6

Reference Designs

This section offers specific examples of how *SIDACtor®* devices can be used to ensure long-term operability of protected equipment and uninterrupted service during transient electrical activity. For additional line interface protection circuits, see "Regulatory Compliant Solutions" on page 7-46.

Note: The circuits referenced in this section represent typical interfaces used in telecommunications equipment. *SIDACtor* devices are not the sole components required to pass applicable regulatory requirements such as UL 60950, GR 1089, or TIA-968-A (formerly known as FCC Part 68), nor are these requirements specifically directed at *SIDACtor* devices.

Customer Premises Equipment (CPE)

CPE is defined as any telephone terminal equipment which resides at the customer's site and is connected to the Public Switched Telephone Network (PSTN). Telephones, modems, caller ID adjunct boxes, PBXs, and answering machines are all considered CPE.

Protection Requirements

CPE should be protected against overvoltages that can exceed 800 V and against surge currents up to 100 A. In Figure 6.1 through Figure 6.6, *SIDACtor*® devices were chosen because their associated peak pulse current (I_{PP}) rating is sufficient to withstand the lightning immunity test of TIA-968-A without the additional use of series line impedance. Likewise, the fuse shown in Figure 6.1 through Figure 6.6 was chosen because the amps^{2}time (I^2t) rating is sufficient to withstand the lightning immunity tests of TIA-968-A without opening, but low enough to pass UL power fault conditions.

The following regulatory requirements apply:
- TIA-968-A (formerly known as FCC Part 68)
- UL 60950

All CPE intended for connection to the PSTN must be registered in compliance with TIA-968-A. Also, because the National Electric Code mandates that equipment intended for connection to the telephone network be listed for that purpose, consideration should be given to certifying equipment with an approved safety lab such as Underwriters Laboratories.

CPE Reference Circuits

Figure 6.1 through Figure 6.6 show examples of interface circuits which meet all applicable regulatory requirements for CPE. The P3100SB and P3100EB are used in these circuits because the peak off-state voltage (V_{DRM}) is greater than the potential of a Type B ringer superimposed on a POTS (plain old telephone service) battery.

$$150\ V_{RMS} \sqrt{2} + 56.6\ V_{PK} = 268.8\ V_{PK}$$

Note that the circuits shown in Figure 6.1 through Figure 6.6 provide an operational solution for TIA-968-A. However TIA-968-A allows CPE designs to pass non-operationally as well.

For a non-operational solution, coordinate the I_{PP} rating of the *SIDACtor* device and the I^2t rating of the fuse so that (1) both will withstand the Type B surge, and (2) during the Type A surge, the fuse will open. (See Table 8.2, Surge Rating Correlation to Fuse Rating on page 8-17.)

Note: For alternative line interface protection circuits, see "Regulatory Compliant Solutions" on page 7-46.

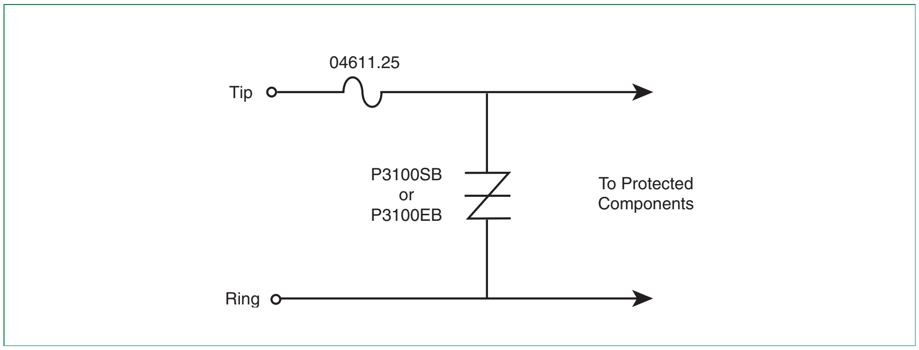


Figure 6.1 Basic CPE Interface

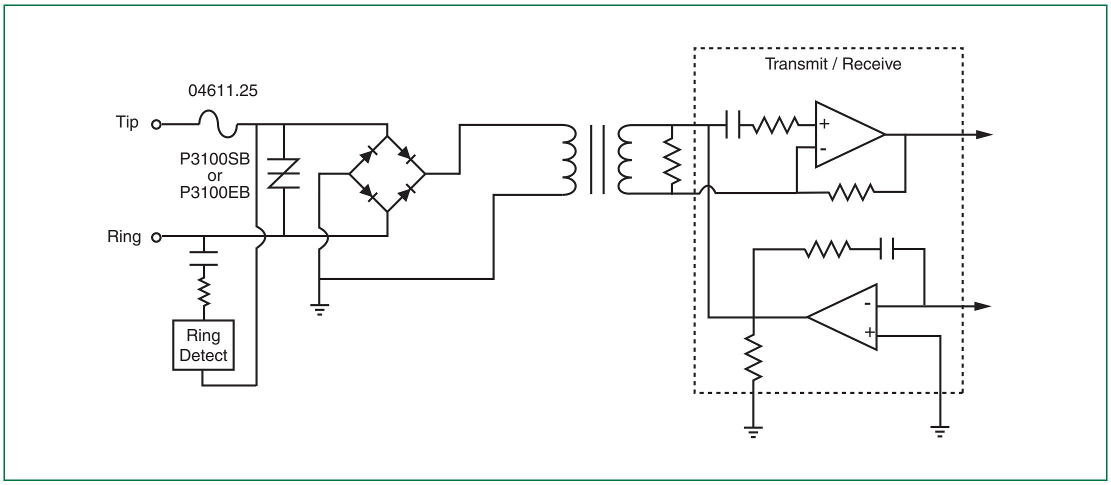


Figure 6.2 Transformer Coupled Tip and Ring Interface

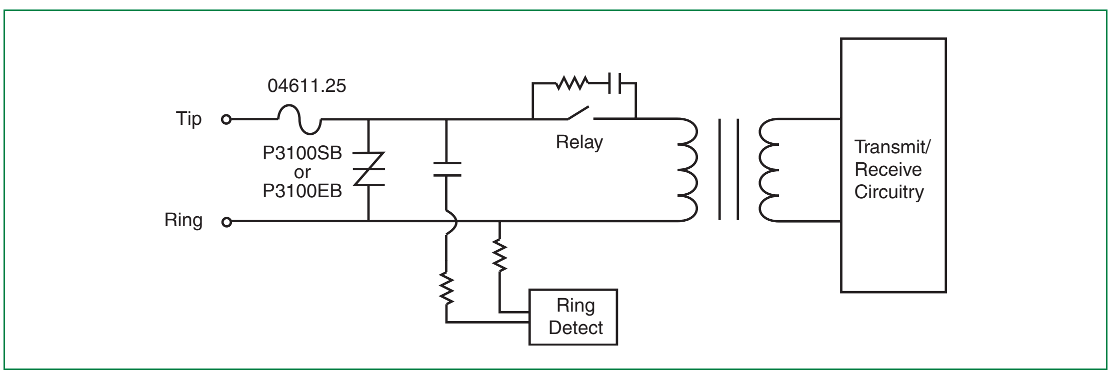


Figure 6.3 Modem Interface

Reference Designs

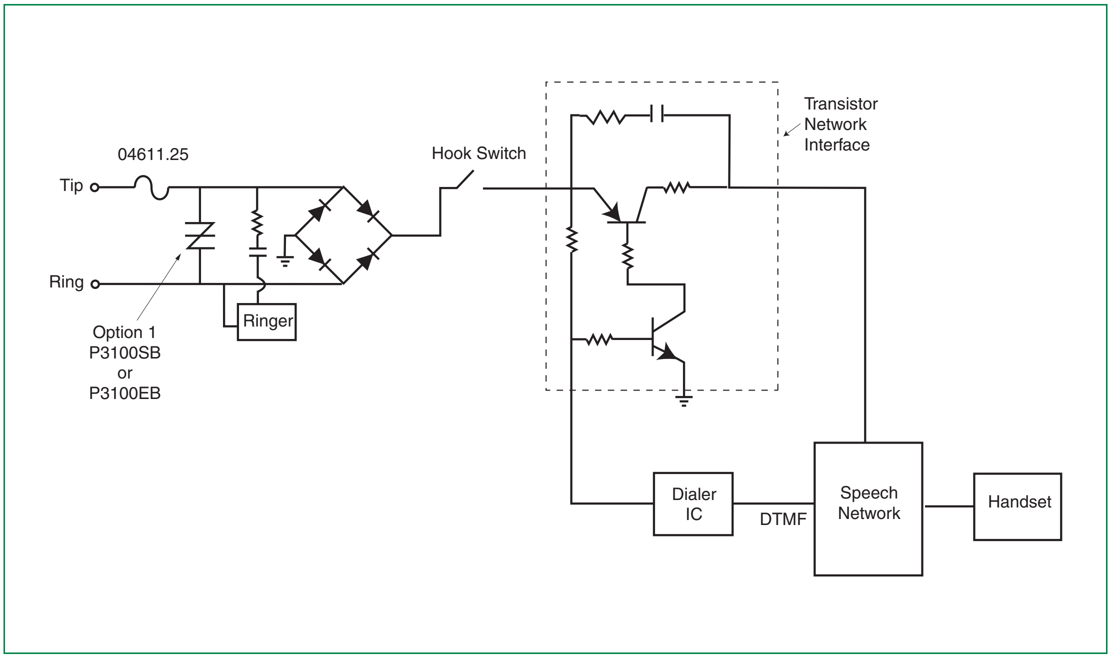


Figure 6.4 CPE Transistor Network Interface—Option 1

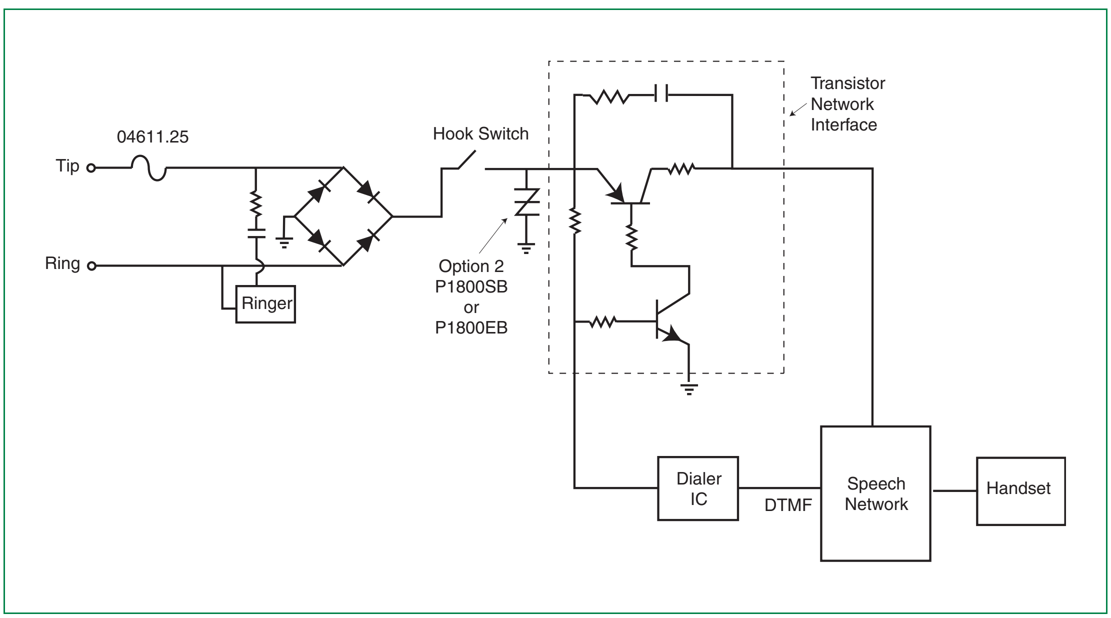


Figure 6.5 CPE Transistor Network Interface—Option 2

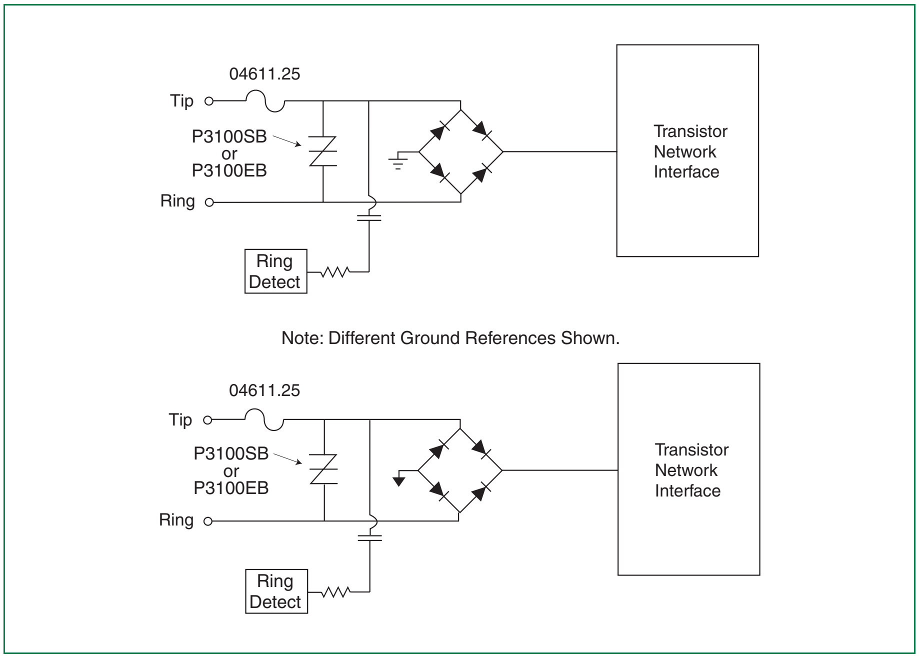


Figure 6.6 Two-line CPE Interface

Reference Designs

Digital Set-top Box Protection

The set-top box consists of power supply and signal ports. Some of the more recent high-end designs also can have a hard drive to facilitate program recording. Unlike traditional analog boxes, the digital devices are more like computers and so have many of the same system and port features.

Cable, satellite, and terrestrial set-top boxes are similar designs with software variations. Digital broadband media (DBM) devices are home gateway devices, offering services including Video On Demand, TV web browsing, email, and communication services.

Figure 6.7 shows an example of the use of Littelfuse products in a set-top box design. (Data sheets for the protection solutions highlighted in the illustration can be found in this *Telecom Design Guide*.)

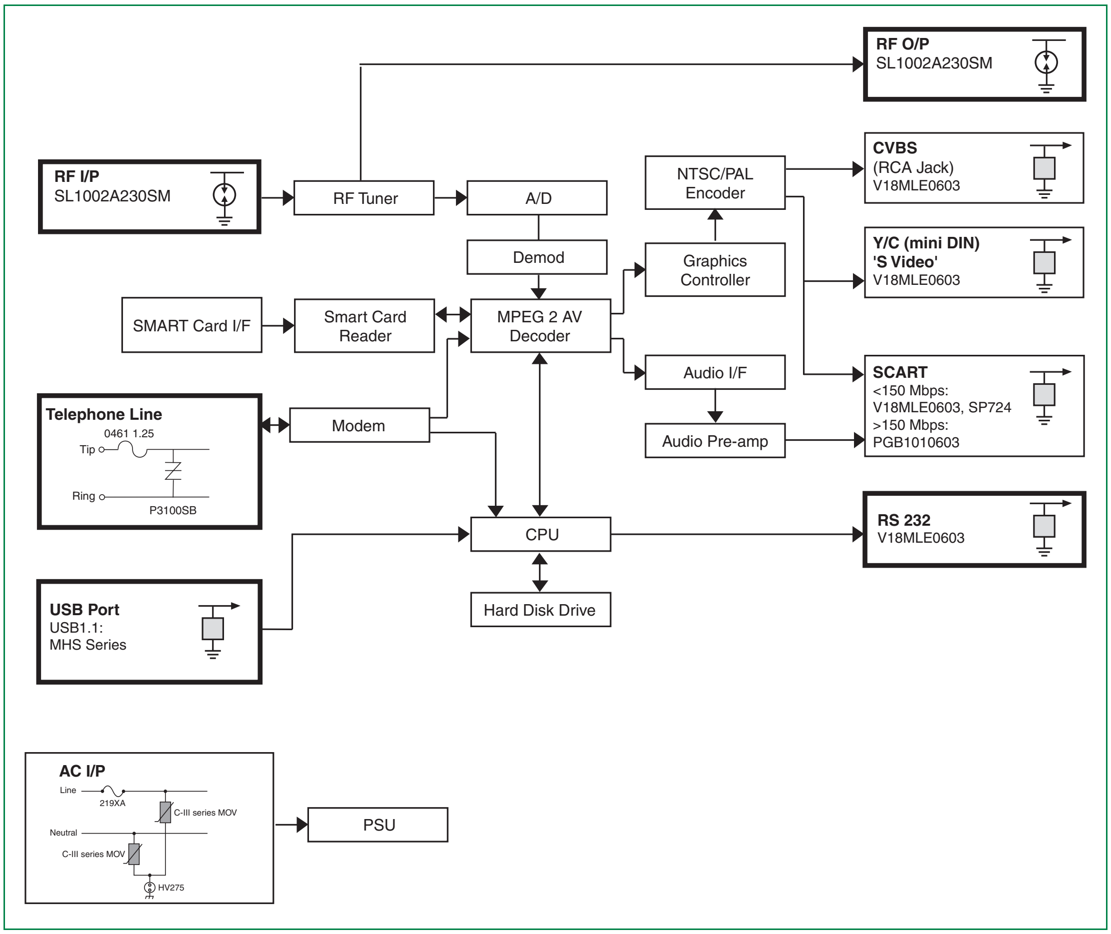


Figure 6.7 Block Diagram of Set-top Box

The following agency standards and industry regulations may apply to digital set-top boxes:

- IEC 61000-4
- ANSI/IEEE C62.41
- TIA-968-A
- UL 60950
- Telcordia GR 1089
- ITU K.20 and K.21

Power Supply

The AC connection can be either a two-wire design (either a live or hot with neutral) or a three-wire design that additionally uses the Ground (earth) connection. In both designs using a fuse for overcurrent protection may be mandatory and using varistors (MOVs) to provide overvoltage protection may be beneficial.

A two-wire solution is a 219XA series 5x20 mm glass fuse used with a C-III series MOV (up to two parts).

In a three-wire system it is possible to connect MOVs across all three conductors (H-N, H-G, and N-G (or L-N, L-G, and N-G). For use in the United States, the device must meet UL 1414 standards, requiring no leakage from H-G (L-G) through the MOV. Typically, an isolation device is used in series with the MOV to pass the UL certification.

The Littelfuse HV 275 device meets the requirement for a 120 V AC system: 219XA series 5x20 mm glass fuse used with a C-III series MOV (up to three parts) along with the HV 275.

Signal Ports

Various communication ports are applicable.

Video Signal Input

The video signal feeds into the set-top box through a co-ax connector from a satellite receiver, a cable company, or a terrestrial antenna. Because of the high frequency of these signals, only very low capacitance protectors can be deployed. Because the feed is from an external source, a high surge rating is usually required and virtually all solutions use a gas plasma arrester for protection. Figure 6.8 shows the recommended solution for satellite receiver protection.

