

IEC 61000-4-x Tests for TI's Protection Devices

ABSTRACT

The IEC 61000-4-X set of standards are used to test system-level transient immunity. Many system designs specify one or more of the tests listed within the IEC 61000-4-X specification to comply with reliability standards for end customers. Covered within this document are the three most common tests that Texas Instrument's protection devices comply to: System ESD Immunity (IEC 61000-4-2), Electrical Fast Transient Immunity (EFT) (IEC 61000-4-4), and Lightning/Surge Immunity (IEC 61000-4-5). In addition to an overview of the specification, we will provide a test setup overview for each test.

1 IEC 61000-4-2 System ESD Immunity

1.1 IEC 61000-4-2 Overview

The IEC 61000-4-2 standard covers system level ESD immunity. Electrostatic Discharge can be very harmful to a system and even a small amount of voltage can damage components. Most systems require some sort of IEC ESD protection, as any user accessible areas can be subjected to ESD strikes. Although this test is considered a 'system level' test, TI measures the immunity of individual protection devices to provide customers with an idea of how high their system will pass with TI protection devices in the system. For more information on what's important in selecting an ESD device, see the TI application note *Design Considerations for System-Level ESD Circuit Protection* ([SLYT492](#)).

1.2 ESD Waveform and Test Levels

TI uses industry standard ESD test generators calibrated to the IEC test waveform to conduct testing. Nearly all TI ESD protection devices are designed to comply to Level 4 testing or higher for contact discharge and most comply to Level 4 or higher for air discharge. See [Table 1](#) for levels specified by the IEC standard and [Figure 1](#) for the IEC 61000-4-2 standardized discharge waveform.

Table 1. ESD Testing Levels

Level	Contact Discharge	Air Discharge
	Test Voltage (\pm kV)	Test Voltage (\pm kV)
1	2	2
2	4	4
3	6	8
4	8	15
X	Custom	Custom

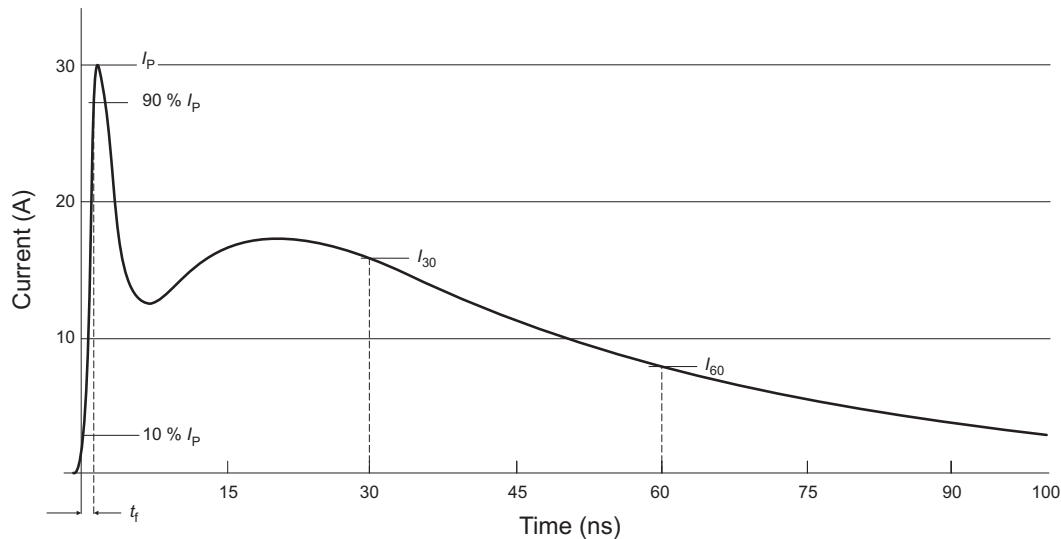


Figure 1. Ideal Contact Discharge Current Waveform at 8 kV

Testing is performed by charging the 150-pF discharge capacitor and discharging it through a 330- Ω resistor into the strike tip. Contact discharge is performed by touching the discharge tip directly to the pin under test then triggering the strike. Conversely, air discharge is performed by triggering the gun then moving the discharge tip towards the pin under test until arcing occurs.

