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.

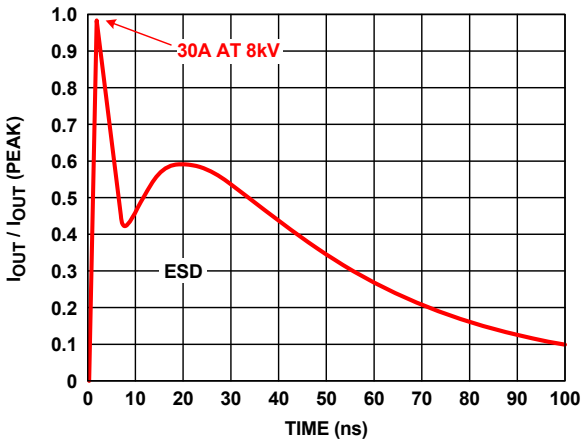

FIGURE 1. CURRENT WAVEFORM OF AN ESD PULSE

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

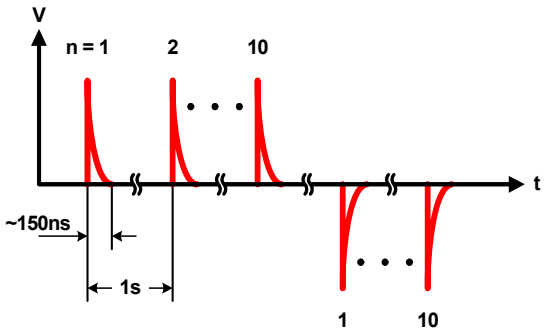

FIGURE 2. TIMING OF A MINIMUM TEST PULSE SEQUENCE

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.

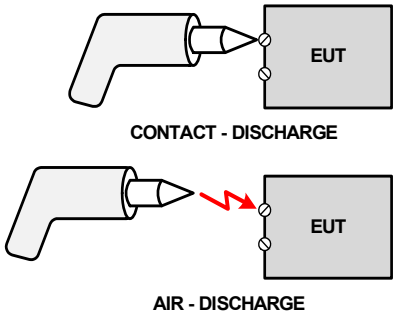

FIGURE 3. METHODS OF ESD PULSE DELIVERY TO THE EUT

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.

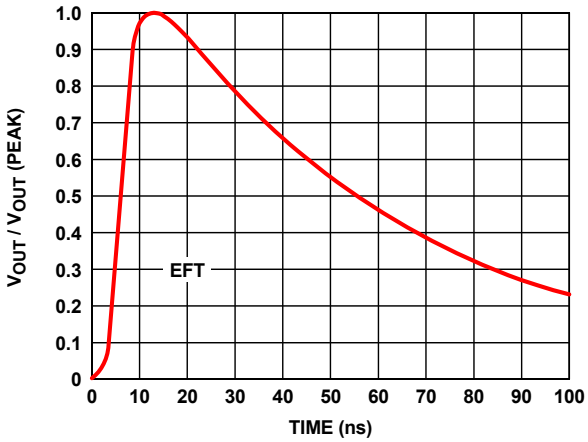

FIGURE 4. CURRENT WAVEFORM OF AN EFT PULSE

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.

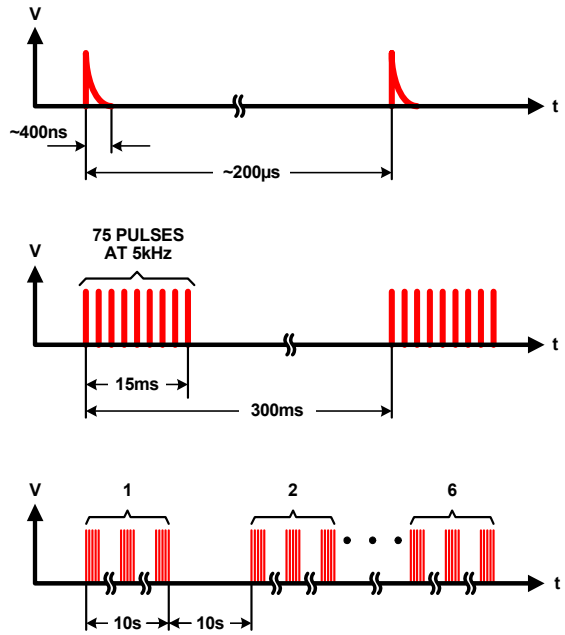

FIGURE 5. TIMING OF A TYPICAL EFT TEST SEQUENCE

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.

