5.2, 5.4, 7.5, 7.6 modified.	
6	10.09.2001	Point 7.6 “Limits of acceptability” added.	
7	03.04.2006	Revised for complying with ISO WD 10605 Technical Procedure.	
8	25.11.2008	Modified: Supervisor Dept. abbreviation, Manager, point 7.5 and 9.	

3.3 Test voltage

For U_B battery voltage (engine OFF) and U_A system voltage (engine ON) values, refer to what is included in **Table 1**.

TABLE 1

Voltage	For 12-V system (V)	For 24-V system (V)
U_A	13.5 ± 0.5	27 ± 1
U_B	12 ± 0.2	24 ± 0.4

4 TEST TYPES, LEVELS AND FUNCTIONAL CLASSES

4.1 Test types

Test types are classified according to the operator's position with respect to the device location and to the type of operation being performed.
The techniques for generating electrostatic discharges are two: one is by approach to simulate accidental discharge, the other one is by contact to simulate discharge during handling / packaging and repairing operations.
Tests are divided into the categories shown below.

4.1.1 Type 1

Operator and device are both on vehicle.
The resistance and capacity unit will be equal to:

- R = 2 KΩ
- C = 330 pF

Discharge will be generated using the approach technique.

4.1.2 Type 2

Device installed on vehicle, the operator shall reach the device also when he is not on the vehicle.
The resistance and capacity unit will be equal to:

- R = 2 KΩ
- C = 150 pF

Discharge will be generated using the approach technique.

4.1.3 Type 3

Contact with the metallic elements of the device shall be performed using a non-conductive body.
The resistance and capacity unit will be equal to:

- R = 2 KΩ
- C = 150 pF

4.1.4 **Type 4**

Contact with the metallic elements of the device shall be performed using a metallic object (e.g.: screwdriver, pliers, tongs, etc.).
The resistance and capacity unit will be equal to:

- R = 330 Ω
- C = 330 pF

4.2 **Functional class classification**

The functional states of the electronic devices during tests can be referred to the following classes:

- *CLASS A:* All device functions meet requirements both during and after the test.
- *CLASS B:* All device functions meet requirements both during and after the test; however, one or more of them can be out of tolerance.
  These functions however reach back their characteristic value at the end of the disturbance.
- *CLASS C:* A device function can be in failure, but automatically goes back to its characteristic value at the end of the disturbance through an autoreset function that brings back the device into conditions that are complying with present parameters.
- *CLASS D:* A device function can be in failure and does not go back to its characteristic value at the end of the disturbance, until a reset from the outside occurs.
- *CLASS E:* One or more device functions can be in failure both during and after the test. These functions do not go back to their property value at the end of the disturbance, until the device is repaired or replaced.

NOTE : *Irreversible failures (FUNCTIONAL CLASS E) are not admissible on tested devices subjected to the maximum test level.*

4.3 **Failure classification**

With respect to the subfunctions carried out by the component/system, the following Failure classification is provided:

- **P**: Priority failure that affects vehicle control, perceivable by the Driver or other road user, or that generates operation alterations which could cause confusion to other road users.
- **NP**: Non-priority failure that does not affect vehicle control or secondary functions for the examined system.

These classifications will be defined on the relevant Product Specifications.

4.4 **Test levels and related functional class**

Tests shall be carried out at:

- ± 15 KV for Type 1
- ≤ ± 25 KV for Type 2
- ≤ ± 8 KV for Type 3
- ≤ ± 4 KV for Type 4

applying the test levels shown in **Table 2**.

TABLE 2

	Test type	Technique	Probe	No. of discharges	Failure type	Test level	Functional class	Discharge injection points
1	Accidental discharge, operator and device are both on vehicle	Approach	2 kΩ 330 pF	50	NP	± 8 KV	A	Device container, connector, wiring and accessible system points
					P	± 15 KV		
2	Accidental discharge, operator is outside vehicle and device is on vehicle	Approach	2 kΩ 150 pF	50	NP	± 8 KV	A	Device container, connector, wiring and accessible system points
					P	± 15 KV		
					P	± 25 KV	A	Ground plane
3	Discharge generated by handling or packaging operations	Contact	2 kΩ 150 pF	3	NP/P	± 8 KV	A	Pin and device container (if metallic)
4	Discharge generated during repair operations by metallic objects	Contact	330 Ω 330 pF	3	NP/P	± 4 KV	A	Pin and device container (if metallic)

5 TEST EQUIPMENT

5.1 Power supply/control unit for electrostatic discharge simulator

It must satisfy the following technical requirements:

- Output voltage adjustable between 1 kV and 25 kV;
- Maximum adjustment pitch: 1 kV;
- Output Voltage accuracy ≤ 5%;
- Selectable impulse polarity both for positive and for negative ones;
- Possible operation both with single discharge and with multiple discharge (max repetition frequency: 20 Hz);
- Selectable discharge method (both possible discharge into air and possible contact discharge).

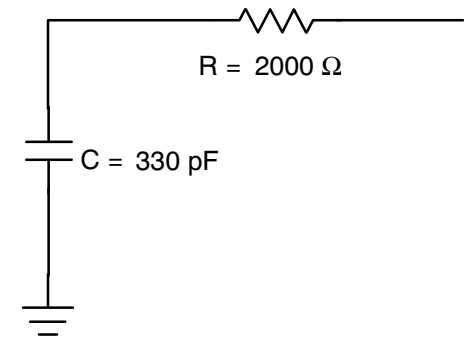
5.2 Electrostatic discharge simulator

The RC discharge unit must be placed on the discharge probe with the following characteristics:

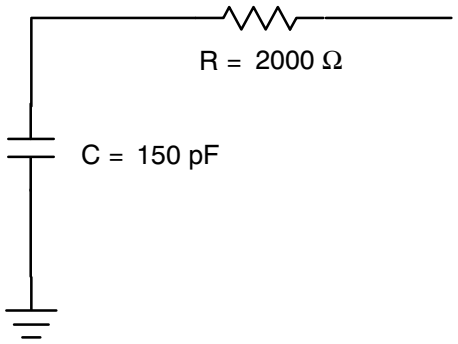
• Discharge resistance	330 Ω	For contact tests through metallic objects
	2000 Ω	Every tests except contact tests through metallic objects
• Selectable discharge capacity	150 pF	For tests on bench and on vehicle with operator outside and for Packaging/Handling tests
	330 pF	For tests on bench and on vehicle with operator inside
• Discharge current rising time on a 2Ω load	<5 ns	For the discharge into air test
	< 1 ns	For the contact discharge test
• Maximum discharge energies:	with C = 150 pF:	47 mJ
	with C = 330 pF:	100 mJ

- The ground-connecting cable that carries the discharge current must be 2 m long and must not be shielded (20-way Flat Cable type)
- The wiring diagram of the simulator is included in **Figure 1** (next page).

