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🌟 New application in this guide
⭐ New TVS Diode in Production
Glossary of Essential Parameters

- $R_{\text{DYN}}$ is the dynamic resistance of the diode, which is calculated according to the procedure described in Infineon AN210.

- $V_{\text{BR}}$ is the break down voltage defined at $I_R = -1\, \text{mA}$.

- $V_{\text{RWM}}$ is the maximum reverse working voltage of the diode.

- $V_{\text{ESD}}$ is the maximum ESD rating of the TVS diode as specified for contact ESD in IEC61000-4-2.

- $V_{\text{CL}}$ is the clamping voltage of the diode. In this guide it is specified at a TLP current of 16A, which is equivalent to nearly 8kV IEC61000-4-2. For clamping voltage values at other ESD levels please refer to product data sheets under www.infineon.com/tvstdiodes.

- $C_L$ is the parasitic capacitance of the diode at 1MHz and 0V bias.

- $I_R$ is the reverse current of the diode specified at a given reverse voltage, $V_R$. Unless otherwise specified, $I_R$ values are shown in this guide at $V_R = V_{\text{RWM}}$. 
## Essential Parameters Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{DYN}$</td>
<td>Dynamic Resistance</td>
</tr>
<tr>
<td>$V_{BR}$</td>
<td>Breakdown Voltage @ $I_R = 1\text{mA}$</td>
</tr>
<tr>
<td>$V_{RWM}$</td>
<td>Reverse Max Working Voltage</td>
</tr>
<tr>
<td>$V_{ESD}$</td>
<td>Destruction Voltage</td>
</tr>
<tr>
<td>$V_{CL}$</td>
<td>Clamping Voltage</td>
</tr>
<tr>
<td>$C_L$</td>
<td>Diode Capacitance</td>
</tr>
</tbody>
</table>

- $R_{DYN}$: Dynamic Resistance
- $V_{BR}$: Breakdown Voltage @ $I_R = 1\text{mA}$
- $V_{RWM}$: Reverse Max Working Voltage
- $V_{ESD}$: Destruction Voltage
- $V_{CL}$: Clamping Voltage
- $C_L$: Diode Capacitance

![Graph](image_url)
Human Interface Devices (HID)
Keyboard, Keypad, Touchpad, Buttons

**Application Requirements**

- Robust ESD protection is required for keyboards, keypads, buttons, and other human interface devices because they are heavily exposed to ESD generated by consumers during routine use.
- ESD can be also self-generated by the equipment if it has moving parts or carries certain materials e.g. printers and copy machines with sliding parts carrying paper sheets.
- In the case of battery-powered equipment, ESD diodes with very low leakage current are required to extend battery life.

**WARNING**

Buttons tend to build up electrostatic charge from repeated use and act as entry points for ESD strikes!
INFINEON ESD Protection Solution

- The ESD5V3L1B offers very robust ESD absorption capability, exceeding the IEC61000-4-2 industry standard, and helps to increase system level reliability of modern electronic devices.
- Due to their very low dynamic resistance, these diodes quickly clamp ESD strikes at very low voltages. After every ESD strike, the diodes recover very fast without any sign of degradation.
- They have very low leakage current for supporting longer battery duration in portable equipment.
- These diodes are available in leadless packages with sizes down to 0.6 x 0.4 mm for maximum protection in the smallest area.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Packages</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DY}$</th>
<th>$V_{CL}$</th>
<th>$I_{R_{max}}$</th>
<th>$C_{L}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD5V3L1B-02LS</td>
<td>1-Line TSSLP-2 0201 size 0.6x0.3x0.31mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>17V</td>
<td>100nA</td>
<td>4pF&lt;sub&gt;min&lt;/sub&gt;</td>
</tr>
<tr>
<td>ESD5V3L1B-02LRH</td>
<td>1-Line TSLP-2 0402 size 1x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>17V</td>
<td>100nA</td>
<td>4pF&lt;sub&gt;min&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Want to know more? → read AN277
**WARNING**
The earpiece of modern low impedance headsets can easily trap and divert ESD into the internal IC/ASIC!

---

**Application Requirements**

- An Audio CODEC is frequently more susceptible to ESD than many other ICs because it interfaces directly with external connectors, such as headset jacks, where ESD discharges can enter.
- For maximum protection, these highly susceptible audio systems require protection devices with extremely low dynamic resistance and low clamping voltages.
- Since audio signals are low frequency analog signals, usually less than 30kHz, diode capacitance is usually a “don’t care”.
- Bidirectional diodes are normally compulsory to accommodate audio signals. Unidirectional devices can be used only in interfaces where there is no negative voltage swing.
INFINEON ESD Protection Solution

