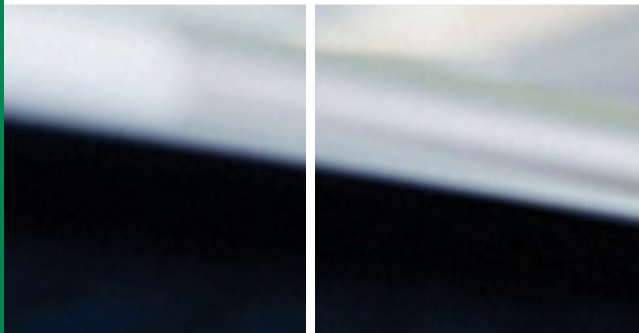
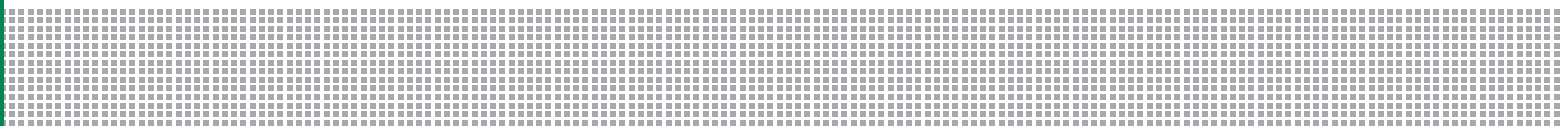




ESD

Electrostatic Discharge (ESD) Protection Design Guide



Expertise Applied | Answers Delivered

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 _{RWM}	Lightning (t _p =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	SP0504BAHTG
						SC70-5	SP0504BAJTG
					5	SOT23-6	SP0505BAHTG
						SC70-6	SP0505BAJTG
					6	MSOP-8	SP0506BAATG
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 _{RWM}	Lightning (t _r =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 0.94x0.61mm	SP1012-05WTG
SP1013	±30kV	30pF	5V	8A	1	Flipchip 0.54x0.29mm	SP1013-01WTG
SP1014	±12kV	6pF	5V	2A	1	Flipchip 0.54x0.29mm	SP1014-01WTG
SP1015	±20kV	5pF	5V	2A	4	Flipchip 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) 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 _{RWM}	Lightning (t _p =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 _{RWM}	Lightning (t _p =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
						MSOP-10	SP3003-04ATG
					8	MSOP-10	SP3003-08ATG
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 _{RWM}	Lightning (t _p =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

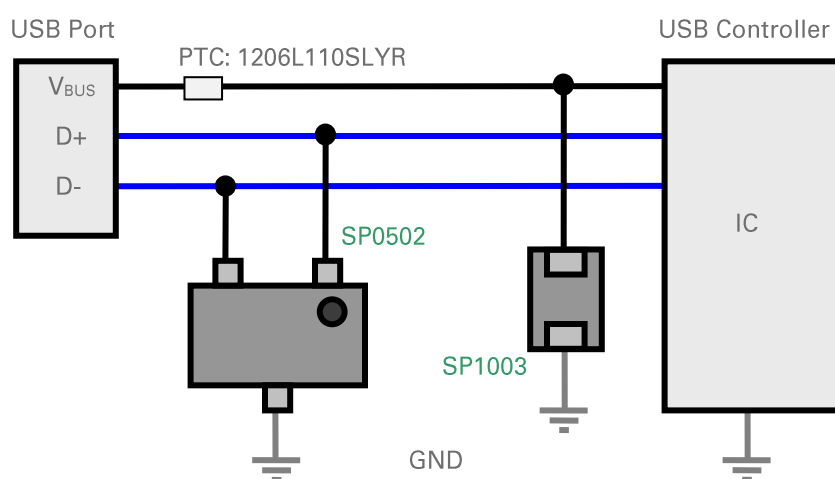
APPLICATION SPECIFIC DEVICE SELECTION

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 $\pm$)
 - 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 $\pm$ 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)

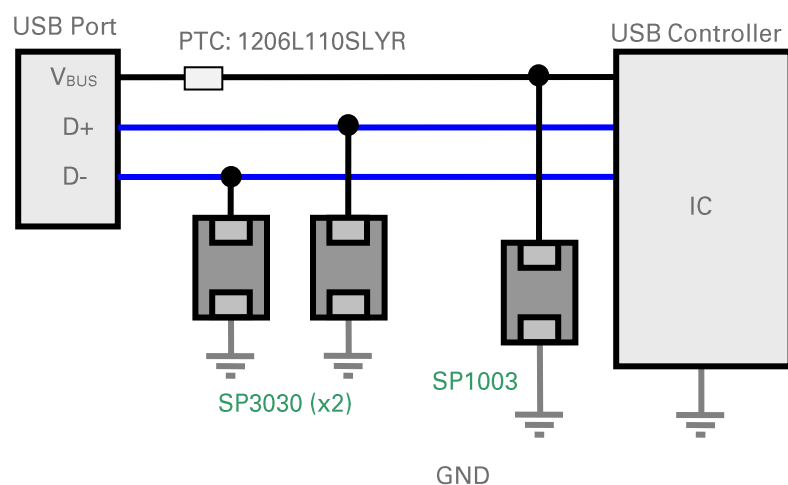
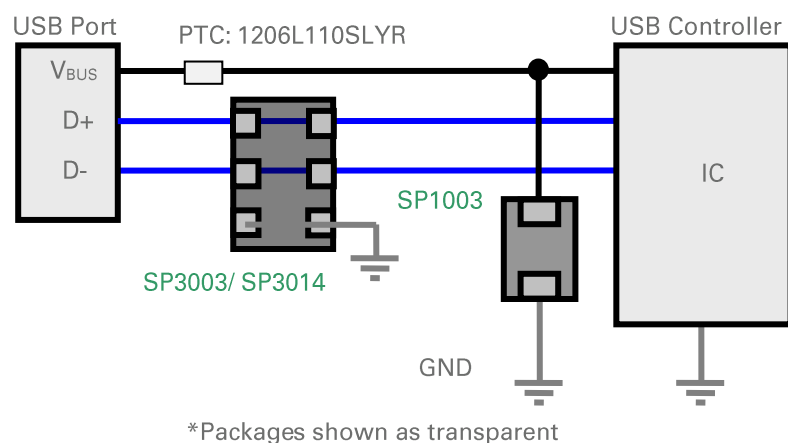
APPLICATION SPECIFIC DEVICE SELECTION

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 $\pm$) 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_{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 =1.65V	# of Channels	V _{RWM}	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)
SP3030-01ETG	±20kV	0.5pF	1	5V	SOD882 (0402)
SP1003-01ETG	±30kV	30pF	1	5V	SOD882 (0402)

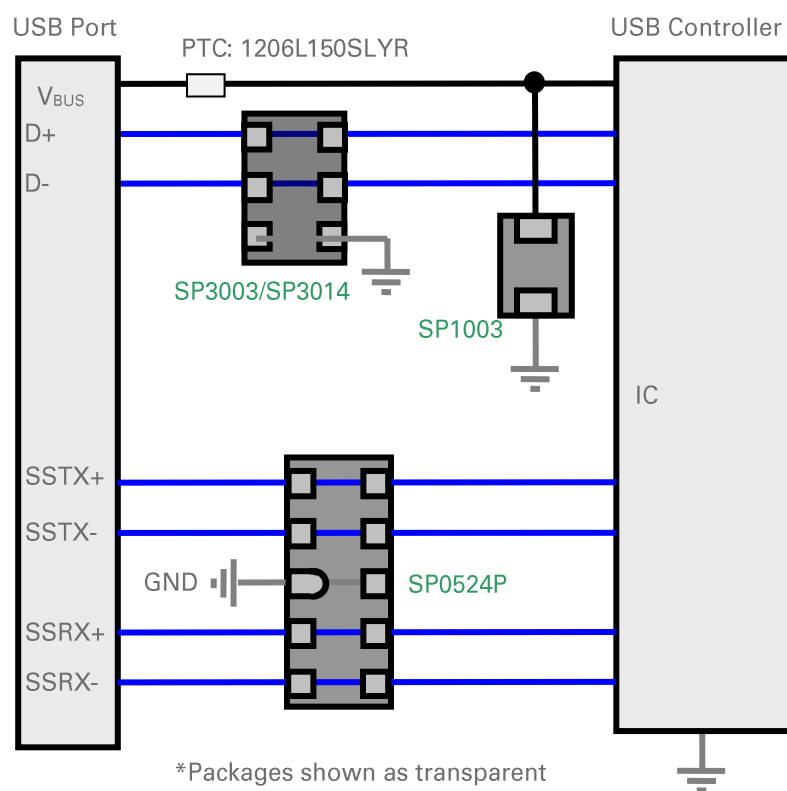
APPLICATION SPECIFIC DEVICE SELECTION

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 $\pm$ and SSRX $\pm$
 - Up to 480Mbps on the legacy data pair, D $\pm$
- Requires 4 channels of ultra-low capacitance protection for the super-speed data pair (i.e. SSTX $\pm$ and SSRX $\pm$)
- Requires 2 channels of protection for the legacy D $\pm$ data pair
- 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 =1.65V	# of Channels	V _{RWM}	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)

