

## *Immunity Testing for the CE Mark*

### **Summary**

The European Union (EU) currently has 25 member countries with 2 additional countries to be added in 2007. The total population at that time will be nearly a half billion people. In 2005, the total exports to the EU accounted for 20% of the total US exports. This number should continue to grow and should create more business for US exporters in years to come. Since January 1, 1996, manufacturers of electronic equipment have had to meet the Electromagnetic Compatibility (EMC) guidelines of EC Council Directive 89/336/EEC when shipping electrical and electronic products to the EU. Manufacturers must test and certify that their equipment meets the directive and they must apply a CE mark as testimony to this. Current and pending changes to the specifications that describe the tests to be made place more stringent requirements on the equipment used for CE mark testing. Indeed, future changes will require that the testing equipment be able to expand its capabilities without causing the equipment to become useless.

### **Introduction**

The legally prescribed test requirements for EMC standards in the EU are issued by CENELEC, the European Committee for Electrotechnical Standardization. CENELEC issues both Generic and Product standards. The generic standards are EN 61000-6-1, which addresses the requirements for immunity testing in the residential, commercial and light industrial environment. The industrial environment immunity testing required is addressed by EN61000-6-2. The generic standard for emission requirements in the residential, commercial and light industrial environment is covered in IEC 61000-6-3 and the industrial environment is addressed in EN 61000-6-4.

The generic standards above apply to products for which no dedicated product or product-family standard exists. If a product or product-family standard exists, it takes the place of the generic standards in prescribing the test requirements. The generic and product-family standards outline the test requirements. They refer to what is known as the Basic Standards to define the tests to be performed, the test methods, the test set-up and the specifications of the generator used to simulate interference phenomena. The International Electrotechnical Commission (IEC) writes the basic standards to which CENELEC refers in their EN's. This article will focus on five of the European Standards from CENELEC used in the immunity portion of the standards, four of which are required by the generic standards for CE mark certification.

### **Basic Standards for EMC Immunity**

The IEC promotes standardization in the fields of electricity, electronics and related technologies. IEC 61000 part 3 covers emission specifications and IEC 61000 part 4 covers immunity specifications. The specifications are further broken down into sections. CENELEC has also adopted the same numbering system and refers to the specifications as EN's or European Norms. They are EN 61000-3 and EN 61000-4. The immunity portions of the specifications are listed below in Table 1.

Table 1: Basic Standards

|   |                |  |
|---|----------------|--|
| EN 61000-6-1 and EN 61000-6-2, Generic Immunity Standards refer to: |                |  |
| EN 61000-4-2  | IEC 61000-4-2  | Electrostatic Discharge (ESD)          |
| EN 61000-4-3  | IEC 61000-4-3  | Radiated EM Field                      |
| EN 61000-4-4  | IEC 61000-4-4  | Burst-Electrical Fast Transients (EFT) |
| EN 61000-4-5  | IEC 61000-4-5  | Surge                                  |
| EN 61000-4-6  | IEC 61000-4-6  | Conducted Radio Frequency disturbances |
| EN 61000-4-8  | IEC 61000-4-8  | Power frequency magnetic field         |
| EN 61000-4-9*   | IEC 61000-4-9* | Pulse magnetic field                   |
| EN 61000-4-11   | IEC 61000-4-11 | Voltage dips, interruptions            |

\*EN 61000-4-9 and IEC 61000-4-9 are not required by the Generic Standards but are referenced here for later use in this application note.

### Interference Generation

The Basic Standards also specify the generator to be used for simulating the interfering phenomena. But, since the disturbance phenomena have to be determined and measured first, the Basic Standards and the generator requirements usually lag behind the real environmental conditions. Consequently, the standards are subjected to constant changes. To reduce the cost of the generator used for testing to the immunity standards, it must be versatile and capable of covering as many of the foreseen specification changes as possible.

Testing of one's own product is a requirement for the CE mark. This viewpoint is satisfactory; however, immunity testing of a manufactured product is also valuable as a tool to achieving customer satisfaction with the end product. If a product is not susceptible to ESD and fast transients for instance, it will not fail as readily during normal use. This is not only important from a performance standpoint, but from a safety and legal liability standpoint as well. Therefore, it is useful to use interference generators in the product design and development stage, as well as in the CE mark certification process.

