Ceramic transient voltage suppressors, CTVS

Application notes

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1 Application notes

1.1 Areas of application for CTVS

A wide selection of types is available to cover very different requirements for protection level and load capability. Easy handling and an attractive price/performance ratio have made CTVS components from EPCOS successful in just about every area of electrical engineering and electronics as given in the table below:

Automotive electronics				
Data bus systems	**Infotainment**	**Safety**	**Body and comfort**	**Battery**
CAN bus, LIN, MOST	Mobile phone modules	Airbags	Air-conditioning	Load dump/ jump-start protection
Ethernet, FlexRay	Navigation	ABS/ ESP	Lighting (LED)	Battery control units
	Audio systems		Diagnostic systems	
			Electrical drives (e.g. wipers, windows)	

Communications			
Mobile applications	**Base stations**	**Interfaces**	**Reception tuners**
Smartphones, PDAs	Secondary surge protection	I/O and power keys	TV, radio, DAB, DVBT
Tablet PCs		Chargers, USB, HDMI	GPS, satellite radio

Industrial applications			
Lighting	**Building applications**	**Automation**	**Medical**
LED lighting	Smoke and fire detectors	Communication interfaces (e.g. USB 2.0, CAN bus, Ethernet)	Hearing aids
	Control and security systems	Serial bus interfaces (e.g. RS-232)	Blood glucose meter
		Human interfaces (e.g. buttons, touchpads, PS/2)	
		Power supply units	

2 Automotive applications

The automotive industry poses some of the toughest demands on electronic components: high operating temperature, high energy transients, fast data transmission, etc. To meet the higher requirements in automotive applications, EPCOS has created a special product series. These comply with RoHS and are qualified based on AEC-Q200, Rev. D.

The range of CTVS components suitable for automotive applications includes the product series multilayer varistors (MLV automotive E series) and leaded transient voltage/RFI suppressors (SHCV series). They meet the following requirements:

1) EIA case sizes: 0402 up to 2220
2) Operating voltage: 10 up to 40 V_{RMS}

Multilayer varistors (MLV automotive E series): components with AgNiSn terminals are tested based on AEC-Q200, Rev. D. Some types do not satisfy all AEC-Q200 requirements. A delta analysis is available on request.

Leaded transient voltage/RFI suppressors (SHCV series): components are qualified based on AEC-Q200, Rev. D. Not all specifications stated in AEC-Q200 are satisfied. A delta analysis is available on request.

Other products from the CTVS range are unsuitable for automotive, medical and other applications that require an extremely high level of operational safety, especially if malfunction or failure of a CTVS could present a danger to human life or health (e.g. in accident prevention, life-saving systems, or automotive battery line applications).

These products from the CTVS range however can be used in automotive applications such as in-car multimedia, entertainment, electronic comfort and convenience, although depending on the concrete purpose, the requirements on the components and the customer's specification.

In general, when CTVS components are used, it is essential to observe the component's specifications and the instructions for its processing, the important notes and the cautions and warnings.

Some of the applications, as well as product recommendation, are listed below.

2.1 ESD and high energy transient protection

In addition to ESD pulses, some automotive applications are exposed to higher energy transients such as load dump. These conditions, as well as other pulse loads, can be mastered reliably using the EPCOS automotive type varistors.

Features

- ESD protection according to ISO 10605/IEC 61000-4-2
- Load dump capability
- Jump-start capability
- Reliability based on AEC-Q200, Rev. D

Varistors for 12 V and 24 V applications

EPCOS offers a variety of CTVS for transient protection in engine management, injection control unit, cooling control unit, electro-hydraulic brake, ABS/ESP, airbag, sun roof, door module, telematic systems, lighting, climate control, tracking systems or car alarm systems both for 12 V and 24 V applications, with their maximum load dump absorption energy W_{LD} ranging from 1 J (case size 0805) up to 25 J (case size 2220). For further details refer to family data sheets for MLV automotive E series.

