Update on EFT/Burst Testing - The revision of IEC 61000-4-4

By Harald Kunkel, EM TEST

SUMMARY

EFT/burst testing has been a part of EMC testing for about 20 years. The first standard that was released for this test procedure was called IEC 801-4 and it was published in 1984. The standard was written by the Working Group 4(WG 4) of TC65A (a technical committee working on IEC standards). At that time TC65A was responsible for EMC problems in the area of Industrial Measuring and Process Control Systems.

IEC 801-4 was converted into IEC 1000-4-4 without any technical changes. Also the IEC technical committee was changed from TC65A to TC 77B.

The next step was made in 1995 when the new IEC version designation was changed to IEC 61000-4-4. In 2001, Amendment 1, which specified how the EFT generator pulse is verified to assure compliance with the standard, was added to IEC 61000-4-4

Over this 20 year period, testers gained a lot of experience in EFT/burst testing and many felt that updates needed to be made to the standard to reflect real world observations. As a result, a new draft based on user inputs was circulated to the National Committees for vote. At the last WG meeting at the end of November 2002, the WG reviewed comments made to the new draft and as far as possible included them into the next draft.

The most significant changes in the standard are in paragraphs " 5 Test Levels" and "6 Test Equipment" specifying the generator and the coupling/ decoupling networks. These are outlined here below.

1. Paragraph “5 Test levels”

A new repetition frequency is introduced!

The preferred test levels for the electrical fast transient test, applicable to power supply; ground, signal and control ports of the equipment are given in table 1.

Open circuit output test voltage			
Level	On power ports	On I/O ports	
	Voltage		Repetition rate (2)
	kV peak		kHz
1	0.5	0.25	5 or 100
2	1	0.5	5 or 100
3	2	1	5 or 100
4	4	2	5 or 100
x (1)	Special	Special	

NOTE 1 - "X" is an open level. The level has to be specified in the dedicated equipment specification.

NOTE 2-5kHz is the traditional frequency, however 100kHz is closer to reality. Product committees should determine which frequencies are relevant for specific products or product types.

Table 1 – Test levels

Remark:

In the existing IEC 61000-4-4 the repetition frequency is set to 5kHz or to 2.5kHz (at the 4kV-test level). These levels are based on a very old generator design. Very old generators use spark gaps as the high voltage switch to generate the fast transients. As explained in paragraph 6 below, these very old generators can no longer be used for the new standard.
Therefore the WG11 of TC 77B believes that a move to higher repetition frequencies is appropriate and closer to the real event. The 100kHz frequency is a value, which can be changed by product committees to any other value, which might be more representative of conditions seen in the field. Annex A1 of the IEC standard discuses the frequencies that might be expected in the field. A range up to 1MHz is reasonable and most generators available on the market today are able to handle these higher frequencies.

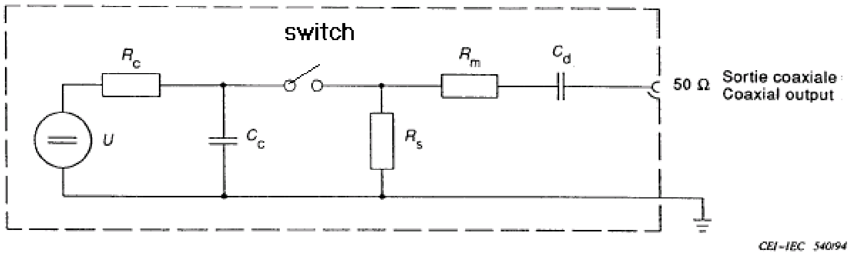
Of course, product committee can also decide to stay with the 5kHz repetition frequency.

The working group also intended to delete the different voltage application levels between AC power ports and I/O ports and give them the same test levels. This change was not accepted by the large majority of National Committees and is therefore no longer under discussion.

2. Paragraph "6 Test equipment specification"

6.1 Burst generator

The simplified circuit diagram of the generator is given in figure 1. The circuit elements Cc, Rs, Rm, and Cd are selected so that the generator delivers a fast transient under open circuit conditions and with a 50Ω resistive load. The effective output impedance of the generator shall be 50Ω.



U = high-voltage source
R_c = charging resistor
C_c = energy storage capacitor
R_s = pulse duration shaping resistor
R_m = impedance matching resistor
C_d = d.c. blocking capacitor

Figure 1 – Simplified circuit diagram of a fast transient/burst generator

Remark:

The EFT/burst generator has to use a controlled high voltage switch and no longer use the spark gap generator. The spark gap is not able to generate the pulses in a consistent matter and it is not able to keep all the generator parameters within the specified tolerances. Therefore, old EFT/burst generators still using spark gaps can no longer be used for the new standard.

