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ETHERNET PROTECTION DESIGN GUIDE

A Guide for Protecting Ethernet Circuits and Equipment From Electrostatic Discharge (ESD), Lightning, Power Faults and Other Electrical Transient Threats

This guide was developed to help electronics designers navigate the consideration factors and selection of appropriate circuit protection components for Ethernet-equipped applications. This document describes categories of Ethernet (including PoE - Power over Ethernet), and presents example circuits, applicable standards, and recommended components.

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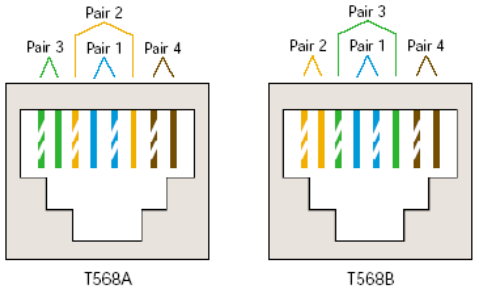
Ethernet Basics

Ethernet is a Local Area Network (LAN) that was standardized as IEEE 802.3. There are four dominant forms in the marketplace today with more on the horizon. These are 10Base-T, 100Base-T, 1000Base-T, and 10GBase-T (Base stands for Baseband signaling, T stands for twisted pair, 10 = 10 Mbps, 100 = 100 Mbps, 100 = 1000 Mbps, 10G = 10Gbps). All the standards use UTP (Unshielded Twisted Pair) wiring or cabling such as CAT5, CAT5e, CAT6, and CAT7. Ethernet connections are typically made with a RJ45 type connector, which is also known as the IEC 60603-7 8P8C modular connector.

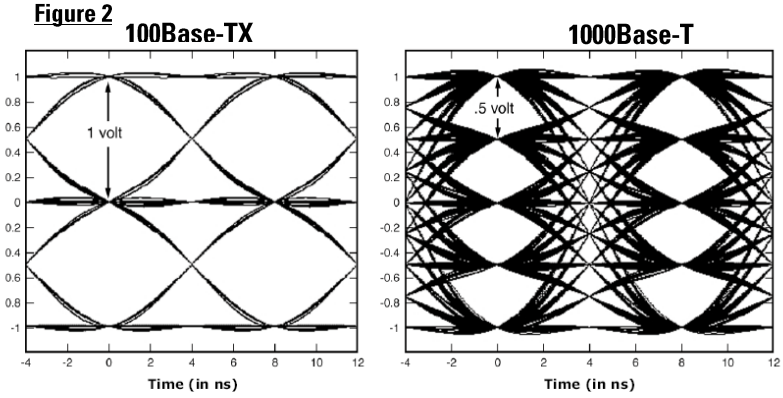
Figure 1 below shows the two different connector designs certified by the TIA (Telecommunications Industry Association) with T568B being the most commonly used throughout the world.

Figure 1



The main difference between the four forms of Ethernet is the speed (see table at right). In general, the signaling scheme became more complex to achieve the higher data rates. Figure 2 shows the differences in eye diagrams between a 100Base-T and 1000Base-T signal. The 10Base-T eye diagram was omitted since it is a simpler, two-level signal. With this basic understanding of Ethernet we will now move into an introduction of Power-over-Ethernet which can be used in conjunction with any of the aforementioned standards.

Figure 2



Below lists differences between each of the four standards:

10Base-T	
Data Rate	10 Mbps
Symbol Rate	20Mbaud with 0.5bits/baud
Data Pairs	2 pairs out of the 4 available are used (1 for transmit and 1 for receive)
Signaling	Differential (i.e. 2 levels)
Encoding	4B5B NRZ Manchester (four bits are scrambled and sent as a 5 bit sequence)
Cabling	CAT3 or higher up to 100M

100Base-T (also known as Fast Ethernet)	
Data Rate	100 Mbps
Symbol Rate	125Mbaud with 0.8bits/baud
Data Pairs	2 pairs out of the 4 available are used (one pair for transmit and one pair for receive)
Signaling	Differential with MLT-3 (Multi Level Transition)
Encoding	4B5B NRZ Manchester (four bits are scrambled and sent as a 5 bit sequence)
Cabling	CAT5 or higher up to 100M

1000Base-T	
Data Rate	1000 Mbps
Symbol Rate	125Mbaud with 2bits/baud
Data Pairs	4 pairs (full duplex) each pair carries 250 Mbps
Signaling	Differential PAM-5 (Pulse Amplitude Modulation five-level) signaling
Encoding	8B/10B
Cabling	Preferably CAT5e or higher up to 100M

10GBase-T (10GbE)	
Data Rate	10 Gbps
Symbol Rate	800M symbols/s
Data Pairs	4 pairs (full duplex)
Signaling	Differential PAM-16 (Pulse Amplitude Modulation sixteen-level) signaling with CRC-8
Encoding	DSQ128 (yields 3.5 bits per symbol)
Cabling	Preferably CAT6 up to 55M or CAT6A/7 up to 100M

Introduction to PoE (Power over Ethernet)

PoE is a powering technique used over the existing Ethernet wiring link. IEEE standard 802.3af specifies the technical requirements so that systems are compatible with one another. The IEEE 802.3at specification provides the guidelines for PoE+, which is a higher power level than the original PoE. Both of these specifications allow the Ethernet wiring to carry both data and DC power. This removes the need for a local ac power port for each individual Ethernet interface. PoE can also provide a continuous power source thus supporting life-line capabilities for IP enabled telephones such as may be seen in EFM (Ethernet in the First Mile) or IEEE 802.3ah or Active Ethernet applications. This is also known as Ethernet to the Home (ETTH). Life-line in this case meaning that the telephone is not dependent on a local power supply, so that it functions during local power outages. EFM needs this capability in order to provide life-line service to residential locations so PoE is an ideal implementation for EFM applications.

Here are two major advantages for PoE:

1) Ethernet devices are not required to be placed next to wall outlets and reduces the need for "wall-warts"

2) Power cables are no longer required to be laid out for the network

In a PoE scheme, the device that receives the power is called the client device or Powered Device (PD) and the device supplying the power is the Power Source Equipment (PSE). The IEEE 802.3af standard limits the PD power consumption to 12.95W and limits the PSE power outputs to 15.4W on a per Ethernet port basis. The network will contain patch panels and various connectors that cause some current limiting restrictions. Therefore, the IEEE 802.3af standard limits the maximum PSE available current to 400mA per device connection and the PD current to 360mA. This standard takes into account line losses for maximum loop lengths of 100m, thereby allowing up to 57 V_{DC} from the PSE. The nominal level is 48 V_{DC}. The PoE+ (IEEE 802.3at) allows the PSE to deliver up to 30W and the PD to consume up to 25.5 W; with the PSE supplying up to a maximum of 600mA. PoE+ also requires the use of low impedance wiring (< 12.5 ohms per loop pair), such as CAT5e or CAT6.

This power can be inserted from (1) an endpoint PSE or (2) a mid-span PSE. The legacy Ethernet systems most likely use a mid-span PSE method. This prevents having to re-work the entire network. For new installations, the endpoint PSE is the most economical and easiest installation choice. Power can be provided in one of two ways over CAT5e, CAT6, or CAT7 cable:

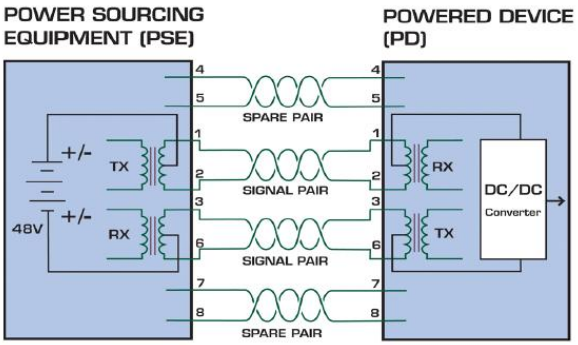
1) Over the same pair used for data signaling in 10BaseT and 100BaseT systems, or

2) Over the unused pair in 10BaseT and 100BaseT systems

Mode A

Mode A power is applied over the "active" data pair found in 10BaseT or 100BaseTX interfaces. In these type systems, two pair are used for data delivery (RJ-45 pins: 1-2 and 3-6) and two pair are unused (pairs 4-5 and 7-8). This is shown in Figure 3 below. PoE uses the "phantom powering" technique so that a single pair carries a zero DC volt potential difference. The power supply voltage is derived as the difference between two different pair sets of wire. This method combines the DC voltage with the signal over the transmit (TX) and receive (RX) pair. The two center tap connections provide access to the DC power and the DC voltage across any single pair (i.e. 1-2 or 3-6) remains at zero volts. This scheme helps to prevent accidental shock hazards when single pairs are handled.

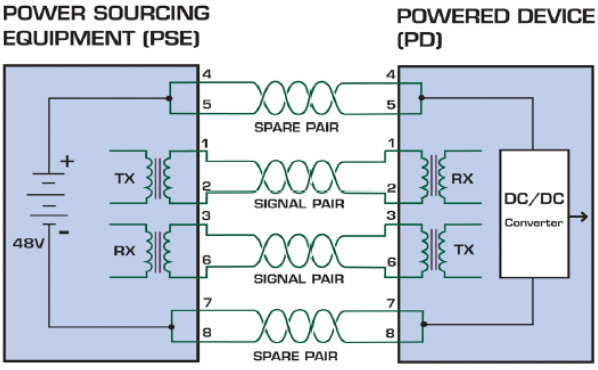
Figure 3 (Mode A)



Mode B

Mode B power is applied over the unused pair (pairs 4-5 and 7-8) for 10BaseT and 100BaseT interfaces. This is shown in Figure 4 below. For 1000BaseT and 10GbE applications, all wire pairs are used for data transfer, therefore there are no "spare pairs" available. So a 1000BaseT and 10GbE system may use either Mode A or Mode B power but the 4-5 and 7-8 pair would be center tap connected instead of directly connected. Mode B can be used with any Ethernet application as can Mode A. The PD end must be compatible with both Mode A and Mode B since its final application is not known. The PSE defines the Mode type, therefore it provides power in a single mode only; it cannot provide power in both Mode A and Mode B simultaneously. More detail regarding PoE can be found in Appendix A.

Figure 4 (Mode B)



Overview of Testing Standards

Depending upon the end use and environment, there are various standards that will apply to a given Ethernet application. Below are brief summaries of some the most common standards encountered in the market today. More detailed information about each standard can be found in the associated Appendix noted below.

Isolation Requirements (IEEE 802.3)
To be compliant with IEEE802.3, an Ethernet port must comply with the following electrical isolation strength test (withstand at least one of the following tests):

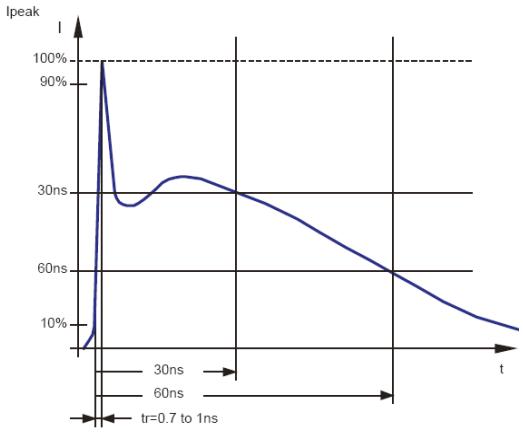
1. 1500V_{RMS} at 50Hz to 60Hz for 60s
2. 2250V_{DC} for 60s OR
3. A waveshape impulse of 1.2/50-8/20µs 2400 volts applied ±10 times with at least one second interval between successive surges (draft version indicates this may change to 10/700-5/310 1500 volts applied ±10 times with at least sixty second interval between successive surges)

There shall be no isolation breakdown during the test and the resistance after test shall be at least 2 MΩ when measured at 500 VDC.

