

ESD5V0S1U-02V

Tailored ESD protection for various electronic interfaces

-ESD protection requirements -
proper ESD protection approach -
design example

Application Note AN248

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1 Efficient and robust ESD protection becomes a MUST

More and more external electronic interfaces are being implemented in modern electronic devices. The interfaces are used for interaction between the machine and the user/operator or to provide connectivity to other electronic devices.

For all kind of external electronic interfaces used in consumer and in industrial application a robust system level ESD protection according IEC61000-4-2 becomes more and more mandatory. The external electrical interfaces can be easily affected by ESD strikes generated by the user or by other devices. These ESD hazards can cause fatal hardware errors, or soft errors. Soft errors are caused by fast ESD transients which are not damaging the hardware, but trigger the interface and corrupt the data integrity. The result can be a software system crash, with time consuming reboot, or a malfunction of the device only. In most times these soft errors are hard to detect, because the fast transients can influence the entire system.

The external electronic interfaces include different data lines and often a voltage supply line. In industrial electronics and even in consumer electronics the 5V interface working with a 5V or 3V logic is very popular. Especially for this application a 5V ESD protection would be tailored.

To achieve an effective system level ESD protection for electronic interface, the use of an appropriate ESD protection device and the correct location for the device is very important to shunt the ESD strike return to GND before the ESD strike enters the interface transceiver.

There is a huge variety of different external interfaces in consumer and industrial electronics. An appropriate separation of these different electronic interfaces can be done by the speed of the data communication. Depending on the transmitting data rate (data speed), the tailored ESD protection requires a low device capacitance (high speed communication), or can tolerate a higher device capacitance (low speed data communication). The device capacitance of the ESD protection structure affects the risetime and the fall time of the data signal and limits the bandwidth of the data channel. This can help to improve the EMI performance.

High speed data transmission can be HDMI, DVI, USB2.0/3.0 or systems providing a data rate >100Mbit/sec. Low speed systems works with <100Mbit/sec and even much lower (e.g. analogue and digital audio, control lines, keypad and mouse interface, VGA/RGB signals, PAL/NTSC FBAS signals and all kind of general data busses). Most of these interfaces are working with a positive signal voltage. The signal voltage swing toggles between 0V and a dedicated positive voltage level (figure 1). For a huge number of low speed application the Infineon ESD5V0S1U-02V fits perfect and serves a very high level of ESD protection at the electronic interface.

