Transient Testing According to the EMC Directive

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An understanding of the background, specification and testing requirements for the IEC burst and lightning specs is important.

BACKGROUND

Investigation has highlighted the vulnerability of electrical and electronic equipment to fast transients with a high repetition frequency. Since the European Directive on EMC calls for equipment to be not unduly susceptible to electromagnetic interference, there is a need for a reproducible basis for testing the performance of equipment when it is subjected to fast transients or bursts on supply, signal or control lines.

Transients produced by inductive load switching or relay contact bounce are examples of phenomena that can be replicated. These bursts consist of numerous sparks rather than one single defined event. The bursts start out quickly with low amplitude and increase in voltage and spacing as the transient progresses. As the relay contacts continue to open, the pulse decays, either because inductive energy is dissipated or the gap between contacts is too great to allow arcing. The transient voltage levels can range from hundreds of volts to 4 kV, and repetition rates can vary from several kHz to more than 100 kHz.

IEC 801-4/1000-4-4 for transient burst immunity and IEC 801-5/1000-4-5 for lightning transient immunity have been written to address the electromagnetic compatibility of industrial process measurement and control equipment. In addition, the standards are used as references for both EN 50082-1, (Residential, Commercial, Light Industrial) and EN 50082-2, (Industrial) "Generic Standards." Actually, IEC 801-4 and 1000-4-4 are very similar, with 1000-4-4 being a re-issue of the earlier IEC 801-4. Some editorial content differs but technical requirements remain the same. It should be noted that IEC 1000-4-4 is currently being revised, although amendments are unlikely to be published until later this year.

THE TESTING PROCESS

For the purposes of evaluation the standard for IEC 1000-4-4 effectively puts forth a "model" transient which is then injected into the equipment under test. This requires a fast transient generator, the specifications for which are outlined in the standard. Essentially, a high voltage dc supply charges an energy storage capacitor via a charging resistor. Once a given voltage level is reached across the capacitor, a discharge takes place with the pulse waveform being shaped by an output filter.

The model transient consists of a series of pulses of 15-ms burst durations, with a total burst period of 300 ms (Figure 1). The transient pulses each have a nominal rise time of 5 ns (±30%) and a nominal duration of 50 ns (30%). This pulse is commonly known as a 5/50 ns waveform. The repetition rate of the pulses is either 5 or 2.5 kHz (±20%), depending upon the peak value of the output voltage (Table 1).

The test generator should have an impedance of 50 ohms. Older generators use a spark gap for the generation of the pulses, but more recent models are solid-state. Coupling the generator to the equipment under test is achieved by two means.

First is the use of a coupling/decoupling network (decoupling prevents pulses from being conducted back onto supply systems). Most commercial fast transient generators incorporate the network which couples the interference onto the mains supply to the EUT as part of the total unit. The result is that the equipment to be tested plugs directly into the fast transient generator.

Secondly, a coupling clamp can be used to couple pulses to signal and control cables. Capable of accommodating cables 4 mm to 40 mm in diameter, generator output is connected between two plates on either side of the cable (Figure 2).

Bursts of fast transients should be applied to each conductor in turn, starting at the lowest severity level and increasing until the required test level is reached. Tests should then be repeated for opposite pulse polarity. The duration of the test can be variable, but should not be less than

Output voltage	Repetition rate
0.125 kV	5 kHz
0.25 kV	5 kHz
0.5 kV	5 kHz
1.0 kV	5 kHz
2.0 kV	2.5 kHz

Table 1. *Repetition Rate of Pulses for IEC 801-4/1000-4-4.*

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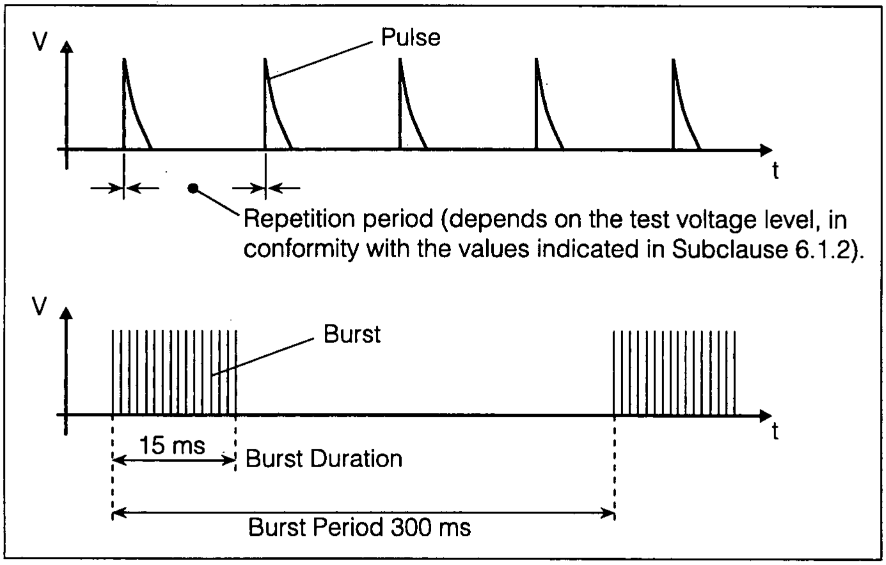

