EMC Immunity Test
Electrostatic discharge

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Agenda

• Background of ESD
• ESD Immunity Test - EN61000-4-2 Standard
  – Scope
  – Test level
  – Test generator
  – Test setup
  – Test procedure
  – Evaluation of test results
  – Test report
• Summary
What is Electrostatic Discharge?

- A person or charged object discharging into another person or object.
- If that object is a sensitive electronic component or circuit, the discharge can cause a component to damage or circuit to be malfunction.
ESD Models

- Human Body Model (HBM)
- Charged Device Model (CDM)
- Electrostatic Sensitive Device Model (ESDM)
EMC Immunity Test – ESD

BS EN 61000- 4- 2: 2009

Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test
Scope of EN61000-4-2

- It relates to immunity requirements and test methods for electrical and electronic equipment subjected to static electricity discharges, from operators directly, and from personnel to adjacent objects.
- It additionally defines ranges of test levels which relate to different environmental and installation conditions and establishes test procedures.
Scope of EN61000-4-2

Objective

• To establish a common and reproducible basis for evaluating the performance of electrical and electronic equipment when subjected to ESD.

• To include ESD which may occur from personnel to objects near vital equipment.
The standard defines:

– typical waveform of the discharge current;
– range of test levels;
– test equipment;
– test setup;
– test procedure;
– calibration procedure;
– measurement uncertainty.

Also, provides specifications for test performed in "laboratories" and "post-installation tests"
# Test Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Contact discharge</th>
<th>Air discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>X</td>
<td>Special</td>
<td>Special</td>
</tr>
</tbody>
</table>

- Threshold of feeling: 2-4kV
- Everyone can feel: 5kV
- Memorable event: 15kV

"x" can be any level. If higher voltages than those shown are specified, special test equipment may be needed.
ESD Generator

Consists of
– Discharging electrode
– Electronic circuit
– Discharge return cable

Example of ESD Generator in HKPC EMC Center

For contact discharge
For air discharge

The generator should be provided with means of preventing unintended radiated or conducted emissions, either of pulse or continuous type, so as not to disturb the EUT or auxiliary test equipment by parasitic effects.
Discharge electrodes of the ESD generator

- Contact discharges
- Air discharges

Note: The electrodes may be covered with insulated coatings, provided the discharge current waveform specifications are met.
Simplified diagram of the ESD generator

- charging resistor $R_c$;
- energy-storage capacitor $C_s$; $C_d + C_s$ : a typical value of 150 pF.
- distributed capacitance $C_d$;  $R_d$ : a typical value of 330 $\Omega$.
- discharge resistor $R_d$;
Discharge return cable

Cable length and structure

• 2 ± 0.05 m long, from generator body to the end of the connecting point.
• up to 3 m may be used when a 2 m length of the discharge return cable is insufficient. The waveform specification shall be met with the cable(s) used during testing
• shall be sufficiently insulated

Specification / Requirement

• constructed to allow the generator to meet waveform specification.
• used for testing shall be the same or identical with the cable used during calibration.
General specifications

- $V_{out, \text{contact}}$ = 1 kV to 8 kV, nominal
- $V_{out, \text{air}}$ = 2 kV to 15 kV, nominal
- Tolerance of $V_{out}$ = $\pm 5\%$
- Polarity of $V_{out}$ = Positive and negative
- Holding time $\geq 5$ s
- Discharge mode = Single
Example: Test Level = 2
Induced Voltage = 4 kV
First peak current of discharge ± 15%
Rise time $t_r = 0.8$ ns
The equation for the idealized waveform (4kV)

\[ I(t) = \frac{I_1}{k_1} \times \frac{\left( \frac{t}{\tau_1} \right)^n}{1 + \left( \frac{t}{\tau_1} \right)^n} \times \exp \left( -\frac{t}{\tau_2} \right) + \frac{I_2}{k_2} \times \frac{\left( \frac{t}{\tau_3} \right)^n}{1 + \left( \frac{t}{\tau_3} \right)^n} \times \exp \left( -\frac{t}{\tau_4} \right) \]