- The ESD3V3S1B and ESD5V3L1B ESD diodes are designed to quickly clamp multiple ESD strikes to a very low and stable voltage, recovering fast to normal state and without any degradation.
- All protection diodes in the table below are suited for implementation in applications with signals having voltage ranges up to ±5.3V or ±3.3V making them appropriate for most audio signals.
- Their very low leakage currents (I_R) support stringent power saving requirements in battery-powered equipment.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>V_RWM</th>
<th>V_ESD</th>
<th>R_DYN</th>
<th>V_CL</th>
<th>I_R_max</th>
<th>C_L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD3V3S1B-02LS</td>
<td>1-Line 0201 size</td>
<td>±3.3V</td>
<td>±30kV</td>
<td>0.13Ω</td>
<td>± 9V</td>
<td>50nA</td>
<td>14pF_{typ}</td>
</tr>
<tr>
<td>ESD5V3L1B-02LS</td>
<td>TSSLP-2 0.6x0.3x0.31mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>±17V</td>
<td>100nA</td>
<td>4pF_{min}</td>
</tr>
<tr>
<td>ESD3V3S1B-02LRH</td>
<td>1-Line 0402 size</td>
<td>±3.3V</td>
<td>±30kV</td>
<td>0.13Ω</td>
<td>±9V</td>
<td>50nA</td>
<td>14pF_{typ}</td>
</tr>
<tr>
<td>ESD5V3L1B-02LRH</td>
<td>TSLP-2 1x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>±17V</td>
<td>100A</td>
<td>4pF_{min}</td>
</tr>
</tbody>
</table>

Want to know more? → read AN277
WARNING
Connectors not only allow the free flow of data between two systems...but also ESD strikes!

Application Requirements
- USB ports are very susceptible to over-voltage transients like ESD discharges and Cable Discharge Events (CDE).
- Transients can propagate through the connector down to the data lines and end up in the heart of the IC/ASIC. To avoid damage, robust protection is required on data lines D+, D- and on the $V_{cc}$ power-line.
- For high-speed USB2.0, the signal voltage on the D+, D- lines vary between -0.5V...+0.5V. For USB Full and Low Speed and for $V_{cc}$ the TVS diode has to handle 5V.
- The data Rate of high-speed USB2.0 is 480Mbps. Capacitive loading from discrete components needs to be minimized for optimal signal integrity.
High Speed Interfaces (cont.)
USB2.0 Single Port (USB2.0, Micro USB..)

INFINEON ESD Protection Solution

- Ultralow capacitance ESD diodes to ensure the highest signal integrity in high-speed data paths.
- High level protection against ESD and Cable Discharge Events increases system level reliability.
- For 1-line protection choose ESD diodes in miniature TSSLP-2 and TSLP-2 packages. For 2-line protection choose from the TSLP-2 leadless or the leaded TSFP-3 packages. These parts have identical electrical performance across all package types. For $V_{CC}$ protection Infineon recommends its general purpose diode series.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_{R_{max}}$</th>
<th>$C_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single line diode options for one I/O line protection</strong> (leadless)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD5V3U1U-02LS</td>
<td>0201 size TSSLP-2 0.6x0.3x0.31mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$<em>{typ}$ 0.6pF$</em>{max}$</td>
</tr>
<tr>
<td>ESD5V3U1U-02LRH</td>
<td>0402 size TSLP-2 1.0x0.6x0.39mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$<em>{typ}$ 0.6pF$</em>{max}$</td>
</tr>
<tr>
<td><strong>Dual line diode options for two I/O lines protection</strong> (leadless or leaded)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD5V3U2U-03LRH</td>
<td>0402 size TSLP-3 1x0.6x0.39mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$<em>{typ}$ 0.6pF$</em>{max}$</td>
</tr>
<tr>
<td>ESD5V3U2U-03F</td>
<td>TSFP-3 leaded 1.2x1.2x.0.55mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$<em>{typ}$ 0.6pF$</em>{max}$</td>
</tr>
</tbody>
</table>

Click [HERE](http://www.infineon.com) to see protection recommendations for the $V_{CC}$ line

Want to know more? → read AN140
High Speed Interfaces
USB2.0 Dual Ports

Application Requirements

- Most modern laptops implement two or more USB2.0 ports very close to one another.
- Identical ESD requirements as for single USB2.0 ports apply (see previous pages).
- Protection is required on all data lines D1+, D1-, D2+, D2- and Vcc.
- Array devices for multi-line protection are preferred in space-constrained applications.

WARNING
Every time the device is connected or disconnected, the circuit receives a current or voltage transient!
### INFINEON ESD Protection Solution

- ESD5V5ULC is a best-in-class solution providing high ESD and surge immunity protection exceeding industry’s standards.
- Very low capacitance ($C_L$) and market-leading capacitance matching ($\Delta C_L$) ensure best compliance with signal integrity requirements without sacrificing protection performance.
- Infineon’s proposal is a cost-effective single-chip solution with complete system protection: It simultaneously provides protection on all vulnerable interface lines ($D1^+$, $D1^-$, $D2^+$, $D2^-$ and $V_{CC}$) in a single protection array.