1.3 ESD Bench Setup

The TI ESD test bench setup complies with the IEC standard and is shown in [Figure 2](#) below. The Device Under Test (DUT) is placed on a horizontal coupling plane (HCP) with insulation in between. Any power connections are made on the non-conductive table and two 470-k Ω resistors are used to connect the HCP to the ground reference plane (GRP). The ESD generator is grounded to the GRP and discharges are performed directly at the DUT Printed Circuit Board (PCB). The typical DUT PCB used for testing our protection devices is a breakout board shown in [Figure 3](#) with a socket for easy testing of multiple devices. The TI protection device is inserted into the socket and clamped down. Once the device is clamped, the ESD gun strikes at the connector or other specified test pads.

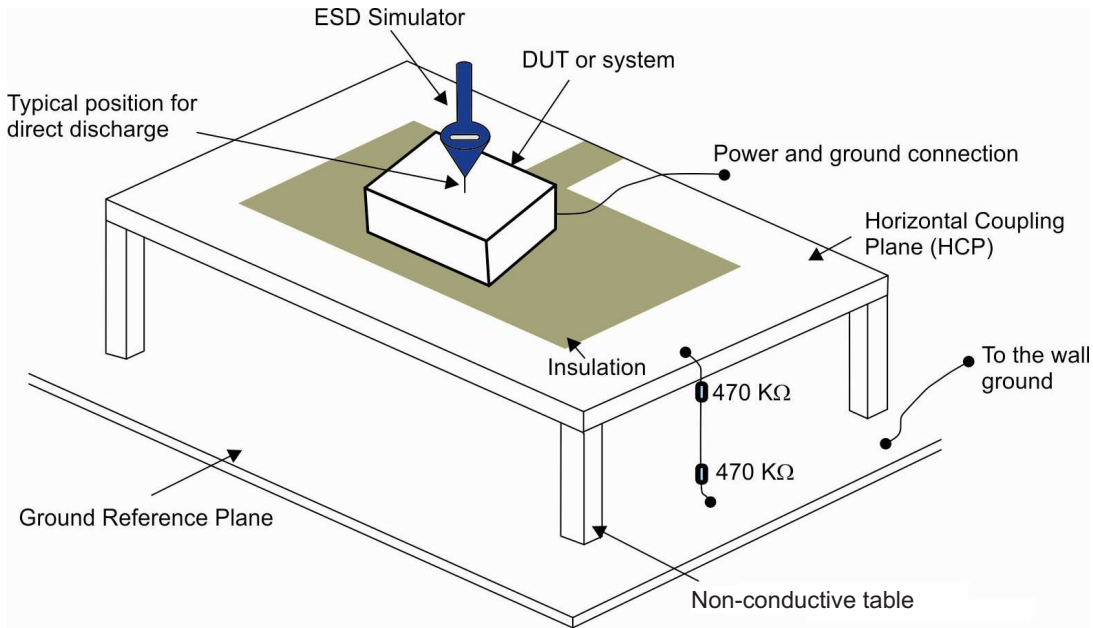


Figure 2. System Level ESD Test Setup

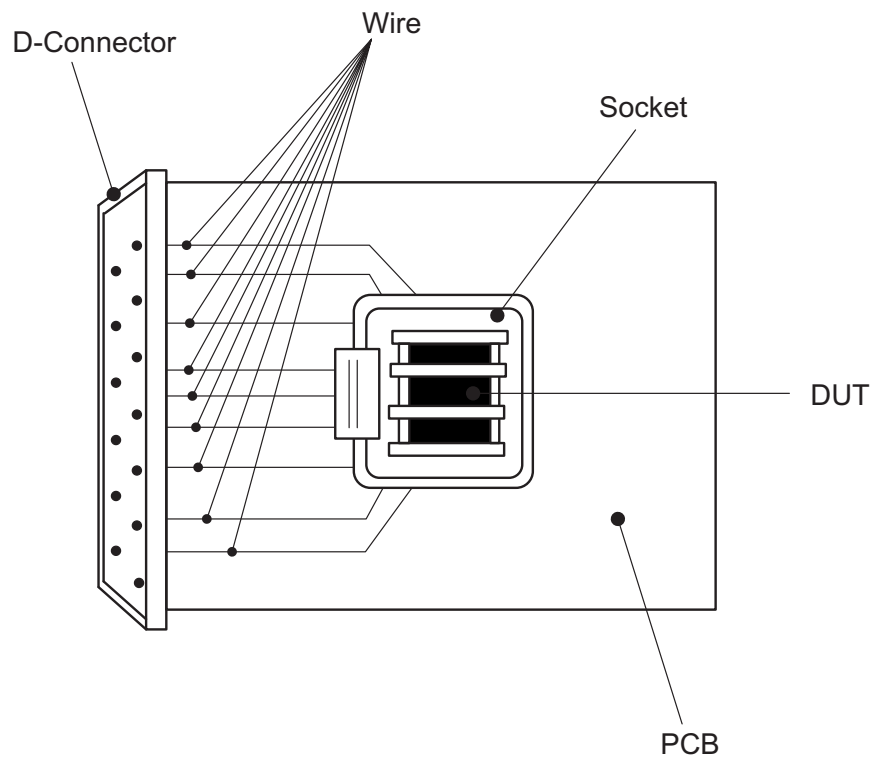


Figure 3. DUT PCB Setup

2 IEC 61000-4-4 EFT Immunity

2.1 IEC 61000-4-4 Overview

Industrial, office and even household applications widely use cables in power delivery and data communications. EFT events ranging from the environment and from surrounding power cables or data cables may interrupt data communications through inductive or capacitive couplings. EFT immunity therefore becomes important for such application environments.