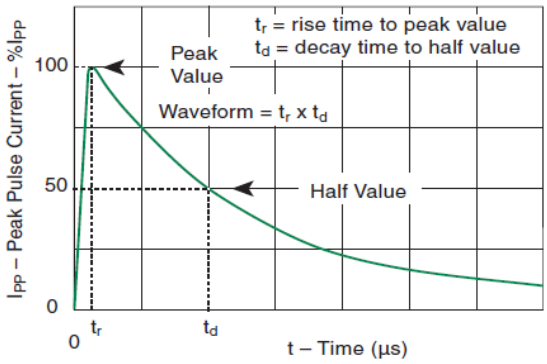
Immunity to Lightning, ESD, EFT, and Power Fault
There are many different regulatory standards used in evaluating an Ethernet port's susceptibility to damage from electrical transients. The surge and ESD resistibility compliance requirements are typically controlled by the local governing bodies where the end equipment is being sold. The standards listed by region are stated below:

Region	Standard	Note
North America	GR-1089 Issue 6	Appendix B
Europe	ITU K.20 & K.21	Appendix C
International	IEC61000-4-2	Appendix D
	IEC61000-4-4	
	IEC61000-4-5	
China	YD/T 950-1998	Appendix E
	YD/T 993-1998	
	YD/T 1082-2000	

Whenever ESD is referenced in this document, it is assumed the waveform is the same as defined by the IEC61000-4-2 for the HBM (Human Body Model) standard seen below. In the appendices there will be test voltages and currents shown for the various levels/classes of ESD immunity.



Furthermore, all lightning waveshapes are described by their peak value and t_r x t_d as shown below.

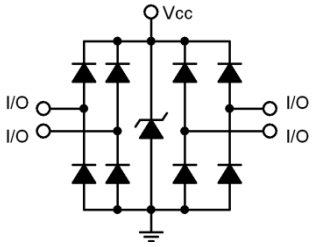
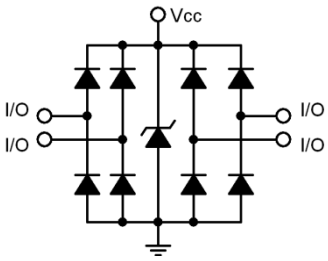
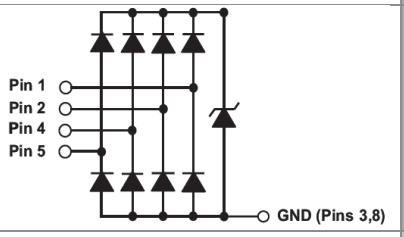
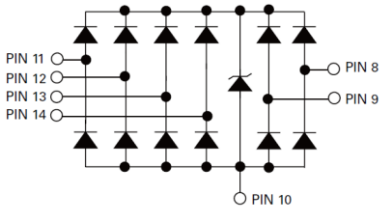
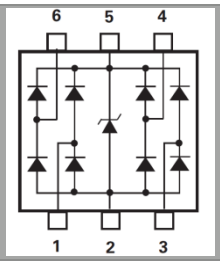


Power Faults
Included in the standards referenced above are the test levels and conditions for power fault testing. Additional, safety standards such as UL60950-1, IEC60950-1, and EN60950-1 are intended to prevent personal injury or harm due to electrical shock, energy hazards, fire, heat hazards, mechanical hazards, radiation hazards, and chemical hazards. Please see Appendix F for detailed information.

Every application is different and the specific protection solution will be dependent upon several factors such as the expected operating environmental conditions, geographical location, transformer physical size/turns ratio/physical size, length of the Ethernet cabling, use of shielded twisted pair (STP)cable vs unshielded twisted pair (UTP) cable, local standard rules and regulations, etc. The appendices referenced above provide information about several world-wide specifications; however, feel free to contact Littelfuse for clarification and further support at any time. Littelfuse laboratory services are available for customer application testing to provide evidence based solutions utilizing Littelfuse recommended solutions. Contact your local Littelfuse Representative to arrange such protection confirmation testing using proven Littelfuse overcurrent and overvoltage protection solutions.

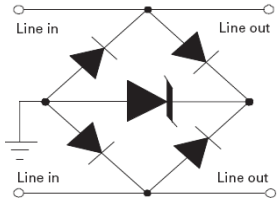
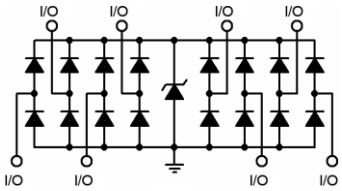
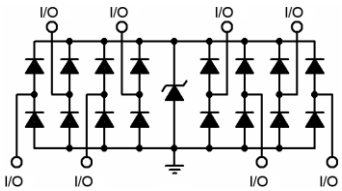
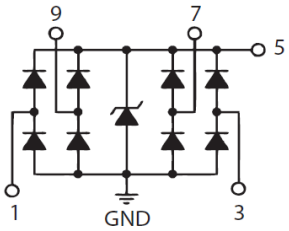
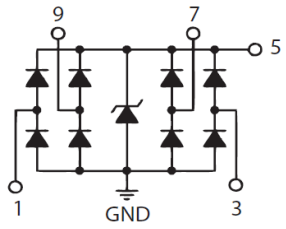
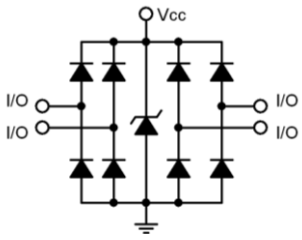
Recommended Littelfuse Protection Components

TVS Diode Arrays (SPA® Diodes)

Series	Schematic (Example)	ESD Level (Contact)	I/O Cap V_R= 1.65V	V_{RWM}	Lightning (t_P=8/20µs)	Number of Channels	Package Options
SP3002		±12kV	0.85pF (Line to Grd)	6V	4.5A	4	SC70-6 SOT23-6 µDFN-6 1.6x1.6mm
SP3003		±8kV	0.65pF (Line to Grd)	6V	2.5A	2	SC70-5 SOT553
						4	SC70-6 SOT563 MSOP-10
SP3012-04UTG		±12kV	0.5pF (Line to Grd) @ V_R = 0	5V	4A	4	µDFN-10 2.5x1.0mm
SP3012-06UTG		±12kV	0.5pF (Line to Grd) @ V_R = 0	5V	4A	6	µDFN-14 3.5x1.35mm
SP3051		±30kV	2.0 pF (Line to Line); 3.8 pF (Line to Grd @ 0 V)	6V	20A	4	SOT23-6

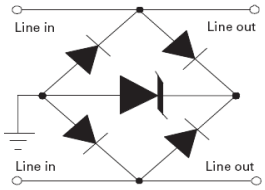
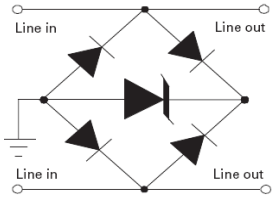
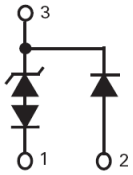
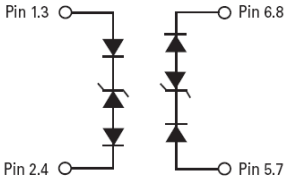
Recommended Littelfuse Protection Components

TVS Diode Arrays (SPA® Diodes)

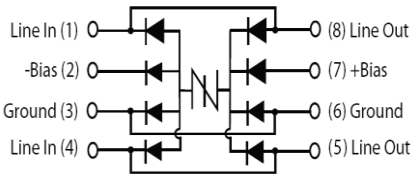
Series	Schematic (Example)	ESD Level (Contact)	I/O Cap V_R= 0V	V_{RWM}	Lightning (t_p=8/20µs)	Number of Channels	Package Options
SP2502L		±30kV	2.5pF (Line to Line); 5 pF (Line to Grd)	3.3V	75A	2	SOIC-8 (MS-012)
SP4060		±30kV	2.2pF (Line to Line); 4.4 pF (Line to Grd)	2.5V	20A	8	MSOP-10
SP4065		±30kV	2.2pF (Line to Line); 4.4 pF (Line to Grd)	3.3V	20A	8	MSOP-10
SP2504N		±30kV	2pF (Line to Line); 3.5pF (Line to Grd)	2.5V (Snap Back Voltage = 2.0V)	20A	4	µDFN-10 2.6x2.6mm
SP3304N		±30kV	2pF (Line to Line); 3.5pF (Line to Grd)	3.3V (Snap Back Voltage = 2.8V)	20A	4	µDFN-10 2.6x2.6mm
SRV05-4		±20kV	1.2pF (Line to Line); 2 pF (Line to Grd @ V_R =1.65 V)	6V	10A	4	SOT23-6

Recommended Littelfuse Protection Components

TVS Diode Arrays (SPA® Diodes)

Series	Schematic (Example)	ESD Level (Contact)	I/O Cap V_R= 0V	V_{RWM}	Lightning (t_p=8/20µs)	Number of Channels	Package Options
SP03-3.3		±30kV	8pF (Line to Line); 16pF (Line to Grd)	3.3V	150A	2	SOIC-8 (MS-012)
LC03-3.3		±30kV	4.5pF (Line to Line); 9pF (Line to Grd)	3.3V	150A	2	SOIC-8 (MS-012)
SLVU2.8		±30kV	2.0pF (Pin 2 to Pin 1)	2.8V	40A	1	SOT23-3
SLVU2.8-4		±30kV	2pF (Each line)	2.8V	40A	4	SOIC-8 (MS-012) (JEDEC MO-223 Issue A)

SIDACtor® Protection Thyristors

Series	Schematic (Example)	MIN V_{DRM}@ I_{DRM}=5µA	MAX V_S@100V/µs	MIN I_H / MAX I_S	Lightning (t_p=2/10µs)	Number of Channels	Package Options
SEP008		6V	25V	50mA / 800mA	500A	2	5x6mm QFN
SEP0640		58V	77V	150mA / 800mA			
SEP0720		65V	88V	150mA / 800mA			
SEP0900		75V	98V	150mA / 800mA			

Protection Guide

Often equipment manufacturers are not sure what level of protection they need or even what regulatory standards or recommendations apply to their Ethernet ports. The matrix below is an attempt to capture potential protection solutions based on a "typical" application. The matrix below should not be taken as authoritative, but merely as a guide to help narrow in on a particular set of solutions. Please contact Littelfuse for an assessment of your equipment and application to help make sure the right solution is selected if you have any doubts or concerns (www.littelfuse.com) or (+1) 773.628.1000.

