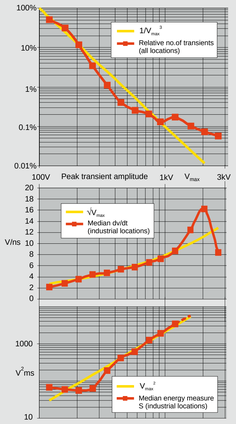
Transient occurence



Transient occurrence in the real world

The data shown here are taken from a study carried out in Germany in the mid-1980s. Around 3,400 hours of recording captured 28,000 transients at 40 different measuring points. The transients were measured between live and protective earth of TN-type 220/380V supply networks. Transient characteristics did not vary much between industrial, business, domestic or laboratory locations, although the total number of transients was much greater in the industrial locations than the others.

The data show that:

- the relative rate of occurrence of a given transient varies roughly proportionally to the inverse of the cube of its peak amplitude;
- the rate of rise (dv/dt) of the transient increases roughly proportionally to the square root of its peak amplitude, as does its rise time;
- the energy measure of a transient is more or less constant up to 200V and then increases roughly proportionally to the square of its peak amplitude at higher voltages; this suggests that the waveshape of transients is fairly constant over a range of amplitudes.

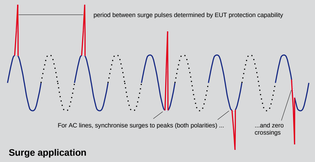
For peak voltages above 1kV, the number of recorded transients was insufficient to give a high degree of statistical coverage.

Reference: *Transients in Low-Voltage Supply Networks*, J J Goedbloed, IEEE Transactions on EMC, Vol EMC-29 No 2, May 1987, pp 104-115

Surge - IEC 61000-4-5

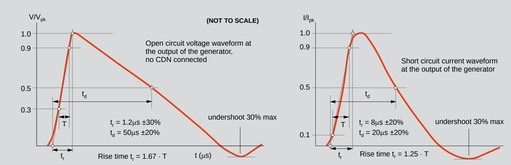
IEC and other surge specifications

Schaffner 2050 module	Test standard		Peak V	Voltage t_r	Voltage t_d	Peak I	Current t_r	Current t_d	Number of pulses
PNW2050	IEC 61000-4-5	1.2/50µs combination wave							
		AC power line-to-line	0.5 – 4kV ±10%	1.2µs ±30%	50µs ±20%	0.25 – 2kA ±10%	8µs ±20%	20µs ±20%	Minimum 5 each polarity
		AC power line-to-earth				Limited by additional 10Ω in series			
		Other lines, line-to-earth				Limited by additional 40Ω in series			
PNW2051	ITU-T (CCITT) K.17, .20	10/700µs wave							
		Transverse and longitudinal	0.5 –5kV	10µs	700µs	12.5 –125A	Defined by circuit components		10, polarity reversed between pulses
PNW2053B	FCC Part 68	Telephone line type A (high energy)							
		metallic	800V min	10µs max	560µs min	100A min	10µs max	560µs min	1 each polarity
		longitudinal	1500V min	10µs max	160µs min	200A min	10µs max	160µs min	
		Telephone line type B (low energy)							
		metallic	1000V min	9µs ±30%	720µs ±20%	25A min	5µs ±30%	320µs ±20%	1 each polarity
		longitudinal	1500V min	9µs ±30%	720µs ±20%	37.5A min	5µs ±30%	320µs ±20%	
		Power line							
		phase-neutral	2500V min	2µs max	10µs min	1000A min	2µs max	10µs min	3 each polarity