#### Part Table

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>EFT</th>
<th>Surge</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_{R\max}$</th>
<th>$C_L$ typ I/O-GND I/O-I/O</th>
<th>$\Delta C_L$ typ I/O-GND I/O-I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD5V5U5ULC</td>
<td>4-Line + $V_{CC}$ SC74 2.9x2.5x0.55mm</td>
<td>5.5V</td>
<td>±25kV</td>
<td>50A</td>
<td>6A</td>
<td>0.3Ω</td>
<td>11.5V</td>
<td>100nA</td>
<td>0.45pF 0.23pF</td>
<td>0.02pF 0.01pF</td>
</tr>
</tbody>
</table>

Multilinie Array for 4 I/O lines + $V_{CC}$ protection (lead)
High Speed Interfaces
USB3.0 Super Speed

Application Requirements

- Due to their construction USB3.0 pins are highly exposed to ESD originating during routine use and the newer USB3.0 microcontrollers are extremely susceptible to ESD.
- The USB3.0 link data transmission rate of 5GBps places formidable requirements on the capacitance of protection components, which needs to be low to achieve the highest signal integrity.
- For these reasons, Infineon offers tailored USB3.0 protection with low $V_{CL}$, high $V_{ESD}$, and ultralow $C_L$.

WARNING
Poor package choices force designers to adopt difficult routing configurations, causing signal integrity issues!
High Speed Interfaces (cont.)
USB3.0 Interface: Infineon Protection Option # 1

**INFINEON ESD Protection Solution**

- Robust and long-term system level protection on multiple ESD strikes of up to ±20kV (IEC61000-4-2 contact discharge) without any signs of degradation.
- Extremely low clamping voltage and fast response time at all levels of ESD make them the ESD diodes of choice for protection of ultra-susceptible USB3.0 micro-controllers.
- The ultralow capacitance and inductance prevent impedance mismatching from going out of control while ensuring optimal signal integrity over a large variation in PCB qualities.
- The flow-through design of the TSLP-9 package simplifies PCB layout. The package can be placed on top of the high speed differential pairs to avoid complex vias or loops, facilitating PCB design.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{\text{RWM}}$</th>
<th>$V_{\text{ESD}}$</th>
<th>$R_{\text{dyn}}$</th>
<th>$V_{\text{CL}}$</th>
<th>$I_{\text{R}}$</th>
<th>$C_{\text{L;typ}}$</th>
<th>$\Delta C_{\text{L;typ}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multiline Array for four I/O lines protection of the USB3.0 link</strong> (leadless)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD3V3U4ULC</td>
<td>Flow-through 4-I/O Line TSLP-9</td>
<td>3.3V</td>
<td>±20kV</td>
<td>0.23Ω</td>
<td>11V</td>
<td>50nA</td>
<td>0.40pF</td>
<td>0.02pF</td>
</tr>
<tr>
<td>1 device protects the</td>
<td>2.3x1.0x0.31mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete USB3.0 link</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.20pF</td>
<td>0.01pF</td>
</tr>
<tr>
<td><strong>Multiline Array for four I/O lines + $V_{\text{cc}}$ protection of the USB2.0 link</strong> (leadless)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD5V3U4U-HDMI</td>
<td>Flow-through 4-I/O line TSLP-9</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>&lt;1nA</td>
<td>0.4pF</td>
<td>0.02pF</td>
</tr>
<tr>
<td>1 device protects the</td>
<td>2.3x1.0x0.31mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2pF</td>
<td>0.01pF</td>
</tr>
<tr>
<td>complete USB2.0 + $V_{\text{cc}}$ link.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Want to see an example? → see next page!*
High Speed Interfaces (cont.)

PCB Layout for USB3.0 Standard Connector “A”

Example with 1x ESD3V3U4ULC (USB3.0) and 1 x ESD5V3U4U-HDMI (USB2.0 + Vcc) for optimized PCB layout

Want to know more? → see next page!
High Speed Interfaces (cont.)
PCB Layout for USB3.0 Micro Connector

Example for an optimized PCB layout using ESD3V3U4ULC (USB3.0) and ESD5V3U4U-HDMI (USB2.0 + Vcc)

1 x ESD5V3U4U-HDMI for the full USB2.0 Link
Including Vcc

Want to know more? → see next page!
INFINEON ESD Protection Solution

- Robust and long-term system level protection on multiple ESD strikes of up to ±20kV (IEC61000-4-2 contact discharge) without any signs of degradation.

- The ultralow capacitance and inductance prevent impedance mismatching from going out of control while ensuring optimal signal integrity over a large variation in PCB qualities.

- The flow-through design of the TSLP-9-1 package simplifies PCB layout. The array can be placed on top of the high speed differential pairs to avoid complex vias or loops, facilitating PCB design. The leaded TSFP-3 package provides a cost-effective solution for the protection of the USB2.0 link.

### Part Name | Package | $V_{RWM}$ | $V_{ESD}$ | $R_{DYN}$ | $V_{CL}$ | $I_R$ | $C_L$ typ | $\Delta C_L$ typ
---|---|---|---|---|---|---|---|---
Multiline Array for four I/O lines protection of USB3.0 link (leadless) | ESD3V3U4ULC | Flow-through 4-I/O Line TSLP-9 2.3x1.0x0.31mm | 3.3V | ±20kV | 0.23Ω | 11V | 50nA | 0.40pF typ 0.20pF max 0.02pF typ 0.01pF max
Multiline line array for 2 lines protection of USB2.0 Link (leadred) | ESD5V3U2U-03F | TSFP-3 leaded 1.2x1.2x.0.55mm | 5.3V | ±20kV | 0.6Ω | 28V | 50nA | 0.4pF typ 0.6pF max n.a.