Equipment	End Application					
	Small Office / Home Office	Enterprise	Remote Terminal	Central Office	Base Station / Rooftop	
Routers / Switches	ESD & EFT Indoor Short-Haul	ESD & EFT Indoor Short-Haul	Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure	Data Line Protection Lightning, ESD, EFT, CDE, Power Fault, Indoor Long-Haul	Lightning, Severe Outdoor Exposure, ESD, EFT, Power Fault	Solutions
ONT		Data Line Protection Low Level Lightning, ESD & EFT Indoor Short-Haul	Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure	Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure	Lightning, Severe Outdoor Exposure, ESD, EFT, Power Fault	
Modems		Data Line Protection Lightning, ESD, EFT, CDE, Power Fault, Indoor Long-Haul	Data Line Protection Lightning, General or Basic and Enhanced, ESD, EFT, CDE, Power Fault	Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure		
Gateways		Data Line Protection Low Level Lightning, ESD & EFT Indoor Short-Haul				
Phones (IP, PBX)		Data Line Protection Lightning, ESD, EFT, CDE, Power Fault, Indoor Long-Haul	Data Line Protection Lightning, General or Basic and Enhanced, ESD, EFT, CDE, Power Fault			
PCs / Desktops		ESD & EFT Indoor Short-Haul				
Set Top Boxes						
LCD/PDP TVs						
IP Cameras / Security DVR	Data Line Protection Lightning, ESD, EFT, CDE, Power Fault, Indoor Long-Haul	Data Line Protection Lightning, General or Basic and Enhanced, ESD, EFT, CDE, Power Fault	Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure		Lightning, Severe Outdoor Exposure, ESD, EFT, Power Fault	
PoE	PoE PD & PSE lightning	PoE PD & PSE Outdoor				

Data Line Protection

ESD & EFT Indoor Short-Haul

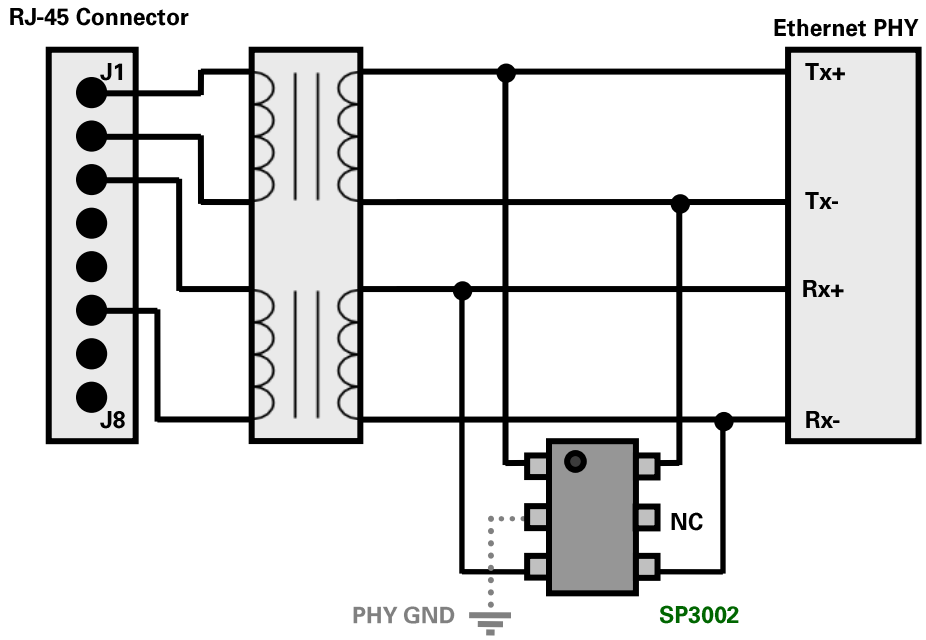
Applicable Standards:

- IEC 61000-4-2 (ESD), 4-4 (EFT)
- ESD & EFT Sections of GR-1089, ESD Sections of ITU-T, and YD/T 950 & 1082

Considerations:

- Some Ethernet ports only need to be protected from ESD and EFTs but not for lightning induced transients.
  - These are sometimes referred to as 2m ports that have very short CAT5/5e cable installations
- Parasitic capacitance should be taken into account especially for 1GbE and higher
- The 4 data lines below (Tx± and Rx±) are being protected against ESD and EFTs by a low capacitance SP3002
  - Any low capacitance SP30xx component is suitable for all "ESD and EFT exposure" Ethernet applications
- 1000Mbps Ethernet (or 1GbE) and 10GbE will require 8 channels of protection for the 4 differential pair so the solution below should be replicated for the remaining 2 differential pair

Application Schematic:



Recommended TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_P=8/20µs)	I/O Capacitance @ V_R=1.65V	# of Channels	V_{RWM}	Packaging
SP3002-04JTG	±12kV	4.5A	0.85pF	4	6V	SC70-6
SP3003-04XTG	±8kV	2.5A	0.65pF	4	6V	SOT563
SP3012-04UTG	±12V	4A	0.5pF (@ 0V)	4	5V	µDFN-10 2.5x1.0mm

Data Line Protection

Low Level Lightning, ESD & EFT Indoor Short-Haul

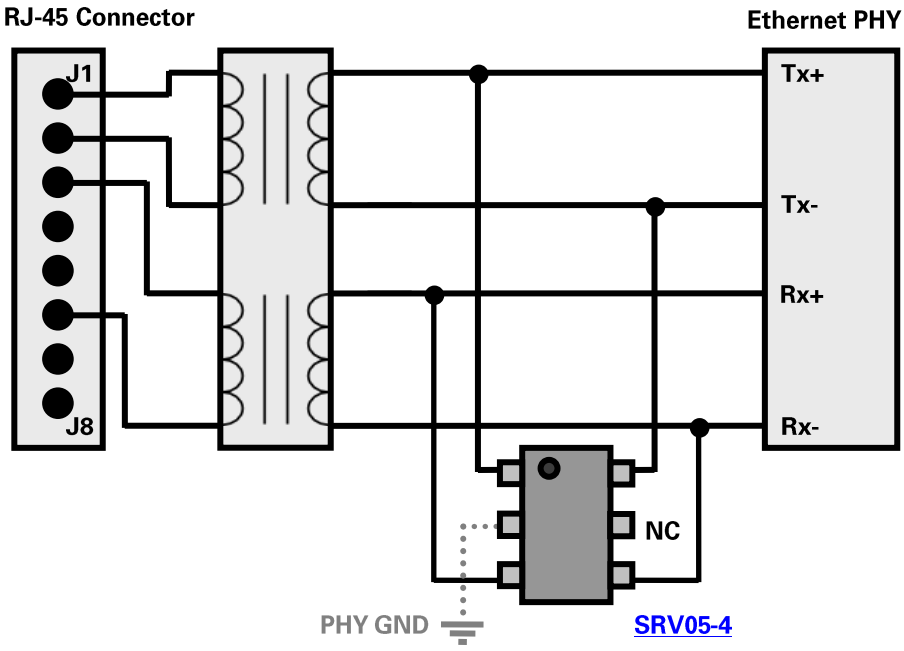
Applicable Standards:

- IEC61000-4-2 (ESD), 4-4 (EFT)
- ESD & EFT Sections of GR-1089, ESD Sections of ITU-T, and YD/T 950 & 1082

Considerations:

- Some Ethernet ports only need to be protected from ESD and EFTs but not for lightning induced transients.
  - These are sometimes referred to as 2m ports that have very short CAT5/5e cable installations
- Parasitic capacitance should be taken into account especially for 1GbE and higher
- The 4 data lines below (Tx± and Rx±) are being protected against ESD and EFTs by a low capacitance SP3002
  - Any low capacitance SP30xx component is suitable for all "ESD and EFT exposure" Ethernet applications
- 1000Mbps Ethernet (or 1GbE) and 10GbE will require 8 channels of protection for the 4 differential pair so the solution below should be replicated for the remaining 2 differential pair

Application Schematic:



Recommended TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_P=8/20µs)	I/O Capacitance @ V_R=0V	# of Channels	V_{RWM}	Packaging
SRV05-4HTG	±20kV	10A	1.2pF	4	6V	SOT23-6
SP2504NUTG	±30kV	20A	2pF	4	2.5V	µDFN-10 2.6x2.6mm
SP3304NUTG	±30kV	20A	2pF	4	3.3V	µDFN-10 2.6x2.6mm

Data Line Protection

Lightning, ESD, EFT, CDE, Power Fault, Indoor Long-Haul

Applicable Standards:

- GR-1089, Intra-Building (Type 2, 3a, 3b, 5a, 5b)
- ITU-T K.20 Internal Ports & YD/T 950-1998
- ITU-T K.21 Internal Ports & YD/T 993-1998
- IEC61000-4-5 (Class0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- If the LC03 component 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 to comply with the isolation requirements of the IEEE 802.3 standard. A properly rated transformer provides the required isolation for IEEE 802.3 compliance.Please consult with your specific compliance testing labs to review this.

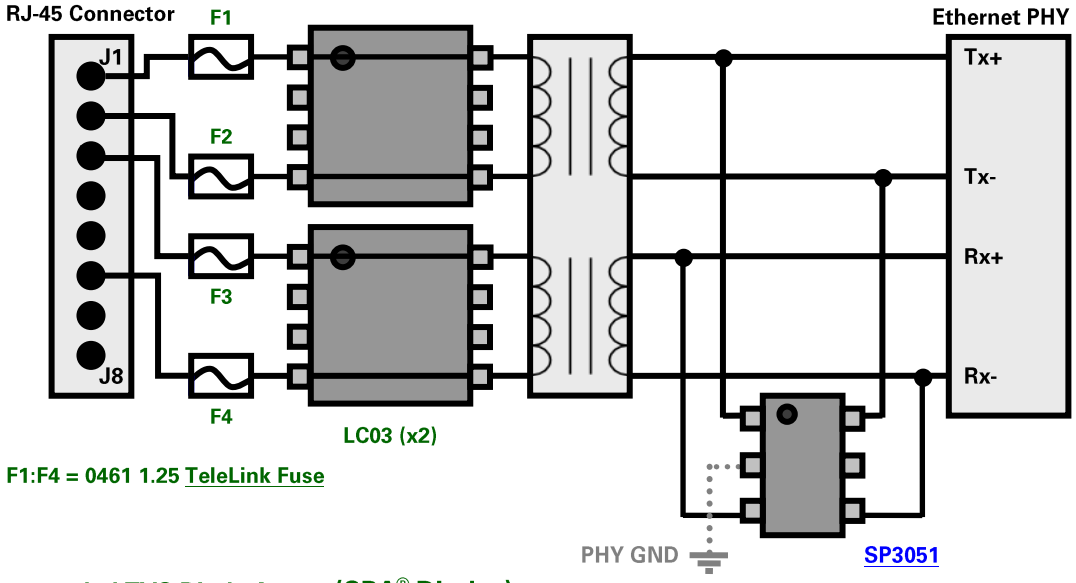
Power Fault Requirements:

- 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. For 10/100BaseT interfaces, a single fuse per wire pair will be sufficient.

Lightning Immunity Requirements:

- The 4 data lines below (Tx± and Rx±) are protected against intra-building lightning transients (100A, t_P=2/10µs for up to 2 pair, 1.2/50-8/20 36.4A per wire for 4 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, SP2204N or SP3304N. The SP3051, SP2504N or
- SP3304N can be connected to ground on the PHY side of the transformer since the IEEE 802.3 isolation requirements are met by the transformer itself.
- 1000Mbps Ethernet (or 1GbE) and 10GbE will require 8 channels of protection for the 4 differential pair so the below scheme should be replicated for the remaining 2 differential pair.

Application Schematic:



F1:F4 = 0461 1.25 TeleLink Fuse

Recommended TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_P=8/20µs)	I/O Capacitance @ V_R=0V	# of Channels	V_{RWM}	Packaging
LC03-3.3BTG	±30kV	150A	4.5pF (I/O to I/O)	2	3.3V	SOIC-8
SP3051-04HTG	±30 kV	20A	2.0 pF (I/O to I/O)	4	6V	SOT23-6
SP2504NUTG	±30 kV	20A	2.0 pF (I/O to I/O)	4	2.5V	µDFN-10
SP3304NUTG	±30 kV	20A	2.0 pF (I/O to I/O)	4	3.3V	µDFN-10

Data Line Protection

Lightning (Inter-building, Basic & Enhanced), ESD, EFT, CDE, Power Fault, Outdoor Exposure

Applicable Standards:

- GR-1089, Inter-Building (Type 1, 3, 5)
- ITU-T K.20 and YD/T 950-1998 (Enhanced Requirements)
- ITU-T K.21 and YD/T 993-1998 (Enhanced Requirements)
- IEC61000-4-5 (Class0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- The SEP component located on the line side of the transformer may have pins 3 and 6 floating in order to be compliant with the IEEE 802.3 isolation requirements. A properly rated transformer wil provide the isolation required for IEEE 802.3 compliance. Please consult with your specific compliance testing labs to review this.