The IEC 61000-4-4 is an IEC standard designed to test fast transient or burst immunity at the system level. Compared to ESD immunity (standard IEC 61000-4-2) and surge immunity (standard IEC 61000-4-5), fast transient/burst immunity specifies system immunity to EFT. Typically, system level EFT immunity tests are required for networking systems, field cable transmissions and numerous other industrial applications.

2.2 IEC 61000-4-4 Test Setup and Test Procedure

The IEC 61000-4-4 standard defines the EFT immunity tests, set-up procedures, and test levels. The EFT immunity test setup for IO ports is shown in Figure 4. A burst signal from a burst generator is sent through the test cable (inside a capacitive trench) and is measured through a coupled data cable (inside the same trench) which is connected to the DUT. The DUT is mounted to a test PCB. For the DUT mount method, refer to Figure 3 above. Power port tests are intrinsically coupled with a tester and applied to the DUT power port. Depending on the application environment and application type, the pulse generator has varying test voltage levels depending on the application. As an example, 2 kV is typically specified for industrial data/signal lines (see Table 2 for all test levels). Test pulses are defined in Figure 5 by IEC 61000-4-4 standard. EFT in IEC 61000-4-4 standard are specified as repeated pulses/bursts for 15 ms with each single pulse 5×50 ns, as in Figure 5.