Click [HERE](#) to see protection recommendations for the $V_{CC}$ line

**Want to know more? → see next page!**
Example with 1 x ESD3V3U4ULC (USB3.0), 1 x ESD5V3U2U-03F (USB2.0), and 1 x ESD5V3L1B-Series (V_{cc})

Identical line-length is imperative for T_{x^{-}}/T_{x^{+}} and for R_{x^{+}}/R_{x^{-}} to minimize skew.

Want to know more? → read AN240!
High Speed Interfaces
HDMI1.3 and HDMI1.4a

Application Requirements

- HDMI uses small CMOS geometries to increase data rate performance. The small geometries of these graphic chips make them highly susceptible to ESD.
- Another common threat when plugging and unplugging cables are Cable Discharge Events (CDE). Common practice in the industry is to test CDE to the IEC61000-4-2 standard.
- ESD protection is required on all differential pairs and $V_{cc}$.
- The signal voltage levels vary between 2.5V and 3.5V, and $V_{cc}$=5V.
- Maximum data rate is 3.4Gb/s per pair. Some common ESD solutions cause signal distortion due to high capacitance resulting in poor signal integrity and video quality.
INFINEON ESD Protection Solution

- Infineon offers a complete portfolio of ultralow capacitance ESD diodes specified to absorb ESD events of up to ±20kV, exceeding IEC61000-4-2 market’s standard.
- Infineon ultralow capacitance supports perfect signal integrity in the HDMI Compliance Specification Testing (CST) and enables great design flexibility regardless of PCB quality.
- Common mode chokes for impedance matching can be eliminated in most cases. If tighter tolerances must be met, capacitance compensation can be implemented by simply using thinner traces [Refer to AN140 for more details].

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>V_{RWM}</th>
<th>V_{ESD}</th>
<th>R_{DYN}</th>
<th>V_{CL}</th>
<th>I_{R}</th>
<th>C_{L typ} I/O-GND</th>
<th>C_{L typ} I/O-I/O</th>
<th>ΔC_{L typ} I/O-I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multiline Array option for four I/O lines protection of HDMI Lines</strong> (leadless)</td>
<td>ESD5V3U4U-HDMI</td>
<td>Flow-through 4-I/O line TSLP-9 2.3x1.0x0.31mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>&lt;1nA</td>
<td>0.4pF</td>
<td>0.2pF</td>
</tr>
<tr>
<td><strong>Multiline Array options for two I/O lines protection of HDMI lines</strong> (leadless or leaded)</td>
<td>ESD5V3U2U-03LRH</td>
<td>TSLP-2 (0402) 1x0.6x0.39mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF</td>
<td>0.6pF_{max}</td>
</tr>
<tr>
<td></td>
<td>ESD5V3U2U-03F</td>
<td>TSFP-3 1.2x1.2x.0.55mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF</td>
<td>0.6pF_{max}</td>
</tr>
</tbody>
</table>

Click HERE to see protection recommendations for the V_{CC} line

Want to know more? → see next page!
Example with 1x ESD5V3U2U-03LRH small 0402 package per differential pair

Compensation of the HDMI receptacle and the diode capacitance is possible. Very good TDR results are achievable. PCB requirement: \( W_{\text{min}} \approx 0.15 \text{mm} \); gap between diode GND and data+ and data- of \(~0.120\text{mm}\), can be relaxed to \(~0.16\text{mm}\) by shifting data+ and data- line at the compensation area.

TVS Diode: IFX ESD5V3U2U-03LRH in TSLP-3-7

Want to know more?
→ see next page!
High Speed Interfaces (cont.)
HDMI PCB Layout Example with TSFP Array

Example with 1 x ESD5V3U2U-03F TSFP package (1.2x1.2x0.55m) per differential pair

Compensation of the HDMI receptacle and the diode capacitance is possible. Very good TDR results are achievable. PCB requirement: W_min~0.15mm.

TVS Diode: IFX ESD5V3U2U-03F in TSFP-3

Want to know more? (e.g TDR fundamentals) → read AN140!
Application Requirements

The Mobile High-Definition Link (MHL) is a mobile audio/video interface that uses the existing Micro USB connector with an extra cable for directly connecting mobile phones, digital cameras and other portable devices to the HDMI port of High-Definition Televisions (HDTV) and Displays.

The MHL standard features a single cable with a low pin-count interface able to support high-definition video and digital audio while simultaneously charging the connected device.

A data rate ~2Gbps for transmission of 1080i/60 signal is required in broadcast applications.