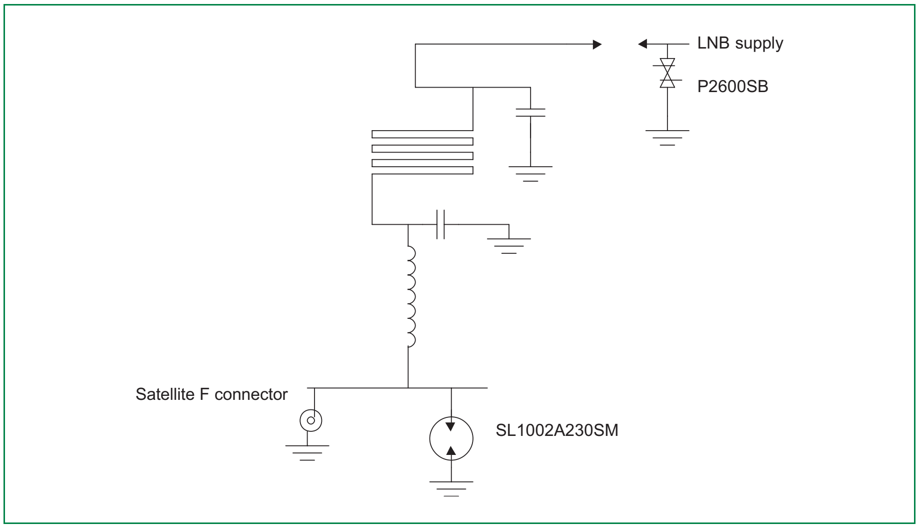


Figure 6.8 Satellite Receiver Protection

Some boxes have both the standard UHF connector to accept terrestrial antenna and the F-type connector used for cable and satellite connections and can support both inputs. In these cases both satellite and the UHF co-ax inputs can use gas plasma arresters for protection.

Solutions include SL1002A090SM or SL1002A230SM.

Video Output

The set-top box has to connect to either a conventional TV set or monitor. The two most common connectors are co-ax or SCART (Syndicat des Constructeurs d'Appareils Radiorécepteurs et Téléviseurs). Like the co-ax inputs, the co-ax output will need a low-capacitance device to be protected.

The multi-pin SCART is a suitable application for a low-capacitance array. On some designs using two SCARTs facilitates recording and viewing. A six-pin device is common.

One solution is the SP05xx series diode array.

Modem Port

A modem port is featured on many designs to facilitate interactive services such as Pay Per View (PPV) and Interactive Pay Per View (IPPV). The modem port requires similar threat protection as the conventional twisted pair telephone connections. The classic overvoltage protection and resettable overcurrent protection can be deployed in this circuit.

Solution examples include *SIDACtor*® P3100SB, SL1002A600SM, PTC, and *TeleLink*® fuse. Solutions may vary depending on the end market.

Audio Output

A stereo jack socket often is provided for home theater applications. While the signal frequency is low and a variety of overvoltage protection can be used, the main concern is electrostatic discharge (ESD).

Solutions include TVS diode Arrays, or Multilayer Varistors.

USB Port

USB ports are provided to support digital cameras, printers, and MP3 players as well as legacy devices. New designs use USB 2.0.

USB 1.1 solutions include Multilayer Varistors or TVS diode Arrays. The USB 2.0 solution uses the PGB1010603.

RS 232

RS 232 serial ports are used for game pads, upgrades, and diagnostics as well as legacy devices.

One protection solution for the RS 232 interface is a Multilayer Varistor.

Ethernet Ports

Ethernet ports enable connection to LANs and so need medium to low energy protectors of low capacitance.

High Speed Transmission Equipment

High speed transmission equipment encompasses a broad range of transmission protocols such as T1/E1, ADSL, ADSL2, ADSL2+, VDSL, VDSL2, and ISDN. Transmission equipment is located at the central office, customer premises, and remote locations.

Protection Requirements

Transmission equipment should be protected against overvoltages that can exceed 2500 V and surge currents up to 500 A. In the illustrations shown in Figure 6.9 through Figure 6.22, *SIDACtor*® devices were chosen because their associated peak pulse current (I_{PP}) rating is sufficient to withstand the lightning immunity tests of GR 1089 without the additional use of series line impedance. Likewise, the fuse shown in each of the following illustrations (Figure 6.9 through Figure 6.22) was chosen because the amps^{2}time (I^2t) rating is sufficient to withstand the lightning immunity tests of GR 1089, but low enough to pass GR 1089 current limiting protector test and power fault conditions (both first and second levels).

The following regulatory requirements apply:

- TIA-968-A (formerly known as FCC Part 68)
- GR 1089-CORE
- ITU-T K.20/K.21
- UL 60950

Most transmission equipment sold in the US must adhere to GR 1089. For Europe and other regions, ITU-T K.20/K.21 is typically the recognized standard.

ADSL / VDSL Circuit Protection

Asymmetric digital subscriber lines (ADSLs) and very high speed digital subscriber lines (VDSLs) employ transmission rates up to 30 Mbps from the Central Office Terminal (COT) to the Remote Terminal (RT) and up to 30 Mbps from the RT to the COT. (Figure 6.9)

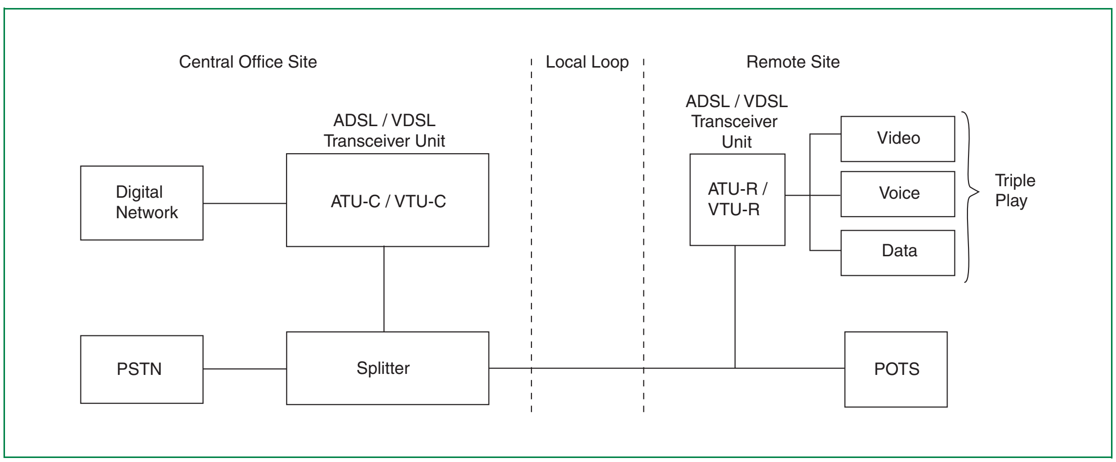


Figure 6.9 ADSL Overview

Protection Circuitry

Longitudinal protection was not used at either the ADSL / VDSL Transceiver Unit–Central Office (ATU-C / VTU-C) interface or the ADSL / VDSL Transceiver Unit–Remote (ATU-R / VTU-R) interface due to the absence of earth ground connections. (Figure 6.10 and Figure 6.12) In both instances, the SL1002A350SM gas plasma arrester or the P3500SCMC *SIDACtor*® device and the 04611.25 *TeleLink*® fuse provide metallic protection. For xTUs not isolated from earth ground, reference the HDSL protection topology.

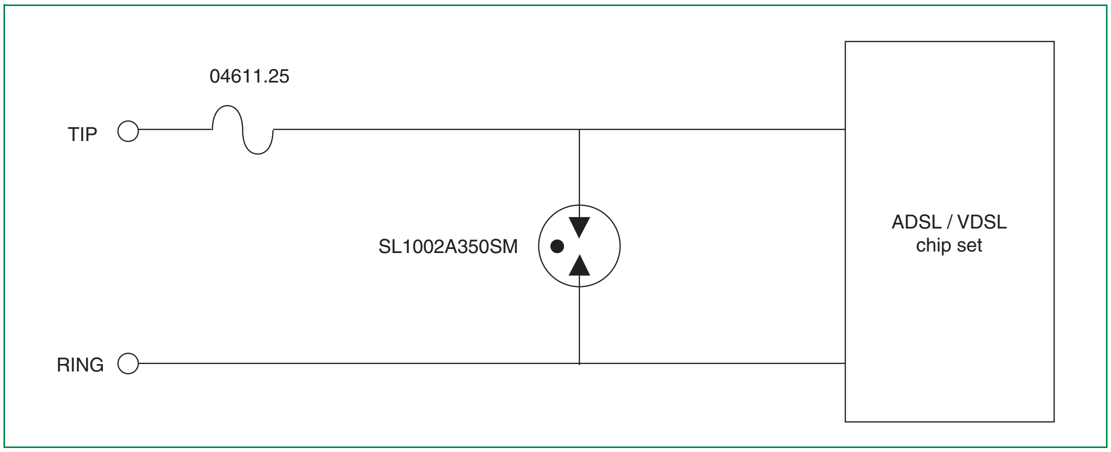


Figure 6.10 Gas Plasma Arrester ADSL Protection

Alternate ADSL Protection and VDSL Protection

Figure 6.11 shows the SL1002A350SM gas plasma arresters connected in the Delta configuration to provide Tip to Ground, Ring to Ground (longitudinal), and Tip to Ring (metallic) protection.

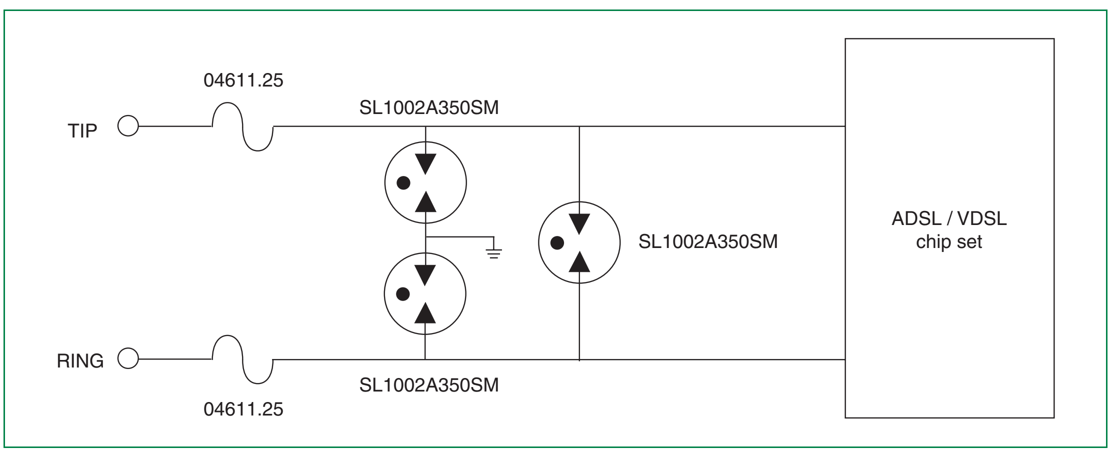


Figure 6.11 Single Port Delta Solution Providing Metallic and Longitudinal Protection

Reference Designs

Protection Circuitry

The capacitance of this device is low (typically 0.8 pF) so this solution provides very low insertion loss.

The 04611.25 fuse provides protection against power fault events, but it is specifically designed not to open during induced lightning surges. This eliminates nuisance blowing while maintaining the ultimate protection needed for safety.

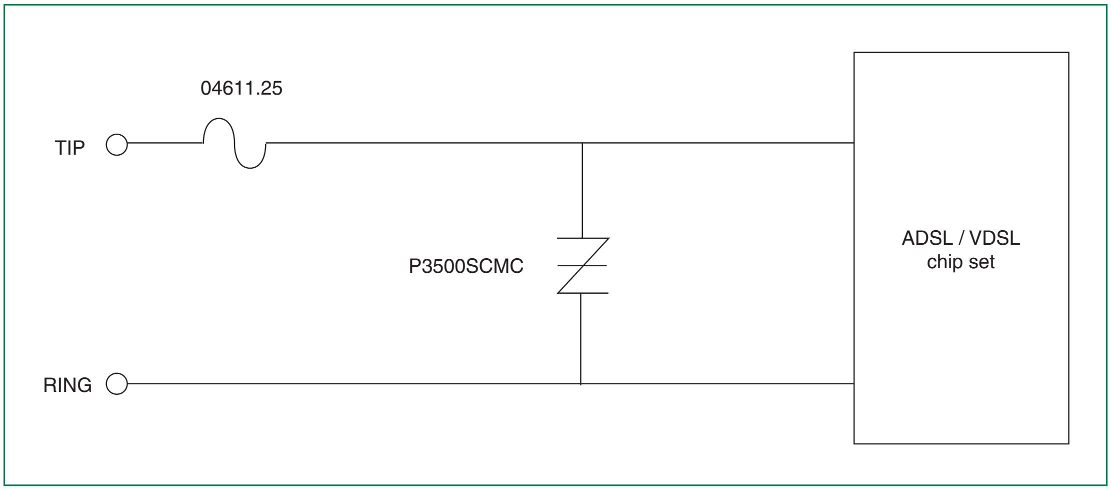


Figure 6.12 *SIDACtor* ADSL / VDSL Protection

Component Selection

The P3500SCMC *SIDACtor* device and 04611.25 *TeleLink* fuse were chosen to protect the ATUs because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. Although the P3100 series *SIDACtor* device may be used to meet current ANSI specifications for xDSL services offered with POTS, Littelfuse recommends the P3500 series to avoid interference with the 20 V_{P-P} ADSL signal on a 150 V rms ringing signal superimposed on a 56.5 V battery. The VDSL signal is smaller than a typical ADSL signal, so the P3100 may be an appropriate solution.

HDSL Circuit Protection

HDSL (High-bit Digital Subscriber Line) is a digital line technology that uses a 1.544 Mbps (T1 equivalent) transmission rate for distances up to 12,000 feet, eliminating the need for repeaters. The signaling levels are a maximum of ±2.5 V while loop powering is typically under 190 V. (Figure 6.13)

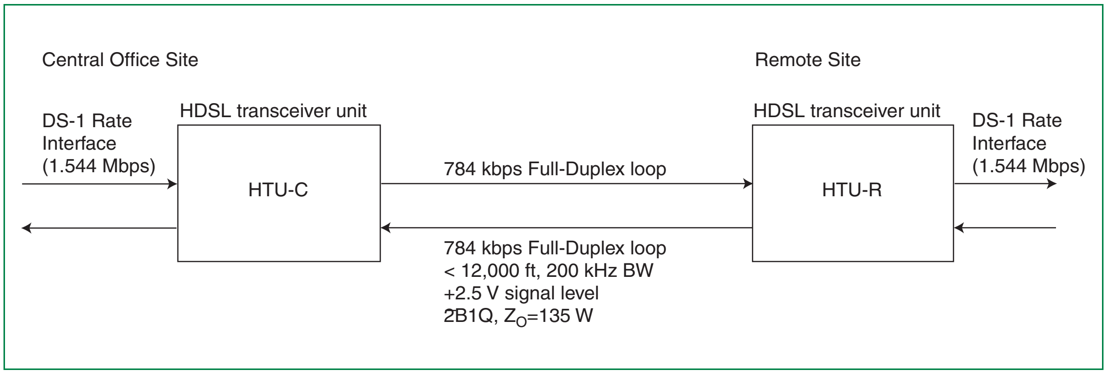


Figure 6.13 HDSL Overview

Protection Circuitry

Longitudinal protection is required at both the HDSL Transceiver Unit–Central Office (HTU-C) and HDSL Transceiver Unit–Remote (HTU-R) interfaces because of the ground connection used with loop powering. Two P2300SCMC *SIDACtor* devices provide overvoltage protection, and two 04611.25 *TeleLink* fuses (one on Tip, one on Ring) provide overcurrent protection. (Figure 6.14 and Figure 6.15) For the transceiver side of the coupling transformer, additional overvoltage protection is provided by the P0080SA *SIDACtor* device. The longitudinal protection on the primary coil of the transformer is an additional design consideration for prevention of EMI coupling and ground loop issues.

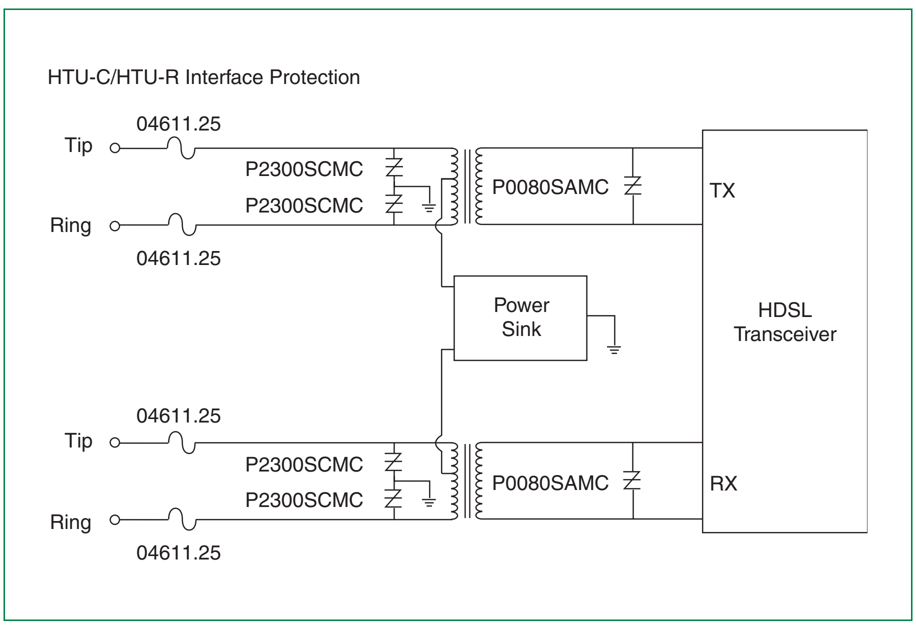


Figure 6.14 HDSL Protection

Reference Designs

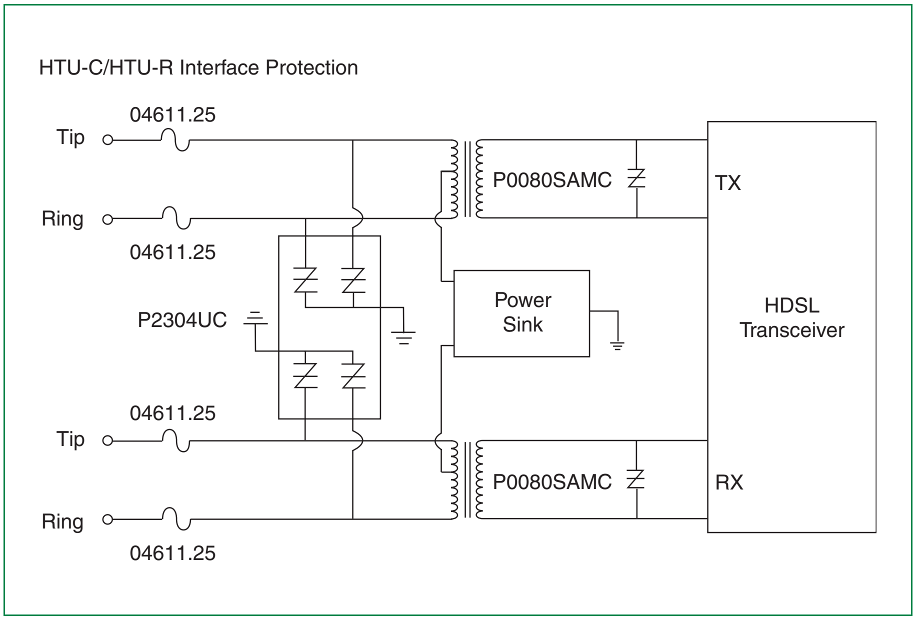


Figure 6.15 HDSL Quad Protection

Component Selection

The P2304UC or P2300SCMC *SIDACtor* device and the 04611.25 *TeleLink* fuse were chosen because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. The P2300SCMC voltage rating was selected to ensure loop powering up to 190 V. For loop powering greater than 190 V, consider the P2600SCMC. The P0080SAMC *SIDACtor* device was chosen to eliminate any sneak voltages that may appear below the voltage rating of the P2300SCMC.

