

Important Transient Immunity Tests for RS-485 Networks

**Introduction**

Network downtimes caused by overvoltage transients amount to more than \$10 billion of annual business losses, hence transient protection of bus nodes has become a major focus in industrial network design.

In order to determine a bus node's transient immunity, the International Electrotechnical Commission (IEC) has created standards that specify the test and measurement techniques for the three major types of overvoltage transients:

1. Electrostatic Discharge (ESD), caused by humans discharging electrostatic energy into electronic equipment.
2. Electrical Fast Transients (EFT), resulting from relay contact bounce, or the interruption of inductive loads.
3. Surge transients due to direct lightning strikes, or induced voltages and currents from an indirect strike, or caused by the switching of power systems including load changes and short-circuits.

Each of the following transient immunity test standards uses a pulse generator that simulates the specific overvoltage transient, and delivers it via a standardized signal path to the Equipment Under Test (EUT).

**Electrostatic Discharge Immunity (IEC61000-4-2)**

In the ESD immunity test the generator creates low-energy pulses of short rise times, 0.7ns to 1ns, and short pulse durations, less than 150ns.

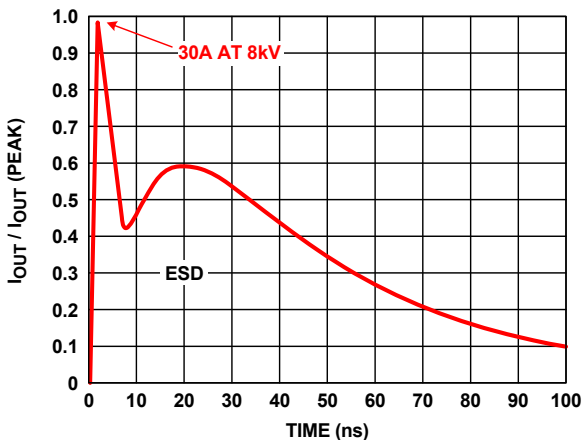


FIGURE 1. CURRENT WAVEFORM OF AN ESD PULSE

A minimum test sequence consists of 20 discharges, ten of positive and ten of negative polarity, with a one second interval between pulses.

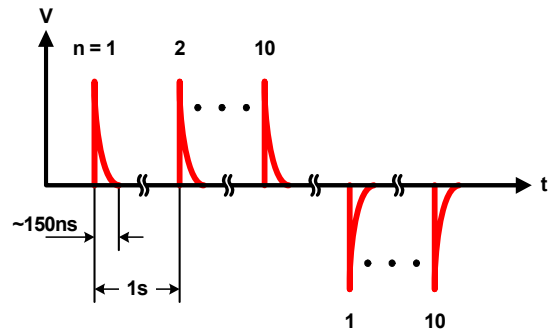


FIGURE 2. TIMING OF A MINIMUM TEST PULSE SEQUENCE

The method of delivery to the EUT is via an ESD gun making direct contact with the EUT, known as contact discharge, or with the gun moving towards the EUT and discharging via an air gap, which then is referred to as air discharge.

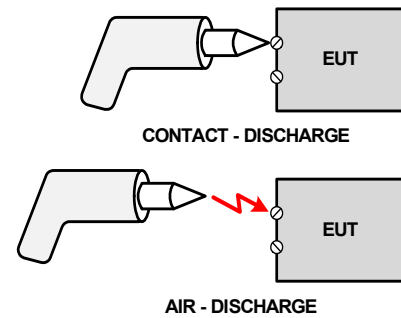


FIGURE 3. METHODS OF ESD PULSE DELIVERY TO THE EUT

For both delivery methods, five different test levels are specified, which are listed in Table 1.

TABLE 1. ESD TEST LEVELS FOR CONTACT AND AIR-DISCHARGE

CONTACT DISCHARGE		AIR DISCHARGE	
LEVEL	TEST VOLTAGE (kV)	LEVEL	TEST VOLTAGE (kV)
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
X*	SPECIAL	X	SPECIAL

\* X is a special level that can be higher or anywhere in between the above levels. This level must be specified in the end equipment specification.

## Electrical Fast Transient Immunity (IEC61000-4-4)

In the EFT immunity test the generator creates a sequence of low-energy pulses known as a burst. Each pulse has a rise time of 5ns and a pulse duration of around 50ns (time-to-half value). The burst period is 300ms and includes 75 transients followed by a pause interval. For a pulse repetition rate of 5kHz the 75 pulses take 15ms, while for a repetition rate of 100kHz they take only 0.75ms.