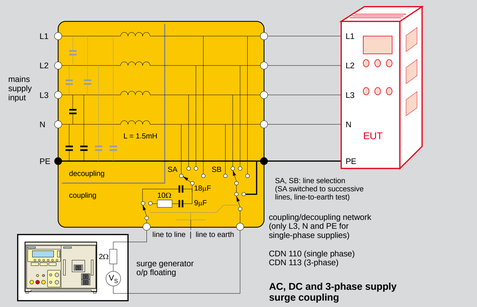


Surge application

- ground reference plane is not essential, provided care is taken with earth connections, except for tests to shielded lines
- physically isolate the EUT, disconnect it from other equipment where possible and insulate the whole setup to prevent flashover during the test
- synchronise each surge to the peak of the AC supply waveform to give maximum stress, and to the zero crossing to induce maximum follow-on energy in case this occurs: five negative and five positive applications each at 0°, 90°, 180° and 270° phases are required in most cases
- all lower test levels must also be satisfied – increase the stress voltage in steps up to the maximum, to check that the protective devices do not allow upset or damage at lower levels of applied voltage despite satisfactorily clamping high levels
- replace protective devices after testing if the EUT is to be re-used, in case of degradation; if tests done faster than one pulse per minute cause failure due to damaged protective devices, testing at one pulse per minute prevails



The combination wave



SA, SB: line selection (SA switched to successive lines, line-to-earth test)

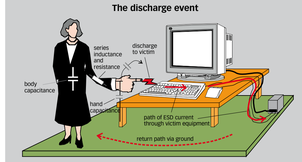
coupling/decoupling network (only L3, N and PE for single-phase supplies)

CDN 110 (single phase)
CDN 113 (3-phase)

AC, DC and 3-phase supply surge coupling

ESD - IEC 61000-4-2

The discharge event



Applying the ESD test

Points of application - all points that are accessible to the user in normal operation; not necessarily pins of open connectors nor points accessible only during maintenance or servicing

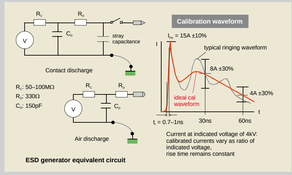
Application method- contact discharge is preferred, air discharge is used where contact cannot be applied, both direct discharges to the EUT, and indirect discharges to the coupling planes), are required

Non-earthed apparatus- should be deliberately discharged between each pulse, e.g. via connection of bleed resistor or by air ionisation

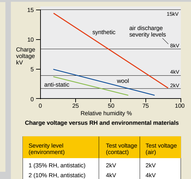
Number of discharges– normally ten in each polarity to each point of application – EN 55024 requires a total of 200, 50 at each point

Mode of application- test generator must be perpendicular to the surface of the EUT; for air discharge, the tip must approach the EUT as fast as possible without causing mechanical damage; for contact, the tip must touch the EUT before the discharge switch is operated

Test levels – all lower test levels must also be satisfied, i.e. if the test specification is 4kV contact, then 2kV and 4kV must also be applied



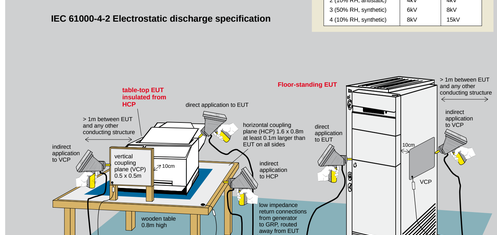
ESD generator equivalent circuit



Charge voltage versus RH and environmental materials

IEC 61000-4-2 Electrostatic discharge specification

Severity level (environment)	Test voltage (contact)	Test voltage (air)
1 (35% RH, antistatic)	2kV	2kV
2 (10% RH, antistatic)	4kV	4kV
3 (50% RH, synthetic)	6kV	8kV
4 (10% RH, synthetic)	8kV	15kV