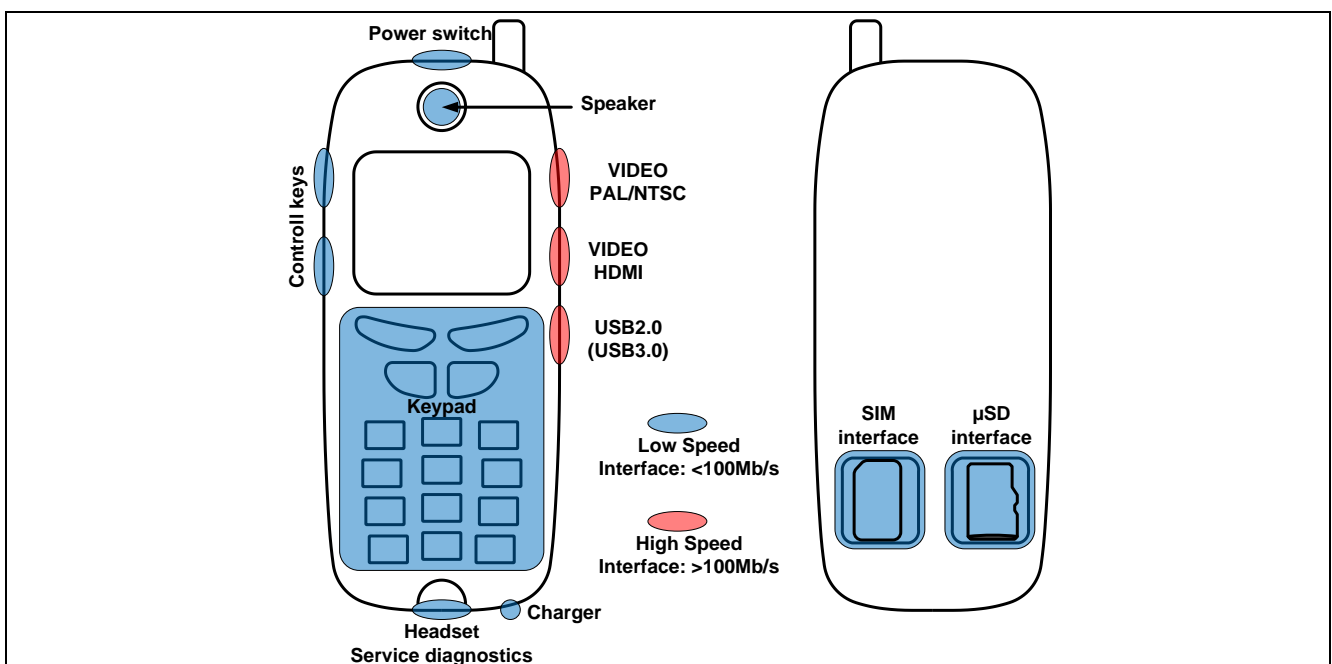


Figure 1 Example for high-speed and low-speed electronic interfaces, used in a mobile phone and often on a computer

ESD protection in 2 steps improves the ESD performance

The internal ESD protection structure of the interface circuits is designed to provide device level ESD protection, of minimum 2kV according e.g. HBM JEDEC JESD 22-A115. This is important for device handling during development, production and board assembly. The more stringent system level protection according IEC61000-4-2 is realized by an external ESD protection structure, tailored to the application. Therefore a reliable ESD protection is mandatory and should be taken into account from the very beginning of electronic device's design phase. ESD protection can be integrated inside the IC itself, or – much better - a smart ESD protection approach shares the ESD current between a tailored external ESD protection circuit and a small ESD protection in the IC. The internal ESD protection structure can be very small because it has to handle only weak ESD strikes, which may occur during manufacturing and board assembly (figure 2).

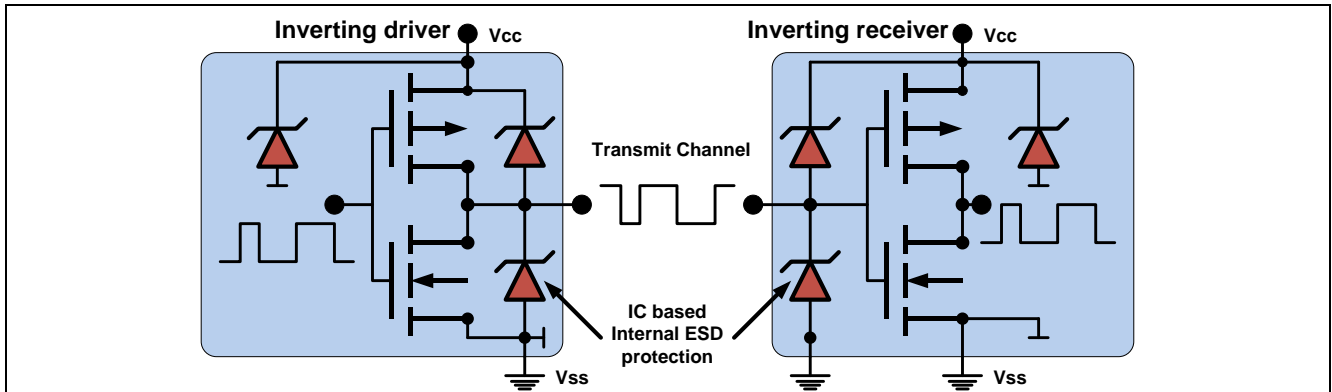


Figure 2 Simplified internal driver and receiver stage in CMOS interface devices

Moving forward in miniaturization of semiconductor structures, ESD handling capability of the miniaturized semiconductor structures is reduced accordingly. Moving according the semiconductor miniaturization trend, adequate ESD protection, which is implemented in the IC only, would require more and more expensive IC chip area. Even semiconductor miniaturization helps to shrink chip functionality, die size would not shrink accordingly, because of increasing demand of chip area for ESD protection.