2.2 ESD protection and EMI filtering in data bus systems

The increased complexity in automotive electronics due to the ongoing integration of complex functional units for safety, comfort or engine applications needs to be served by providing data bus systems for high-speed data transfer between the control units at up to 100 Mbit/s. Currently, CAN and FlexRay are the primary high-speed bus systems employed for automotive networks. These need to be properly protected not only against damage due to ESD or high energy transient, but often also against signal disturbances due to high-frequency noise caused by electromagnetic interference (EMI).
By its MLV high-speed series and automotive E series, EPCOS offers both single chips (see figure 1) and arrays for data bus protection solutions. By means of EPCOS matched capacitance varistor array (MCVA) that comprises two varistor elements with controlled capacitance that are “matched” such that the relative deviation between the capacitances is less than 3% (see figure 2), it is possible besides general EMI filtering to additionally avoid crosstalk of high-frequency noise between the bus data lines (see figure 3).

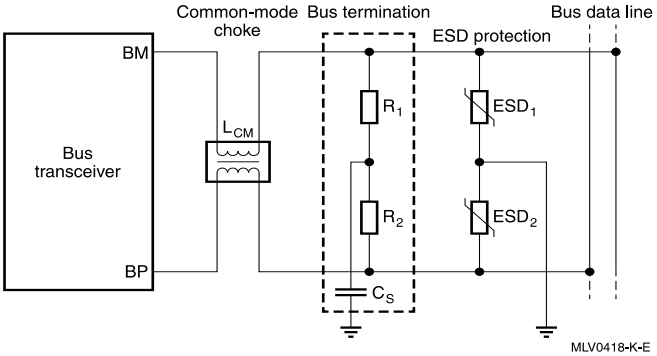

Figure 1

Typical protection circuit for high-speed CAN and FlexRay with discrete ESD solution using two discrete high-speed varistors.

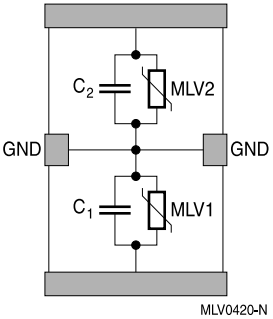

Figure 2
Equivalent electrical circuit of the matched capacitance varistor array (MCVA)

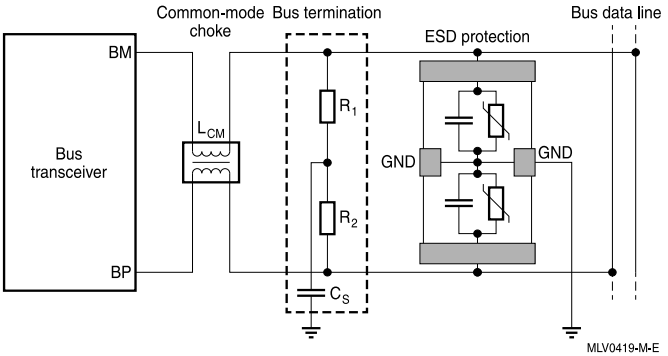

Figure 3
Typical protection circuit for high-speed CAN and FlexRay with integrated ESD solution using the matched capacitance varistor array (MCVA).

2.3 Overvoltage protection and RFI suppression for DC motors

Switching off inductive loads can lead to overvoltages that may become sources of line interference as well as of inductively and/or capacitively coupled interference. This kind of interference can be suppressed using varistors connected as a flywheel circuit. However, sometimes the capacitance of varistors alone is not enough for RFI suppression. For this reason EPCOS offers an SHCV series, which is specially well-suited for radio-frequency interference suppression.

These components are comprised of a multilayer varistor connected in parallel with a multilayer capacitor and offer transient protection and RFI suppression in one component.

Requirements on the protective device:

- ESD protection according to AEC-Q200 Rev. D, ISO 10605, IEC 61000-4-2
- High capacitance
- Load dump capability
- Jump-start capability

SHCV varistors

for noise suppression (RFI/EMI) and surge suppression on DC lines of small electromotors (e.g. windscreen wipers, power windows, mirror, central locking, memory seat, sun roof). For available types refer to the SHCV series.

