

Ceramic transient voltage suppressors, CTVS

Protection standards for electromagnetic
compatibility (EMC)

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1 CE conformity

A wide range of legislation and of harmonized standards have come into force and been published in the field of EMC in recent years. In the European Union EMC Directive 89/336/EEC of the Council of the European Communities and its successor, the 2004/108/EC, do apply. All electronic equipment must comply with the protective aims of the EMC Directive. Conformity with the respective standards must be guaranteed by the manufacturer or importer in the form of a declaration of conformity. A dedicated CE mark of conformity must be applied to all equipment.

As a matter of principle, all electrical or electronic equipment, installations and systems must meet the protection requirements of the EMC Directive and/or national EMC legislation. A declaration of conformity by the manufacturer or importer and a CE mark are required for most equipment. Exceptions to this rule and special rulings are described in detail in EMC legislation.

There are binding regulations both for maximum interference emission and for immunity to interference. In this respect, in addition to having an optimum price/performance ratio, varistors have proved themselves to be a reliable solution for most requirements concerning immunity to interference and transient overvoltages. The IEC 61000 or EN 61000 series of standards serve as the central EMC standards into which all EMC regulations have been integrated.

The European standards are subdivided into generic, basic, and product family standards. This makes it easier to find the rules that apply to the respective equipment. Generic standards define the EMC environment in which a device is to operate according to its intended use and always apply to all equipment for which there is no specific product family standard or dedicated product standard. Basic standards contain information on interference phenomena and general measuring methods.

1.1 Generic standards on electromagnetic compatibility (EMC)

Harmonized European standards have been drawn up in relation to the EMC Directive of the EEC and national EMC laws. These specify measurement techniques and limit values or severity levels, both for interference emission and for the interference susceptibility (or rather, immunity to interference) of electronic devices, equipment and systems.

Adherence to the standards for EMC is especially important. These are:

■ Immunity to interference	EN 61000-6-1 and	IEC 61000-6-1 and
	EN 61000-6-2	IEC 61000-6-2
■ Interference emission	EN 61000-6-3 and	IEC 61000-6-3 and
	EN 61000-6-4	IEC 61000-6-4

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1.2 Basic standards: IEC standards for measurement of immunity to interference

One important IEC standard relating to EMC is IEC 61000-4, which in turn comprises a number of EMC-specific norms. Of these the following refer to measurement of immunity to interference and transient overvoltages and thus are especially applicable to CTVS:

1. IEC 61000-4-1 - Introduction
2. IEC 61000-4-2 - ESD (electrostatic discharge)
3. IEC 61000-4-3 - Field-related electromagnetic interference
4. IEC 61000-4-4 - Burst (electrical fast transients)
5. IEC 61000-4-5 - Surges (high-energy transients)
6. IEC 61000-4-6 - Conducted disturbance

Each part of this standard focuses on measurement of different classes for electromagnetic disturbance:

Electrostatic discharge (ESD)

Standard	Test characteristics	Phenomena
IEC 61000-4-2	8 kV contact discharge (level 4) 15 kV air discharge (level 4)	Electrostatic discharge

Field-related electromagnetic interference

Standard	Test characteristics	Phenomena
IEC 61000-4-3	1 V/m, 3 V/m, 10 V/m, 30 V/m or higher 80 MHz to 6 GHz	High-frequency interference fields

Conducted interference

Standard	Test characteristics	Phenomena
IEC 61000-4-4	5/50 ns pulse, up to 4 kV 5 kHz burst for a duration of 15 ms, 100 kHz burst for a duration of 0.75 ms	Electrical fast transient/ burst Cause: switching processes
IEC 61000-4-5	1.2/50 μ s (open-circuit voltage) 8/20 μ s (short-circuit current)	Surge (high-energy transients) Cause: lightning strikes, switching processes near power mains
IEC 61000-4-6	1 V, 3 V, 10 V 150 kHz to 230 MHz	Conducted disturbance Cause: induced by radio-frequency fields

The standards relevant for transient overvoltage protection with varistors are explained in detail in the next sections.

1.2.1 Electrostatic discharge (ESD) to IEC 61000-4-2

The standard IEC 61000-4-2 describes the test procedures and specifies severity levels. Figure 1 shows the discharge circuit (high-voltage source, charge resistor R_c , effective capacitor C , discharge resistor R_d), figure 2 the waveform of the discharge current with an extremely short rise time of 0.8 ns and amplitudes of up to 30 to 40 A.

