Ceramic transient voltage suppressors

Protection standards on electromagnetic compatibility (EMC)

Date: November 2010

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 the past few years. In the European Union the EMC Directive 89/336/EEC of the Council of the European Communities came into effect on the 1st of January 1996. As of this date, 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 CE mark of conformity must be applied to all equipment[1)].

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 the EMC laws.

Whereas regulations concerning maximum interference emission have been in existence for some time, binding requirements concerning immunity to interference have only come into existence since 1996 for many types of equipment. 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 are planned as central EMC standards into which all EMC regulations are to be integrated in the next few years.

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)

New, harmonized European standards have been drawn up in relation to the EEC's EMC Directive 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 EN 61000-6-2	IEC 61000-6-1 and IEC 61000-6-2
■ Interference emission	EN 61000-6-3 and EN 61000-6-4	IEC 61000-6-3 and IEC 61000-6-4

1) Kohlin, Anton "CE Conformity Marking" ISBN 3-89578-037-5, ordering code: A19100-L531-B666

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

The most important IEC standard on measurement for immunity to interference and transient overvoltages is IEC 61000-4, which is divided into six parts:

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	3 V/m, 10 V/m, 30 V/m 80 to 2000 MHz	High-frequency interference fields

Conducted interference

Standard	Test characteristics	Phenomena
IEC 61000-4-4	5/50 ns pulse, up to 4 kV 2.5 or 5 kHz burst	Electrical fast transient / burst Cause: switching processes
IEC 61000-4-5	1.2/50 µs (open-circuit voltage) 8/20 µs (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 80 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, figure 2 the waveform of the discharge current with an extremely short rise time of 0.7 to 1.0 ns and amplitudes of up to 45 A.
Secondary effects caused by this edge steepness are high electrical and magnetic fields strengths.
In the ESD test, at least 10 test pulses are applied of the polarity to which the device under test is most sensitive.

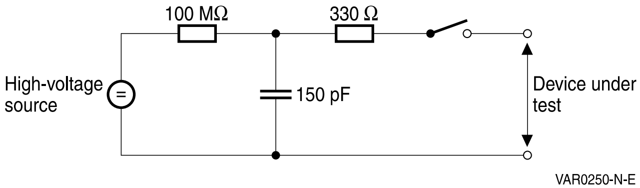


Figure 1
ESD discharge circuit to IEC 61000-4-2

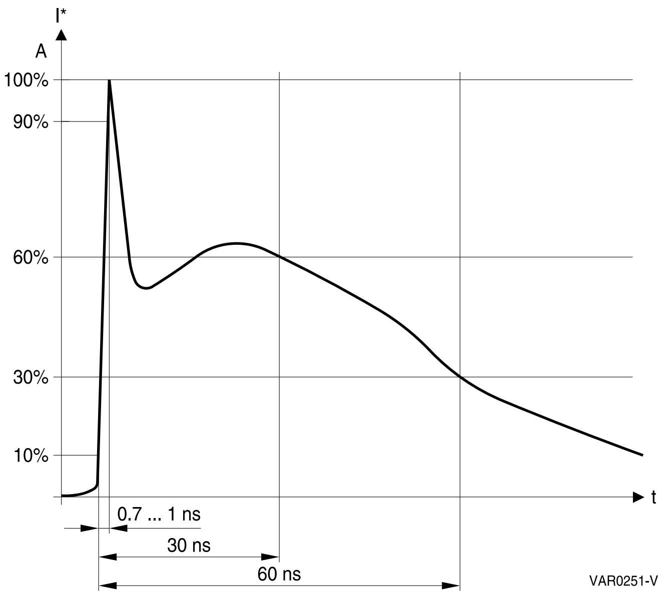


Figure 2
ESD discharge current to IEC 61000-4-2

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, 2 kV applied via 2 Ω) 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 transfered 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 the previous section)
- AEC-Q200 Rev.C
- ISO 10605 (2001)

1.3.1.1 AEC-Q200 Rev. C

Figure 3 shows the human body model, a capacitance and resistance model that characterizes a person as a source of electrostatic charging, for automotive conditions.