While the 2-step ESD approach keeps the required ESD protection capability alive, it also keeps the required ESD structure on the die minimized. Furthermore the 2-step ESD approach enables the designer to pass high system level ESD requirements according IEC61000-4-2 (figure 3).

2 ESD protection in 2 steps improves the ESD performance

External connectivity of electronic devices is very susceptible to ESD strikes. The interface cables itself can trap the ESD strike, or the ESD strike enters the electronic device directly via the interface connector.

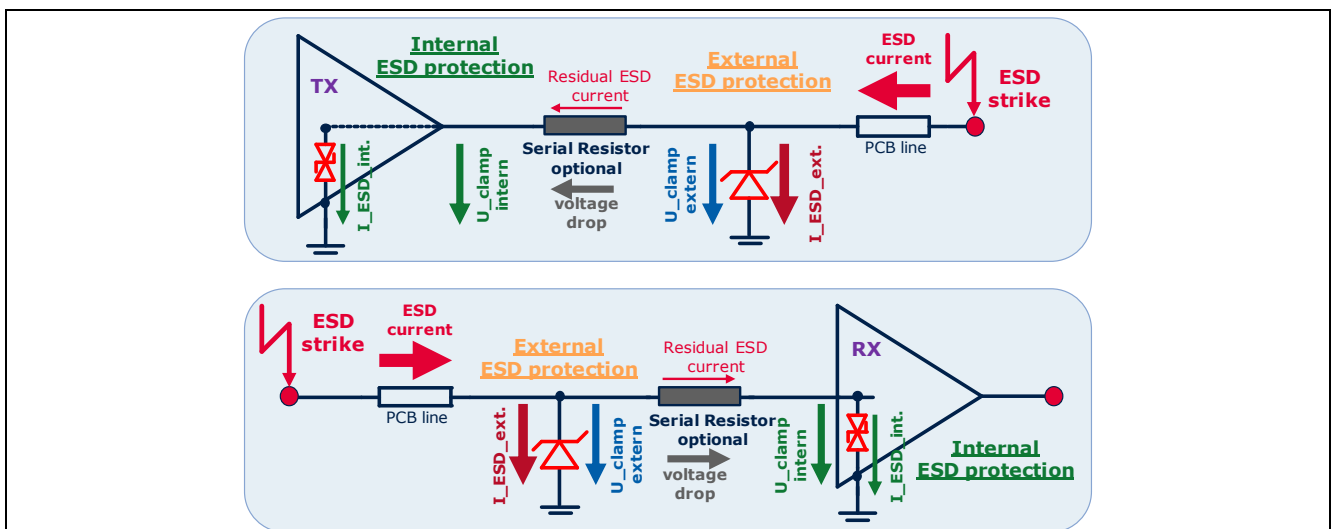


Figure 3 Proper 2-stage ESD protection, divided in external and internal protection

ESD protection in 2 steps improves the ESD performance

Most of these electronic interfaces are working with a positive signal voltage. The signal voltage swing is only between 0V and a dedicated positive voltage level. Therefore a so called “uni-directional” TVS diode for ESD protection fits very well here.

Following requirements have to be fulfilled by a proper ESD protection diode.

- For all (wanted) signals having a **positive voltage swing only**, the so called “uni-directional” TVS diode clamping characteristic fits very well here. The maximum voltage swing of the wanted signal must not exceed the maximum working voltage (V_{rwm}) of the TVS diode (figure 4).
 For all (wanted) signals having a **positive AND a negative voltage swing**, the so called “bi-directional” TVS diode clamping characteristic for the TVS diode is mandatory. These wanted signals can be analogue signals (audio signals) and special digital signals (figure 5).
 The maximum voltage swing (V_{rwm}) of the wanted signal is defined: $-V_{rwm} \dots 0V \dots V_{rwm}$.
- Lowest dynamical resistance R_{dyn} to grant best protection for the audio driver IC.
 R_{dyn} is characterised by Transmission Line Pulse (TLP) measurement.
- Very fast switch-on time to shunt the initial ESD peak of a strike according IEC61000-4-2.
- No performance degradation over a huge number of ESD zaps (>1000)
- Small size to place it where ever required.
- TVS diode capacitance has to fit to the signal speed of the application, to avoid signal distortion and Signal Integrity violation.