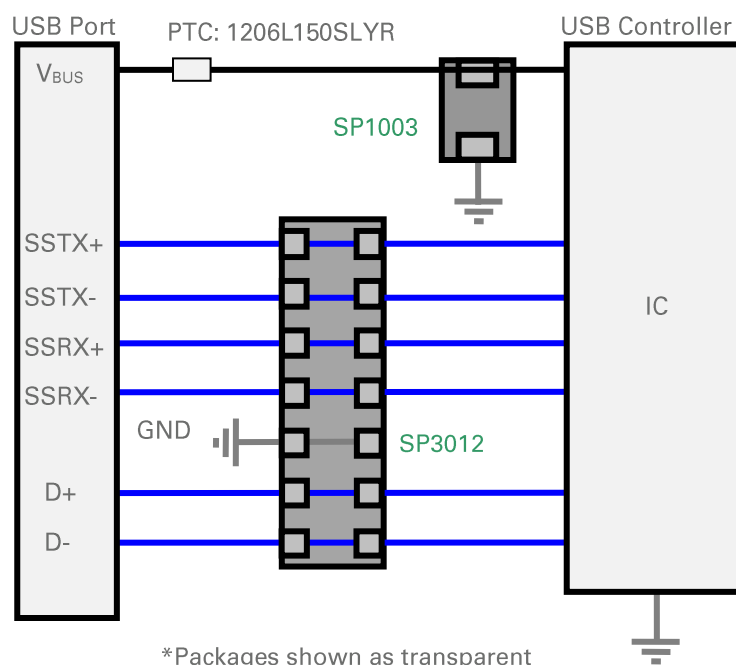
APPLICATION SPECIFIC DEVICE SELECTION

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 $\pm$ and SSRX $\pm$
 - Up to 480Mbps on the legacy data pair, D $\pm$
- Requires 4 channels of ultra-low capacitance protection for the super-speed data pair (i.e. SSTX $\pm$ and SSRX $\pm$) and 2 channels of protection for the legacy D $\pm$ data pair. The SP3012 shown below integrates all 6 channels of protection into a small form factor μ 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	±12kV	0.5pF	6	5V	μ DFN-14 (3.5x1.35mm)
SP1003-01ETG	±30kV	30pF	1	5V	SOD882 (0402)

APPLICATION SPECIFIC DEVICE SELECTION

USB3.1 (Type C Compliance)

Considerations:

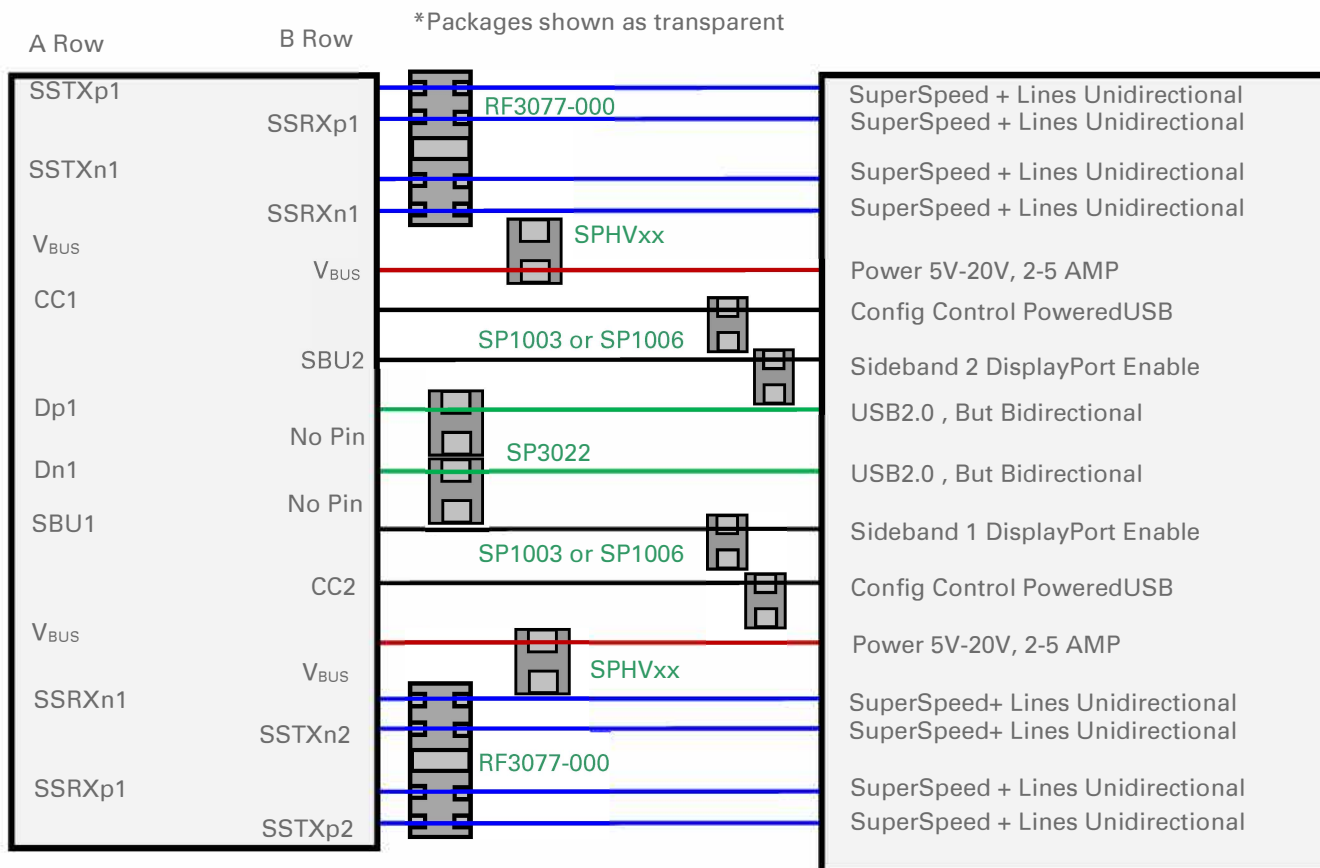
SuperSpeed+ lines operate up to 10 Gbps, so lowest unidirectional capacitance is required.

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 _R =0V	# of Channels	V _{RWM}	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

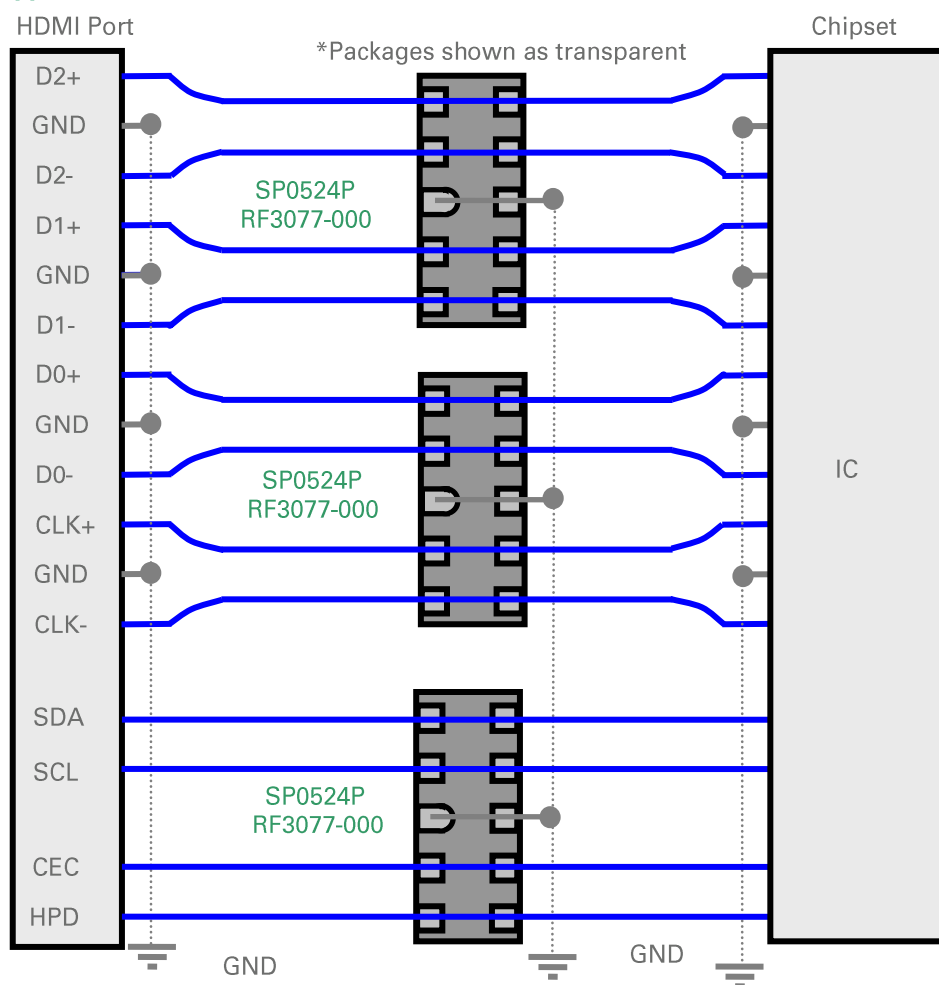
APPLICATION SPECIFIC DEVICE SELECTION

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	$\pm 12kV$	0.5pF	4	5V	μ DFN-10 (2.5x1.0mm)
RF3077-000	$\pm 12kV$	0.2pF	4	6V	μ DFN-10 (2.5x1.0mm)
SP3012-06UTG	$\pm 12kV$	0.5pF	6	5V	μ DFN-14 (3.5x1.35mm)