ISDN Circuit Protection

Integrated Services Digital Network (ISDN) circuits require protection at the Network Termination Layer 1 (NT1) U-interface and at the Terminating Equipment (TE) or Terminating Adapter (TA) S/T interface. Signal levels at the U-interface are typically ±2.5 V; however, with sealing currents and maintenance loop test (MLT) procedures, voltages approaching 150 V rms can occur. (Figure 6.16)

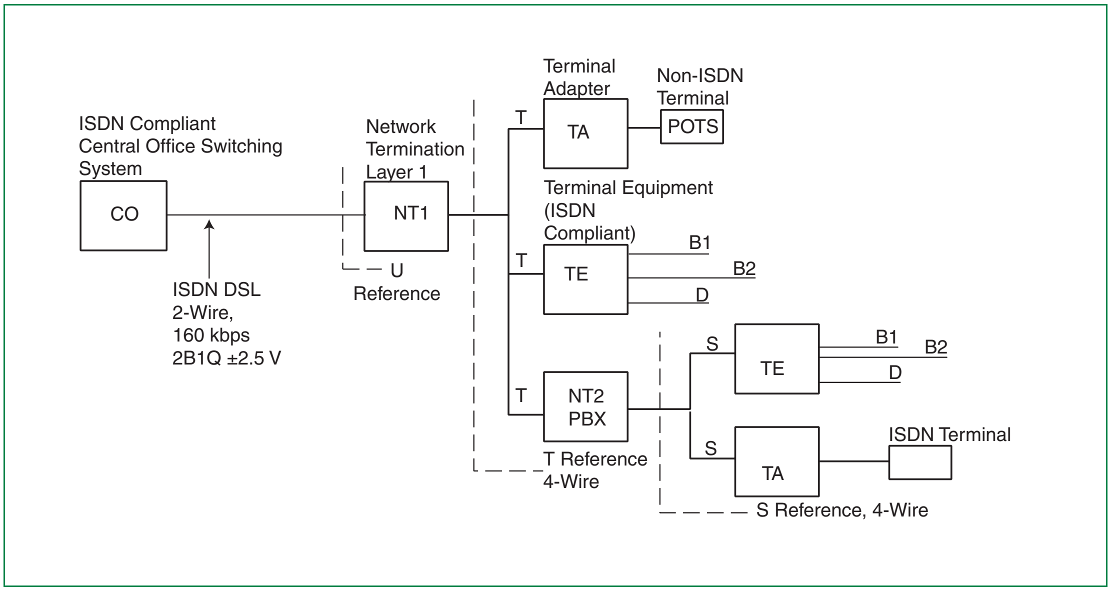


Figure 6.16 ISDN Overview

Protection Circuitry

Longitudinal protection was not used at either the U- or the TA/TE-interface due to the absence of an earth-to-ground connection. (Figure 6.17) At the U-interface, the P2600SCMC *SIDACtor* device and 04611.25 *TeleLink* fuse provide metallic protection, while the TA/TE-interface uses the P0640SCMC *SIDACtor* device and 04611.25 *TeleLink* fuse. Figure 6.17 also shows interfaces not isolated from earth ground.

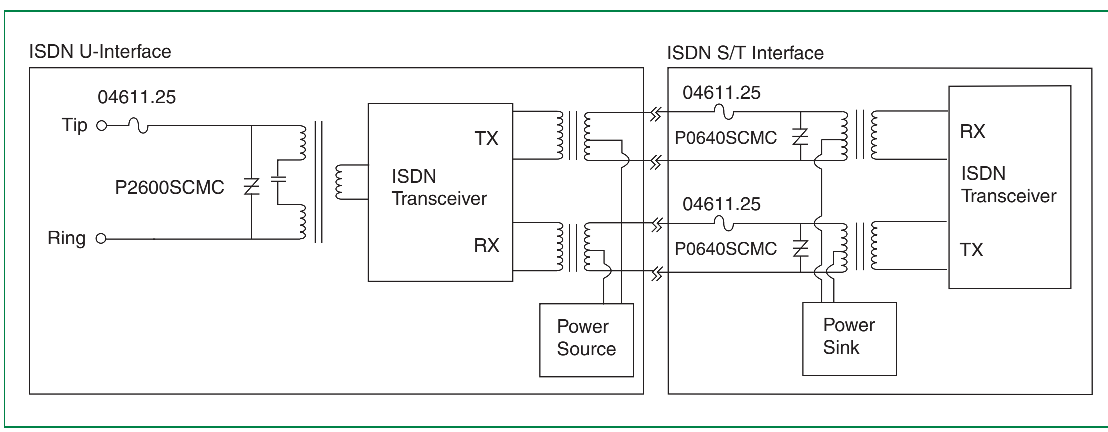


Figure 6.17 ISDN Protection

Reference Designs

Component Selection

The "SCMC" *SIDACtor* devices and 04611.25 *TeleLink* fuse were chosen because these components meet GR 1089 surge immunity requirements without the use of additional series resistance. An MC is chosen to reduce degradation of data rates. The P2600SCMC voltage rating was selected to ensure coordination with MLT voltages that can approach 150 V rms. The voltage rating of the P0640SCMC was selected to ensure coordination with varying signal voltages.

Pair Gain Circuit Protection

A digital pair gain system differs from an ISDN circuit in that ring detection, ring trip, ring forward, and off-hook detection are carried within the 64 kbps bit stream for each channel rather than using a separate D channel. The pair gain system also uses loop powering from 10 V up to 145 V with a typical maximum current of 75 mA. (Figure 6.18)

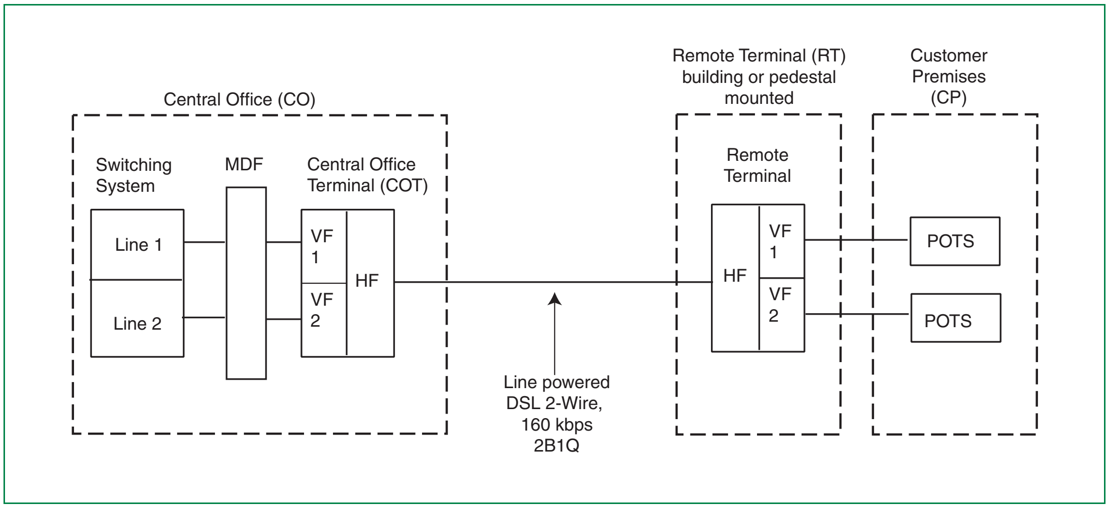


Figure 6.18 Pair Gain Overview

Protection Circuitry

Longitudinal protection is required at the Central Office Terminal (COT) interface because of the ground connection used with loop powering. (Figure 6.19) Two P1800SCMC *SIDACtor* devices provide overvoltage protection, and two 04611.25 *TeleLink* fuses (one on Tip, one on Ring) provide overcurrent protection. For the U-interface side of the coupling transformer, the illustration shows the P0080SAMC *SIDACtor* device used for additional overvoltage protection.

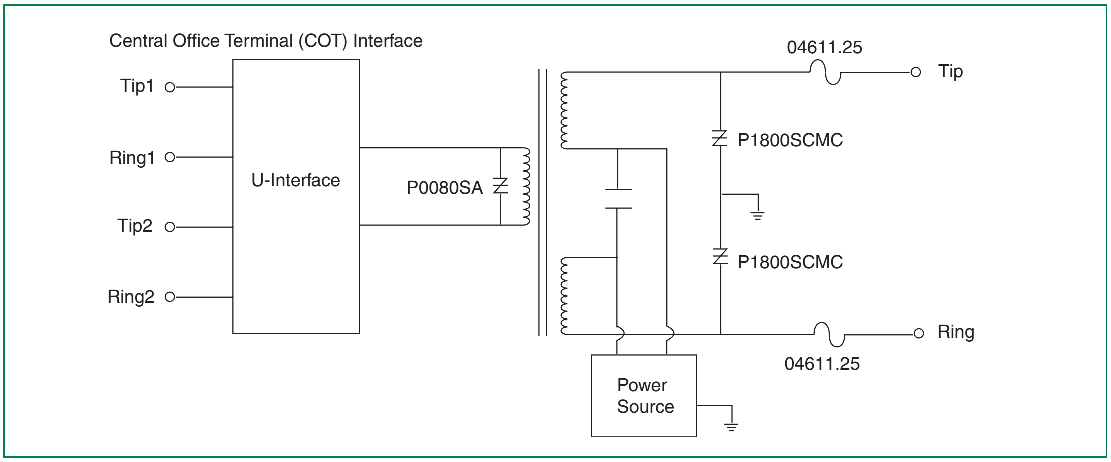


Figure 6.19 Pair Gain COT Protection

For Customer Premises (CP) and Remote Terminal (RT) interfaces where an earth ground connection is not used, only metallic protection is required. Figure 6.20 shows metallic protection satisfied using a single P3100SCMC across Tip and Ring and a single 04611.25 on either Tip or Ring to satisfy metallic protection.

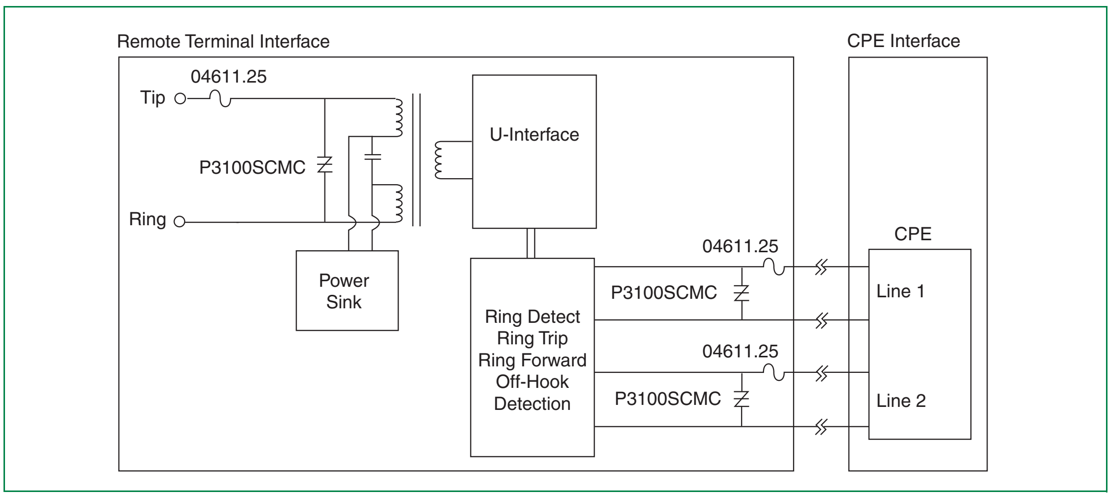


Figure 6.20 Pair Gain RT Protection

Component Selection

The "SCMC" *SIDACtor* device and 04611.25 *TeleLink* fuse were chosen because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. An MC is chosen to reduce degradation of data rates. The voltage rating of the P1800SCMC was selected to ensure coordination with loop powering up to 150 V.

The voltage rating of the P3100SCMC was selected to ensure coordination with POTS ringing and battery voltages.

T1/E1/J1 Circuit Protection

T1/E1 networks offer data rates up to 1.544 Mbps (2.058 for E1) on four-wire systems. Signal levels on the transmit (TX) pair are typically between 2.4 V and 3.6 V while the receive (RX) pair could go as high as 12 V. Loop powering is typically ±130 V at 60 mA, although some systems can go as high as 150 V. (Figure 6.21)

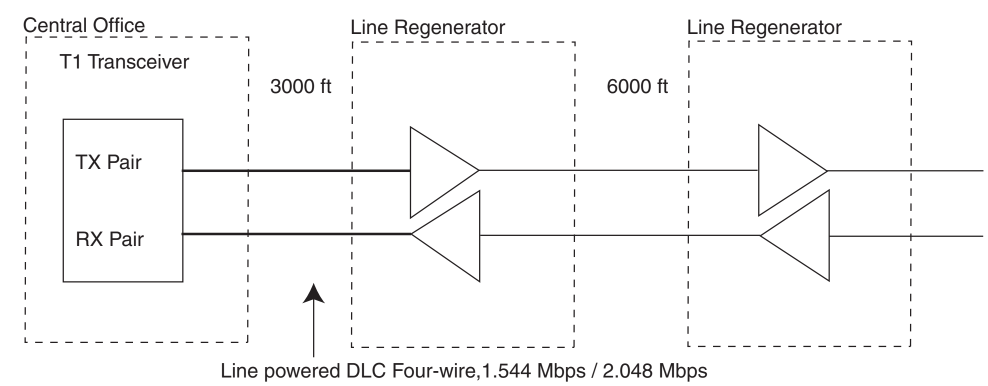


Figure 6.21 T1/E1 Overview

Protection Circuitry

Longitudinal protection is required at the Central Office Terminal (COT) interface because of the ground connection used with loop powering. (Figure 6.22, Figure 6.23, Figure 6.24) Two P1800SCMC (or P1804UC or P2106UC) *SIDACtor* devices provide overvoltage protection, and two 04611.25 *TeleLink* fuses (one on Tip, one on Ring) provide overcurrent protection. The P1800SCMC device is chosen because its V drm is compliant with TIA-968-A regulations, Section 4.4.5.2, “Connections with protection paths to ground.” These regulations state:

> Approved terminal equipment and protective circuitry having an intentional dc conducting path to earth ground for protection purposes at the leakage current test voltage that was removed during the leakage current test of section 4.3 shall, upon its replacement, have a 50 Hz or 60 Hz voltage source applied between the following points:
>
> a. Simplexed telephone connections, including Tip and Ring, Tip-1 and Ring-1, E&M leads and auxiliary leads
> b. Earth grounding connections
>
> The voltage shall be gradually increased from zero to 120 V rms for approved terminal equipment, or 300 V rms for protective circuitry, then maintained for one minute. The current between a. and b. shall not exceed 10 mA_{PK} at any time. As an alternative to carrying out this test on the complete equipment or device, the test may be carried out separately on components, subassemblies, and simulated

circuits, outside the unit, provided that the test results would be representative of the results of testing the complete unit.

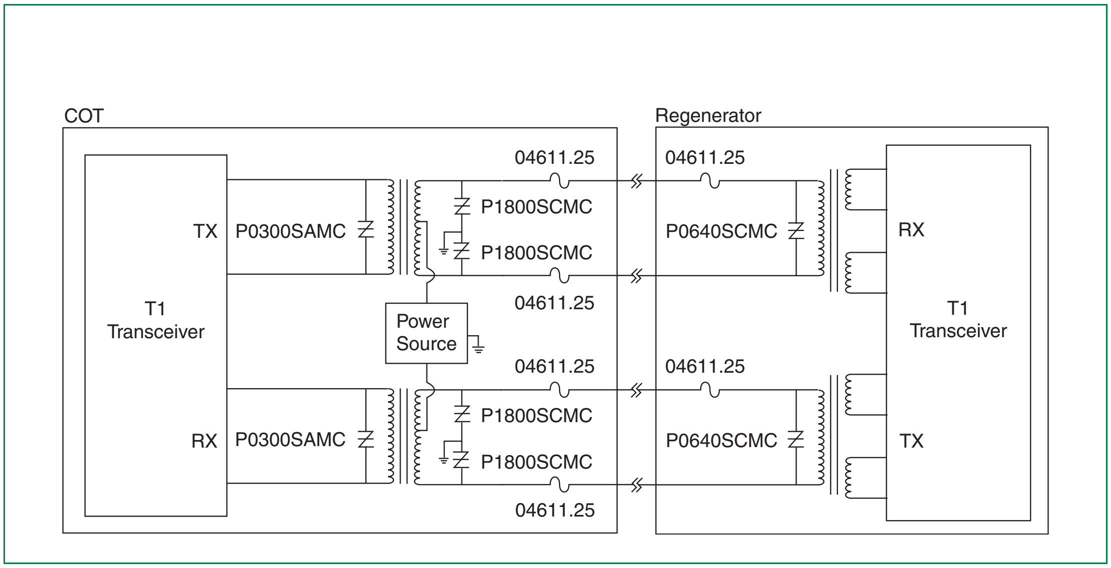


Figure 6.22 T1/E1 Protection

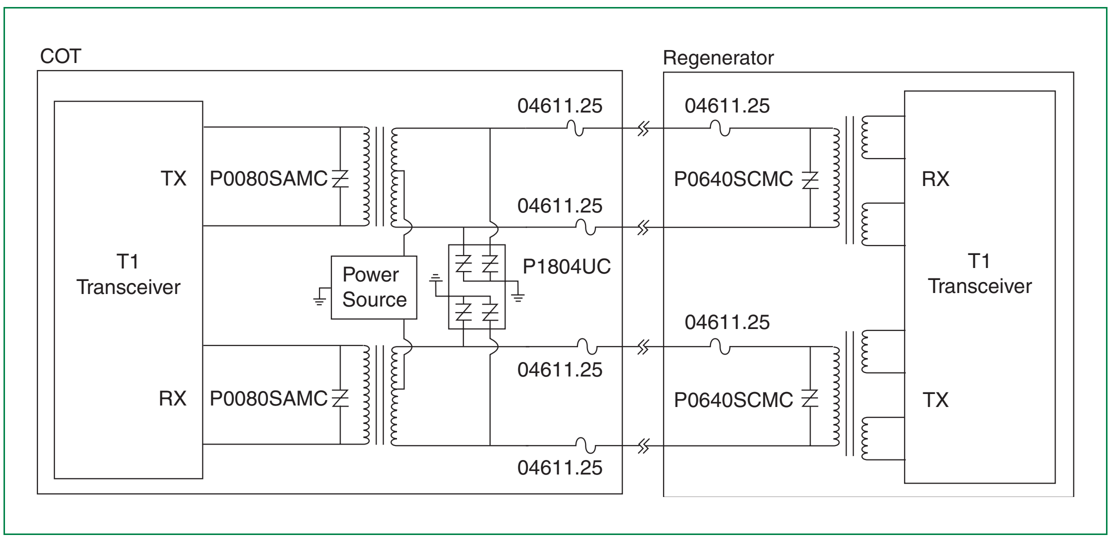


Figure 6.23 T1/E1 Quad Protection

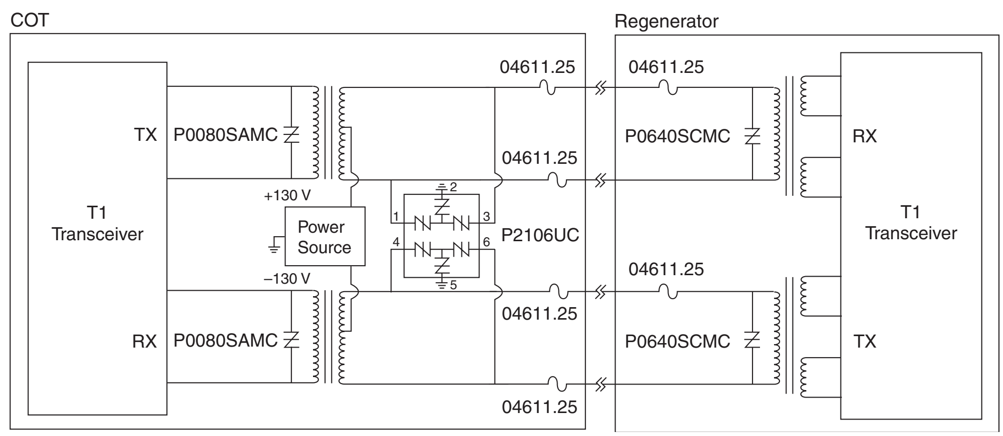


Figure 6.24 T1/E1 Symmetrical Protection

The peak voltage for 120 V rms is 169.7 V. The minimum stand-off voltage for the P1800 (or P1804 and P2106) is 170 V, therefore, the P1800SCMC will pass the test in Section 4.4.5.2 by not allowing 10 mA of current to flow during the application of this test voltage.