ESD test set-up for table-top and floor-standing EUTs

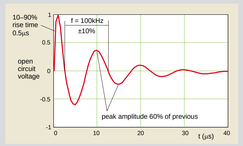
Ring wave - IEC 61000-4-12

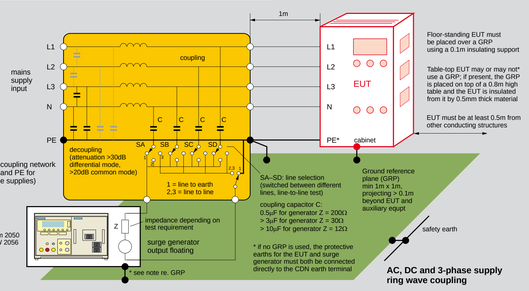
Ring wave application

Generator output impedance Z	Minimum repetition period	Application
12Ω	10s	EUT supply ports connected to major feeders Application between communication ports on cabinets interconnected with 10m long screened data comms cables
30Ω	6s	EUT supply ports connected to outlets
200Ω	1s	I/O ports, unless the test involves protection devices or filters, in which case 12Ω or 30Ω is applicable

A minimum of 5 positive and 5 negative transients are to be applied, both line to ground (common mode, simultaneously between all terminals and ground) and line to line (differential mode), and/or between cabinets (communication ports)

IEC 61000-4-12 Ring wave



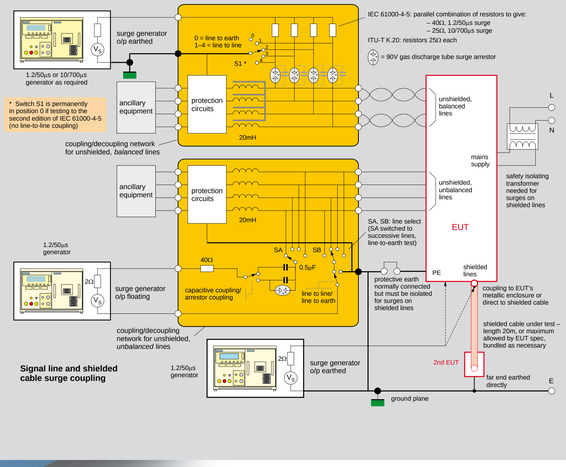


Floor-standing EUT must be placed over a GRP, using a 0.1m insulating support

Table-top EUT may or may not* use a GRP; if present, the GRP is placed on top of a 0.8m high table and the EUT is insulated from it by 0.5mm thick material