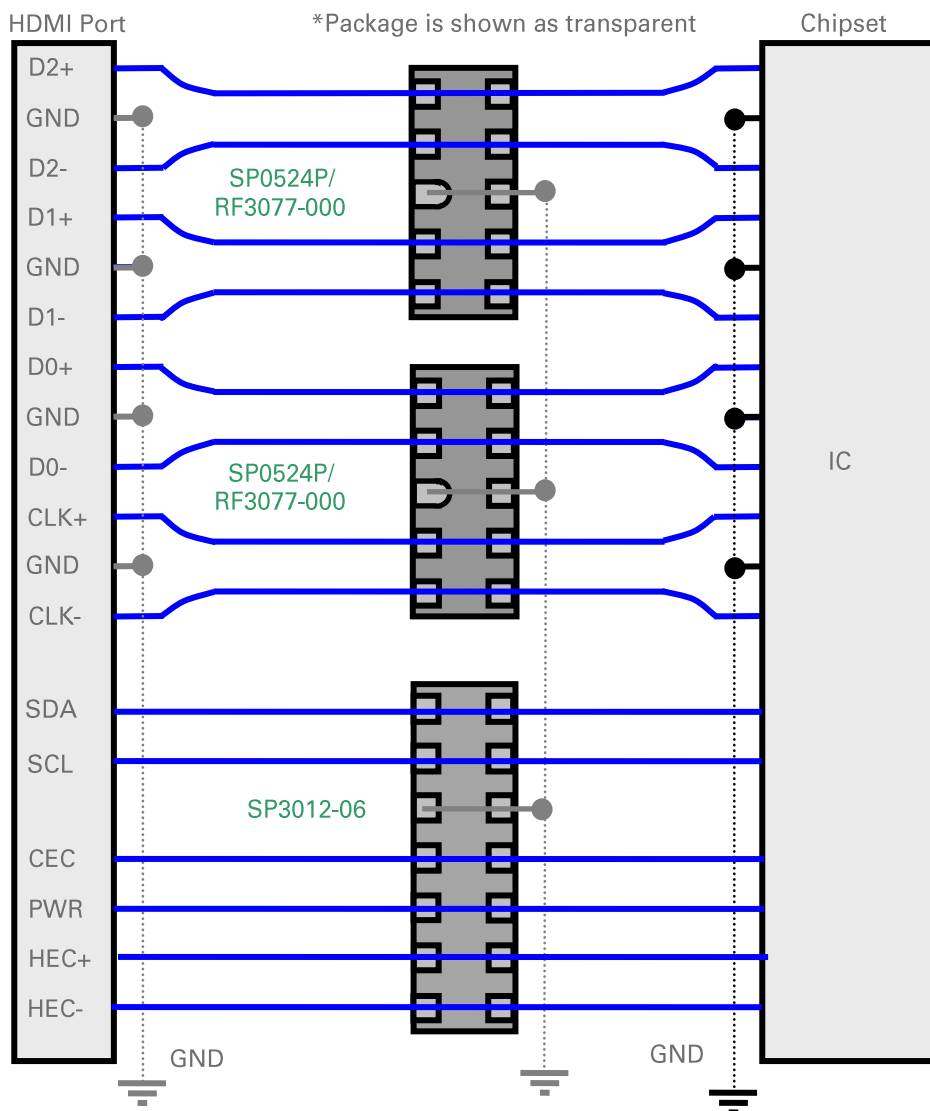
APPLICATION SPECIFIC DEVICE SELECTION

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 @ $V_R=0V$	# of Channels	V_{RWM}	Packaging
SP0524PUTG	$\pm 12kV$	0.5pF	4	5V	μ DFN-10 (2.5x1.0mm)
RF3077-000	$\pm 12kV$	0.2pF	4	6V	μ DFN-10 (2.5x1.0mm)
SP3012-06UTG	$\pm 12kV$	0.5pF	6	5V	μ DFN-14 (3.5x1.35mm)
SP3030-01ETG	$\pm 20kV$	0.5pF	1	5V	SOD882 (0402)

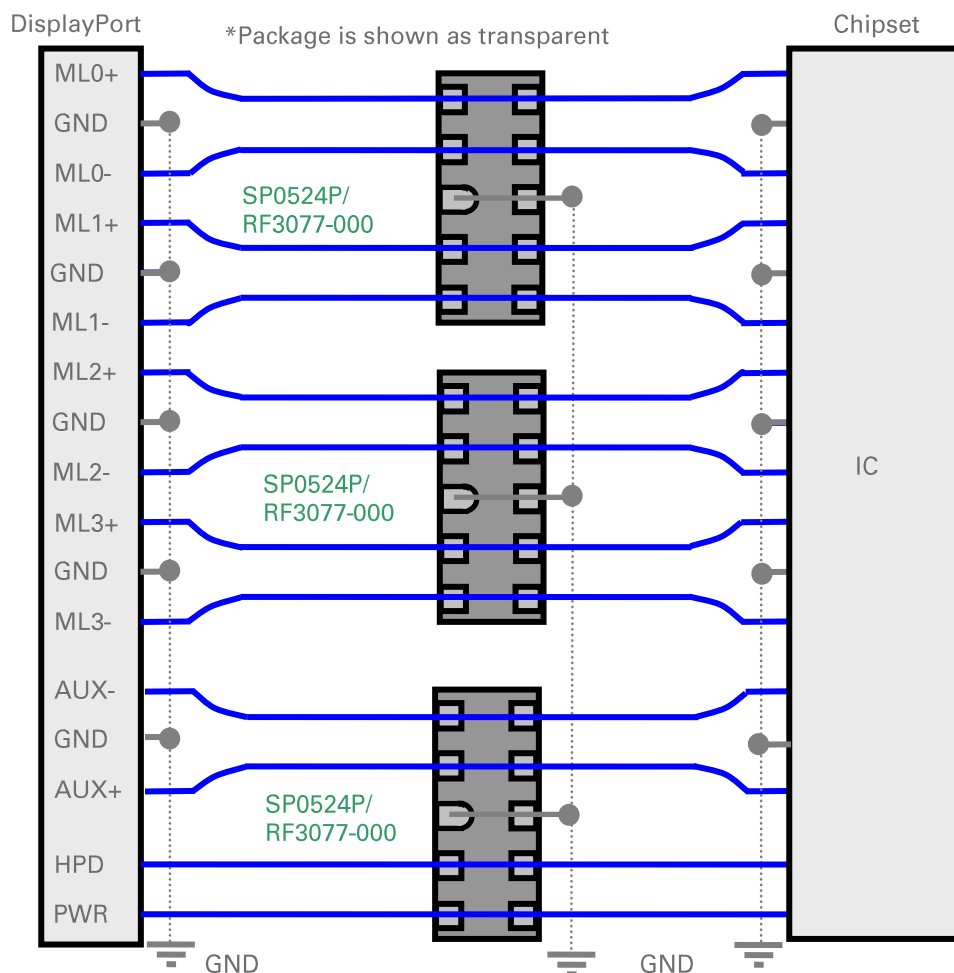
APPLICATION SPECIFIC DEVICE SELECTION

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)