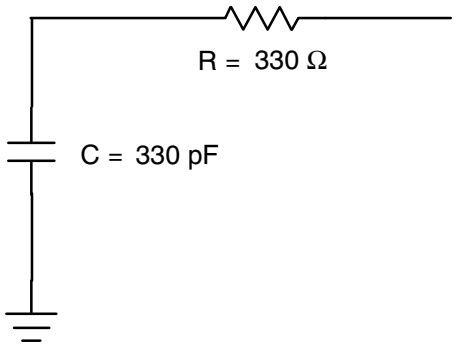
FIGURE 1
Electric diagrams of the E.S.D. simulator



Test on bench (and optional on vehicle) when both operator and device are inside the vehicle



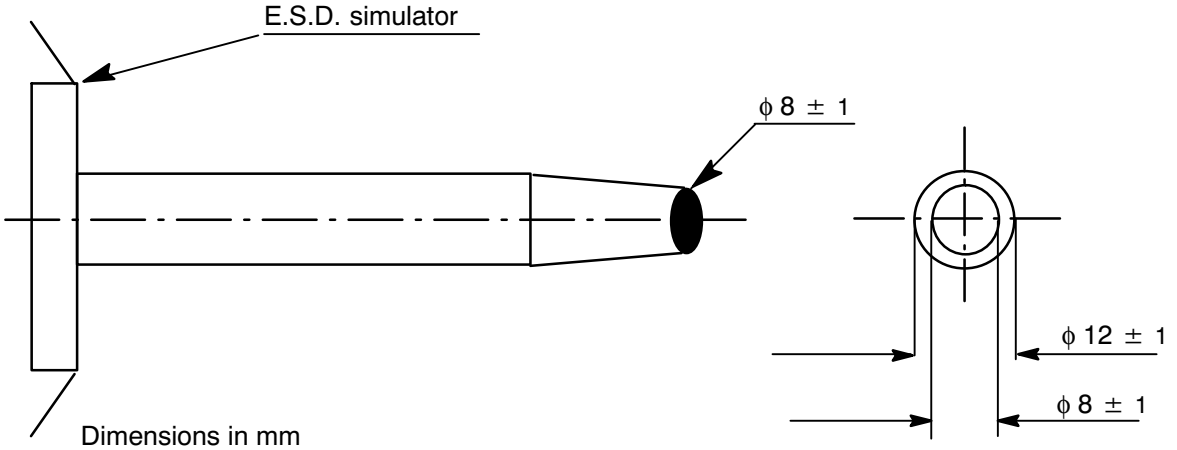
Test on bench (and optional on vehicle) when the operator is outside the vehicle both for accidental discharge simulations, for handling or packaging simulations ones, through not conductive objects.



Test on bench for handling or packaging simulations through metallic objects.

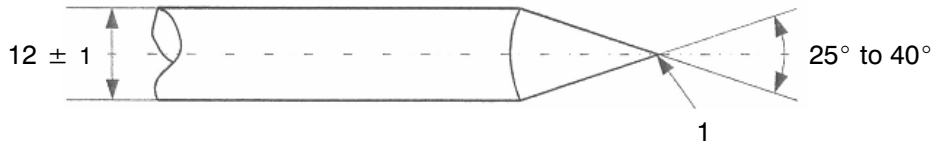
- The electrostatic discharge simulator terminals (injection points) must have, to be able to carry out the discharge into air, the dimensions shown in **Figure 2** and to carry out contact discharge, the dimensions shown in **Figure 3** (next page).

FIGURE 2
E.S.D. simulator terminals for discharge into air



The electrode for contact discharge generator is shown in **Figure 3.**
The point is generally in stainless steel.

FIGURE 3
E.S.D. simulator end for contact discharge



Dimensions in mm

5.3 Reference table

Highly electrically conductive metallic reference table (made of copper, brass, galvanized steel), min thickness 1 mm, min sizes 1 x 1 m (sizes at least 3 times greater than the tested component; in any case, the ground plane must extend over the tested system surface by at least 10 cm with respect to every side of its); the table must be electrically grounded through a copper plait welded to the building earth. This connection must be less than 1 m long and the inductance must be < 2 μH; the tested product is placed on the table, separated by an insulating support at least 2.5 cm thicker and 2 cm wider than the device on both sides.

5.4 Device under test (D.U.T.)

The D.U.T. must have dimensions that are less than 1/3 of the overall dimensions of the metallic table and must be at least 50 cm far from the discharge generator and its related supply cable.
The D.U.T. must be at least 1 m far from walls and any metallic structure.
Wirings shall have 1 ± 0.1 m length.

5.5 Simulator/control unit exciter

The control unit under test will have to be stimulated through an adequate Test pattern, either stimulating physical sensors, or stimulating the D.U.T. inputs with signals that are coherent with the ones generated using real sensors.

NOTE **:** *If a simulator is used, it will have to be able not to modify its signal test even in the presence of the disturbance generated by the electrostatic discharge simulator.*

5.6 Power supply

Power supply with adjustable voltage between 0 V and 40 V, 80 A, as per IVECO STD. 16-2108 , with a 12 V, 70 Ah 350 A battery as a backup. (1 battery for 12 V tests - 2 batteries in series for 24 V tests).

5.7 Line impedance stabilizing network (L.I.S.N.)

The impedance stabilizing network must be realized according to the electric diagram included in **Figure 4** and must have impedance properties, when frequency changes, as indicated in **Figure 5**.
It must further satisfy the following requirements:

- The resistance between P and A terminals must be less than 5 mΩ;
- The impedance measured between P and B terminals, when A and B terminals are short-circuited, must not be different more than 10% from the theoretical curve shown in **Figure 5**, in the frequency band between 100 kHz and 100 MHz;
- The C2 capacity must support continuous voltages at least equal to 1500 V;
- The L inductance must support the supply current of the device under test (max. 70 A).

