

# New ESD standard and influence on test equipment requirements

Nicholas WRIGHT

EMC PARTNER AG, Baselstrasse 160 CH-4242 Laufen-SWITZERLAND  
e-mail: sales@emc-partner.ch

## Abstract

*The IEC61000-4 series of standards form a basic framework for the immunity and emissions testing of electrical and electronic equipment. They are the basis for EN standards used to test CE compliance of electrical and electronic products sold within the European Union. After a period of relative stability, changes are being introduced, designed to improve reliable application of the basic standards and ensure that the same results are obtained no matter where the tests are performed. Many changes relate to the calibration procedures for the test equipment. The surge standard, IEC61000-4-5, was revised at Edition 2 to amend impulse performance when applied through Coupling Decoupling Networks (CDNs) of varying current ratings. The Electric Fast Transient (EFT) standard, IEC61000-4-4, is also currently being studied with a view to changing the calibration requirements when used with CDNs and the Electrostatic Discharge (ESD) standard, IEC61000-4-2, is spearheading the application of measurement uncertainties and reviewing failure criteria.*

*While these changes do not directly influence the test procedure or methodology, the test equipment used is being subjected to much tighter scrutiny. ESD phenomenon is possibly the most complex EMC event to characterise or model. The IEC has accumulated experience over many years with ESD and is now updating the standard to reflect current technology. In the process of these changes, one aim is to improve the reliability of ESD tests. A result of these improvements is an increase in generator calibration and test time.*

## 1. Introduction

For the uninitiated, ElectroStatic Discharge (ESD) is a phenomenon as old as history itself. Particularly in cold dry climates, ESD events are extremely common. Who has not experienced a “shock” when getting out of a car in winter? Although unpleasant, ESD is not dangerous to humans as the energy content is very low. Figure 1 puts ESD in perspective in relation to other Electro-Magnetic (EM) events.

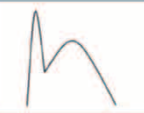


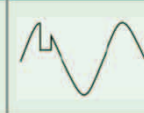
CHARACTERISTICS	STATIC DISCHARGE	SWITCHING OPERATIONS	LIGHTNING	POWER TRIP
PHENOMENON	ESD	EFT/BURST	SURGE	DIPS
VOLTAGE U	Up to 15kV	Up to 4kV	Up to 6kV	Mains
ENERGY AT MAXIMUM VOLTAGE	Below 10mJ	300mJ	300J	N/A
REPETITION RATE	Single impulse	Multiple pulses in kHz range	Ca. 1 per minute	Related to power frequency
APPLICATION (EUT)	Metal parts which can be touched by persons	Power, signal measuring & data lines	Power, signal measuring & data lines	Anything connected to AC or DC supplies
UPPER FREQUENCY LIMIT	Ca. 4GHz	Ca. 100MHz	Ca. 350kHz	Ca. 100kHz
WAVEFORM				

Figure 1. Transient overview.

## 2. International standard for ESD

IEC61000-4-2 [1] relates to the immunity requirements and test methods for electrical and electronic equipment subjected to static electricity discharges. The standard defines the following:

- ranges of test levels;
- different environmental installation conditions;
- establishes test procedures.

The object of this standard is to establish a common and reproducible basis for evaluating the performance of electrical and electronic equipment when subjected to electrostatic discharges. This standard has been used for many years and is an evolution of the IEC801-2 dating from 1991 [2]. In light of modern measurement methods and experience gained over the last 30 years, changes have been proposed and will be adopted during 2009.

## 3. Reasons for revision of IEC 61000-4-2

Today, using the equipment available and the current test standard, it has been found that any EUT could either pass or fail based on which type of simulator is used. Also new high speed technology is in use which operates into the GHz range. The Maintenance Team responsible for ESD standards (MT12) have issued a Committee Draft (CD) [3] proposing the following changes:

- Calibration and verification of measurement equipment to be more clearly defined
- Standard current waveform defined as a mathematical equation
- Measurement uncertainty defined for different parameters
- No tests at lower level for contact discharge

## 4. The “good old days”

Before everything got high-tech, ESD was a simple affair. Anything resembling the specified waveform that “magically” (and unexpectedly) appeared on the analogue oscilloscopes at the time, was acceptable and nobody could do anything to prove the contrary.