For the transceiver side of the coupling transformer, additional overvoltage protection is shown in Figure 6.22 using the P0300SA *SIDACtor* device. When an earth ground connection is not used, only metallic protection is required. Metallic protection is satisfied using a single P0640SCMC *SIDACtor* device across Tip and Ring and a single 04611.25 *TeleLink* fuse on either Tip or Ring.

Component Selection

The "SCMC" *SIDACtor* device and 04611.25 *TeleLink* fuse were chosen because these components meet GR 1089 surge immunity requirements without the use of additional series resistance. An MC is chosen to reduce degradation of data rates. The voltage rating of the P1800SCMC (or P1804UC or P2106UC) was selected to ensure loop powering up to 150 V. The voltage rating of the P0640SCMC was selected to ensure coordination with varying voltage signals.

T1/E1/J1 Asymmetrical Circuit Protection

The A2106UC6 Surface Mount *SIDACtor* device provides asymmetrical protection for T1/E1/J1 transceivers. (Figure 6.25) Metallic events are limited to less than 80 V on the line side of the transformer. The minimum turn on voltage for the A2106 is 170 V from Tip to Ground and Ring to Ground. This is compliant with TIA-968-A. The secondary side of the transformer has the P0080SAMC *SIDACtor* device that limits differential voltages to less than 25 V.

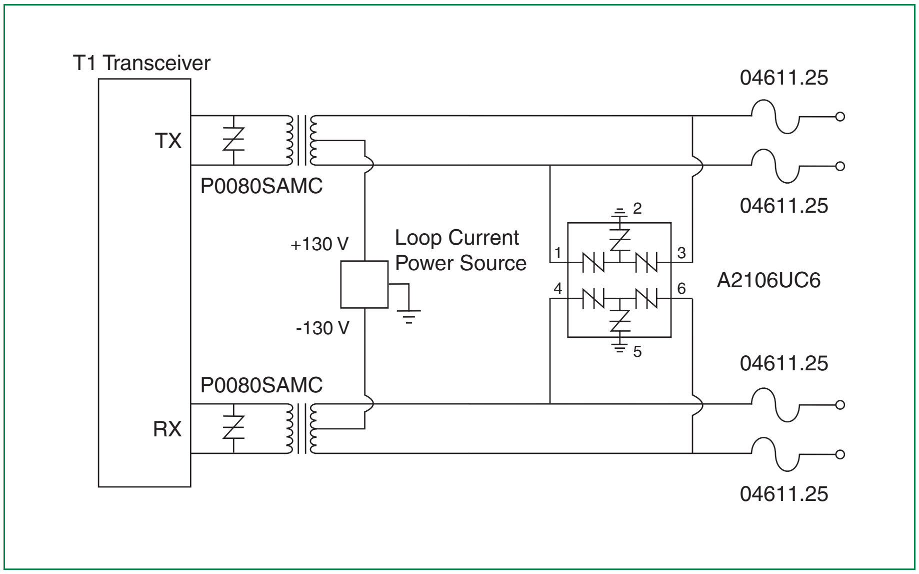


Figure 6.25 T1/E1/J1 Asymmetrical Protection

Protection Circuitry

The T1/E1 transceiver circuit is protected from AC power fault events (also known as over current events) by the 04611.25 *TeleLink* fuses. The *TeleLink* fuses in combination with the *SIDACtor* devices are compliant with the requirements of GR 1089, TIA-968-A, and UL 60950.

Additional T1 Design Considerations

A T1 application can be TIA-968-A approved as two different possible device types. An XD device means an external CSU is used, and while the unit does not have to meet the TIA-968-A environmental test conditions, it must connect only behind a separately registered DE device. This XD equipment does not have to meet the T1 pulse template requirements. If not classified as an XD device, then typically the application must adhere to TIA-968-A environmental test conditions.

Reference Designs

T3 Protection

The SL1002A090 in combination with the *TeleLink* fuse (Figure 6.26) is one low off-state capacitance solution. Figure 6.27 shows an alternate solution. The capacitance across the pair of wires = (D1 || D2) + P0640EC/SC. The diode capacitance is approximately (10 pF || 10 pF) 20 pF. Then adding the capacitive effect of the P0640EC/SCMC, which is typically 60 pF, the total capacitance across the pair of wires is approximately 15 pF. The MUR 1100E diodes are fast-switching diodes that will exhibit this level of capacitance. MURS160T3 is a surface mount equivalent. (Figure 6.27)

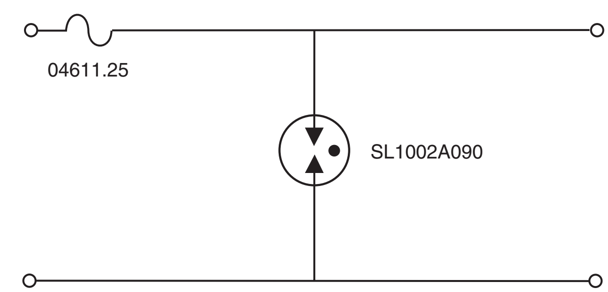


Figure 6.26 T3 Protection—Gas Plasma Arrester

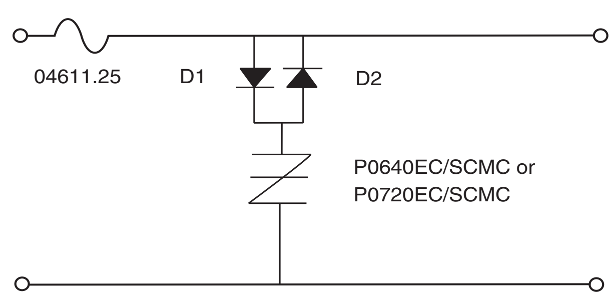


Figure 6.27 T3 Protection—*SIDACtor* Device and Diodes

Alternately, the advanced P0642SA exhibits very low capacitance and can be used as a stand-alone device. (Figure 6.28)

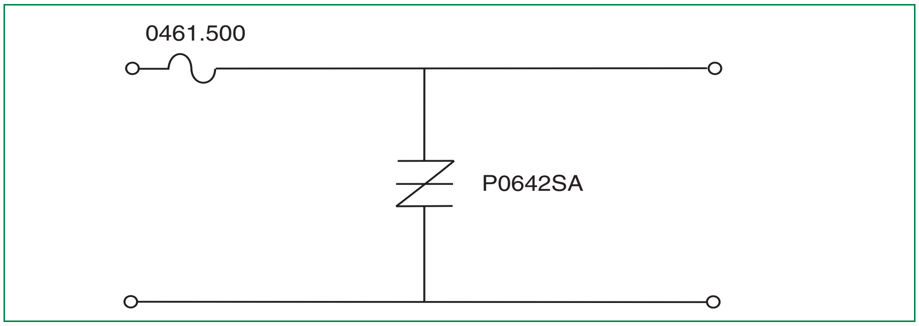


Figure 6.28 T3 Protection—*SIDACtor* Device

Coordination Considerations

Coordination between the primary protection and the secondary protection may require the addition of a resistor. (Figure 6.29)

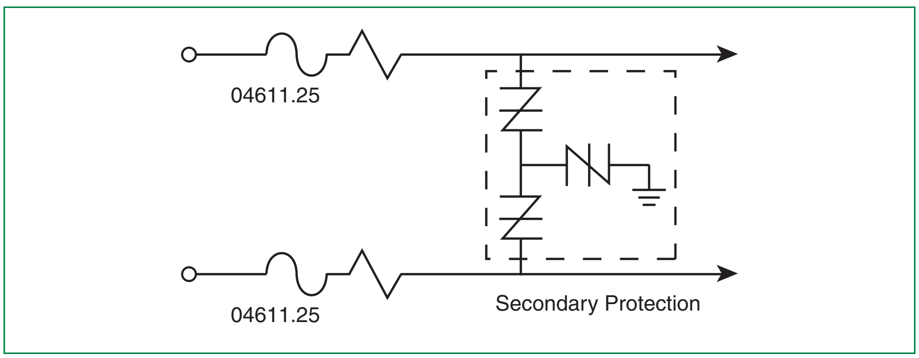


Figure 6.29 Coordination Solution with Resistor

The coordinating resistor value depends on:

- Distance between the primary and secondary protector
- Turn-on characteristics of the primary and secondary protector
- Surge rating of the secondary protector

For compliance with the GR 1089 requirement, the additional component is not required IF the peak pulse surge rating of the secondary protector is at least 100 A for a 10x1000 event. The ITU recommendations have an alternative solution as well, depending on whether Basic or Enhanced compliance is desired.

For Basic compliance, if the secondary protector has a peak pulse surge rating of at least 1000 A for an 8x20 event, then the additional component is not required. For the Enhanced level, it must be able to withstand a 5000 A for an 8x20 event. Otherwise, a coordinating component is required. This component allows the primary protector to turn on during surge events even though the secondary protector may turn on first. The power rating of this resistor can be reduced by including the *TeleLink* overcurrent protection device. However, it must not open during the surge events. Typically, a 1-3 W resistor will be sufficient.

Analog Line Cards

Given that line cards are highly susceptible to transient voltages, network hazards such as lightning and power fault conditions pose a serious threat to equipment deployed at the central office and in remote switching locations. To minimize this threat, adequate levels of protection must be incorporated to ensure reliable operation and regulatory compliance.

Protection Requirements

When designing overvoltage protection for analog line cards, it is often necessary to provide both on-hook (relay) and off-hook (SLIC) protection. This can be accomplished in two stages, as shown in Figure 6.30.

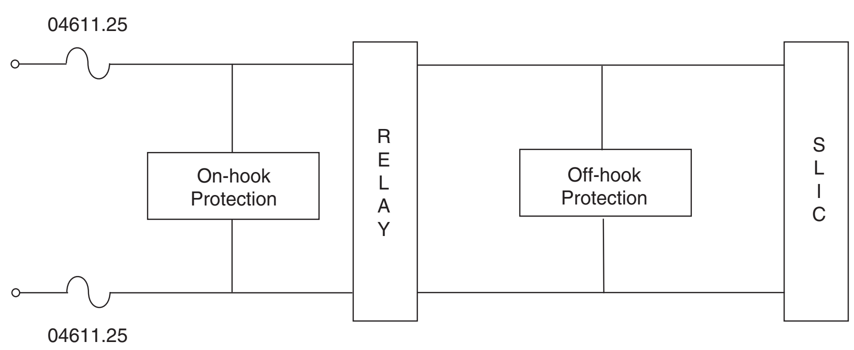


Figure 6.30 SLIC Overview

The following regulatory requirements may apply:

- GR 1089-CORE
- ITU-T K.20/K.21
- UL 60950
- TIA-968-A (formerly known as FCC Part 68)

On-Hook (Relay) Protection

On-hook protection is accomplished by choosing a *SIDACtor*® device that meets the following criteria to ensure proper coordination between the ring voltage and the maximum voltage rating of the relay to be protected.

$$V_{DRM} > V_{BATT} + V_{RING}$$

$$V_S \leq V_{Relay\ Breakdown}$$

This criterion is typically accomplished using two P2600S_ *SIDACtor* devices (where _ denotes the surge current rating) connected from Tip to Ground and Ring to Ground. However, for applications using relays such as an LCAS (Line Card Access Switch), consider the P1200S_ from Tip to Ground and the P2000S_ from Ring to Ground.

Off-Hook (SLIC) Protection

Off-hook protection is accomplished by choosing a *SIDACtor* device that meets the following criteria to ensure proper coordination between the supply voltage (V_{REF}) and the maximum voltage rating of the SLIC to be protected.

$V_{DRM} > V_{REF}$

$V_S \leq V_{SLIC\ Breakdown}$

This criterion can be accomplished in a variety of ways. Applications using an external ringing generator and a fixed battery voltage can be protected with a single P0641CA2 or two P0641SA *SIDACtor* devices or with any of the following, depending on the actual value of the battery reference voltage:

- P0721UA or two P0721CA2 or four P0721SA
- P0901UA or two P0901CA2 or four P0901SA
- P1101UA or two P1101CA2 or four P1101SA
- P1301UA or two P1301CA2 or four P1301SA
- P1701UA or two P1701CA2 or four P1701SA

Use the SC version for applications complying to GR 1089 inter-building or ITU K20/21 Enhanced Recommendations. For ring-generating SLIC chipsets, the *Battrax*® protector (B1xxx 6-pin devices) can be used.

I_{PP} Selection

The I_{PP} of the *SIDACtor* device must be greater than or equal to the maximum available surge current ($I_{PK(available)}$) of the applicable regulatory requirements. Calculate the maximum available surge current by dividing the peak surge voltage supplied by the voltage generator (V_{PK}) by the total circuit resistance (R_{TOTAL}). The total circuit resistance is determined by adding the source resistance (R_S) of the surge generator to the series resistance in front of the *SIDACtor* device on Tip and Ring (R_{TIP} and R_{RING}).

$I_{PP} \geq I_{PK(available)}$

$I_{PK(available)} = V_{PK} / R_{TOTAL}$

For metallic surges:

$R_{TOTAL} = R_S + R_{TIP} + R_{RING}$

For longitudinal surges:

$R_{TOTAL} = R_S + R_{TIP}$

$R_{TOTAL} = R_S + R_{RING}$

Reference Diagrams

Littelfuse offers a wide variety of protection solutions for SLIC applications. Some non-ringing SLIC applications require an asymmetrical type of protection, while others require a balanced protection solution. The ringing SLIC applications can be protected with fixed voltage *SIDACtor* devices or with programmable *Battrax* devices. Figure 6.31 through Figure 6.53 illustrate these many different solutions. The *TeleLink* fuse is also included in these illustrations so that GR 1089-compliant overvoltage and overcurrent protection is provided.

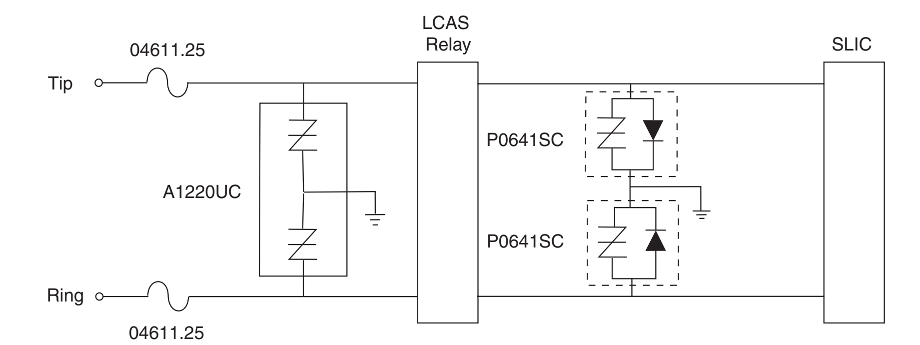
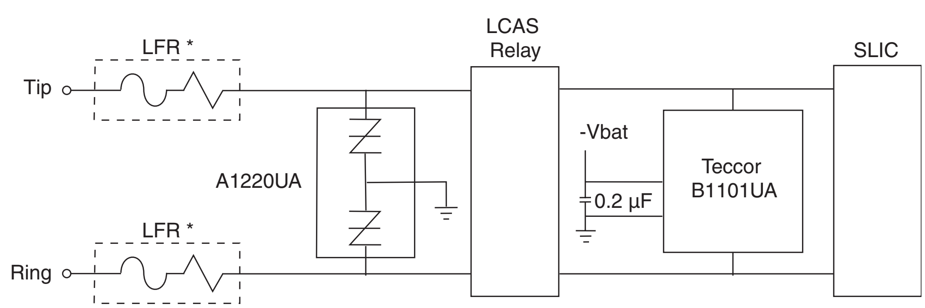
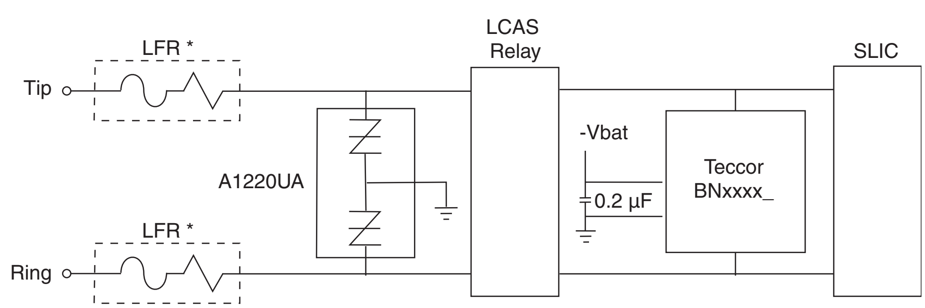


Figure 6.31 SLIC Protection for LCAS



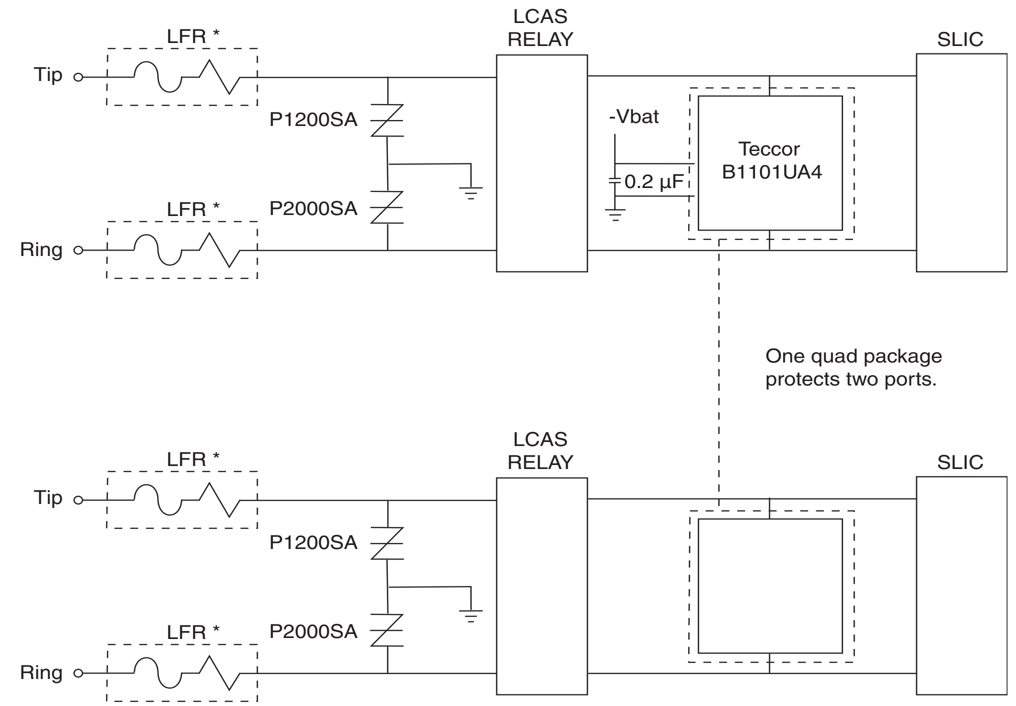
* Assumed minimum resistance of 20 Ω. If the LFR does not have a fusible link, then the 04611.25 is recommended for overcurrent protection.

