# UL60950 and TIA-968-A Requirements
Application Note

## Problem/Solution

Subscriber equipment, also known as customer premise equipment (CPE), includes any equipment that is connected to the telecommunications network and located at a customer's site. Examples of this type of equipment are telephones, set-top equipment, fax machines, answering machines, modems, and PBX systems.

This equipment is prone to hazards caused by lightning surges, power contact, and power induction. If left unprotected from these hazards, CPE may fail to operate or may risk the safety of subscribers and maintenance personnel.

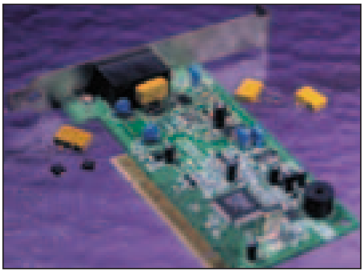
In North America, agency requirements such as UL60950 and TIA-968-A, (formerly FCC part 68) set a minimum performance standard for CPE. A PolySwitch resettable overcurrent device may be used in conjunction with a SiBar thyristor surge protector to assist equipment manufacturers in meeting these agency requirements.

## CPE Industry Specifications: UL60950 and TIA-968-A

This note describes methods that can be used to meet the standards for secondary protection of subscriber premise equipment in North America, specifically UL60950 and TIA-968-A. Special attention will be given to solutions involving resettable overvoltage and overcurrent devices.

## TIA-968-A Standards

Lightning tests for CPE are governed by the Telecommunications Industry Association Regulations TIA-968-A. Table 1 provides further details on the actual tests. The intent of the prescribed surge tests is to ensure that network operation will not be adversely affected by any equipment connected to it, should that equipment fail. TIA requirements state that this lightning surge must not cause any opening or shorting of the equipment—for example, if a fuse is used for overcurrent protection it must not blow during the test surge.



## UL60950 Standards

The power contact and power induction requirements for CPE are specified by Underwriters Laboratories in section 6.6 of the UL60950 3rd Edition, Safety of Information Technology Equipment, Including Electrical Business Equipment. This standard has been merged with the UL1459 Standard for Technology Equipment to become the relevant standard for all telecommunications (CPE) and information technology equipment (ITE).



**Table 1. TIA-968-A Lightning Surge Requirements**

| Spec Type and Level | Primary Protection? | Waveform (µs, open circuit) | Voltage (V, open circuit) | Current (A, short circuit) | No. of Hits | Test Results | Note |
|---|---|---|---|---|---|---|---|
| **Lightning Type A** | | | | | | | |
| Metallic | Not specified | 10/560 | 800 | 100 | 2 | A | |
| Longitudinal | Not specified | 10/160 | 1,500 | 200 | 2 | A | 1 |
| **Lightning Type B** | | | | | | | |
| Metallic | No | 9/720 | 1,000 | 25.0 | 2 | B | |
| Longitudinal | No | 9/720 | 1,500 | 37.5 | 2 | B | 1 |