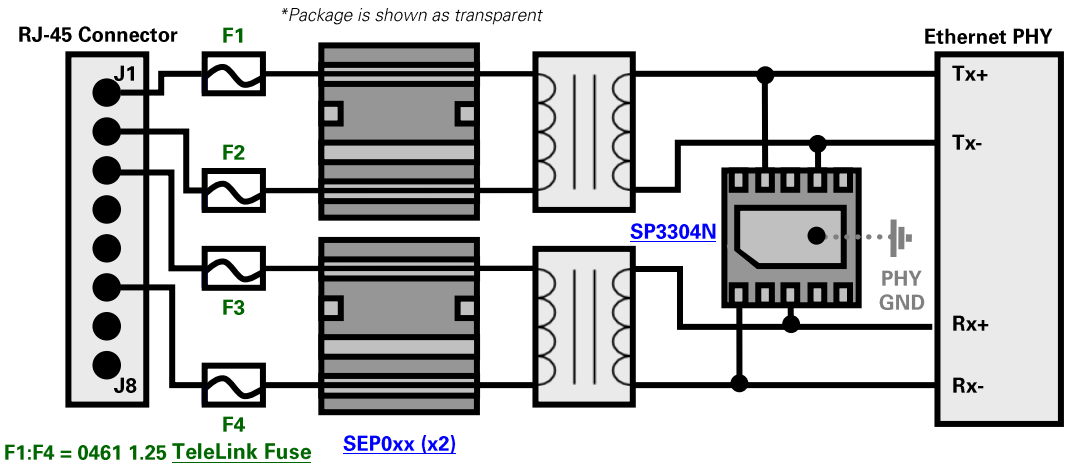
Power Fault Requirements:

- 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 950/1082 power fault requirements. For 10/100BaseT interfaces, a single fuse per wire pair will be sufficient.

Lightning Immunity Requirements:

- The 4 data lines below (Tx± and Rx±) are being protected against GR-1089 Type 3b/5b inter-building lightning transients (1000V, 200A, 2/10µs & 1000V, 25A 10/360µs).
- The SEP diverts the majority of energy away from the transformer, however, any common mode energy coupled through the transformer interwinding capacitance will be returned to GND by the SP3304N shown below. The SP3304N can be connected to ground since it is positioned behind the transformer and thus complies with the IEEE 802.3 isolation requirements.
- 1000Mbps Ethernet (or 1GbE) and 10GbE will require 8 channels of protection for the 4 differential pair so the scheme below should be replicated for the remaining 2 differential pair.
    - In this case the SP4060-08ATG or SP4065-08ATG may be a more suitable option replacing (2x) SP3304N components. The SP3304N component has a snap-back voltage of 2.8, thus it can be used on Ethernet PHY devices with signaling voltages < 2.8 V.

Application Schematic:



Recommended SIDACtor and TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_P=8/20µs)	I/O Capacitance @ V_R=0V	# of Channels	V_{RWM}	Packaging
SEP0640Q38CB	±30kV	400A	See datasheet	2	6V	QFN
SP3304NUTG	±30kV	20A	3.5pF	4	3.3V	µDFN-10 (2.6x2.6mm)
SP4060-08ATG	±30kV	20A	4.4pF	8	2.5V	MSOP-10
SP4065-08ATG	±30kV	20A	4.4pF	8	3.3V	MSOP-10

Data Line Protection

Lightning, General or Basic and Enhanced, ESD, EFT, CDE, Power Fault

Applicable Standards:

- GR-1089, Intra/Inter-Building (Type 1, 2, 3, 3a, 3b, 5, 5a, 5b)
- ITU-T K.20 and YD/T 950-1998 (Basic & Enhanced Requirements)
- ITU-T K.21 and YD/T 993-1998 (Basic & Enhanced Requirements)
- YT/D 1082
- IEC61000-4-5 (Class0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- A properly rated transformer provides the required isolation for IEEE 802.3 compliance.

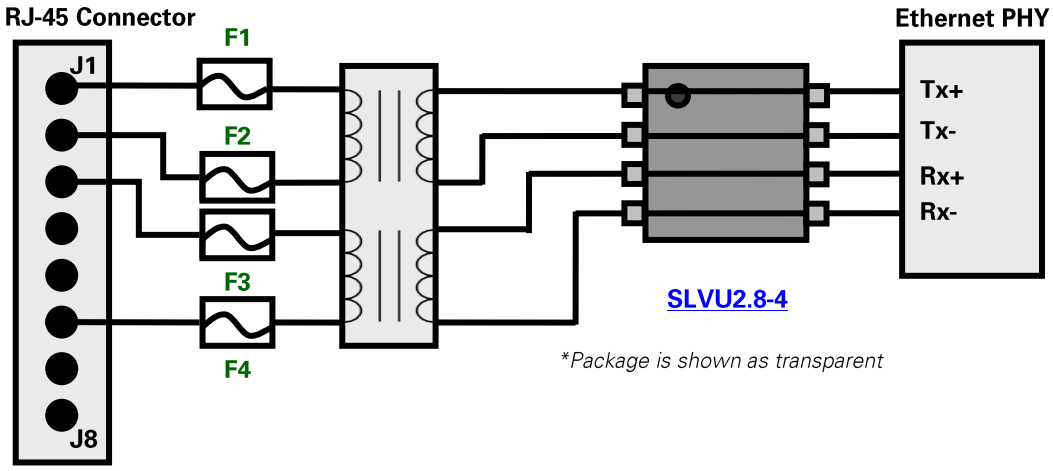
Power Fault Requirements:

- 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 950/1082 power fault requirements. For 10/100BaseT interfaces, a single fuse per wire pair will be sufficient.

Lightning Immunity Requirements:

- Some designers choose to use a high voltage 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 (line side) protector.
- Using such a technique will require a robust PHY side protection component because the transformer saturation occurs later and one such option is the SLVU2.8-4BTG shown below. It should be noted that this component will only provide differential protection between the data pairs.
- If longitudinal and differential protection are required, the SP3304N-UTG (with 2 I/O's tied per line) or SP4060-08ATG (if the PHY line driving voltage is ≤ 2.5 V) or the SP4065-08ATG (for PHY voltage ≤ 3.3V) can be considered as alternatives.
- Protection for Fast Ethernet (100Mbps) is shown below. For 1000Mbps (or 1GbE) and 10GbE interfaces, 2x SLVU2.8-4BTG are required

Application Schematic:



Recommended TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_p=8/20µs)	I/O Capacitance @ V_R=0V	# of Channels	V_{RWM}	Packaging
SLVU2.8-4BTG	±30kV	40A	2.0pF	4	2.8V	SOIC-8
SP3304NUTG	±30kV	20A	3.5pF	4	3.3V	µDFN-10 (2.6x2.6mm)
SP4060-08ATG	±30kV	20A	4.4pF	8	2.5V	MSOP-10
SP4065-08ATG	±30kV	20A	4.4pF	8	3.3V	MSOP-10

Data Line Protection

Lightning, Severe Outdoor Exposure, ESD, EFT, Power Fault

Applicable Standards:

- GR-1089, Inter-Building (Type 1, 3, & 5)
- ITU-T K.20 and YD/T 950-1998 (Enhanced Requirements)
- ITU-T K.21 and YD/T 993-1998 (Enhanced Requirements)
- YT/D 1082
- IEC61000-4-5 (Class0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- The GDTs (Gas Discharge Tubes) are connected between the data pair (and not GND) to be compliant with the IEEE802.3 standard. A properly rated transformer provides the required isolation for IEEE 802.3 compliance.

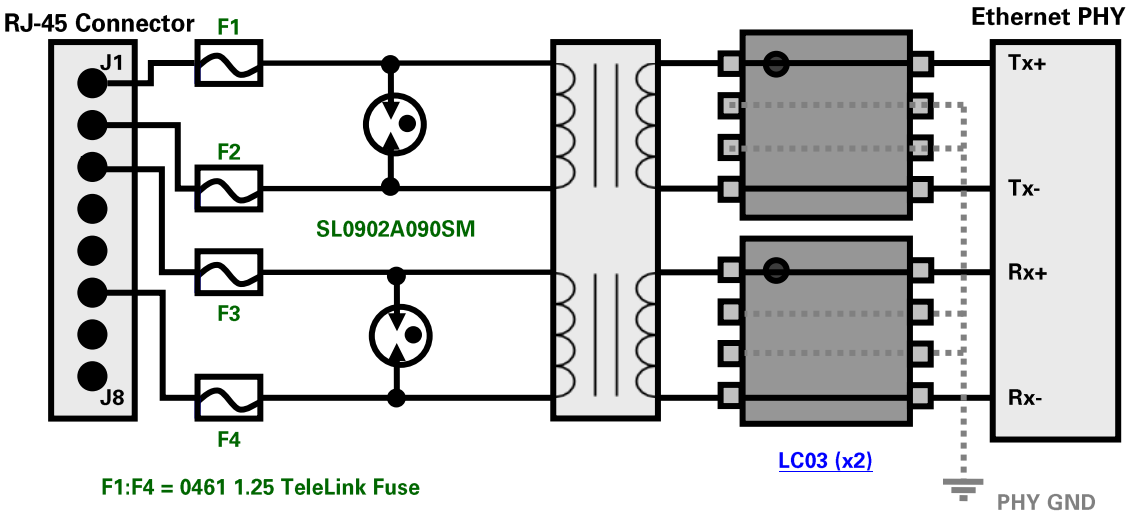
Power Fault Requirements:

- 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 950/1082 power fault requirements. For 10/100BaseT interfaces, a single fuse per wire pair will be sufficient.

Lightning Immunity Requirements:

- Some customers have applications that may see severe levels of lightning that exceed the limits of today's silicon technology.
- For these applications (e.g. >500A, 2/10µs or 400A 1.2/50-8/20) a GDT is recommended to protect the transformer along with very robust protection component to suppress the let-through energy at the PHY.
- The SL0902A090SM (1.5pF, 5000A, 8/20µs) is shown below along with the LC03-xBTG for PHY protection. A single SP4060-08ATG (if the PHY line driving voltage is ≤ 2.5 V) or the SP4065-08ATG (for PHY voltage ≤ 3.3V)or two SLVU2.8-4 (for PHY voltage ≤ 2.8V)may be considered as an alternate solution but would NOT be as robust as the LC03 for 1GbE and 10GbE applications.

Application Schematic:



Recommended TVS Diode Arrays (SPA® Diodes):

Ordering Number	ESD Level (Contact)	Lightning (t_P=8/20µs)	I/O Capacitance @ V_R=0V	# of Channels	V_{RWM}	Packaging
LC03-3.3BTG	±30kV	150A	9pF	2	3.3V	SOIC-8
SP2502LBTG	±30kV	75A	5pF	2	3.3V	MS-012
SLVU2.8-4BTG	±30kV	40A	2.0pF	4	2.8V	SOIC-8
SP4060-08ATG	±30kV	20A	4.4pF	8	2.5V	MSOP-10
SP4065-08ATG	±30kV	20A	4.4pF	8	3.3V	MSOP-10

PoE PD (Powered Device) Protection or PoE PSE (Power Supply Equipment) Protection

PoE PD & PSE lightning low to high exposure

Applicable Standards:

- GR-1089, Intra-Building (Type 2)
- ITU-T K.20 Internal Ports & YD/T 950-1998
- ITU-T K.21 Internal Ports & YD/T 993-1998
- IEC61000-4-5 (Class0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- A properly rated transformer and power supply provides the required isolation for IEEE 802.3 compliance.