### Burst

The burst pulses, also called electrical fast transients (EFT), are created on public power lines by electrical arcs across switch contacts during opening of the switch. The nature of the loads connected to the power lines causes short bursts of pulses across the switch, which can generate interference in electrical/electronic equipment connected to the lines. Figure 1 shows the bursts called out by IEC 61000-4-4. The most recent version of the burst standard is IEC 61000-4-4:2004 Ed 2. The pulses within the 15-millisecond burst period are defined by the specification as having a frequency of 5 KHz. The latest edition of the standard added 100 KHz as a new frequency and the burst duration for this pulse will be 0.75 millisecond. The reduction in the burst duration is due to the energy content having to remain the same as the 5 KHz pulse. The burst pulses are applied in peak voltage levels from 500 volts to 4 KV on the power supply lines of the equipment under test (EUT). Because the burst pulses can be radiated into equipment signal lines (from nearby power leads), the burst pulses are also required to be capacitively coupled to the signal leads.

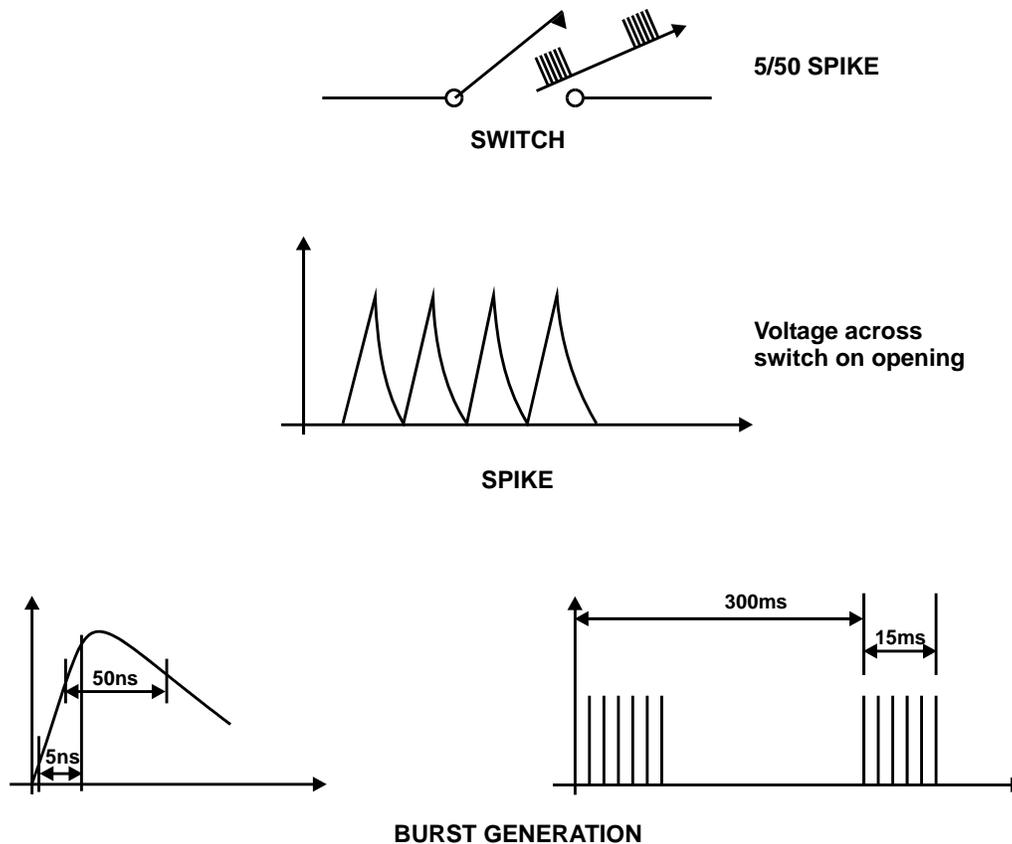


Figure1: Fast Transient/Burst Pulses

The burst test is a low energy test, and as such, it is not destructive. The burst test is particularly hard on complex digital equipment with high clock frequencies. The test can cause degradation of performance, loss of function, uncontrolled process sequences, failures in programmable equipment, loss of information stored in memory and incorrect data processing. For these reasons, the burst test should be the first test performed on an EUT. In order to take into account constantly increasing clock frequencies of microprocessor applications, higher burst pulse frequencies exceeding the 5 KHz specified frequency and even higher than the 100 KHz proposed frequency should be used in developmental testing. If the burst testing were done at 5 KHz, it would take many tests to find and isolate a burst susceptibility design problem. If, for example, the EUT were to have a clock frequency of 10 MHz, the 5 KHz burst pulse tests only every 2,000th function state. The test piece's critical states are likely to be among the 1,999 function states not tested. If the testing is done at 100 KHz, the design problems can be more quickly discovered because 20 times as many function states are tested in any given testing time.

