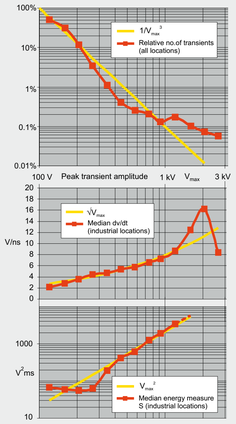
Transient occurence



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 220/380 V 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 200 V 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.

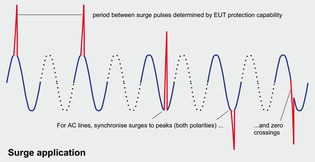
For peak voltages above 1 kV, the number of recorded transients was insufficient to give a high degree of statistical coverage.

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/EN 61000-4-5

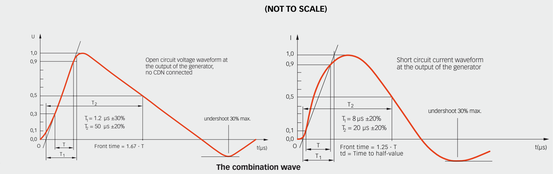
IEC and other surge specifications

Test standard		Peak V	Voltage Front time	Voltage time to half-value	Peak I	Current t_r	Current t_d	Number of pulses
IEC/EN 61000-4-5	1.2/50 µs combination wave							
	AC power line-to-line	0.5 – 4 kV ±10%	1.2 µs ±30%	50 µs ±20%	0.25 – 2 kA ±10%	8 µs ±20%	20 µs ±20%	Minimum 5 each polarity
	AC power line-to-earth				Limited by additional 10 Ω in series			
	Other lines, line-to-earth				Limited by additional 40 Ω in series			
ITU-T K 20, K 44	10/700 µs wave							
	Communication lines	0.5 – 5 kV	10 µs	700 µs	12.5 –125 A	Defined by circuit components		10, polarity reversed between pulses

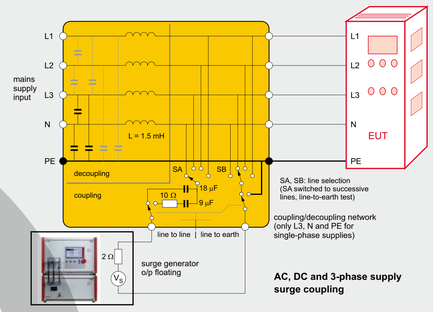


Surge application

- 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



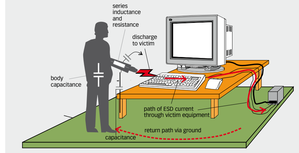
SA, SB: line selection (SA switched to successive lines, line-to-earth test)

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

AC, DC and 3-phase supply surge coupling

ESD - IEC/EN 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

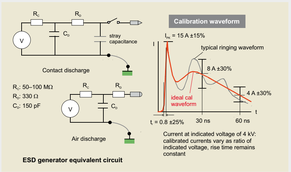
Application method– contact discharge is preferred, air discharge is used where contact cannot be applied; both direct discharges to the EUT, and indirect discharges to the coupling plane(s), are required

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

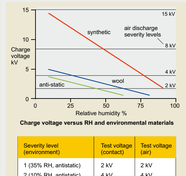
Test levels – all lower test levels must also be satisfied, i.e. if the test specification is 4 kV contact, then 2 and 4 kV must also be applied



ESD generator equivalent circuit

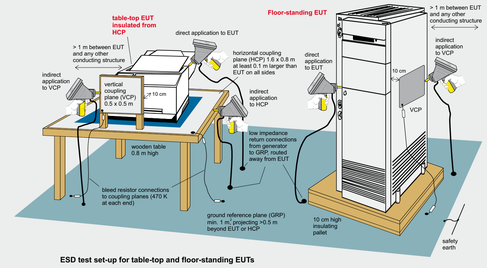
Current at indicated voltage of 4 kV: calibrated currents vary as ratio of indicated voltage, rise time remains constant

IEC/EN 61000-4-2 Electrostatic discharge specification



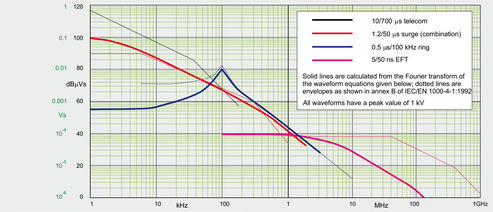
Charge voltage versus RH and environmental materials