Power Fault Requirements:

- The TeleLink fuses F1 - F8 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.

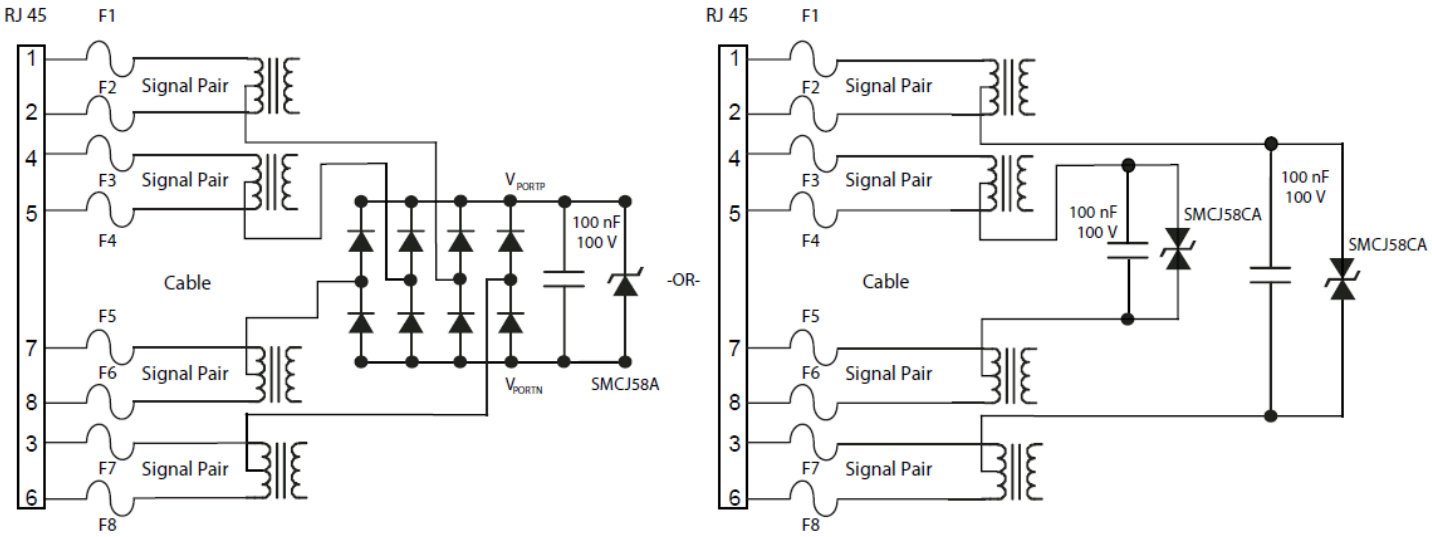
Lightning Immunity Requirements:

- For low exposure intra-building PoE applications, the SMAJ58A (400W or 4.3A @ 10/1000 µs) provides both Mode A and Mode B protection when the diode bridge is implemented as shown below for the PD. For the PSE, only four diodes would be needed as the PSE defines whether Mode A or Mode B is used. An alternative method would be to place a single SMAJ58CA (bi-directional version) across the center tap signal pair and a second SMAJ58CA across the center tap spare pair. For the PSE, a single SMAJ58CA would be used, since the PSE controls whether Mode A or Mode B powering is used. The bi-directional version SMAJ58CA is used to insure no polarity issues and thus does not require the diode bridge polarity guard circuit. The SMBJ58A (58CA) version would provide a higher surge rating solution (600W or 6.5A @ 10/1000 µs), the SMCJ58 (58CA) would provide the next surge rating increase (1500W or 16.1A @ 10/1000 µs) and the SMDJ58A (58CA) version would provide another increase in surge rating (3000W or 32.1A @ 10/1000 µs).

- The TeleLink fuses (0461 1.25ER) F1 – F8 will comply with the power fault requirements and NOT open during lightning surge events.

- Small form-factor, chip fuses may be selected for F1 - F8 when protection of PSE ONLY requires over-current protection for safety reasons and is not subjected to Intra-building surges. At the 57V, 600mA maximum power PoE+ requirement, the circuit falls under IEC60950-1, Limited Power Source, Sec 2.5, Table 2B. For standard PoE (400ma) or for PoE+ (600ma), the recommended over-current component for F1 – F8 is the 04611.25 fuse.

Application Schematic:



Note: for two wire pair 10/100BaseT systems, there are two "spare pair" instead of all signal pair and those spare pairs would not be connected via center tap transformer point

PoE PD Protection or PoE PSE Protection

PoE PD & PSE Outdoor exposure (high)

Applicable Standards:

- GR-1089, Inter-Building (Type 1, 3 & 5)
- ITU-T K.20 & K.21
- YD/T 950-1998, 993, & 1082
- IEC61000-4-5 (Class 0 - 4)
- IEC61000-4-2 (ESD) & 4-4 (EFT)
- UL60950-1 / IEC60950-1 / EN60950-1

Isolation Requirements:

- A properly rated transformer and power supply provides the required isolation for IEEE 802.3 compliance.

Power Fault Requirements:

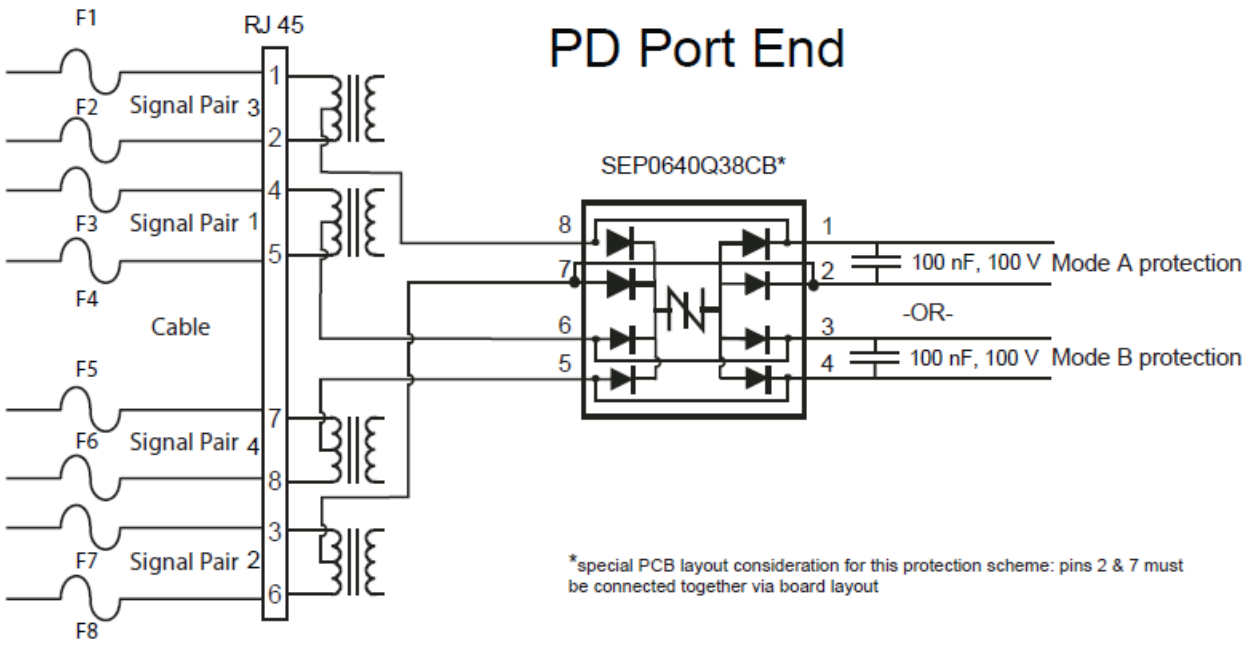
- The TeleLink fuses F1 – F8 provide overcurrent protection that complies with the GR-1089, ITU K20/21, UL60950-1 / IEC60950-1 / EN60950-1 and YD/T 950 & 1082 power fault requirements.

Lightning Immunity Requirements:

- For high exposure inter-building PoE applications, the SEP0640Q38CB can provide both Mode A and Mode B protection for the PD equipment without the need of an external diode bridge. Normally pins 2 & 7 of the SEP component are used for biasing purposes but in this application these two pins are connected together via PCB traces and used as part of the protection solution. For a PSE solution, only two wire pairs would require protection since the powr Mode is defined by the PSE side and thus would not have to protect both Mode A and Mode B.

- The TeleLink fuses F1 - & F8 (0461 1.25ER) will comply with the power fault requirements but NOT open during lightning surge events.

Application Schematic:



Ordering Guide

Series	Number of Channels	Package	Orderable Part Number
SP3002	4	SOT23-6	SP3002-04HTG
		SC70-6	SP3002-04JTG
		µDFN-6 (1.6x1.6mm)	SP3002-04UTG
SP3003	2	SC70-5	SP3003-02JTG
		SOT553	SP3003-02XTG
	4	SC70-6	SP3003-04JTG
		SOT563	SP3003-04XTG
		MSOP-10	SP3003-04ATG
SP3012	4	µDFN-10 (2.5x1.0mm)	SP3012-04UTG
	6	µDFN-14 (3.5x1.35mm)	SP3012-06UTG
SRV05-4	4	SOT23-6	SRV05-4HTG
SP3051	4	SOT23-6	SP3051-04HTG
SP2502L	2	SOIC-8 (MS-012)	SP2502LBTG
SP4060	8	MSOP-10	SP4060-08ATG
SP4065	8	MSOP-10	SP4065-08ATG
SP2504N	4	µDFN-10 (2.5x1.0mm)	SP2504NUTG
SP3304N			SP3304NUTG
SP03-3.3	2	SOIC-8 (MS-012)	SP03-3.3BTG
LC03-3.3			LC03-3.3BTG
SLVU2.8	1	SOT23-3	SLVU2.8HTG
SLVU2.8-4	4	SOIC-8	SLVU2.8-4BTG
SEP008	2	5x6mm QFN	SEP0080Q38CB
SEP0640			SEP0640Q38CB
SEP0720			SEP0720Q38CB
SEP0900			SEP0900Q38CB

Appendix A

Supplemental PoE and PoE+

The PoE specification provides a "handshaking" routine between the PSE (Power Supply Equipment) and the PD (Powered Device) before power is applied. This insures power compatibility and helps to prevent safety violations. The PSE can apply power to the wire pairs only when an attached device has indicated its ability to receive power. This "handshaking" routing is known as Resistive Power Discovery. It relies on a 25kΩ (nominal) resistance that is part of the network devices. The PSE will test the resistance of the network device before sending full power onto the wiring pair. This test is conducted with a series of two low-voltage "discovery" signals. The second signal uses a slightly higher voltage than the first, but neither is enough to damage an incompatible device. After the PSE has determined that IEEE 802.3af/at compliant devices are connected, it injects power to those ports. It will not send power to devices that failed either of these two resistance tests. An IEEE 802.3af compliant PSE can source up to 15.4W (PD can accept up to 13 W)while an IEEE 802.3at compliant PSE can source up to 30W (PD can accept up to 25.5W). Table 1 below contrasts the differences between PoE and PoE+ allowed voltages and currents.