Infineon ESD5V0S1U-02V fits perfect for a lot of low speed applications, keeping away the ESD stress very effective from the devices which has to be ESD protected.

2.1 Uni-directional TVS diode vs. Bi-directional TVS diode

Uni-directional TVS diode:

A **uni-directional** TVS diode is designed for a wanted signal between $\sim 0V$ and “maximum working voltage” at electronic interface. The ESD protection capability is granted for a **uni-directional** diode for positive **AND** negative ESD strikes in the same way.

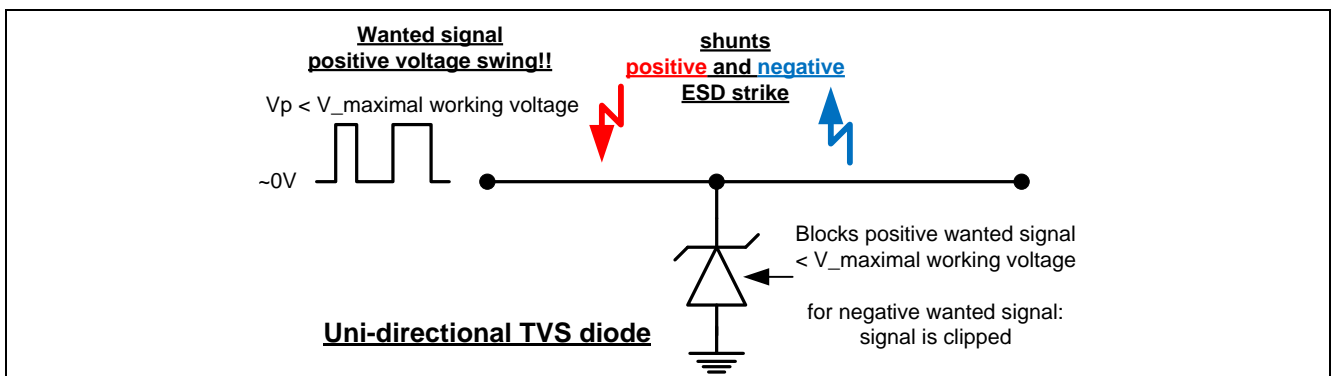


Figure 4 Application for a uni-directional TVS diode at electronic interface

Design example for a 2-step ESD protection approach

Bi-directional TVS diode:

A **bi-directional TVS diode** is designed for a wanted signal between “**negative** maximum working voltage” and “**positive** maximum working voltage” at electronic interface. The ESD protection capability is granted for a **bi-directional** diode for positive **AND** negative ESD strikes in the same way.