EFT generators made within the last 10 years normally are designed with semiconductor high voltage switches. The semiconductor switches can guarantee longer life, high reproducibility and in addition can generate higher frequencies than the previous 5kHz upper limit that could be handled by spark gaps and similar devices.

6.1.1 Characteristics of the fast transient/burst generator

- Output voltage range with 1000 Ω load shall be at least 0.25kV to 4 kV
- Output voltage range with 50 Ω load shall be at least 0.125kV to 2kV

The generator shall be capable of operating under short-circuit conditions.

Characteristics:

- Polarity:	positive/negative
- Output type:	coaxial, 50 Ω
- DC blocking capacitor	10 nF ± 20%
- Repetition frequency:	5kHz or 100kHz ± 20%
- Relation to power supply:	asynchronous
- Burst duration: (see figure 2)	15 ms ± 20 % at 5kHz 0,75ms ± 20% at 100kHz
- Burst period (see figure 2):	300 ms ± 20%
- Wave shape of the pulse	
- into 50Ω load (see figure 3)	rise time t_r = 5ns ± 30% duration t_d (to 50%) = 50ns ± 30% Vp at 50Ω = according to Table 2, ±10%
- into 1000 Ω load	rise time tr = 5ns ± 30% duration t_d (to 50%) = 50ns with a tolerance of minus 15ns to plus 100ns Vp at 1000Ω = according to Table 2, ±20%
- Test load impedance	50Ω ± 2% 1000Ω ± 2% in parallel with ≤ 6pF. The resistance measurement is made at DC and the capacitance measurement is made using a commercially available capacitance meter that operates at low frequencies.

Remark:

The proposed change to higher frequencies must not result in higher energy injected into the EUT. Therefore, if the repetition frequency is increased from 5kHz to 100kHz (by the factor 20) the burst duration is reduced to 0.75ms (from 15ms by the same factor 20). This measure should keep the energy constant and the only influence of the higher frequency is dependent upon the EUT design and how it responds to the higher frequencies.

EM TEST

6.1.2 Verification of the characteristics of the fast transient/burst generator

The test generator characteristics specified in clause 6.1.1(above) shall be verified in order to establish a common reference for all generators. For this purpose the following procedure shall be undertaken.

The test generator output shall be connected to a 50 Ω and 1000 Ω coaxial termination respectively and the voltage monitored with an oscilloscope. The –3dB bandwidth of the measuring equipment and the test load impedance shall be at least 400 MHz. The test load impedance at 1000 Ω is likely to become a complex network. The rise time, impulse duration and repetition rate of the impulses within one burst shall be monitored as well as the burst duration and burst period.

For each of the set voltages of Table 2, measure the output voltage at a 50Ω load – Vp (50Ω). This measured voltage shall be [0.5 x Vp(open circuit)] ± 10%.

With the same generator setting (Set Voltage), measure the voltage at a 1000Ω load – Vp (1000Ω). This measured voltage shall be Vp (open circuit) ± 20%.

Note: Measures shall be taken to ensure that stray capacitance is kept to a minimum.

Set voltage (kV)	*V*p (open circuit) (kV)	*V*p (1 000 Ω) (kV)	*V*p (50 Ω) (kV)	Repetition frequency (kHz)
0.25	0.25	0.24	0.125	5 or 100
0.5	0.5	0.48	0.25	5 or 100
1	1	0.95	0.5	5 or 100)
2	2	1.9	1	5 or 100
4	4	3.8	2	5 or 100

Table 2-Output voltage peak values and repetition rates

NOTE 1 - Use of a 1000 Ω load resistor will automatically result in a voltage reading that is 5 % lower than the set voltage as shown in column Vp (1000 Ω). The reading *V*p at 1000 Ω = Vp (open circuit) multiplied times 1000/1050 (the ratio of the test load to the total circuit impedance of 1000 Ω plus 50 Ω). The voltage tolerance specified in 6.1.1 is referred to nominal values given in column Vp (1000 Ω) of Table 2.

NOTE 2 - With the 50 Ω load, the measured output voltage is 0.5 times the value of the unloaded voltage as reflected in the table above.

6.2 Coupling/decoupling network for a.c./d.c. mains supply port

The coupling/decoupling network is required for acceptance tests of a.c./d.c. power supply ports. The circuit diagram (example for a three-phase power mains supply) is given in figure 4.

The waveform of the EFT generator shall be verified at the output of the coupling network according to 6.2.2.