where

\[ k_1 = \exp \left( -\frac{\tau_1}{\tau_2} \left( \frac{n \tau_2}{\tau_1} \right)^{1/n} \right) \]

\[ k_2 = \exp \left( -\frac{\tau_3}{\tau_4} \left( \frac{n \tau_4}{\tau_3} \right)^{1/n} \right) \]

and

\[ \tau_1 = 1.1 \text{ ns}; \tau_2 = 2 \text{ ns}; \tau_3 = 12 \text{ ns}; \tau_4 = 37 \text{ ns}; \]
\[ I_1 = 16.6 \text{ A (at 4 kV)}; I_2 = 9.3 \text{ A (at 4 kV)}; \]
\[ n = 1.8. \]
Verification of the ESD Setup

The purpose of verification is to ensure that the ESD test setup is operating. The ESD test setup includes:

- ESD generator;
- discharge return cable;
- 470 kΩ bleeder resistors;
- ground reference plane, and,
- all of the connections that form the discharge path
Test set-up

• EN61000-4-2 standard mentioned test set-up for

➢ Tabletop
  ▪ Personal computer

➢ Floor-standing
  ▪ Washing Machine, Refrigerator

➢ Ungrounded equipment
  ➢ Includes both tabletop and Floor-standing equipment
  ▪ Mobile Phone, Watch and Clock
Test Requirement

• Laboratory testing environment shall meet within environmental reference conditions.

• Ground reference plane (GRP)
  – copper or aluminum of 0,25 mm minimum thickness;
  – other metallic materials may be used, at least 0,65 mm minimum thickness.
  – shall project beyond the EUT or the horizontal coupling plane (when applicable) by at least 0.5 m on all sides, and
  – shall be connected to the protective grounding system.

• Local safety regulations shall always be met.

• EUT - arranged and connected according to its functional requirements.

• Distance between the EUT and the walls of the laboratory and any other metallic structure = 0.8 m minimum.
Test Requirement

• EUT and ESD generator
  – grounded in accordance with their installation specifications.
  – No additional grounding connections are allowed.

• Positioning of power/signal cables
  – representative of installation practice.

• Discharge return cable
  – connected to the ground reference plane.
  – shall not come closer than 0.2 m to other conductive parts in the test setup except the ground reference plane.
Test Requirement

- Connection of the earth cables to the ground reference plane and all bondings
  - shall be of low impedance, for example by using mechanical clamping devices for high frequency applications.

- Where coupling planes are specified, e.g. indirect discharge,
  - metallic sheet (copper or aluminum) of 0.25 mm minimum in thickness (other metallic materials may be used but they shall have at least 0.65 mm minimum in thickness)
  - connected to the GRP via a cable with a 470 kΩ resistor located at each end. These resistors shall be capable of withstanding the discharge voltage. The resistors and cables shall be insulated to avoid short circuits to the GRP when the cable lies on the GRP.
Test set-up for tabletop equipment

For direct testing,
- EUT
- Wooden Table
- Insulating support
  - 0.5 mm thickness
- Ground Plane
- Horizontal Coupling Plane
- 2 x 470kΩ Resistors

For indirect testing,
- Vertical Coupling Plane is required
Test set-up for floor standing equipment

Insulating support
- 0.05 – 0.15 m thick

EUT
• cables isolated from the GRP by an insulating support of 0.5 mm.
• cable isolation shall extend beyond the edge of the EUT isolation.
• any mounting feet associated with the EUT shall remain in place.
Test Setup for ungrounded equipment

• Applicable to equipment or part(s) of equipment whose installation specifications or design precludes connection to any grounding system.