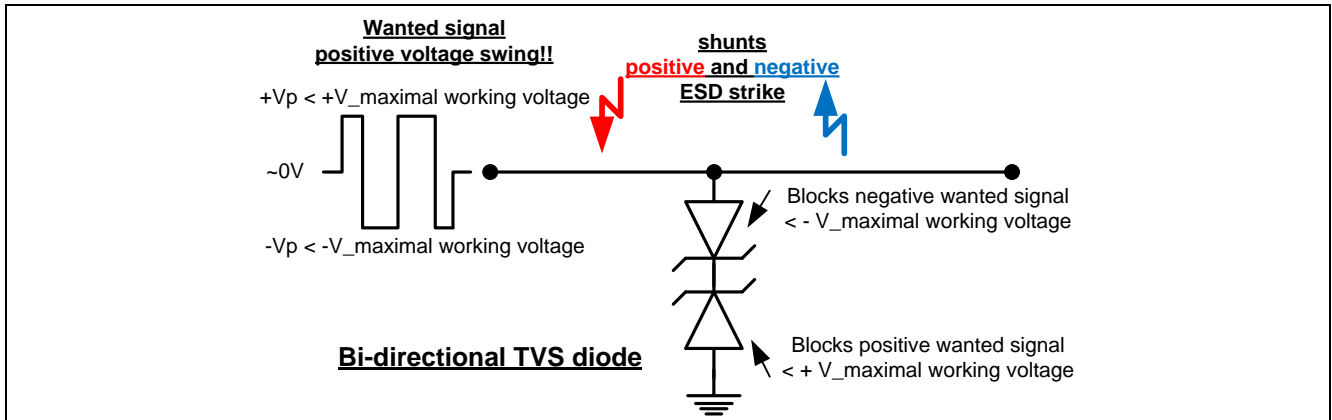


Figure 5 Application for a bi-directional TVS diode at electronic interface

3 Design example for a 2-step ESD protection approach

Required characteristic for the second (external) ESD protection to achieve 8kV system level ESD robustness according to IEC61000-4-2.

Comment: 8kV IEC61000-4-2 ESD handling correlates with 16A ESD current measured @ 30nsec (referring to Fig.4). 15kV IEC61000-4-2 ESD handling correlates with 30A (figure 6).

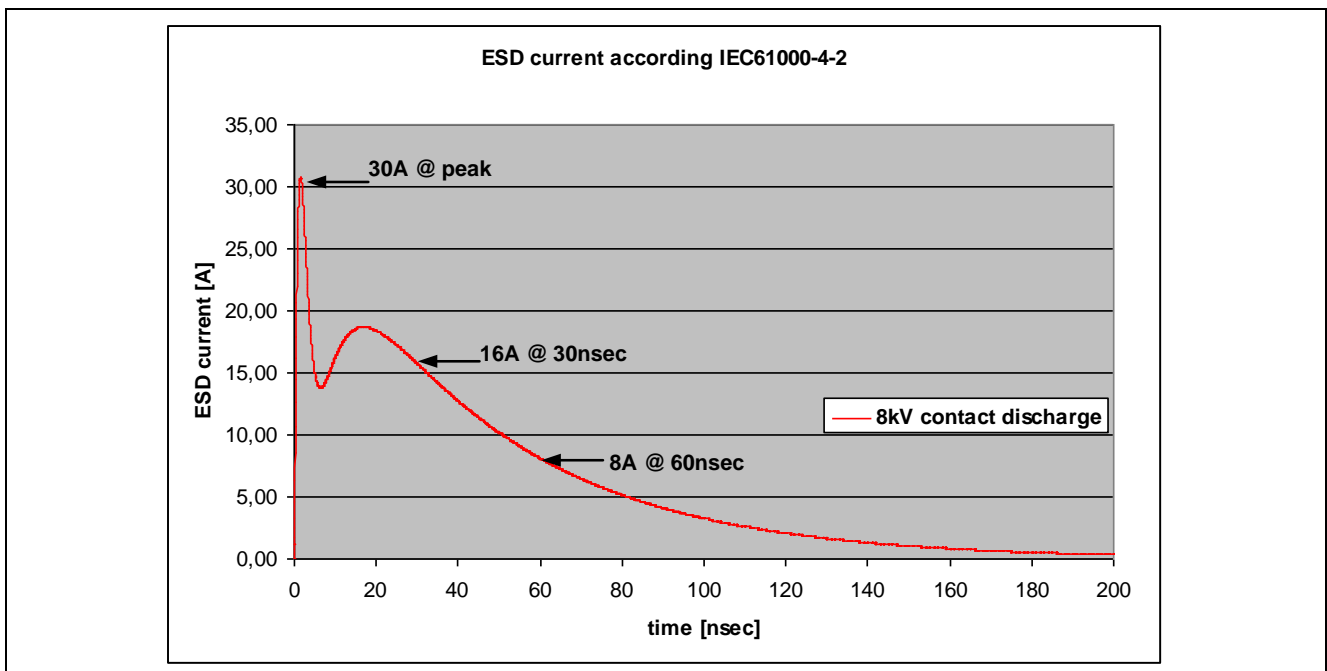


Figure 6 ESD current according IEC61000-4-2 for a 8kV contact discharge

Characteristic of the internal (designed in the IC) ESD protection structure.