But, technology moves on and with the advent of digital oscilloscopes, bandwidths increased and, oops!, suddenly our ESD doesn't look so good anymore. Taking these advances into account and the view that ESD test results appeared to vary between locations led the standards organization to investigate further.

## 5. Round robin test waveform

Various “remedies” were proposed to improve the situation. One such was an attempt to modify the waveform tolerances, controlling the waveform to within much tighter limits and eliminating high frequency ringing. Additionally, a series of round-robin tests on six EUTs was conducted at different international locations using both the existing and modified simulators. The problem is no correlation could be found. To start with, the EUTs did not exhibit failures when subjected to the standard ESD test levels. Some EUTs had to be modified to even show a failure. Huge variations were observed as a result of changing the ESD simulator model. However, the modified simulators did not give an improved variation in results compared with the non-modified generators. Significantly, no direct correlation was found between current, fields or frequency related parameters and EUT failure level. As the final “nail in the coffin,” test result variations were observed between ESD simulators from the same manufacturer!

## 6. Variation in test results and escalation strategy

As no definitive source could be identified to explain the differences, a new approach had to be adopted for the whole test process. This involves the following steps:

1. Verify the test setup; examine all the details, including the position of each cable and the condition of the EUT (e.g., covers, doors).
2. Verify the test procedure, including the EUT operation mode, position and location of auxiliary equipment, operator position, software state, application of discharges to the EUT.
3. Verify the test generator; is it operating correctly? When was it calibrated last? Is it operating within specifications? Are test result differences due to the use of different generators?

## 7. Variation in test results due to the ESD simulator

If test results are varying because of the ESD simulator, apply the following procedure:

1. If differences in test results are caused by the use of different ESD generators, then the results with any generator that meets the requirements of 6.1 can be used for determining compliance with this standard.
2. Note: In terms of compliance with the standard, it is sufficient to consider only the results given by the ESD generator which is less aggressive to the EUT. In terms of EUT quality/reliability and customer satisfaction, it may be advisable to ensure the EUT exhibits error-free performance with the ESD generator which is more aggressive to the EUT.

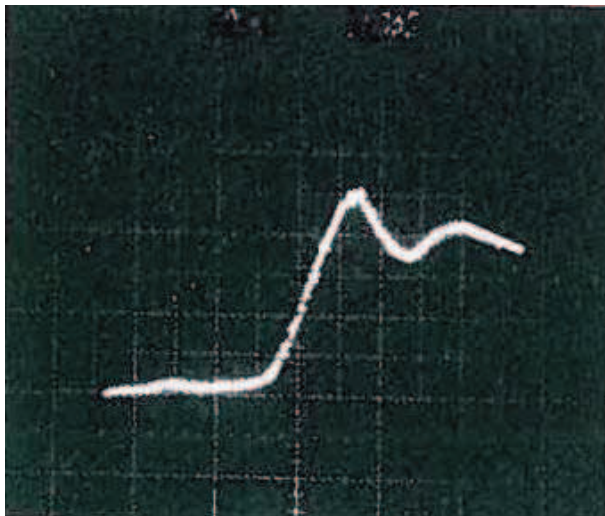


Figure 2. Analogue ESD measurement.

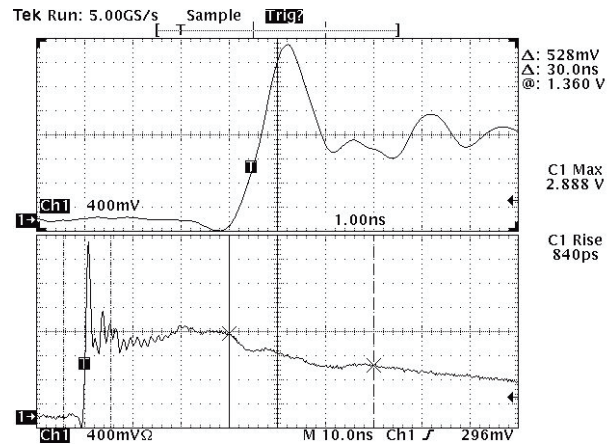


Figure 3. Existing simulator.