• This includes
  – Portable equipment,
  – battery-operated (internal and external) with/without charger (ungrounded power cable) equipment
  – double-insulated equipment.
Test set-up for ungrounded table-top equipment

Similar to grounded table-top equipment discharge test set-up, in additional:

- remove charge on EUT before ESD pulse injection
  
  e.g. metallic point/part  
  connector shells  
  battery charge pins  
  metallic antennas

**Method to remove charges**

1. A cable with 470 kΩ bleeder resistors
2. Extend the time interval between successive discharges
3. Sweeping of the EUT with a grounded carbon fibre brush with bleeder resistors (2 × 470 kΩ) in the grounding cable.
Test set-up for ungrounded floor standing equipment

grounded

ungrounded
Test Procedure

Testing Environment

Climatic conditions

• Ambient temperature: 15 °C to 35 °C;
• Relative humidity: 30 % to 60 %;
• Atmospheric pressure: 86 kPa to 106 kPa;

Electromagnetic conditions

• The electromagnetic environment of the laboratory shall not influence the test results.
EUT exercising

• The test programs and software shall be chosen so as to exercise all normal modes of operation of the EUT. The use of special exercising software is encouraged, but permitted only where it can be shown that the EUT is being comprehensively exercised.

• For conformance testing, the EUT shall be continually operated in its most sensitive mode (program cycle) which shall be determined by preliminary testing.

• If monitoring equipment is required, it should be decoupled from the EUT in order to reduce the possibility of false indications.
Discharges to the EUT

Shall be performed by direct and/or indirect discharges to the EUT according to a test plan.

This should include:

• EUT operating conditions of the EUT
• Determine the EUT whether is table-top or floor-standing equipment
• contact or air discharges points
• Test level
• Number of discharges to be applied at each point
Test Procedure – Direct

• The static electricity discharges shall be applied only to those points and surfaces of the EUT which are accessible to persons during normal use.

• Exclusions case:
  – only accessible under maintenance;
  – only accessible under service by the user;
  – no longer accessible after fixed installation;
  – connectors or contacts with a metallic connector shell;
  – connectors are labeled with ESD sensitive
## Cases for application of ESD on connectors

<table>
<thead>
<tr>
<th>Case</th>
<th>Connector shell</th>
<th>Cover material</th>
<th>Air discharge to:</th>
<th>Contact discharge to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metallic</td>
<td>None</td>
<td>–</td>
<td>Shell</td>
</tr>
<tr>
<td>2</td>
<td>Metallic</td>
<td>Insulated</td>
<td>Cover</td>
<td>Shell when accessible</td>
</tr>
<tr>
<td>3</td>
<td>Metallic</td>
<td>Metallic</td>
<td>–</td>
<td>Shell and cover</td>
</tr>
<tr>
<td>4</td>
<td>Insulated</td>
<td>None</td>
<td>a</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>Insulated</td>
<td>Insulated</td>
<td>Cover</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>Insulated</td>
<td>Metallic</td>
<td>–</td>
<td>Cover</td>
</tr>
</tbody>
</table>

**NOTE** In case a cover is applied to provide (ESD) shielding to the connector pins, the cover or the equipment near to the connector to which the cover is applied should be labelled with an ESD warning.

*a* If the product (family) standard requires testing to individual pins of an insulated connector, air discharges shall apply.
Test Procedure – Direct

- Test voltage: minimum => selected test level
- At least 10 discharges / point
- Each discharge time interval > 1 second (recommended)
- ESD generator perpendicular to EUT surface
- Distance between discharge return cable and ESD discharge points > 0.2m
Test Procedure – Indirect

- Similar to direct test procedure
- Applied at the edge of HCP and VCP with 0.1 m away from the EUT individually.
Evaluation result of the test

Performance Criteria

• Criteria A – Normal performance

• Criteria B – Temporary loss of function, without operator intervention

• Criteria C – Temporary loss of function, with operator intervention

• Criteria D – Loss of function
Test report

Contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

1. Test plan
2. IDs of the EUT and test equipment
e.g. brand name, product type, serial number
3. Any special environmental conditions
e.g. shielded enclosure
4. Any specific test conditions
5. performance level
6. Performance criterion
7. Effects on the EUT observed during/after the application of the test disturbance
8. Rationale for the pass/fail decision
9. Specific conditions of use
e.g. cable length/type, shielding/grounding, or EUT operating conditions, which are required to achieve compliance;
10. Climatic conditions;
11. Drawing/pictures of test setup and EUT arrangement.
Summary

This talk covered:

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Thanks for your attention!

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