The secondary effects caused by this edge steepness are high electrical and magnetic field strengths.

In the ESD test, at least 10 test pulses are applied, which have the polarity to which the device under test is most sensitive.

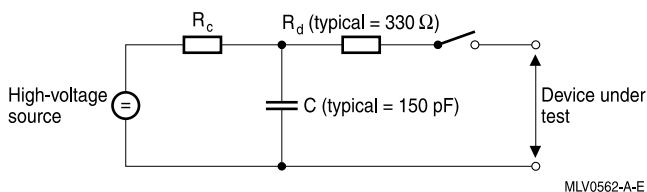


Figure 1

ESD discharge circuit to IEC 61000-4-2 (typical values: $C = 150 \text{ pF}$, $R_d = 330 \text{ } \Omega$)

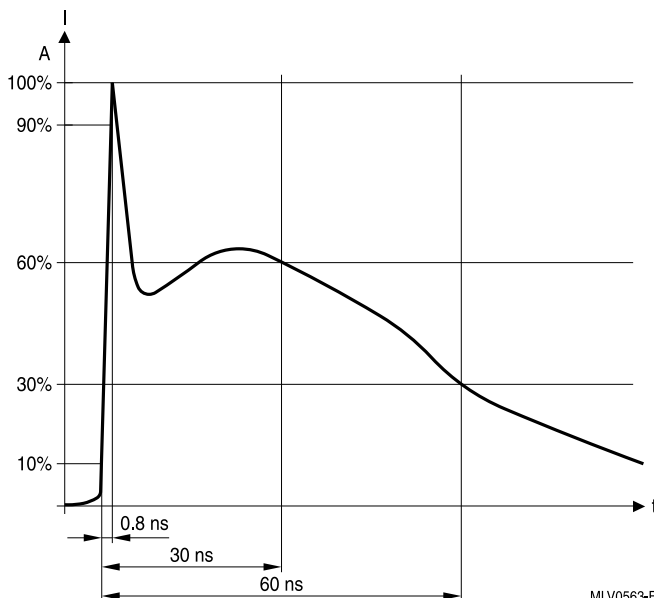


Figure 2

ESD discharge current to IEC 61000-4-2

Response time of CTVS

Taking into account the very short rise times of ESD pulses in the sub-nanosecond regime (see figure 2), in order to provide efficient ESD protection the response time of CTVS, i.e. the elapsed time from the beginning of the ESD pulse impact until the CTVS device clamps the overvoltage down to uncritical values needs to be rather low. Due to the very low parasitic inductances of the device with typical values from 3 nH for large case sizes (e.g. 2220) down to < 1 nH for small case sizes (e.g. 0201), multilayer CTVS achieve response times of < 0.5 ns. Figure 3 shows the virtually delay-free voltage response to a 4 kV ESD pulse in the time domain.

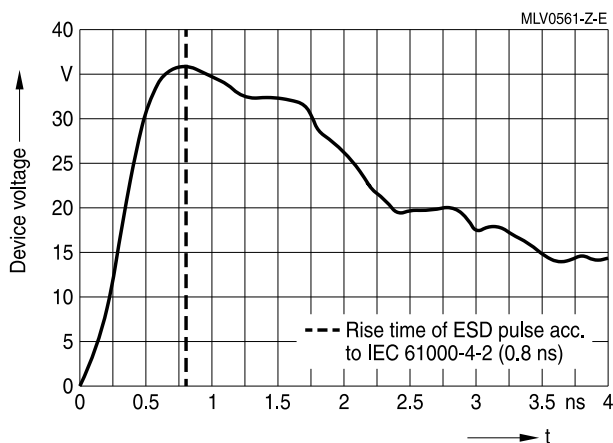


Figure 3

Voltage response in the time domain to a standard ESD pulse acc. to IEC 61000-4-2 (4 kV contact discharge) for an exemplary CTVS of the low clamping voltage series.

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1.2.2 Electrical fast transient (EFT) - burst to IEC 61000-4-4

According to IEC 61000-4-4, burst pulses are low-energy transients with steep edges and high repetition rate. Thus, for equipment to pass burst testing successfully, design (line filter, grounding concept, case) is as critical as the choice of the CTVS. If IEC 61000-4-5 has been taken into account when selecting CTVS, they will normally also handle the burst pulse energy without any problems.