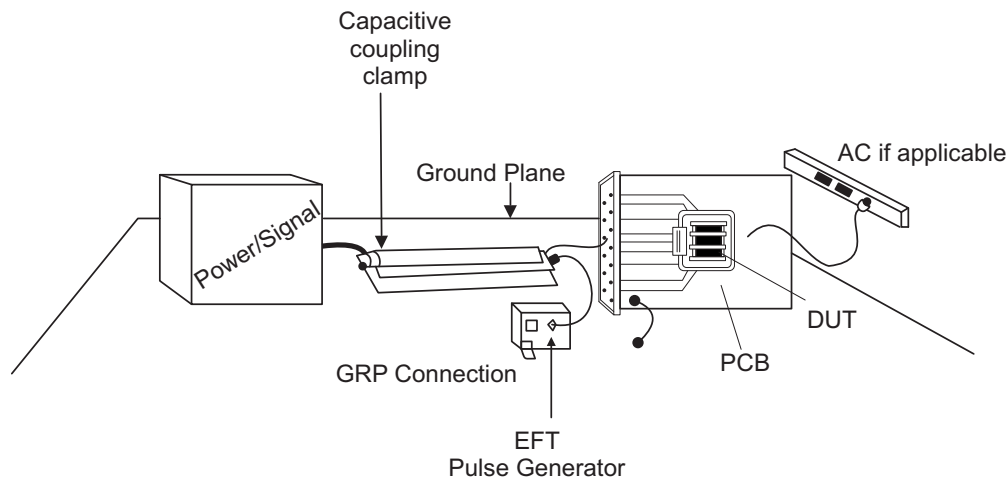


Figure 4. IEC 61000-4-4 IO Port Test Set Up

Table 2. IEC61000-4-4 stress levels

Level	Peak Amplitude			
	Power Supply Port		I/O, Signal, Data & Control Lines	
	V _{CC} (kV)	I _{SC} (A)	V _{CC} (kV)	I _{SC} (A)
1	0.5	10	0.25	5
2	1	20	0.5	10
3	2	40	1	20
4	4	80	2	40

2.3 IEC 61000-4-4 Type Burst Suppression Through TVS Diodes

The amount of energy of EFT events is around several hundreds of milli-Joules. Transient events at these energy levels can corrupt data transmitted in many situations from households to industrial environments; therefore, a good system design requires EFT suppression.

TVS diodes are designed to suppress transient voltage pulses with power levels that vary from tens of milli-Joules to hundreds of Joules; therefore, they can handle not only ESD and surge events, but also EFT events. The mechanism for TVS diodes to suppress EFT bursts are intrinsically the same as ESD and surge suppression.

A high percentage of TI's ESD protection solutions are capable and specified with IEC 61000-4-4 performance, with a wide variety in the number of protection channels as well as various working voltages to accommodate a wide variety of signal swings.

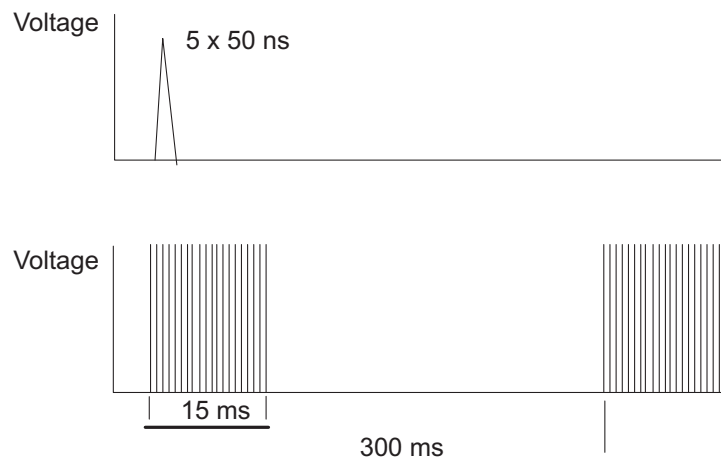


Figure 5. IEC 61000-4-4 Bursts and Waveforms

3 IEC 61000-4-5 Lightning/Surge Immunity

3.1 IEC 61000-4-5 Overview

The IEC 61000-4-5 introduces the testing and measurement techniques of a surge immunity test. Surge, unlike ESD and EFT, has a longer period and a higher power. Surge events are usually produced by the power system switching activities or lightning events. Examples of power system switching activities are local minor switching activities and load changes; Main power system disturbances like capacitor bank switching; System faults such as shorting events; and a disturbed ground caused by arcing. Examples of lightning induced surge are directly coupled lightning to the outdoor equipment and circuits; indirect lightning that creates electromagnetic fields which thus induces transients to the circuit; a ground disturbance that is created by lightning coupled to the whole grounding system. Apart from these, we've also seen an increase of surge requirement in personal electronics. A good example is the USB VBUS surge protection to suppress plugging/unplugging transients (for VBUS surge and overvoltage protection, see [TPD1S514](#)). The IEC 61000-4-5 provides the guideline of standard tests to represent these cases and to evaluate if the equipment survives the tests.