FIGURE 4
Line impedance stabilizing network (L.I.S.N.) - Electrical properties

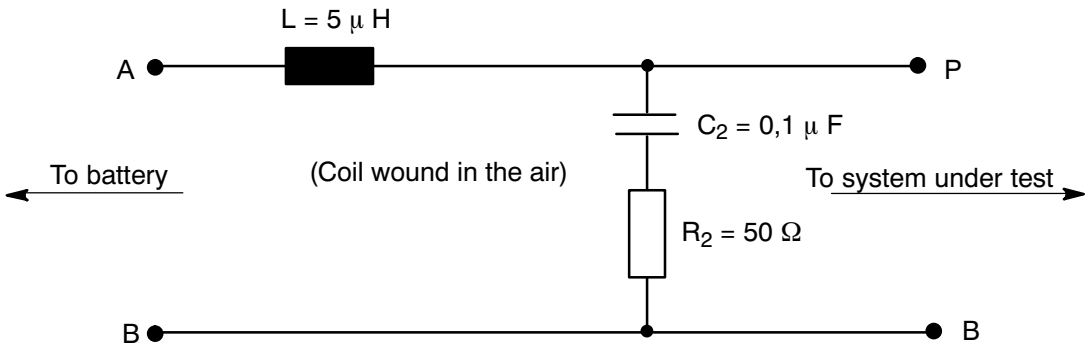
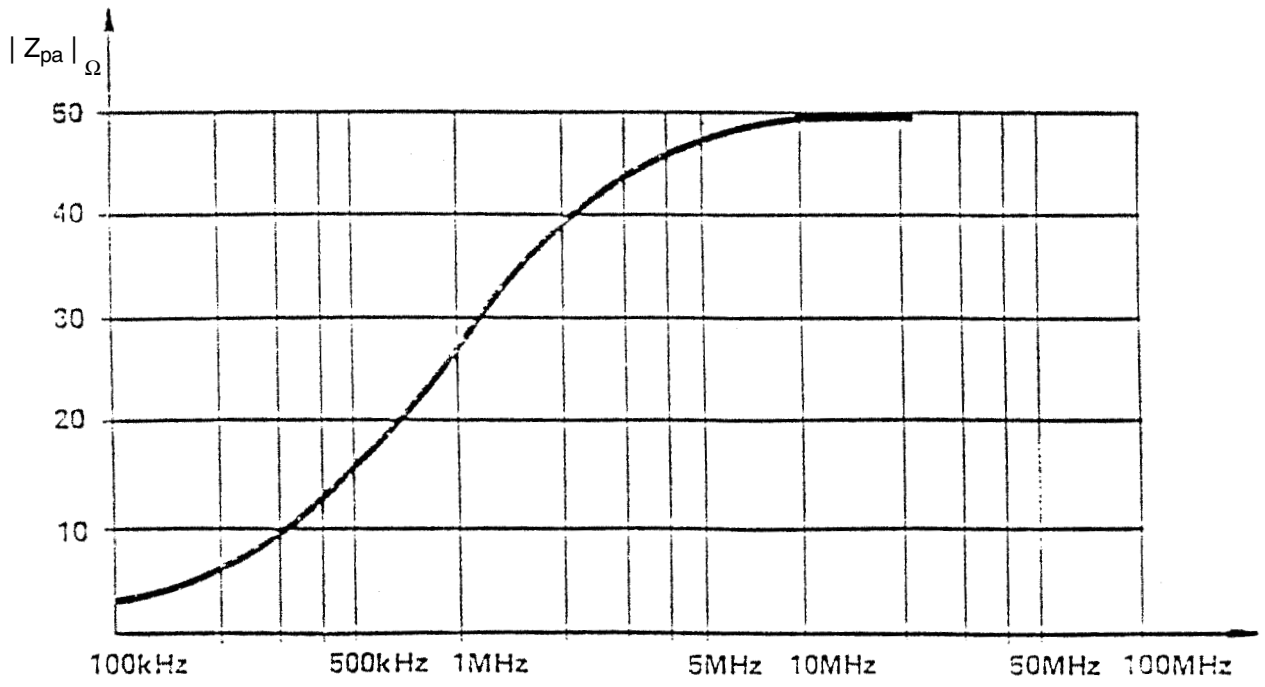


FIGURE 5
Impedance module trend - (A and B terminals are short-circuited)



5.8 **Arbitrary load**

It must allow, during gauging, the measure of transients generated by the electrostatic discharge simulator.
It must be made according to what is indicated in **Figures 6** and **7**.

FIGURE 6
Arbitrary load

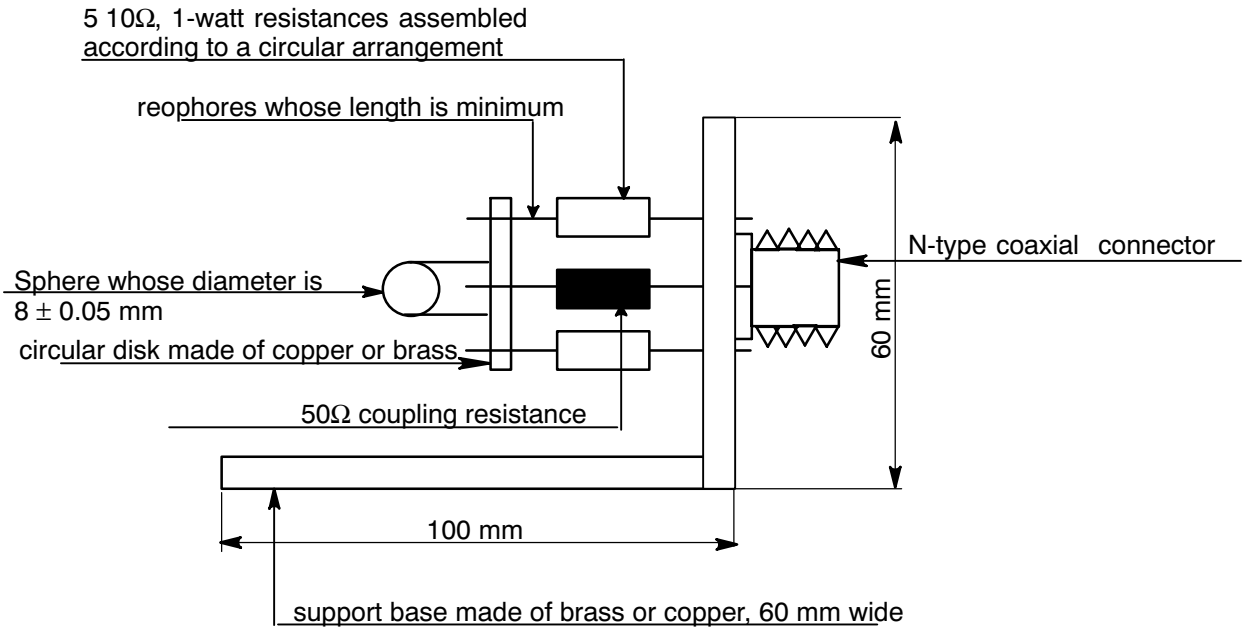
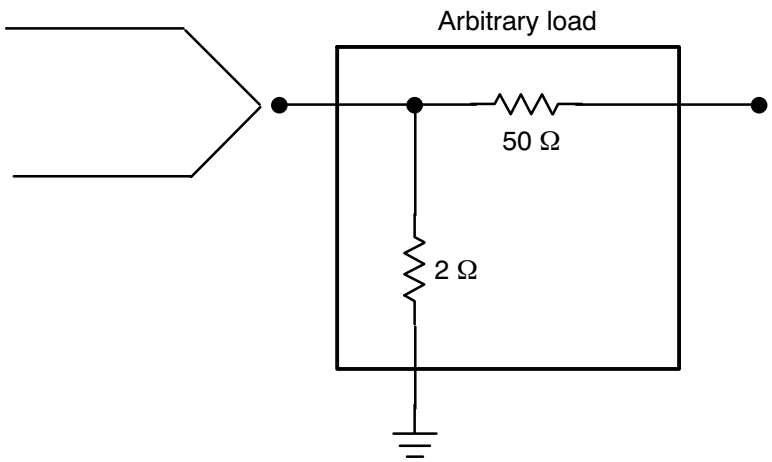