Due to the steepness of the pulse edges, the CTVS must be connected in a way which keeps parasitic circuit inductance low.

1.2.3 Surge voltage to IEC 61000-4-5

The immunity to interference against surge voltages is tested in accordance with IEC 61000-4-5. The transient is generated using a combination wave hybrid generator.

The severity level to be applied in the immunity test must be defined as a function of the installation conditions.

In most cases, the respective product standards demand five positive and five negative voltage pulses. Standard IEC 61000-4-5 specifies severity level 4 (line-to-line, 4 kV) as being the highest energy load.

1.3 EMC protection standards in the automotive sector

1.3.1 ESD protection

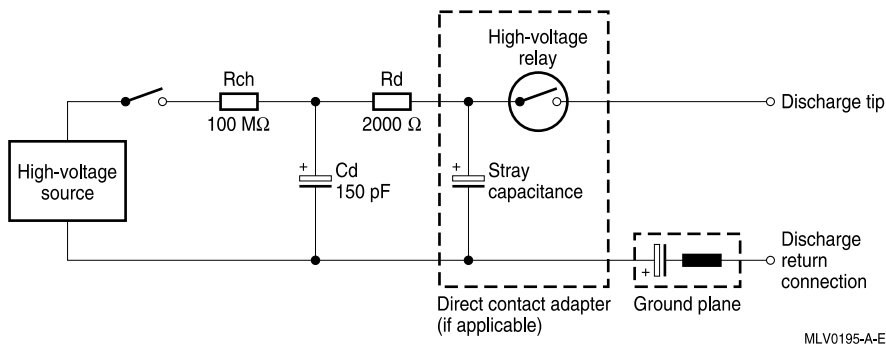
Electrostatic discharge (ESD) is a rapid and short lasting surge of electric current that flows between two different objects when they come together and an excess of electric charge is transferred between them. Voltages up to 25 kV can be generated in this way. To ensure proper functionality in automotive systems, ESD protection must be available from the component level up to the system level. At the component level there are three standards for passive electronic components:

- IEC 61000-4-2 level 4 (explained in previous section)
- AEC-Q200, Rev. D
- ISO 10605 (2008)

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1.3.1.1 AEC-Q200, Rev. D

Figure 4 shows the human body model (HBM), a capacitance and resistance model that uses the elements of the electrical circuit to characterize a person as a source of electrostatic charging for automotive conditions.



MLV0195-A-E

Figure 4
HBM ESD simulator circuit according to AEC-Q200, Rev. D

Further ESD models are the machine model (MM) or the charged device model (CDM), for example. The MM simulates the discharge of a machine into an electronic device via metal contact. This is reflected in the discharge current by a smaller resistance and a higher capacitance. Generally, the MM test case is sufficiently covered by the HBM test. The CDM simulates the discharge of a charged component package into a low-ohmic contact via displacement current over the intrinsic equivalent component capacitance. This method is generally not applicable to multi-layer CTVS.

The table below shows the classification levels for passive components to AEC-Q200, Rev. D.

Component classification	Max. withstand voltage
1A	< 500 V (DC)
1B	500 V (DC) to < 1000 V (DC)
1C	1000 V (DC) to < 2000 V (DC)
2	2000 V (DC) to < 4000 V (DC)
3	4000 V (DC) to < 6000 V (DC)
4	6000 V (DC) to < 8000 V (DC)
5A	8000 V (DC) to < 12000 V (AD)
5B	12000 V (AD) to < 16000 V (AD)
5C	16000 V (AD) to < 25000 V (AD)
6	≥ 25000 V (AD)

DC = contact discharge

AD = air discharge

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1.3.1.2 ISO 10605

ISO 10605 (2008) specifies test methods for electrical disturbance from ESD related to automotive electronics both for components (simulated discharge from humans during assembly process or service case) and for integrated systems in cars. The HBM circuitry is similar to that shown in the IEC 61000-4-2 (see section 1.2.1) or the AEC-Q200, Rev. D (see section 1.3.1.1) but the capacitance is changed depending on whether or not the discharge is applied to an area that can be reached by the person inside the vehicle (e.g. switches, displays, controls) or if it is applied from outside the car. This is shown in the table below.