Figure 1. *Fast Transient Burst According to IEC 1000-4-4.*

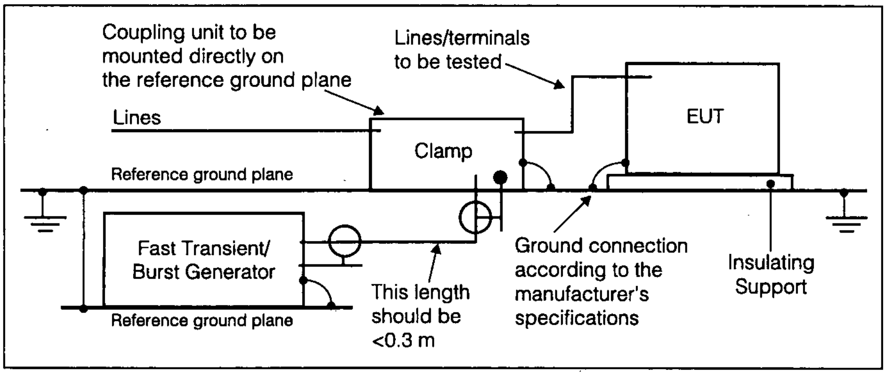

Figure 2. *Electrical Fast Transient/Burst Test According to IEC 1000-4-4.*

Level	On Power Supply	On 1/0 signal, data & control lines
1	0.5 kV	0.25 kV
2	1 kV	0.5 kV
3	2 kV	1 kV
4	4 kV	2 kV
X	Special*	Special *

*An open level subject to agreement between the manufacturer and end user or as specified by manufacturer.

Table 2. *Severity Levels Specified by IEC 801-4.*

one minute. A word of caution is warranted: the application of fast transients can be destructive if the EUT does not have adequate immunity. In a series of EMC tests, it is advisable to do these tests after all others except for the ESD tests.

TEST SEVERITY LEVELS

Severity levels are specified in IEC801-4 (Table 2). The voltage level shown is the peak voltage of the pulse measured on an open circuit ±10%.

The severity level should be chosen in accordance with the most likely environmental conditions that the product is expected to experience, once installed. These are described in more detail.

Level 1:
Well Protected Environment

Example: computer room.

Features:
- Suppression of all fast transient/bursts in the switched control circuits.
- Separation of power lines from sensitive circuits.
- Power cables shielded with screens grounded at both ends.
- Filtered power supply.

Level 2: Protected Environment

Example: control or terminal room in an industrial or electrical plant.

Features:
- Partial suppression of fast transient/burst in the switched control circuits.
- Separation of all circuits from circuits with higher severity levels.
- Physical separation of power lines from sensitive lines.

Level 3:
Typical Industrial Environment

Example: area of industrial process equipment, power plant or HV substation.

Features:
- No suppression of fast transient/burst in the switched control circuits.
- Poor separation of industrial circuits from circuits with higher severity levels.
- Poor separation of power lines from sensitive lines.
- Dedicated cables for power supply, control, signal and communication lines.
- Typical grounding system would be via conductive pipes, ground conductors in cables trays or ground mesh.

Level 4:
Severe Industrial Environment

Example: outdoor area of industrial process equipment of power stations, open air HV substation with switchgear up to 500 kV.

Features:
- No suppression of fast transient/burst in the switched control circuits.

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- No separation of industrial circuits from circuits with higher severity levels.
- No separation of power lines from sensitive lines.
- Use of multicore cables in common for control and signal lines.

Level X:
Special Situations to be Analyzed
The separation of interference sources from equipment circuits, cables, lines, etc., and the quality of the installations may require the use of a higher or lower environmental level than those described above. It should be noted that equipment lines of a higher severity level can penetrate a lower severity environment.

