



# ESD

## Electrostatic Discharge (ESD) Protection Design Guide



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# ESD Electrostatic Discharge (ESD) Protection Design Guide

## ABOUT THIS GUIDE

Choosing the most appropriate suppressor technology requires a balance between equipment protection needs and operating requirements, taking into account the anticipated threat level. In addition to the electrical characteristics of suppression devices, the form factor/package style must also be considered. This guide is designed to summarize some of the comprehensive ESD solutions that Littelfuse offers, and help designers narrow to technologies appropriate to their end application:

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**Introduction:**

Designers of today’s electronic devices have demanded more functionality with greater flexibility and higher levels of user interaction. These circumstances have helped in driving the development of nanometer sized chipsets for a multitude of user interfaces or ports. The confluence of these smaller sizes and a wider variety of application types has made electronic components more susceptible to ESD and thus require a more robust solution.

**ESD Standards:**

MIL-STD-883E, Method 3015.7

Historically, analog and digital designers have been required to have ESD protection “on-chip” to protect the IC during the manufacturing process. The most commonly used ESD standard in the manufacturing environment is the MIL-STD-883E, Method 3015.7. It is also referred to as the Human Body Model (HBM). This model discharges a 100pF capacitor through a 1500Ω resistor into the device under test (DUT). The table below points out the four test levels as defined in the standard.

| HBM Level | Contact Discharge (kV) | Peak Current (A) |
|-----------|------------------------|------------------|
| 1         | ±0.5                   | 0.33             |
| 2         | ±1                     | 0.67             |
| 3         | ±2                     | 1.33             |
| 4         | ±4                     | 2.67             |

The maximum level required for a typical IC had been ±2kV up until 2007, but today that level has been drastically reduced to ±0.5kV. Obviously, this has helped chip designers save valuable silicon area for more functionality, but in turn, it has made the IC much more susceptible to damage from ESD.

**IEC61000-4-2**

Conversely, equipment manufacturers have traditionally used an ESD standard defined by the IEC (International Electrotechnical Commission) for system or application level testing. This model uses a 150pF capacitor which is discharged through a 330Ω resistor. The table below displays the four test levels for contact discharge as defined in this standard.

| IEC Level | Contact Discharge (kV) | Peak Current (A) |
|-----------|------------------------|------------------|
| 1         | ±2                     | 7.5              |
| 2         | ±4                     | 15               |
| 3         | ±6                     | 22.5             |
| 4         | ±8                     | 30               |

Most all manufacturers require that their equipment pass Level 4, or ±8kV, as a minimum, however, some are looking for increased reliability and require that their devices pass a much higher level like ±15kV or ±30kV.

**Conclusions:**

The system level ESD test defined by the IEC produces a substantial increase in peak current compared to the military standard. If an IC is rated for 0.5kV per the MIL-STD and the equipment manufacturer tests this same IC at 8kV per the IEC specification, the chip will see nearly a 100 fold increase in the initial peak current (i.e. 0.33A vs. 30A)!

Ultimately, hardware or board designers must add supplementary ESD devices to protect these sensitive chipsets from the high level ESD threats seen in the field.

**Solutions:**

Littelfuse TVS Diode Arrays (SPA® Diodes) are an ideal choice for suppressing ESD as their switching speed and superior clamping levels are essential to protect today’s integrated circuits, surpassing the capabilities of MLV, MOV, and polymer technologies. The TVS Diode Array portfolio offers a wide range of components to suit the majority of application needs available in the market today, and this guide will steer the designer toward the appropriate ESD component for the particular application they are trying to protect.

**Some of the applications discussed in this guide are:**

- USB1.1/2.0/3.0/3.1
- HDMI
- DVI
- Ethernet (10/100/1000 Mbps)
- 2.5 and 5 Gigabit Ethernet
- xDSL
- eSATA
- 1394a/b
- LVDS
- Audio (Speaker/Microphone)
- Analog Video
- SIM Sockets
- Keypad/Push button
- CAN bus and LIN bus
- Touchscreen

**Many of these applications can be found in electronic devices such as:**

- Laptops/Ultrabooks
- Portable Medical Devices
- Set Top Boxes
- LCD TV’s
- Portable Navigation Devices
- Keyboards/Mouse
- Gaming Consoles
- MP3/PMP
- PDA’s
- Digital Cameras
- Smart Phones
- External Storage
- Switch/Router/Hub
- Gateways

## PRODUCT SELECTION GUIDE

### General Purpose ESD Protection

#### Unidirectional ESD Protection

| Series | ESD Level (Contact) | I/O Capacitance | V <sub>RWM</sub> | Lightning (t <sub>p</sub> =8/20μs) | Number of Channels | Package       | Orderable Part Number |
|--------|---------------------|-----------------|------------------|------------------------------------|--------------------|---------------|-----------------------|
| SP05   | ±30kV               | 30pF            | 5.5V             | N/A                                | 2                  | SOT23-3       | SP0502BAHTG           |
|        |                     |                 |                  |                                    |                    | SC70-3        | SP0502BAJTG           |
|        |                     |                 |                  |                                    | 3                  | SOT143        | SP0503BAHTG           |
|        |                     |                 |                  |                                    |                    | 4             | SOT23-5               |
|        |                     |                 |                  |                                    | SC70-5             |               | SP0504BAJTG           |
|        |                     |                 |                  |                                    | 5                  | SOT23-6       | SP0505BAHTG           |
| SC70-6 | SP0505BAJTG         |                 |                  |                                    |                    |               |                       |
| SP1001 | ±15kV               | 8pF             | 5.5V             | 2A                                 | 2                  | SC70-3        | SP1001-02JTG          |
|        |                     |                 |                  |                                    |                    | SOT553        | SP1001-02XTG          |
|        |                     |                 |                  |                                    | 4                  | SC70-5        | SP1001-04JTG          |
|        |                     |                 |                  |                                    |                    | SOT553        | SP1001-04XTG          |
|        |                     |                 |                  |                                    | 5                  | SC70-6        | SP1001-05JTG          |
|        |                     |                 |                  |                                    |                    | SOT563        | SP1001-05XTG          |
| SOT963 | SP1001-05VTG        |                 |                  |                                    |                    |               |                       |
| SP1003 | ±30kV               | 30pF            | 5V               | 7A                                 | 1                  | SOD723        | SP1003-01DTG          |
|        |                     |                 |                  |                                    |                    | SOD882 (0402) | SP1003-01ETG          |
| SP1006 | ±30kV               | 15pF            | 6V               | 5A                                 | 1                  | μDFN-2 (0201) | SP1006-01UTG          |
| SP1011 | ±15kV               | 7pF             | 6V               | 2A                                 | 4                  | μDFN-6        | SP1011-04UTG          |
| SDxx   | ±30kV               | 350pF           | 5V               | 30A                                | 1                  | SOD323 (0805) | SD05-01FTG            |
|        |                     | 150pF           | 12V              | 17A                                |                    |               | SD12-01FTG            |
|        |                     | 100pF           | 15V              | 12A                                |                    |               | SD15-01FTG            |
|        |                     | 65pF            | 24V              | 7A                                 |                    |               | SD24-01FTG            |
|        |                     | 50pF            | 36V              | 5A                                 |                    |               | SD36-01FTG            |
| SMxx   | ±30kV               | 400pF           | 5V               | 24A                                | 2                  | SOT23-3       | SM05-02HTG            |
|        |                     | 150pF           | 12V              | 17A                                |                    |               | SM12-02HTG            |
|        |                     | 100pF           | 15V              | 12A                                |                    |               | SM15-02HTG            |
|        |                     | 65pF            | 24V              | 7A                                 |                    |               | SM24-02HTG            |
|        |                     | 50pF            | 36V              | 5A                                 |                    |               | SM36-02HTG            |
| SM712  | ±30kV               | 75pF            | +12V/-7V         | 17A                                | 2                  | SOT23-3       | SM712-02HTG           |

## General Purpose ESD Protection (cont)

### Bidirectional ESD Protection

| Series          | ESD Level (Contact) | I/O Capacitance | V <sub>RWM</sub> | Lightning (t <sub>r</sub> =8/20μs) | Number of Channels | Package                        | Orderable Part Number |
|-----------------|---------------------|-----------------|------------------|------------------------------------|--------------------|--------------------------------|-----------------------|
| SP1002          | ±8kV                | 5pF             | 6V               | 2A                                 | 1                  | SC70-3                         | SP1002-01JTG          |
|                 |                     |                 |                  |                                    | 2                  | SC70-5                         | SP1002-02JTG          |
| SP1004          | ±8kV                | 5pF             | 6V               | 2A                                 | 4                  | SOT953                         | SP1004-04VTG          |
| SP1005          | ±30kV               | 23pF            | 6V               | 10A                                | 1                  | Flipchip (0201)                | SP1005-01WTG          |
|                 |                     |                 |                  |                                    |                    | SOD882 (0402)                  | SP1005-01ETG          |
| SP1007          | ±8kV                | 5pF             | 6V               | 2A                                 | 1                  | Flipchip (0201)                | SP1007-01WTG          |
|                 |                     |                 |                  |                                    |                    | SOD882 (0402)                  | SP1007-01ETG          |
| SP1008          | ±15kV               | 8pF             | 6V               | 3A                                 | 1                  | Flipchip (0201)                | SP1008-01WTG          |
| SP1012          | ±15kV               | 6.5pF           | 5V               | 3A                                 | 5                  | Flipchip<br>0.94x0.61mm        | SP1012-05WTG          |
| SP1013          | ±30kV               | 30pF            | 5V               | 8A                                 | 1                  | Flipchip<br>0.54x0.29mm        | SP1013-01WTG          |
| SP1014          | ±12kV               | 6pF             | 5V               | 2A                                 | 1                  | Flipchip<br>0.54x0.29mm        | SP1014-01WTG          |
| SP1015          | ±20kV               | 5pF             | 5V               | 2A                                 | 4                  | Flipchip<br>0.93x0.53mm        | SP1015-04WTG          |
| SP1020          | ±30kV               | 20pF            | 6V               | 5A                                 | 1                  | Flipchip 01005                 | SP1020-01WTG          |
| SP1021          | ±12kV               | 6pF             | 6V               | 2A                                 | 1                  | Flipchip 01005                 | SP1021-01WTG          |
| SDxxC           | ±30kV               | 200pF           | 5V               | 30A                                | 1                  | SOD323 (0805)                  | SD05C-01FTG           |
|                 |                     | 100pF           | 12V              | 17A                                |                    |                                | SD12C-01FTG           |
|                 |                     | 75pF            | 15V              | 12A                                |                    |                                | SD15C-01FTG           |
|                 |                     | 50pF            | 24V              | 7A                                 |                    |                                | SD24C-01FTG           |
|                 |                     | 30pF            | 36V              | 5A                                 |                    |                                | SD36C-01FTG           |
| SPHVxx-01ETG    | ±30kV               | 30pF            | 12V              | 8A                                 | 1                  | SOD882 (0402)                  | SPHV12-01ETG          |
|                 | ±30kV               | 24pF            | 15V              | 5A                                 |                    |                                | SPHV15-01ETG          |
|                 | ±24kV               | 17pF            | 24V              | 3A                                 |                    |                                | SPHV24-01ETG          |
|                 | ±15kV               | 13pF            | 36V              | 2A                                 |                    |                                | SPHV36-01ETG          |
| SPHVxx-01ETG-C  | ±30kV               | 60pF            | 12V              | 8A                                 | 1                  | SOD882 (0402)                  | SPHV12-01ETG-C        |
|                 | ±30kV               | 46pF            | 15V              | 5A                                 |                    |                                | SPHV15-01ETG-C        |
|                 | ±24kV               | 32pF            | 24V              | 3A                                 |                    |                                | SPHV24-01ETG-C        |
|                 | ±15kV               | 25pF            | 36V              | 2A                                 |                    |                                | SPHV36-01ETG-C        |
| SPHVxx-01KTG-C  | ±30kV               | 60pF            | 12V              | 8A                                 | 1                  | SOD882 (0402)<br>exposed leads | SPHV12-01KTG-C        |
|                 | ±30kV               | 46pF            | 15V              | 5A                                 |                    |                                | SPHV15-01KTG-C        |
|                 | ±24kV               | 32pF            | 24V              | 3A                                 |                    |                                | SPHV24-01KTG-C        |
|                 | ±15kV               | 25pF            | 36V              | 2A                                 |                    |                                | SPHV36-01KTG-C        |
| SPxx-01WTG-C-HV | ±30kV               | 26pF            | 12V              | 8A                                 | 1                  | Flipchip (0201)                | SP12-01WTG-C-HV       |
|                 | ±30kV               | 21pF            | 15V              | 5A                                 |                    |                                | SP15-01WTG-C-HV       |
|                 | ±18kV               | 13pF            | 24V              | 3A                                 |                    |                                | SP24-01WTG-C-HV       |
|                 | ±10kV               | 10pF            | 36V              | 1.5A                               |                    |                                | SP36-01WTG-C-HV       |
| SM24CANA        | ±24kV               | 11pF            | 24V              | 3A                                 | 2                  | SOT23-3                        | SM24CANA-02HTG        |
| SM24CANB        | ±30kV               | 30pF            | 24V              | 10A                                | 2                  | SOT23-3                        | SM24CANB-02HTG        |

## Ethernet and Lightning Surge Protection

| Series    | ESD Level (Contact) | I/O to I/O Capacitance | V <sub>RWM</sub> | Lightning (t <sub>p</sub> =8/20μs) | Number of Channels | Package       | Orderable Part Number |
|-----------|---------------------|------------------------|------------------|------------------------------------|--------------------|---------------|-----------------------|
| SRV05-4   | ±20kV               | 1.2pF                  | 6V               | 10A                                | 4                  | SOT23-6       | SRV05-4HTG            |
| SP2504N   | ±30kV               | 2.0pF                  | 2.5V             | 20A                                | 4                  | μDFN-10       | SP2504NUTG            |
| SP3304N   | ±30kV               | 2.0pF                  | 3.3V             | 20A                                | 4                  | μDFN-10       | SP3304NUTG            |
| SP4044    | ±30kV               | 1.5pF                  | 2.8V             | 24A                                | 4                  | MSOP-10       | SP4044-04ATG          |
| SP4045    | ±30kV               | 1.5pF                  | 3.3V             | 24A                                | 4                  | MSOP-10       | SP4045-04ATG          |
| SP4060    | ±30kV               | 2.2pF                  | 2.5V             | 20A                                | 8                  | MSOP-10       | SP4060-08ATG          |
| SP4065    | ±30kV               | 2.2pF                  | 3.3V             | 20A                                | 8                  | MSOP-10       | SP4065-08ATG          |
| SP3051    | ±30kV               | 2.0pF                  | 6V               | 20A                                | 4                  | SOT23-6       | SP3051-04HTG          |
| SP3312T   | ±30kV               | 1.3pF                  | 3.3V             | 15A                                | 4                  | uDFN-8        | SP3312TUTG            |
| SR05      | ±30kV               | 3.0pF                  | 5V               | 25A                                | 2                  | SOT143        | SR05-02CTG            |
| SP4020    | ±30kV               | 2.5pF                  | 3.3V             | 30A                                | 1 (uni)            | SOD323 (0805) | SP4020-01FTG          |
|           |                     |                        |                  |                                    | 1 (bidir)          |               | SP4020-01FTG-C        |
| SP4021    | ±30kV               | 2.5pF                  | 5V               | 25A                                | 1 (uni)            | SOD323 (0805) | SP4021-01FTG          |
|           |                     |                        |                  |                                    | 1 (bidir)          |               | SP4021-01FTG-C        |
| SP4022    | ±30kV               | 1.3pF                  | 12V              | 15A                                | 1 (uni)            | SOD323 (0805) | SP4022-01FTG          |
|           |                     |                        |                  |                                    | 1 (bidir)          |               | SP4022-01FTG-C        |
| SP4023    | ±30kV               | 1.3pF                  | 15V              | 12A                                | 1 (uni)            | SOD323 (0805) | SP4023-01FTG          |
|           |                     |                        |                  |                                    | 1 (bidir)          |               | SP4023-01FTG-C        |
| SP4024    | ±30kV               | 1.3pF                  | 24V              | 7A                                 | 1 (uni)            | SOD323 (0805) | SP4024-01FTG          |
|           |                     |                        |                  |                                    | 1 (bidir)          |               | SP4024-01FTG-C        |
| SRDA05    | ±30kV               | 4.0pF                  | 5V               | 30A                                | 4                  | SOIC-8        | SRDA05-4BTG           |
| SRDA3.3   | ±30kV               | 4.0pF                  | 3.3V             | 35A                                | 4                  | SOIC-8        | SRDA3.3-4BTG          |
| SR70      | ±30kV               | 2.0pF                  | 70V              | 40A                                | 2                  | SOT143        | SR70-02CTG            |
| SLVU2.8-4 | ±30kV               | 2.0pF                  | 2.8V             | 40A                                | 4                  | SOIC-8        | SLVU2.8-4BTG          |
| SLVU2.8-8 | ±30kV               | 2.6pF                  | 2.8V             | 30A                                | 8                  | SOIC-8        | SLVU2.8-8BTG          |
| SP2502L   | ±30kV               | 2.5pF                  | 3.3V             | 75A                                | 2                  | SOIC-8        | SP2502LBTG            |
| SP2574N   | ±30kV               | 3.8pF                  | 2.5V             | 40A                                | 4                  | uDFN-10       | SP2574NUTG            |
| SP03-3.3  | ±30kV               | 8pF                    | 3.3V             | 150A                               | 2                  | SOIC-8        | SP03-3.3BTG           |
| LC03-3.3  | ±30kV               | 4.5pF                  | 3.3V             | 150A                               | 2                  | SOIC-8        | LC03-3.3BTG           |
| SP03-6    | ±30kV               | 8pF                    | 6V               | 150A                               | 2                  | SOIC-8        | SP03-6BTG             |