**Test Results:**

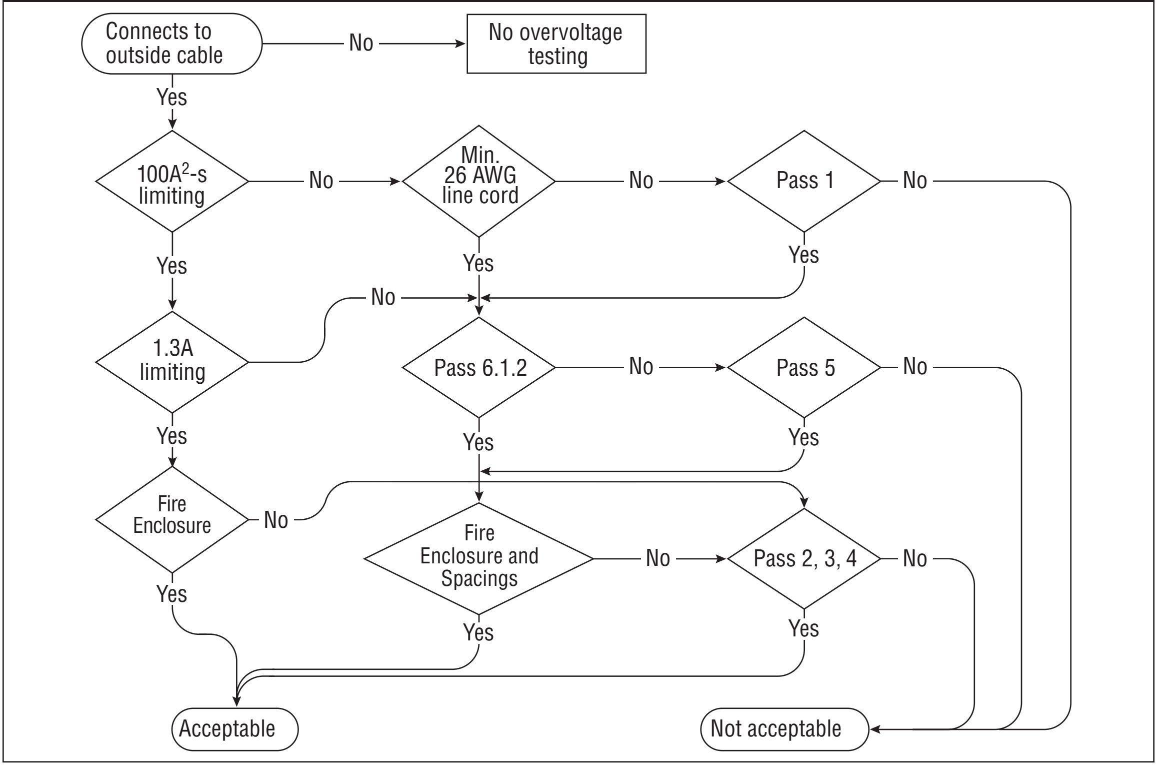
A = Product must remain safe; integrity of the network is maintained (R > 5 milliOhms).

B = Product must remain operational; no permanent open or short.

**Notes:**

1 = Longitudinal surge is tip-and-ring pair to ground.

**Figure 1. UL60950-1 3rd Edition Overvoltage Flow Chart**

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As of April 1, 2000, all new equipment may only be listed to UL60950 3rd Edition. Listings previously granted under earlier versions of UL60950 and under UL1459 will remain valid until April 1, 2005.

Late in 2000, UL and CSA published a new version of UL/CSA 1950 as UL/CSA 60950. The requirements for overvoltage protection remain unchanged from those discussed in this note.

The flowchart shown in Figure 1 reproduces Figure 6C from UL60950-1 (pg. 212) and provides the allowable pathways for meeting the power contact and powerinduction requirements in section 6.6 of the standard.

Starting from the right, three common paths are:

1. A "performance" path comprising testing the equipment to diamonds "Pass 1," "Pass 5," and "Pass 2, 3, 4."

2. A "construction" path comprising meeting the requirements of diamonds "Min. 26 AWG line cord," "Pass 6.1.2," and "Fire Enclosure and Spacings."

3. A "construction using current-limiting" path comprising meeting the requirements of diamonds "100A$^2$-sec. limiting," "1.3A limiting," and "Fire Enclosure."

### "Performance" Path

The performance path comprises meeting the decision diamonds on the far right side of Figure 1. It comprises testing the equipment — hence the term "performance" — to essentially the same set of requirements that are contained in UL1459 and CSA C22.2 No. 225. These test requirements are described in Annex NAC of UL60950-1 and summarized in Table 2 below.

In meeting the requirements of this path, an OEM will have ensured that the equipment complies with the overvoltage conditions which have been traditionally agreed to by the telecommunications industry. In addition, protection coordination with building wiring and primary overvoltage protectors is obtained, since passing Test 1 requires that the equipment limit fault energy to less than 100A$^2$-seconds under 600V power contact conditions.

Raychem Circuit Protection offers PolySwitch devices in both surface-mount (TS/TSM600 family) and radial-leaded (TR600 family) form factors, which can assist OEMs in meeting the requirements of the performance path.

### "Construction" Path

The construction path requires meeting the three vertical diamonds in the center of Figure 1. The construction requirements were developed to provide an equivalent level of equipment safety to the performance path[1], though differences exist in performance and design. There are three requirements to meet:

- **Min. 26 AWG Line Cord**
  To meet this requirement, the manufacturer must either supply a telecommunications line cord comprising 26 AWG wire or a larger wire size, or describe the necessity of using such wire in the safety instructions. An example of such a statement is provided in Annex NAA: "CAUTION — To reduce the risk of fire, use only No. 26 AWG or larger telecommunications line cord." The rationale for this line cord exemption is that a cord of this size or larger will not melt through and present a shock or fire hazard under the equivalent energy contained in Test Condition 1 (600V/40A/1.5 seconds).