Internal ESD protection limits (assumption):

$I_{ESD_int} : 3A @ U_{clamp_int} : 10.5V$

External ESD protection has to fit with following requirement:

$I_{ESD_ext} = 16A - I_{ESD_int} = 16A - 3A = 13A$

$I_{ESD_ext} : 13A @ U_{clamp_ext} : 10.5V$ (referring to figure 7)

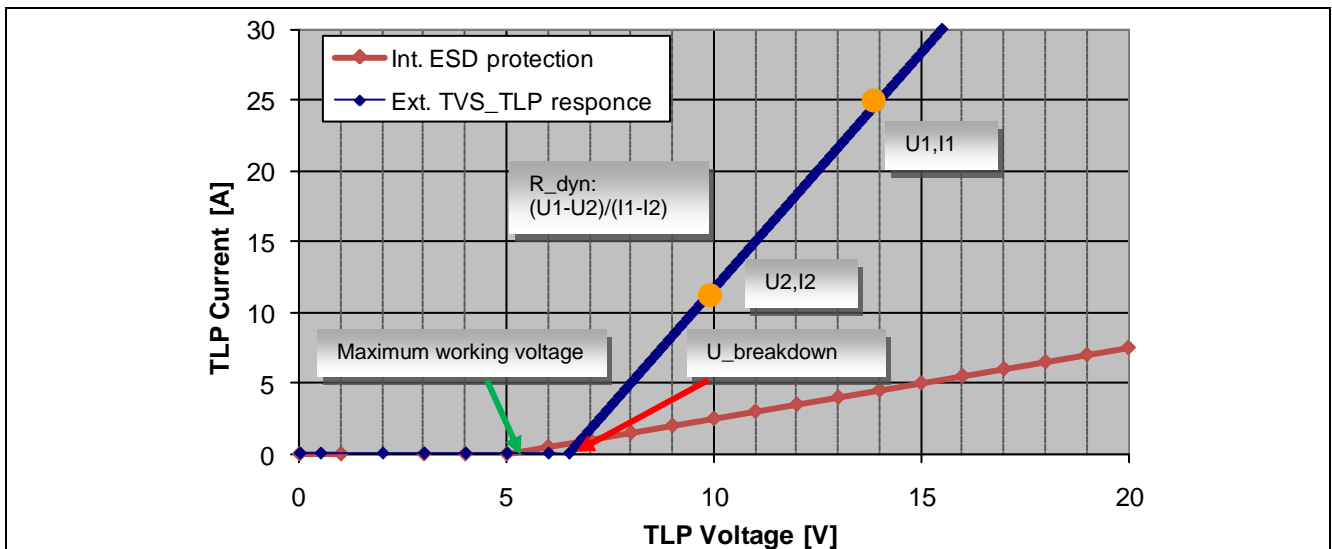


Figure 7 TLP characteristic of an typical internal ESD protection and the ESD5V0S1U-02Vv for external ESD protection

Calculating external ESD protection ($U_{breakdown_external}$, R_{dyn_ext})

$$U_{clamp_ext} = U_{breakdown_ext} + (I_{ESD_ext} * R_{dyn_ext})$$

$$\Rightarrow U_{breakdown_ext} = U_{clamp_ext} - (I_{ESD_ext} * R_{dyn_ext})$$

$$\Rightarrow R_{dyn_ext} = (U_{clamp_ext} - U_{breakdown_ext}) / I_{ESD_ext}$$

Assuming an $U_{breakdown_ext}$ of 6.5V the required R_{dyn_ext} would be 0.3 Ohm, which is really low. The ESD5V0S1U-02V provides an R_{dyn} of 0.27 Ohm (270 mOhm !!!) typical.

According to these calculations, the significance of a low dynamic resistance (R_{dyn}) and a correct $U_{breakdown}$ for the external ESD protection device is evident.