CENELEC has also added new requirements related to pulse verification and calibration of the burst generator. These are included in Ed 2 of the IEC 61000-4-4 standard. According to Amendment A2:2001 to the IEC 61000-4-4:1995 standard, test generators must meet the verification and calibration requirements effective July 1, 2004. The changes made require that the burst pulse be verified at the generator coaxial output into an open circuit (1000 ohms) and into a 50-ohm load. Newly added to the Ed 2 standard, the burst verification also needs to be performed at the generator coupling/decoupling output with a 50 ohm load. Because of the high frequency character of the burst pulses, to reduce stray capacitance, a special coaxial adapter (see Figure 2 below) and a minimum 400 MHz bandwidth oscilloscope is required to make the pulse verification. The specification changes were made to achieve

more uniform pulse characteristics among the various transient generator manufacturers and to provide repeatable test results.



Figure 2: Coaxial Adapter for Burst Pulse Observation

Since the burst test is relatively easy to set up and its reproducibility is high, the test is suitable for in-house developmental testing.

### Surge

IEC 61000-4-5 prescribes tests for simulating the effects of lightning discharges as well as voltage surges caused by switching disturbances in power stations. The surge waveforms are defined by the specification as shown in Figures 3 and 4 below. The peak voltage for the voltage waveform in Figure 3 varies between 500V and 4.0KV. The peak current in Figure 4 is between 250A and 2.0KA.

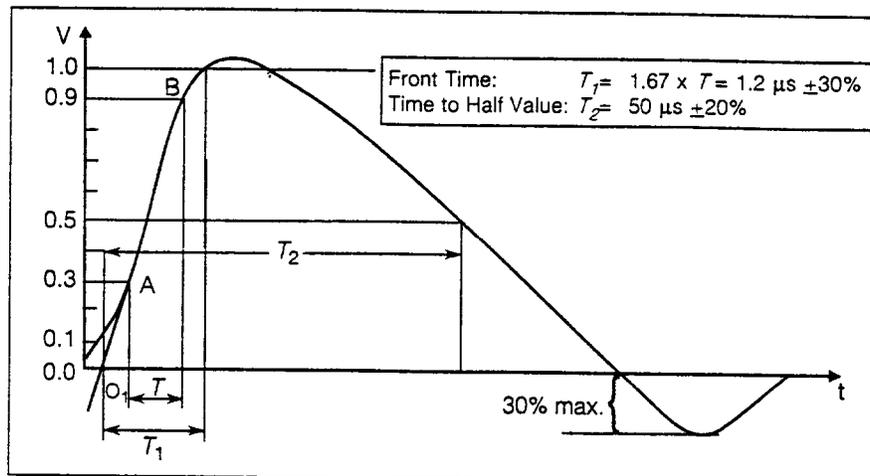


Figure 3: Waveform of Open Circuit Voltage (1.2/50  $\mu$ s)

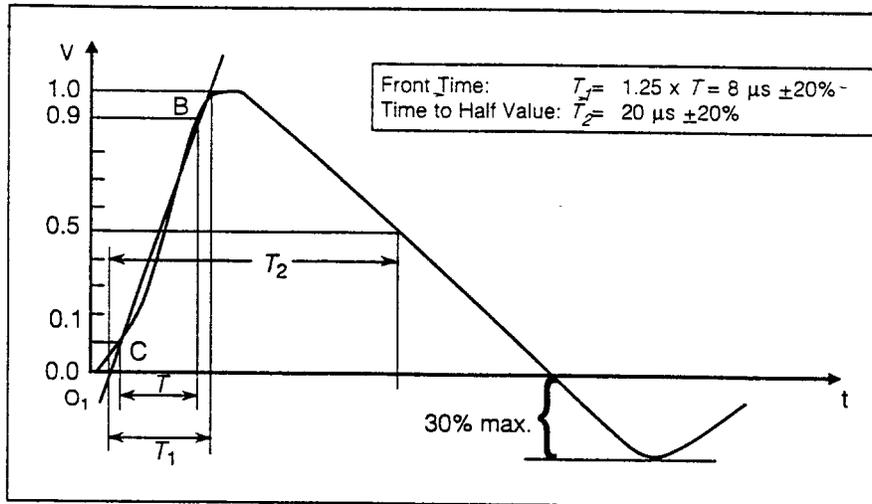


Figure 4: Waveform of Short Circuit Current (8/20  $\mu$ s)