Assuming no external charging capability, the MHL signaling voltage is ≤3Vpeak.
High Speed Interfaces (cont.)
MHL Interface

**INFINEON ESD Protection Solution**

- ESD5V3U4U-HDMI is designed to reduce ESD events of up to ±20kV to very low clamping voltages.
- Infineon ultralow capacitance supports perfect signal integrity in MHL applications and enables great design flexibility regardless of PCB quality.
- One device ESD3V3U4ULC can protect the entire MHL link including Vcc.
- Very low leakage current contributes to extend battery’s life in portable applications e.g. handsets.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_{R}$</th>
<th>$C_L$ typ I/O-GND</th>
<th>$C_L$ typ I/O-I/O</th>
<th>$\Delta C_L$ typ I/O-GND</th>
<th>$\Delta C_L$ typ I/O-I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD3V3U4ULC</td>
<td>Flow-through 4-I/O Line TSLP-9 2.3x1.0x0.31mm</td>
<td>3.3V</td>
<td>±20kV</td>
<td>0.23Ω</td>
<td>11V</td>
<td>50nA</td>
<td>0.40pF</td>
<td>0.20pF</td>
<td>0.02pF</td>
<td>0.01pF</td>
</tr>
</tbody>
</table>

**Multiline Array for four I/O lines protection** (leadless)
High Speed Interfaces

DisplayPort

Application Requirements

- **Hot-plugging features**: users can connect any source equipment while at least one of the applications is still running. Such a powered port may be affected by serious ESD issues.
- Data speeds up to 5Gb/s per pair requires dedicated protection components with minimized parasitic effects to ensure signal integrity for low BER.
- The signal voltage varies between 2.5V and 3.5V, and $V_{cc}=3.3V$.

**WARNING**
The VESA Display Port standard specifies all exposed pins to withstand Level 4 IEC61000-4-2 ($\pm15kV$ air, $\pm8kV$ contact) without any damage!
High Speed Interfaces (cont.)
DisplayPort

**INFINEON ESD Protection Solution**

- Infineon offers a complete portfolio of ultralow capacitance ESD diodes specified to absorb ESD events of up to ±20kV, exceeding the IEC61000-4-2 industry standard.
- Infineon’s ultralow capacitance ESD diodes support perfect signal integrity in the Display Compliance Specification Testing (CST) and enables great design flexibility regardless of PCB quality.
- Common mode chokes for impedance matching can be eliminated in most cases. If tighter tolerances must be met, capacitance compensation can be implemented by simply using thinner traces [Refer to AN140 for more details].

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_R$</th>
<th>$C_L\text{typ}$</th>
<th>$C_L\text{max}$</th>
<th>$\Delta C_L\text{typ}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD5V3U4U-HDMI</td>
<td>Flow-through 4-I/O line TSLP-9 2.3x1.0x0.31mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>&lt;1nA</td>
<td>0.4pF</td>
<td>0.2pF</td>
<td>0.02pF</td>
</tr>
<tr>
<td>ESD5V3U2U-03LRH</td>
<td>0402 size TSLP-2 1x0.6x0.39mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$_{typ}$</td>
<td>0.6pF$_{max}$</td>
<td>n.a.</td>
</tr>
<tr>
<td>ESD5V3U2U-03F</td>
<td>TSFP-3 1.2x1.2x0.55mm</td>
<td>5.3V</td>
<td>±20kV</td>
<td>0.6Ω</td>
<td>28V</td>
<td>50nA</td>
<td>0.4pF$_{typ}$</td>
<td>0.6pF$_{max}$</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Click [HERE](#) to see protection recommendations for the $V_{CC}$ line
High Speed Interfaces
Serial ATA 3GBps and 6GBps

Application Requirements

- Serial ATA supports data rates of 3GBps and 6GBps with a DC blocking design and a minimum voltage swing requirement of $V_{pp} = 400\text{mV}$.
- SATA voltage swing can rise to 700mV, and in dedicated SATA II mode, the peak voltage can rise to 1600mV (on one line the signal is +800mV vs. GND and on the other line it is -800mV). The DC level of data lines at the connector is floating.
- In this configuration, bi-directional ESD diodes are mandatory.
- Normal location for ESD diodes would be between the blocking capacitors (~10nF) and the connector to keep the blocking capacitor safe from ESD.
- Ultralow capacitance components are compulsory to maintain the signal integrity at the high data transmission rates of Serial ATA interfaces.

WARNING
User’s routine interaction with these interfaces exposes the IC/ASIC to dangerous ESD!
INFOEON ESD Protection Solution

- In designs equipped with SATA or eSATA interfaces Infineon recommends its bidirectional TVS diodes featuring ultralow capacitance and high ESD absorption capabilities.
- ESD0P2RF with only 0.2pF provides robust absorption capability of at least ±20kV (IEC61000-4-2) without effects on the signal integrity of the high speed data transmission lines.
- The diode offers symmetrical and low clamping voltage of 29V (for 8kV contact discharge).