Figure 6.32 SLIC Protection with Limiting Resistance



* Assumed minimum resistance of 20 Ω. If the LFR does not have a fusible link, then the 04611.25 is recommended for overcurrent protection.

Figure 6.33 SLIC Protection with Limiting Resistance—Buffered *Battrax*



* Assumed minimum resistance of 20 Ω. If the LFR does not have a fusible link, then the 04611.25 is recommended for overcurrent protection.

Figure 6.34 SLIC Protection with Quad *Battrax*

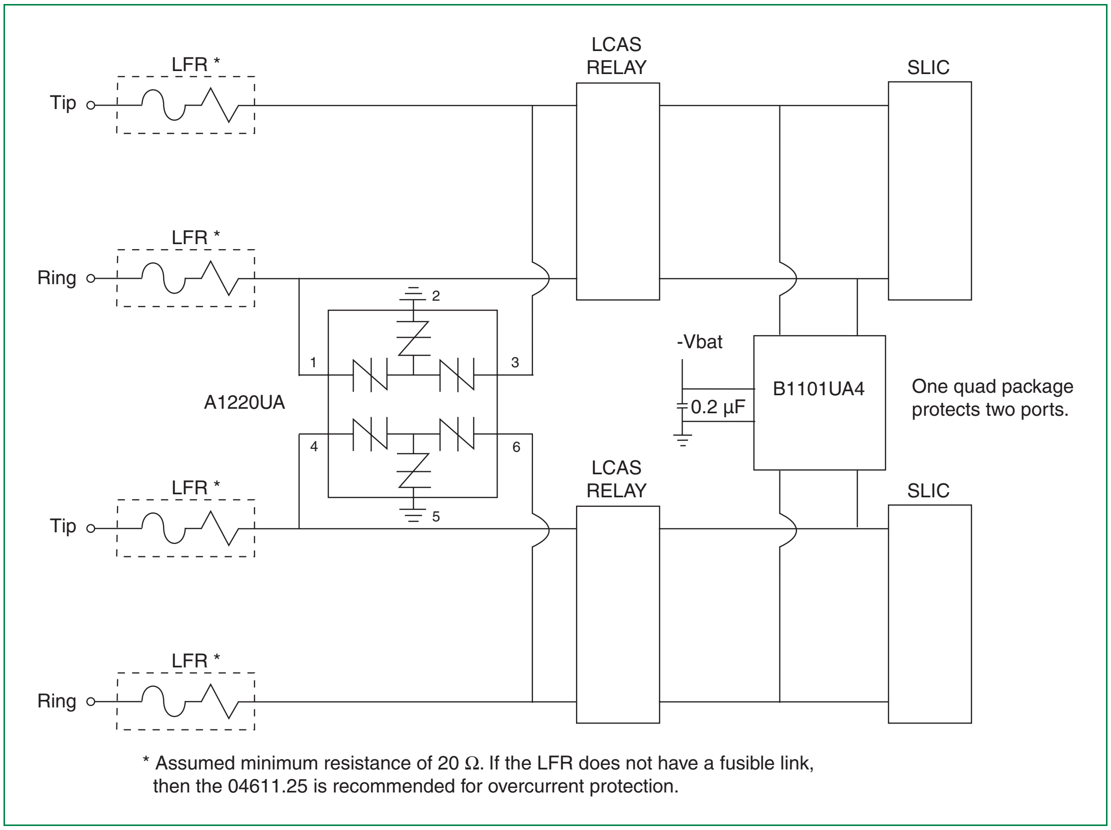


Figure 6.35 SLIC Protection with Quad *Battrax* and Balanced Relay Protector

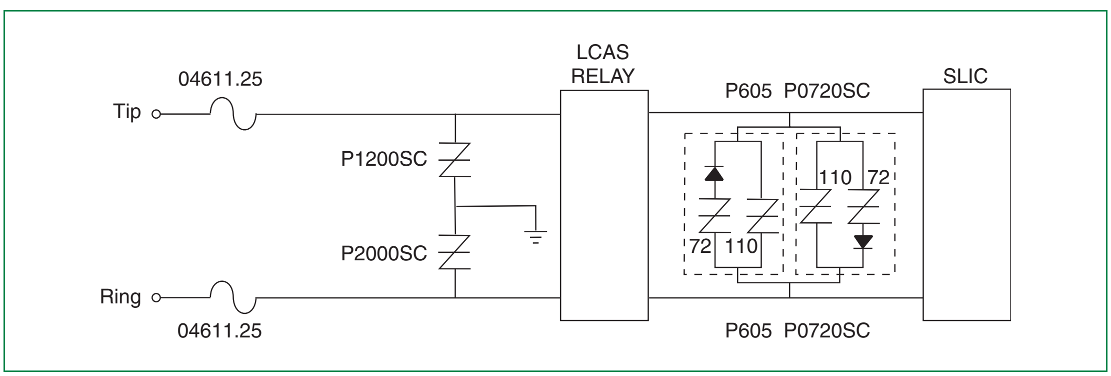


Figure 6.36 SLIC Protection with Asymmetrical Devices

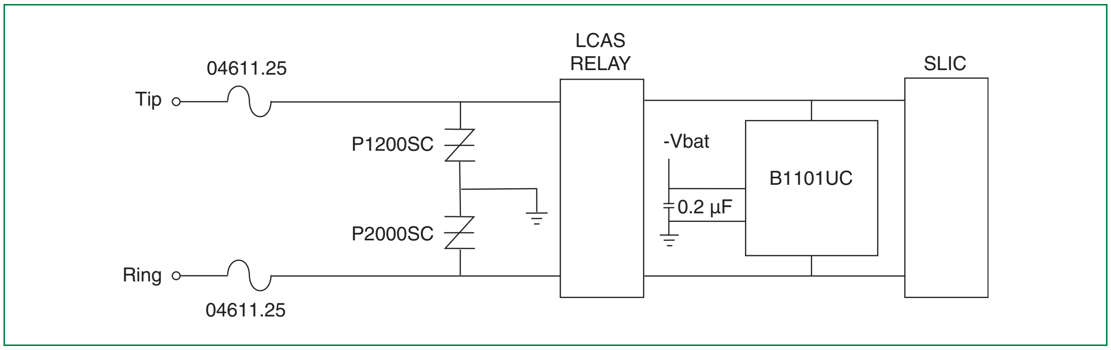


Figure 6.37 SLIC Protection with *Battrax*

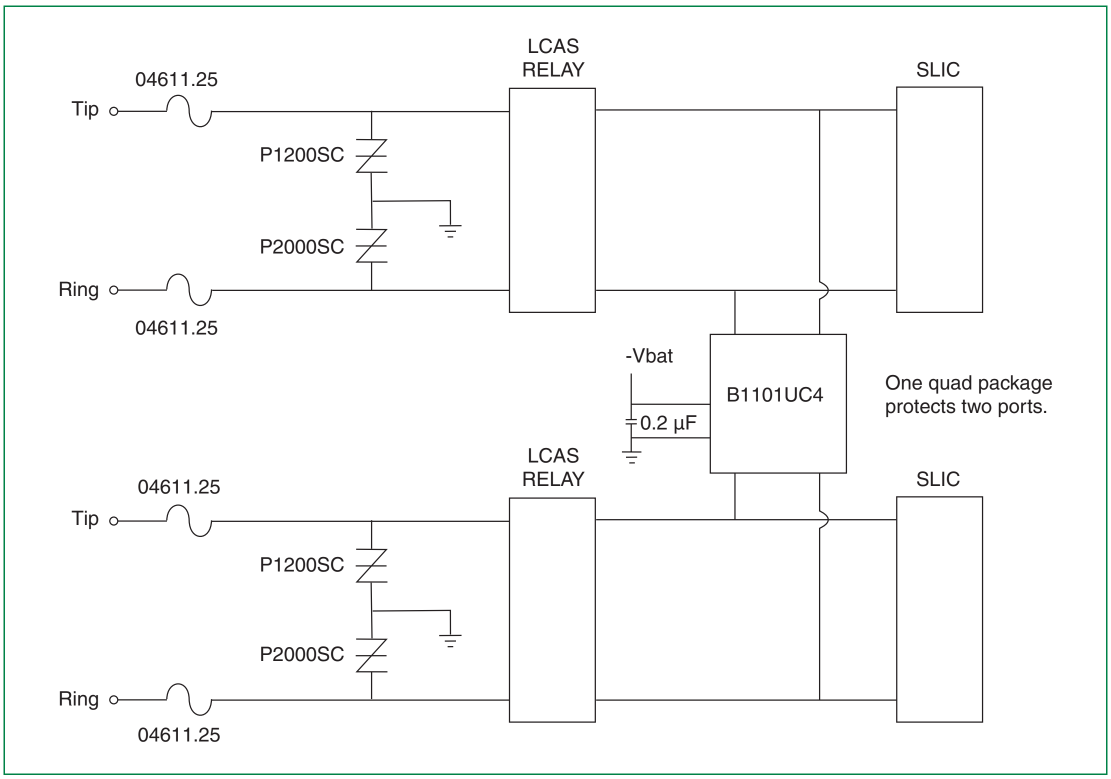


Figure 6.38 SLIC Protection with Quad *Battrax* with Asymmetrical Relay Protection

Figure 6.39 illustrates uses of asymmetrical *SIDACtor* protection for overvoltage conditions and the 04611.25 for overcurrent conditions.

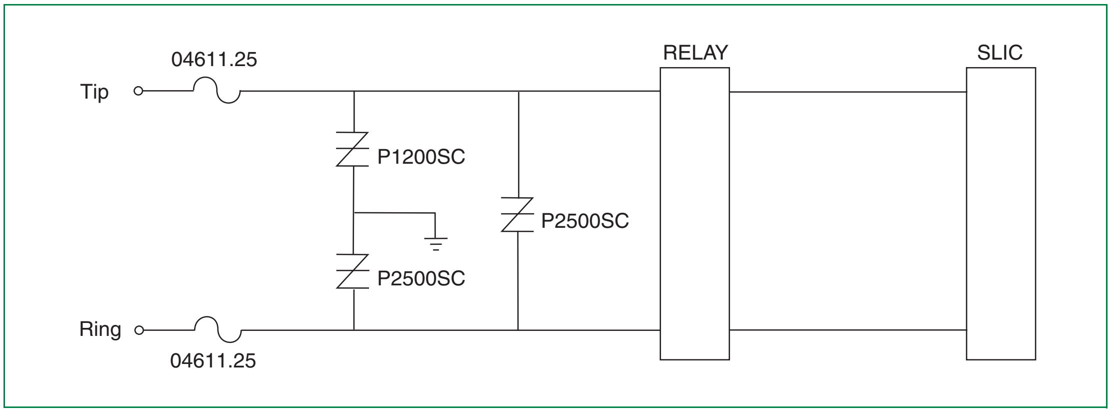


Figure 6.39 SLIC Asymmetrical Protection

Figure 6.40 illustrates the use of the P2600SA and P0721CA2 for overvoltage protection and the 0461.500 for overcurrent protection in addition to 20 Ω of series resistance on both Tip and Ring. The series resistance is required to limit the transient surge currents to within the surge current rating of the "A" series *SIDACtor* devices and the 0461.500 *TeleLink*® fuse.

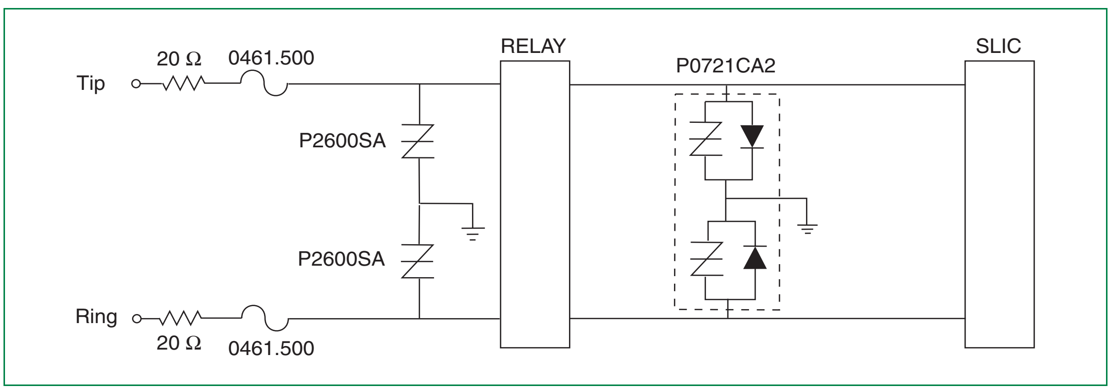


Figure 6.40 SLIC Protection with Fixed Voltage *SIDACtor* Devices

Figure 6.41, Figure 6.42, and Figure 6.43 illustrate the use of different circuits to coordinate overvoltage and overcurrent protection when protecting the LCAS family of solid state switches. Figure 6.41 illustrates the use of the *TeleLink* and the *SIDACtor*. The *TeleLink* is a surface mount, surge resistant fuse that saves cost and PCB real estate over more traditional solutions.

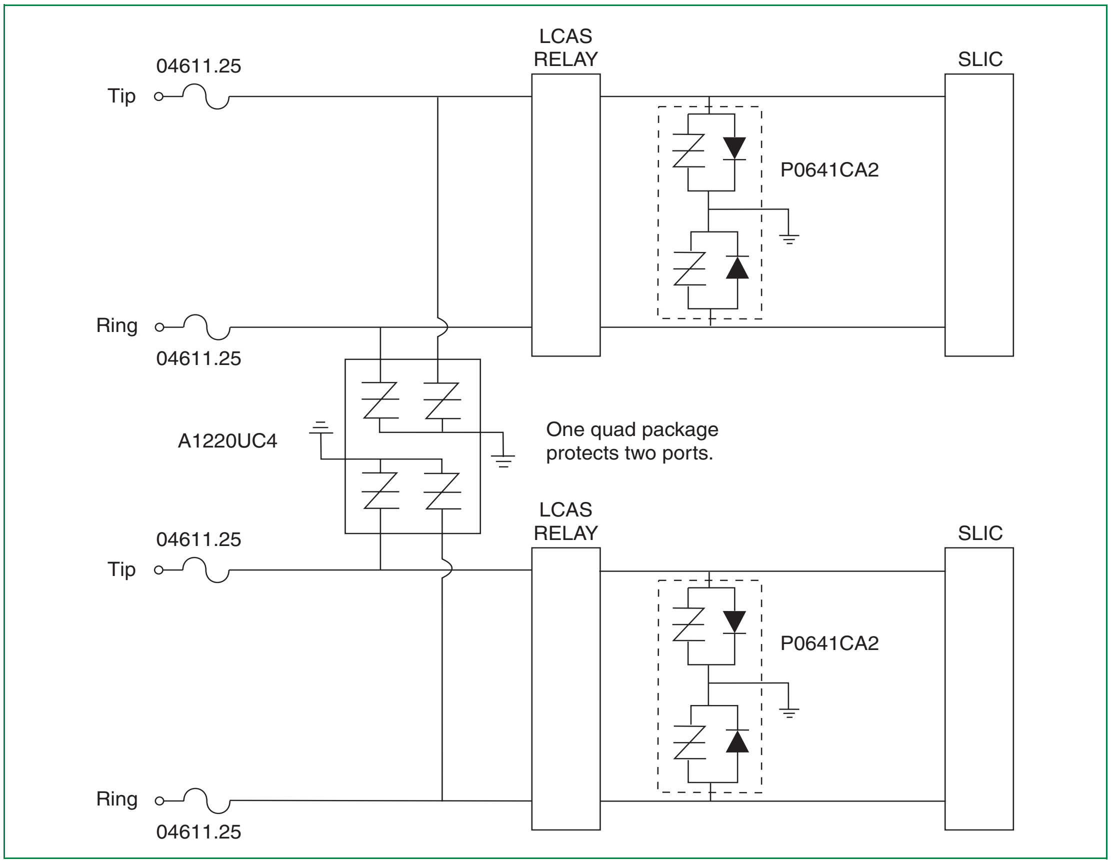
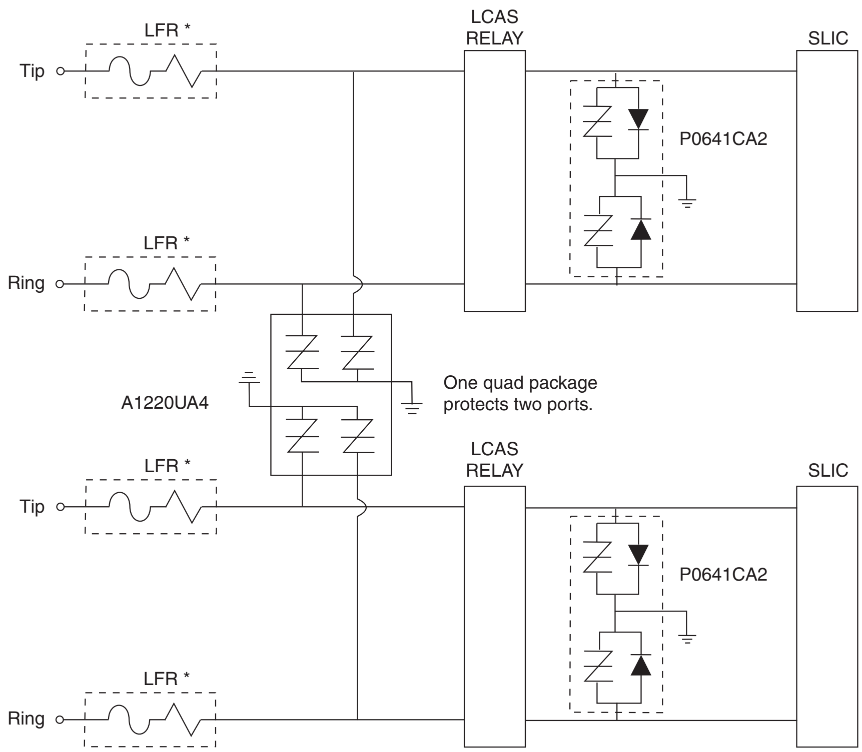


Figure 6.41 SLIC Protection with *TeleLink* Multiport

Reference Designs

Figure 6.42 illustrates the use of a line feed resistor with a thermal link and the *SIDACtor*. The advantage of using an LFR is that it attenuates surge currents, allowing use of a *SIDACtor* with a lower surge current rating.



