ESD5V3S1B-02LRH/02LS
ESD5V3S1U-02LRH/02LS

Efficient and cost effective ESD protection for electronic interfaces

ESD protection for Audio systems and for general interfaces

Application Note AN192
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1 Tailored ESD protection for various electronic interfaces using the Infineon TVS diode ESD5v3s1b or ESD5v3s1u

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. These electronic interfaces can be realized by a connector providing a variety of external electrical interface lines or by a human-machine interface (e.g. keypad, display). For all external electronic interfaces electrostatic discharge (ESD) is a common risk. Uncontrolled ESD strikes can hit the interface connectors directly or the internal electronic circuits via the human interface (keypad, touch screen, LC-display).

The effect of these ESD strike can be permanent performance degradation or even a destruction of the interface circuit, resulting in a failure of the entire electronic device. 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 (referring to Fig.1).

![Figure 1 Smart 2-step ESD approach based on external and internal ESD protection structure](image)

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-steps 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.

Various applications demand different ESD protection devices. The right TVS diode has to be used.

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

**Uni-directional TVS diode – ESD5v3s1u:**

A uni-directional TVS diode is designed for a wanted signal between ~0V and “maximum working voltage”. The ESD protection capability is granted for a uni-directional diode for positive AND negative ESD strikes in the same way. Most standard data signalling, Vcc supply, are unidirectional signals.

**Bi-directional TVS diode – ESD5V3s1b:**

A bi-directional TVS diode is designed for a wanted signal between “negative” maximum working voltage” and “positive” maximum working voltage”. The ESD protection capability is granted for a bi-directional diode for positive AND negative ESD strikes in the same way. Use a bidirectional TVS diode for audio signals.
2 Design example for a 2-step ESD protection approach used in the audio system of a mobile phone

External connectivity of a mobile phone is very susceptible to ESD strikes. The audio headset itself can trap the ESD strike, or the ESD strike enters the phone directly via the audio jack. For low impedance audio headset, the ear-pieces are one of the most challenging for ESD protection. On one hand power loss and audio distortion caused by the ESD protection method has to be minimized, on the other hand ESD protection has to work safely over a long life-time and over a lot of powerful ESD strikes (referring to Fig.2).

![Diagram of ESD protection in audio system](image)

**Figure 2** Typical ear-stick driver stage in the audio system

An ESD protection device, tailored for audio signals and other AF analogue and digital signals, has to fulfill the following requirements:

- For all (wanted) signals having a positive AND a negative voltage swing, dual clamping characteristic for the TVS diode is mandatory. These wanted signals are analoge signals (audio signals) and special digital signals.
  The maximum voltage swing ($V_{rwm}$) of the wanted signal is defined: $-V_{rwm} \ldots 0V \ldots V_{rwm}$.
  For the audio speaker and for the ear-peace the dual clamping TVS diodes (bi-directional diode) is the right one (e.g. Infineon ESD5v3s1b-02lrh).
- $U_{breakdown}$ 5V...10V to avoid clipping of the AF / Audio signal and distortion caused by Audio-signal vs. RF-EMI intermodulation.
- 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.
- Low interaction between audio signal and RF EMI picked up by the headset cable.
- No performance degradation over a huge number of ESD zaps (>1000)
- Small size to place it where ever required.

Based on this requirement, best ESD protection capability for audio system can be achieved only with silicon based TVS diode.
3 Configuration of the 2-step ESD protection approach under real world conditions for the mobile phone audio system

![Diagram of ESD protection](image)

**Figure 3** Internal and external ESD current distribution and correlating clamping voltage

Calculation of the 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).

![ESD current IEC61000-4-2](image)

**Figure 4** 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:

\[ I_{\text{ESD\_int}} = 5A \quad @ \quad U_{\text{clamp\_int}} = 13V \]

**External ESD protection has to fit with following requirement:**

\[ I_{\text{ESD\_ext}} = 16A - I_{\text{ESD\_int}} = 16A - 5A = 11A \]

\[ I_{\text{ESD\_ext}} = 11A \quad @ \quad U_{\text{clamp\_ext}} = 13V \] (referring to Fig.5)
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Calculating external ESD protection ($U_{\text{breakdown external}}, R_{\text{dyn ext}}$)

$$U_{\text{clamp ext}} = U_{\text{breakdown ext}} + (I_{\text{ESD ext}} \times R_{\text{dyn ext}})$$

$$=> U_{\text{breakdown ext}} = U_{\text{clamp ext}} - (I_{\text{ESD ext}} \times R_{\text{dyn ext}})$$

$$=> R_{\text{dyn ext}} = \frac{(U_{\text{clamp ext}} - U_{\text{breakdown ext}})}{I_{\text{ESD ext}}}$$

Assuming an $U_{\text{breakdown ext}}$ of 7.5V the required $R_{\text{dyn ext}}$ would be 0.5 Ohm, which is really low.

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

This extreme low $R_{\text{dyn}}$ and the tailored $U_{\text{breakdown}}$ 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 ($R_{\text{dyn}}$). Therefore such a low loss ESD protection structure for the audio section is never possible on basis of MOVs or MLVs.

Infineon is designing and is producing tailored TVS diodes for high level ESD protection on external electronic interfaces. For ESD protection of audio- or other AF analogue and digital signal lines, suitable uni-directional and bi-directional TVS diodes are available.

4 Conclusion

The latest TVS component family in size 0402 (TSLP-2-17) shows an $R_{\text{dyn}}$ of 0.4 Ohm for the bidirectional TVS diode ESD5v3s1b-02lrh and even 0.3 Ohm for the unidirectional ESD5v3s1u-02lrh.

For further miniaturization in ESD protection on audio system, diodes of the same family are finalizes currently yet in TSSLP-2-1 package correlating to SMD size 0201.

For applications working with a positive voltage swing only the uni-directional ESD5v3s1u_02ls fits perfect. For application providing a positive and a negative voltage swing the bi-directional ESD5v3s1b-02ls is the right one. The ESD5v3s1b_02ls is tailored to work in challenging applications like audio speaker or ear-stick circuits in mobile phone or other portable gadgets. The dynamic resistance $R_{\text{dyn}}$ of the ESD5v3s1b_02ls is about 0.5 Ohm.

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