3 Smartphones and wireless devices

Due to their small size and high robustness, multilayer varistors, ESD/EMI filters and CeraDiodes are already being used for ESD protection in a wide range of mobile phone applications (see figure 4). Some of the applications, requirements and recommended types are listed below.

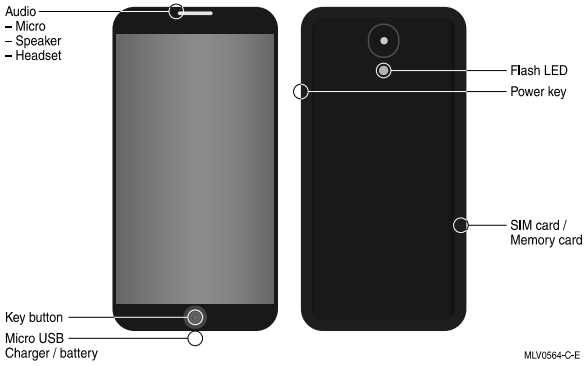

Figure 4
Typical applications for CTVS as protective devices in smartphones

3.1 ESD protection

ESD can occur when touching a smartphone. The unwanted pulse may damage the components inside and thus its function. Multilayer ESD protection devices are used to protect ESD-sensitive components preventing damage to the board and offer the following features:

- ESD protection to IEC 61000-4-2, level 4
- Ultra-low DC leakage current
- Low device capacitance
- Small package

3.2 Application examples

3.2.1 Side keys, touchscreen, on/off button

The most used interfaces in a mobile phone are side keys and touchscreen. When these are touched there is a high probability that ESD can enter the phone. This could then damage the electronic circuitry.

MLV low clamping voltage series offers high ESD protection performance in miniaturized EIA case size 0201 for all mobile devices.

3.2.2 Battery contact, charger, car kit

This low-voltage input is used to charge the battery and provide direct power to the circuits. This circuit could experience transients of ESD and such with even higher energy (lightning, system surges). The multilayer varistor is an optimal solution since it has surge protection capabilities beyond ESD protection.

For further details refer to the high-speed series.

3.2.3 Memory card, SIM card and USB port

The main characteristic of these interfaces are the high data rates. Thus a low capacitance is required for the protection components to avoid signal distortion.

The MLV low clamping voltage series provides low capacitance, low clamping voltage and a very short response time.

3.2.4 Audio interfaces (microphone, speaker, headset)

Most audio interfaces are sensitive to both ESD and EMI noise.

The headset of a mobile phone for example acts like a dipole antenna, emitting or picking up noise from radio-frequency carrier signals. As a consequence, voice and sound quality deteriorate and in the case of the GSM bands a clicking pulse of 217 Hz is audible to the user on the earphone. It is possible to minimize the audio quality degradation by implementing ESD/EMI filters as close as possible to the entry of the interference.
The integrated audio filter design offers substantially improved EMI noise attenuation of typically −60 dB at 900 MHz. The attenuation is higher than −25 dB for a wide frequency range covering the GSM frequency bands (850/900/1800/1900 MHz), the UMTS 2100 MHz bands and the GPRS/WLAN and Bluetooth frequency standards. Due to its ultra-low THD+N (total harmonic distortion + noise) value less than −100 dB at 1 kHz (acc. to AES 17) the audio filter provides high audio quality capabilities.
The audio filters of the ESD/ EMI filter series offer both ESD and EMI protection in one component (see figure 5).