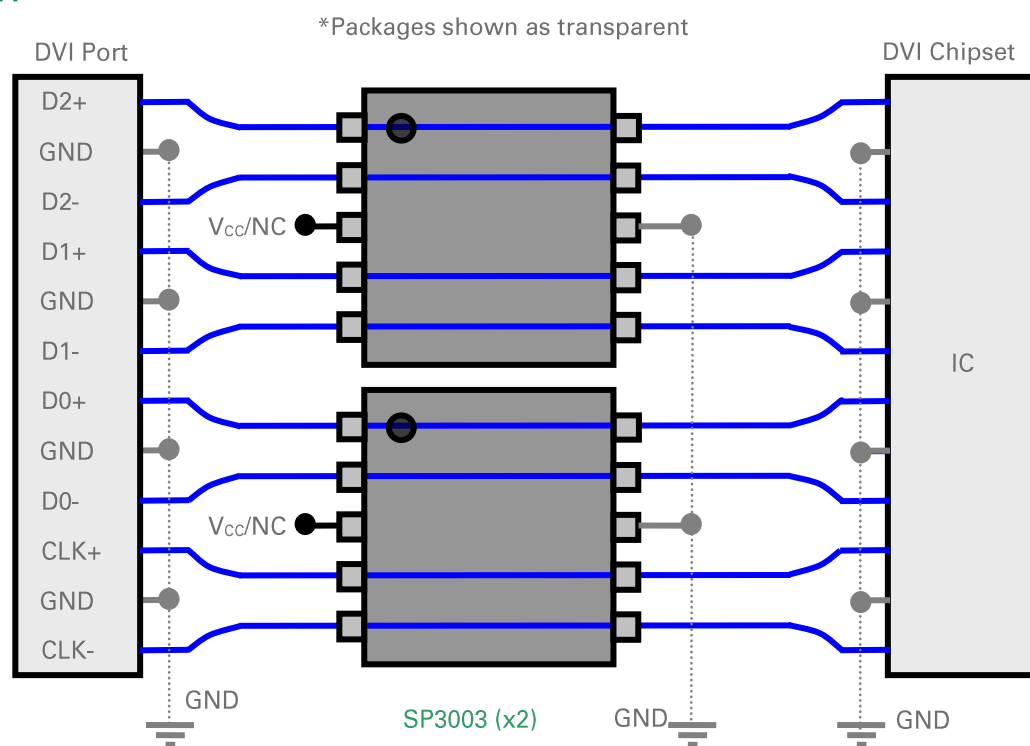
APPLICATION SPECIFIC DEVICE SELECTION

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_{CC} should not be connected if backdrive is a concern

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
SP3003-08ATG	±8kV	0.65pF	8	6V	MSOP-10
SP0524PUTG	±12kV	0.5pF	4	5V	μDFN-10 (2.5x1.0mm)

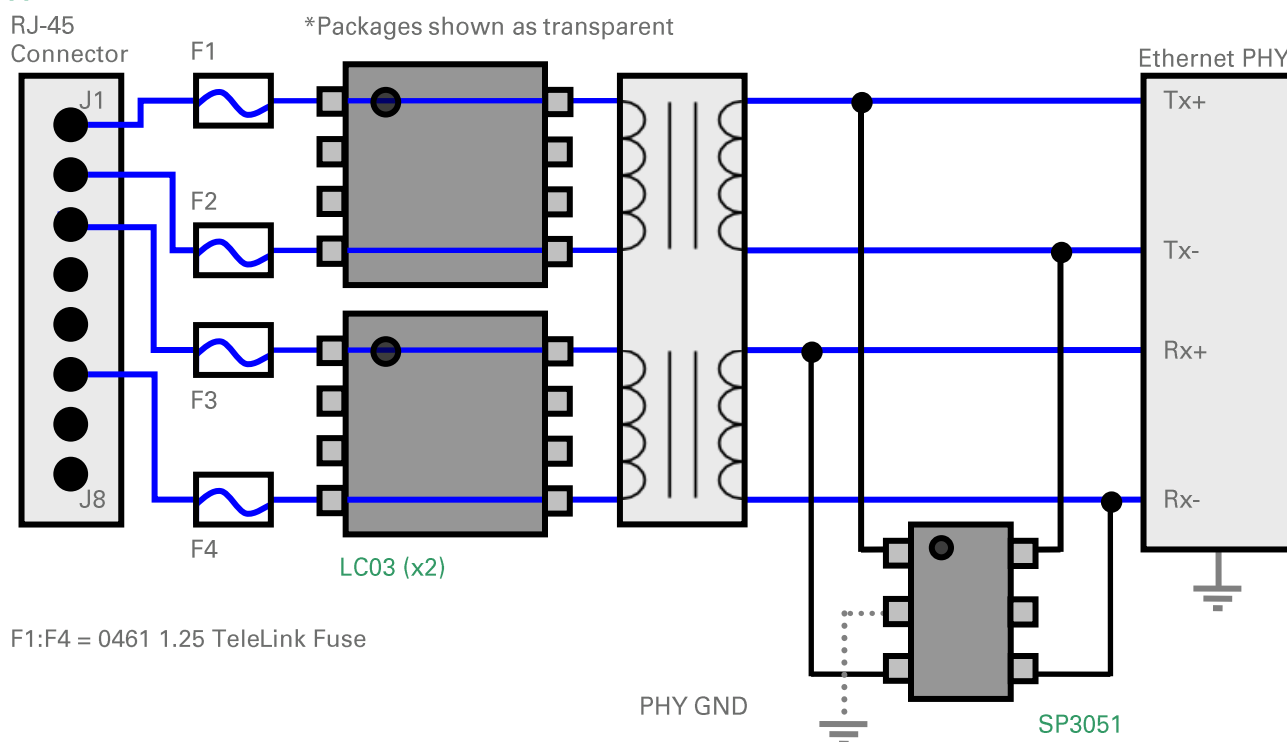
APPLICATION SPECIFIC DEVICE SELECTION

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, $t_F=2/10\mu s$) 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 ($t_F=8/20\mu s$)	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

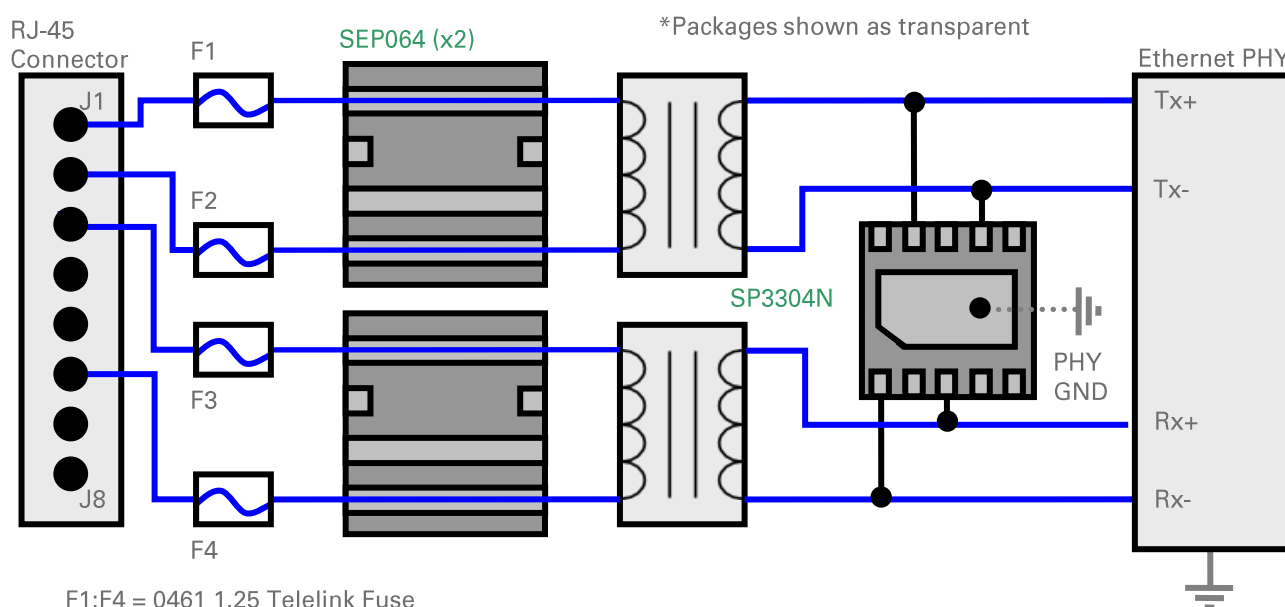
APPLICATION SPECIFIC DEVICE SELECTION

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. worse 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)