EUT must be at least 0.5m from other conducting structures

AC, DC and 3-phase supply ring wave coupling



Generic and product standards

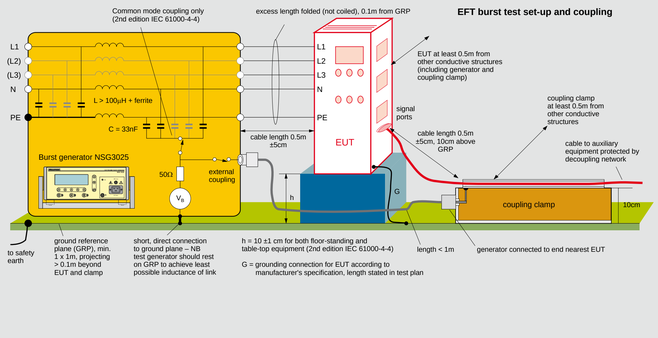
Standard	Scope		ESD	EFT-burst	Surge
EN 61000-6-1: 2001	Residential, commercial & light industrial generic		4kV contact, 8kV air to EN 61000-4-2	1kV AC power, 0.5kV DC power > 10m, signal and functional earth > 3m to EN 61000-4-4	1kV L-L, 2kV L-E on AC power input; 0.5kV L-L & L-E DC power > 10m, to EN 61000-4-5
EN 61000-6-2: 2005	Industrial generic		4kV contact, 8kV air to IEC 61000-4-2	2kV AC power, DC power > 3m, 1kV signal and functional earth > 3m to IEC 61000-4-4	1kV L-L, 2kV L-E on AC power; 0.5kV L-L & L-E DC power connected to a distribution network; 1kV L-E signal > 30m, to IEC 61000-4-5
EN 55014-2: 1997 + A1: 2001	Household appliances etc.		4kV contact, 8kV air to EN 61000-4-2	1kV AC power, 0.5kV DC power, signal and control > 3m to EN 61000-4-4	1kV L-L, 2kV L-E on AC mains, to EN 61000-4-5
EN 55020: 2002	Broadcast receivers etc.		4kV contact, 8kV air to EN 61000-4-2	1kV AC power to EN 61000-4-4	Not required
EN 55024: 1998	Information technology equipment		4kV contact, 8kV air to IEC 61000-4-2	1kV AC power, 0.5kV DC power, signal and telecom > 3m to IEC 61000-4-4	1kV L-L, 2kV L-E on AC mains, 0.5kV L-E on DC power with outdoor cables, to IEC 61000-4-5; 1.5kV 10/700µs on signal/telecom ports with outdoor cables, to ITU-T K recs.
EN 50130-4: 1995 + A2: 2003	Fire, intruder and social alarm systems		6kV contact, 8kV air to EN 61000-4-2	2kV AC mains supply, 1kV other supply/signal lines to EN 61000-4-4	1kV L-L, 2kV L-E on AC mains supply; 1kV L-E other supply/signal lines, to EN 61000-4-5
EN 61326-1: 2006	Measurement, control and lab equipment, min. requirements		4kV contact, 4kV air to IEC 61000-4-2	1kV AC & DC power, 0.5kV I/O signal/ control > 3m to IEC 61000-4-4	0.5kV power L-L, 1kV power & long distance I/O signal/control L-E to IEC 61000-4-5
EN 61547: 1995 + A1: 2000	General lighting equipment		4kV contact, 8kV air to IEC 61000-4-2	1kV AC power, 0.5kV DC power, signal and control > 3m to IEC 61000-4-4	0.5kV L-L, 1kV L-E on AC power, to IEC 61000-4-5
EN 300386	Telecom network equipment, immunity only	Telecom centres	4kV contact, 4kV air to EN 61000-4-2	1kV AC power, 0.5kV DC power, outdoor signal and indoor signal > 3m to EN 61000-4-4	0.5kV L-L, 1kV L-E on AC power; 0.5kV L-E indoor signal lines > 10m, 1kV on outdoor signal lines, to EN 61000-4-5
		Not telecom centres	6kV contact, 8kV air to EN 61000-4-2	1kV AC power and DC power > 3m, 0.5kV outdoor signal and indoor signal > 3m to EN 61000-4-4	1kV L-L, 2kV L-E on AC power; 0.5kV L-E indoor signal lines > 10m, 1kV L-E on outdoor signal lines, to EN 61000-4-5

L-L = line to line; L-E = line to earth. Always check the appropriate standard for detailed applicability

4 of a series of wallchart guides

Transient immunity testing

EFT - IEC 61000-4-4



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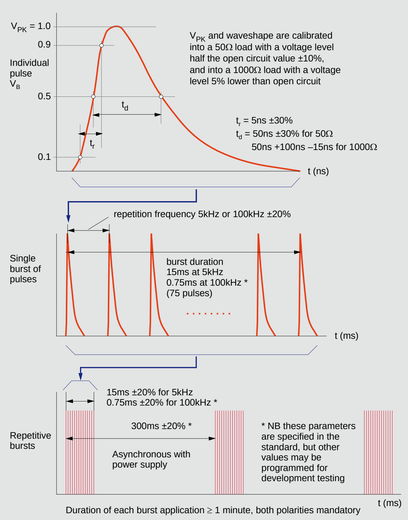
691-006A