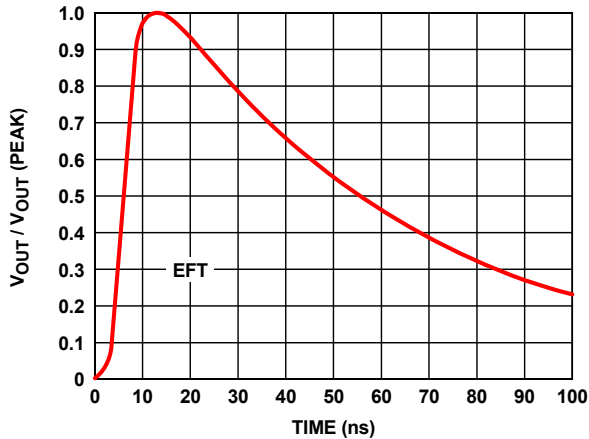


FIGURE 4. CURRENT WAVEFORM OF AN EFT PULSE

The minimum required test duration is two minutes. A typical test sequence consists of three windows of ten seconds of positive pulses, each followed by a 10 second pause interval, and three ten second windows of negative pulses, with a 10 second pause interval between pulses.

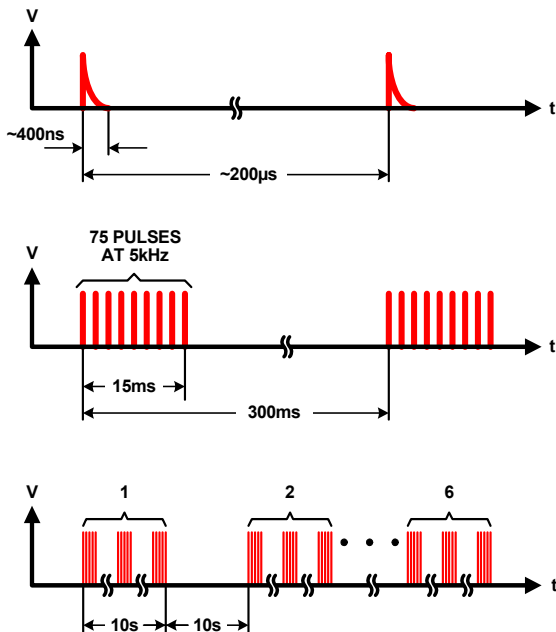


FIGURE 5. TIMING OF A TYPICAL EFT TEST SEQUENCE

During a 10 second window, 33.3 bursts or 2500 pulses are generated, thus resulting in a total of 15000 positive and 15000 negative pulses during a two minute test sequence.

While the individual pulse represents a low-energy transient, the entire pulse train does not. For a given test voltage, the energy of an EFT pulse train is some 250 times higher than the energy of a single EFT pulse, as shown in [Figure 10 on page 4](#).

The method of pulse delivery to the EUT is via a capacitive clamp which surrounds the data or power lines of the EUT. The EFT test therefore represents a common-mode test for differential mode data lines.

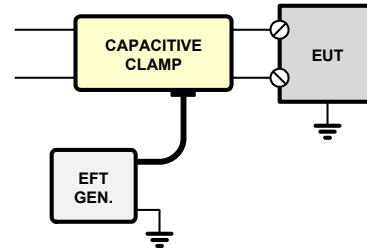


FIGURE 6. METHOD OF EFT PULSE DELIVERY TO THE EUT

[Table 2](#) shows there are five test levels which differ in test voltage severity for power and data lines. For the first four levels the test voltage doubles with each level increment. The fifth level, X, is a special level that can assume any test voltage. However, the voltage level must be specified in the end equipment manufacturer's specification.

TABLE 2. EFT TEST LEVELS FOR POWER AND DATA LINES

LEVEL	REPETITION RATE (kHz)	TEST VOLTAGE (kV)	
		POWER PORTS	DATA LINES
1	5	0.5	0.25
2		1	0.5
3		2	1
4		4	2
X	SPECIAL	SPECIAL	SPECIAL

## Surge Immunity (IEC61000-4-5)

In the surge immunity test, a combination waveform generator (CWG) creates high-energy, low frequency test pulses whose waveform is a combination of two separately defined waveforms: an open-circuit voltage waveform and a short-circuit current waveform.

The open-circuit voltage waveform has a rise time of 1.2µs and a time to half-value of 50µs (often called a "1.2/50µs" pulse), while the short-circuit current waveform has a rise time of 8µs and a time to half-value of 20µs and is therefore referred to as an "8/20µs" pulse.

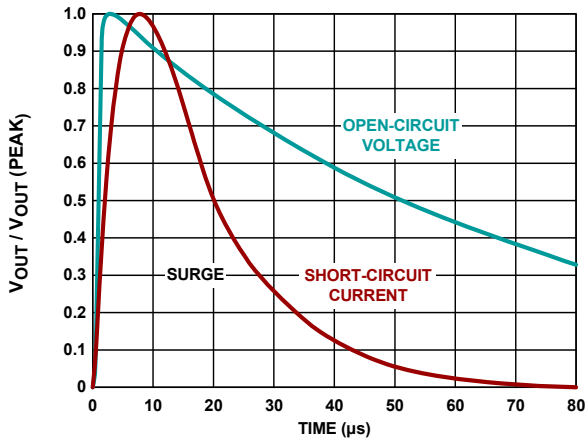


FIGURE 7. VOLTAGE AND CURRENT WAVEFORMS OF A CWG

A test sequence requires 5 positive and 5 negative surge pulses with a pause interval between successive pulses of one minute or less. It is common procedure to shorten the pause intervals down to 12 seconds, thus reducing the total test time below 2 minutes. While this approach significantly reduces test time and cost, it intensifies the surge impact due to the protection circuit's reduced recovery time between pulses.