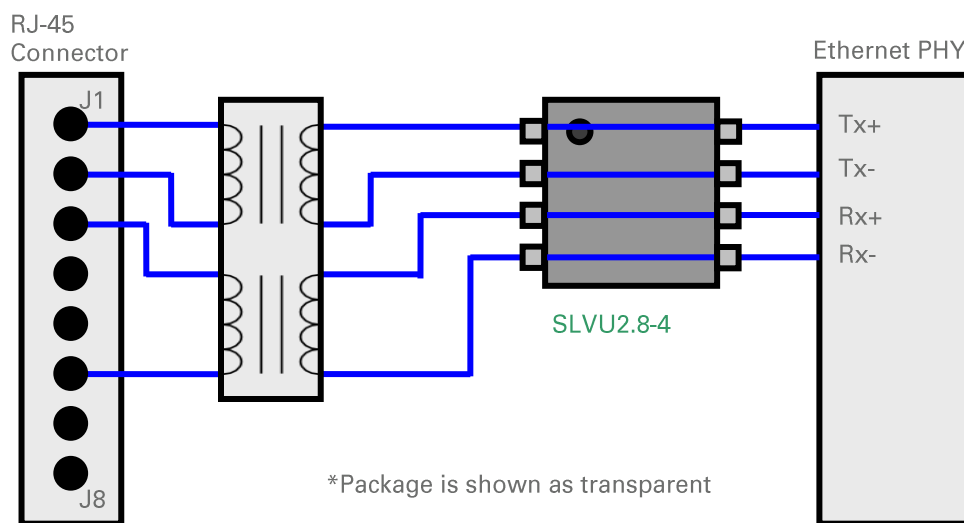
APPLICATION SPECIFIC DEVICE SELECTION

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 ($t_p=8/20\mu s$)	I/O Capacitance @ $V_R=0V$	# of Channels	V_{RWM}	Packaging
SLVU2.8-4BTG	$\pm 30kV$	40A	2.0pF	4	2.8V	SOIC-8
SLVU2.8-8BTG	$\pm 30kV$	30A	3.0pF	8	2.8V	SOIC-8
SP4060-08ATG	$\pm 30kV$	20A	2.2pF	8	2.5V	MSOP-8
SP4065-08ATG	$\pm 30kV$	20A	2.2pF	8	3.3V	MSOP-8
SP2504NUTG	$\pm 30kV$	20A	2.0pF	4	2.5V	μ DFN-10 (2.6x2.6mm)
SP2574NUTG	$\pm 30kV$	40A	5.0pF	4	2.5V	μ DFN-10 (3.0x2.0mm)
SP3304NUTG	$\pm 30kV$	20A	2.0pF	4	3.3V	μ 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)

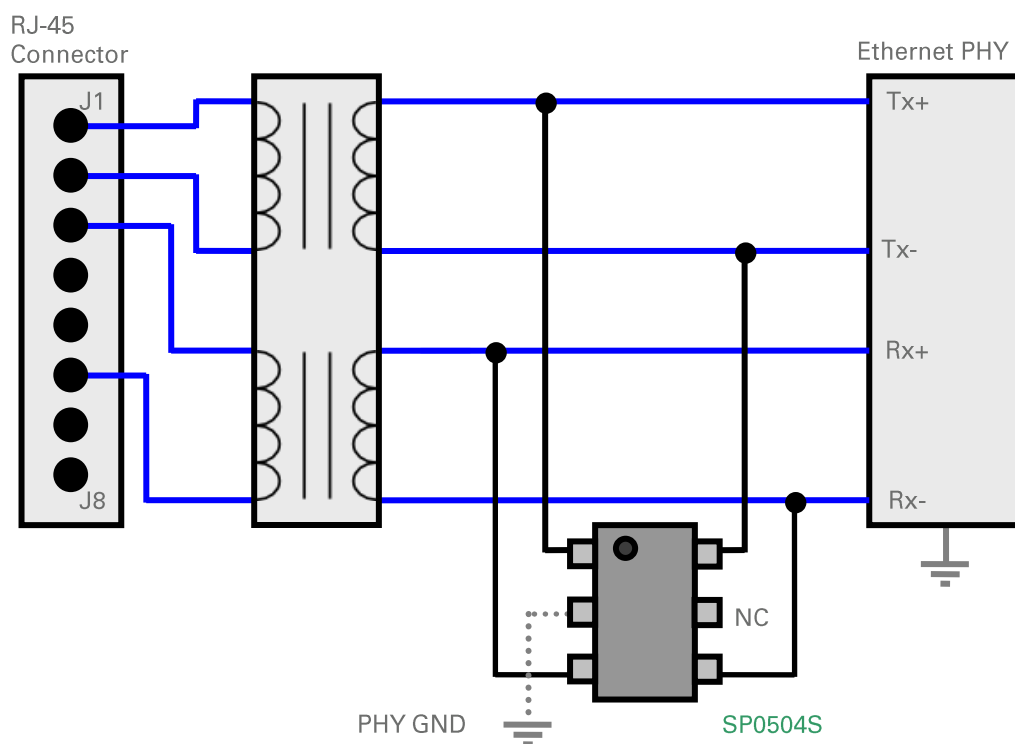
APPLICATION SPECIFIC DEVICE SELECTION

Ethernet (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

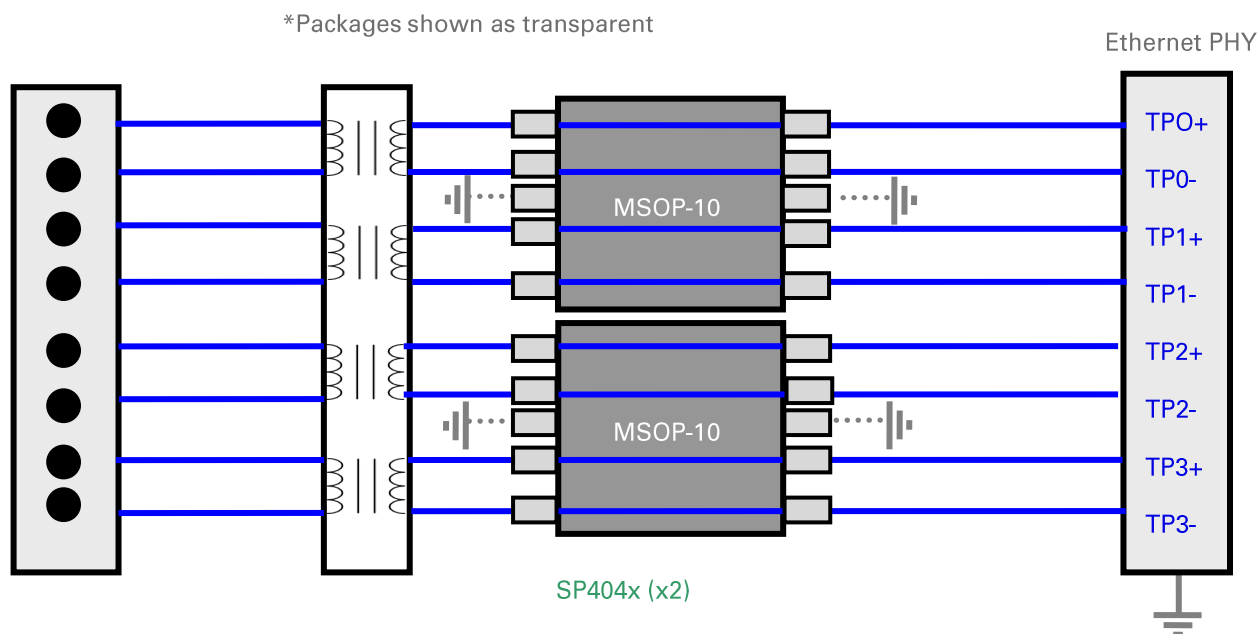
2.5 and 5.0 Gigabit Ethernet

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

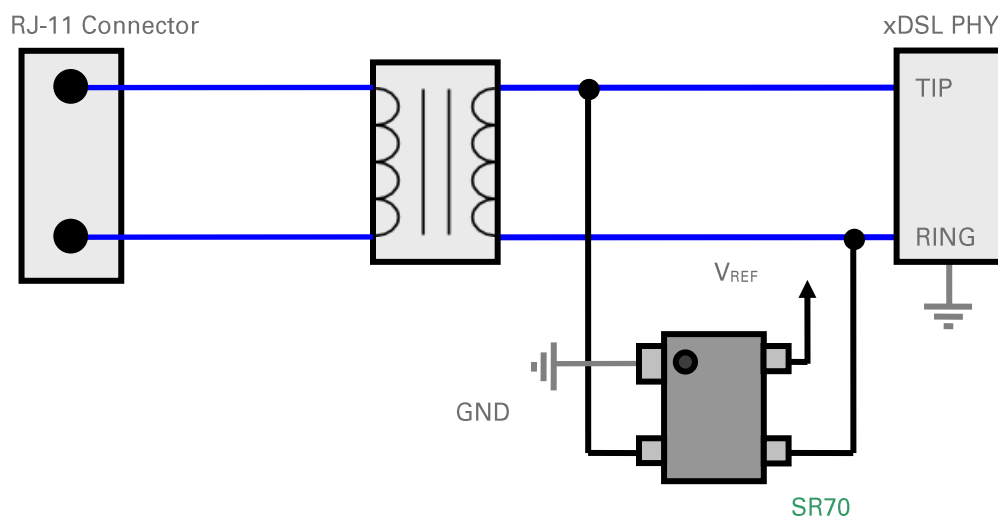
Considerations:

- 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.