## Low Capacitance ESD Protection

| Series  | ESD Level (Contact) | I/O Capacitance | V <sub>RWM</sub> | Lightning (t <sub>p</sub> =8/20μs) | Number of Channels | Package       | Orderable Part Number |
|---------|---------------------|-----------------|------------------|------------------------------------|--------------------|---------------|-----------------------|
| SP1255P | ±12kV               | 0.5pF           | 4V               | 4A                                 | 3                  | uDFN-6        | SP1255PUTG            |
| SP3001  | ±8kV                | 0.65pF          | 6V               | 2.5A                               | 4                  | SC70-6        | SP3001-04JTG          |
| SP3002  | ±12kV               | 0.85pF          | 6V               | 4.5A                               | 4                  | SC70-6        | SP3002-04JTG          |
|         |                     |                 |                  |                                    |                    | μDFN-6        | SP3002-04UTG          |
| SP0504S | ±12kV               | 0.85pF          | 6V               | 4.5A                               | 4                  | SOT23-6       | SP0504SHTG            |
| SP3003  | ±8kV                | 0.65pF          | 6V               | 2.5A                               | 2                  | SC70-5        | SP3003-02JTG          |
|         |                     |                 |                  |                                    |                    | SOT553        | SP3003-02XTG          |
|         |                     |                 |                  |                                    |                    | μDFN-6        | SP3003-02UTG          |
|         |                     |                 |                  |                                    | 4                  | SC70-6        | SP3003-04JTG          |
|         |                     |                 |                  |                                    |                    | SOT563        | SP3003-04XTG          |
| 8       | MSOP-10             | SP3003-04ATG    |                  |                                    |                    |               |                       |
| SP3004  | ±12kV               | 0.85pF          | 6V               | 4A                                 | 4                  | SOT563        | SP3004-04XTG          |
| SP3010  | ±8kV                | 0.45pF          | 6V               | 3A                                 | 4                  | μDFN-10       | SP3010-04UTG          |
| SP3011  | ±8kV                | 0.4pF           | 6V               | 3A                                 | 6                  | μDFN-14       | SP3011-06UTG          |
| SP3012  | ±12kV               | 0.5pF           | 5V               | 4A                                 | 3                  | μDFN-6        | SP3012-03UTG          |
|         |                     |                 |                  |                                    | 4                  | SOT23-6       | SP3012-04HTG          |
|         |                     |                 |                  |                                    | 4                  | μDFN-10       | SP3012-04UTG          |
|         |                     |                 |                  |                                    | 6                  | μDFN-14       | SP3012-06UTG          |
| SP3014  | ±15kV               | 1.0pF           | 5V               | 8A                                 | 2                  | μDFN-6L       | SP3014-02UTG          |
| SP0524P | ±12kV               | 0.5pF           | 5V               | 4A                                 | 4                  | μDFN-10       | SP0524PUTG            |
| SP3021  | ±8kV                | 0.5pF           | 5V               | 2A                                 | 1                  | SOD882 (0402) | SP3021-01ETG          |
| SP3022  | ±20kV               | 0.35pF          | 5.3V             | 3A                                 | 1                  | Flipchip 0201 | SP3022-01WTG          |
|         |                     |                 |                  |                                    |                    | SOD882 (0402) | SP3022-01ETG          |
| SP3030  | ±20kV               | 0.5pF           | 5V               | 3A                                 | 1                  | SOD882 (0402) | SP3030-01ETG          |
| SP3031  | ±10kV               | 0.8pF           | 5V               | 5A                                 | 1                  | SOD882 (0402) | SP3031-01ETG          |

**Low Capacitance ESD Protection (cont.)**

| Series                | ESD Level (Contact) | I/O Capacitance | V <sub>RWM</sub> | Lightning (t <sub>p</sub> =8/20μs) | Number of Channels | Package           | Orderable Part Number |
|-----------------------|---------------------|-----------------|------------------|------------------------------------|--------------------|-------------------|-----------------------|
| SESD0201X1UN-0030-088 | ±22kV               | 0.30 pF         | 7V               | 2.5A                               | 1                  | 0201 DFN          | RF3917-000            |
| SESD0201X1BN-0015-096 | ±22kV               | 0.15 pF         | 7V               | 2.5A                               | 1                  | 0201 DFN          | RF3918-000            |
| SESD0402X1UN-0030-088 | ±22kV               | 0.30 pF         | 7V               | 2.5A                               | 1                  | SOD882 (0402)     | RF3920-000            |
| SESD0402X1BN-0015-096 | ±22kV               | 0.15 pF         | 7V               | 2.5A                               | 1                  | SOD882 (0402)     | RF3922-000            |
| SESD0402Q2UG-0030-088 | ±22kV               | 0.30 pF         | 7V               | 2.2A                               | 2                  | 0402 DFN (SOD883) | RF3925-000            |
| SESD1004Q4UG-0030-088 | ±22kV               | 0.30 pF         | 7V               | 2.2A                               | 4                  | 1004 DFN          | RF3923-000            |
| SESD0402Q2UG-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 2                  | 0402 DFN (SOD883) | RF2946-000            |
| SESD0802Q4UG-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 4                  | 0802 DFN          | RF3076-000            |
| SESD1004Q4UG-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 4                  | 1004 DFN          | RF3077-000            |
| SESD1103Q6UG-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 6                  | 1103 DFN          | RF3078-000            |
| SESD0201X1UN-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 1                  | 0201 DFN          | RF2192-000            |
| SESD0201X1BN-0010-098 | ±20kV               | 0.10pF          | 7V               | 2.0A                               | 1                  | 0201 DFN          | RF2193-000            |
| SESD0402X1UN-0020-090 | ±20kV               | 0.20pF          | 7V               | 2.0A                               | 1                  | SOD882 (0402)     | RF2943-000            |
| SESD0402X1BN-0010-098 | ±20kV               | 0.10pF          | 7V               | 2.0A                               | 1                  | SOD882 (0402)     | RF2945-000            |

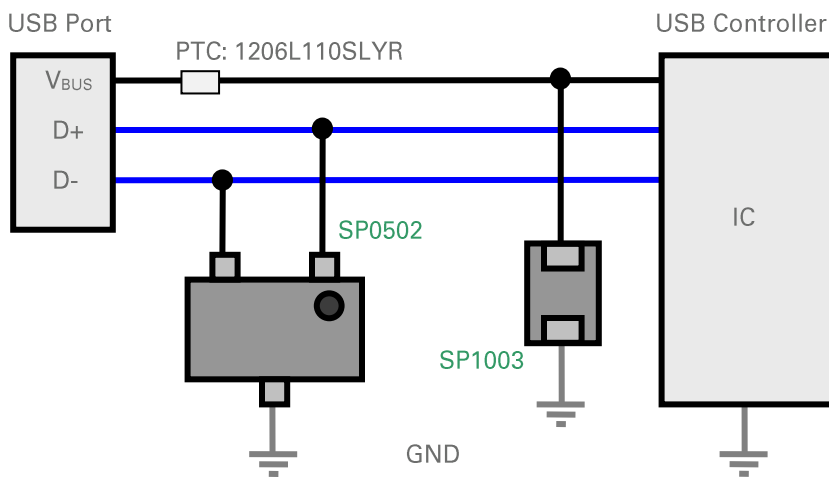


## APPLICATION SPECIFIC DEVICE SELECTION USB1.1

### Considerations:

- Each port operates at either 1.5Mbps or 12Mbps (low and full speed respectively)
  - Parasitic capacitance should be taken into account although these relatively slow speeds can tolerate tens of picofarads
  - Requires 2 channels of data line protection per port (i.e. D±)
  - A 4 channel device can be useful if protecting a USB stack of 2 ports to make the ESD footprint as small as possible
  - $V_{BUS}$  can be protected separately with a single channel device in an 0402 or 0201 form factor (0402 shown)
- Protection for  $V_{BUS}$  is optional and can be done via a single channel device or included with the protection for D± in a single 3 channel device such as the SP0503

### Application Schematic:



### Recommended TVS Diode Arrays:

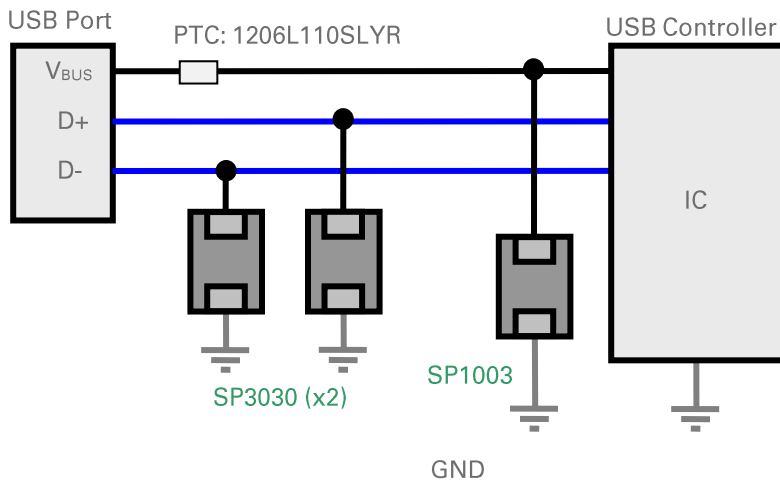
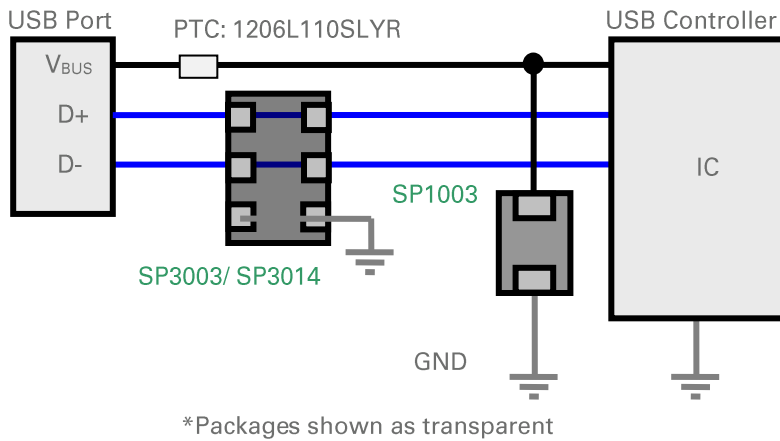
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging     |
|-----------------|---------------------|----------------------------|---------------|-----------|---------------|
| SP0502BAJTG     | ±30kV               | 50pF                       | 2             | 5.5V      | SC70-3        |
| SP0503BAHTG     | ±30kV               | 50pF                       | 3             | 5.5V      | SOT143        |
| SP1001-02XTG    | ±15kV               | 12pF                       | 2             | 5.5V      | SOT553        |
| SP1003-01ETG    | ±30kV               | 30pF                       | 1             | 5.0V      | SOD882 (0402) |

## APPLICATION SPECIFIC DEVICE SELECTION USB2.0

### Considerations:

- Each port can operate up to 480Mbps
  - The high data rate requires a low capacitance device to preserve signal integrity
- Requires 2 channels of data line protection per port (i.e. D±) which can be done via array or discretely
  - A 4 channel device can be useful if protecting a USB stack of 2 ports to make the ESD footprint as small as possible
- Protection for V<sub>BUS</sub> is optional and can be done via a single channel device like the SP1003

### Application Schematic:



### Recommended TVS Diode Arrays:

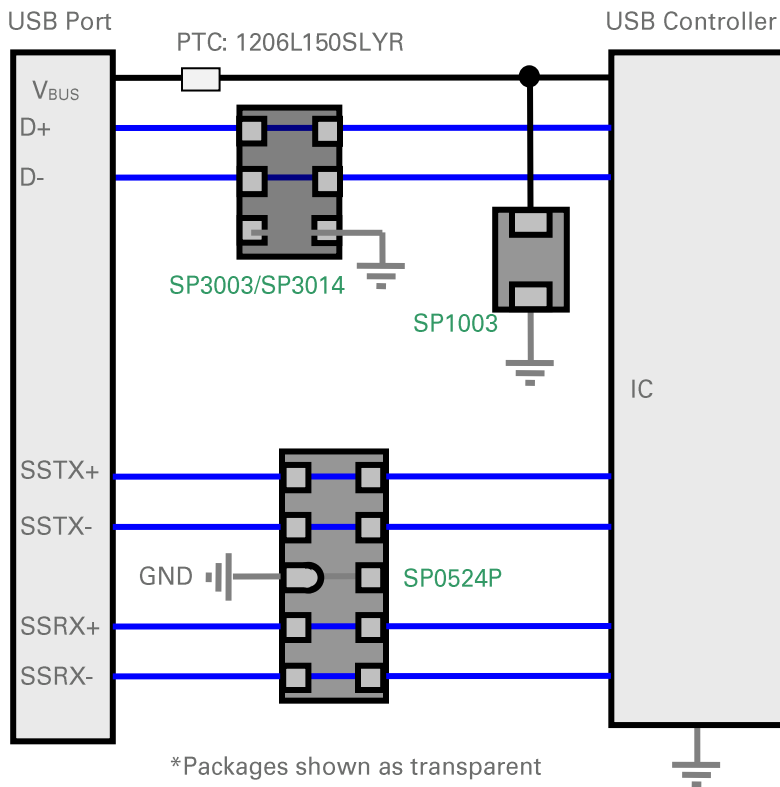
| Ordering Number | ESD Level (Contact) | I/O Capacitance @<br>V <sub>R</sub> =1.65V | # of Channels | V <sub>RWM</sub> | Packaging             |
|-----------------|---------------------|--|---------------|------------------|-----------------------|
| SP3003-02UTG    | ±8kV                | 0.65pF                                     | 2             | 6V               | μDFN-6<br>(1.6x1.0mm) |
| SP3014-02UTG    | ±15kV               | 1.0pF                                      | 2             | 5V               | μDFN-6<br>(1.6x1.0mm) |
| SP3030-01ETG    | ±20kV               | 0.5pF                                      | 1             | 5V               | SOD882 (0402)         |
| SP1003-01ETG    | ±30kV               | 30pF                                       | 1             | 5V               | SOD882 (0402)         |