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>VRWM</th>
<th>VESD</th>
<th>R_DYN</th>
<th>VCL</th>
<th>IR_max</th>
<th>CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD0P2RF-02LS 1-line 0201 size TSSLP-2 0.6x0.3x0.31mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ} 0.4pF_{max}</td>
<td></td>
</tr>
<tr>
<td>ESD0P2RF-02LRH 1-line 0402 size TSLP-2 1.0x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ} 0.4pF_{max}</td>
<td></td>
</tr>
</tbody>
</table>
High Speed Interfaces
Gigabit Ethernet

Application Requirements

- Gigabit Ethernet operates transmitting and receiving data on four twisted cable pairs.
- The data signal voltage varies between 1.0V (100 and 1000Base) & 2.5V (10Base Ethernet).
- The data rates are 125Mb/s (100 and 1000 Base) and 12.5Mb/s (10 Base Ethernet).
- ESD robustness is required on both sides of the transformer.

WARNING

The small geometries of Ethernet PHY chips are very susceptible to transients and require high quality protection against ESD and surges!
INFINEON ESD Protection Solution

- Infineon TVS3V3L4U array on the secondary side of the transformer is recommended for protection of the Gigabit-Ethernet link. TVS3V3L4U is back guard compatible with 10 and 100Base Ethernet.
- TVS3V3L4U efficiently clamps ESD strikes and any surge that is coupled through the transformer to a safe and stable level for the downstream circuit.
- The low capacitance of this diode makes it suitable for efficient protection of Gigabit Ethernet without causing signal distortion issues at high data transmission rates.
- The complete Gigabit-Ethernet link can be protected with only 2 x TVS3V3L4U, which are available in a cost-effective SC74 package.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>EFT</th>
<th>Surge</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_R$</th>
<th>$C_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVS3V3L4U</td>
<td>4-Line SC74 2.9x2.5x0.55mm</td>
<td>3.3V</td>
<td>±30kV</td>
<td>80A</td>
<td>20A</td>
<td>0.1Ω</td>
<td>6V</td>
<td>&lt;50nA</td>
<td>2.9pF</td>
</tr>
</tbody>
</table>
High Speed Interfaces (cont.)

PCB Layout Proposal for Gigabit Ethernet

- TVS3V3L4U ESD/Surge Protector
- Magnetic module
- RJ45 socket
- 8 times 0 Ohm bridges
- Primary (RJ45) frontend side
- Secondary (Gbit PHY) frontend side

2.9x2.5x0.55mm Including leads

Application Requirements

- Wire line telecom systems are vulnerable to ESD, surge and cable discharge events and therefore subject to strict regulatory compliance to ensure system reliability.
- Primary protection is typically implemented where the outside line enters a structure, and secondary protection is applied to the equipment itself (see picture).
- The system is usually required to pass surge, power contact and power induction tests according to the ITU K20/21 telecommunication standard.
- The high-speed lines on the secondary side of the transformer demand protection devices with low capacitance to avoid signal distortion on the line.

WARNING
Secondary protection is required to further reduce surge voltages and currents to tolerable levels for the equipment being protected!
High Speed Interfaces (cont.)
xDSL (ADSL, VDSL..)

**DSL70 – INFINEON’s ESD Protection Solution for xDSL**

- Optimized to provide secondary protection on xDSL lines either at the central office or the subscriber side.
- Supports system compliance with telecom regulatory requirements including surge, power induction or power contact tests according to ITU K20/21.
- Overtakes competition by offering almost two times higher ESD absorption capability than competitor devices in the same package.
- Capacitance is 50% below the capacitance offered by the next alternative existing in the market.
- SOT143 (SC-61A) industry standard package.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>( V_{RWM} )</th>
<th>( V_{ESD} )</th>
<th>EFT</th>
<th>Surge</th>
<th>( R_{DYN} )</th>
<th>( V_{CL} )</th>
<th>( I_R )</th>
<th>( C_L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSL70</td>
<td>2-Line SOT143 2.9x2.4x1mm</td>
<td>50V [1]</td>
<td>±15kV</td>
<td>80A</td>
<td>27A</td>
<td>0.1Ω</td>
<td>4V+Vcc</td>
<td>&lt;5nA</td>
<td>2.5pF typ</td>
</tr>
</tbody>
</table>

\[1\] Rail to rail configuration

*Want to know more? → read the Surge & Burst Report!*
**Antenna Protection**

**Global Positioning System (GPS)**

Example: Antenna Protection in Global Navigation Satellite System (GNSS) Application

- **GPS**: 1575.42 MHz
- **GLONASS**: 1598.0625 – 1609.3125 MHz
- **Galileo & COMPASS (北斗)**: 1559.052 – 1591.788 MHz

**Application Requirements**

- Due to the high operating frequencies >1.5GHz, the ESD protection capacitance must be <<1pF.
- The protection device needs to be as linear as possible to avoid unwanted harmonics and intermodulation distortion in the presence of a strong RF interferer.
- To keep the residual ESD stress minimized for the frontend system, the protection device should have as low of a clamping voltage as possible.
- Small package sizes are favored to allow integration into miniaturized modules and frontend systems.