FIGURE 7
Arbitrary load (equivalent circuit)



5.9 **Attenuator**

It must satisfy, during gauging, the following technical requirements:

- 20 dB damping (10:1 voltage);
- Characteristic impedance: 50 Ω ± 5%;
- Frequency band from DC - 1 GHz.

5.10 **Oscilloscope**

Digital memory-oscilloscope to be used during gauging with pass band > 400 MHz, with sampling by single impulse 1 x 10^9 samples per channel; input impedance 50 Ω.

5.11 **Voltmeter**

Digital electronic voltmeter to be used during gauging with very high input impedance (> 1 GΩ) obtained through an adequate actenuated probe whose insulating voltage is > 40 kV.

6 TEST INSTRUMENT GAUGING

6.1 Power supply/control unit gauging for approach discharge

This procedure must be carried out before every electrostatic discharge simulator gauging and every test.
Connect power supply/control unit to the simulator and the latter one to the digital electronic voltmeter.
Adjust power supply voltage to the required level and verify, through the digital electronic voltmeter, that the voltage read, corrected according to the (A/K) factor, is equal to the set one with a ± 10% tolerance.

$$V_c = AV$$

$$V_c = KV$$

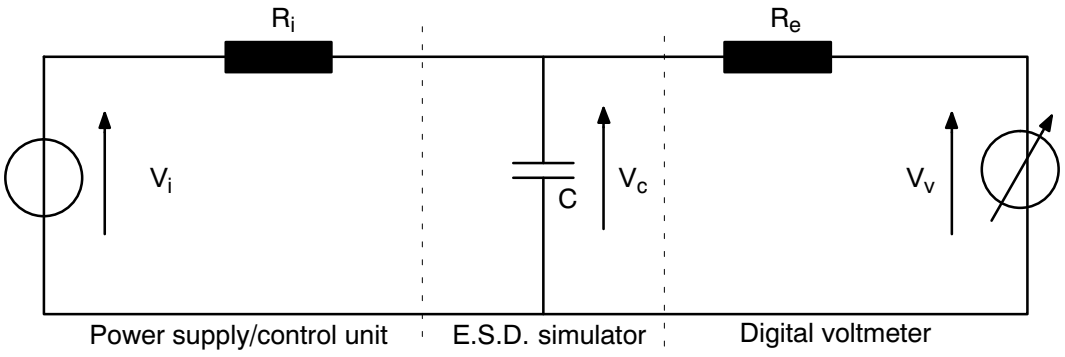
$$V_i = V_v \frac{A}{K}$$

where:

- V_c E.S.D. simulator voltage
- V_v Voltage read on the voltmeter
- V_i Voltage set on the control power supply
- A Damping generated by the probe
- K Correction factor ($R_e/R_e + R_i$)
- R_e Resistance of digital voltmeter with probe
- R_i Internal resistance of the control power supply

Figure 8 shows the equivalent diagram for the gauging circuit.

FIGURE 8
Equivalent diagram for the gauging circuit



6.2 **Test circuit at the bench for gauging with approach tecnique**

This gauging procedure must be repeated every three months and must be preceded by the one related to the power supply included in paragraph 6.1.
Instruments for simulator gauging must be placed as indicated in **Figure 9** (the related electric diagram is included in **Figure 10**). The arbitrary load will have to be placed at the center of the ground plane and secured with screws to it (see **Figure 9**).

The arbitrary load with attenuator must be connected to the oscilloscope through a 50Ω, double--shielded or half-rigid coaxial cable, whose length is less than 20 m.
This cable must not be wound on itself and must be insulated from the ground plane.
The ground terminal of the electrostatic discharge simulator must be directly connected to the ground plane.
Position the E.S.D. simulator so that the half-spheric end is at the following distance from the arbitrary load sphere:

- 0.5 mm for the 4 kV gauging
- 2.5 mm for the 25 kV gauging.

Simulator and arbitrary load must be aligned and on the same axis.
During gauging, single discharges only must be obtained and their related wave-forms must be able to be repeated at least 6 times on 10.
For every discharge, record the T_r rising time and the RC time constant defined in **Figure 11**.
The rising time must always be < 5 ns, while the RC time constant must be:

- 660 ± 130 ns for 330 pF simulators
- 300 ± 60 ns for 150 pF simulators.