3.2 How To Choose the Right Protection Device for Surge?

Choosing the right device to protect circuitry to withstand surge has a significant impact on the reliability of the systems. To do that, V_{CL} and I_{PP} specs are the two main factors to be considered. V_{CL} is the peak clamping voltage that the protection device provides during the surge. Choose a protection device that has a lower V_{CL} value than the max tolerance of the circuit being protected. I_{PP} is the peak current a system takes during the surge. Make sure that the I_{PP} rating of the protection device exceeds the level of the standard the system is designed to pass. The IEC 61000-4-5 has two surge pulse durations specified:

8/20 μ s and 10/1000 μ s, both of which define the shape of the current waveform. The latter is dedicated to telecommunication lines. The I_{pp} value related to the 8/20- μ s surge is larger than that related to the 10/1000- μ s surge. During shorter surge periods, a protection device is able to take more peak power without sustaining damage. So choosing the I_{pp} related to the right surge period without an unnecessary overhead in margin is essential for a cost and performance optimized system.

3.3 IEC 61000-4-5 Test Setup and Test Procedure

TI's surge tests are compliant with the IEC 61000-4-5 standard. Depending on what environment a system is designed for, the IEC 61000-4-5 specifies several levels of tests in association with an environment. The chart below summarizes the surge voltages of different test levels and what these levels mean. From level 1 and up, the applications require protection devices to minimize the surge energy seen by the internal circuitry.

Table 3. Test Levels

Level	Open-Circuit Test Voltage $\pm 10\%$ kV
1	0.5
2	1.0
3	2.0
4	4.0
X ⁽¹⁾	Custom

⁽¹⁾ X can be any level above, below or in between the other levels. This level can be specified in the product standard.

- Class 1: Partly protected electrical environment.
- Class 2: Electrical environment where the cables are well-separated, even at short runs.
- Class 3: Electrical environment where cables run in parallel.
- Class 4: Electrical environment where the interconnections are run as outdoor cables along with power cables, and the cables are used for both electronic and electric circuits.
- Class X: Special conditions specified in the product specification.

The level of surge voltage, together with the impedance (R_{eq}) from the surge strike determines how much surge current the protection device takes. Different kinds of equipment setups entail different impedances used in the tests.

A 2- Ω impedance models the source impedance of a low voltage power supply and is the inherent source impedance of the combinational waveform generator (CWG). It represents the case where the surge is coupled onto the power AC or DC mains in a differential way. This impedance gives the highest level of surge current for a certain surge voltage level.

A 12- Ω (2 Ω is the CWG source impedance, 10 Ω from coupling network) impedance models the impedance of the power source and the ground network and is used when the surge happens between the mains and the ground.

A 42- Ω (2 Ω is the CWG source impedance, 40 Ω from coupling network) impedance represents the impedance between all the other lines and ground. Data lines are one example where this impedance level is used.

Below is a matrix that provides a quick reference of the surge current levels of different surge voltages and impedances. For the protection devices that are not used in the high surge applications, (for example, audio lines and pushbuttons, etc.) it's still good to include the surge rating for reference. See [TPD1E10B06](#), a bidirectional signal clamping device with a surge current of 6 A (8/20 μ s).

Table 4. Maximum Peak Current Values Depending on Voltage Level and R_{eq}

	Class 1	Class 2	Class 3	Class 4
	500 V	1 kV	2 kV	4 kV
$R_{eq} = 42 \Omega$	12 A	24 A	48 A	96 A
$R_{eq} = 12 \Omega$	42 A	84 A	167 A	334 A
$R_{eq} = 2 \Omega$	250 A	500 A	1000 A	2000 A

TI uses a PCB board with the DUT for the surge tests, as in [Figure 3](#). In these tests, surge pulses are generated by a CWG. The IEC 61000-4-5 specifies two types of CWGs. 10/700- μ s CWG is used to test the ports of symmetrical communication lines. The 1.2/50- μ s CWG is for all other cases. With the same level of peak power, the 10/700 μ s surge contains more energy due to a longer pulse width.

A simplified CWG has a power supply that charges the coupling capacitor, C_C , through a resistance. Upon the closing of the switch, C_C discharges through a pulse shaping network including R_{s1} , R_m , L_r and R_{s2} . The values of these components are tuned to yield the compliance waveforms in the short circuit and open circuit conditions according to the IEC 61000-4-5.