IEC 61000-4-5 requires that the generator be capable of applying surge pulses at a rate of "at least one per minute". The surge pulse must be applied at 0, 90, 180, and 270 degrees of the power input waveform. This requires that the surge generator be synchronized to the AC input. The surge pulses must be coupled from line to line and from the line(s) to earth of the power leads. The peak voltage level of the surge pulse is adjusted in steps starting at 500V to 4000V. In total, 600 pulses are required. The simulator must have sufficient energy available to complete this test in a timely matter because if a generator just meets the bare minimum requirement of one pulse per minute, the test will take 10 hours total. If the generator is capable of providing surge pulses faster than one per minute, the test time can be reduced. This assumes the EUT itself is designed to handle the faster surge pulse repetition rate. The surge test can be destructive to the EUT if adequate protection is not incorporated into the design. Therefore, this test should be carried out only after a successful burst test so that if the EUT is destroyed, the tester at least has some useful test data.

The coupling and decoupling networks for applying the burst and surge pulses are usually contained within the surge generator. For coupling to the signal leads for both burst and surge pulses, external coupling clamps or networks are required.

### Power Fail Simulation

IEC 61000-4-11 specifies the levels for testing supply line dips, interruptions and variations. Faults in the power distribution networks, brownouts or sudden large changes in the load on the lines cause voltage dips and short interruptions. The line voltage variations are caused by continuously varying loads connected to the network.

These phenomena occur randomly. When large rotating machines are connected to the network, they can act as generators on the power lines during interruptions resulting in gradual variations in the line voltage rather than abrupt interruptions. The line voltage dips and interruptions are required tests of IEC 61000-4-11, but the voltage variations test in the IEC standard are optional dependent on the EUT product specification and the product's sensitivity to voltage variations.

The specifications for the voltage dips and short interruptions are given in Tables 2 and 3 below. Table 4 shows the optional power supply variations test levels.

Table 2 - Test Levels for Voltage Dips and Interruptions

| Class <sup>a</sup>   | Test Level and durations for voltage dips (50Hz/60Hz) |                   |                         |                  |                           |
|----------------------|---|-------------------|-------------------------|------------------|---------------------------|
| Class 1              | Case-by-case according to the equipment requirements  |                   |                         |                  |                           |
| Class 2              | 0% during ½ cycle                                     | 0% during ½ cycle | 70% during 25/30 cycles |                  | 80% during 250/300 cycles |
| Class 3              | 0% during ½ cycle                                     | 0% during ½ cycle | 40% during 10/12 cycles | 70% 25/30 cycles | 80% during 250/300 cycles |
| Class x <sup>b</sup> | x   | x                 | x                       | x                | x                         |

<sup>a</sup> classes as per 61000-2-4, see Annex B in this present document

<sup>b</sup> to be defined by product committee. For equipment connected directly or indirectly to public network, the levels must not be below class 2.

Table 3 – Test Level and Durations for Short Interruptions

| Classes <sup>a</sup> | Test Level and Durations for Short Interruptions (t <sub>s</sub> ) (50Hz/60Hz) |
|----------------------|--|
| Class 1              | Case-by-case according to the equipment requirements                           |
| Class 2              | 0% during 250/300 cycles   |
| Class 3              | 0% during 250/300 cycles   |
| Class x <sup>b</sup> | x  |

<sup>a</sup> classes as per 61000-2-4, see Annex B in this present document

<sup>b</sup> to be defined by product committee. For equipment connected directly or indirectly to public network, the levels must not be below class 2.

Table 4- Timing of Short-Term Supply Voltage Variations

| Voltage Test Level | Time for Decreasing Voltage (t <sub>d</sub> ) | Time at Reduced Voltage (t <sub>r</sub> ) | Time for Increasing Voltage (t <sub>i</sub> ) (50/60Hz) |
|--------------------|---|---|---|
| 70%                | Abrupt  | 1 cycle                                   | 25-30 cycles  |
| x <sup>a</sup>     | x <sup>a</sup>                                | x <sup>a</sup>                            | x <sup>a</sup>  |

<sup>a</sup> to be defined by product committee

For dips and interruptions, the transient generator usually contains built-in electronic switches to switch in the appropriate voltage dip or interruption. The generator controls must allow adjustment of the phase, synchronization and duration of the dips and interruptions.