**WARNING**

For any antenna exposed to the outside world, ESD is a continuous threat to device reliability!
Antenna Protection
Global Positioning System (GPS)

INFINEON ESD Protection Solution

- The ESD0P2RF diode is tailored for ESD protection for various kinds of antenna systems in the low and medium power range. Its bidirectional characteristics enable it to handle AC coupled signals without clipping or distorting the RF signal, expanding its range of applications.
- The diode respond to ESD by quickly clamping the transient to only 29V for an 8kV strike (IEC61000-4-2).
- With only 0.2pF parasitic capacitance it enables high RF signal integrity with maximum ESD protection and without degradation effects from multiple strikes.
- The leakage current of the diode in normal operating conditions (5.3V max) does not exceed 50nA max. making it ideal for battery-powered applications.
- The miniature packages allow drastic space savings on PCBs and integration into miniaturized modules and frontend systems.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DYN}$</th>
<th>$V_{CL}$</th>
<th>$I_{R_{max}}$</th>
<th>$C_{L}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD0P2RF-02LS</td>
<td>1-line 0201 size TSSLP-2 0.6x0.3x0.31mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF typ 0.4pF max</td>
</tr>
<tr>
<td>ESD0P2RF-02LRH</td>
<td>1-line 0402 size TSLP-2 1.0x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF typ 0.4pF max</td>
</tr>
</tbody>
</table>

Want to know more? → read AN178!
For any antenna exposed to the outside world, ESD is a continuous threat to device reliability!

**Application Requirements**

- FM radio is a standard feature in most modern mobile phones and operates at frequencies from 76MHz to 108Mhz with an antenna power range of ≤20dBm.
- A protection circuit is necessary at the antenna to protect the delicate frontend system from ESD events originating during routine use.
- The protection device needs to have bidirectional characteristics and breakdown voltage from 5V to 10V to handle the DC free signal without clipping.
- Small package sizes are required to allow easier integration into miniaturized modules and frontend systems.
**INFINEON ESD Protection Solution**

- The ESD0P2RF diode is tailored for ESD protection of various kinds of antenna systems in the low and medium power range. Its bidirectional characteristics enable it to handle AC coupled signals without clipping or distorting the RF signal, expanding its range of applications.
- The diodes respond to ESD by quickly clamping the transient down to only 29V for an 8kV strike (IEC61000-4-2).
- With only 0.2pF parasitic capacitance it enables high RF signal integrity with a maximum of ESD protection without degradation effects.
- The leakage current of the diode in normal operating conditions (5.3V max) does not exceed 50nA max., favoring its application in battery-powered devices.
- The miniature packages allow drastic space savings on PCBs and integration into miniaturized modules and frontend systems.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>(V_{RWM})</th>
<th>(V_{ESD})</th>
<th>(R_{DYN})</th>
<th>(V_{CL})</th>
<th>(I_{R\max})</th>
<th>(C_L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD0P2RF-02LS</td>
<td>1-line 0201 size TSSLP-2 0.6x0.3x0.31mm</td>
<td>(\pm5.3V)</td>
<td>(\pm20kV)</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ} 0.4pF_{max}</td>
</tr>
<tr>
<td>ESD0P2RF-02LRH</td>
<td>1-line 0402 size TSLP-2 1.0x0.6x0.39mm</td>
<td>(\pm5.3V)</td>
<td>(\pm20kV)</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ} 0.4pF_{max}</td>
</tr>
</tbody>
</table>
Application Requirements

- Receivers for wireless broadcasting services use frequency bands from 170MHz to 1.7GHz (reference list above). The signal lines are AC coupled and operate at low RF signal levels.
- To protect the delicate downstream IC/ASIC, fast-clamping protection devices are required immediately after the antenna.
- Due to the high operating frequencies protection components with extremely low capacitance and high linearity are required.

Example: Antenna Protection in Mobile TV Application

WARNING
For any antenna exposed to the outside world, electrostatic discharges are a continuous threat to device reliability!
Antenna Protection
Mobile TV

INFINEON ESD Protection Solution

- The ESD0P2RF diode series is tailored for ESD protection of various kinds of antenna systems in the low and medium power range. Its bidirectional characteristics enable it to handle AC coupled signals without clipping or distorting the RF signal, expanding its range of applications.
- The diodes respond to ESD by quickly clamping the transient to only 29V for an 8kV strike (IEC61000-4-2).
- With only 0.2pF parasitic capacitance it enables high RF signal integrity with a maximum of ESD protection without degradation effects.
- The leakage current of the diode in normal operating conditions (5.3V max) does not exceed 50nA max., favoring its application in battery-powered devices.
- The miniature packages allow drastic space savings on PCBs and integration into miniaturized modules and frontend systems.