These "discovery" signals require the PSE to conduct voltage-current measurements with a current limited voltage probe technique. When the probing voltage is applied, then the appropriate values must be detected to discern that a valid load exists BEFORE power can be applied. Table 2 below shows these requirements for IEEE 802.af while Table 2a shows the signature parameters for PoE+ (IEEE 802.at). The main difference between these two powering schemes is the maximum cable loop resistance limit for PoE+ is reduced to 12.5 ohms from 20 ohms for PoE. The Type 1 PoE+ is almost exactly the same as PoE, while PoE+ Type 2 takes advantage of the higher power delivery.

Table 1: PoE vs PoE + Voltage/current values

PARAMETER	MIN	MAX
PoE PSE Voltage Range	44V	57V
PoE+ PSE Voltage Range Type 1	44 V	57 V
PoE+ PSE Voltage Range Type 2	50 V	57 V
PoE PSE Current Range	-	400 mA
PoE+ PSE Current Range	350 mA	600 mA
PoE PD Voltage Range	36V	57V
PoE+ PD Voltage Range Type 1	37.0 V	57 V
PoE+ PD Voltage Range Type 2	42.5 V	57 V
PoE PD Current Range	-	360 mA
PoE+ PD Current Range	350 mA	600 mA

Table 2: Valid PD Signature Parameters for PoE (IEEE 802.af)

PARAMETER	CONDITIONS (V)	MIN	MAX
V-I slope	-2.7 to -10.1	23.7kΩ	26.3kΩ
Voltage offset	-	-	1.9V
Current offset	-	-	10µA
Signature Capacitance	-2.7 to -10.1	0.05µF	0.12µF
Input inductance	-2.7 to -10.1	-	100mH

Table 2a: Valid PD Signature Parameters for PoE+ (IEEE 802.at)

PARAMETER	CONDITIONS (V)	MIN	MAX
V-I slope	-2.7 to -10.1	23.7Ω	26.3kΩ
Voltage offset	-	0V	1.9V
Current offset	-	0µA	10µA
Input Capacitance	-2.7to -10.1	0.050µF	0.120µF
Input inductance	-2.7 to -10.1	-	100mH

The PSE also detects the power classification of the client devices by applying a probing voltage between for up to 75ms. The PD device indicates its power classification (one out of four currently available classes as shown in Table 3 and 3a below). This information allows the PSE to intelligently manage power delivery and prevents PD's power requirements from exceeding the PSE's ability. Under this scenario, an intelligent PSE can refuse to deliver any power to the port under question until the PD power classification is met. This can also provide a method of prioritizing ports to be powered during UPS or backup generator operation.

Appendix A (continued)

Table 3: PD Power Classifications and Signatures for PoE (IEEE 802.3af)

CLASS	CONDITIONS (V)	CLASSIFICATION CURRENT (mA)	PD POWER RANGE (W)
0 (Default)	-14.5 to -20.5	0 to 4	0.44 to 12.95
1	-14.5 to -20.5	9 to 12	0.44 to 3.84
2	-14.5 to -20.5	17 to 20	3.84 to 6.49
3	-14.5 to -20.5	26 to 30	6.49 to 12.95
4 (Reserved for future use)	-	-	-

Table 3a: PD Power Classifications and Signatures for PoE+ (IEEE 802.3at)

CLASS	CONDITIONS (V)	CLASSIFICA-TION CURRENT (mA)	PD POWER AVG (W)	PD Type
0	-14.5 to -20.5	0 to 4	13.0	1
1	-14.5 to -20.5	9 to 12	3.84	1
2	-14.5 to -20.5	17 to 20	6.49	1
3	-14.5 to -20.5	26 to 30	13.0	1
4*	-14.5 to -20.5/ -6.90 to -10.1	36 to 44	25.5	2

* The PoE+ Type 2 returns a Class 4 classification signature

The PSE will constantly monitor the connected clients in order to maintain power. For PoE, a PD must draw a minimum current of 10mA for at least 75ms out of a 250ms period and continue to present an input resistance of no more than 26.3kΩ. If the current drawn falls below this minimum threshold, the PSE will disconnect the -48V supply and restart the detection sequence. (Most PoE PD devices draw 100mA to 300mA). It will also disconnect for excessive current draw for the PD's classification. The PSE may also provide a probing AC voltage up to 500Hz and disconnect if minimum values are not maintained (27kΩ at 5mA max is a valid impedance).

The resulting voltage level the PSE is allowed to apply is between -44V to -57V. The PD device will see between -36V and -57V, depending on the length and category type of cable used.

The PDs and PSEs must provide an electrical isolation that can withstand at least one of the following to be fully compliant to the IEEE 802.3af/at standard:

1) 1500 V_{RMS} at 50Hz to 60Hz for 60s
2) 2250 V_{DC} for 60s OR
3) An impulse of 2400V, with a voltage waveshape of 1.2x50µs applied ±10 times with a 60s interval between successive surges

There shall be no insulation breakdown during the test and the resistance after test shall be at least 2 MΩ when measured at 500 V_{DC}. The IEEE 802.3at PoE+ 2009 version actual states a 1500V, 10/700µs waveshape but it is expected that this will be modified to agree with the IEEE 802.3af standard.

These voltage levels used during the discovery processes along with the electrical isolation requirements provide the minimum longitudinal turn on voltage threshold for any protection devices placed across an Ethernet pair on the line side of the coupling (isolating) transformer.

Any clamping or crowbarring device placed across a wire pair used for power delivery must not react nor interfere with these handshaking routines. This requires voltage activated surge protection devices located on the line side of the isolating transformer in a PoE application to NOT turn on;

1) For one of the following (user's choice): common mode 1500V_{RMS}, 2250 V_{DC} or 2400V 1.2/50-8/20µs surge
2) between pairs during classification testing voltage worse case, which is 20.5V
3) between pairs or common mode due to highest possible PSE voltage, which could be - 57 V_{DC}
4) differentially for normal operating condition of the Ethernet data signal, which is typically less than 5V
5) between pairs for the original discovery voltage of 10.1 volts

Therefore, it can be seen that strict adherence to IEEE 802.3 does NOT allow for common mode protection on the line side of the coupling transformer other than the transformer itself. However, IEEE 802.3 refers to the insulation test requirements in subclause 5.2.2 of UL 60950-1, which allows removal of any common mode connected overvoltage protector BEFORE conducting the surge insulation test. Therefore, it is recommended that the user consult with their compliance department or compliance testing professional to determine the correct interpretation for their application.

Appendix B

GR-1089 Issue 6 Ethernet type ports

ESD (Electrostatic Discharge)
The EUT (equipment under test) shall be tested using the methods of IEC 61000-4-2 (ESD), clauses 7 and 8, with the preferred method being the contact discharge method as specified in clause 7. The EUT shall not be damaged and shall continue to operate without negatively affecting service or requiring the need for manual intervention. Examples of test points includes: panels, doors, exposed frame areas, consoles, pushbuttons, keypads, faceplates, extractor tabs, lamps, LEDs, circuit breakers, accessible fuses and fuse holders, metallic covers of D-subminiature connectors, and test-plug jacks.

ESD Test Conditions

Test Level	Air Discharge	Contact Discharge	Repetition
2	4kV	---	±20*
4	15kV	---	±20*
4	---	8kV	±10*

*For a total of 40 times for air discharge or a total of 20 times for contact discharges

EFT (Electrical Fast Transient)
The EUT shall be tested using the methods of IEC 61000-4-4 (EFT). The EUT shall not be damaged and shall continue to operate without negatively affecting service or requiring the need for manual intervention. Five single minute burst test of each polarity as shown below are applied.

Peak voltage	Port Type	Repetition Rate
250 volts	1 & 2	5 kHz or 100 kHz (higher frequency is closer to actual field conditions)
500 volts	3 & 4	
500 volts	Non-customer premises ac & dc ports	
1,000 volts	Customer premises ac & dc ports	

Lightning Immunity
GR-1089 contains 1st Level and 2nd Level Inter-building and Intra-Building test conditions. The specific surge condition depends on the port type.

Port Type Number	Description
1	Network Inter-building
2	Network Intra-building
3	Customer premises (CP) inter-building and cell site locations
3a	Intra-building cell site CP ports
3b	Short reach Outside Plant (OSP) CP ports*
4	CP intra-building
4a	Customer side ONT intra-building
5	OSP inter-building
5a	Intra-cell site
5b	Short reach OSP ports
6	Antenna ports
7	AC power ports
8	Local DC power ports
8a	DC power to antenna
8b	Intra-cell DC power

* Typically less than 500 feet

Ethernet ports are most commonly intra-building port types but can be Type 1, 2, or 3 depending on their connection environment. All Ethernet ports are subjected to metallic and longitudinal surges and power fault testing with the exception of Type 2 Ethernet ports. The following Type 2 Ethernet ports are subjected to only longitudinal (common mode) type surges IF it meets the following criteria:

a) LAN cabling that is not connected to external ports
b) LAN equipment powered from a single power feed
c) There are no ground referenced SPDs installed
d) It is a non-PoE interface.

For the 10/100 BaseT Ethernet interfaces some wire pairs are not used for data but will have a "Bob Smith" termination circuit. These "unused" pairs are also tested and the termination components cannot be damaged since their failure could result in increased radiation emissions. PoE interfaces also have their inter-powering wire pair surge tested. PoE pairs are also surge tested.

Appendix B (continued)

1st Level Inter-building (Type 3b/5b surge test #1 & 2 only)

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±1000	25	10/360	±5
2	@±Vs of secondary protector	25@ 1000V		
3	±100 to ±1000 (100V increments)	10 to 100	10/1000	
4	±1000 to ±2000	100 to 200		
5	±2500	500	2/10	±10
6	@±Vs of secondary protector	100@ 1000V	10/1000	±5
7	±4000	100	10/700-5/310	

1st Level Port Types 3 & 5 (3b/5b surge #1 only)

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±1000	200	2/10	±5
2	±1000	100	10/1000	
3	±400 to ±4000 (high exposure)	50 @ 400V; 500 @ 4000V		

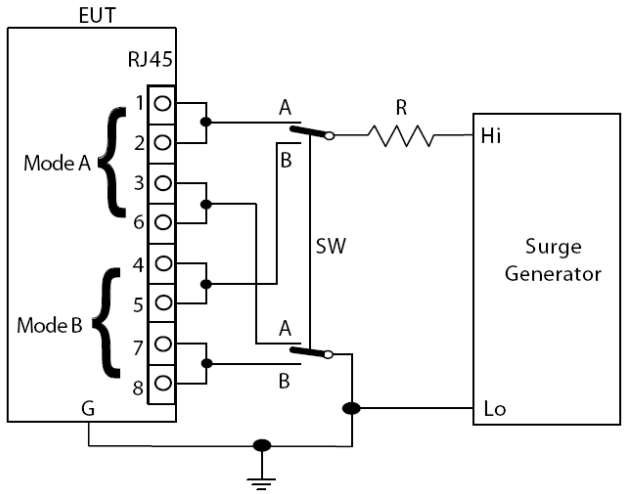
1st Level Intra-building surges for Port Types 2, 3a/5a. 4, 4a with three and four wire pairs (test 1 & 3 for unshielded PoE)

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±800 (external 6 ohms per wire)	44.4/three wire pair 36.4/four wire pair	1.2/50-8/20	±5
2	±1500 (external 20 ohms per wire)	47/three wire pair 42/four wire pair		
3	±Vs	100 @ 800V		
4		68 @ 1500V		