* Assumed minimum resistance of 20 Ω. If the LFR does not have a fusible link, then the 04611.25 is recommended for overcurrent protection.

Figure 6.42 SLIC Protection with LFR Multiport

Figure 6.43 illustrates a single port version with the *TeleLink* and discrete *SIDACtors*.

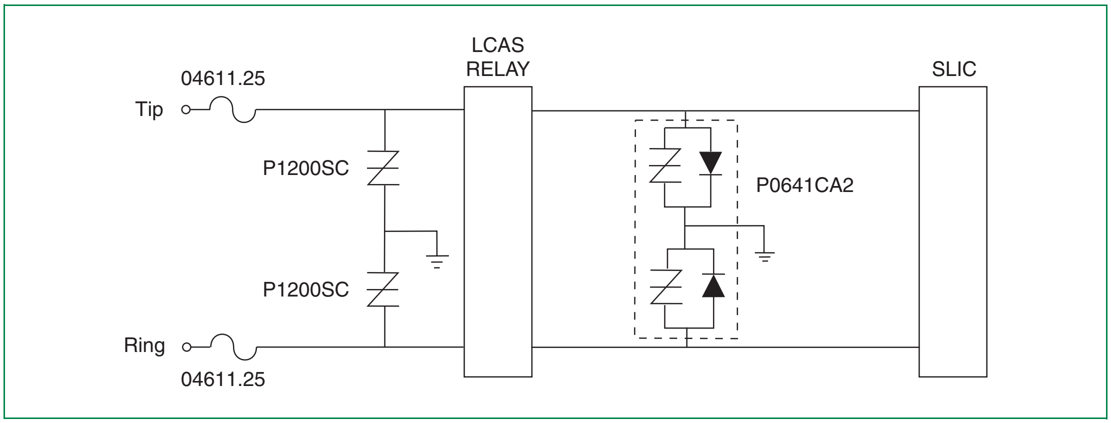


Figure 6.43 SLIC Protection with Single Port Discrete

Figure 6.44 shows protection of a SLIC using 20 Ω series resistors on both Tip and Ring in addition to Littelfuse's *Battrax* (B1100CC) and a diode bridge (General Semiconductor part number EDF1BS). However, the overshoot caused by the diode bridge must be considered. The series resistance (a minimum of 20 Ω on Tip and 20 Ω on Ring) limits the simultaneous surge currents of 100 A from Tip to Ground and 100 A from Ring to Ground (200 A total) to within the surge current rating of the SA-rated *SIDACtor* device and *Battrax*. The diode bridge shunts all positive voltages to Ground, and the B1100CC shunts all negative voltages greater than $|-V_{REF} -1.2\ V|$ to Ground.

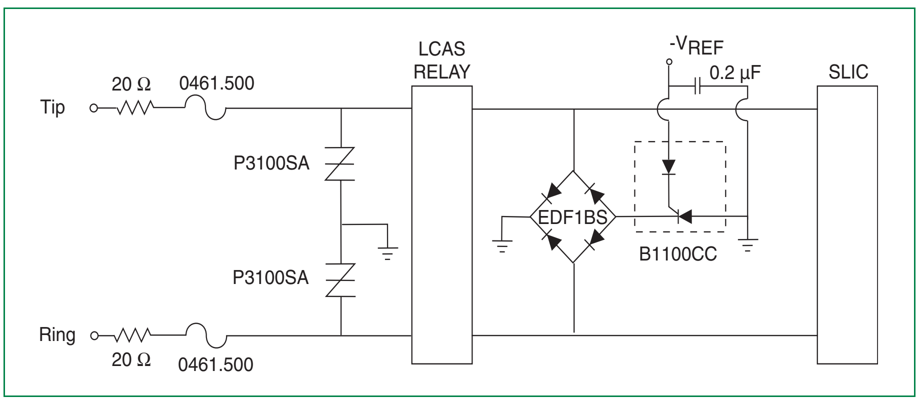


Figure 6.44 SLIC Protection with a Single *Battrax* Device

In Figure 6.45 and Figure 6.46 an application that requires 50 Ω Line Feed Resistors (LFR) uses one B1160CC and two EDF1BS diode bridges in place of multiple SLIC protectors. The overshoot caused by the diode bridge must be considered; however, with this approach it is imperative that the sum of the loop currents does not exceed the *Battrax*'s holding current. In the application shown in Figure 6.45 and Figure 6.46, each loop current would have to be limited to 80 mA. For applications requiring the protection of four twisted pair with one *Battrax*, use the B1200CC and limit each individual loop current to 50 mA.

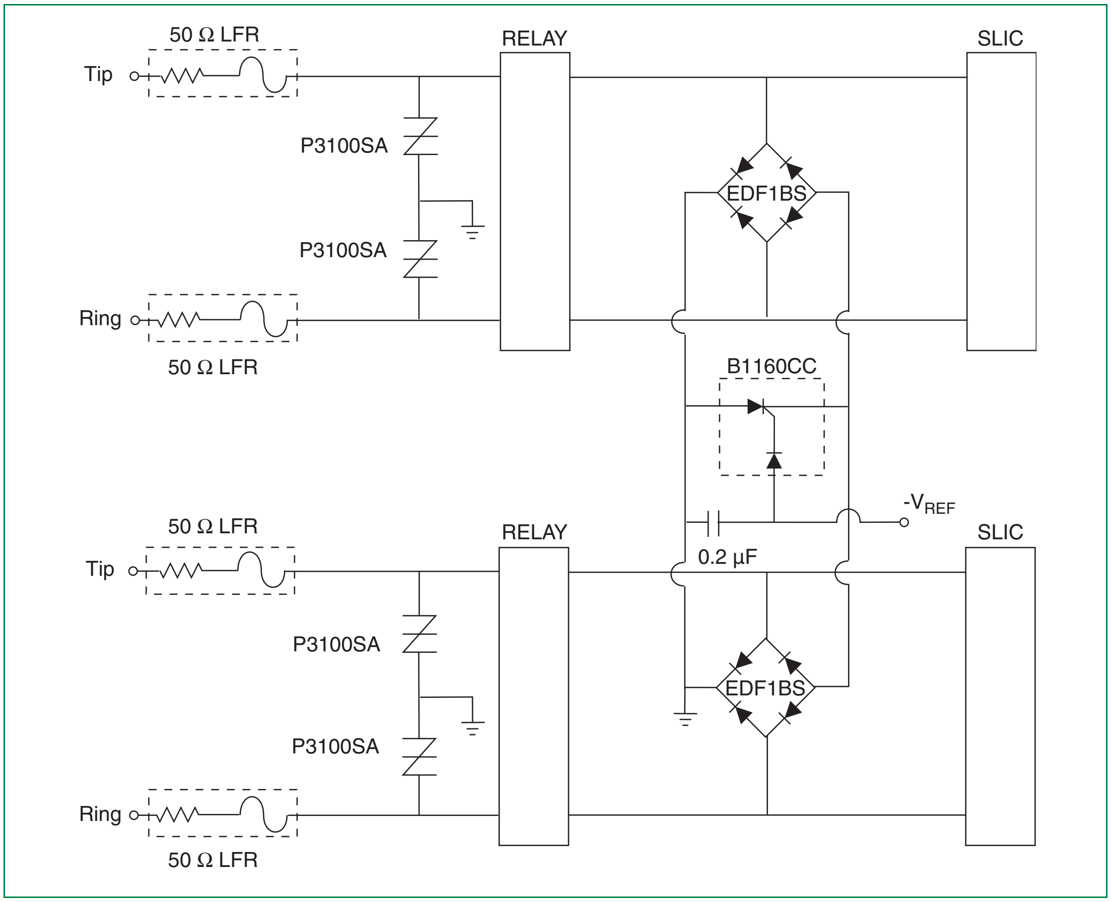


Figure 6.45 SLIC Protection with a Single *Battrax* Device

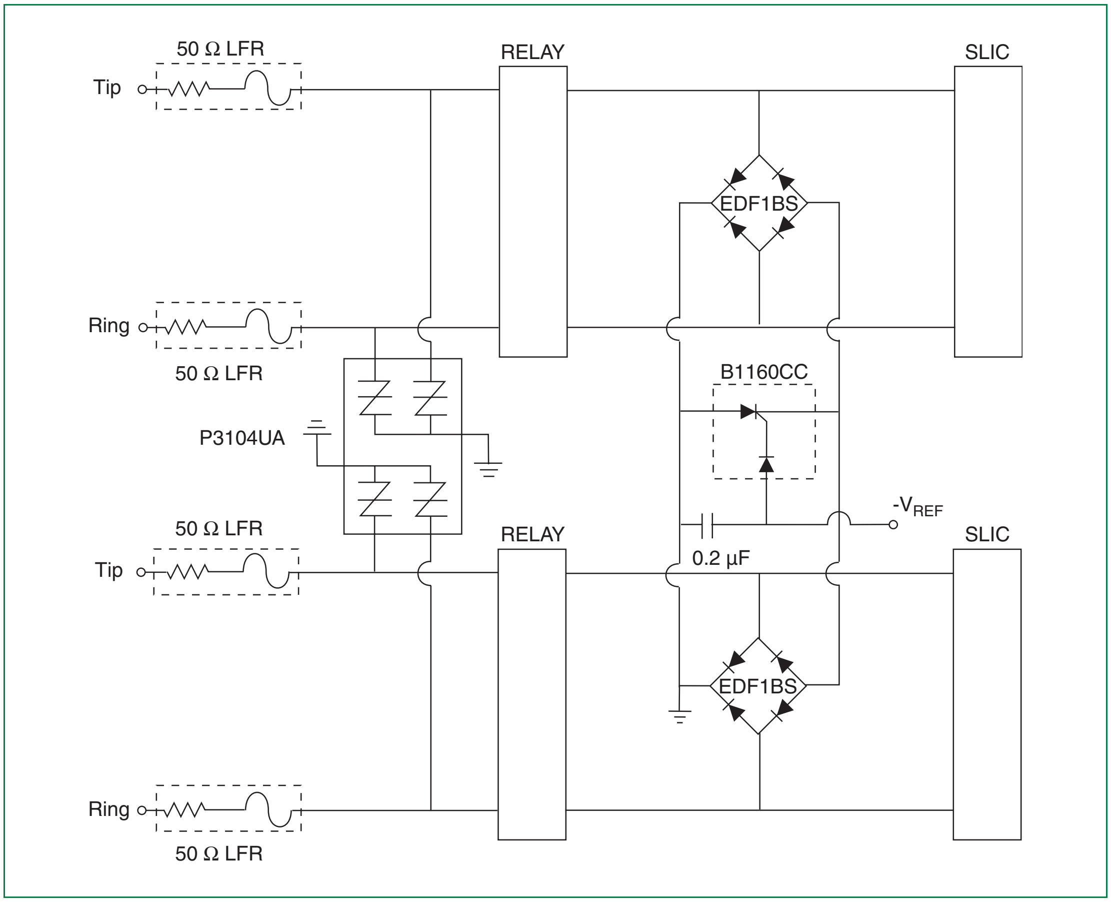


Figure 6.46 SLIC Protection with Diode Bridge

Figure 6.47, Figure 6.48, and Figure 6.49 show circuits that use negative *Battrax* devices containing an internal diode for positive surge protection. This obviates using the discrete diodes shown in Figure 6.44, Figure 6.45, and Figure 6.46.

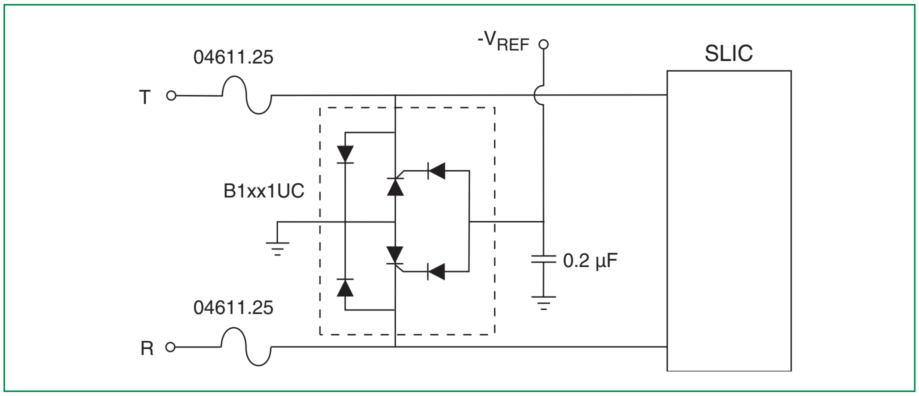


Figure 6.47 SLIC Protection with a Dual *Battrax* Device

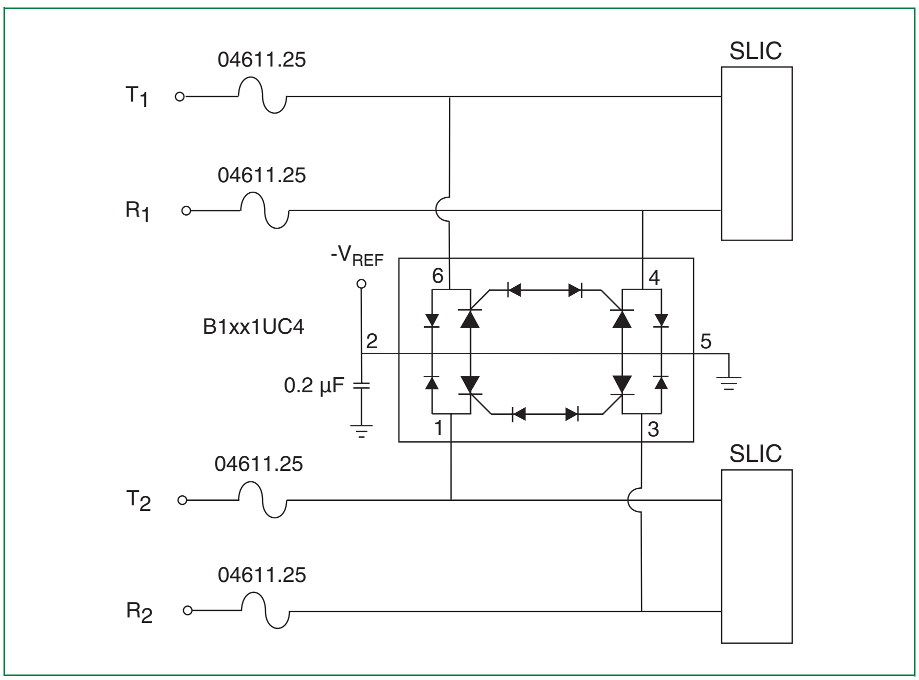


Figure 6.48 SLIC Protection with a Single *Battrax* Quad Negative Device

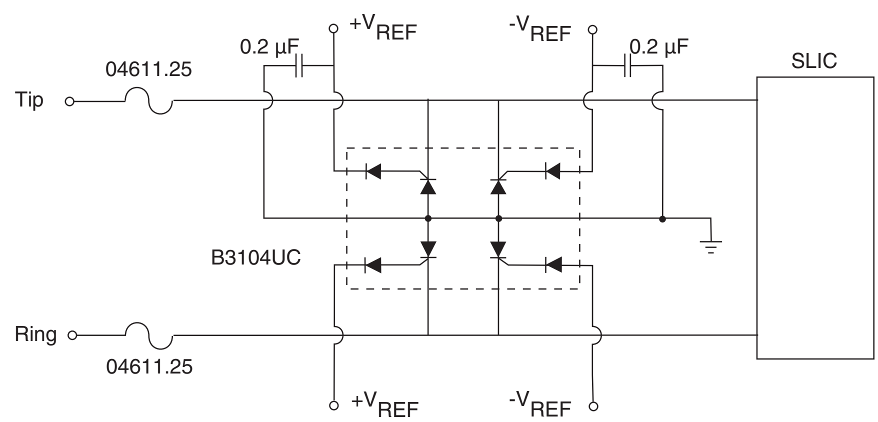


Figure 6.49 SLIC Protection with a *Battrax* Dual Positive/Negative Device

Figure 6.50 shows a SLIC application protected by the BN1718C *Battrax* device and two *TeleLink* fuses. This surface mount arrangement provides a minimum footprint solution for both overcurrent and overvoltage protection. The BN1718C Battrax protects against both positive and negative induced surge events. The integrated diode within this package provides the positive polarity protection.

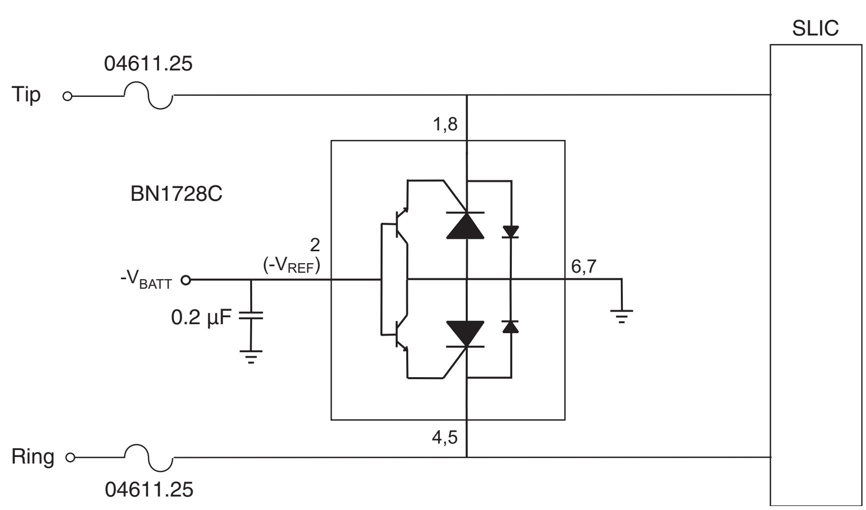


Figure 6.50 SLIC Protection with an 8-pin *Battrax* Dual Positive/Negative Device

SLIC Protection Options

Figure 6.51 through Figure 6.54 illustrate SLIC protection options.