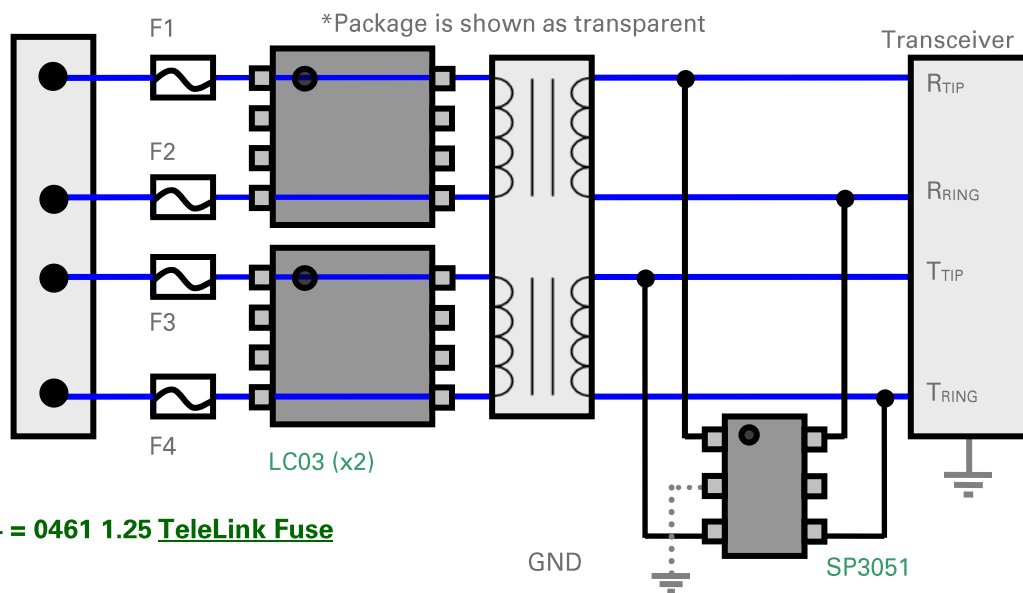
Power Fault Requirements:

- 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

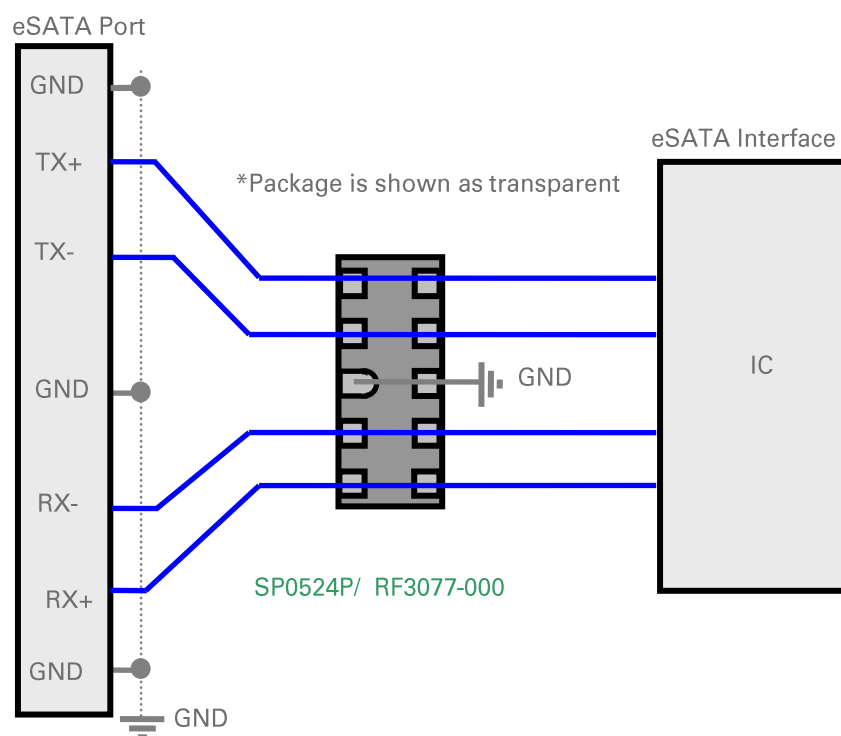
APPLICATION SPECIFIC DEVICE SELECTION

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 $\pm$ and RX $\pm$)
 - Currently eSATA is capable of running raw data rates of 1.5Gbps (Gen 1) and 3.0Gbps (Gen 2), as well as SATA-IO 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)

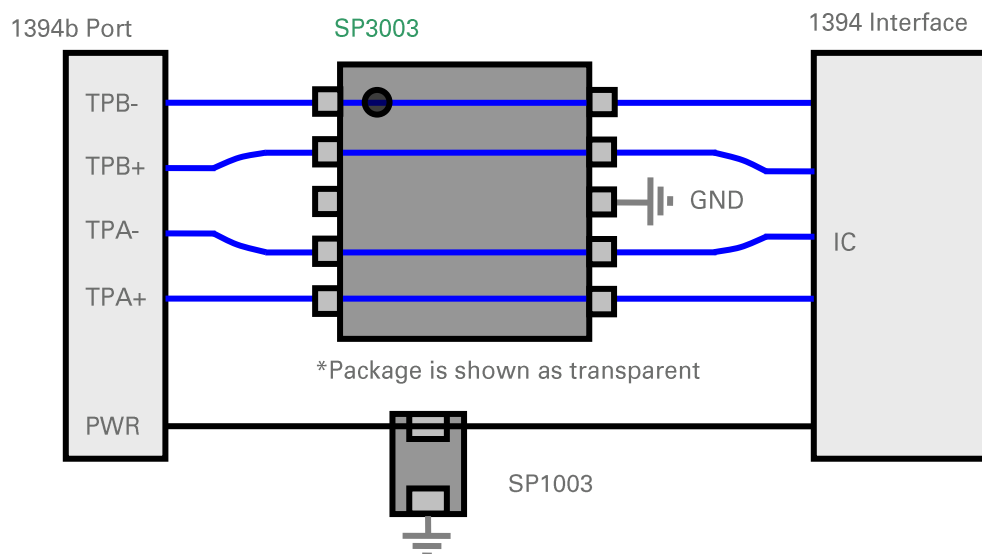
APPLICATION SPECIFIC DEVICE SELECTION

1394a/b

Considerations:

- 1394a (FireWire 400 or S400) was the original (1st 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 2nd 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)

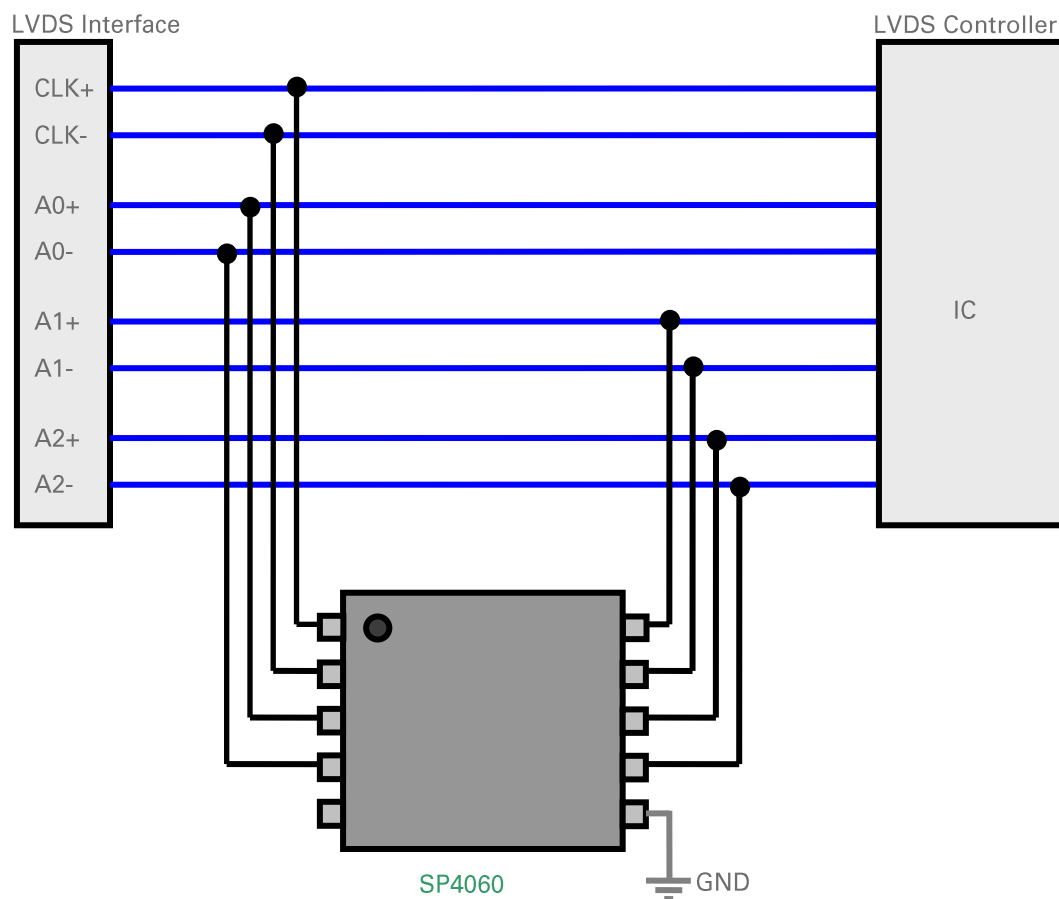
APPLICATION SPECIFIC DEVICE SELECTION

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 ($t_P=8/20\mu s$)	I/O to I/O Capacitance @ $V_R=0V$	# of Channels	V_{RWM}	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