## APPLICATION SPECIFIC DEVICE SELECTION USB3.0 (Two Device Solution)

### Considerations:

- Each port depending upon what it's connected to can operate:
  - Up to 5Gbps over the new super-speed data pairs, SSTX± and SSRX±
  - Up to 480Mbps on the legacy data pair, D±
- Requires 4 channels of ultra-low capacitance protection for the super-speed data pair (i.e. SSTX± and SSRX±)
- Requires 2 channels of protection for the legacy D± data pair
- Protection for V<sub>BUS</sub> is optional and can be done via a single channel device like the SP1003

### Application Schematic:



### Recommended TVS Diode Arrays:

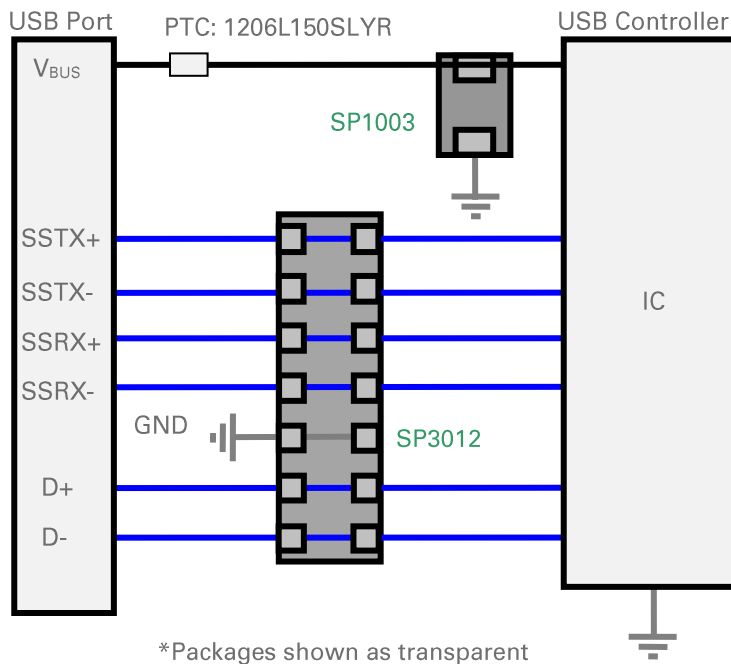
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ V <sub>R</sub> =1.65V | # of Channels | V <sub>RWM</sub> | Packaging           |
|-----------------|---------------------|---|---------------|------------------|---------------------|
| SP3003-02UTG    | ±8kV                | 0.65pF                                  | 2             | 6V               | μDFN-6 (1.6x1.0mm)  |
| SP3014-02UTG    | ±15kV               | 1.0pF                                   | 2             | 5V               | μDFN-6 (1.6x1.0mm)  |
| SP0524PUTG      | ±12kV               | 0.5pF                                   | 4             | 5V               | μDFN-10 (2.5x1.0mm) |
| SP1003-01ETG    | ±30kV               | 30pF                                    | 1             | 5V               | SOD882 (0402)       |

## APPLICATION SPECIFIC DEVICE SELECTION USB3.0 (Integrated Solution)

### Considerations:

- Each port depending upon what it's connected to can operate:
  - Up to 5Gbps over the new super-speed data pairs, SSTX± and SSRX±
  - Up to 480Mbps on the legacy data pair, D±
- Requires 4 channels of ultra-low capacitance protection for the super-speed data pair (i.e. SSTX± and SSRX±) and 2 channels of protection for the legacy D± data pair. The SP3012 shown below integrates all 6 channels of protection into a small form factor  $\mu$ DFN-14 package.
- Protection for  $V_{BUS}$  is optional and can be done via a single channel device like the SP1003

### Application Schematic:



### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging                 |
|-----------------|---------------------|----------------------------|---------------|-----------|---------------------------|
| SP3012-06UTG    | $\pm 12kV$          | 0.5pF                      | 6             | 5V        | $\mu$ DFN-14 (3.5x1.35mm) |
| SP1003-01ETG    | $\pm 30kV$          | 30pF                       | 1             | 5V        | SOD882 (0402)             |

## APPLICATION SPECIFIC DEVICE SELECTION USB3.1 (Type C Compliance)

### Considerations:

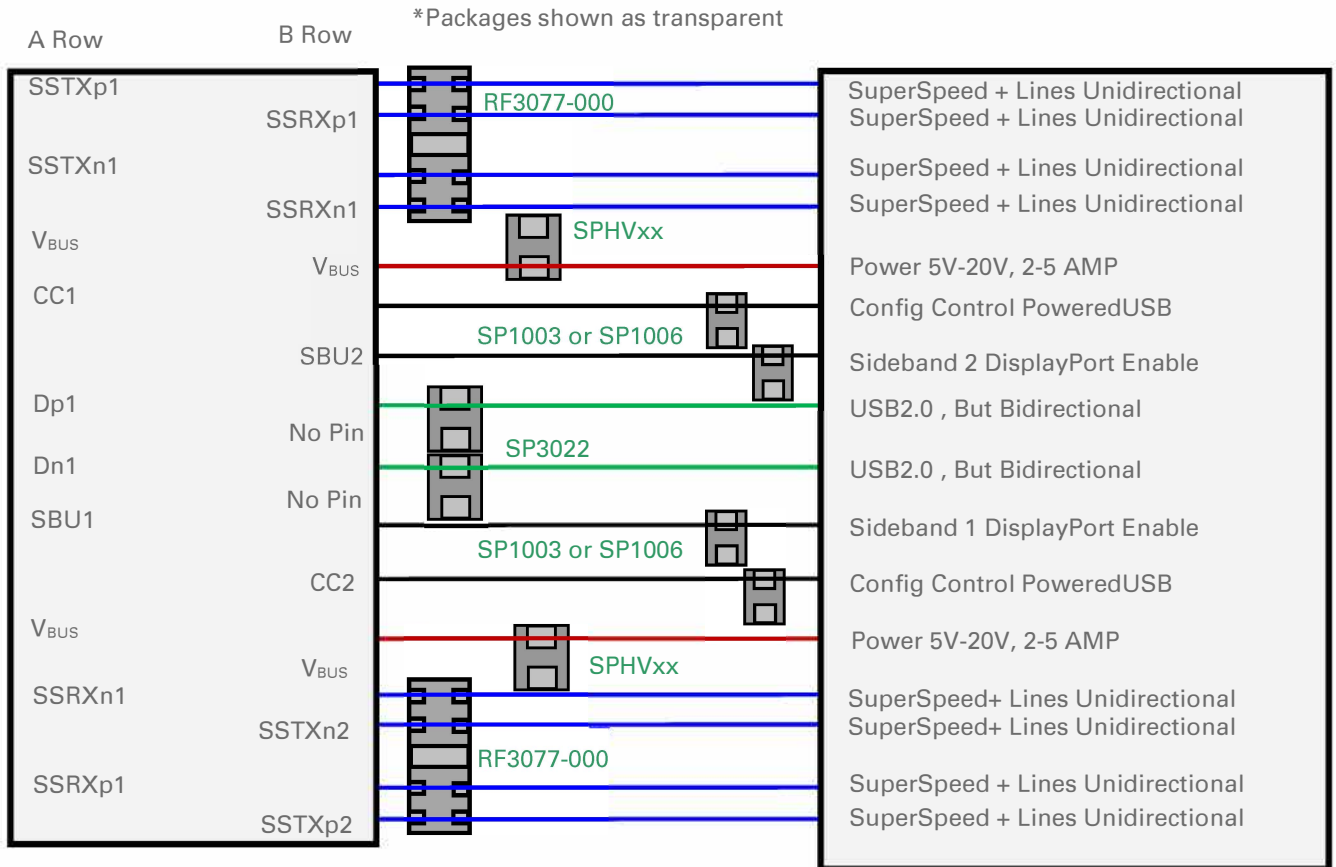
SuperSpeed+ lines operate up to 10 Gbps, so lowest unidirectional capacitance is required.

Configuration control is logic line, helps determine polarity of the connection, and voltage transfer level.

SBUx is used to support DisplayPort communication across the SuperSpeed+ lines

USB 2.0 is a bidirectional interface under Type C protocol, different than historical USB 2.0

### Application Schematic:



### Recommended TVS Diode Arrays:

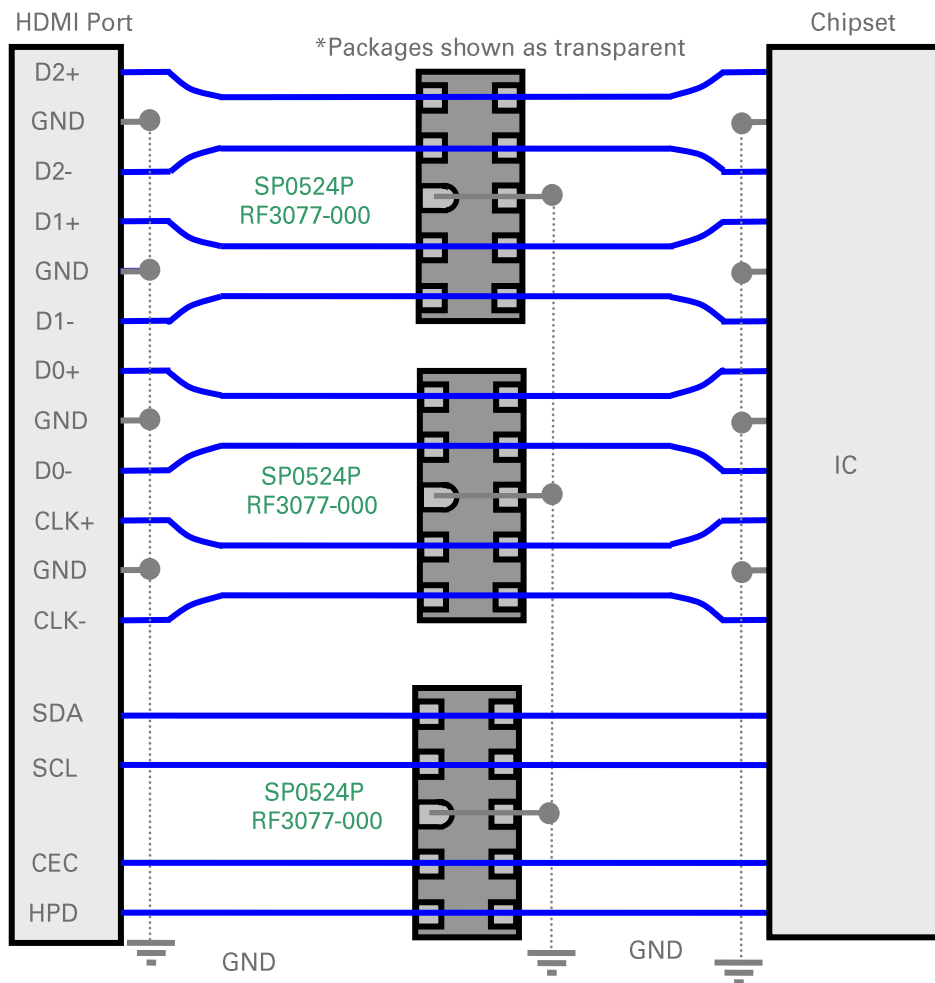
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ V <sub>R</sub> =0V | # of Channels | V <sub>RWM</sub> | Packaging           |
|-----------------|---------------------|--------------------------------------|---------------|------------------|---------------------|
| RF3077-000      | ±12kV               | 0.2pF                                | 4             | 6V               | μDFN-10 (2.5x1.0mm) |
| SP1003-01ETG    | ±30kV               | 30pF                                 | 1             | 5V               | SOD882 (0402)       |
| SP1006-01UTG    | ±30kV               | 25pF                                 | 1             | 6V               | 0201 DFN            |
| SPHVxx-01ETG    | ±15 to 30kV         | 25 to 60pF                           | 1             | 12-36V           | SOD882 (0402)       |
| SP3022-01ETG    | ±22kV               | 0.35pF                               | 1             | 5.3V             | SOD882 (0402)       |
| SP3022-01WTG    | ±22kV               | 0.35pF                               | 1             | 5.3V             | Flipchip 0201       |

## APPLICATION SPECIFIC DEVICE SELECTION HDMI

### Considerations:

- Each port has 3 differential pairs of data (i.e. D0±, D1±, D2±) plus a clock (CLK±)
  - For HDMI 1.1-1.2 the maximum throughput is a total of 4.95Gbps (1.65Gbps per lane)
  - For HDMI 1.3-1.4 the maximum throughput is a total of 10.2Gbps (3.4Gbps per lane)
  - For HDMI 2.0a the maximum throughput is a total of 18 Gbps (6.0Gbps per lane)
- To maintain the differential impedance per the HDMI Compliance Test Specification (and consequently signal integrity) a very low capacitance device must be used
- To maintain the differential impedance the designer should avoid using 90° angles and vias
  - This can be accomplished by the use of an ESD device that offers a “straight-through” routing scheme
- Requires 12 channels of protection : 8 TMDS data pairs, SDA, SCL, CEC, and HPD and the SP3012-06 (x2) could be considered as well

### Application Schematic:



### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=1.65V$ | # of Channels | $V_{RWM}$ | Packaging            |
|-----------------|---------------------|-------------------------------|---------------|-----------|----------------------|
| SP0524PUTG      | ±12kV               | 0.5pF                         | 4             | 5V        | μDFN-10 (2.5x1.0mm)  |
| RF3077-000      | ±12kV               | 0.2pF                         | 4             | 6V        | μDFN-10 (2.5x1.0mm)  |
| SP3012-06UTG    | ±12kV               | 0.5pF                         | 6             | 5V        | μDFN-14 (3.5x1.35mm) |