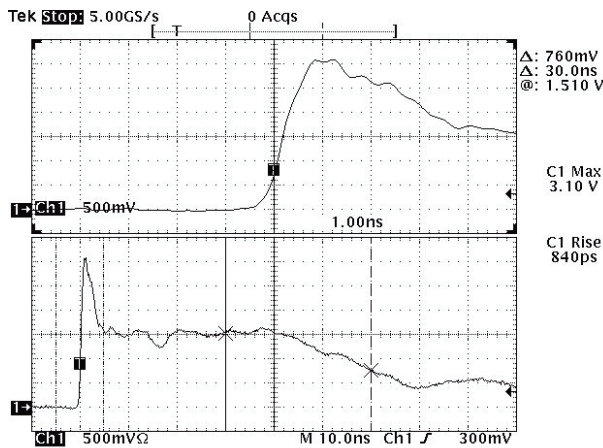


Figure 4. Modified simulator.

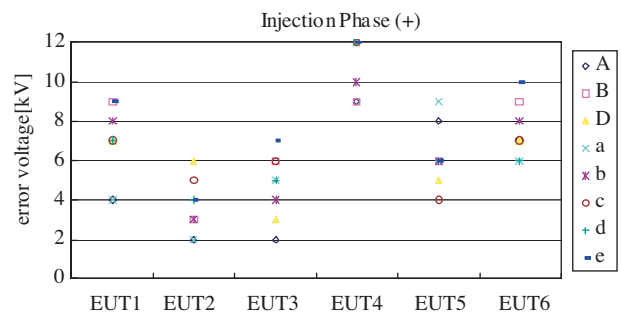


Figure 5. Round robin results.

## 8. Escalation strategy

As a further verification of test results, it was decided that an escalation strategy should be employed.

1. If more than 1 error occurs in the first 50 discharges applied to a test point, the EUT fails the test at that test point and test level.
2. If 1 error occurs in the first 50 discharges applied to a test point, a second test is run at that test point applying 100 new discharges. If no error occurs in this set of 100 discharges, the EUT passes the test at that test point. If more than one error occurs in this set of 100 discharges, the EUT fails the test. If exactly 1 error occurs in this set of 100 discharges, a third test is performed.
3. The third test is a repetition of point 2. If no error occurs in this set of 100 discharges, the EUT passes the test at that test point. If 1 or more errors occur in this set of 100 discharges, the EUT fails the test.

## 9. Immediate effects

These measures are intended to increase the reliability and repeatability of test results, making them independent of the ESD simulator model. The immediate effect for EVERYBODY is a dramatic increase in test time. Test laboratories, who charge by the hour, will be delighted by this.

## 10. Proposed new target

As part of the new calibration procedure, an updated target has been proposed. In the late 1980's, the existing "Pelligrini" target [2] represented the height of technology with a bandwidth of approximately 1GHz. This was perfectly matched to the oscilloscopes of the time. With increasing bandwidth, measurement discrepancies started to creep in so it became evident a matched, higher bandwidth, measurement chain was necessary. The result is a revised target with 4 GHz bandwidth [4]. From the schematic diagram,  $Z_{SYS} = V_{50} / I_{SYS}$  and therefore  $I_{ESD} = V_{ESD} / Z_{SYS}$ .  $Z_{SYS}$  must be used to calculate the ESD current.  $V_2$  is a factor 2 higher because of the missing 50 ohm. Because of the high bandwidth and very tight tolerances on variation across the frequency range, any discontinuity will have a significant effect on frequency response. It is therefore important to employ good RF engineering practice and calibrate the target together with any cables and connectors necessary for the ESD calibration.