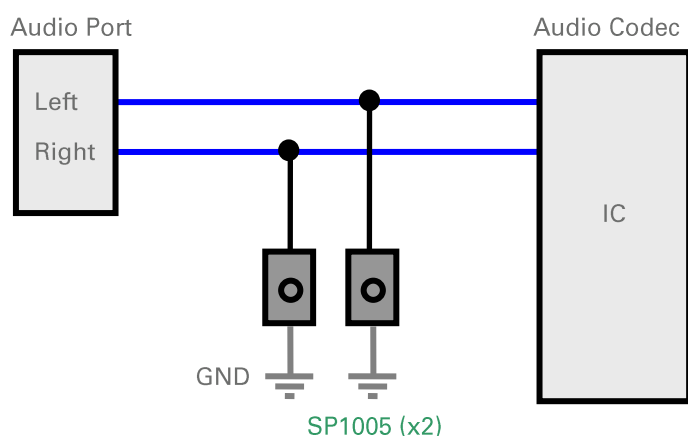
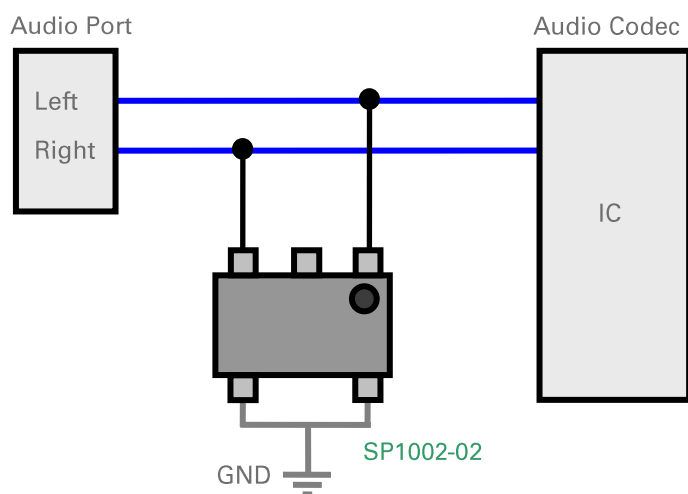
APPLICATION SPECIFIC DEVICE SELECTION

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

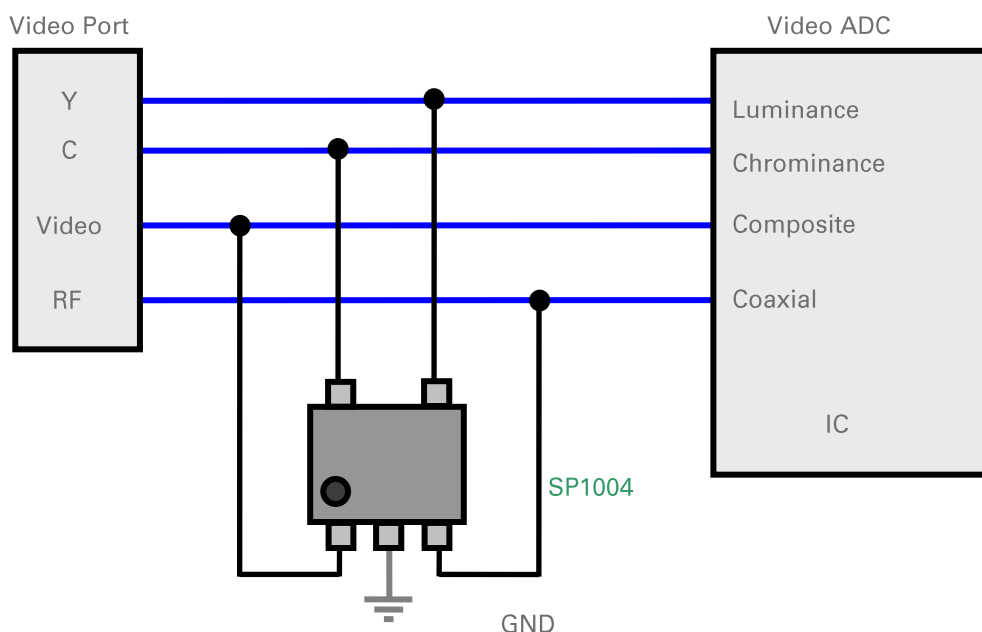
APPLICATION SPECIFIC DEVICE SELECTION

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)

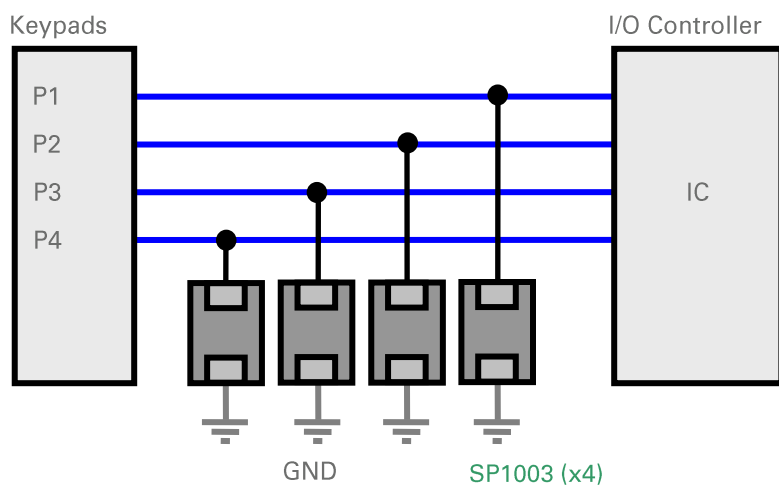
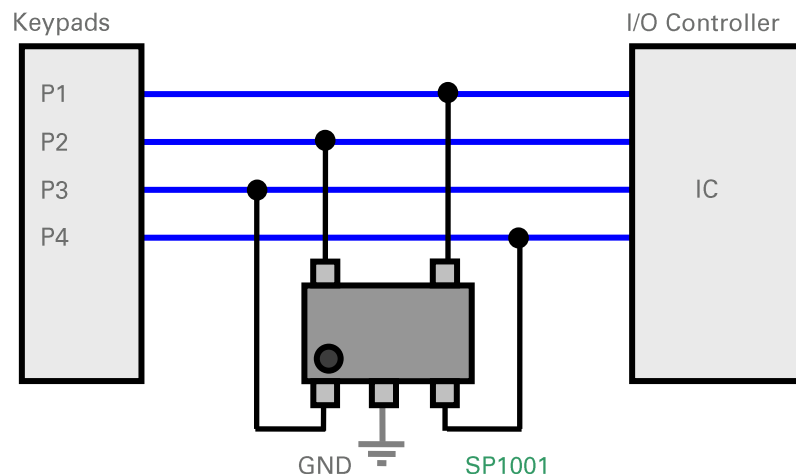
APPLICATION SPECIFIC DEVICE SELECTION

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 =8/20μs)	I/O Capacitance @ V _R =0V	# of Channels	V _{RWM}	Packaging
SP1001-04XTG	±15kV	2A	12pF	4	6V	SOT553
SP1003-01ETG	±30kV	7A	30pF	1	5V	SOD882 (0402)
SP1005-01WTG	±30kV	10A	30pF	1	6V	Flipchip (0201)
SP1008-01WTG	±15kV	2A	8pF	1	6V	Flipchip (0201)