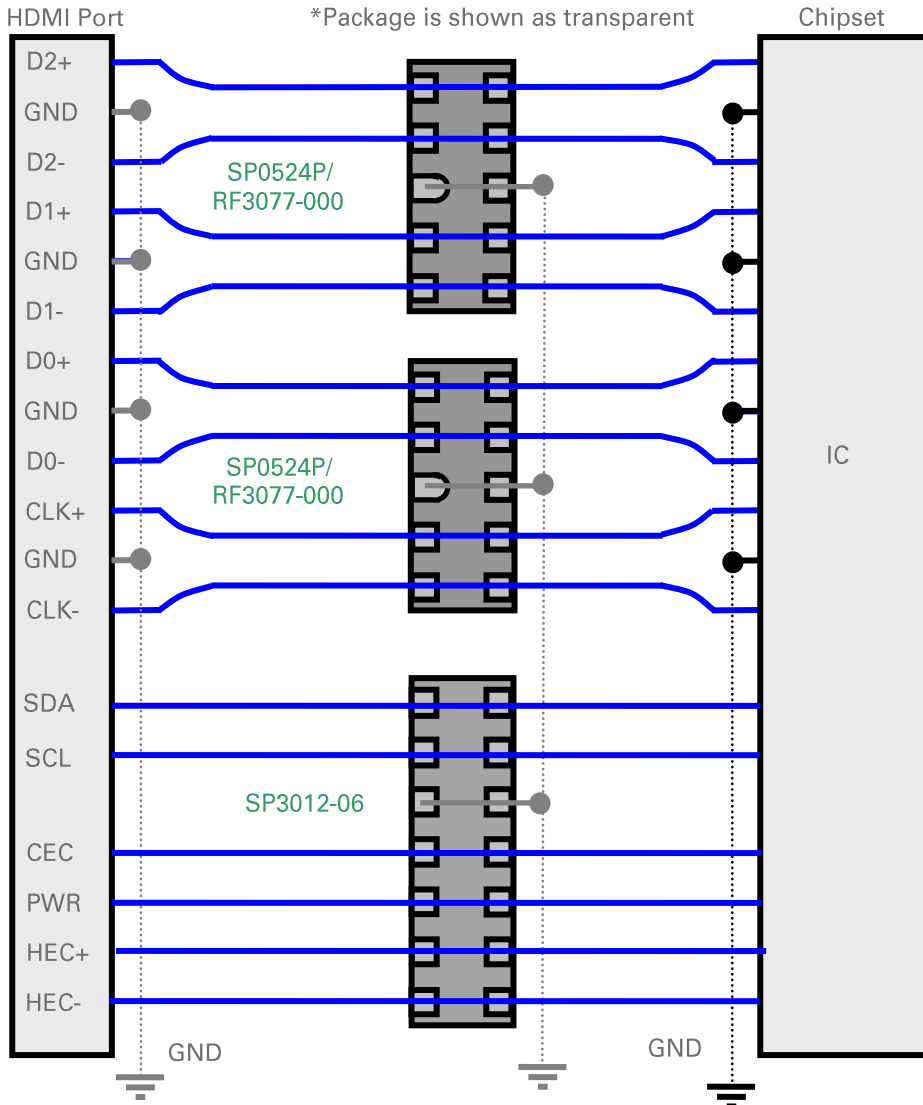
## APPLICATION SPECIFIC DEVICE SELECTION

### HDMI (Includes protection for Ethernet and 5V power)

#### Considerations:

- Same as noted on previous page except the protection scheme below includes options for protecting additional Ethernet and 5V power pins.
- Other combinations exist such as using 3x SP0524P and 1x SP3003-02UTG (for Ethernet) and many combinations using discretes

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | I/O Capacitance @<br>$V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging                    |
|-----------------|---------------------|-------------------------------|---------------|-----------|------------------------------|
| SP0524PUTG      | $\pm 12kV$          | 0.5pF                         | 4             | 5V        | $\mu$ DFN-10<br>(2.5x1.0mm)  |
| RF3077-000      | $\pm 12kV$          | 0.2pF                         | 4             | 6V        | $\mu$ DFN-10<br>(2.5x1.0mm)  |
| SP3012-06UTG    | $\pm 12kV$          | 0.5pF                         | 6             | 5V        | $\mu$ DFN-14<br>(3.5x1.35mm) |
| SP3030-01ETG    | $\pm 20kV$          | 0.5pF                         | 1             | 5V        | SOD882 (0402)                |

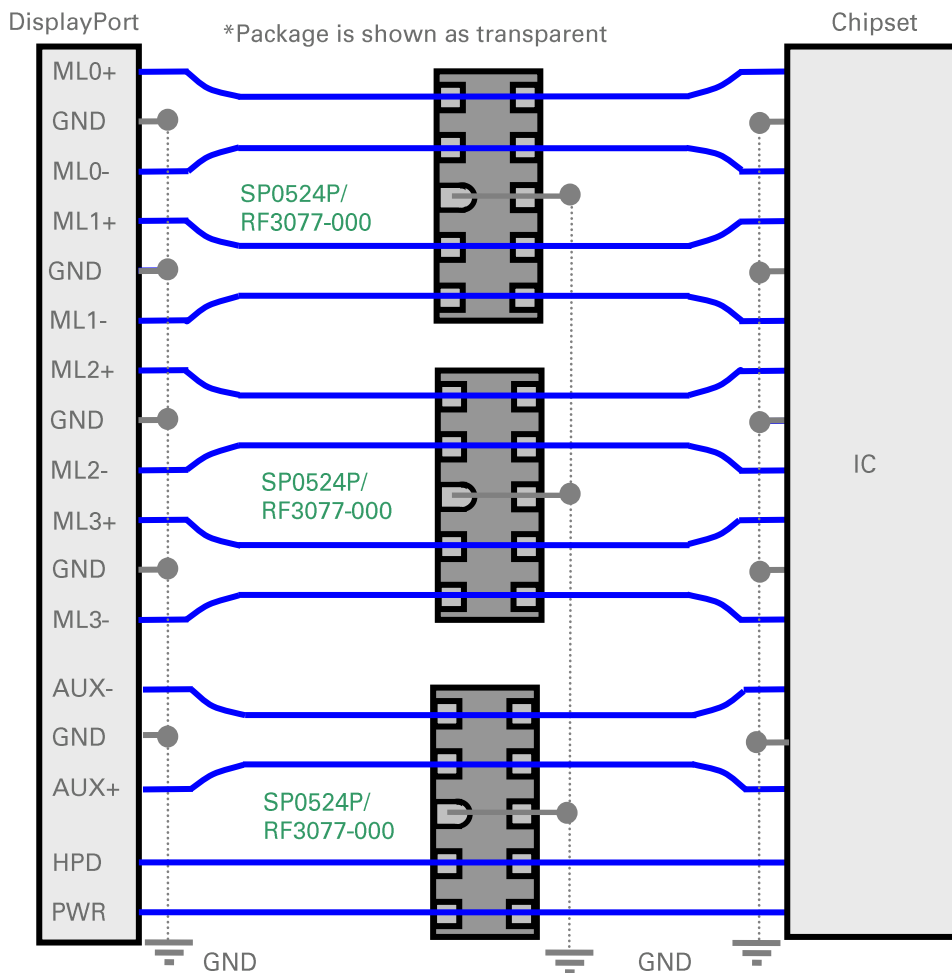
## APPLICATION SPECIFIC DEVICE SELECTION

### Display Port

#### Considerations:

- Each port has a main link which contains 4 differential pairs or lanes (i.e. ML0±, ML1±, ML2±, and ML3±)
  - The total throughput is 32.4Gbps or 8.1Gbps per lane
  - The clock signal is embedded in the lanes and does not exist separately as in HDMI
  - There is also an auxiliary channel (AUX±), hot plug detect (HPD), and power pin (PWR) as well.
- To maintain the differential impedance (and consequently signal integrity) a very low capacitance device must be used
  - To maintain the differential impedance the designer should avoid using 90° angles and vias
  - This can be accomplished by the use of an ESD device that offers a “straight-through” routing scheme
- Requires 12 channels of protection per port (ML0±, ML1±, ML2±, ML3±, AUX±, HPD, and PWR) and 2, SP3012-06UTG would be another option

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging            |
|-----------------|---------------------|----------------------------|---------------|-----------|----------------------|
| SP0524PUTG      | ±12kV               | 0.5pF                      | 4             | 5V        | μDFN-10 (2.5x1.0mm)  |
| RF3077-000      | ±12kV               | 0.2pF                      | 4             | 6V        | μDFN-10 (2.5x1.0mm)  |
| RF3920-000      | ±22kV               | 0.3pF                      | 1             | 6V        | SOD882 (0402)        |
| SP3012-06UTG    | ±12kV               | 0.5pF                      | 6             | 5V        | μDFN-14 (3.5x1.35mm) |

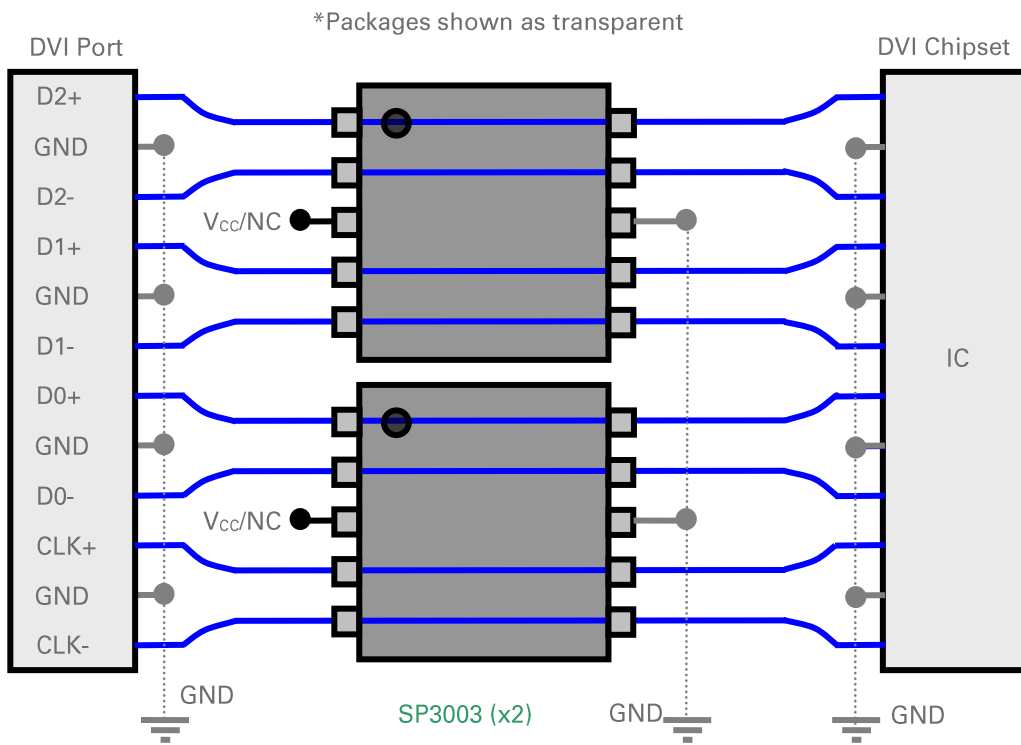


## APPLICATION SPECIFIC DEVICE SELECTION DVI (Digital Video Interface)

### Considerations:

- A DVI port may have single or dual link capability
  - Each link has 3 differential lanes of data (i.e. D0±, D1±, D2±) plus a clock (CLK±)
  - For single link, the maximum throughput can approach a total of 4.95Gbps or 1.65Gbps per lane
  - For dual link, the maximum throughput can approach a total of 8Gbps or 2.67Gbps per lane
- To maintain signal integrity a very low capacitance device must be used
- To maintain the differential impedance the designer should avoid using 90° angles and vias
  - This can be accomplished by the use of an ESD device that offers a “straight-through” routing scheme
- Requires 8 channels of protection per port (D0±, D1±, D2±, CLK±) and the V<sub>CC</sub> should not be connected if backdrive is a concern

### Application Schematic:



### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | I/O Capacitance @ V <sub>R</sub> =1.65V | # of Channels | V <sub>RWM</sub> | Packaging           |
|-----------------|---------------------|---|---------------|------------------|---------------------|
| SP3003-04ATG    | ±8kV                | 0.65pF                                  | 4             | 6V               | MSOP-10             |
| SP3003-08ATG    | ±8kV                | 0.65pF                                  | 8             | 6V               | MSOP-10             |
| SP0524PUTG      | ±12kV               | 0.5pF                                   | 4             | 5V               | μDFN-10 (2.5x1.0mm) |

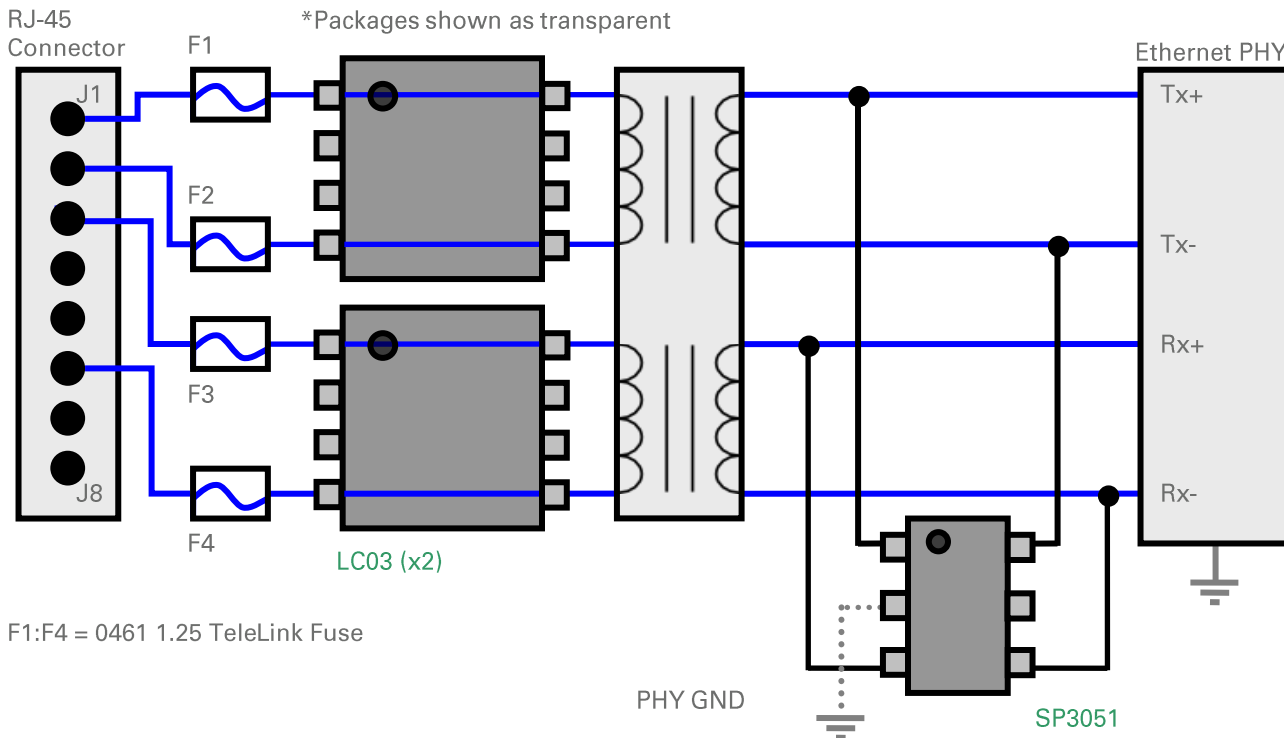
## APPLICATION SPECIFIC DEVICE SELECTION

### Ethernet, Intra-building Lightning Immunity (GR-1089) Non-PoE

#### Considerations:

- 10/100/1000 relates to the data rate in Mbps (i.e. 10Mbps, 100Mbps, and 1000Mbps)
  - For 10 Base-T, data is transmitted over 2 UTP (unshielded twisted pairs) using a 10MHz clock
  - For 100 Base-TX, data is transmitted over 2 UTP using a 125MHz clock
  - For 1000 Base-T data is transmitted over 4 UTP using a 125MHz clock
  - For these data rates the parasitic capacitance needs to be taken into account to preserve signal integrity (i.e. rate and reach capabilities)
- The 4 data lines below (Tx± and Rx±) are being protected against intra-building (i.e. 100A,  $t_r=2/10\mu s$ ) lightning transients by a two-stage protection scheme
- 1000Mbps Ethernet (or 1GbE) will require 8 channels of protection for the 4 differential pair so the below scheme should be replicated for the remaining 2 data pair

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_r=8/20\mu s$ ) | I/O to I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging                |
|-----------------|---------------------|-------------------------------|-----------------------------------|---------------|-----------|--------------------------|
| LC03-3.3BTG     | $\pm 30kV$          | 150A                          | 4.5pF                             | 2             | 3.3V      | SOIC-8                   |
| SP3051-04HTG    | $\pm 30kV$          | 20A                           | 2.0pF                             | 4             | 6V        | SOT23-6                  |
| SRV05-4HTG      | $\pm 20kV$          | 10A                           | 1.2pF                             | 4             | 6V        | SOT23-6                  |
| SP2504NUTG      | $\pm 30kV$          | 20A                           | 2.0pF                             | 4             | 2.5V      | $\mu$ DFN-10 (2.6x2.6mm) |
| SP2574NUTG      | $\pm 30kV$          | 40A                           | 5.0pF                             | 4             | 2.5V      | $\mu$ DFN-10 (3.0x2.0mm) |
| SP3304NUTG      | $\pm 30kV$          | 20A                           | 2.0pF                             | 4             | 3.3V      | $\mu$ DFN-10 (2.6x2.6mm) |
| SP4044-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 2.8V      | MSOP-10                  |
| SP4045-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 3.3V      | MSOP-10                  |