- **Pass 6.1.2**
  Section 6.1.2 of the standard ensures that there is appropriate electrical isolation of the telecommunications network from ground. Compliance is checked by inspection and by performing an AC or DC insulation strength test at 1.5kV between the telecommunications network voltage (TNV) circuit and unearthed parts of the equipment expected to be

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**Table 2. Performance Path Test Requirements**

| Test | Connection[1] | Test Condition | Passing Criteria[2] |
|---|---|---|---|
| 1 | M, L, F | 600V, 40A, 1.5 sec. | a, b1, b2, c |
| 2 | M, L, F | 600V, 7A, 5 sec. | a, c |
| 3 | M, L, F | 600V, 2.2A, 30 min. or until open circuit — if open circuit test at 3A | a, c |
| 3A | M, L, F | 600V, I < 2.2A so no open circuit to produce max. heating, 30 min. | a, c |
| 4[3] | M, L, F | V < conduction voltage, I < 2.2A to produce maximum heating, 30 min. or until open circuit | a, c |
| 5 | L | 120V, 25A 30 min. or until open circuit | a, b1, c |

**Notes**:

1 = Connection:

M = differential mode (metallic) — apply voltage source across tip-and-ring

L = common mode (longitudinal) — apply voltage source from tip-to-ground and ring-to-ground

F = four-wire test mode — apply voltage from pair 1 to pair 2

2 = Passing Criteria:

a = No charring of cheesecloth indicator

b1 = fuse or wiring simulator (Bussman MDL-2A fuse) does not interrupt

b2 = $I^2t < 100A^2$-sec.

c = Meet dielectric withstand or leakage current requirements after test

3 = To be done if voltage limiter operated in test 3.

held during normal use (e.g., telephone handset). For parts that can be touched by a test finger or that provide connection to other equipment, a voltage of 1.0kV is used. The test is conducted by slowly raising the voltage to the appropriate level and holding it for 60 seconds. Passing the test requires that there be no insulation breakdown, and current flow should not exceed 10mA.

If surge suppressors bridge the TNV circuit insulation, they must have a minimum DC sparkover voltage equal to 1.6 times the rated voltage of the equipment (e.g., 120 or 240V times 1.6). They are typically removed during the insulation strength test.

The rationale for this test comes from the possibility that the telephone line may be subject to power cross from the 120V mains circuit. Voltages of 1.0 or 1.5kV confirm the adequacy of the insulation under these conditions. If the equipment is grounded, surge suppressors will typically bridge the TNV circuit and ground and therefore must be able to withstand the mains voltage with some margin. An alternative procedure which is allowed per Figure 1 is to perform Test 5 shown in Table 2 (120V, 25A, 30 min.).

- **Fire Enclosure and Spacings**
  The most critical and often the most difficult element to meet in following the construction path is to provide a Fire Enclosure with the appropriate spacings. The spacings separate the TNV circuit from internal materials, some of which may be potentially flammable.

  In the standard, a Fire Enclosure is a structure designed to minimize the possible emission of flame, molten metal, flaming or glowing particles, or flaming drops. The enclosure must meet strict requirements for size and spacing of any holes in the structure, depending on the materials used for the enclosure and the flammability rating of components enclosed within. The Fire Enclosure itself must meet certain flammability tests described in Annex A of the standard. These tests comprise applying the flame from a Bunsen burner directly to the material (five applications of five seconds duration each) and confirm that no flaming or molten materials fall from the test sample and ignite a cheesecloth indicator. In order to meet these requirements, Fire Enclosures are typically made of either metal or specially formulated flame-rated plastics.

  The Spacings requirement places an additional burden on the construction. All parts of the TNV circuit must be separated from materials of flammability class V-2 or lower by 25 mm of air or a flammability barrier made from materials of class V-1 or better. In addition, parts in the TNV circuit must be separated from openings in the sides or top of the Fire Enclosure by at least 25 mm of air or a barrier of class V-1 or better. The flammability class rating refers to the resistance of these materials to combustion after application of a direct flame, class V-0 being the highest rated material.

  The use of Fire Enclosures has been well established in the computer industry as a way of mitigating potential hazards. The addition of the Spacings requirement is a recognition that TNV circuits may be subject to overvoltages as high as 600V with energies as much as $100A^2$-seconds. Without any overcurrent protection in place, these fault conditions could produce arcing and internal component explosions. By requiring a Fire Enclosure and Spacings, the standard minimizes the possibility of an unsafe condition resulting from these events.