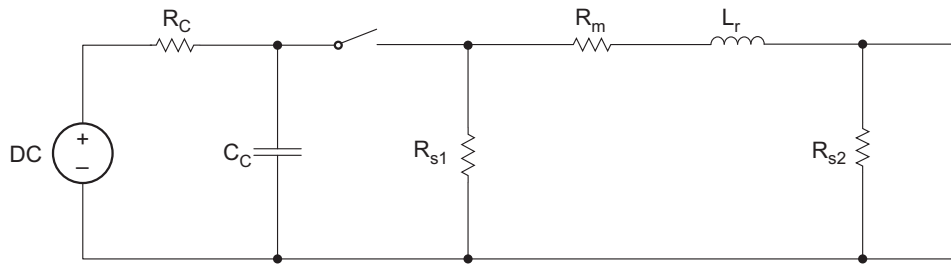
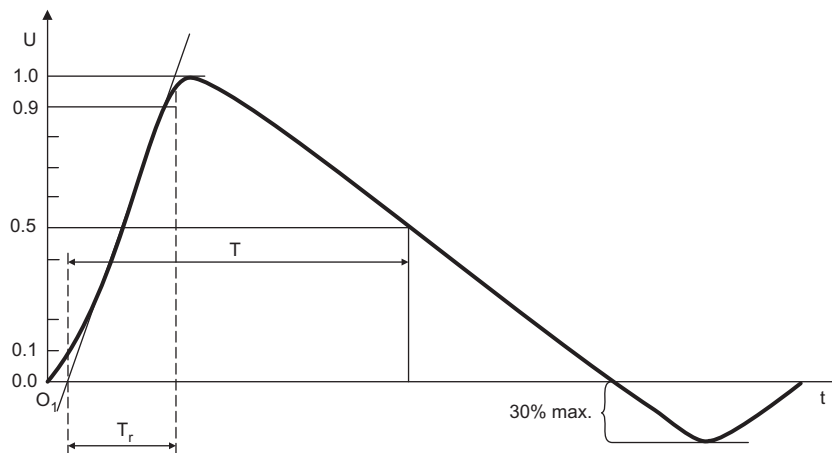


Figure 6. Simplified circuit diagram of the CWG (1.2/50 μ s)

The open circuit voltage waveform of the 1.2/50- μ s shape has a front time of 1.2 μ s and a time to half value of 50 μ s.



Front time: $T_r = 1.2 \mu\text{s} \pm 30\%$
 Time to half-value: $T = 50 \mu\text{s} \pm 20\%$

Figure 7. Waveform of open-circuit voltage (1.2/50 μ s) at the output of the CWG

The short circuit current waveform of the same generator has an 8- μ s front time and a 20- μ s time to half value.

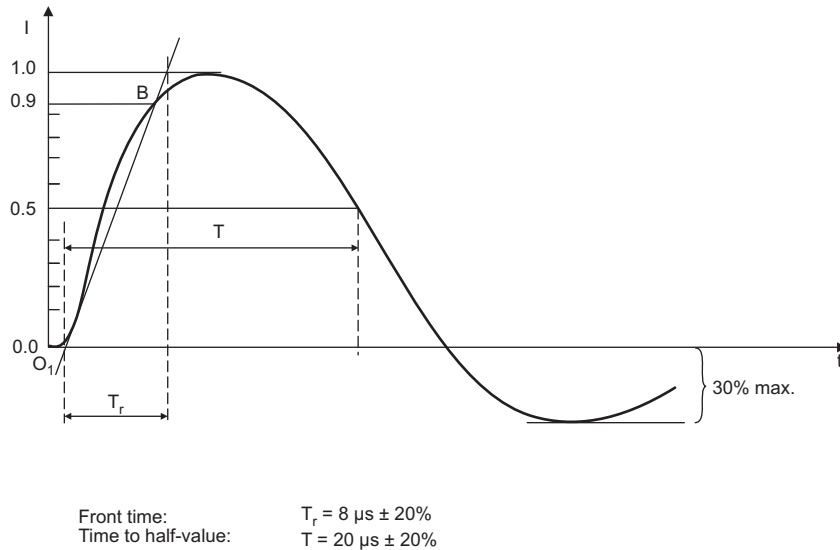


Figure 8. Waveform of short-circuit current (1.2/50 μ s) at the output of the CWG

The circuit of the 10/700- μ s CWG is different to that of the 1.2/50- μ s CWG. These details can be found in the IEC 61000-4-5 specification.