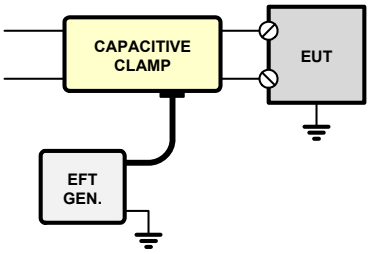

FIGURE 6. METHOD OF EFT PULSE DELIVERY TO THE EUT

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.

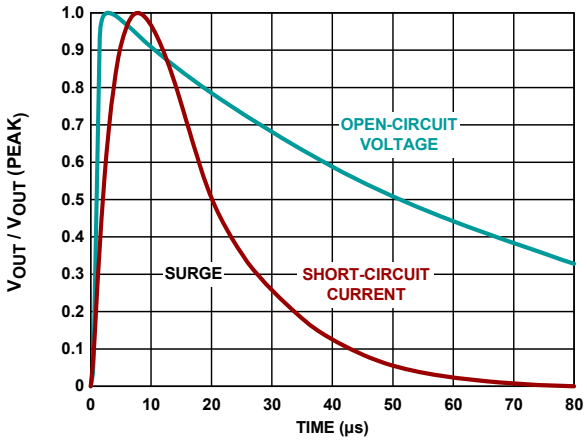

FIGURE 7. VOLTAGE AND CURRENT WAVEFORMS OF A CWG

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.

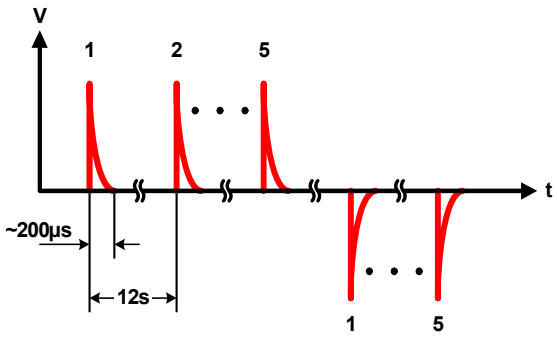

FIGURE 8. TIMING OF A TYPICAL SURGE TEST PULSE SEQUENCE

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 42Ω, which, in the case of RS-485, consists of the 2Ω generator output resistance, defined by the ratio of peak open-circuit output voltage to peak short-circuit output current, and two 80Ω 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.

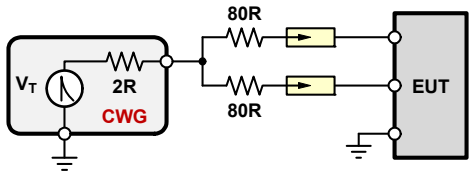

FIGURE 9. METHOD OF SURGE PULSE DELIVERY TO THE EUT

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.

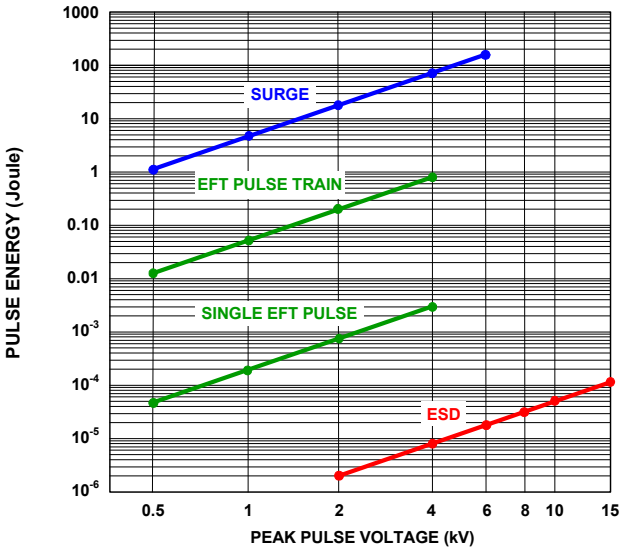

FIGURE 10. COMPARISON OF PULSE ENERGIES FOR VARIOUS TRANSIENT IMMUNITY TESTS

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”.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

RENESAS

SALES OFFICES

Renesas Electronics Corporation

http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338

Colophon 7.0