ESD Protection for HDMI Applications

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Since its creation in 2002, High-Definition Multimedia Interface (HDMI) has remained one of the most popular interfaces for transmitting video and audio data. With each HDMI standard update, improvements in process technology have allowed manufacturers to increase data bandwidth and add additional features in smaller and smaller chipsets. However, with this decrease in size, HDMI components have become more sensitive to transient voltages such as electrostatic discharge. This has created a need for ESD protection that clamp at very low voltages without compromising high speed signal integrity.

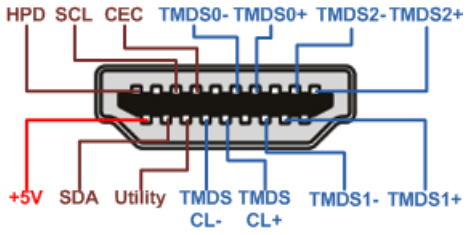

Figure 1. Pinout of the HDMI Receptacle

In the HDMI connector (figure 1), there are four differential pairs of transmission minimized digital signaling (TMDS) channels. For HDMI 2.0, three TMDS pairs (TMDS0, TMDS1 and TMDS2) are responsible for transferring millions of pixels of data per second while the TMDS CL pair provides the clocking signal to synchronize this information.

Apart from the four TMDS pairs, the HDMI connector also has six other channels: The hot plug detect (HPD) channel senses when a connection is established, the consumer electronic control (CEC) channel allows users to control devices through HDMI, the utility channel can be used for HDMI Ethernet or an audio return channel, the SDA and SCL channels provide I2C control, and the final channel provides 5V of power.

To protect against ESD failure, a 5V working voltage, 6-channel TVS diode such as the TPD6E05U06 can be placed on the non-TMDS channels by the HDMI connector (5V power, SDA, SCL, HPD, CEC and utility). 5V working voltage, 1-channel TVS diodes (TPD1E05U06) can also be used here for layout flexibility. Since these non-TMDS channels do not pass high speed data, minimizing the capacitance of the diodes is usually not a concern.

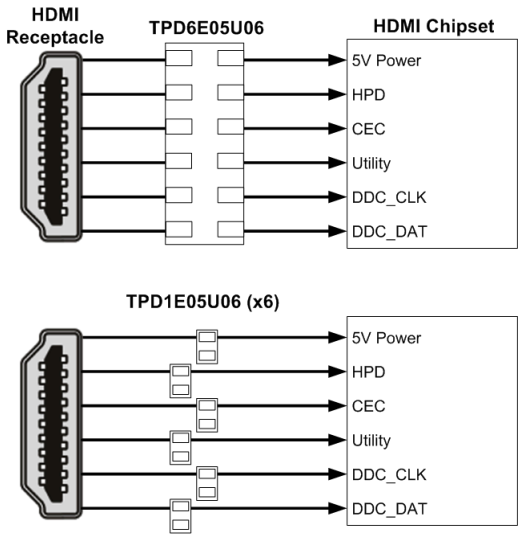

Figure 2. 6-channel TVS diode array (top) vs. 1-channel TVS diodes (bottom) for non-TMDS protection

On the other hand, the TMDS channels pass differential data that can reach 18Gbps (6Gbps for each pair) for HDMI 2.0, with a maximum single-ended operating voltage of 3.3V on each differential line. As a result, the ESD protection diodes that are placed on these high speed traces must have low enough capacitance to maintain signal integrity and meet the HDMI compliance standard.

Due to the sensitive nature of the TMDS I/O pins, clamping voltage must also be minimized for TMDS ESD protection. This is accomplished by selecting an ESD diode that has an ultra low dynamic resistance (R_{DYN}) so when an ESD strike is present, the diode provides a low impedance path to steer current away from sensitive circuitry downstream.

However, ESD R_{DYN} and capacitance have an inverse relationship. Increasing the diode junction area would decrease the R_{DYN} but increase the diode capacitance which may degrade signal integrity. As a result, selecting TVS diodes that protect the TMDS channels without compromising the data transfer is challenging. In spite of this, the ESD224 is a 4-channel ESD protection device that is able to clamp ±8kV IEC ESD events to sufficient levels while maintaining an ultra-low capacitance by employing TI's proprietary ESD

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process technology. Since there are four pairs of TMDS channels, two ESD224 protection diodes would provide the necessary protection on TMDS traces while passing the signal integrity eye diagram mask test (Figure 3).