To increase the system level ESD performance of the entire system from 8kV contact discharge to 15kV contact discharge, a serial resistor is placed between the external and the internal ESD protection can help (figure 3).

Bases on the conditions mentioned above, the appropriate serial resistor can be estimated:

15kV IEC61000-4-2 ESD handling correlates with 30A ESD current measured @ 30nsec (figure 6).

Internal ESD protection limits (assumption): $I_{ESD_int} 3A @ U_{clamp_int} : 10.5V$

External ESD protection characteristic:

$I_{ESD_ext} = 30A - I_{ESD_int} = 30A - 3A = 27A$

$I_{ESD_ext} : 27A @ U_{clamp_ext} : 15V$ (referring to Fig. 5)

$$\Rightarrow \text{Voltage drop @ } R_{serial} = (15V-10.5V) / 3A = 4.5V / 3A = 1.5 \text{ Ohm}$$

\Rightarrow To cover the peak voltage current of ~60A, a 4.7 Ohm serial resistor is recommended.

This extreme low R_{dyn} and the tailored $U_{breakdown}$ can only be provided by TVS diodes based on silicon. Metal-Oxide Varistors (MOV) or Multilayer Varistors (MLV) in the same component size and capacitance class shows often a 10 times higher (R_{dyn}). Therefore such a low loss ESD protection structure for the audio section is never possible on basis of MOVs or MLVs.

4 Conclusion

Infineon is designing and is producing tailored TVS diodes for high level ESD protection on various external electronic interfaces. For a lot of applications below 100Mbit/s like audio- or other AF analogue and digital signal lines, suitable uni-directional and bi-directional TVS diodes are available.

The latest TVS component family shows an R_{dyn} of 0.3 Ohm for the **uni**-directional TVS diode version (ESD5V0S1U-02V in SC79 package). Diode capacitance is 35pF typical at 0V bias. The SC79 package with the size of 1.6mm*0.8mm*0.55mm provides bend shaped soldering tags to enable an easy solder process control. The possibility for solder process control is often very welcome for industry applications.

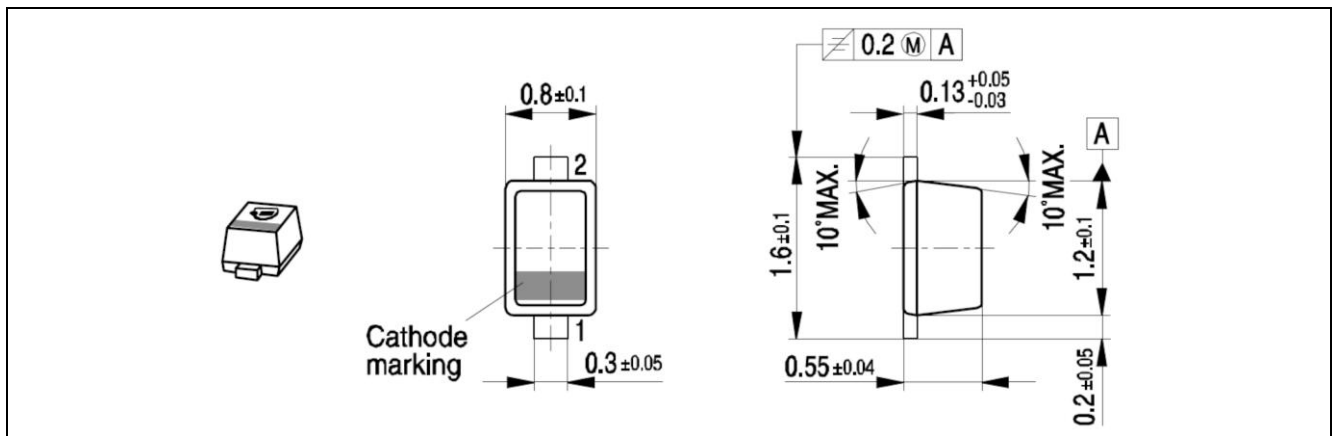


Figure 8 ESD5V0S1U_02V in SC79 package

5 Author

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