	R in Ω	C in pF	Maximum test voltage
Inside vehicle	330 or 2 k	330	15 kV
Outside vehicle	330 or 2 k	150	25 kV

HBM conditions to ISO 10605 (2008)

There are different severity levels for the vehicle test methods defined in the standard, depending on the discharge mode (contact discharge, air discharge) and the applied test voltage.

1.3.2 Automotive transients acc. to ISO 7637-2 and ISO 16750-2

The standards ISO 7637-2 and ISO 16750-2 detail EMC testing for automotive electrical systems, including test pulses 1, 2a/2b and 3a/3b (acc. to ISO 7637-2), and test pulses A and B (acc. to ISO 16750-2). The toughest tests for transient suppression are pulses A and B (shown in figures 5 and 6), which simulate load dump. **Load dump** occurs when a battery is accidentally disconnected from the generator while the engine is running, e.g. because of a broken cable. For test pulse A, 10 pulses are to be applied at 1 minute intervals, whereas for test pulse B, 5 pulses at 1 minute intervals are required.

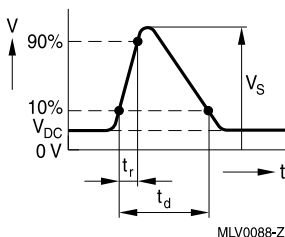


Figure 5
Load dump test pulse A to ISO 16750-2
(unsuppressed)

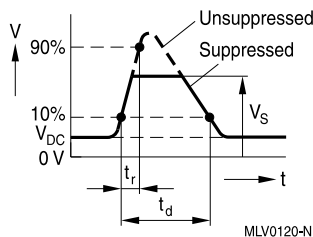


Figure 6
Load dump test pulse B to ISO 16750-2
(suppressed)

Legend:

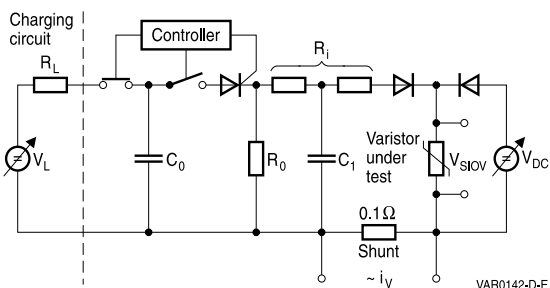
- Charge voltage (test level)
- Rise time
- Duration

V_S
 t_r
 t_d

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1.3.2.1 Tests

Maintenance of EMC requirements can be checked with conventional test generators. Figures 7 and 8 show block diagrams for load dump tests with operating voltage applied.

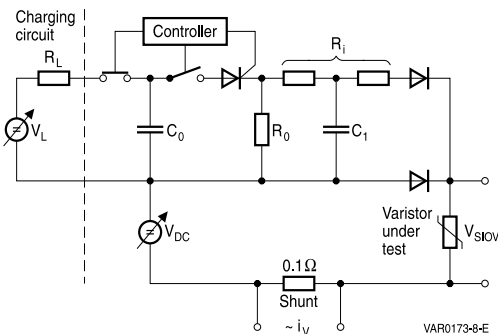


Typical values

C_0	20 ... 35 mF
R_0	4 ... 10 Ω
C_1	0 ... 10 μ F
R_i	0.5 ... 8 Ω
V_L	0 ... 200 V
V_{DC}	12 ... 28 V
t_d	40 ... 400 ms
V_{VAR}	Protection level of varistor
i_{VAR}	Current through varistor

Figure 7
Principle of load dump generator with battery connected in parallel

The circuit in figure 8 produces test pulse A to ISO 16750-2; the 10% time constant t_d can be set independently of the battery voltage. Note that the maximum discharge current is not limited by the source V_{DC} .



Typical values

C_0	4.7 ... 47 mF
R_0	4 ... 5 Ω
C_1	47 ... 470 μ F
R_i	0.5 ... 8 Ω
V_L	0 ... 200 V
V_{DC}	12 ... 28 V
t_d	40 ... 400 ms
V_{VAR}	Protection level of varistor
i_{VAR}	Current through varistor

Figure 8
Principle of load dump generator with battery connected in series