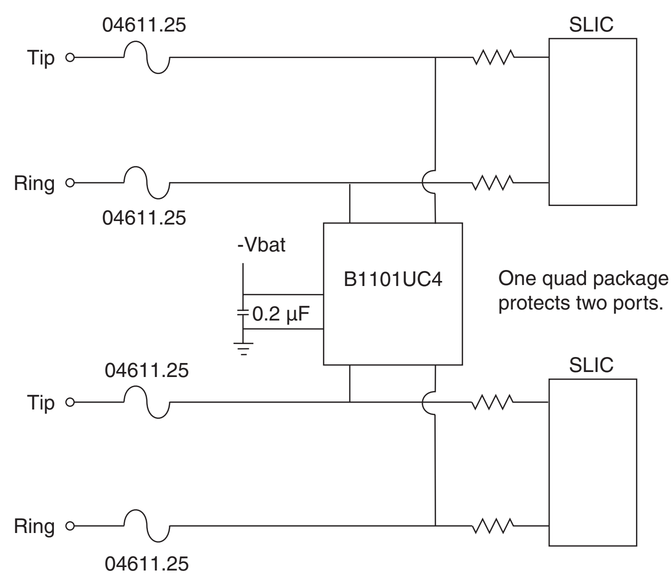


Figure 6.51 SLIC Protection with Quad *Battrax*

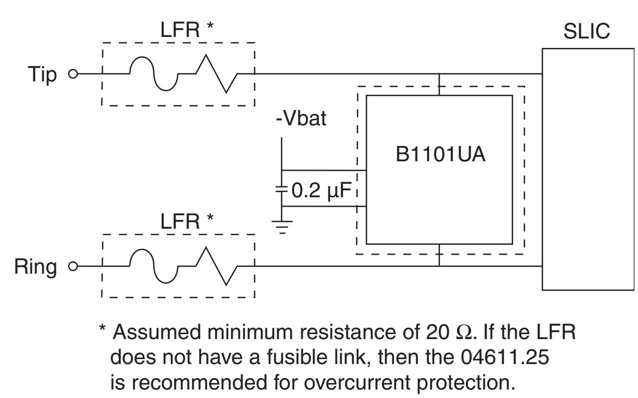


Figure 6.52 SLIC Protection with Series R and *Battrax*

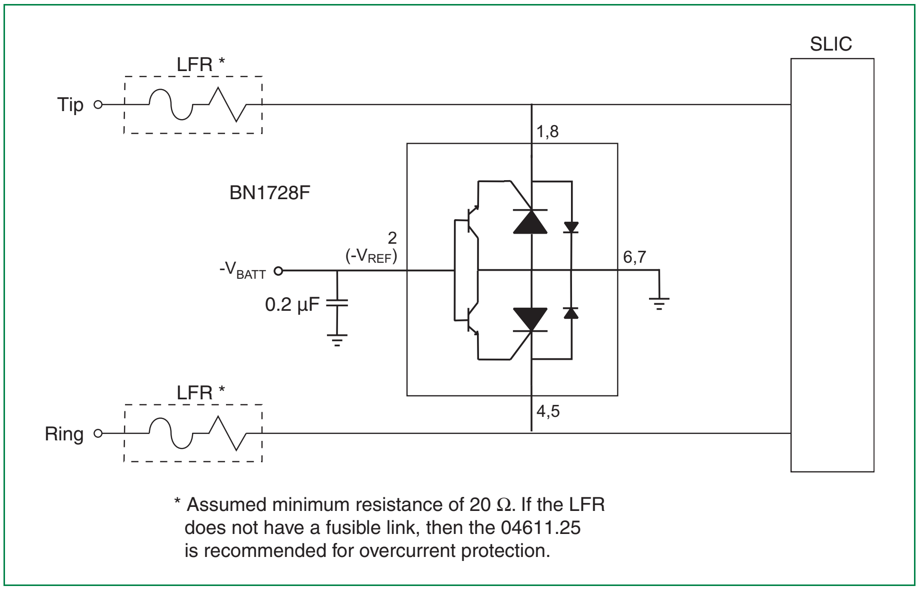


Figure 6.53 SLIC Protection with Series R and 8-pin *Battrax*

Reference Designs

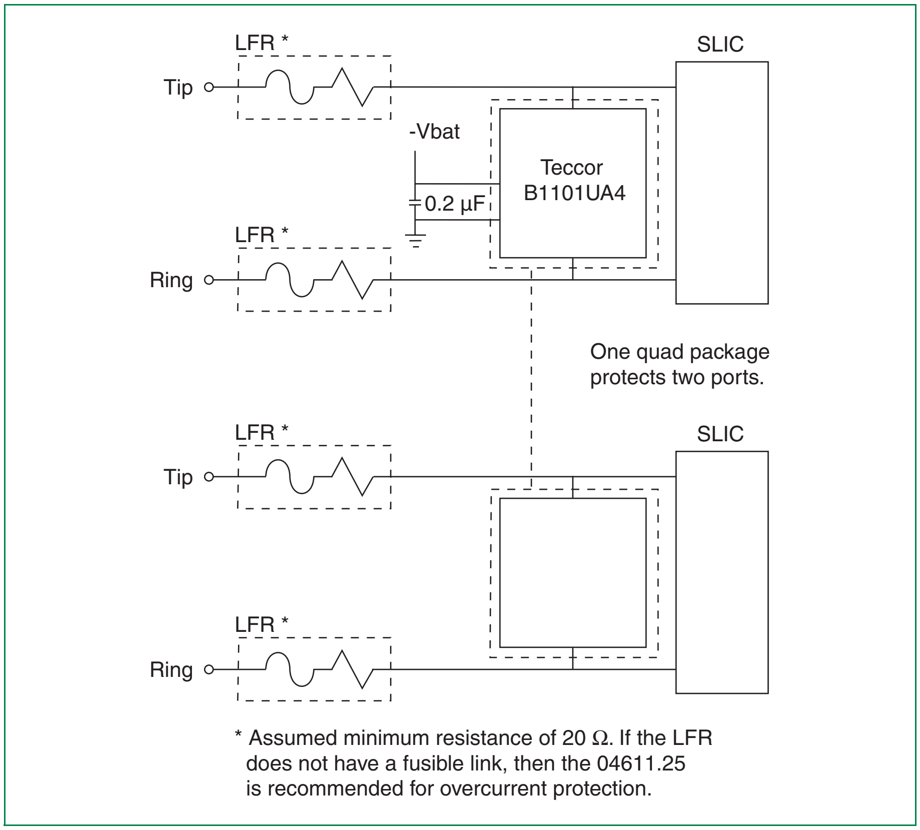


Figure 6.54 SLIC Protection with Series R and Quad *Battrax*

Battrax® Protection Gate Buffer Circuit

Many SLIC card designs do not require the *Battrax* protection gate buffer circuit shown in Figure 6.55. This circuit is useful to improve the voltage overshoot performance during AC power fault events. There is no impact on lightning surge performance as the gate capacitor is the only current source required during high dv/dt events.

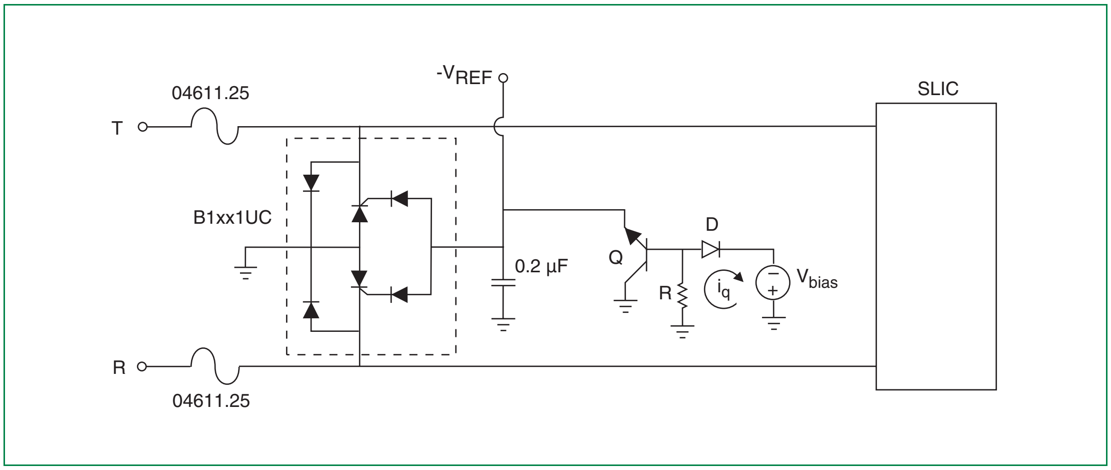


Figure 6.55 *Battrax* Protection Gate Buffer Circuit

During slower events (such as power fault), the current from the capacitor (C x dv/dt) may not source the needed current (100 mA max) to gate the SCR on. This does not apply to the BNxxxx series as its gate trigger valve is 5 mA. Under these conditions, this buffer circuit will source the needed current. The SLIC card bias supply is a negative (sinking) supply and cannot source any current.

In many designs, the bias supply is also the main supply powering the SLIC card. As such, the supply has a significant load at all times. This is the source of the gate current. When sourcing the gate current, the bias supply is actually being relieved of the load. As long as the load on the bias supply is 100 mA for each line protected, this buffer circuit is not needed. For lightly loaded bias supplies, this circuit may be useful.

Reference Designs

Protection Circuitry

The buffer circuit consists of a diode, a resistor, and a transistor connected as shown. A small current i_q circulates constantly from the supply through the resistor and diode. When required to source current (during a fault condition where the emitter is being pulled more negative than the V_{bias} supply), the transistor Q will turn on because i_q is available as base current and Q will provide the needed current from its collector, out the emitter and into the gate of the *Battrax* device. One buffer circuit may provide current to several *Battrax* devices if properly designed.

Component Selection

Transistor Q should be selected to have a collector breakdown voltage well in excess of the bias supply voltage. The current available from Q will be H_{fe} x V_{bias} / R where H_{fe} is the gain of the transistor. The current available should be at least 100 mA per line protected. Selection of a Darlington pair transistor with a large gain can greatly increase the allowed value of R, reducing the quiescent dissipation.

The diode D need only be a small signal diode and may not be needed if the supply has its own source current protection built in.

The resistor R should be selected by the equation above to yield the needed source current. Keep in mind that it will dissipate V_{bias}^2 / R and should be sized appropriately. If there is ANY constant load on the V_{bias} supply due to the SLIC card design, the equivalent resistance of that load may be lumped into the R calculation and, in many cases, make R unnecessary.

This buffer circuit is not required for the new BNxxxx series *Battrax* devices. The internal structure of this device accomplishes the function of this darlington pair circuit.

PBX Systems

Branch Exchange Switches

PBXs, KSUs, and PABXs contain line cards that support various transmission protocols such as ISDN, T1/E1, HDSL, and ADSL (Figure 6.56). PBXs also have features such as a POTS (plain old telephone service) pull-through which allows stations to have outside line access in the event of power failure. All incoming lines to the PBX are subject to environmental hazards such as lightning and power fault.

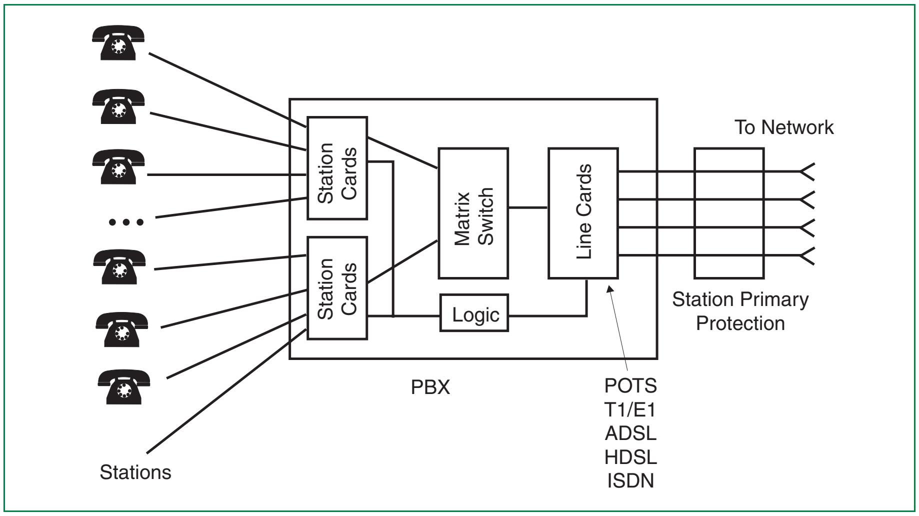


Figure 6.56 PBX Overview

Protection Requirements

Branch exchange switches should be protected against overvoltages that can exceed 800 V and surge currents up to 100 A.

The following regulatory requirements apply:
- TIA-968-A (formerly known as FCC Part 68)
- UL 60950

Branch Exchange Reference Circuit

Refer to the following for information on interface circuits used to protect of PBX line cards:
- For POTS protection, see "Customer Premises Equipment (CPE)" on page 6-2.
- For ADSL protection, see "ADSL / VDSL Circuit Protection" on page 6-10.
- For HDSL protection, see "HDSL Circuit Protection" on page 6-12.
- For ISDN protection, see "ISDN Circuit Protection" on page 6-14.
- For T1/E1 protection, see "T1/E1/J1 Circuit Protection" on page 6-18.
- For Station Protection, see "Analog Line Cards" on page 6-24.

CATV Equipment

As cable providers enter the local exchange market, protection of CATV (Community Antenna TV) equipment becomes even more critical in order to ensure reliable operation of equipment and uninterrupted service.

Protection Requirements

CATV line equipment should be able to withstand overvoltages that exceed 6000 V and surge currents up to 5000 A. CATV station protectors should be able to withstand overvoltages that exceed 5000 V and surge currents up to 1000 A. The *SIDACtor*® devices illustrated in Figure 6.57 through Figure 6.61 meet these requirements.

The following regulatory requirements may apply:
- UL 497C
- SCTE IPS-SP-204
- SCTE Practices
- NEC Article 830

Power Inserter and Line Amplifier Reference Circuit

Figure 6.57 and Figure 6.59 show how the P1900ME *SIDACtor* device is used to protect line amplifiers and power supplies versus using two SCRs and one *SIDACtor* device, as shown in Figure 6.60. The P1900ME is used because the peak off-state voltage (V_{DRM}) is well above the peak voltage of the CATV power supply (90 V_{RMS} $\sqrt{2}$), and the peak pulse current rating (I_{PP}) is 3000 A.

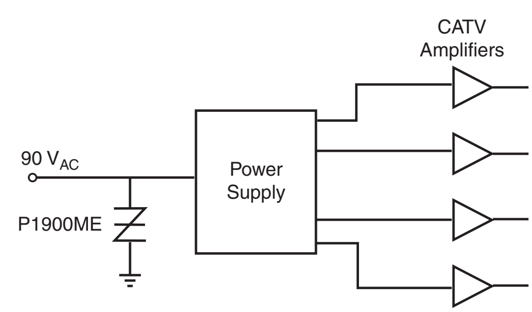


Figure 6.57   CATV Amplifier Diagram

The circuits shown in Figure 6.58, Figure 6.59, and Figure 6.60 may be covered by one or more patents.

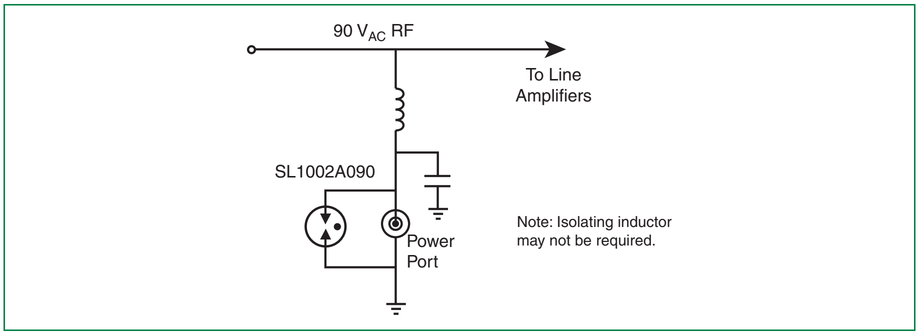


Figure 6.58 Gas Plasma Arrester CATV Amplifier Protection (incorporated into a power inserter module)

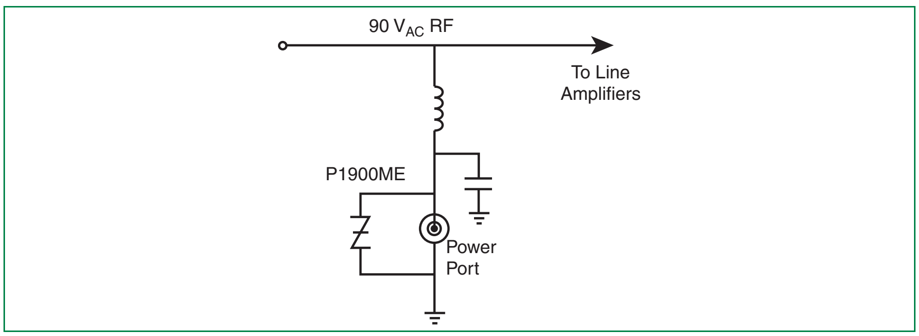


Figure 6.59 *SIDACtor* CATV Amplifier Protection (incorporated into a power inserter module)

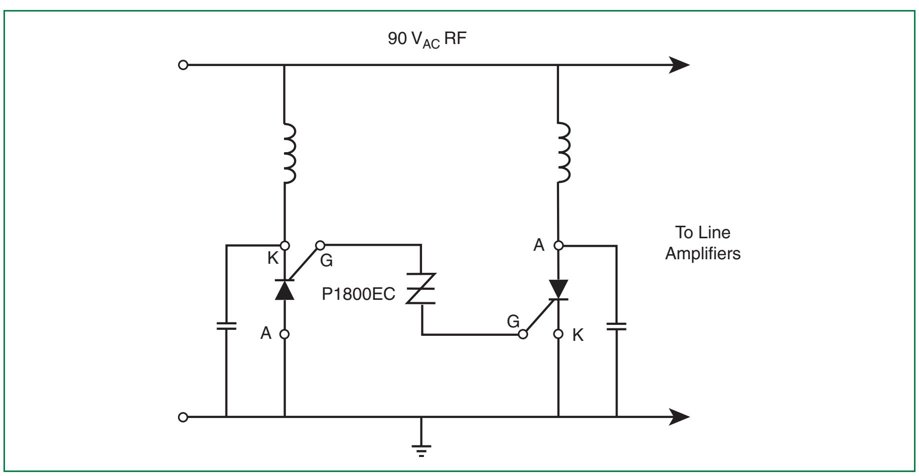


Figure 6.60 CATV Amplifier Protection

CATV Station Protection Reference Circuit

Figure 6.61 shows a P1400AD *SIDACtor* device used in a CATV station protection application. Note that a compensation inductor may be required to meet insertion and reflection loss requirements for CATV networks. If so, the inductor should be designed to saturate quickly and withstand surges up to 200 V and 1000 A. An inductor with a core permeability of approximately 900 Wb/A·m and wound with 24-gauge wire to an inductance of 20 µH to 30 µH is an example of a suitable starting point, but the actual value depends on the design and must be verified through laboratory testing.

Figure 6.62 is a protection circuit that does not require the compensating inductor.

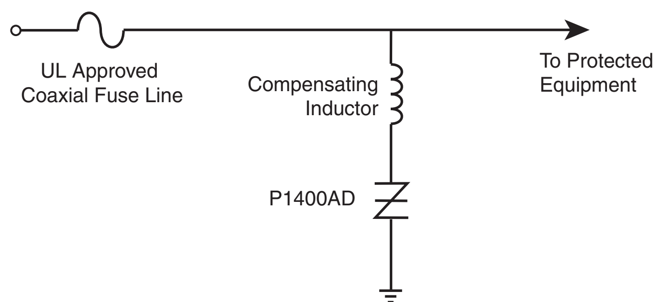


Figure 6.61 *SIDACtor* CATV Station Protection

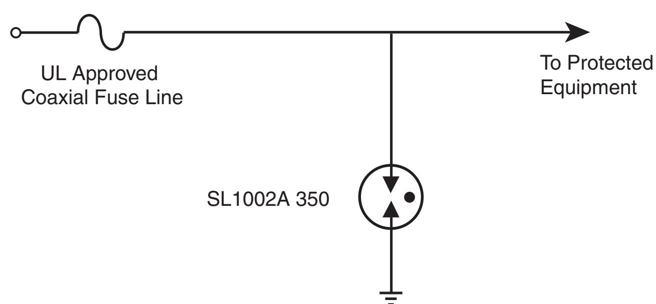


Figure 6.62 Gas Plasma Arrester CATV Station Protection

Primary Protection

Primary telecommunications protectors must be deployed at points where exposed twisted pairs enter an office building or residence. This requirement is mandated in North America by the National Electric Code (NEC) to protect end users from the hazards associated with lightning and power fault conditions.