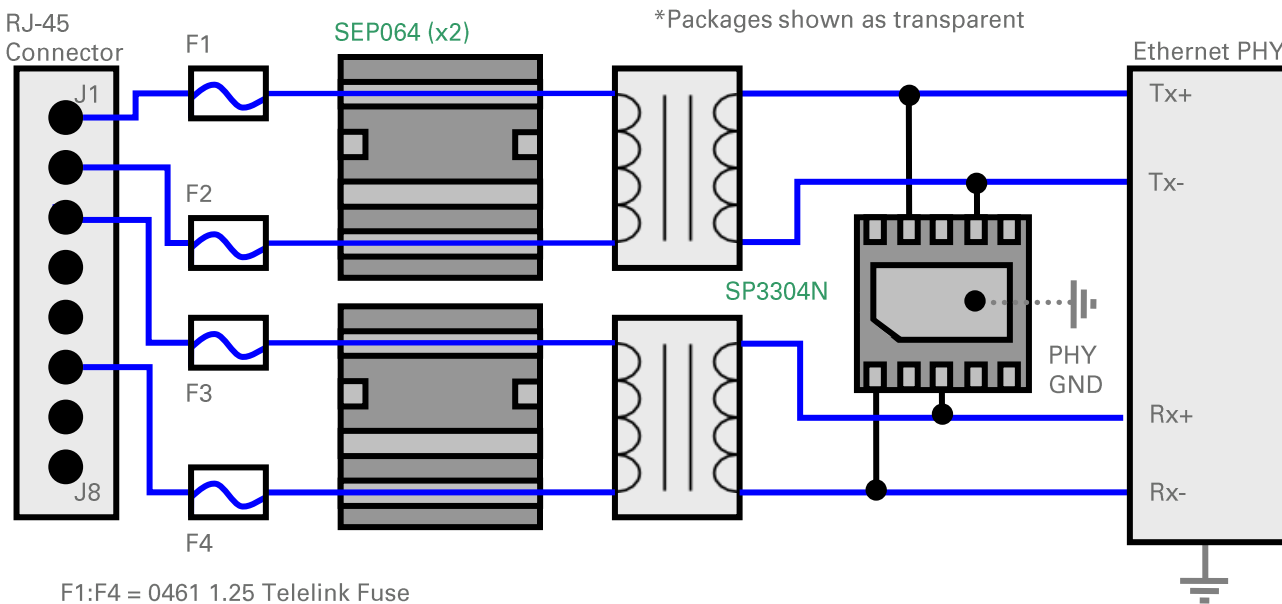
## APPLICATION SPECIFIC DEVICE SELECTION

### Ethernet, Inter-building Lightning Immunity (GR-1089)

#### Considerations:

- 10/100/1000 relates to the data rate in Mbps (i.e. 10Mbps, 100Mbps, and 1000Mbps)
  - For 10 Base-T, data is transmitted over 2 UTP (unshielded twisted pairs) using a 10MHz clock
  - For 100 Base-TX, data is transmitted over 2 UTP using a 125MHz clock
  - For 1000 Base-T data is transmitted over 4 UTP using a 125MHz clock
  - For these data rates the parasitic capacitance needs to be taken into account to preserve signal integrity (i.e. rate and reach capabilities)
- The 4 data lines below are being protected against inter-building (i.e. worst case 500A,  $t_p=2/10\mu s$ ) lightning transients by a two-stage protection scheme. The 4 channel, SP2504N or SP3304N should be selected based on the operating voltage of the PHY and if discrete devices are preferred the SP4020 and SP4021 Series are ideal.
- The standoff voltage of the SEP Series device will be dictated by the use of PoE. If PoE is present the SEP0640 should be used; otherwise, the SEP0080 is ok for non-PoE applications. (Note: Higher voltage options are available for atypical PoE voltages.) Also, PoE applications will require inter-powering pair protection since surges are applied between the center taps (Mode A and Mode B power connections are surged)
- 1000Mbps Ethernet (or 1GbE) will require 8 channels of protection for the 4 differential pair so the below scheme should be replicated for the remaining 2 data pair

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_p=8/20\mu s$ ) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging                |
|-----------------|---------------------|-------------------------------|----------------------------|---------------|-----------|--------------------------|
| SP2504NUTG      | $\pm 30kV$          | 20A                           | 2.0pF                      | 4             | 2.5V      | $\mu$ DFN-10 (2.6x2.6mm) |
| SP2574NUTG      | $\pm 30kV$          | 40A                           | 5.0pF                      | 4             | 2.5V      | $\mu$ DFN-10 (3.0x2.0mm) |
| SP3304NUTG      | $\pm 30kV$          | 20A                           | 2.0pF                      | 4             | 3.3V      | $\mu$ DFN-10 (2.6x2.6mm) |
| SP4044-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                      | 4             | 2.8V      | MSOP-10                  |
| SP4045-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                      | 4             | 3.3V      | MSOP-10                  |
| SP4020-01FTG    | $\pm 30kV$          | 30A                           | 2.5pF                      | 1             | 3.3V      | SOD323 (0805)            |
| SP4021-01FTG    | $\pm 30kV$          | 25A                           | 2.5pF                      | 1             | 5V        | SOD323 (0805)            |

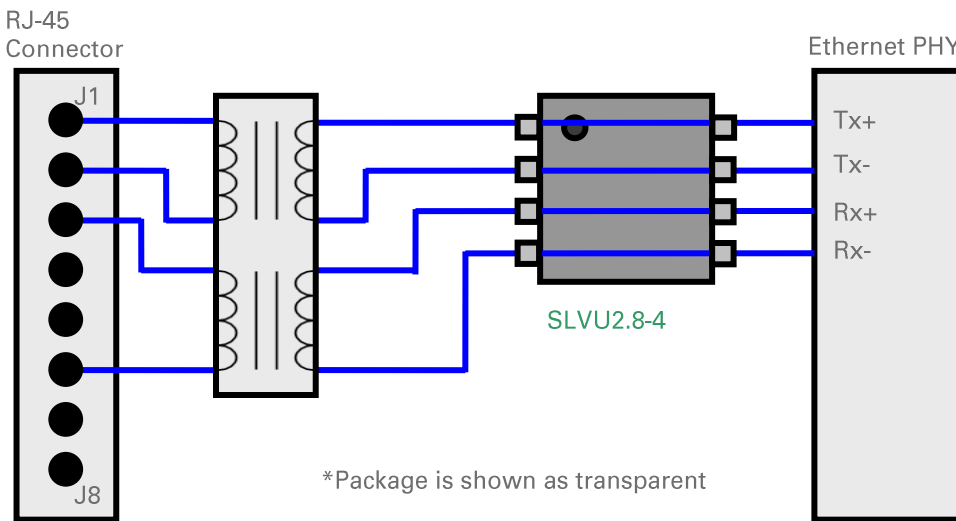
## APPLICATION SPECIFIC DEVICE SELECTION

### Ethernet, Tertiary Only Lightning Immunity (General)

#### Considerations:

- 10/100/1000 relates to the data rate in Mbps (i.e. 10Mbps, 100Mbps, and 1000Mbps)
  - For 10 Base-T, data is transmitted over 2 UTP (unshielded twisted pairs) using a 10MHz clock
  - For 100 Base-TX, data is transmitted over 2 UTP using a 125MHz clock
  - For 1000 Base-T data is transmitted over 4 UTP using a 125MHz clock
  - For these data rates the parasitic capacitance needs to be taken into account to preserve signal integrity (i.e. rate and reach capabilities)
- Some designers choose to use a robust transformer in their design to act as the first line of protection against an incoming surge event. This is usually done to minimize the parasitic capacitance on the data line and to save on the cost of the secondary protector (i.e. line side)
- Using such a technique will require a robust PHY side protection device and one such option is the SLVU2.8-4 shown below. It should be noted that this device will only provide differential protection between the data pairs.
- If longitudinal and differential protection are required, the SP3051 or SP4060/SP2504N/SP3304N can be considered as alternatives for an array format. For discrete implementations, the SP4020 and SP4021 Series are ideal.
- Protection for 10 /100Mbps is shown below. For 1000Mbps (or 1GbE) interfaces, two SLVU2.8-4BTG devices are required

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning (t <sub>p</sub> =8/20μs) | I/O Capacitance @ V <sub>R</sub> =0V | # of Channels | V <sub>RWM</sub> | Packaging           |
|-----------------|---------------------|------------------------------------|--------------------------------------|---------------|------------------|---------------------|
| SLVU2.8-4BTG    | ±30kV               | 40A                                | 2.0pF                                | 4             | 2.8V             | SOIC-8              |
| SLVU2.8-8BTG    | ±30kV               | 30A                                | 3.0pF                                | 8             | 2.8V             | SOIC-8              |
| SP4060-08ATG    | ±30kV               | 20A                                | 2.2pF                                | 8             | 2.5V             | MSOP-8              |
| SP4065-08ATG    | ±30kV               | 20A                                | 2.2pF                                | 8             | 3.3V             | MSOP-8              |
| SP2504NUTG      | ±30kV               | 20A                                | 2.0pF                                | 4             | 2.5V             | μDFN-10 (2.6x2.6mm) |
| SP2574NUTG      | ±30kV               | 40A                                | 5.0pF                                | 4             | 2.5V             | μDFN-10 (3.0x2.0mm) |
| SP3304NUTG      | ±30kV               | 20A                                | 2.0pF                                | 4             | 3.3V             | μDFN-10 (2.6x2.6mm) |
| SP4044-04ATG    | ±30kV               | 24A                                | 1.5pF                                | 4             | 2.8V             | MSOP-10             |
| SP4045-04ATG    | ±30kV               | 24A                                | 1.5pF                                | 4             | 3.3V             | MSOP-10             |
| SP4020-01FTG    | ±30kV               | 30A                                | 2.5pF                                | 1             | 3.3V             | SOD323 (0805)       |
| SP4021-01FTG    | ±30kV               | 25A                                | 2.5pF                                | 1             | 5V               | SOD323 (0805)       |

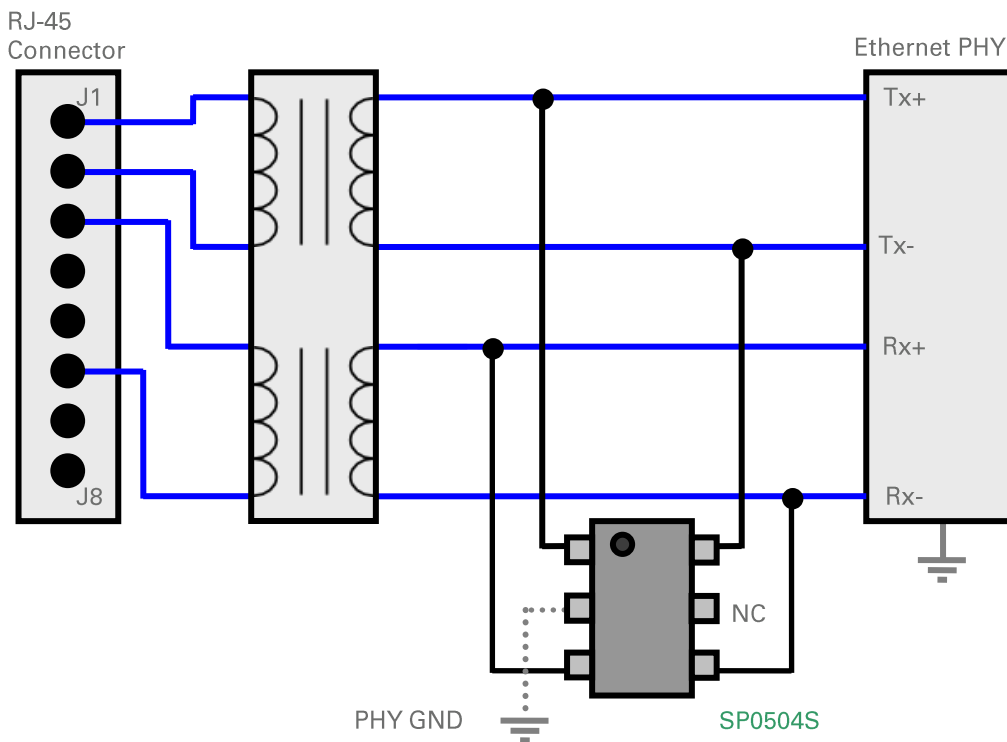
## APPLICATION SPECIFIC DEVICE SELECTION

### Ethernet (ESD only)

#### Considerations:

- Some Ethernet ports only need to be protected for ESD and not for lightning induced transients
  - These are sometimes referred to as “2M” ports or 2 Meter ports that have very short CAT5 cable installations
- Parasitic capacitance should be taken into account especially for 1GbE
- The 4 data lines below (Tx± and Rx±) are being protected against ESD by a low capacitance SP0504S which is suitable for all Ethernet data rates
  - Additionally, any low capacitance SP30xx device is suitable for any “ESD only” Ethernet application
- 1000Mbps Ethernet (or 1GbE) will require 8 channels of protection for the 4 differential pair so the below scheme can be replicated or the 8 channel SP3003-08ATG can be used.

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_p=8/20\mu s$ ) | I/O Capacitance @ $V_R=1.65V$ | # of Channels | $V_{RWM}$ | Packaging |
|-----------------|---------------------|-------------------------------|-------------------------------|---------------|-----------|-----------|
| SP0504SHTG      | $\pm 12kV$          | 4.5A                          | 0.85pF                        | 4             | 6V        | SOT23-6   |
| SP3003-04XTG    | $\pm 8kV$           | 2.5A                          | 0.65pF                        | 4             | 6V        | SOT563    |
| SP3004-04XTG    | $\pm 12kV$          | 4A                            | 0.85pF                        | 4             | 6V        | SOT563    |
| SP3003-08ATG    | $\pm 8kV$           | 2.5A                          | 0.65pF                        | 8             | 6V        | MSOP-10   |
| SRV05-4HTG      | $\pm 20kV$          | 10A                           | 1.2pF                         | 4             | 6V        | SOT23-6   |

## APPLICATION SPECIFIC DEVICE SELECTION

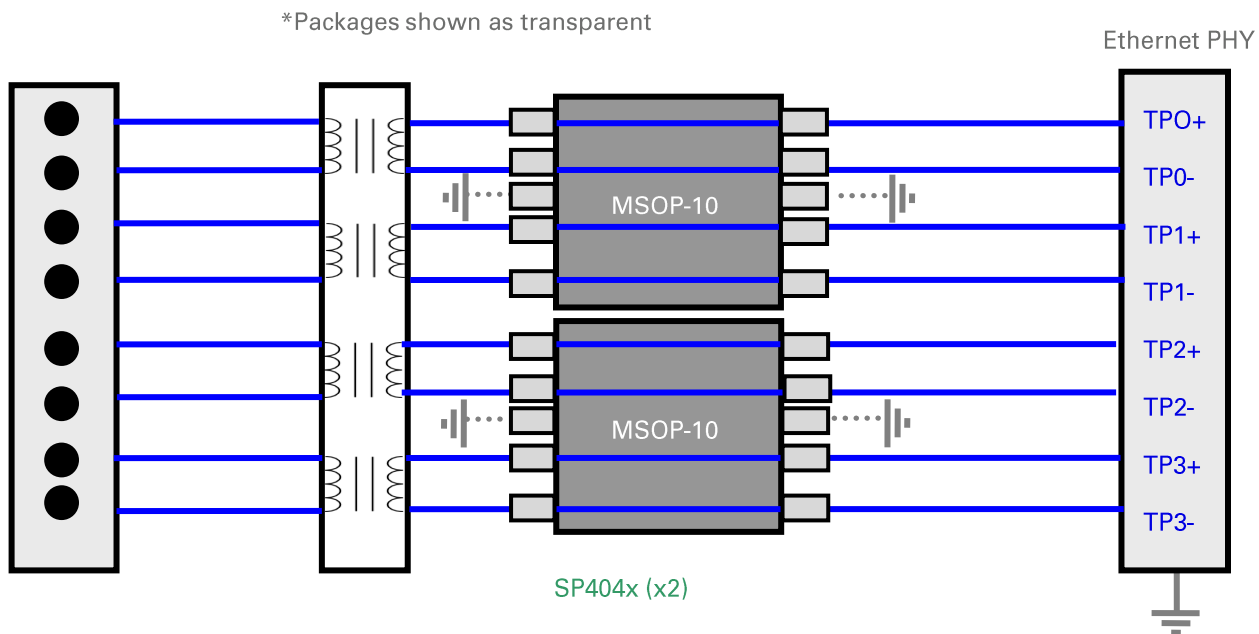
### 2.5 and 5.0 Gigabit Ethernet

2.5 and 5.0 GbE is an evolutionary step above 1 GbE speeds, using the same installed infrastructure to achieve significantly more data throughput at affordable price points. Using existing cabling, and existing PCB technology, solutions providers are able to offer faster data rates, at modest premiums to their standard 1GbE offerings. It provides an intermediary step between legacy and 10 GbE offerings.