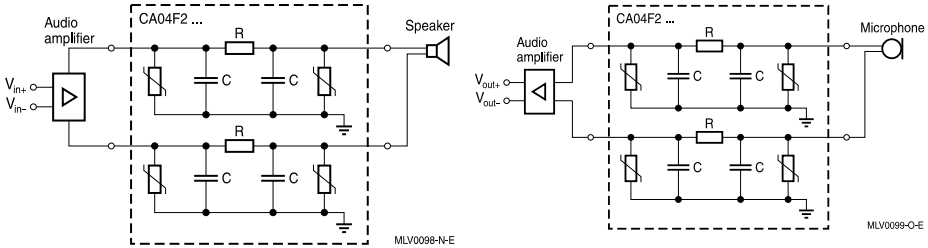

Figure 5
Schematics of audio circuits in differential lines with ESD/EMI filter protection

4 Overvoltage protection for LED applications

LED semiconductors are very susceptible to electrostatic discharge, especially during handling. Proper ESD protection is needed for all handling stages from the initial phase of production, the installation on site, during service or exchange. The driver circuit for lighting devices on LED basis requires ESD protection as well (see figure 6).

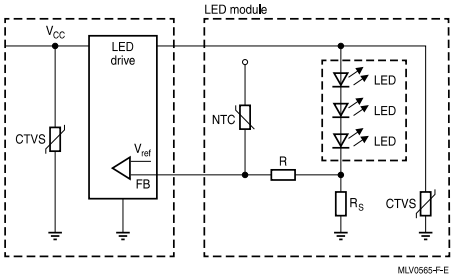

Figure 6
LED circuit with multilayer varistors and temperature control

EPCOS CeraDiodes of the LED series provide miniaturized protection devices for all LED applications and modules, with voltage rating from 4 V for single LEDs up to 200 V for serial LED strings. The designer can easily find an adequate and cost-effective CeraDiode for strings of up to 48 LEDs.

CeraDiodes of the LED series are designed for constant operation at high temperatures without any derating up to 125 °C. Thus they fulfill the temperature requirements for power LED engines. Beside electrostatic discharge during handling LED modules can be impaired and damaged by other electrical transients. Large LED strings in outdoor applications behave like an antenna for static charges while LED modules for automotive applications may have to withstand the automotive transients of ISO 7637-2 and ISO 16750-2 (see chapter "Protection standards"). For automotive application the multilayer varistors of the automotive E series can provide both ESD and transient protection for LED modules.

5 Consumer electronics and data processing

Electronic systems and circuits including integrated circuits (IC) are sensitive to overvoltage transients like ESD pulses. These can enter an electric device when touching the port or when removing the connector from the port. The ESD pulse travels through the connector into the PC board. Once it reaches the PCB, the pulse will propagate down the data lines and/or power lines to the components on it. Without sufficient protection the latter may become inoperable or even be destroyed. Due to their particular importance the ICs are of special concern to protect.

EPCOS offers a broad range of CeraDiodes especially designed for reliable ESD protection in consumer and EDP applications.

5.1 USB

The universal serial bus (USB) has become a standard interface in EDP. Due to the merger of EDP and entertainment electronics, the USB is appearing in more and more electronic devices. The USB is extremely sensitive to ESD. Data rates up to 480 Mbps require an extremely low line capacitance to avoid signal distortion. The USB uses two high-speed data lines.

EPCOS offers a broad spectrum of CeraDiodes as single or array packages to protect USB ports.

The CeraDiodes of the high-speed series passed the USB 2.0 compliance test.

Different scenarios for the use of CeraDiodes in a USB are illustrated below (see figures 7 and 8):

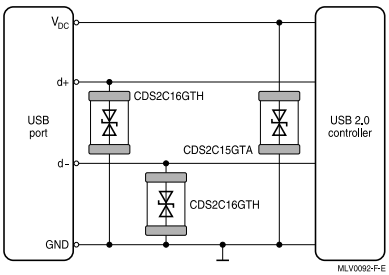

Figure 7
USB 2.0 line protection with single CeraDiodes

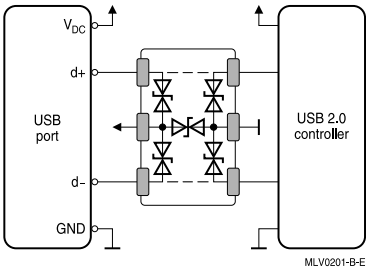

Figure 8
USB 2.0 line protection with special array CDA3C05GTH

EPCOS CeraDiodes CDA6C05GTH and CDA3C05GTH are recommended for protection of both data and supply lines of two USB 2.0 ports as shown in figure 9.