## 11. New target calibration requirements

For the first time in an ESD standard, the calibration target is carefully defined. As with any high frequency calibration measurement, the actual test equipment can be a significant factor and must be carefully considered. The standard doesn't specify the exact measurement equipment, but a network analyser capable of measuring S-Parameters is practically indispensable. The other problem is how to make a connection to the target that does not introduce electrical discontinuities. Other adapter shapes than conical are also acceptable.

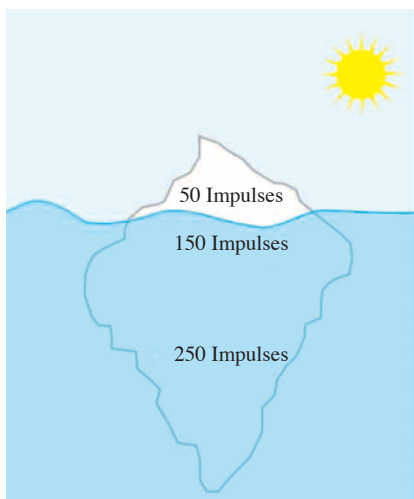


Figure 6. Hidden "detail".



Figure 7. Existing IEC 61000-4-2 Ed1 "pelligrini target" approx. 1 Ghz.

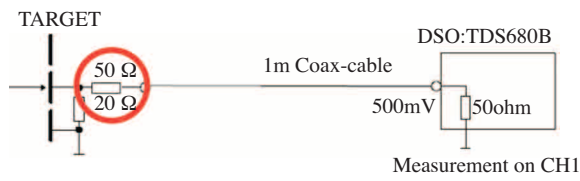


Figure 8. Schematic of existing target.

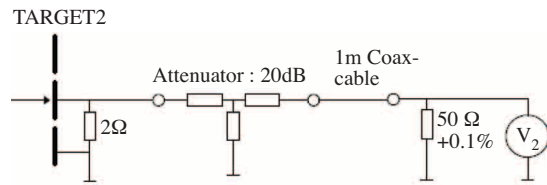


Figure 9. New target.



Figure 10. New 4 Ghz ESD target.

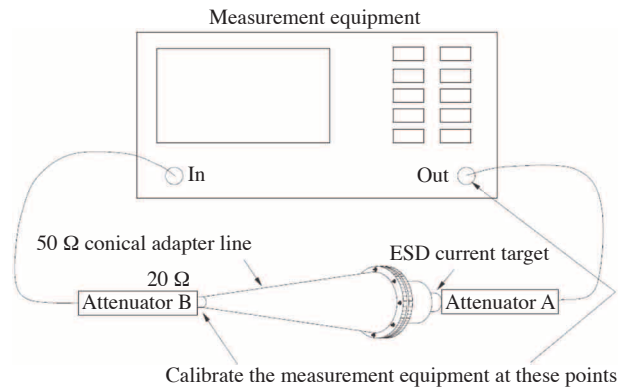


Figure 11. Target calibration.

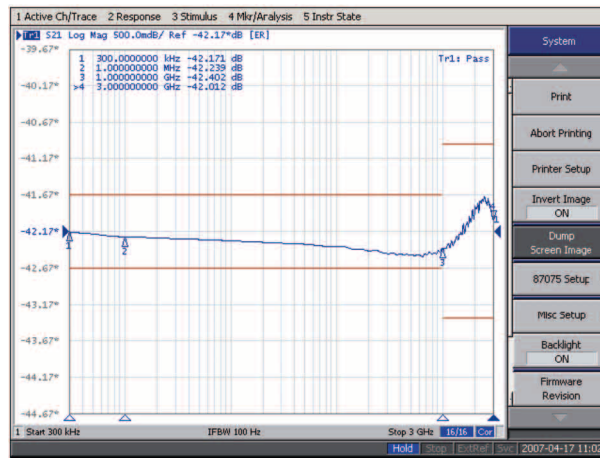


Figure 12. Frequency response of new target.

## 12. Calibration procedure

A new calibration procedure for ESD simulators is designed to remove the “one shot wonder” approach by specifying the exact number of discharges and levels to be verified. This approach, like the new test procedure, will increase the time necessary to calibrate ESD simulators. 5 (discharges) x 2(each polarity) x 4 test levels = 40 impulses minimum. This simple change will mean more time in the calibration laboratory and therefore calibration costs for ESD simulators will increase.