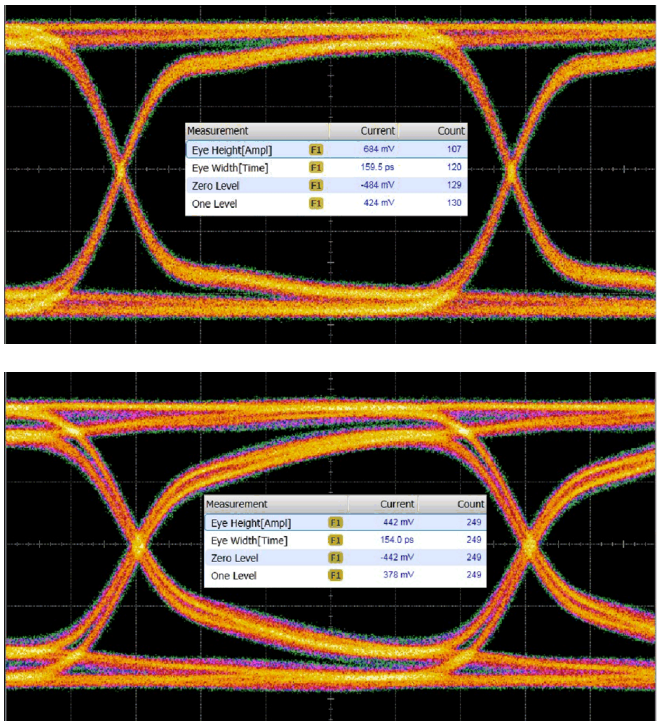

Figure 3. 6Gbps HDMI 2.0 Eye Diagram Without (top) and With (bottom) ESD224 Protection

The ESD224 is also able to provide the necessary ESD clamping protection for sensitive HDMI 2.0 redrivers, retimers and chipsets. For example, the BCM7250 is a Broadcom HDMI 2.0 SoC that fails at a low transient voltages: 9.15V and -5.71V. In Figure 4, a 100ns transmission line pulse (TLP) is used to determine the ESD failure voltage since 100ns is approximately the length of an IEC ESD pulse.

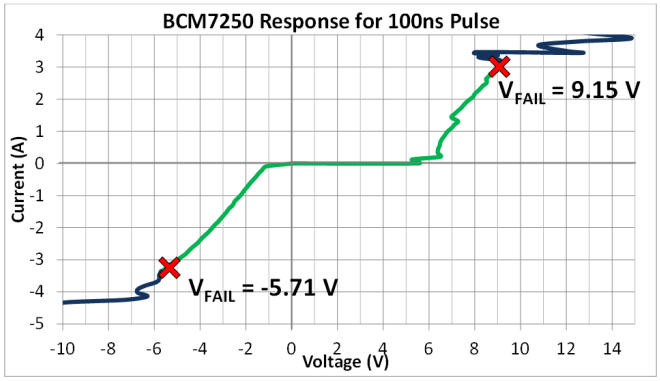

Figure 4. BCM7250 Fails at 9.15V and -5.71V During ESD Events

To protect sensitive HDMI 2.0 SoCs such as the BCM7250 against ESD strikes, the TVS diode must ensure that the positive clamping voltage does not exceed 9.15V and the negative clamping voltage does not exceed -5.71V. Figure 5 shows that the ESD224 provides this protection by clamping an 8kV IEC ESD strike to 8.1V and a -8kV IEC ESD strike to -5V.

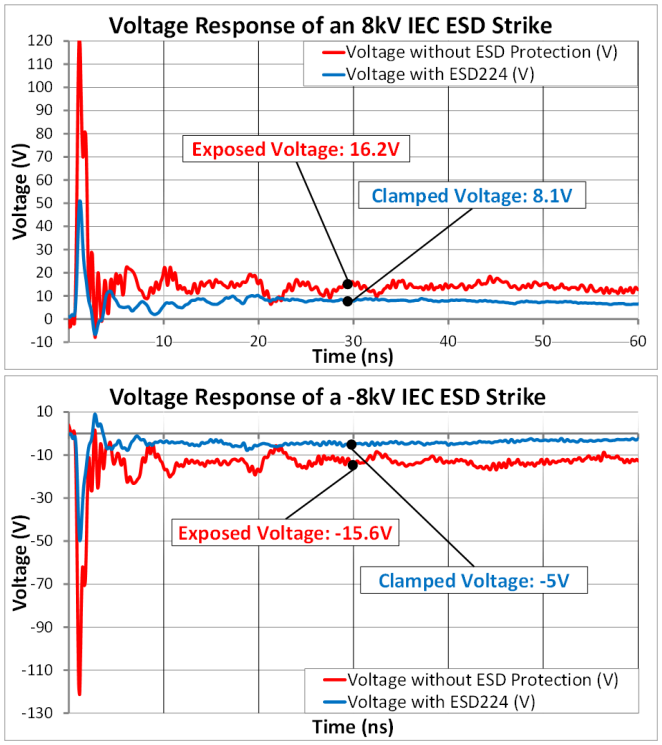

Figure 5. ESD224 Clamps +8kV ESD Voltage to 8.1V and -8kV ESD to -5V

For a complete HDMI 2.0 solution, 2x ESD224 can be used to protect the TMDS channels and 6x TPD1E05U06 can be used to protect the other channels. If the ultra low clamping performance of the ESD224 is not required, the TPD4E02B04 can be used to protect the TMDS channels.

Table 1. Alternative Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
TPD4E02B04	0.25pF capacitance, flow through routing	Higher clamping voltage
TPD4E05U06	5V working voltage, flow through routing	Higher clamping voltage
ESD204	30kV/30kV IEC rating, 5.5A surge protection, flow through routing	Higher capacitance

Related Documentation

- System Level ESD Selection Guide
- ESD224 HDMI 2.0 Compliance AppNote
- ESD Essentials Video Series

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