FIGURE 9
Test circuit at the bench

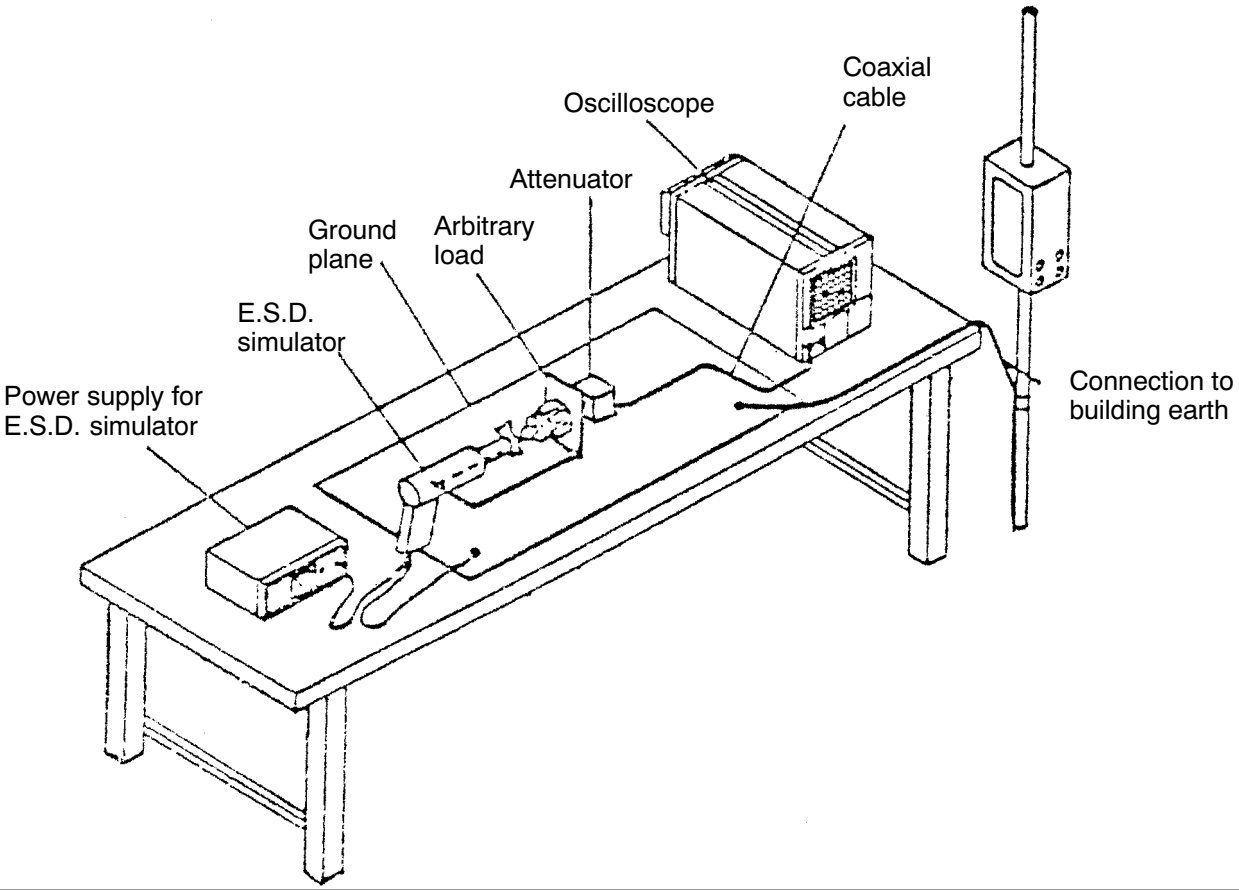


FIGURE 10

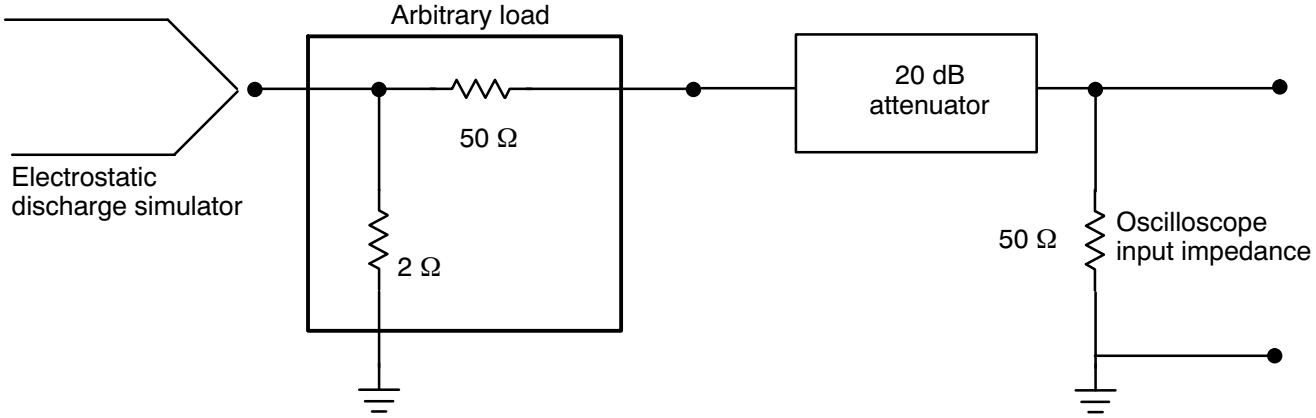
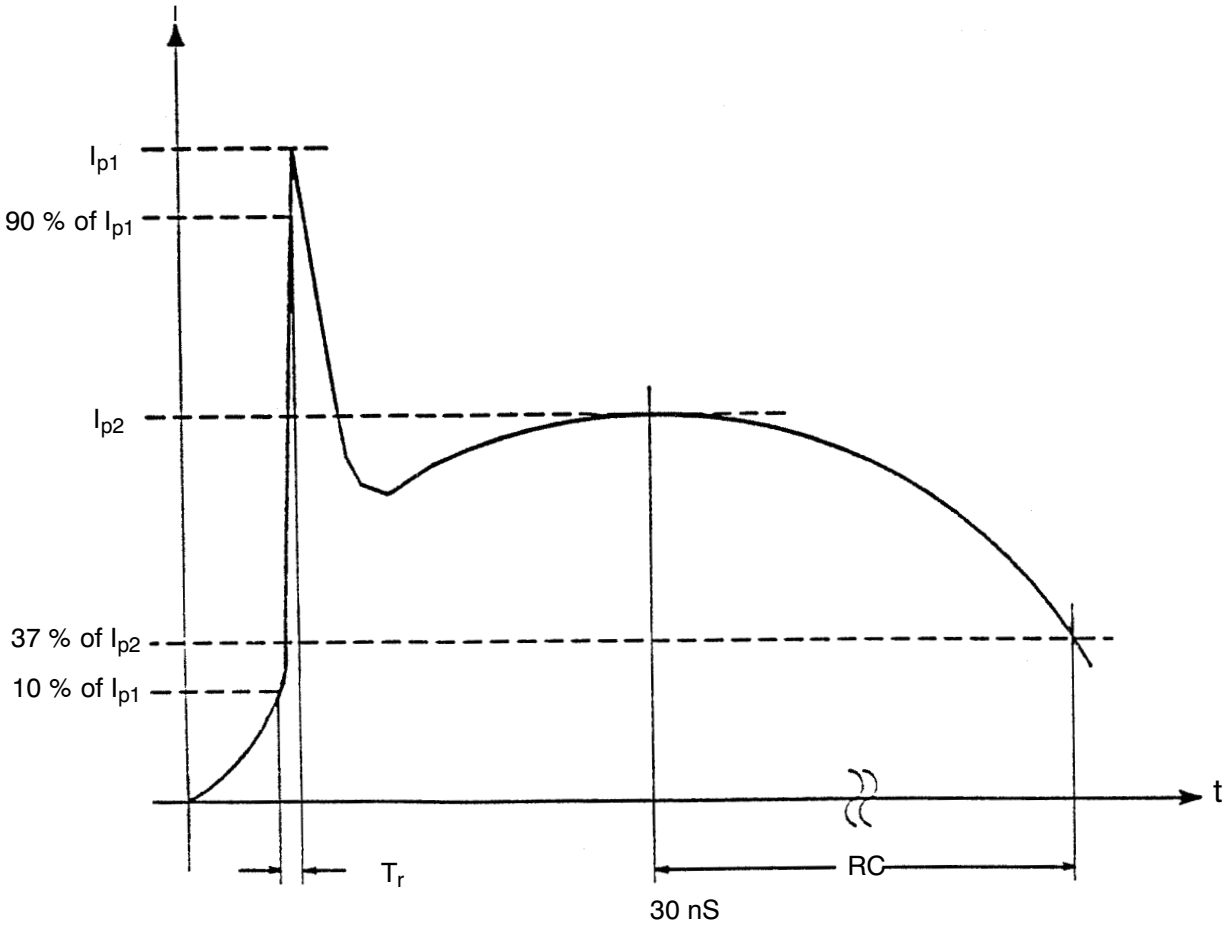