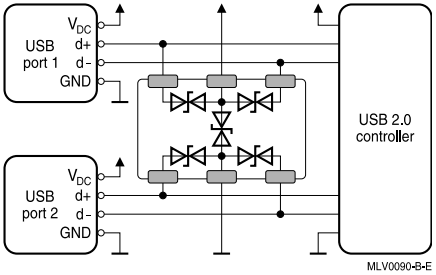

Figure 9:
High-speed arrays CDA6C05GTH and CDA3C05GTH protecting data and supply lines of two USB 2.0 ports

5.2 DVI and HDMI

With the advent of flat panel displays (LCD and plasma), DVI and HDMI have become established as the digital audio and video interfaces between computers and monitors (DVI) and between DVD players/recorders, set-top boxes, etc. and TV sets (HDMI). Their high-frequency operation requires a very low/ultra-low line capacitance to avoid signal distortion (see figures 10 and 11). For further details refer to the high-speed series.

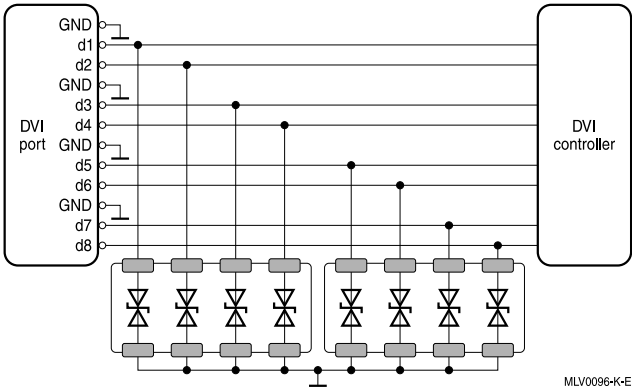

Figure 10
DVI line protection with two CeraDiode arrays

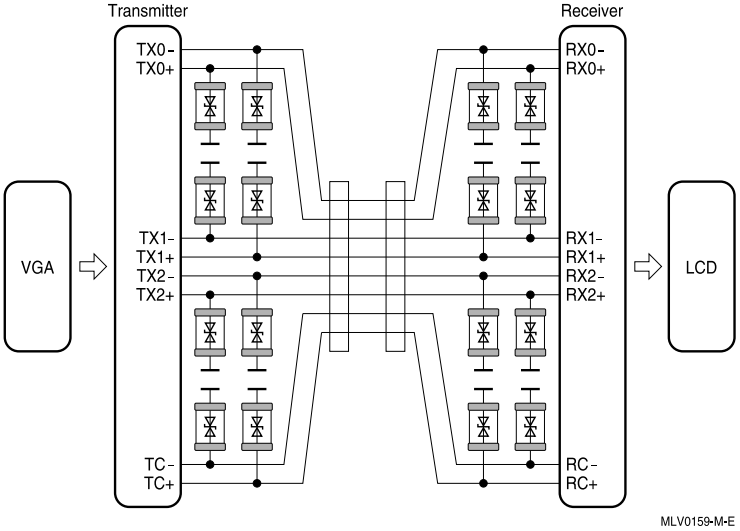

Figure 11
HDMI line protection with CDS2C05HDMI2 or CDS3C05HDMI1

HDMI 1.3a compliance test

The purpose of this test is to ensure that ESD protection components only minimally degrade the differential transmission signal so that it can be properly detected as such in the terminal after transmission. In the test the mask is moved to the left until it is violated, i.e. the signal touches the mask. Then the signal jitter is calculated. The HDMI 1.3a specification requires that the calculated data jitter be less than 0.3 x T_{BIT}. A data jitter of 0.05 x T_{BIT} was demonstrated in the test performed for the CeraDiode CDS2C05HDMI2 (see figure 12).