6.2.1 Characteristics of the coupling/decoupling network

- Coupling capacitors: 33 nF;
- Coupling mode all lines to earth

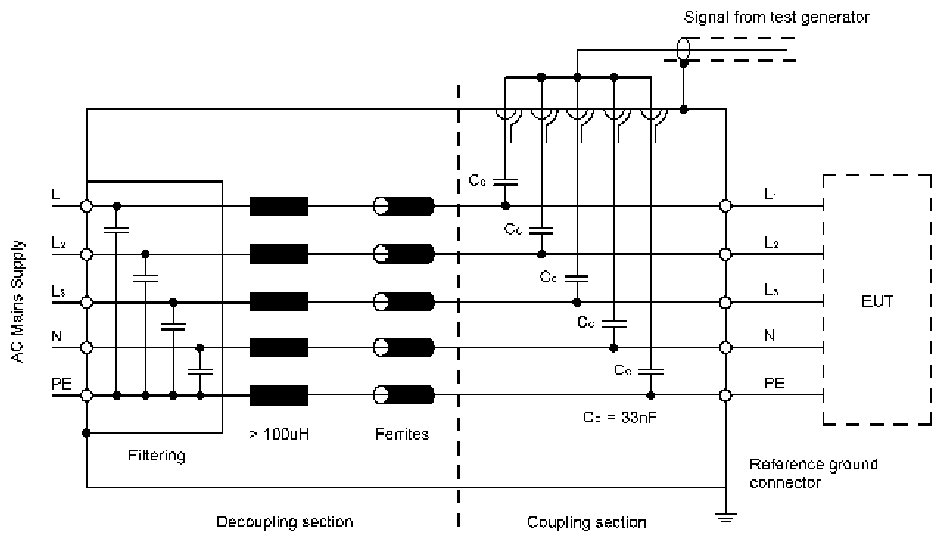


Figure 4-Coupling/decoupling network for a.c./d.c. power mains supply ports/terminals

Remark:

The change, "coupling mode to all lines", has changed the test into a common mode test. This means that tests on single power supply lines is no longer required. The author would like to point out that there are some experts who prefer to keep the line by line testing in the standard because not all failures can be detected by the common mode procedure. Existing coupling/decoupling networks do support all possible coupling modes. Therefore, it will be the responsibility of the user to decide whether the line by line test will be done or not.

Generally, from a legal standpoint, the common mode procedure is required. But, from a product quality aspect, the author recommends that, at least during the product design phase, line by line tests be conducted to gain experience and knowledge about the product performance and to enhance the margin of design for the product.

6.1.2 Verification of the characteristics of the coupling/decoupling network

The requirements given in 6.1.2 apply for the measuring equipment that is used for the verification of the characteristics of the coupling/decoupling network.
The waveform shall be verified at the common mode output of the coupling/decoupling network with a single 50Ω termination.
The verification is performed with the generator output voltage set to a nominal voltage of 4kV. The generator is connected to the 50Ω load through the output of the coupling/decoupling network and the voltage is recorded again.
Rise time of the pulses shall be 5ns ± 30%.
Impulse duration (50% value) shall be 50ns ± 30%

Remark:

This is an important technical change in the new standard. In the past it was not required to calibrate or verify the EFT/burst transients at the output of the coupling/decoupling network.
Now, the new standard requires that the test generator and its CDN's must be verified as follows:

1. At the generator coaxial output into a 50Ω and a 1000Ω load.
2. At the coupling/decoupling networkoutput in the common mode output into a 50Ω load.

These verification procedures should increase the repeatability between different generators.

7.2 Test set-up for type tests performed in laboratories

7.2.1 Test conditions

In the case of table-top equipment, the EUT should be located 0.1m ± 0.01m above the ground plane (see figure 7a).

The test generator and the coupling/decoupling network shall be placed directly on, and bonded to the ground plane.

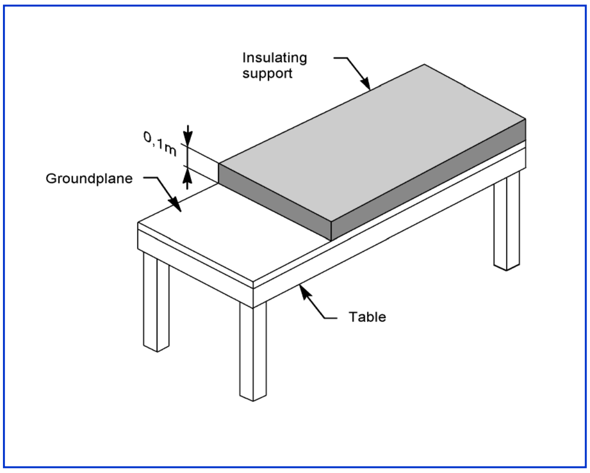


Figure 7a – Test set-up for table-top equipment

Remark:

In IEC 61000-4-4, tabletop equipment is placed on a wooden test table 0.8m above the ground reference plane (the ground plane upon which the table is placed-see Figure 7 in the standard). The EFT tests as well as the test for "Conducted Immunity" per IEC 61000-4-6 are high frequency tests. Therefore, the test setup must be carefully arranged so that high frequency return paths to the transient generator are provided for. To take this into account, the test setup of IEC 61000-4-4 is harmonized with the test setup in IEC 61000-4-6 where both the test instrumentation and the DUT are located on the ground reference plane (GRP) on the test table top. The generator and the CDN are bonded to the GRP using lead lengths as short as possible. The DUT is located 10cm above the GRP on an insulated standoff.

For this reason Figure 7a was introduced to clearly show the required tabletop set-up and Fig. 7 must be modified accordingly.

It is also important to mention that the same test setup can be used for the following standards:

- IEC 61000-4-2 (the test setup will also be modified in the next draft)
- IEC 61000-4-4
- IEC 61000-4-5 (for which the GRP is not required but can be used)
- IEC 61000-4-6
- IEC 61000-4-11 (for which the GRP is not required but can be used)
- IEC 61000-4-12

A new test setup (Figure 7b) is introduced for rack systems where the cables under test exit the product on top.

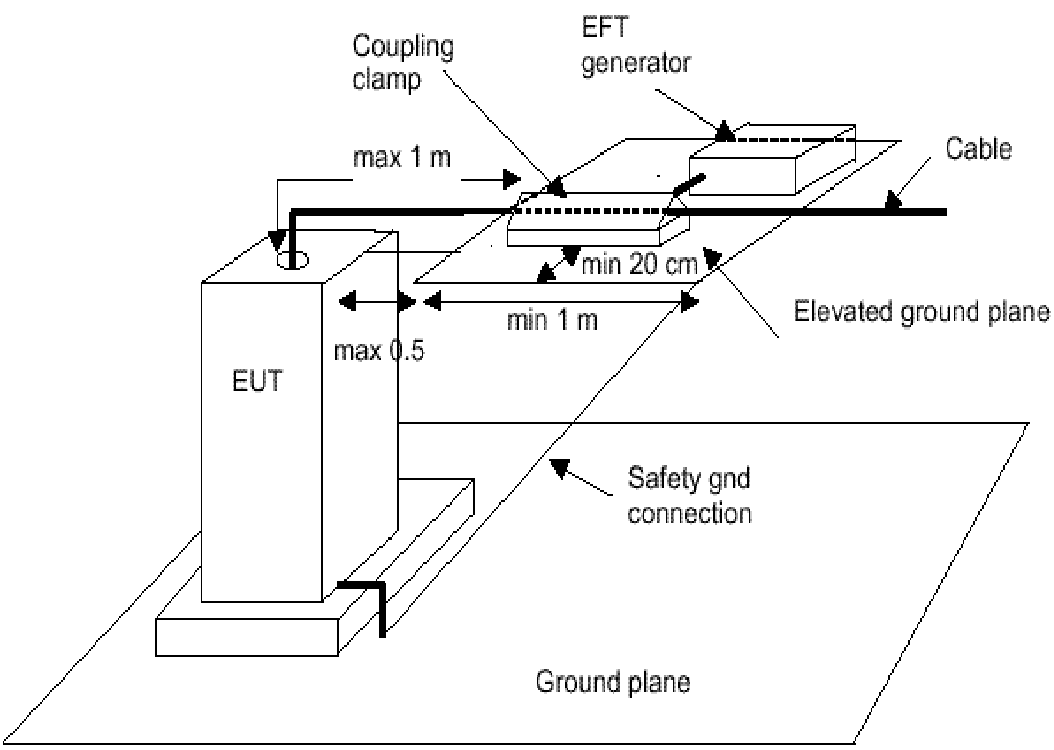


Figure 7b-Example of a test set up for rack mounted equipment

Conclusion

The revised IEC 61000-4-4 standard is outlined in this paper. The author was a member of TC65/WG4 and he is also on the current TC77/WG11 that is responsible for the maintenance of the standard. Therefore, this paper has provided the reader with some background information that will help in understanding the scope of the changes being made to the standard. The author cannot guarantee that there will not be more technical changes in the future or that existing changes will not be withdrawn in a later versions of the standard draft.

It should also be noted that the text in the final version of the standard may look different as compared to that given this paper. This paper only deals with the <u>most</u> significant changes and not with all technical changes nor does it refer to any editorial changes.