IEC 61000-4-4: 2004 Electrical fast transient burst

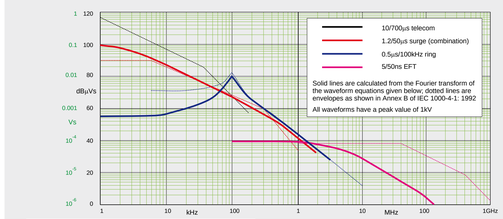
Waveform specifications



V_{PK} and waveshape are calibrated into a 50Ω load with a voltage level half the open circuit value ±10%, and into a 1000Ω load with a voltage level 5% lower than open circuit

t_r = 5ns ±30%
t_d = 50ns ±30% for 50Ω
50ns +100ns –15ns for 1000Ω

Amplitude density spectra



Solid lines are calculated from the Fourier transform of the waveform equations given below; dotted lines are envelopes as shown in Annex B of IEC 1000-4-1: 1992

All waveforms have a peak value of 1kV

Equations

Source: IEEE Cs2.41: 1991, except ESD: IEC 61000-4-2 draft Ed 2

ESD current waveform (4kV indicated voltage, t in ns)

$$I(t) = 55 \cdot \left(\frac{\left(\frac{t}{1.3}\right)^{1.8}}{1+\left(\frac{t}{1.3}\right)^{1.8}}\right) \cdot \exp\left(\frac{-t}{2}\right) + 20.7 \cdot \left(\frac{\left(\frac{t}{12}\right)^{1.8}}{1+\left(\frac{t}{12}\right)^{1.8}}\right) \cdot \exp\left(\frac{-t}{37.8}\right)$$

Surge voltage 1.2/50µs waveform (t in µs)

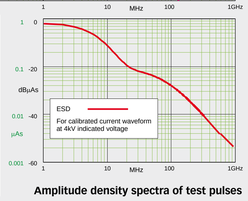
$$V(t) = 1037 \cdot V_p \cdot \left(1 - \exp\left(\frac{-t}{0.407}\right)\right) \cdot \exp\left(\frac{-t}{68.22}\right)$$

EFT 5/50ns waveform (t in ns)

$$V(t) = 127 \cdot V_p \cdot \left(1 - \exp\left(\frac{-t}{3.5}\right)\right) \cdot \exp\left(\frac{-t}{55.6}\right)$$

0.5µs/100kHz ring waveform (t in µs, $\omega = 2\pi \cdot 10^5$ rad/s)

$$V(t) = 159 \cdot V_p \cdot \left(1 - \exp\left(\frac{-t}{0.533}\right)\right) \cdot \exp\left(\frac{-t}{9.788}\right) \cdot \cos(\omega t)$$



Amplitude density spectra of test pulses

Energy content

Energy versus test level

Transient energy

The energy content of transients and surges is not simple to define. The actual energy stored in the test generator is not all dissipated in the load. That proportion which is, depends on the ratio of the load and generator impedances. In general, a load such as a surge suppressor will be non-linear and will also have a time or frequency dependence.

The "energy measure" of a given waveform can be described by

$$S = \int_0^T V^2(t)dt$$

which gives the energy that would be delivered by that voltage waveform into a 1Ω resistor, whether or not the generator is capable of this (i.e., assuming zero output impedance). These figures are shown in the lower graph opposite.

Alternatively, the actual energy delivered by the generator into a defined resistive load can be calculated. For the ESD and EFT waveforms, these can be the calibration loads of 2Ω and 50Ω respectively. For the surge and ring waves, a load which matches the output impedance can be chosen, and the voltage or current waveform is delivered* into this resistance with half the open circuit (or short circuit, for current) amplitude. In these cases the energy in Joules (watt seconds) is shown in the upper graph and is given by

$$W = \frac{1}{R}\int_0^T \left(\frac{V(t)}{2}\right)^2 dt \qquad W = R \cdot \int_0^T \left(\frac{I(t)}{2}\right)^2 dt$$

where *V(t)* and *I(t)* are the open circuit voltage and short circuit current waveforms, respectively.

These graphs are for comparative purposes only – the real energy delivered to a particular EUT can only be calculated if the load impedance and characteristics, and the actual waveshape applied to this load, are known accurately.

The symbols on the graphs represent test levels 1 to 4 as defined in each standard.

* This simplifying assumption is not found in practice as the current and voltage waveforms vary depending on the load impedance.