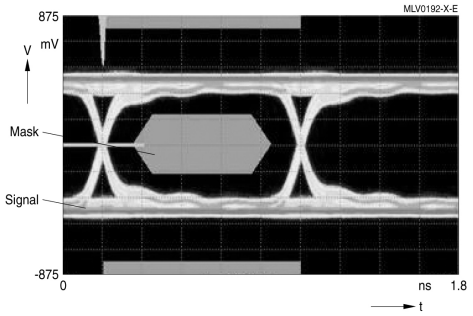

Figure 12
HDMI 1.3a compliance test result (eye diagram) of CDS2C05HDMI2

Differential transmission links used for high-speed data transfer are very sensitive in terms of impedance matching. If only a small parasitic capacitance (e.g. ESD protection component) is added to the line, the total impedance reduces. According to the HDMI Compliance Tests Specification (CTS) the HDMI receiver ports require a differential impedance of 100 Ω ±15%. Time domain reflectometry is used to measure the impedance. Figure 13 shows that the impedance (see the grey area, position of the ESD protection component on the board) is within the specified band.

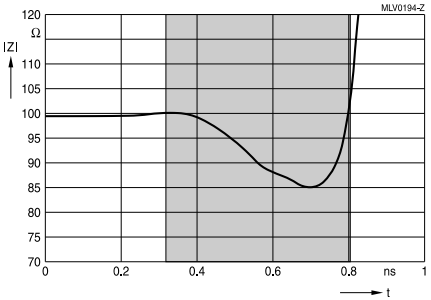

Figure 13
HDMI 1.3a compliance test result (impedance measurement) of example CDS2C05HDMI2

6 Industrial

Industrial electronics are sensitive to transients caused by both ESD and overvoltage. ESD can be caused by the human body (e.g. on operator terminals by keypads, I/O button) but also by the machine itself.
In addition to ESD, overvoltage transients with high energy respectively high surge currents can damage sensitive components or modules of industrial systems. In general it is recommended placing a CTVS as close as possible to the source of transients, e.g. on interfaces for ESD protection.

6.1 Protection against ESD on interfaces

ESD protection of interfaces in industrial applications is recommended. Typical industrial interfaces are:

- serial interfaces: COM, LPT, CCITT, RS-232
- serial buses: SSI, LVDS, ECL, CML, TMDS
- communication interfaces: USB 2.0, Ethernet, FireWire, CAN bus, RS-422, RS-423, RS-485
- communication on PCB level: I²C bus, SPI, 1-Wire bus
- communication inside device: S-ATA, serial attached SCSI (SAS), PCI
- distance communication: FireWire (i.LINK or IEEE 1394), USB, PS/2, CBM bus, DVI, HDMI
- robust bus systems: CAN, Profibus, DIN bus, MPI, BITBUS, LON, AS interface

The table below shows examples of typical industrial interfaces including a solution from our standard series and from our CeraDiode series for protection against ESD.

Interface	Solution
RS-232	CDS2C05GTA or CDS2C15GTA, case size 0402 CDS3C05GTA or CDS2C15GTA, case size 0603
PS/2	CDS2C05GTA or CDS2C15GTA, case size 0402 CDS3C05GTA or CDS2C15GTA, case size 0603
USB 2.0	CDS2C05HDMI2, case size 0402 CDS3C05HDMI, case size 0603 CDA5C16GHT, 4-fold array
Ethernet	CDS2C05HDMI2, case size 0402 CDS3C05HDMI, case size 0603 CDA5C16GHT, 4-fold array
CAN bus	CT0402S14AHSG, case size 0402 CT0603S14AHSG, case size 0603 CA05F2S10T100G, 2-fold array

6.2 Protection against overvoltage transients

Typical overvoltage transients in industrial applications are surge, burst, cable discharges and so-called electrical fast transients (EFT).

These transients are often caused by switching of inductive loads (e.g. emergency stop of a DC motor).

For protection against such high energy transients on PCB level, our surge protection series with EIA case sizes 0805 up to 2220 is recommended.