Step	Explanation
Discharge the ESD generator at each test level as defined in Table 1 five times for both polarities, store each result.	The specifications shall be met for all 5 discharges.
Measure $I_p$ , $I_{30}$ , $I_{60}$ , $t_r$ on each waveform.	The parameters shall be checked at each test level
<b>Current at 30 ns</b> Check if $I_{30}$ is 2 A $\pm$ 30 %	The parameters shall be checked at each test level <sup>a</sup>
<b>Current at 60 ns</b> Check if $I_{60}$ is 1 A $\pm$ 30 %	The parameters shall be checked at each test level <sup>a</sup>
<b>Peak current</b> Check if $I_p$ is 3,75 A $\pm$ 15 %	The parameters shall be checked at each test level <sup>a</sup>
<b>Rise time</b> Check if $t_r$ is 0,8 ns $\pm$ 25 %	The parameters shall be checked at each test level
<sup>a</sup> The value of the current given in this table corresponds to a voltage of 1 kV. This measured value changes proportionally to the generator voltage.	

Figure 13. Simulator calibration procedure.

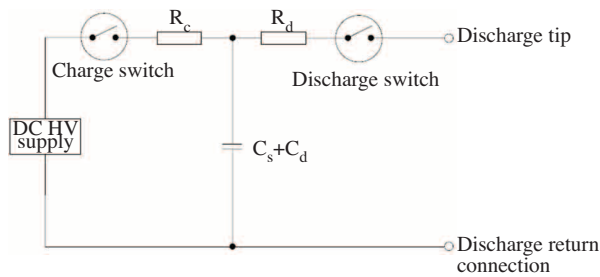


Figure 14. ESD simulator schematic.

Parameters	Values
Output voltage, contact discharge mode (see NOTE 1)	At least 1 kV to 8 kV, nominal
Output voltage, air discharge mode (see NOTE 1)	At least 2 kV to 15 kV, nominal (see NOTE 3)
Tolerance of output voltage	$\pm$ 5 %
Polarity of output voltage	Positive and negative
Holding time	$\geq$ 5 s
Discharge mode of operation	Single discharges (see NOTE 2)
NOTE 1 Open circuit voltage measured at the discharge electrode of the ESD generator.	
NOTE 2 The generator should be able to generate at a repetition rate of at least 20 discharges per second for exploratory purposes.	
NOTE 3 It is not necessary to use a generator with 15 kV air discharge capability if the maximum test voltage to be used is lower.	

Figure 15. ESD simulator performance.

### **13. No change here!**

ESD simulators shall meet the requirements given in paragraph 6.1, of IEC61000-4-2 Ed2, when evaluated according to the procedures in Annex B of the standard. Therefore, neither the diagram in Figure 14, nor the element values are specified in detail. The intent is not to define a generator in terms of the component values, rather the calibration waveshape. Because of this, there should be no problem with existing ESD simulators complying with the edition 2 requirements.

### **14. Exploration of EUT using 20Hz discharge repetition**

Note 1 indicates that the voltage should be measured at the point of discharge. This has been a controversial point for many years. The only way to be absolutely certain the voltage is as specified (assuming the ESD indication is ignored) is by use of an external measurement device. Note 2 is specifically intended for finding weak spots in the EUT. Because of the electro-mechanical switches used in ESD simulators, the 20 Hz test is best performed in air discharge mode. Such a high repetition reduces the life span of the high voltage relay.

## **References**

- [1] International Electrotechnical Commission, "Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test", IEC61000-4-2 Ed 1, 1995.
- [2] International Electrotechnical Commission, "Electromagnetic compatibility for industrial process measurement and control equipment – Part 4-2: Electrostatic discharge requirements", IEC801-2, 1991.
- [3] International Electrotechnical Commission, "Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test", IEC61000-4-2 Ed 2, 2008.
- [4] EMC PARTNER, "ESD-TARGET2 for calibration of the ESD discharge current waveform, target type SMD as proposed for gun comparison.", 2008.