1st Level Intra-building surges for Port Types 2, 3a/5a. 4, 4a with more than four wire pairs (test 1 & 3 for unshielded PoE)

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±800 (external 6 ohms per wire) metallic only	< 36/wire	1.2/50-8/20	±5
2	±1500 (external 40 ohms per wire) longitudinal only	<42/wire		
3	±Vs	100 @ 800V		
4		35.7 @ 1500V		

Unshielded PoE Port metallic testing

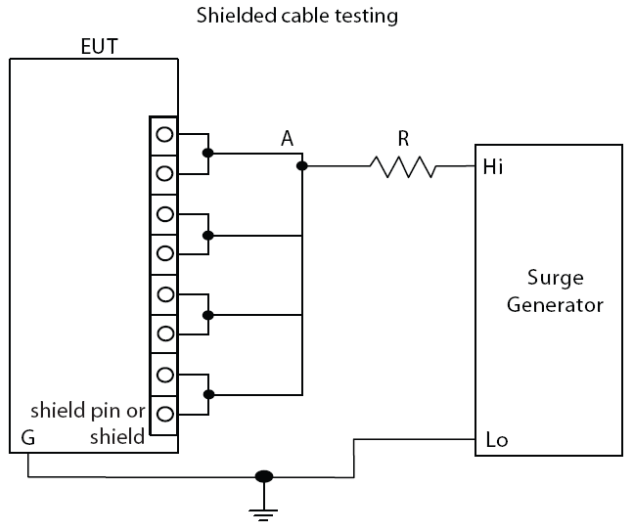


Appendix B (continued)

Shielded Cable Testing

For Equipment Port Types 2, 3a/5a, 4, 4a, or 8b that use a shielded cable that is grounded and bonded to earth ground at **both** ends, then the following tests are conducted instead of those outlined above using the figure below for the surge generator connections.

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±1500	750 (before external 2-ohm is added resulting in 375 total)	1.2/50-8/20	±5



The Type 2 Ethernet ports are exempted from metallic (differential) testing **IF**

1) the port does not contain a grounded secondary protector
2) any unused pins are not grounded (Bob Smith termination is not considered as a grounded connection in this context)

Type 4 and 4a are exempted from the metallic testing until August 1, 2012.

2nd Level surges for Port Types 1, 3, and 5

Surge #	Peak Voltage Minimum (V)	Peak Current Minimum (A)	Waveshape	Reps
1	±5000	500	2/10	±5

Appendix B (continued)

GR-1089 Issue 6 Power Fault

Power companies and telephone operating companies often share telephone poles and trenches; therefore, network equipment is often subjected to the voltages seen on power lines. If direct contact between the Ethernet port and the primary power line occurs, the Ethernet port could see as much as $600V_{RMS}$ for up to five seconds. If direct contact occurs with the secondary power line, voltages will be limited to $277V_{RMS}$; however, these secondary voltages may persists indefinitely since the resultant current may not be sufficiently high enough to cause the power system to reset itself. Indirect contact between the Ethernet line and the power line may result in large voltages being induced upon the Ethernet line (the large power line currents can create interfering magnetic fields). Primary protectors should limit these levels to 1000V peak and $600V_{RMS}$. Issue 6 assumes a high voltage category primary protector is always replacing the older 3-mil carbon-gap technology. This newer technology limits the 60 Hz events to 425 V rms (600 V peak). As a result of this newer technology being used, the power fault events are limited to a lower peak voltage level as reflected in the following two tables. For intra-building applications, the power fault is limited to the normal household voltage level of 120 volts.

1st Level Power Fault Tests (Port Types 1, 3, & 5)

Test #	Min voltage peak value (V)	Min current per conductor (A)	Reps	Duration	Test Connections
1	50	0.33	1	15 minutes	Metallic and longitudinal
2	V_s	0.33 @ 50 V			
3	100	0.17			
4	V_s	0.17 @ 100 V			
5	200	0.47	60	1 s	
6	425	1			
7	V_s	1 @ 425 V			
8	1000	1			Longitudinal
9	425	0.50	1	4 s	Metallic & longitudinal
10	425	0.71	5	2 s	

V_s tests are conducted at the primary protector maximum voltage breakdown with the primary protector removed from the circuit.
*For more on test connections please refer to the Littelfuse SIDACtor catalog
Notes:
1. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.
2. Sufficient time may be allowed between applications to preclude thermal accumulation.

2nd Level Power Fault (Port Types 1, 3, & 5; Test 1 at 120V also applies to Port Types 3a, 3b, 4, 4a, 5a, & 5b)

Test	Applied Voltage, 60Hz (V_{RMS})	Short Circuit Current per Conductor (A_{RMS})	Duration	Test Connections*
1	120, 277	25	15min	Metallic and longitudinal
2	425	40	5s	
3	425	7, 10, 12.5, 20, 25, & 30	5s	
4	425	2.2, 2.6, 3.0, 3.75, & 5	15min	
5	Vs	Vs/60.7	5s	
6	Vs	Vs/193.2 & at 2.2	15 min	

*For more on test connections please refer to the Littelfuse SIDACtor catalog.
Notes:
1. Primary protectors are removed for all tests.
2. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.
3. These tests are repeated using a short-circuit value just below the operating threshold of the current limiting component, or, if the EUT uses a fuse as current limiting protection, the fuse may be bypassed and the short circuit current available adjusted to 135 percent of the fuse rating.

Appendix C

ITU-T K.20 & K.21 Ethernet type ports

ITU-T, the Telecommunication Standardization Sector of the ITU, developed fundamental testing methods that cover various environmental conditions to help predict the survivability of network and customer-based equipment. The testing methods cover the following conditions:

1. Surges due to lightning strikes on or near twisted pairs and plant equipment (excluding a direct strike)
2. Short-term induction of an AC voltage from adjacent power lines or railway systems
3. Direct contact between telecommunication lines and power lines (often referred to as AC power fault)
4. ESD events as outlined in IEC 61000-4-2 and EFT events as outlined in IEC 61000-4-4

Two ITU-T Recommendations apply for most telecommunications equipment:

1. ITU-T K.20
2. ITU-T K.21

ITU-T K.20 is primarily for equipment located in the telecommunication centers where the bonding and grounding is installed according to ITU K.27 Recommendation.

K.21 covers telecommunication equipment installed at customer premises.

However, for complex subscriber equipment, test administrators may choose either K.20 or K.21, depending on which is deemed most appropriate. ITU K20 and K21 contain tests for both external and internal ports.

Note: Both specifications are intended to address equipment resistibility to lightning induced events, liability versus equipment safety. For specific concerns regarding equipment safety, research and follow national standards for each country in which the equipment is intended for use.

Equipment submitted under either of these two Recommendations must meet one of two levels: basic or enhanced. Guidelines for determining which level of these two levels are appropriate for the equipment under test (EUT) can be found in ITU-T K.11, but the final authority rests with the test administrator. ITU-T K.44 describes the test conditions used in K.20 and K.21.

ITU-T defines the following acceptance criteria:

Criterion A states that equipment shall withstand the test without damage and shall operate properly after the test without an operator or user manual intervention. It is not required to operate correctly during the test.

Criterion B states that a fire hazard must not occur as a result of the tests. Any damage shall be confined to a small part of the equipment and it shall not emit hot materials and any flame occurrence shall not propagate beyond the equipment.

Lightning Immunity

K. .20 Lightning Test Conditions for Ethernet Equipment in Central Office/Remote Terminal and connected to external ports

Voltage (10/700µs)		Current (5/310µs) Basic/Enhanced (A)	Reps*	Primary Protection	Acceptance Criteria
Single Port Metallic and Longitudinal Basic/Enhanced	Multiple Ports Longitudinal Only Basic/Enhanced				
1kV / 1.5kV		25 / 37.5	±5	None **	A
4kV / 4kV		100 / 100	±5	Agreed primary protector is installed and primary to secondary coordination is required	A
	1.5kV / 1.5kV	37.5 / 37.5	±5	None**	A
	4kV / 6kV	100 / 150	±5	Agreed primary protector is installed and primary to secondary coordination is required	A

Appendix C (continued)

Lightning Immunity (continued)

K. 21 Lightning Test Conditions for Ethernet Equipment in Customer Premises connected to external ports

Voltage (10/700µs)		Current (5/310µs) Basic/Enhanced (A)	Repetitions*	Primary Protection	Acceptance Criteria
Single Port Metallic and Longitudinal Basic/Enhanced	Multiple Ports Longitudinal Only Basic/Enhanced				
1.5kV / 1.5kV (6 kV longitudinal)		25 / 37.5 (150)	±5	None **	A
4kV / 6kV	4kV / 6kV	100 / 150	±5	Agreed primary protector is installed and primary to secondary coordination is required	A
	1.5kV / 1.5kV	37.5 / 37.5	±5	None**	A

* One-minute rest between repetitions ** Test not conducted if primary protection is used

IEC 61000-4-2 ESD ±5 air discharges at Level 3 are required for the Basic test level and at Level 4 for Enhanced test level for both ITU K.20 and K.21. IEC 61000-4-2 ESD ±5 contact discharges at Level 3 are required for the Basic test level and at Level 4 for Enhanced test level for both ITU K.20 and K.21.

K.20/21 Lightning Test Conditions for Ethernet Equipment Internal ports

Voltage (1.2/50µs)		Current (8/20µs) Basic (A)	Current (8/20µs) Enhanced (A)	Repetitions*	Acceptance Criteria
Unshielded Cable Basic/Enhanced simultaneous longitudinal	Shielded Cable Basic/Enhanced Simultaneous longitudinal w/conductor & shield connected				
500V / 1000V (K.20) 1000V/1500 V (K.21)		27.7 (K.20) per wire (for four conductor interfaces) 55.56 (K.21)	55.56 (K.20) per wire (for four conductor interfaces) 83.34 (K.21)	±5	A
	500V / 1000V (K.20) 1000/1500 (K.21)	250 (K.20) per wire 500 (K.21)	500 (K.20) per wire 750 (K.21)	±5	A

Power Fault

K.20/K.21 Power Fault Test Conditions for Ethernet Ports connected to external ports (Metallic and Longitudinal)

Voltage Basic/Enhanced	Current Basic/Enhanced	Duration Basic/Enhanced	Repetitions *	Primary Protection	Acceptance Criteria Basic/Enhanced
600V/600 V 50 or 60Hz	1 / 1	0.2s	5	None	A / A
600V/1.5kV 50 or 60Hz	1 / 7.5	1s / 2s	5	None	A / A
230V/230V 50 or 60Hz	23 / 23	15min	1	None	B / B
	11.5 / 11.5				B / B
	5.75 / 5.75				B / B
	2.975 / 2.875				B / B
	1.44 / 1.44				B / A
	0.77 / 0.77				B / A
	0.383 / 0.383				B / A
	0.23 / 0.23				B / B

* One-minute rest between repetitions

Appendix D

IEC 61000 Series Ethernet type ports

IEC 61000-4-2

The IEC 61000-4-2 defines test procedures to evaluate equipment ESD resistibility performance.

IEC61000-4-2: ESD Test Levels

Level	Contact Discharge	Air Discharge
	Voltage	
1	2kV	2kV
2	4kV	4kV
3	6kV	8kV
4	8kV	15kV
x	Special	Special

IEC 61000-4-2: ESD Test Current Values vs. Time

Level	Voltage	Rise Time	Peak Current	Current at 30ns	Current at 60ns
1	2kV	0.7-1ns	7.5A	4A	2A
2	4kV		15A	8A	4A
3	6kV		22.5A	12A	6A
4	8kV		30A	16A	8A

IEC 61000-4-2: Guidelines for Test Selection

Class	Relative Humidity as low as	Anti-Static Material	Synthetic Material	Maximum Voltage
1	35%	X		2kV
2	10%	X		4kV
3	50%		X	8kV
4	10%		X	15kV

The test level chosen for a particular application should consider its installation and environmental conditions.