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>V_{RWM}</th>
<th>V_{ESD}</th>
<th>R_{DYN}</th>
<th>V_{CL}</th>
<th>I_{R_{max}}</th>
<th>C_{L}</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD0P2RF-02LS</td>
<td>1-line 0201 size</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ}</td>
</tr>
<tr>
<td></td>
<td>TSSLP-2 0.6x0.3x0.31mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD0P2RF-02LRH</td>
<td>1-line 0402 size</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>1.0Ω</td>
<td>29V</td>
<td>50nA</td>
<td>0.2pF_{typ}</td>
</tr>
<tr>
<td></td>
<td>TSLP-2 1.0x0.6x0.39mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Want to know more? → read AN167!
## INFINEON ESD Protection Solution

- Infineon offers a variety of general purpose diodes tailored for protection of power lines.
- The diodes offer very robust ESD absorption capability, exceeding the IEC61000-4-2 industry standard, and help to increase system level reliability of modern electronic devices.
- Due to their very low dynamic resistance, these diodes quickly clamp ESD strikes at very low voltages. After every ESD strike, the diodes recover very fast without any sign of degradation.
- The leakage current of the diode in normal operating conditions does not exceed 100nA max., favoring its application in battery-powered devices.
- These diodes are available in leadless packages with sizes down to 0.6 x 0.4 mm for maximum protection in the smallest area.

### Single Line Diode options for $V_{cc}$ Protection

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{RWM}$</th>
<th>$V_{ESD}$</th>
<th>$R_{DY}$</th>
<th>$V_{CL}$</th>
<th>$I_{R_{max}}$</th>
<th>$C_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESD8V0R1B-02LS</strong></td>
<td>1-Line TSSL-2 (0201) 0.6x0.3x0.31mm</td>
<td>-8/14V</td>
<td>±15kV</td>
<td>0.7Ω</td>
<td>&lt;30V</td>
<td>50nA</td>
<td>4pF$_{typ}$</td>
</tr>
<tr>
<td><strong>ESD5V3L1B-02LS</strong></td>
<td>1-Line TSSL-2 (0402) 1x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>17V</td>
<td>100nA</td>
<td>4pF$_{min}$</td>
</tr>
<tr>
<td><strong>ESD8V0R1B-02LRH</strong></td>
<td>1-Line TSSL-2 (0201) 0.6x0.3x0.31mm</td>
<td>±3.3V</td>
<td>±15kV</td>
<td>0.7Ω</td>
<td>&lt;30V</td>
<td>50nA</td>
<td>4pF$_{typ}$</td>
</tr>
<tr>
<td><strong>ESD5V3L1B-02LRH</strong></td>
<td>1-Line TSSL-2 (0402) 1x0.6x0.39mm</td>
<td>±5.3V</td>
<td>±20kV</td>
<td>0.22Ω</td>
<td>17V</td>
<td>100A</td>
<td>4pF$_{min}$</td>
</tr>
</tbody>
</table>

### Single Line Diode options for $V_{cc}$ Protection (leaded)

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Package</th>
<th>$V_{ESD}$</th>
<th>$R_{DY}$</th>
<th>$V_{CL}$</th>
<th>$I_{R_{max}}$</th>
<th>$C_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESD5V0L1B-02V</strong></td>
<td>1-Line SC79 1.6x0.8x0.55mm</td>
<td>±5.0V</td>
<td>±25kV</td>
<td>0.3Ω</td>
<td>22V</td>
<td>50nA</td>
</tr>
</tbody>
</table>

Infineon offers a variety of general purpose diodes tailored for protection of power lines. The diodes offer very robust ESD absorption capability, exceeding the IEC61000-4-2 industry standard, and help to increase system level reliability of modern electronic devices. Due to their very low dynamic resistance, these diodes quickly clamp ESD strikes at very low voltages. After every ESD strike, the diodes recover very fast without any sign of degradation. The leakage current of the diode in normal operating conditions does not exceed 100nA max., favoring its application in battery-powered devices. These diodes are available in leadless packages with sizes down to 0.6 x 0.4 mm for maximum protection in the smallest area.
Want to know more? check www.infineon.com/tvsdiodes!

- **TVS Diode Data Sheets**: [www.infineon.com/tvsdiodes](http://www.infineon.com/tvsdiodes)
- **Simulation Models** [www.infineon.com/ESDSimulationModels](http://www.infineon.com/ESDSimulationModels)
- **Application Guide for Protection (Brochure)**: [www.infineon.com/rpd_appguide_protection](http://www.infineon.com/rpd_appguide_protection)
- **Sample Kit**: “Fast and Indestructible ESD Protection for Your Electronic System”

- **Application Notes** [www.infineon.com/tvs.appnotes](http://www.infineon.com/tvs.appnotes)
  - AN140 “ESD Protection for Digital High-Speed Interfaces (HDMI etc) using ESD5V3U1U”
  - AN178 “ESD Protection for RF Antennas using Infineon ESD0P4RFL and ESD0P2RF”
  - AN167 “ESD Protection for Broadband LNA BGA728L7 for Portable and Mobile TV”
  - AN210 “Effective ESD Protection Design at System Level using VF-TLP Characterization”
  - AN240 “Effective ESD Protection for USB3.0 combined with perfect signal integrity”
  - AN277 “General Purpose and Audio ESD Protection using ESD5V3L1b and ESD3V3S1B Diodes”

- **Further Literature**
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ENERGY EFFICIENCY
MOBILITY
SECURITY

Innovative semiconductor solutions for energy efficiency, mobility and security.