FIGURE 11
E.S.D. impulse



6.3 Procedure for measuring the E.S.D. generator wave form for contact discharge

Gauging shall be performed as specified by the E.S.D. manufacturer or according to the quality system specifications of the testing lab.
To ensure repeatability and compatibility with other E.S.D. devices, the following environmental conditions shall be guaranteed during the whole gauging stages:

- Temperature: keep 25 ±10 °C temperature during the test
- Relative humidity: shall be included between 20 and 60% (30% relative humidity and 20 °C temperature is the preferred condition).
- Atmospheric pressure: shall be included between 68 KPa (680 mbar) and 106 KPa (1060 mbar). Different values shall be indicated in the test report.

6.3.1 Current intensity specification with the contact discharge method

Wave form parameters are those shown in **Table 3**

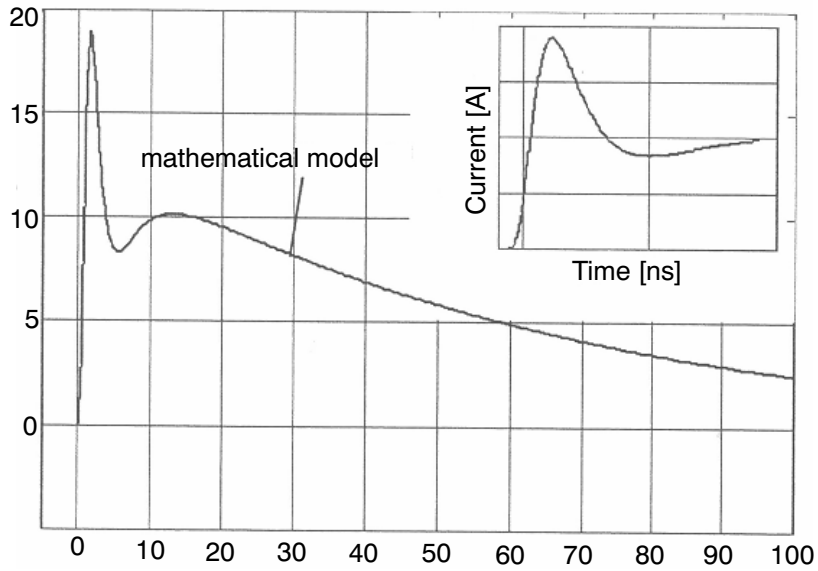
TABLE 3

R/C discharge unit	Peak current [A/KV]	Tolerance [%]	Current intensity at moment 1 [A/KV]	Tolerance [%]	Current intensity at moment 2 [A/KV]	Tolerance [%]
150 pF 330 Ω	3.75	±10	2 at 30 ns	±30	1 at 60 ns	±30
330 pF 330 Ω	3.75	±10	2 at 65 ns	±30	1 at 130 ns	±30
150 pF 2000 Ω	3.75	±10	0.25 at 180 ns	±30	0.15 at 360 ns	±30
330 pF 2000 Ω	3.75	±10	0.25 at 400 ns	±30	0.15 at 800 ns	±30

6.3.2 Calculation of the E.S.D. generator wave form for contact discharge

Wave form calculation with contact discharge technique is shown in **Figure 12** using discharge unit consisting of 150 pF capacity, 330 Ω resistance and generating 5 KV intensity discharge.

FIGURE 12

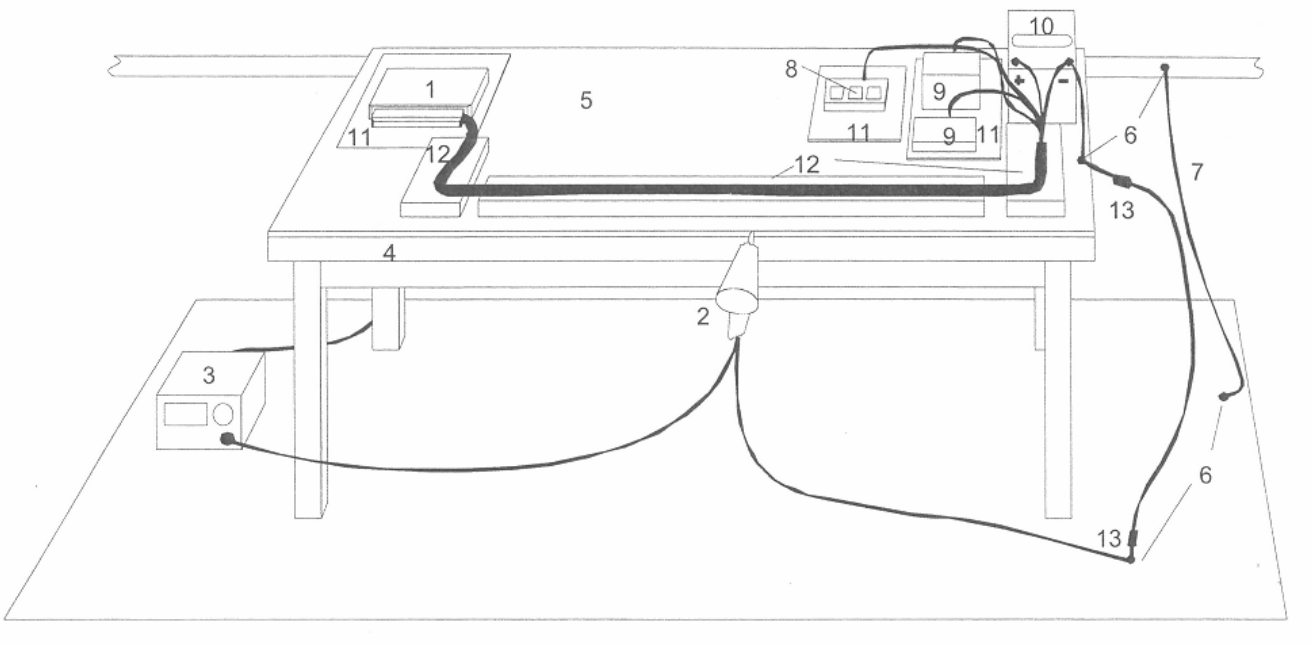


7 CARRYING OUT THE TEST

7.1 Test circuit at the bench for descharge simulation generated with approach tecnique

Test circuit at the bench for descharges generated with approach tecnique as shown in **Figure 13**