#### Considerations:

- Increased speeds necessitate “straight thru” routing, minimizing the negative effects of stubs, and the corresponding affect on Signal Integrity
  - Tertiary protection, or PHY side protection placed after the magnetic, the protection closest to the PHY
  - To reduce Electro Magnetic Interference (EMI), some designs employ Ethernet pairs routed on the top and bottom side of the PCB
  - MSOP-10 permits “straight thru” routing and doesn’t not require “Fan In” or “Fan Out” on PCB, enhancing signal integrity
- Low capacitance permits high data rates, does not degrade signal integrity.

#### Application Schematic:



| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | I/O to I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging |
|-----------------|---------------------|-------------------------------|-----------------------------------|---------------|-----------|-----------|
| SP4044-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 2.8V      | MSOP-10   |
| SP4045-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 3.3V      | MSOP-10   |

## APPLICATION SPECIFIC DEVICE SELECTION

### xDSL, Intra-building Lightning Immunity (GR-1089) and ESD

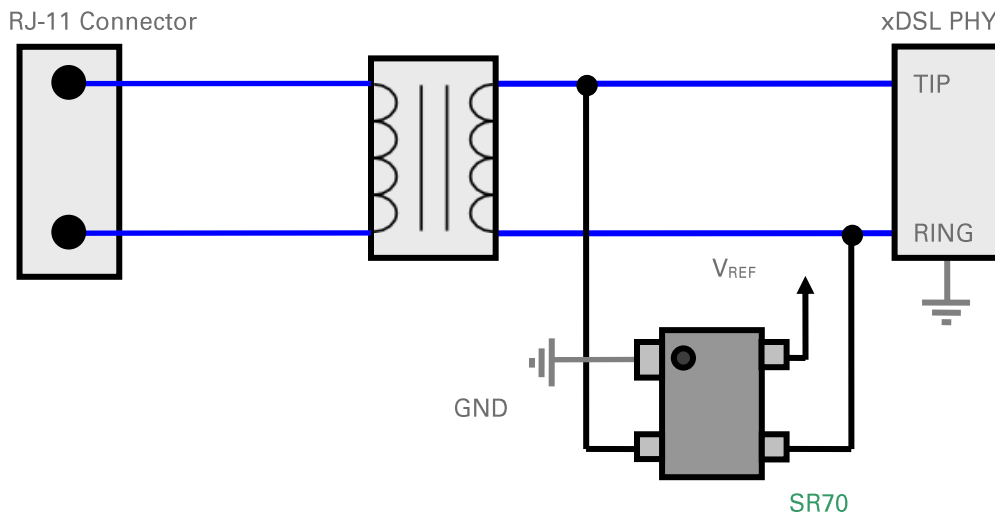
#### Considerations:

- There are many options for xDSL today including ADSLx and VDSLx all with varying data rates.

In general ADSLx runs between 8-24Mbps and VDSLx provides 50-100Mbps and at these data rates capacitance of the suppressor needs to be considered

- All implementations are done over legacy POTS wiring (TIP and RING) and the SR70 is shown below capable of protecting against intra-building (i.e. 100A,  $t_F=2/10\mu s$ ) lightning transients when situated behind the transformer
- If PHY side differential protection is needed, then the SIDACTor SDPxxxxT023G5 / SDPxxxxT023G6 series can be considered
- A line side protection device is optional and its selection will depend on the transient and whether or not the application involves a wet or dry loop

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_F=8/20\mu s$ ) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging     |
|-----------------|---------------------|-------------------------------|----------------------------|---------------|-----------|---------------|
| SR70-02CTG      | $\pm 30kV$          | 40A                           | 2.0pF                      | 2             | 70V       | SOT143        |
| SP4022-01FTG    | $\pm 30kV$          | 15A                           | 2.0pF                      | 1             | 12V       | SOD323 (0805) |
| SP4023-01FTG    | $\pm 30kV$          | 12A                           | 2.0pF                      | 1             | 15V       | SOD323 (0805) |
| SP4024-01FTG    | $\pm 30kV$          | 7A                            | 2.0pF                      | 1             | 24V       | SOD323 (0805) |

## APPLICATION SPECIFIC DEVICE SELECTION

### T1/E1/J1 Carrier

#### Isolation Requirements:

If the **LC03** device is used on the line side of the coupling transformer, then ground reference pins 2, 3, 6, and 7 should not be connected to ground.

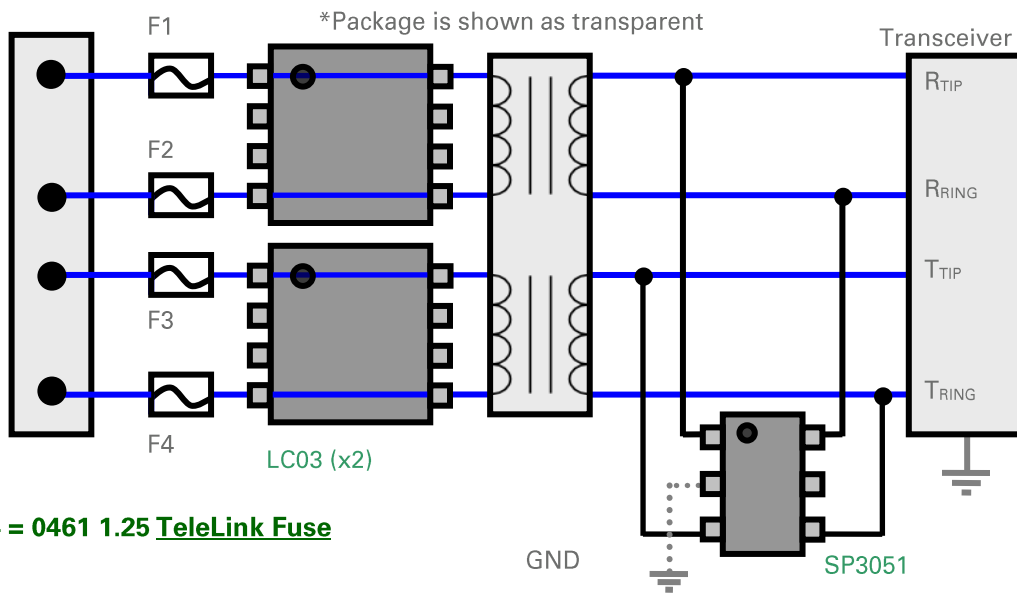
#### Power Fault Requirements:

- The TeleLink fuses F1-F4 provide overcurrent protection that complies with the GR-1089, ITU K20/21, UL60950-1 / IEC60950-1 / EN60950-1 and YD/T 950 power fault requirements.

#### Lightning Immunity Requirements:

- The 4 data lines below are protected against intra-building lightning transients (100A,  $t_P=2/10\mu s$  for up to 2 pair).
- The **LC03** diverts the majority of energy away from the transformer, but any common mode energy that does get coupled across the transformer interwinding capacitance will be diverted to GND by the SP3051. The SP3051 can be connected to ground on the PHY side of the transformer to protect against common mode transients.
- Alternatively, the SRDA05 or SRDA3.3 could be used in place of the SP3051 if a more robust device is needed. These would be the best alternatives in protection on the line side is not used.

#### Application Schematic:



**F1:F4 = 0461 1.25 TeleLink Fuse**

#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | I/O to I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging |
|-----------------|---------------------|-------------------------------|-----------------------------------|---------------|-----------|-----------|
| LC03-3.3BTG     | $\pm 30kV$          | 150A                          | 4.5pF                             | 2             | 3.3V      | SOIC-8    |
| SP03-xBTG       | $\pm 30kV$          | 150A                          | 8.0pF                             | 2             | 3.3V,6V   | SOIC-8    |
| SP3051-04HTG    | $\pm 30kV$          | 20A                           | 2.0pF                             | 4             | 6V        | SOT23-6   |
| SRDA05-4BTG     | $\pm 30kV$          | 30A                           | 4.0pF                             | 4             | 5V        | SOIC-8    |
| SRDA3.3-4BTG    | $\pm 30kV$          | 35A                           | 4.0pF                             | 4             | 3.3V      | SOIC-8    |
| SP4044-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 2.8V      | MSOP-10   |
| SP4045-04ATG    | $\pm 30kV$          | 24A                           | 1.5pF                             | 4             | 3.3V      | MSOP-10   |

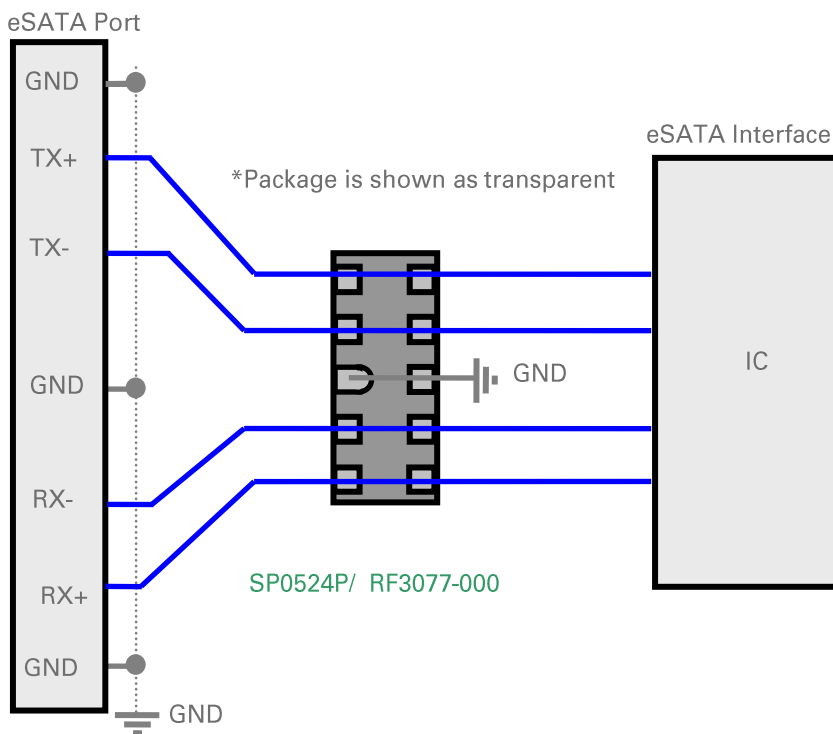


## APPLICATION SPECIFIC DEVICE SELECTION eSATA

### Considerations:

- eSATA is a subset of the SATA protocol that uses 2 differential pairs for communication
  - Four lines need to be protected per port (i.e. TX± and RX±)
  - Currently eSATA is capable of running raw data rates of 1.5Gbps (Gen 1) and 3.0Gbps (Gen 2), as well as SATA-I/O at 6.0 Gbps
- These high bus speeds require very low capacitance devices to prevent signal degradation, and to maintain the line impedance the designer should avoid using 90° angles and vias
- A single 4 channel device such as the SP0524P can be used or alternatively 4 discrete SP3030's could be used

### Application Schematic:



### Recommended TVS Diode Arrays:

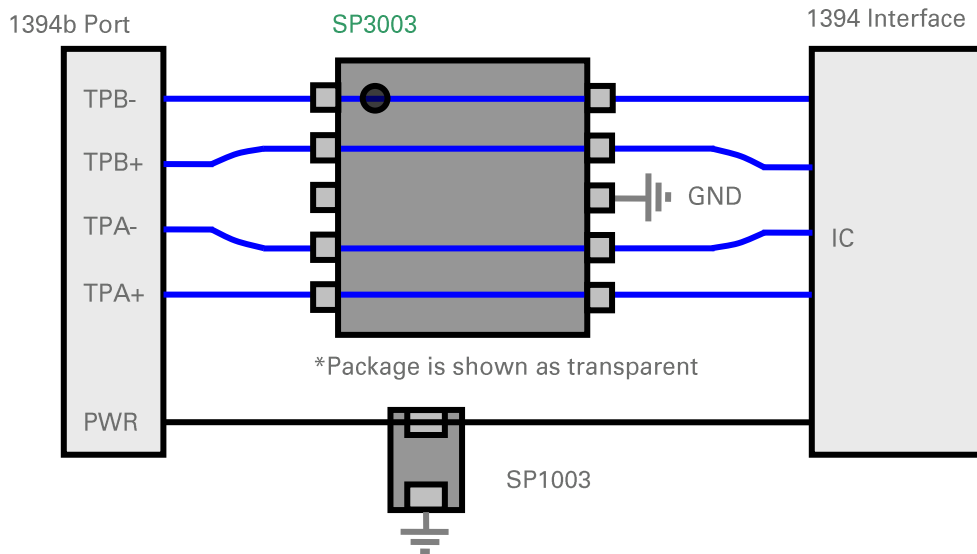
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=1.65V$ | # of Channels | $V_{RWM}$ | Packaging           |
|-----------------|---------------------|-------------------------------|---------------|-----------|---------------------|
| SP0524PUTG      | ±12kV               | 0.5pF                         | 4             | 5V        | μDFN-10 (2.5x1.0mm) |
| RF3077-000      | ±12kV               | 0.2pF                         | 4             | 6V        | μDFN-10 (2.5x1.0mm) |
| RF3920-000      | ±22kV               | 0.3pF                         | 1             | 6V        | SOD882 (0402)       |
| SP3030-01ETG    | ±20kV               | 0.5pF                         | 1             | 5V        | SOD882 (0402)       |

## APPLICATION SPECIFIC DEVICE SELECTION 1394a/b

### Considerations:

- 1394a (FireWire 400 or S400) was the original (1<sup>st</sup> generation) implementation
  - Allowed for two connectors, powered (6 pin) and unpowered (4 pin)
  - Data rates up to 400Mbps using 2 differential pair
- 1394b (FireWire 800 or S800) was the 2<sup>nd</sup> generation
  - Required a new 9 pin connector but was backwards compatible to S400
  - Data rates up to 800Mbps using 2 differential pair
- 1394b also had provisions for 1600Mbps and 3200Mbps (or S1600 and S3200)
  - Uses same 9 pin connector as S800
- S800, S1600, and S3200 require very low capacitance devices for the high speed data rates
  - Protection of 4 data lines is needed (i.e. TPB± and TPA±) and can be done with an array or with discrete low capacitance devices