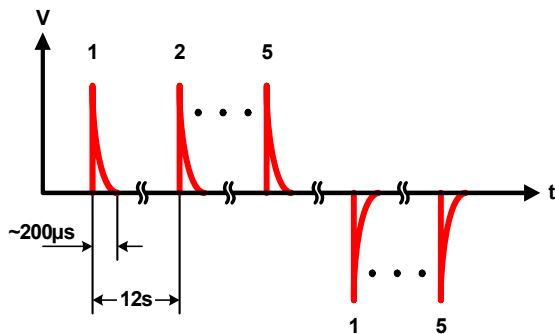


FIGURE 8. TIMING OF A TYPICAL SURGE TEST PULSE SEQUENCE

The method of pulse delivery to the EUT is via resistive coupling onto the balanced data lines of the EUT. For surge immunity tests on symmetrical interconnections, IEC61000-4-5 specifies a source impedance of  $42\Omega$ , which, in the case of RS-485, consists of the  $2\Omega$  generator output resistance, defined by the ratio of peak open-circuit output voltage to peak short-circuit output current, and two  $80\Omega$  resistors of a Coupling/Decoupling Network (CDN), each forming a separate signal path from the CWG to the EUT data lines, shown in Figure 9.

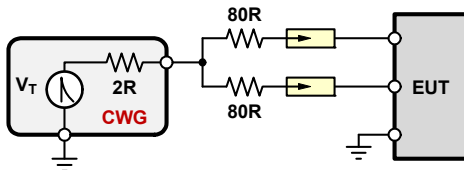


FIGURE 9. METHOD OF SURGE PULSE DELIVERY TO THE EUT

Table 3 shows there are five test levels which differ in test voltage severity. For the first four levels the test voltage doubles with each level increment. The fifth level, X, is a special level that can assume any test voltage, but must be specified in the end equipment manufacturer's specifications.

TABLE 3. SURGE TEST LEVELS

LEVEL	TEST VOLTAGE (kV)
1	0.5
2	1
3	2
4	4
X	SPECIAL

For symmetrically operated data lines, such as RS-485, IEC61000-4-5, specifies the test voltages by installation classes, shown in Table 4.

TABLE 4. SURGE TEST VOLTAGE BY INSTALLATION CLASS

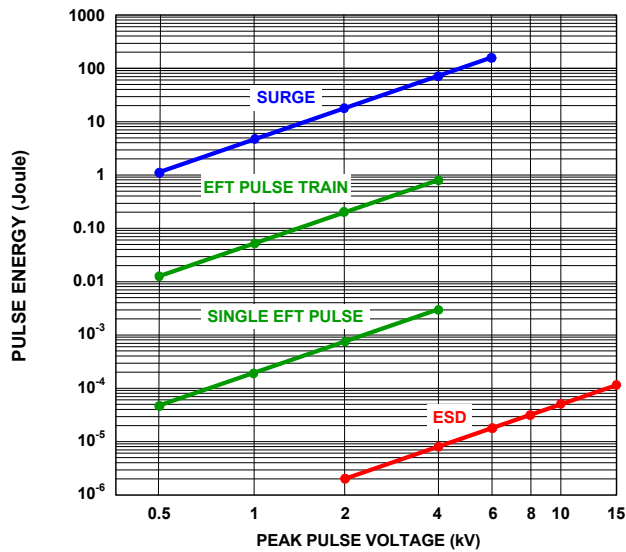
INSTALLATION CLASS	SYMMETRICAL LINES TEST VOLTAGE (kV)
0	NA
1	0.5
2	1
3	2
4	2
5	4

The standard defines the installation classes as follows:

- **Class 0:** Well-protected electrical environment
- **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 run as outdoor cables along with power cables, and cables are used for both electronic and electric circuits
- **Class 5:** Electrical environment for electronic equipment connected to communication cables and overhead power lines in a non-densely populated area
- **Class X:** Special conditions specified in the product specification

The combination of high currents, high voltages and long pulse duration makes the surge test undoubtedly the most severe amongst all transient immunity tests.

Measurement results from test equipment manufacturers have yielded the energy-versus-test voltage diagram in [Figure 10](#).



**FIGURE 10. COMPARISON OF PULSE ENERGIES FOR VARIOUS TRANSIENT IMMUNITY TESTS**

It can be seen that for a given test voltage the energy content of a surge pulse is around 100 times higher than that of an EFT pulse train and more than 8-million times higher than the energy of an ESD pulse!

To successfully protect RS-485 networks against lethal surge transients, semiconductor manufacturers offer transient voltage suppressors capable of absorbing powers from a few hundred up to several thousand watts. Their functionality and main features are discussed in application note [AN1977](#), "Transient Voltage Suppressors: Operation and Features".

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