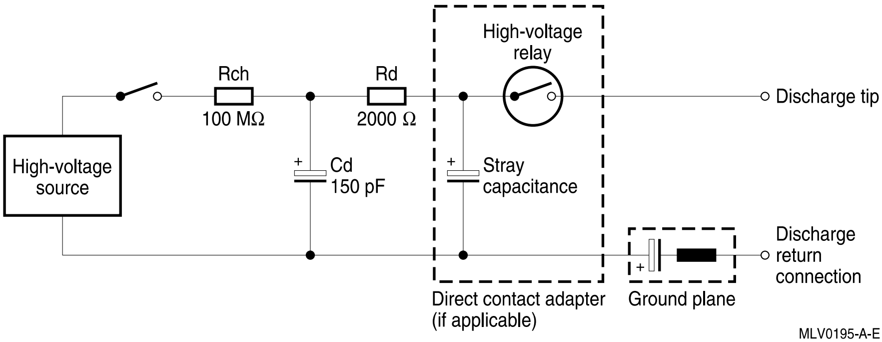


Figure 3
HBM ESD simulator circuit according to AEC-Q200 Rev. C

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

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

1.3.1.2 ISO 10605

ISO 10605 (2001) specifies test methods for electrical disturbance from ESD related to automotive electronics. The HBM circuitry is similar to that shown in the AEC-Q200-Rev. C but the capacitance is changed depending on whether or not the discharge occurs inside or outside the vehicle. This is shown in the table below.

	R in kΩ	C in pF	Probe at
Inside vehicle	2	330	4 kV, 8 kV and 15 kV
Outside vehicle	2	150	25 kV

HBM conditions to ISO 10605 (2001)

There are different levels for the vehicles

	Test levels for vehicles			
Test point accessible	I	II	III	IV
From inside vehicle	±4 kV	±8 kV	±14 kV	±15 kV
From outside vehicle	±4 kV	±4 kV	±15 kV	±25 kV

Test levels for vehicles to ISO 10605 (2001)

1.3.2 Automotive transients acc. to ISO 7637

Standard ISO 7637 (DIN 40839) details the EMC in automotive electrical systems, including test pulses 1a/1b, 2a/2b, 3a/3b, 4 and test pulses 5a/5b. The toughest test for transient suppression is pulse 5 (shown in figure 4), simulating 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.

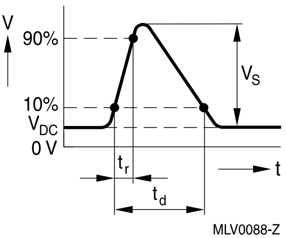


Figure 4
Test pulse 5a to ISO 7637 (unsuppressed)

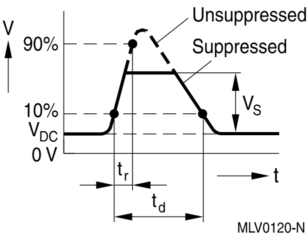


Figure 5
Test pulse 5b to ISO 7637 (suppressed)

Legend:

- Charge voltage (test level) V_S
- Rise time t_r
- Duration t_d

1.3.2.1 Tests

Maintenance of EMC requirements can be checked with conventional test generators. Figures 6 and 7 show block diagrams for load dump tests with operating voltage applied.

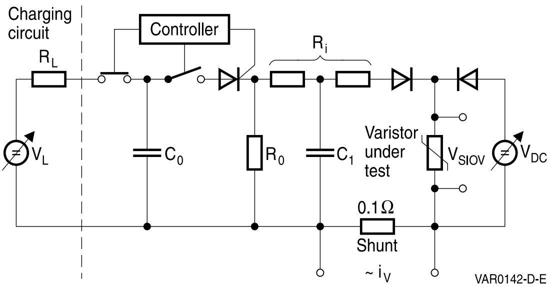
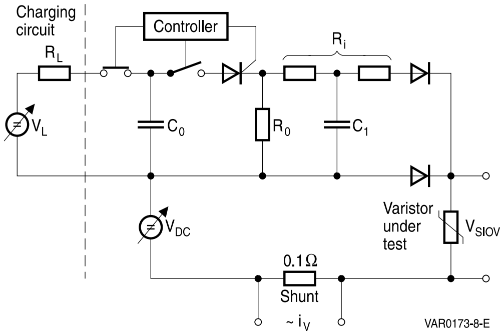


Figure 6
Principle of load dump generator with battery connected in parallel

Typical values

C_0	20 ... 35 mF
R_0	4 ... 10 Ω
C_1	0 ... 10 µF
R_i	0.5 ... 4 Ω
V_L	0 ... 200 V
V_{DC}	12 ... 28 V
t_d	100 ... 800 ms
v_{VAR}	Protection level of varistor
i_{VAR}	Current through varistor

The circuit in figure 7 produces test pulse 5 to ISO 7637 (DIN 40 839); 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 µF
R_i	0.5 ... 5 Ω
V_L	0 ... 200 V
V_{DC}	12 ... 28 V
t_d	40 ... 500 ms
v_{VAR}	Protection level of varistor
i_{VAR}	Current through varistor

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