A Coupling/Decoupling Network (CDN) is another integral part of the test setup. The coupling network couples the surge pulse generated by the CWG to the DUT whereas the decoupling network sits between the CWG and the biasing equipment to make sure that the biasing equipment does not get damaged during the surge test.

The IEC 61000-4-5 defines the impedances used in the coupling networks in different cases. One example of a coupling network is coupling the surge between the mains lines. An 18- μ F capacitor is used to couple the surge to the DUT.

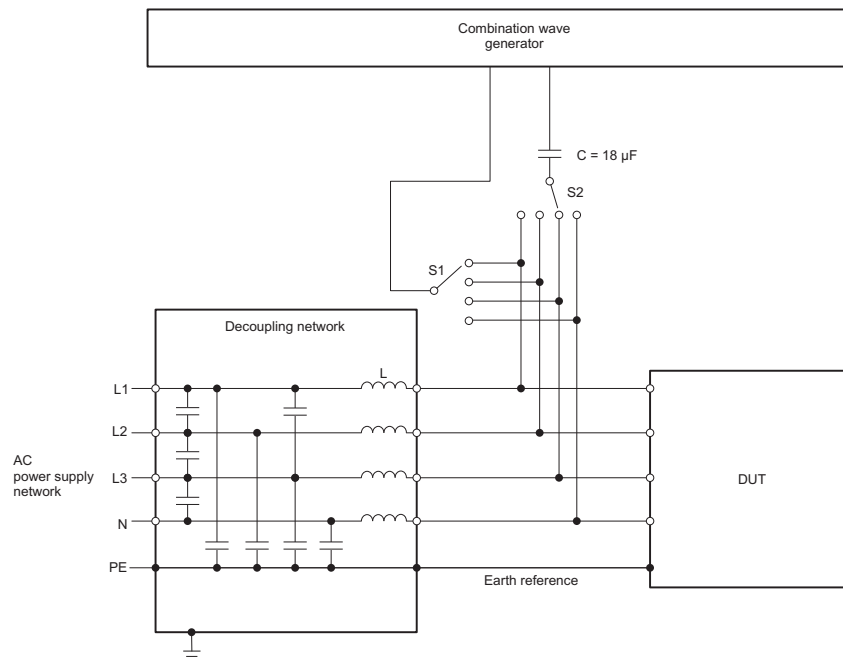


Figure 9. Example of test setup for capacitive coupling on a.c. lines (3 phases); line to line coupling

The surge test where a pulse is coupled between a mains line and the ground has a coupling capacitor of $9\ \mu\text{F}$ and a resistance of $10\ \Omega$. So together with the $2\ \Omega$ from the CWG, the total source impedance of the surge pulse is $12\ \Omega$.

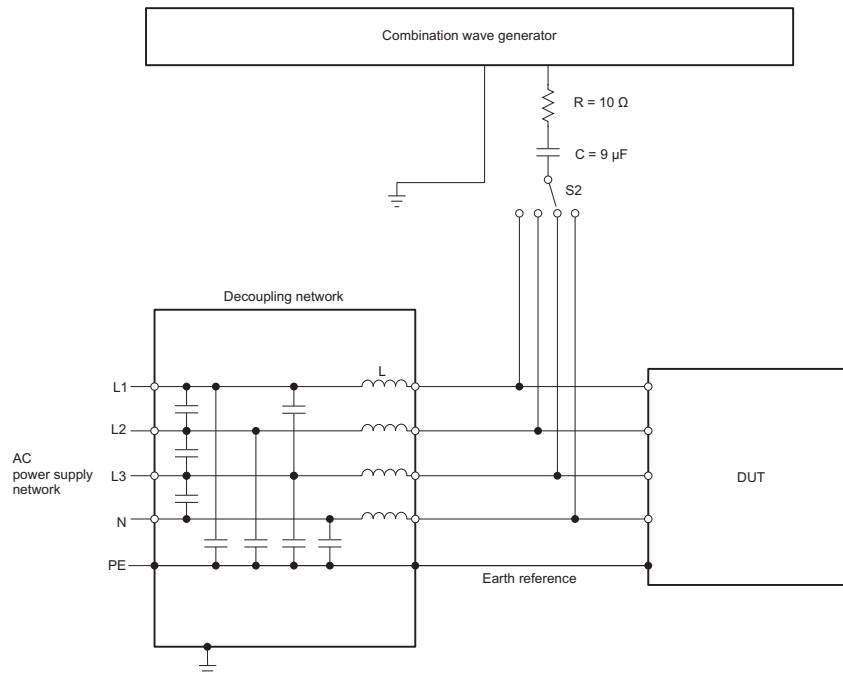


Figure 10. Example of test setup for capacitive coupling on a.c. lines (3 phases); line to ground coupling