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



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

Amplitude density spectra



Equations

Source: IEEE C62.41: 1991, except ESD: IEC/EN 61000-4-2 draft Ed 2

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

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

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

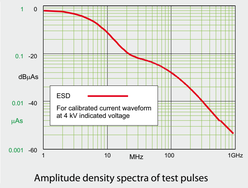
$$V(t) = 1037 \cdot V_p \cdot \left(1-\exp\left(\frac{-t}{0.407}\right)\right)\exp\left(\frac{-t}{68.22}\right)$$

EFT 5/50 ns waveform (t in ns)

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

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

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



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 1 Ω 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 2 Ω and 50 Ω 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

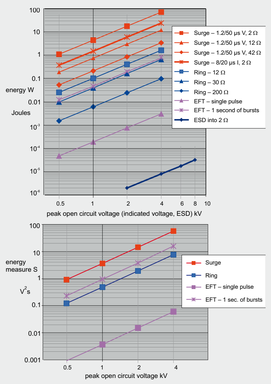
$$W = \frac{1}{R}\int_0^T \left(\frac{V(t)}{2}\right)^2 dt \qquad W = R\cdot\int_0^T \left(\frac{I(t)}{2}\right)^2 dt$$

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.

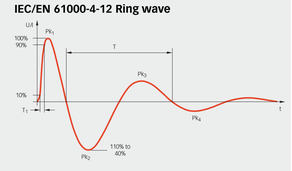


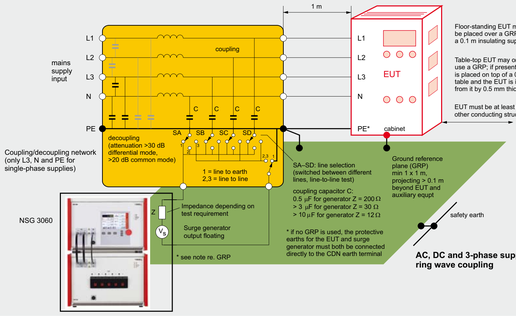
Ring wave - IEC/EN 61000-4-12

Ring wave application

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





AC, DC and 3-phase supply ring wave coupling

Generic and product standards

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

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

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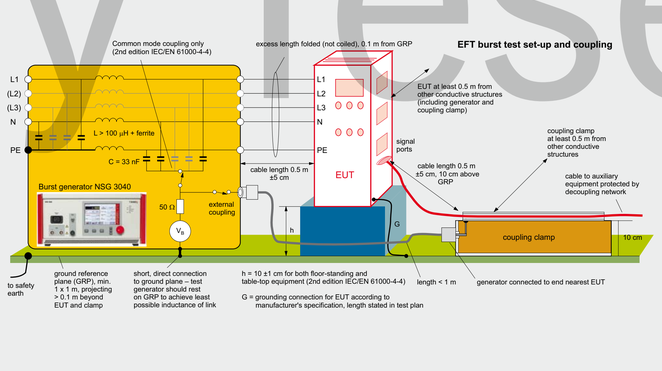
Standards are subject to change and it is strongly recommended that before any tests are carried out, the latest issue of the standard is obtained from the relevant standards body.

4 of a series of wallchart guides

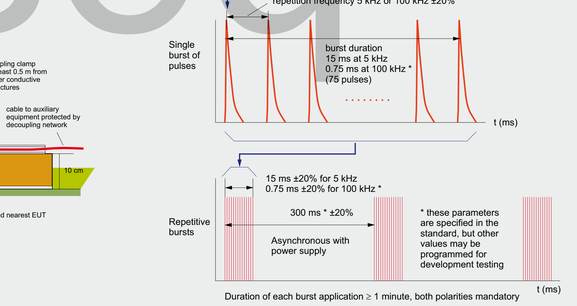
Transient immunity testing

EFT - IEC/EN 61000-4-4



Teseq AG
Nordstrasse 11F
4542 Luterbach
Switzerland
Tel: +41 (0)32 681 40 40
Fax: +41 (0)32 681 40 48

691-006B



Signal line surge coupling

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

Waveform specifications

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

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

* these parameters are specified in the standard, but other values may be programmed for development testing

Duration of each burst application ≥ 1 minute, both polarities mandatory