### Application Schematic:



### Recommended TVS Diode Arrays:

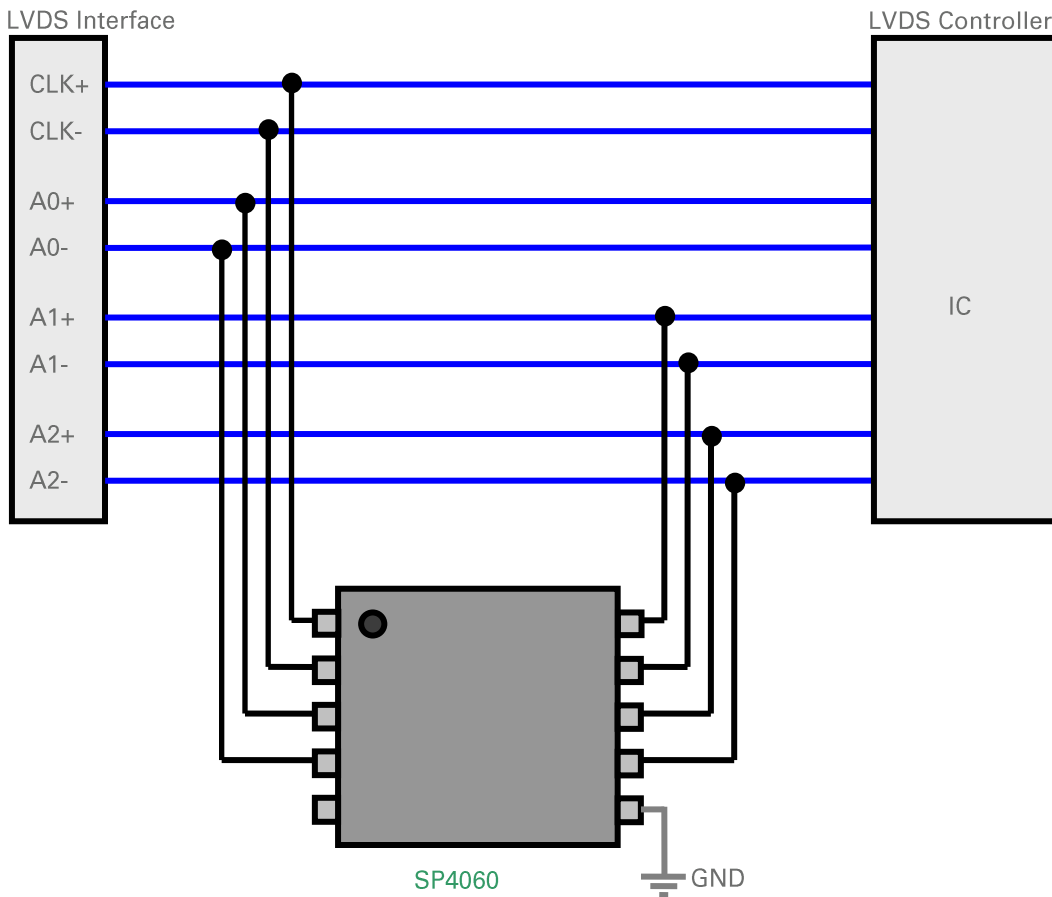
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=1.65V$ | # of Channels | $V_{RWM}$ | Packaging           |
|-----------------|---------------------|-------------------------------|---------------|-----------|---------------------|
| SP3003-04ATG    | ±8kV                | 0.65pF                        | 4             | 6V        | MSOP-10             |
| SP0524PUTG      | ±12kV               | 0.5pF                         | 4             | 5V        | uDFN-10 (2.5x1.0mm) |
| RF3077-000      | ±12kV               | 0.2pF                         | 4             | 6V        | uDFN-10 (2.5x1.0mm) |
| SP3030-01ETG    | ±20kV               | 0.5pF                         | 1             | 5V        | SOD882 (0402)       |
| SP1003-01ETG    | ±30kV               | 17pF                          | 1             | 5V        | SOD882 (0402)       |

## APPLICATION SPECIFIC DEVICE SELECTION LVDS (Low Voltage Differential Signaling)

### Considerations:

- LVDS is a low noise, low-voltage signal scheme that uses a small current (typically 3.5mA) to generate a voltage drop across a 100Ω resistor to convey information or data
  - Data rates can vary per application but the ANSI/TIA/EIA-644-A standard recommends a maximum of 655Mbps
  - The medium/high speed bus requires a low capacitance device in 1-6pF range (typically)
  - LVDS schemes will vary in terms of the total number of channels used
  - Protection of 8 data lines is shown below (i.e. CLK± and Ax±)

### Application Schematic:



### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning (t <sub>P</sub> =8/20μs) | I/O to I/O Capacitance @ V <sub>R</sub> =0V | # of Channels | V <sub>RWM</sub> | Packaging |
|-----------------|---------------------|------------------------------------|---|---------------|------------------|-----------|
| SP4060-08ATG    | ±30kV               | 20A                                | 2.2pF                                       | 8             | 2.5V             | MSOP-10   |
| SP4065-08ATG    | ±30kV               | 20A                                | 2.2pF                                       | 8             | 3.3V             | MSOP-10   |
| SP4050-12UTG    | ±30kV               | 20A                                | 5.0pF                                       | 12            | 2.5V             | uDFN-12   |
| SRV05-4HTG      | ±20kV               | 10A                                | 1.2pF                                       | 4             | 6V               | SOT23-6   |

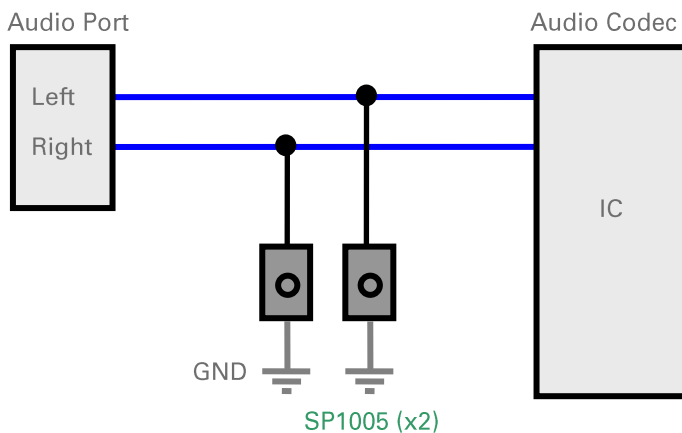
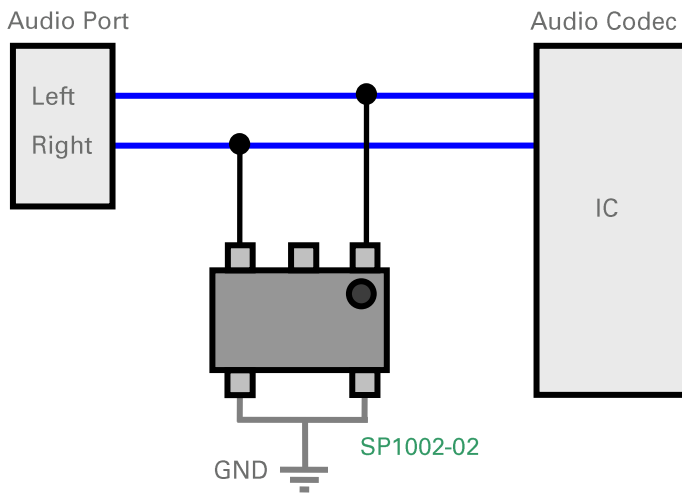
## APPLICATION SPECIFIC DEVICE SELECTION

### Audio (Speaker/Microphone)

#### Considerations:

- Audio ports typically have signals that swing above and below GND (i.e.  $\pm 2.5V$ )
  - If no DC bias is applied, a bidirectional protection device should be used as these devices will not clip the analog signal
  - Protection of 2 data lines is shown below (i.e. Left and Right) with an array and with discrete devices
- Some audio ports will bias the data bus so that the signal never swings below GND (i.e. 0-5V)
  - If a bias is applied, a unidirectional OR bidirectional protection device could be used as neither device would clip the analog signal
  - The SP1001-02XTG is a good option in this case (not shown for Left and Right but is listed below)

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_p=8/20\mu s$ ) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging       |
|-----------------|---------------------|-------------------------------|----------------------------|---------------|-----------|-----------------|
| SP1002-02JTG    | $\pm 8kV$           | 2A                            | 5pF                        | 2             | 6V        | SC70-5          |
| SP1005-01WTG    | $\pm 30kV$          | 10A                           | 30pF                       | 1             | 6V        | Flipchip (0201) |
| SPHV12-01ETG-C  | $\pm 30kV$          | 8A                            | 30pF                       | 1             | 12V       | SOD882 (0402)   |
| SP12-01WTG-C-HV | $\pm 30kV$          | 8A                            | 30pF                       | 1             | 12V       | Flipchip (0201) |
| SP1005-01ETG    | $\pm 30kV$          | 8A                            | 30pF                       | 1             | 6V        | SOD882 (0402)   |
| SP1001-02XTG    | $\pm 15kV$          | 2A                            | 12pF                       | 2             | 5.5V      | SOT553          |

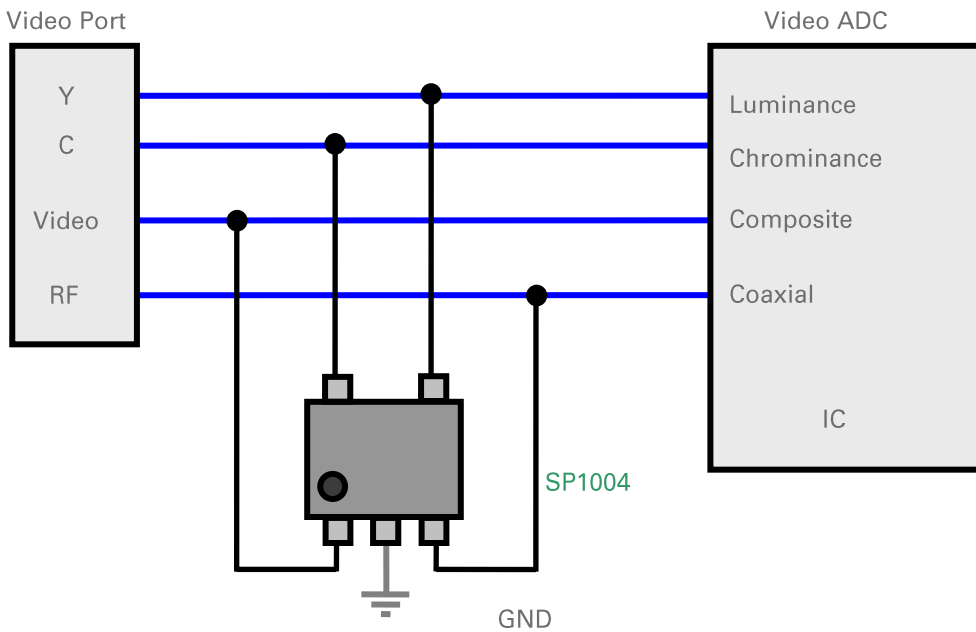
## APPLICATION SPECIFIC DEVICE SELECTION

### Analog Video

#### Considerations:

- Analog video ports typically have signals that swing above and below GND (i.e.  $\pm 2V$ )
  - A bidirectional protection device should be used as these devices will not clip the analog signal
- S-Video, Composite, and RF/Coaxial are a few of the common low-speed analog video signals in use today
  - Typical bus speeds will not exceed 5MHz so capacitance is not much of a concern
  - Protection of the four are shown below (Y, C, Video, and RF)

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_p=8/20\mu s$ ) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging       |
|-----------------|---------------------|-------------------------------|----------------------------|---------------|-----------|-----------------|
| SP1004-04VTG    | $\pm 8kV$           | 2A                            | 5pF                        | 4             | 6V        | SOT953          |
| SP1008-01WTG    | $\pm 15kV$          | 2A                            | 8pF                        | 1             | 6V        | Flipchip (0201) |
| SP1007-01WTG    | $\pm 8kV$           | 2A                            | 5pF                        | 1             | 6V        | Flipchip (0201) |
| SP1007-01ETG    | $\pm 8kV$           | 2A                            | 5pF                        | 1             | 6V        | SOD882 (0402)   |

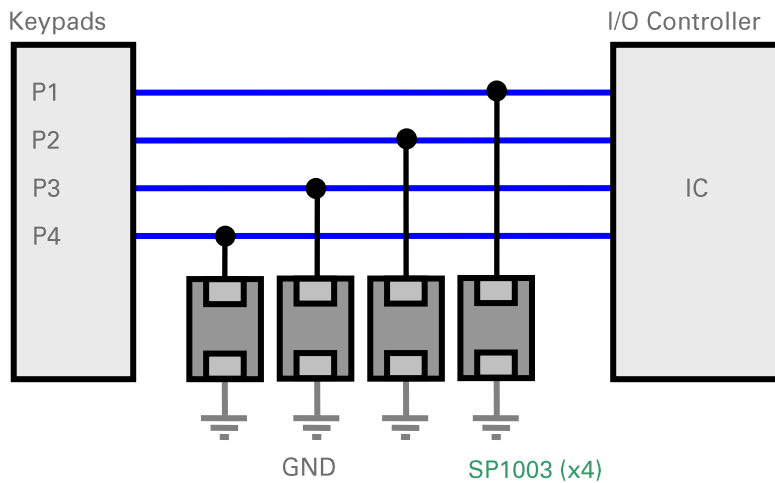
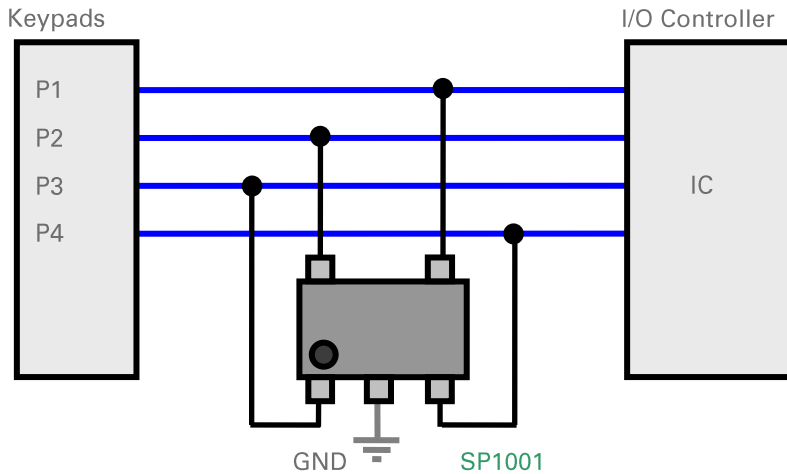
## APPLICATION SPECIFIC DEVICE SELECTION

### Keypad/Push Buttons

#### Considerations:

- Keypads and push buttons on electronic devices are particularly susceptible to ESD due to constant human interaction
  - Most are DC switches that operate at less than 5V, and for most applications capacitance will not be a concern
- The number of ports will vary with the particular application, but as an example, 4 data lines are shown below (i.e.Px)
- For space constrained applications the SP1003 or SP1005/SP1008 may be considered as they are 0402 and 0201 footprints, respectively

#### Application Schematics:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging       |
|-----------------|---------------------|-------------------------------|----------------------------|---------------|-----------|-----------------|
| SP1001-04XTG    | $\pm 15kV$          | 2A                            | 12pF                       | 4             | 6V        | SOT553          |
| SP1003-01ETG    | $\pm 30kV$          | 7A                            | 30pF                       | 1             | 5V        | SOD882 (0402)   |
| SP1005-01WTG    | $\pm 30kV$          | 10A                           | 30pF                       | 1             | 6V        | Flipchip (0201) |
| SP1008-01WTG    | $\pm 15kV$          | 2A                            | 8pF                        | 1             | 6V        | Flipchip (0201) |