FIGURE 13
Set-up for test circuit at the bench for descharge simulation generated with approach tecnique



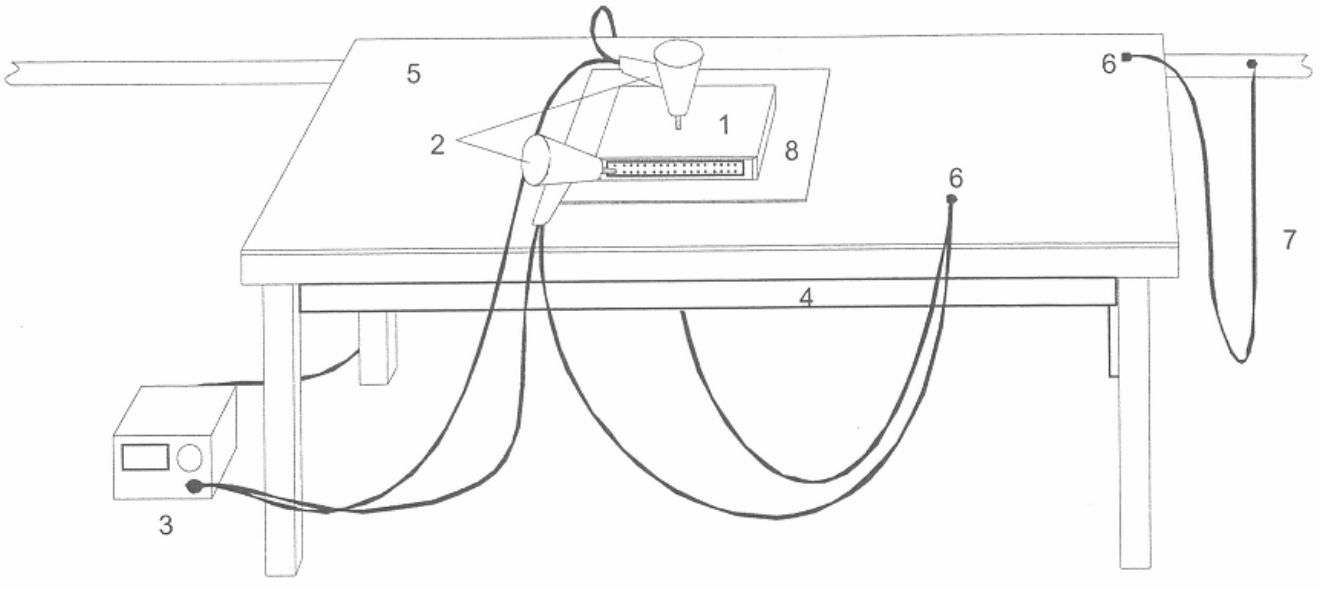
where:

1) (DUT) device under test
2) ESD generator
3) ESD generator main unit
4) Wooden table
5) (HCP - Horizontal Coupling Plane)
6) Ground point
7) Ground connection
8) Control unit
9) Peripheral units
10) Battery
11) Insulating support (if required)
12) Insulating blocks
13) 470 Ω resistances

7.2 **Test circuit at the bench for packaging and handling simulation through contact tecnique**

Set the test circuit for packaging and handling simulation as shown in **Figure 14**.

FIGURE 14
Set-up for test circuit for packaging and handling simulation through contact tecnique



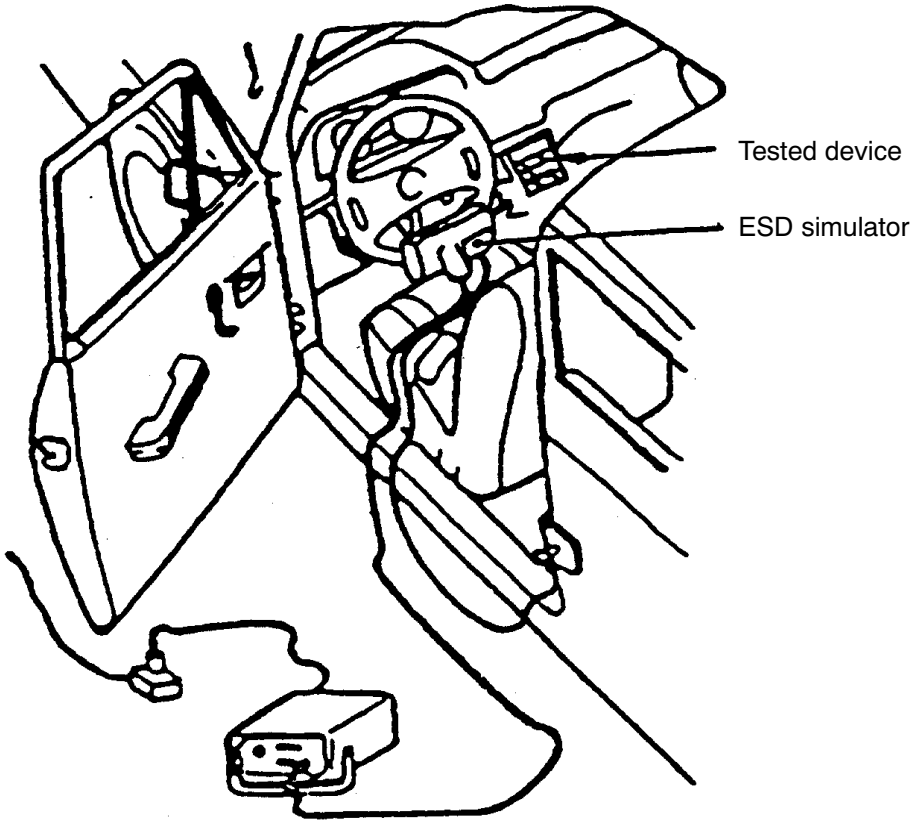
where:

1) (DUT) device under test
2) ESD generator
3) ESD generator main unit
4) Wooden table
5) (HCP - Horizontal Coupling Plane)
6) Ground point
7) Ground connection
8) Insulating carpet (if required)

7.3 Test circuit on vehicle

Set the test circuit as shown in **Figure 15**.