Primary protection is provided by the local exchange carrier and can be segregated into three distinct categories:

- Station protection—typically associated with a single twisted pair
- Building entrance protection—typically associated with multiple (25 or more) twisted pair
- Central office protection—typically associated with numerous twisted pair feeding into a switch

Station protectors provide primary protection for a single-dwelling residence or office. The station protector is located at the Network Interface Unit (NIU), which acts as the point of demarcation, separating the operating company's lines from the customer's.

Building entrance protection is accomplished by installing a multi-line distribution panel with integrated overvoltage protection. These panels are normally located where multiple twisted pairs enter a building.

A five-pin protection module plugged into a Main Distribution Frame (MDF) provides Central and Remote Office protection. Like station and building entrance protection, the MDF is located where exposed cables enter the switching office.

Littelfuse offers components used in five-pin protectors. For further details, contact factory.

Protection Requirements

Station protectors must be able to withstand 300 A 10x1000 surge events. The building entrance protectors and CO protectors must be able to withstand 100 A 10x1000 surge events. Figure 6.64 shows building entrance protector and CO protector asymmetrical solutions. Figure 6.66 shows building entrance protector and CO protector balanced solutions.

The following regulatory requirements apply:

- UL 497
- GR 974-CORE
- ITU K.28

Primary Protection Reference Circuit

Figure 6.63 through Figure 6.66 show different configurations used in primary protection. Note that the peak off-state voltage (V_{DRM}) of any device intended for use in primary protection applications should be greater than the potential of a Type B ringer superimposed on a POTS (plain old telephone service) battery.

$$150\ V_{RMS}\sqrt{2} + 56.6\ V_{PK} = 268.8\ V_{PK}$$

Reference Designs

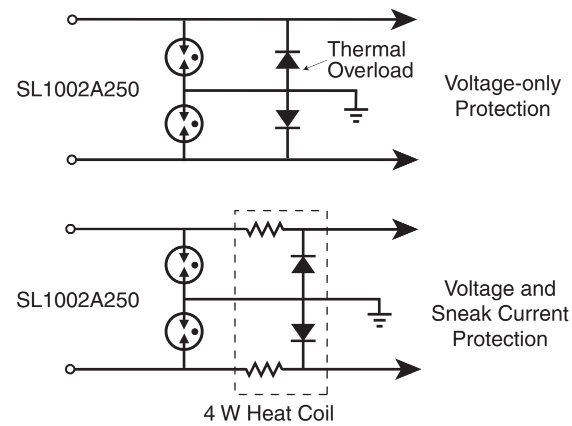


Figure 6.63 Gas Plasma Arrester Primary Protection

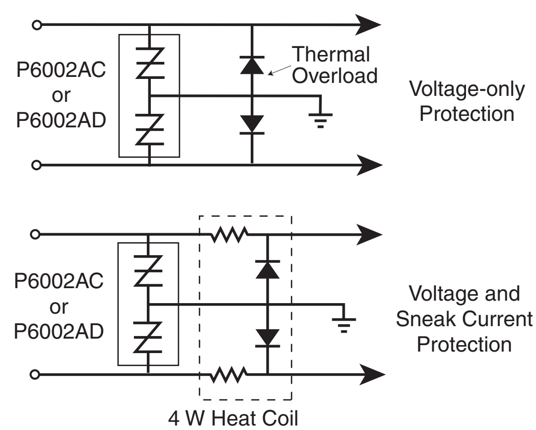


Figure 6.64 *SIDACtor* Primary Protection

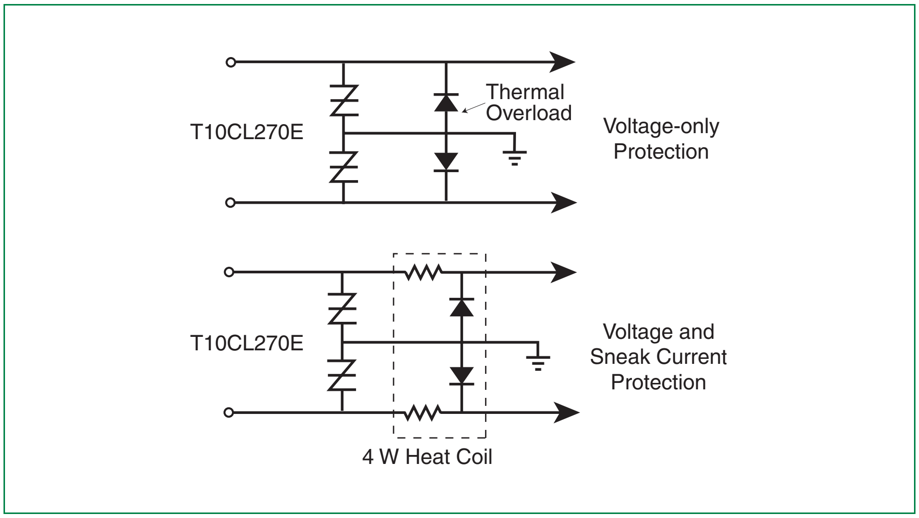


Figure 6.65 *SIDACtor* Cell Primary Protection

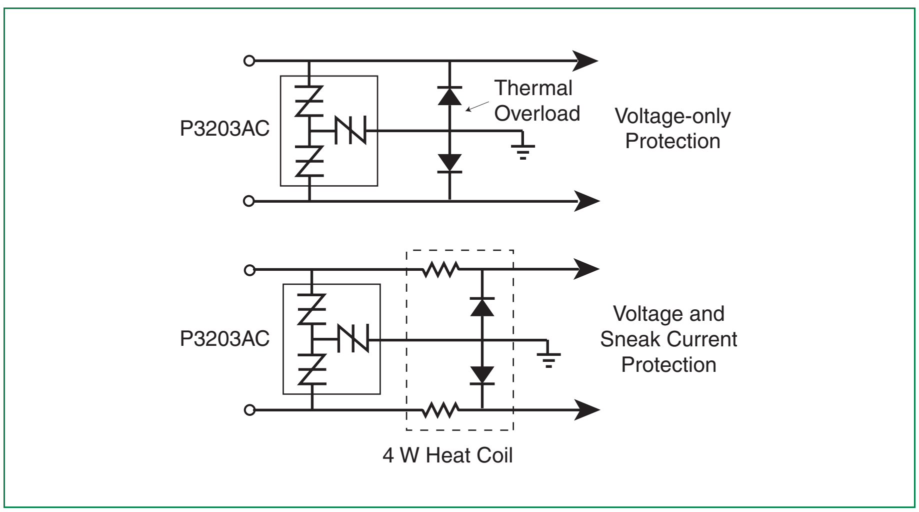


Figure 6.66 Balanced *SIDACtor* Primary Protection

Secondary Protection

Secondary protectors (stand alone units or integrated into strip protectors and UPSs) are adjunct devices used to enhance the protection level of customer premise equipment (CPE). Due to the inadequate level of protection designed into CPE, secondary protectors often are required to prevent premature failure of equipment exposed to environmental hazards. (Figure 6.67)

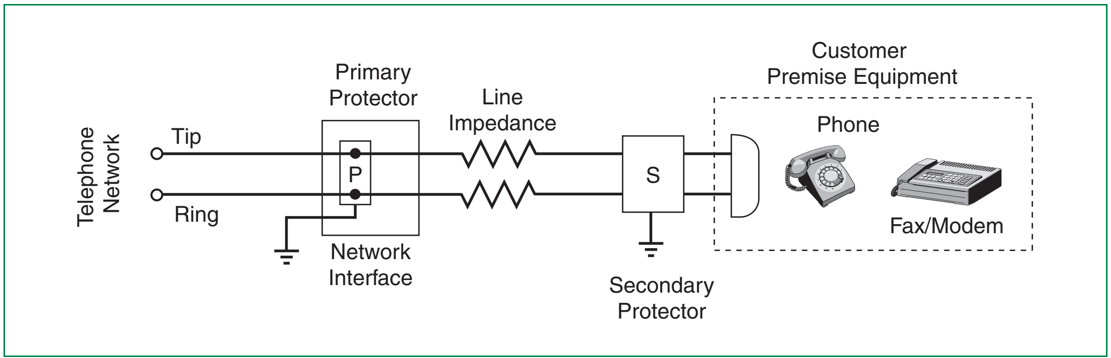


Figure 6.67 CPE Secondary Protection

Protection Requirements

Secondary protectors should be able to withstand overvoltages that can exceed 800 V and surge currents up to 100 A. Figure 6.68 illustrates a *SIDACtor*® device selected because the associated peak pulse current (I_{PP}) is sufficient to withstand the lightning immunity tests of TIA-968-A (formerly known as FCC Part 68) without the additional use of series line impedance. Likewise, Figure 6.68 illustrates a fuse selected because the amps^{2}time (I^2t) rating is sufficient to withstand the lightning immunity tests of TIA-968-A, but low enough to pass UL power fault conditions.

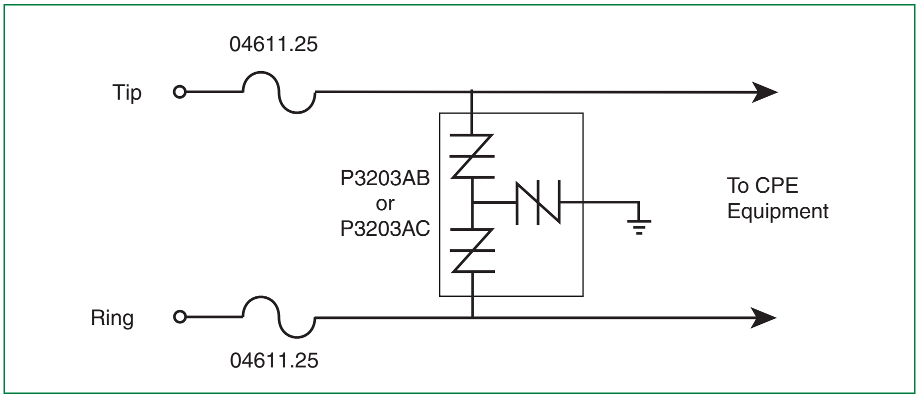


Figure 6.68 CPE Protection

Secondary Protection Reference Circuit

Figure 6.67 also shows an example of an interface design for a secondary protector. The P3203AB *SIDACtor* device is used because the peak off-state voltage (V_{DRM}) is greater than the potential of a Type B ringer signal superimposed on the POTS (plain old telephone service) battery.

$$150\ V_{RMS}\sqrt{2} + 56.6\ V_{PK} = 268.8\ V_{PK}$$

Coordination between the station protector and the secondary protector occurs due to the line impedance between the two devices. The line impedance helps ensure that the primary protector will begin to conduct while the secondary protector limits any of the let-through voltage to within the V_S rating of the *SIDACtor* device.

Triac Protection

Thyristors

Damage can occur to a thyristor if the thyristor's repetitive peak off-state voltage is exceeded. A thyristor's repetitive peak off-state voltage may be exceeded due to dirty AC power mains, inductive spikes, motor latch up, and so on.

Thyristor Reference Circuit

Figure 6.69 and Figure 6.70 show two different methods of protecting a triac. In Figure 6.69 a *SIDACtor*® device is connected from MT2 to the gate of the triac. When the voltage applied to the triac exceeds the *SIDACtor* device's V_{DRM}, the *SIDACtor* device turns on, producing a gate current which turns the triac on.

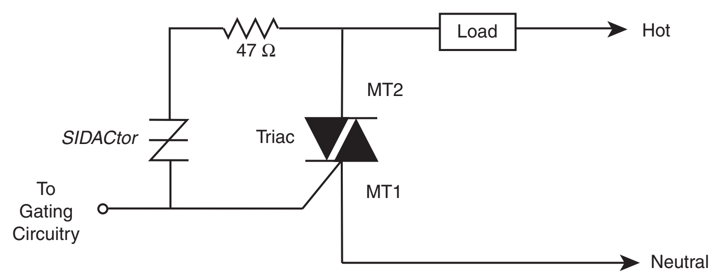


Figure 6.69 Triac Protection

The circuit in Figure 6.70 places a *SIDACtor* device across MT2 and MT1 of the triac. In this instance the *SIDACtor* device protects the triac by turning on and shunting the transient before it exceeds the V_{DRM} rating of the triac.

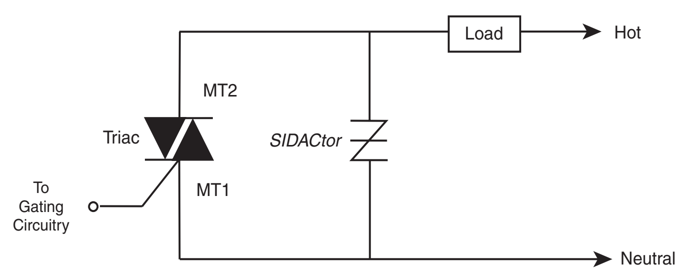


Figure 6.70 Triac Protection

With both methods, consider the following designs when using a *SIDACtor* device to protect a thyristor:

- V_{DRM} of the *SIDACtor* device < V_{DRM} of Triac
- *SIDACtor* device V_{DRM} > 120% $V_{PK(power\ supply)}$
- *SIDACtor* device must be placed behind the load

Data Line Protectors

In many office and industrial locations, data lines (such as RS-232 and ethernet) and AC power lines run in close proximity to each other, which often results in voltage spikes being induced onto the data line, causing damage to sensitive equipment.

Protection Requirements

Data lines should be protected against overvoltages that can exceed 1500 V and surge currents up to 50 A.

Data Line Reference Circuit

Figure 6.71 shows how a *SIDACtor* device is used to protect low voltage data line circuits.

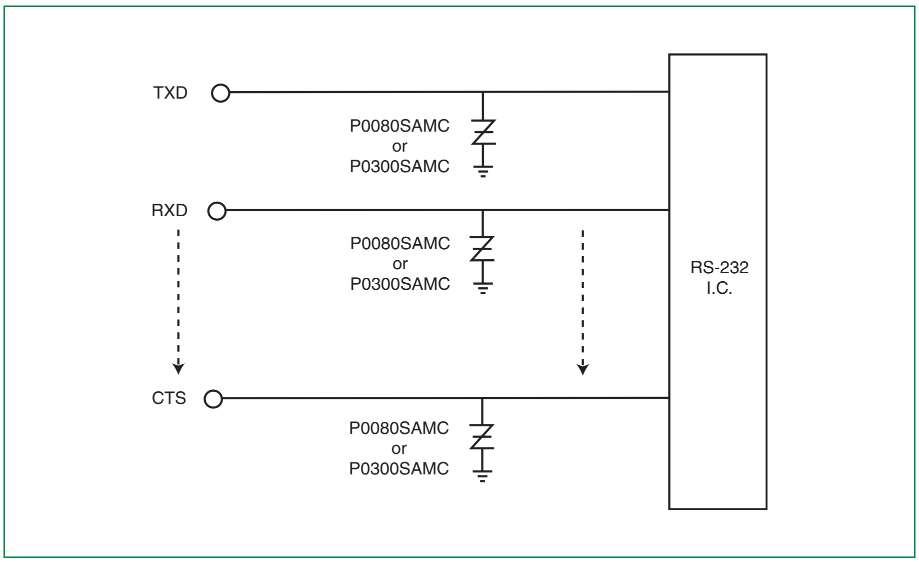


Figure 6.71 Data Line Protection

Reference Designs

LAN and VoIP Protectors

10Base-T Protection

Capacitance across the pair of wires = (D1 II D2) + P0640EA/SA

The MUR 1100E diodes capacitance is approximately (10 pF II 10 pF) 20 pF. Then, adding the capacitive effect of the *SIDACtor* (typically 35 pF), the total capacitance across the pair of wires is approximately 14 pF. This provides a GR 1089 intra-building compliant design. (Figure 6.72)

Note: MURS160T3 is an SMT equivalent of the MUR 1100E.

Figure 6.73 shows an application requiring longitudinal protection.

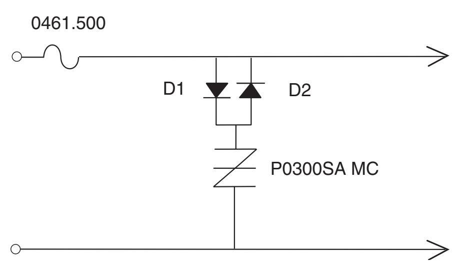


Figure 6.72 10Base-T Metallic-only Protection

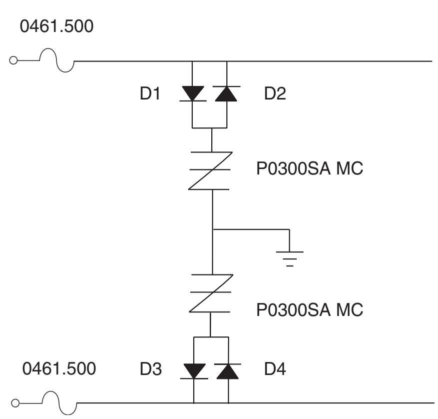


Figure 6.73 10Base-T Metallic and Longitudinal Protection

100Base-T Protection

Capacitance across the pair of wires = (D1 || D2) + P0640EA/SA + (D3 || D4)

The MUR 1100E pair of diodes capacitance is approximately (10 pF || 10 pF) 20 pF. Then, adding the capacitive effect of the P0300SA MC (typically 35pF), the total capacitance across the pair of wires is approximately 8 pF. This will provide a GR 1089 intra-building compliant design. (Figure 6.74)

Note: MURS160T3 is a SMT equivalent of the MUR 1100E.

The P0642SA is a very low capacitance device that requires no compensating diodes. (Figure 6.75)

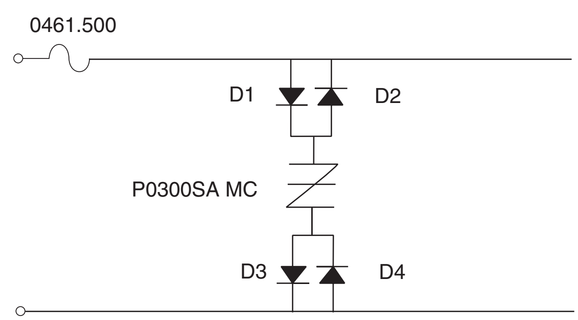


Figure 6.74 100 Base-T Protection

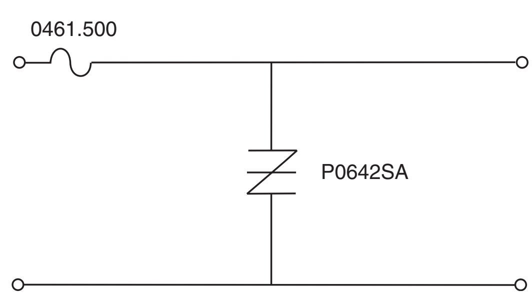


Figure 6.75 100 Base-T Protection Without External Compensation

NOTES