### Power Frequency Magnetic Field and Pulse Magnetic Field Immunity Testing

IEC 61000-4-8 describes the tests and levels for power frequency magnetic fields and IEC 61000-4-9 defines the tests and levels used for pulsed magnetic field immunity testing. These two specifications are grouped together because they are very similar. Magnetic fields can affect the reliable operation of electrical and electronic equipment. The power frequency magnetic field simulates power frequency current in conductors or leakage from transformers or other current carrying conductors in the area. Pulse magnetic fields are generated by lightning strikes on buildings and other metal structures near electrical or electronic equipment.

The generic immunity standards now require that IEC 61000-4-8 testing be completed for the CE mark. IEC 61000-4-9 is only a requirement of some product specifications at this time. The products usually tested to IEC 61000-4-9 are railroad equipment and those products associated with power sub-stations. One way to test for the power frequency magnetic field requires an external one meter square coil and a current transformer to drive the square coil. One configuration using this method for power frequency magnetic field immunity testing is shown below in Figure 5.

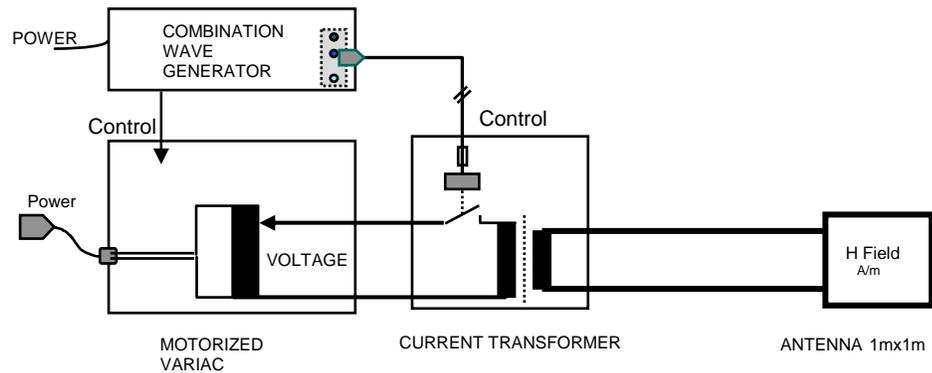


Figure 5: Power Frequency Magnetic Field Testing

Connecting the surge current output of the transient generator directly to the external one-meter square coil generates the pulsed magnetic field. The generator controls are used to adjust the level of current through the coil to the proper magnetic field level. Figure 6 below shows the test diagram.

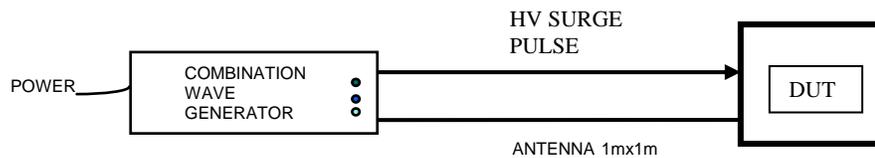


Figure 6: Pulsed Magnetic Field Testing

### Electrostatic Discharge Immunity Testing

The pulse waveform generated for ESD simulation is a very fast transient pulse up to 15KV in amplitude and containing high impulse current. Because of this, the test can be very destructive in nature. ESD testing should be completed after EFT testing to insure that the EUT has a solid board layout, satisfactory lead dress and a proper grounding system to reduce the possibility of EUT damage from the ESD pulse.

The set-up and application of ESD testing is critical. Because of this testing complexity, a specific description of ESD testing is out of the scope of this paper (refer to figure 5 of IEC 61000-4-2). In fact, the subject of ESD testing is worthy of an entire paper of its own.

### Conclusion

CENELEC refers to basic standards issued by the International Electrotechnical Commission (IEC). CE Marking requires emissions and immunity testing. This paper addresses some of the immunity tests required by the generic standards. The basic standards describe the transient phenomena waveforms characteristics and the generator characteristics used to simulate the transient waveforms in the test environment. Testing electrical and electronic products to achieve the CE Mark requires using test generators that simulate the transient phenomenon occurring on power lines. Transient generators are available which incorporate the ability to test burst, surge, magnetic field and voltage dips and drops in one package to simplify the test engineer's task. Recent changes in the generic and basic standards require that the generator be chosen with the ability to meet the new specification requirements.