EVALUATION OF RESULTS

Because of the diversity of the equipment and systems to be tested, it is difficult to establish general criteria for the evaluation of the effects of the test. The results may be classified on the basis of the operating conditions of the EUT as follows:

- Normal performance within the specification limits.
- Temporary degradation or loss of function or performance which is self-recoverable.
- Temporary degradation or loss of function or performance which requires operator intervention or system reset.
- Degradation or loss of function or performance due to damage of equipment (components).

The test results are subject to agreement between the manufacturer and the end user.

If IEC 801-4 is being used as a test method *under the generic standards,* then the performance criteria laid down in the generic standard should be used.

GENERIC STANDARD PERFORMANCE CRITERIA

The diversity of products covered by this standard make precise criteria for evaluation of the immunity tests difficult to apply. However, apparatus should never become dangerous as a result of the application of the tests. A description and definition of the performance criteria used during testing should be noted on the test report, based on the following criteria:

Performance Criterion A: The apparatus should continue to operate as intended. No degradation of performance is allowed below a performance level specified by the manufacturer.

Performance Criterion B: The apparatus should continue to operate as intended after the test. Temporary degradation below a level specified by the manufacturer during the test is, however, allowed.

Performance Criterion C: Temporary loss of function is allowed, provided the function is self recoverable or can be restored by the operation of the controls.

In both EN 50082-1 and EN 50082-2 Performance Criteria B is specified for fast transient testing.

IEC801-5/IEC1000-4-5 BACKGROUND

This standard has been written to address the surge immunity needs for electronic and electrical equipment. The requirements for this form of testing are currently contained in an annex to EN 50082-1, (Residential, Commercial, Light Industrial Generic Standard).

The standard is designed to test the equipment's immunity to unidirectional surges caused by overvoltages from switching and lightning transients. In terms of lightning transients, both direct and indirect strikes need to be considered, particularly their occurrence on power transmission lines which can then pass through the system to equipment connected in houses and offices. In these cases the closer the strike to secondary and tertiary branches, the more severe the surge phenomena on the equipment. These events can produce very high currents with high energy, low impedance pulses causing insulation tracking, and PCB trace destruction in connected equipment.

Direct lightning strikes are of obvious concern, although indirect events to nearby objects and current flow from nearby direct to ground discharges coupling into common grounding paths need to be considered. In addition to natural phenomena, there are manmade events such as capacitor bank switching, resonating circuits from switching thyristor devices and fuse blows, and short circuits, all of which can induce transients down the line. The increasing demand for surge suppression equipment and components is indicative of the persistence of this phenomena and the inability of a great deal of existing apparatus to cope satisfactorily with its effect.

The method for surge testing is similar to static and fast transient/ burst testing in that the equipment should be tested at all levels up to the required level and not beyond that specified by the manufacturer (Table 3). Unless otherwise specified, the pulses (both positive and negative) must be applied such that they are synchronized to the mains zero crossing and maximum voltage levels (i.e., at four points on the cycle). At least five applications of the pulse must be made in each case, care being taken to ensure that any protection devices are allowed time to recover between applications. As with fast transient/ burst tests the levels refer to the

Level Voltage	Open-Circuit Test (+/- 10%)
1	0.5 kV
2	1.0 kV
3	2.0 kV
4	4.0 kV
X	Special*

*A level open to negotiation between the manufacturer and end user or as specified by the manufacturer.

Table 3. *Test Severity Levels for IEC 1000-4-5.*

appropriate environment in which the EUT is situated. The test results should be analyzed to determine to which performance criterion the equipment corresponds.

The test equipment required for surge testing is a combination waveform generator which can produce the required voltage waveform and then switch instantaneously to the required current waveform if breakdown occurs. The generator should have an effective output impedance of 2 ohms, additional resistances are placed in series for some tests (refer to the standard). The generator must be capable of providing both positive and negative polarity pulses with a repetition rate of at least 1 per minute. It must also be possible to vary the position of the pulse with respect to the phase of the ac mains supply. A floating output is also preferred.

Companies looking to conduct in-house transient burst testing either for design and development or for final compliance testing will require an EFT (electrical fast transient) burst generator with a capacitive coupling clamp for testing signal cables, etc. For lightning transient testing a surge generator capable of the 1.2/50 - 8/20 hybrid waveform is necessary.

CONCLUSION

Immunity testing continues to be an essential part of the EMC equation and the European EMC Directive's reference to transient and surge testing needs to be understood. In understanding the testing process it is useful to consider the phenomena which are being simulated. Both IEC 801-4/1000-4 and IEC 801-5/1000-4-5 contain specifications for testing which have been described. Evaluation of results is to some extent subjective, but can be made against the differing performance criteria outlined above. Manufacturers wishing to carrying out transient and surge testing can use the types of testing equipment described which are now commercially available.

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