Appendix D (continued)

IEC 61000-4-5

Lightning Immunity (IEC 61000-4-5)

This standard defines test procedures to evaluate equipment immunity to uni-directional surges resulting from electrical switching and nearby lightning strikes. The switching transients are associated with power system switching disturbances, and various system faults. The lightning transients are associated with direct lightning strikes to an outdoor circuit; indirect lightning strikes such a cloud to cloud, and nearby lightning strikes.

IEC 61000-4-5: 10/700-5/320 generator

Waveform Description	Voltage Waveform	Current Waveform	Output Impedance	Open Circuit Voltage	Short Circuit Current	Repetition Rate
CWG of ITU K	10 / 700µs	5 / 320µs	40Ω	500V to 4kV	12.5A to 100A	1/minute

IEC 61000-4-5: Guidelines for Test Level Selection

Class	Description
0	Well-protected, generally considered intra-building (Surge Voltage < 25 V)
1	Partly protected (Surge Voltage < 500 V)
2	Cables well separated (Surge Voltage < 1000 V)
3	Cables run in parallel (Surge Voltage < 2000 V)
4	Outside connections running along with power (Surge Voltage < 4000 V)
5	Telecommunication cables and overhead power lines in non-dense populated areas
X	Special conditions as specified in the product requirements

IEC 61000-4-5: Test Level Selection Criteria

Installation Class	Test Levels					
	PoE (dc power supply)		Unshielded Ethernet		Shielded Ethernet	
	Metallic	Longitudinal	Metallic	Longitudinal	Metallic	Longitudinal
0	NA	NA	NA	NA	NA	NA
1	NA	NA	NA	500V	NA	NA
2	NA	NA	NA	1kV	NA	500V
3	1kV^	2kV*^	NA	2kV*^	NA	2kV^
4	2kV^	4kV*^	NA	2kV*^	NA	4kV^
5	2kV	4kV*	NA	4kV*^	NA	4kV^

* Tested with primary protection

^ For cable < 10 m this test level may be lowered by one level

CLASS 1-5 uses the 10/700-5/310 µs for long telecom lines, but high speed circuits (> 100 kHz) will use the 1.2/50-8/20 waveshape.

Appendix E

YD/T 950-1998

YD/T 950-1998 establishes the technical requirements and test methods for protection against overvoltages and overcurrents on telecommunication switching equipment for Mainland China. This Standard is based on the ITU-T Recommendation K.20 "Resistibility of Telecommunications Equipment Installed in a Telecommunications Center for Overvoltages and Overcurrents" (1996 version). It was approved by the Ministry of Information Industry of the People's Republic of China on August 7, 1998 and has been in effect since September 1, 1998.

After the following tests are conducted, the equipment should provide normal communications functions and comply with these requirements.

Without primary protection:

1. When the lightning waveform is 10/700µs and the peak voltage is 1kV
2. When the induction voltage of the power line is 600V_{RMS} and the duration is 0.2s

With primary protection:

1. When the lightning waveform is 10/700µs and the peak voltage is 4kV
2. When the induction voltage of the power line is 600V_{RMS} and the duration is 1s

After the equipment is tested for contact discharge at an electrostatic voltage of 6 kV or for air discharge at 8 kV, it should provide normal communications functions.

Power Faults

Without primary protection: 600V, 1A, 0.2s applied between Tip and Ring to Ground 5 times

With primary protection: 600V, 1A, 1s applied between Tip and Ring to Ground 5 times

Time between successive events shall be one minute.

Characteristics and parameters shall be tested within 30 minutes after the completion of these events

ESD (Electrostatic Discharge)

Indicated Voltage	Peak of Initiation of the Discharge Currents, I_P	Rise Time During Discharge Switch On / Off (t_R)	Current at 20 ns (I_1)	Current at 60 ns (I_2)
6kV	22.5A ± 10%	0.7–1ns	12A ± 30%	6A ± 30%

±5 repetitions direct contact with one-second duration between successive discharges
±5 repetitions indirect contact (0.1m distance) with one second duration between successive discharges

Lightning Immunity

Testing Terminals	Voltage / Current Waveform	Peak Voltage	Peak Current	Number of Tests	Primary Protection
Tip to Ring Grounded	10x700µs / 5x310µs	1kV	25 A	±5	No
Ring to Tip Grounded		1kV	25 A	±5	No
Tip and Ring to Ground		1kV	25 A	±5	No
Tip to Ring Grounded		4kV	100A	±5	Yes
Ring to Tip Grounded		4kV	100A	±5	Yes
Tip and Ring to Ground		4kV	100A	±5	Yes
Tip and Ring to Ground*		1kV	25 A	±5	No

* Simultaneous surge for 50% of the ports

Appendix E (continued)

YD/T 993-1998

YD/T 993-1998 establishes the technical requirements and test methods for lightning protection of telecommunication terminal equipment for Mainland China. This Chinese Standard parallels the ITU-T K.21 "Resistibility of Subscriber's Terminal to Overvoltages and Overcurrents" (1996) document very closely. This standard is the technical basis for simulated lightning induced event testing requirements for Telecommunication Terminal Equipment such as modems, fax machines, telephone sets, and so on. Normal operation of EUT is not required during the lightning surge simulation test. However, all functions of the EUT should meet the requirements of relevant standards after the completion of these tests.

Lightning Immunity

Lightning Surge Test Conditions			Voltage / Current Waveform	Test Voltage / Current* (kV/A)
Without Primary Protection	Metallic Test	Single Tip and Ring Pair	10/700µs - 5/310µs	1.5 / 37.5
	Longitudinal Test	Single Tip and Ring Pair		1 / 25
		All Tip and Ring Pair		
With Primary Protection	Metallic Test	Single Tip and Ring Pair		4 / 100
	Longitudinal Test	Single Tip and Ring Pair		
		All Tip and Ring Pair		

* All tests are conducted ±5 times with at least one minute between events.

Appendix E (continued)

YD/T 1082-2000

YD/T 1082-2000 establishes the technical specifications on overvoltage and overcurrent protection of access network equipment for Mainland China. This Chinese Standard parallels the ITU-T K series. This standard specifies the technical requirements and test methods for overvoltage and overcurrent protection and the basic environmental adaptability of access network equipment. This Standard does not deal with protection against radiated electromagnetic fields. The specifications as presented here are a succinct summary of the lightning surge, power fault, and ESD testing required by this document. The ports of the Network equipment are classified into five categories:

I. Ports used to connect the twisted pairs introduced from outside of the building, namely analog user interface, ISDN-BRA interface, ADSL interface, and so on
II. Twisted pair ports used to interconnect the different equipment inside the building, namely V.24 interface, V.35 interface, 2048kbps interface connected to twisted pairs, 10/100 Base-T Ethernet interface, and so on
III. Coaxial cable port: 2048kbps interface connected to coaxial cables, ISDN-PRA interface, and so on
IV. AC Power interface
V. DC power interface

Power Faults

Tested Port	Number of Ports		Test Conditions
	Central Office	Remote	
I	3	---	600V, 600Ω, 50Hz, 1s
I	1	---	220V, 50Hz, 1h, 600/200/10Ω

ESD (Electrostatic Discharge)

Indicated Voltage	Peak of Initiation of the Discharge Currents, I_P	Rise Time During Discharge Switch On / Off (t_R)	Current at 20 ns (I_1)	Current at 60 ns (I_2)
6kV	22.5A ± 10%	0.7–1 ns	12A ± 30%	6A ± 30%

±5 repetitions direct contact with one-second duration between successive discharges
±5 repetitions indirect contact (0.1m distance) with one second duration between successive discharges

Lightning Immunity

Class of Port	Number of Ports		Voltage / Current Waveforms	Amplitude*
	Central Office	Remote		
I	---	3	10/700µs - 5/310µs	4kV
		8	1.2/50µs – 8/20µs	6kV
II	1	1		500V
III	1	1		500V
IV	---	1		10kV (5kA)
V	1	1		500 V

Appendix F

UL60950-1 / IEC60950-1 / EN60950-1

This safety standard is intended to prevent injury or harm due to electrical shock, energy hazards, fire, heat hazards, mechanical hazards, radiation hazards, and chemical hazards. For the USA market, the National Electric Code (NEC) implemented Article 800-4, which mandates that "all equipment intended for connection to the public telephone network be listed for that purpose" in order to ensure electrical safety. A manufacturer can meet this requirement by listing their product with Underwriters Laboratories under UL 60950-1 (based on IEC 60950-1,). The NEC requires all telecommunication wiring that enters a building to pass through a primary protector, which is designed to limit AC transients in excess of $600V_{RMS}$. These transients are due to the fact that telephone lines run in close proximity to AC power lines.

Most telecommunication equipment uses a secondary overvoltage protector such as the *SIDACtor* component. The secondary components typically limit transients in excess of $350V_{RMS}$. Therefore, a potentially dangerous condition exists because of the voltage threshold difference of the primary protector and the secondary protector. To minimize this danger, compliance with UL 60950-1 is required. UL 60950- 1 covers equipment with a rated voltage (primary power voltage) not exceeding 600 V and equipment designed to be installed in accordance with the NEC NFPA 70. This standard does not apply to air-conditioning equipment, fire detection equipment, power supply systems, or transformers.

UL 60950-1 Annex A (this is a National Deviation applicable specifically to North America) Overvoltage Test

Test	Voltage (V_{RMS})	Current (A)	Time	Comments
L1	600V	40	1.5s	
L2	600V	7	5s	
L3	600V	2.2	See note 2	Reduce to 135% fuse rating
L4	See Note 1	2.2	See note 2	Reduce to 135% fuse rating
L5	120V	25	See note 2	
M1	600V	40	1.5s	
M2	600V	7	5s	
M3	600V	2.2	See note 2	Reduce to 135% fuse rating
M4	See Note 1	2.2	See note 2	Reduce to 135% fuse rating

Notes:
[1] Voltage < conduction voltage of protection
[2] Test for 30 minutes or until an open circuit occurs unless it appears possible that risk of fire or safety hazard may result; then continue test until ultimate results are obtained (maximum 7 hours).

General Notes:
- ISDN S/T interface only L1, L2, L5, M1, and M2.
- If Test 3 resulted in open condition, bypass the fuse, reduce current to 135% of the fuse rating and continue the test.
- L4 and M4 are conducted at a voltage level just below Vs only if *SIDACtor* VS ≥285 VS.
- For test conditions M1, L1, M5, and L5 a wiring simulator (MDL 2 A fuse) is used.
- Compliance means no ignition or charring of the cheesecloth, and/or wiring simulator does not open.
- Tests 2, 3, and 4 are required only if the unit is not a fire enclosure.
- EUT shall continue to comply with the requirements of Clause 6.2 (Separation requirements and electric strength requirements) at the conclusion of these overvoltage tests.

Littelfuse, Inc.
8755 West Higgins Road
O'Hare Plaza, Suite 500
Chicago, IL 60631 USA
Phone: (773) 628-1000
www.littelfuse.com
spa@littelfuse.com

Authored by: Chad Marak & Phillip Havens

As the world's #1 brand in circuit protection, Littelfuse offers the broadest and deepest portfolio of circuit protection products and a global network of technical support backed by more than 80 years of application design expertise. Visit our design support center to access:

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