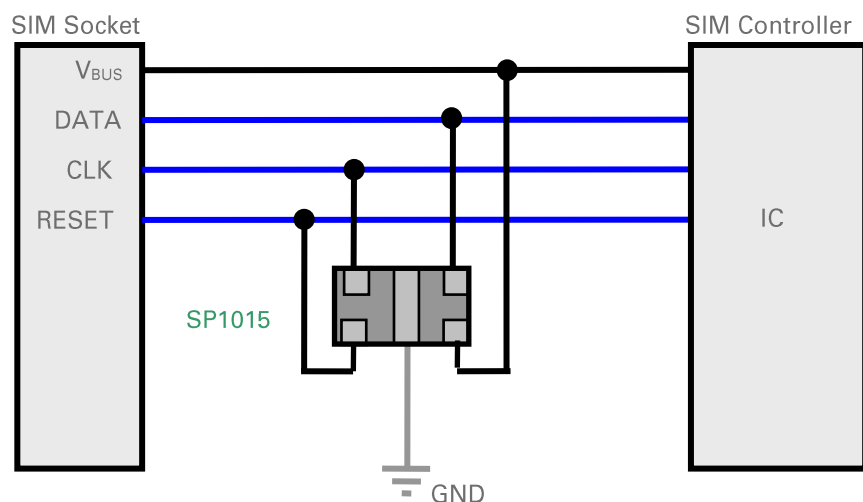
APPLICATION SPECIFIC DEVICE SELECTION

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

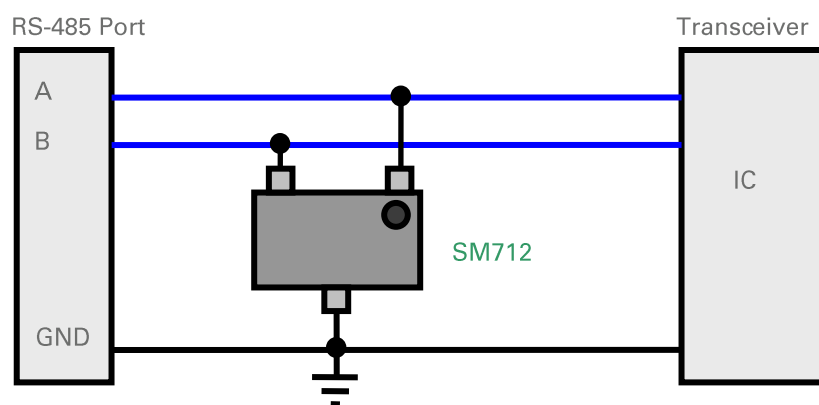
APPLICATION SPECIFIC DEVICE SELECTION

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:

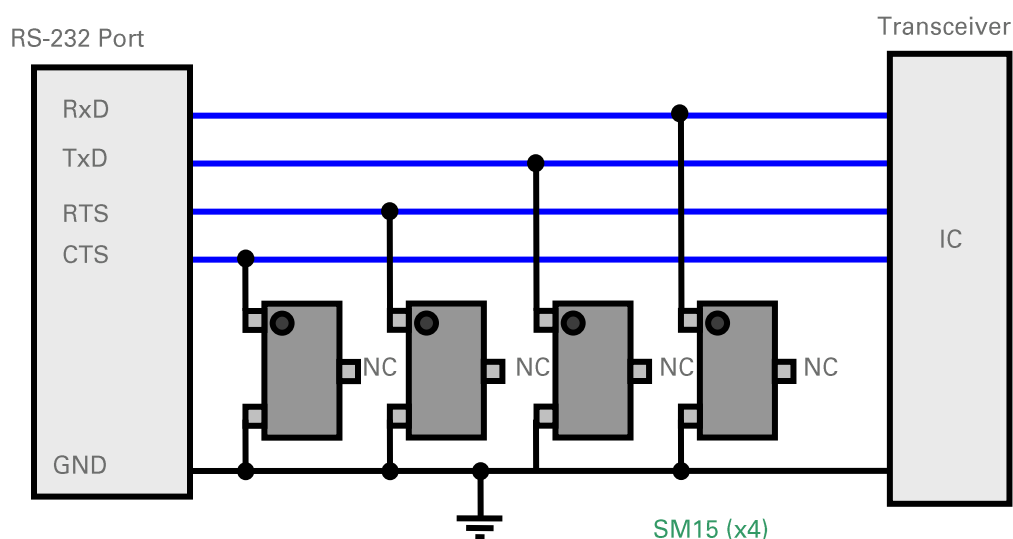
Ordering Number	ESD Level (Contact)	Lightning ($t_P=8/20\mu s$)	MAX I/O Capacitance @ $V_R=0V$	# of Channels	V_{RWM}	Packaging
SM712-02HTG	$\pm 30kV$	17A	75pF	2	+12V / -7V	SOT23-3

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)

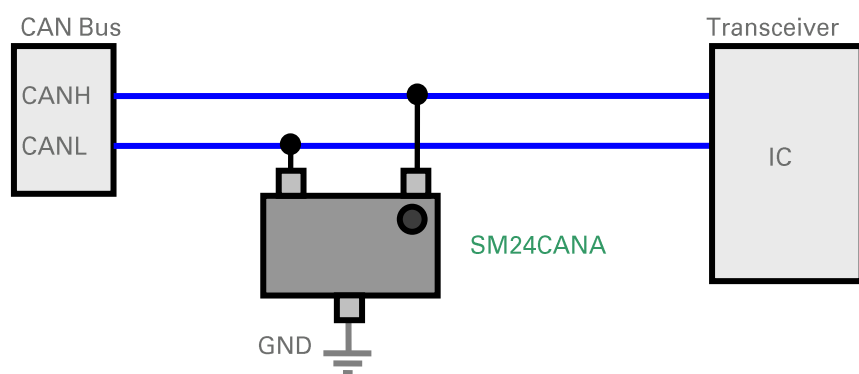
APPLICATION SPECIFIC DEVICE SELECTION

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 where 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

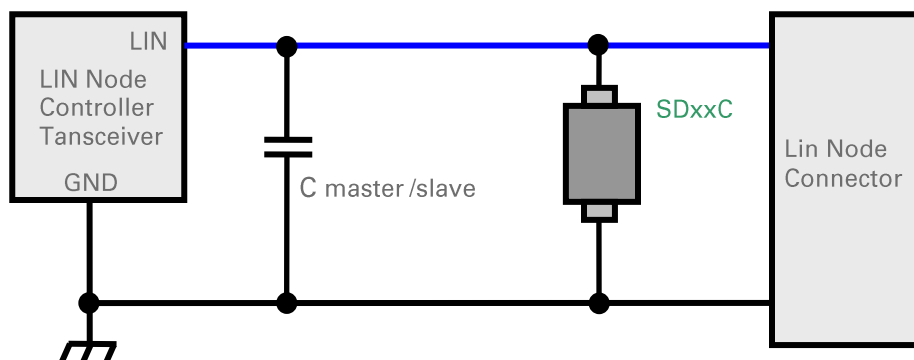
APPLICATION SPECIFIC DEVICE SELECTION

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 ($t_p=8/20\mu s$)	I/O Capacitance @ $V_R=0V$	# of Channels	V_{RWM}	Packaging
SD15C-01FTG	$\pm 30kV$	12A	75pF	1	15V	SOD323 (0805)
SD24C-01FTG	$\pm 30kV$	7A	50pF	1	24V	SOD323 (0805)

APPLICATION SPECIFIC DEVICE SELECTION

Touchscreen

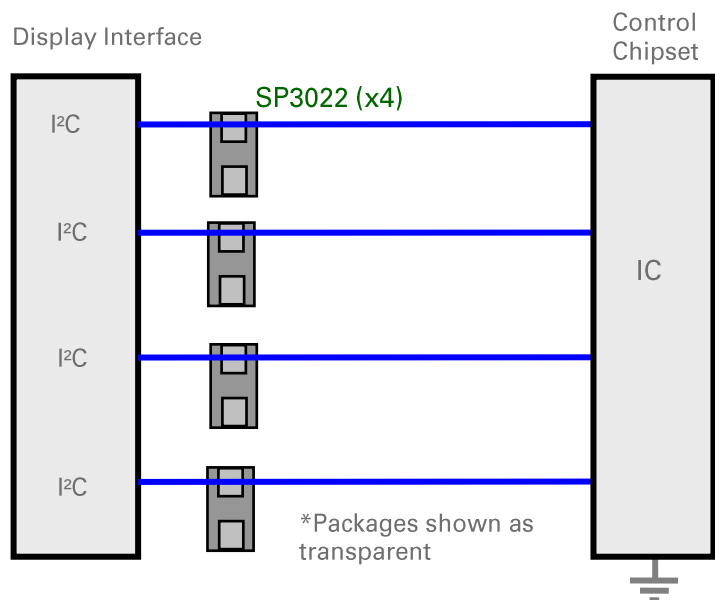
Considerations:

- 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 @ $V_R=2.5V$	# of Channels	V_{RWM}	Packaging
SP3022-01ETG	$\pm 22kV$	0.35pF	1	5.3V	SOD882 (0402)
SP3022-01WTG	$\pm 22kV$	0.35pF	1	5.3V	0201 Flipchip
SP1005-01WTG	$\pm 30kV$	30pF	1	6V	Flipchip (0201)
SP12-01WTG-C-HV	$\pm 30kV$	30pF	1	12V	Flipchip (0201)
SP24-01WTG-C-HV	$\pm 18kV$	17pF	1	24V	Flipchip (0201)
SPHV12-01ETG	$\pm 30kV$	60pF	1	12V	SOD882 (0402)
SPHV24-01ETG	$\pm 24kV$	32pF	1	24V	SOD882 (0402)

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