If the surge is imposed between all other kinds of lines and ground, a $40\text{-}\Omega$ resistance and a $0.5\text{-}\mu\text{F}$ capacitor are used in the coupling network. Together with the $2\ \Omega$ from the CWG, the total source impedance of the surge pulse is $42\ \Omega$.

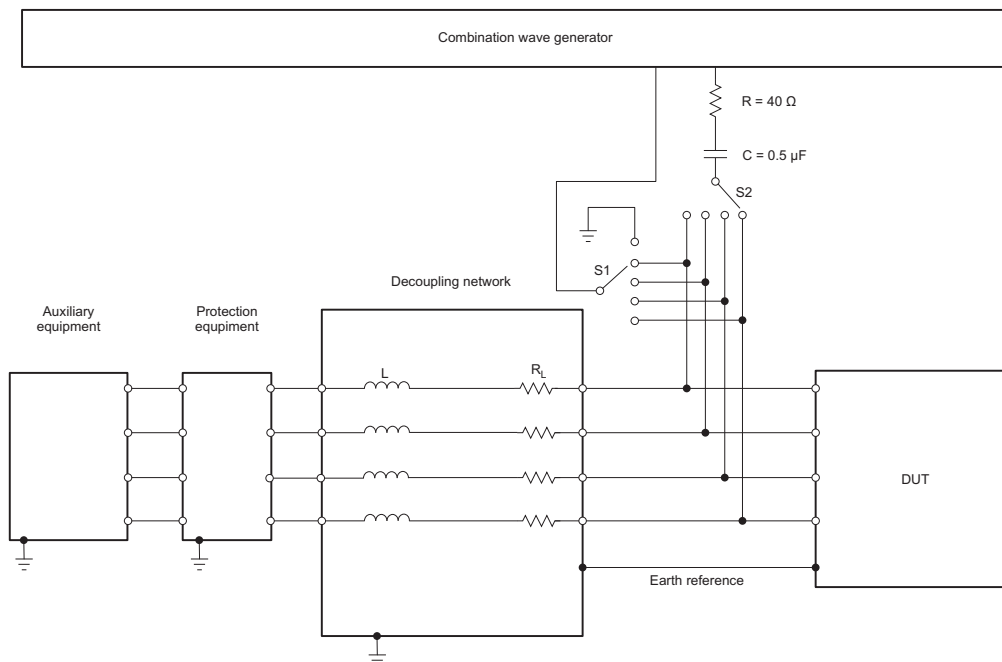


Figure 11. Example of test setup for unshielded unsymmetrical interconnection lines; line-to-line and line-to-ground coupling

Results of the surge test should be classified according to the loss of function and degradation. From most protected systems to the least, the classes in the IEC 61000-4-5 are:

- (A) Normal performance within the limits specified by the manufacturer, requester or purchaser.
- (B) Temporary loss of function or temporary degradation of performance not requiring an operator.
- (C) Temporary loss of function or degradation of performance, the correction of which requires operator intervention.
- (D) Loss of function or degradation of performance which is not recoverable, owing to damage of the hardware or software, or loss of data.

Class A is for the most reliable applications. Class D is usually not acceptable to the manufacturers.

4 Conclusions

Transient immunity is very important in modern electronics. This application note introduces the System ESD Immunity (IEC 61000-4-2), Electrical Fast Transient Immunity (IEC 61000-4-4), and Lightning/Surge Immunity (IEC 61000-4-5) standards. Covered in each one of the sections are the backgrounds of the standard, how TI carries out the tests and some guidelines that help our customers choose the appropriate devices to protect their systems.

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