FIGURE 15
Test circuit on vehicle



7.4 Injection point selection

For finding injection points on tested systems inject multiple discharges on all the points accessible to operator (connector PIN excluded) starting from the lower test level and increasing this level until possible faults appear.
Points identified with this method must be submitted to qualification test level required by product specification through the injection of 20 individual positive and then negative discharges with a 5 s interval between each other.
Carry out this operation using the approaching technique and the type required by the specific case.
Injection points are usually as follows:

a) max. ± 25 KV are reached on the ground plane that simulates the vehicle body (2000 Ohm/150 pF).

b) tested device housing is usually set on the same operator reference point, the max. levels that can be reached are therefore ± 15 KV (2000 Ohm/330 pF).

c) to simulate the required tests, specially at Servicing, injections shall also be performed on installed control units/components Pins. Adopt the contact technique for higher accuracy, the max. levels that can be reached are equal to ± 8 KV (2000 Ohm/150 pF) to protect us from contact with non conductive body. Otherwise use the 330 Ohm/330 pF probe and inject max. ± 4 KV.

7.5 **Test carrying out**

The test is carried out in order to simulate, in the way that is most similar to reality, an operator that is electrostatically charged in certain environmental conditions and afterwards is discharged on the device.
The human body simulation is obtained through a generator having adequate properties:

- Charge capacity: 150 pF (for type 2 - 3), 330 pF (for type 1);
- Discharge resistance: 2000 Ω for all types; excluding the metallic object contact ones (in this event use 330 Ω).
- Discharge current rising time < 5 ns (for type 1 and 2), < 1 ns (type 3-4);
- Discharge voltage on the component:
  max ± 15 kV (for type 1), ± 25 kV (for type 2), ± 8 kV (for type 3);
- The RC discharge unit must be placed on the discharge probe;
- Possible generation of both single and multiple discharges (maximum repetition frequency: 20 Hz).

The ground connection cable that carries the discharge current must be 2 m long and must not be shielded; it can be obtained through a high-frequency plait with insulating coating, or through a Flat Cable with a minimum of 20 wires connected in parallel one with the other.
The cable connection with the ground plane must be a low-impedance one at high frequencies, and therefore must be realized with nut screws with conductive finishing and enough contact area. If the 2 m length in not enough to reach all the parts of the tested device, it is possible to move the connection point between discharger and ground plane to other points of the connection between discharger and ground plane on other points of the metallic plane. In these cases, it could be useful to employ adequate clamping devices, suitable for high frequency applications.
The device must be more than 50 cm far (minimum 10 cm) from all the reference plane edges, and more than 50 cm far from the discharge generator and its related power cable.
The device under test must be at least 1 m far from walls and any metallic structure.
All tests must be carried out keeping the working part of the cable carrying the probe at a distance of at least 10 cm from the device and of at least 20 cm from the reference plane.
The tested unit will be connected or insulated (through a wooden insulating support whose thickness is 2.5 cm) from the ground plane, coherently with its real installation on a vehicle.
Test unit wirings, both powering ones connected to LISN and those connected to other system devices, shall have 1 m ± 0.1 m.

Approach tests (type 1 - 2) shall be run on device in both Standby (powered only) and normal operating conditions, generating a single positive and negative discharge, repeated every 5 s for 50 times, whereas contact tests(type 3-4) shall be run with device not powered, generating them 5 times for 5 seconds.
The discharge points will have to be choosen depending on point 7.4 and anyway defined by the related Test Specification or Product Specification.
For electrostatic discharges with approaching techniques select simulator at the required voltage and approach to the selected discharge point without touching it.
For electrostatic discharges with contact techniques directly position the discharge probe on the selected point and operate the simulator precharged at the required discharge level.
After possible decreases of the generator discharge adjustment, make a discharge on the generator mass occur before all following tests.

During Handling and Packaging simulations perform grounding, between one discharge and the other, in the point where the electrostatic discharge has been injected using 470 KΩ resistor.

During the test on vehicle, generator ground cable shall be connected to a metallic point set as near as possible to the disturbance injection point.

8 ACCEPTABILITY LIMITS

The functional class (A - B - C - D - E) achieved by the product being examined during discharge application shall be compliant with or higher than what specified for all the test levels. In case of device malfunctioning, carry out a minimal manual detection of voltage levels at which the device restarts regular operation (susceptibility limit detection).
Permanent failures, i.e.: class “E” failures on test components submitted to max. test level (different according to the test type) are not admitted.

TABLE 4

Type 1	up to ±8 KV	no defect admitted
	±8 KV to ±15 KV	certain non-priority functions can be out of tolerance but they shall return automatically to conformity as soon as disturbance disappears
Type 2	up to ±8 KV	no defect admitted
	±8 KV to ±15 KV	certain non-priority functions can be out of tolerance but they shall return automatically to conformity as soon as disturbance disappears
	±15 KV to ±25 KV	discharging only on ground plane must not show defects
Type 3	up to ±8 KV	no permanent failure admitted
Type 4	up to ±4 KV	no permanent failure admitted

9 PRESENTING RESULTS

For each test level (≤ to preset level), the obtained results should be shown together with any possible malfunctions, specifying whether these are permanent or temporary and their functional classes.
These results should be indicated as shown in **Table 5**.

TABLE 5

Test type at the bench		Technique	Probe	Type of impulse	No. of discharges	Test levels	Test result		Discharge injection points
							NP	P	
1	Accidental discharge, operator and device are both on vehicle	Approach	2 kΩ 330 pF	single	50	± 15KV	± 8KV in class A	± 15KV in class A	Device container, connector, wiring and accessible system points
2	Accidental discharge, operator is outside vehicle and device is on vehicle	Approach	2 kΩ 150 pF	single	50	± 15KV	± 8KV in class A	± 15KV in class A	Device container, connector, wiring and accessible system points
			2 kΩ 150 pF			± 25KV	± 25KV in class A		Ground plane
3	Discharge generated by handling or packaging operations	Contact	2 kΩ 150 pF	single	5	± 8KV	± 8KV in class A		Pin and device container (if metallic)
4	Discharge generated during repair operations by metallic objects	Contact	330 Ω 330 pF	single	5	± 4KV	± 4KV in class A		Pin and device container (if metallic)

STANDARDS QUOTED

IVECO STD.: 16-2108, 18-2252.

ISO: TW 10605.