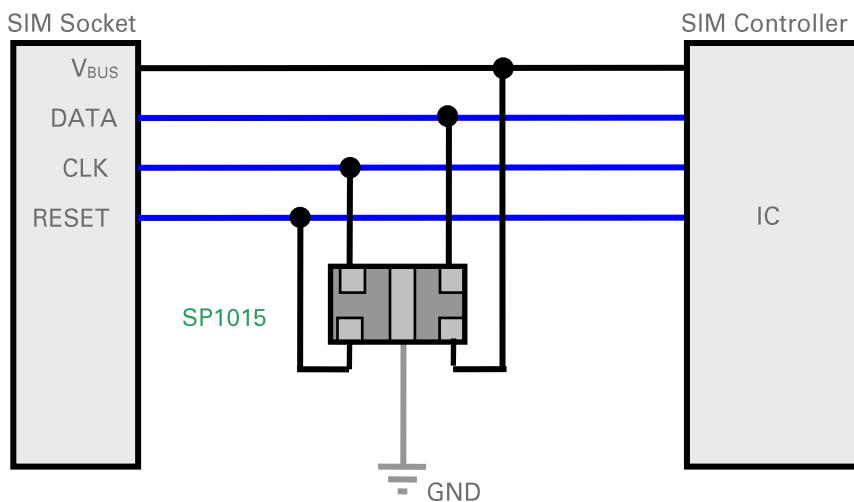
## APPLICATION SPECIFIC DEVICE SELECTION

### SIM Socket

#### Considerations:

- The SIM (Subscriber Identification Module) card has 3 data lines that are low-speed and low-voltage
  - Given the low speed of the signals, the capacitance will not be a concern
- Protection of the 3 data lines and  $V_{BUS}$  are shown below (i.e. CLK, DATA, RESET, PWR) using a single 4 channel device and alternatively discrete 0402 or 0201 devices could be used as well

#### Application Schematics:



#### Recommended TVS Diode Arrays:

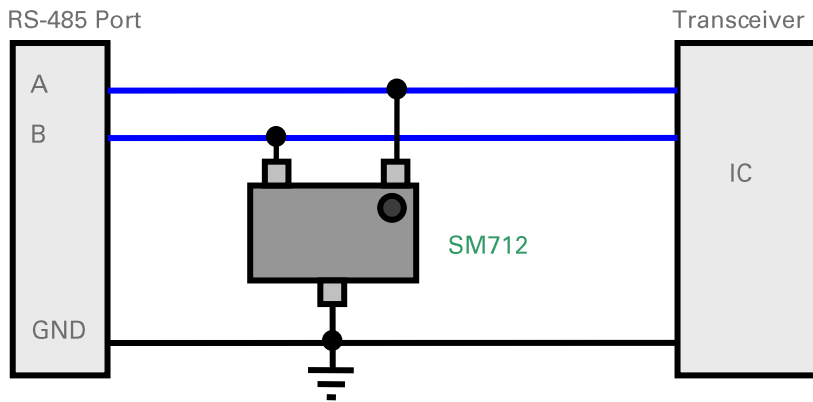
| Ordering Number | ESD Level (Contact) | I/O Capacitance @ $V_R=2.5V$ | # of Channels | $V_{RWM}$ | Packaging            |
|-----------------|---------------------|------------------------------|---------------|-----------|----------------------|
| SP1012-05WTG    | $\pm 15kV$          | 6.5pF                        | 5             | 5V        | Flipchip 0.94x0.61mm |
| SP1015-04WTG    | $\pm 15kV$          | 6.5pF                        | 5             | 5V        | Flipchip 0.93x0.53mm |
| SP3002-04UTG    | $\pm 12kV$          | 0.85pF                       | 4             | 6V        | uDFN-6 (1.6x1.6mm)   |
| SP1003-01ETG    | $\pm 30kV$          | 17pF                         | 1             | 5V        | SOD882 (0402)        |
| SP1005-01WTG    | $\pm 30kV$          | 23pF                         | 1             | 6V        | Flipchip (0201)      |
| SP1013-01WTG    | $\pm 30kV$          | 30pF                         | 1             | 5V        | Flipchip 0.54x0.29mm |
| SP1020-01WTG    | $\pm 30kV$          | 20pF                         | 1             | 5V        | 01005 Flipchip       |

## APPLICATION SPECIFIC DEVICE SELECTION RS-485

### Considerations:

- There are numerous implementations and applications of RS-485
  - Most applications are multipoint and involve two wires (i.e. A and B)
  - Depending on cable length, data rates can vary from 100kbps- 20Mbps
  - Signaling is assymetrical going from -7V to +12V
- The SM712 shown below was designed specifically for RS-485 consisting of 2 channels with a 12V and 7V standoff voltage in the positive and negative direction , respectively, to match the signal levels of the bus.
- To provide only differential protection between A and B, the GND connection can be removed from the SM712 but is obviously still connected between the two end points.

### Application Schematic:



### Recommended TVS Diode Arrays:

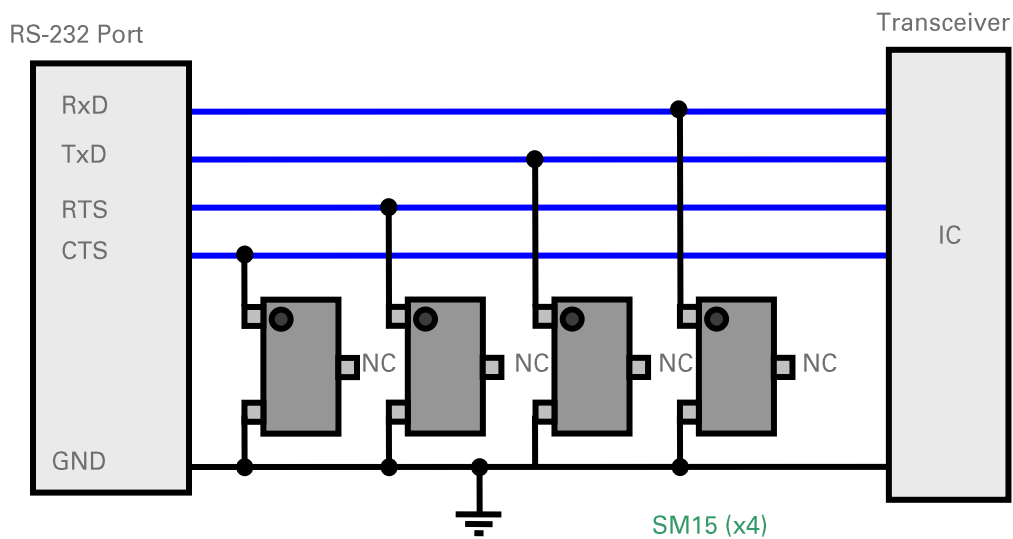
| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | MAX I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$  | Packaging |
|-----------------|---------------------|-------------------------------|--------------------------------|---------------|------------|-----------|
| SM712-02HTG     | $\pm 30kV$          | 17A                           | 75pF                           | 2             | +12V / -7V | SOT23-3   |



## APPLICATION SPECIFIC DEVICE SELECTION RS-232

### Considerations:

- There are numerous implementations and applications of RS-232
  - Many applications use just 3 wires: transmit data (TxD), receive data (RxD) and, ground; however, some installations also include RTS (Request to Send) and CTS (Clear to Send) to control the data flow. This is the example shown below.
  - Depending on cable length, data rates can vary from roughly a few kbps up to 100kbps
  - Signaling is determined by the line driver being used but in most cases 12-15V is the maximum
- The SM15 shown below will standoff off up to 15V and can be used in a bidirectional manner to achieve a 15V standoff in both directions.



### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | MAX I/O to I/O Capacitance @ $V_R=0V$ | # of Channels | $V_{RWM}$ | Packaging     |
|-----------------|---------------------|-------------------------------|---------------------------------------|---------------|-----------|---------------|
| SM15-02HTG      | $\pm 30kV$          | 17A                           | 75pF                                  | 2             | 15V       | SOT23-3       |
| SPHV12-01ETG-C  | $\pm 30kV$          | 5A                            | 46pF                                  | 1             | 15V       | SOD882 (0402) |

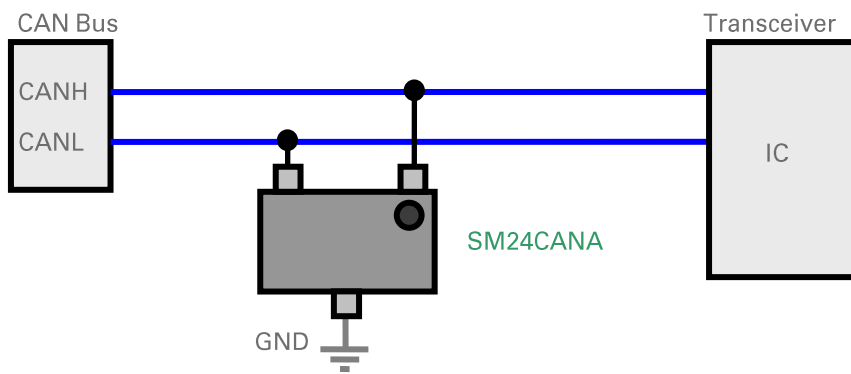
## APPLICATION SPECIFIC DEVICE SELECTION

### CAN Bus

#### Considerations:

- There are numerous implementations and applications of a CAN bus
  - Most applications involve two wires (i.e. CANH and CANL)
  - Depending on cable length, data rates can vary from 10kbps-1Mbps
  - The common mode voltage can differ in the particular application from -2V to 7V or up to -12V to 12V. The latter case is shown below were the SM24CANA can withstand up to 24V in either direction (i.e. bidirectional)
- Nonetheless, every application should be evaluated thoroughly before using the recommended devices below
- For applications, that will not exceed 6V in either direction, the SP1002-02JTG can be considered.

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning ( $t_P=8/20\mu s$ ) | I/O Capacitance @ $V_R=2.5V/0V$ | # of Channels | $V_{RWM}$ | Packaging |
|-----------------|---------------------|-------------------------------|---------------------------------|---------------|-----------|-----------|
| SM24CANA-02HTG  | $\pm 24kV$          | 3A                            | 11pF                            | 2             | 24V       | SOT23-3   |
| SM24CANB-02HTG  | $\pm 30kV$          | 10A                           | 30pF                            | 2             | 24V       | SOT23-3   |

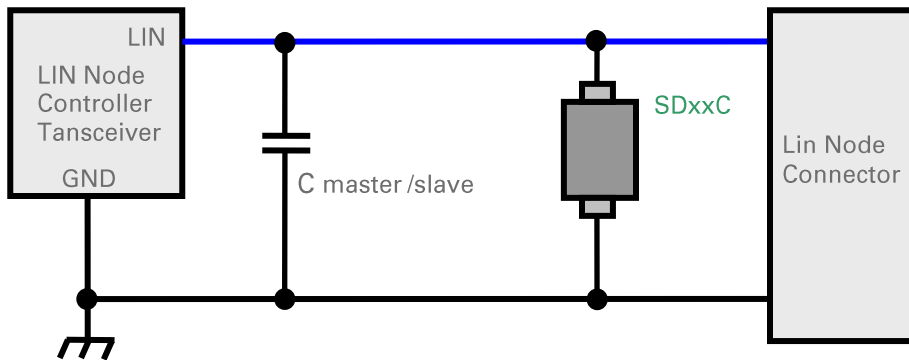
## APPLICATION SPECIFIC DEVICE SELECTION

### LIN Bus

#### Considerations:

- There are numerous implementations and applications of a LIN bus implementation
  - Flat topology – one master node and up to 16 slave nodes
  - The data bus has only one conductor, and one connection to ground
  - The length of the bus can be up to 40m; the data rate is limited to 19.2kbps
  - The common mode voltage can differ in the particular application up to 18V. For lower voltage implementations, the SD15C should be used; for higher voltage installations, the SD24C should be used.
- Every application should be evaluated thoroughly before finalizing the use of the recommended device below

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Lightning (t <sub>P</sub> =8/20μs) | I/O Capacitance @ V <sub>R</sub> =0V | # of Channels | V <sub>RWM</sub> | Packaging     |
|-----------------|---------------------|------------------------------------|--------------------------------------|---------------|------------------|---------------|
| SD15C-01FTG     | ±30kV               | 12A                                | 75pF                                 | 1             | 15V              | SOD323 (0805) |
| SD24C-01FTG     | ±30kV               | 7A                                 | 50pF                                 | 1             | 24V              | SOD323 (0805) |

## APPLICATION SPECIFIC DEVICE SELECTION

### Touchscreen

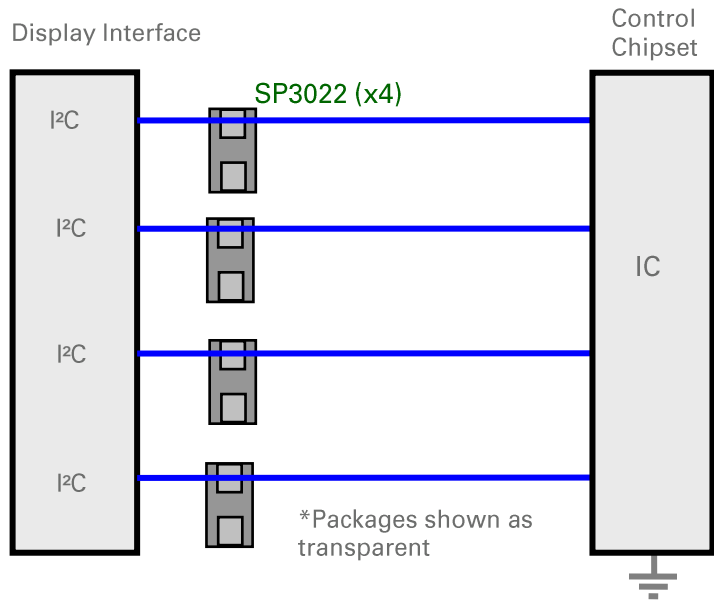
#### Considerations:

- There are many different types of touchscreens (i.e. resistive, capacitive, optical, etc) and each may require unique protection schemes

The protection scheme shown below is for a touchscreen interface that requires 4 channels of protection

Many device options exist but the ones shown below provide robust ESD protection in small form factor packages with a minimal package height that provide design flexibility

#### Application Schematic:



#### Recommended TVS Diode Arrays:

| Ordering Number | ESD Level (Contact) | Line Capacitance @ V <sub>R</sub> =2.5V | # of Channels | V <sub>RWM</sub> | Packaging       |
|-----------------|---------------------|---|---------------|------------------|-----------------|
| SP3022-01ETG    | ±22kV               | 0.35pF                                  | 1             | 5.3V             | SOD882 (0402)   |
| SP3022-01WTG    | ±22kV               | 0.35pF                                  | 1             | 5.3V             | 0201 Flipchip   |
| SP1005-01WTG    | ±30kV               | 30pF                                    | 1             | 6V               | Flipchip (0201) |
| SP12-01WTG-C-HV | ±30kV               | 30pF                                    | 1             | 12V              | Flipchip (0201) |
| SP24-01WTG-C-HV | ±18kV               | 17pF                                    | 1             | 24V              | Flipchip (0201) |
| SPHV12-01ETG    | ±30kV               | 60pF                                    | 1             | 12V              | SOD882 (0402)   |
| SPHV24-01ETG    | ±24kV               | 32pF                                    | 1             | 24V              | SOD882 (0402)   |

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