### "Construction Using Current-Limiting" Path

This path achieves the safety of the ITE through a combination of current-limiting and the use of a Fire Enclosure as shown by the three diamonds on the left-hand side of Figure 1. A unique feature of this path is that compliance may be achieved through inspection without performing any testing, thus saving a manufacturer the time, money, and risk of not passing the tests. The three diamonds comprise the following requirements:

- **$100A^2$-sec. Limiting**
  This diamond establishes the requirement to limit fault energy to less than $100A^2$-seconds per the 600V/40A Test Condition 1 as described in Table 1 on page 63. The standard allows that circuits or components which have been listed to UL497A or CSA C22.2 No. 226, Secondary Protectors for Communications Circuits, may be used to meet this requirement without additional testing. The overvoltage test requirements of UL497A and CSA C22.2 No. 226 are essentially the same as those in UL1459; however, an ITE OEM

must understand that UL497A is not a “component” specification, but is in fact an “equipment” specification used for listing multi-component protection modules. As described above, if such a module is used in the equipment, this diamond can be passed without testing.

- **1.3A Limiting**
  Meeting the requirements of this diamond requires that the TNV circuit contains a method for limiting current to 1.3A maximum steady state that also complies with UL497A. An example cited by the standard is a 1.0A rated fuse. Note that meeting the 1.3A limiting specification is not automatically achieved by meeting the UL497A requirements, an example being a 1.6A fuse which by definition will not limit current to 1.3A.

- **Fire Enclosure**
  The Fire Enclosure requirements are described in the Fire Enclosure and Spacings discussion. This decision diamond does not require the additional Spacings conditions because current-limiting is already provided for in the previous diamonds

  As stated previously, a key benefit of following this path is that performance testing is not required. Raychem Circuit Protection’s surface-mount PolySwitch TS600-170, TS600-200 and TSM600-250 products have received component recognition under UL497A for use as power cross protection for this pathway. The devices have been tested and determined to be in compliance with the $100A^2$-sec. limiting and 1.3A limiting power cross protection requirements of the safety standard. As such, they may be used together with a suitable Fire Enclosure (as previously described) to satisfy the requirements of UL60950-1 with no additional testing required.

  An alternative to providing the Fire Enclosure can be seen by following the “No” path at the “Fire Enclosure” decision diamond and moving to the “Pass 2, 3, 4” diamond. Since Tests 2, 3, and 4 are also subsets of the UL497A requirements, circuit protection modules or discrete components used to meet the “$100A^2$-sec. limiting” diamond should also pass these tests.

## Construction and Test Path

In working through the standard with equipment manufacturers and UL, there is another interesting and valid path—the “construction and test” path. This path comprises meeting the requirements of diamonds “Min. 26 AWG line cord,” “Pass 6.3.3” or “Pass 5,” and “Pass 2, 3, 4”. This path provides for the safety of the equipment by testing to a subset of the overvoltage tests (Tests 2, 3, 4, and 5 or section 6.3.3), and by ensuring the $100A^2$-sec. energy withstand capabilities of the equipment through use of the Min. 26 AWG line cord.

From an equipment design perspective, this pathway is interesting because it avoids the potential engineering difficulties of providing a Fire Enclosure with Spacings.

## Choosing the Appropriate Path

Each of the potential paths provides a means for designing safe equipment per the overvoltage requirements of the standard, but the paths are clearly not equivalent in the performance of the equipment that results. By using a Fire Enclosure and Spacings to meet the Construction Path, the equipment designer is essentially controlling and limiting the damage following an overvoltage event on the telecommunications line. By using circuit protection components, either for the Performance Path or the Construction with Current Limiting Path, the equipment designer meets the safety requirement by limiting and interrupting current. In addition, this type of protection provides additional protection coordination with the building wiring and primary overvoltage protection devices. The latter benefit is not required by the UL60950 standard but may be desirable in some installations.

## Application Details

The typical overvoltage and overcurrent protection circuits are shown in Figure 2 for ungrounded CPE and in Figure 3 for grounded CPE. The series overcurrent protection should provide resettable overcurrent protection, mainly against power cross events. Overvoltage protection in parallel with the CPE load should provide resettable overvoltage protection as well.

Surge tests may be either metallic, defined as applying the surge between tip-and-ring, or longitudinal, defined as applying the surge between both tip-and-ring lines tied together and ground. In an ungrounded system, the longitudinal test should not cause the overvoltage or overcurrent protection to operate. For grounded systems, a voltage above the threshold of the overvoltage protection will cause either the protection between the tip-and-ground, or the ring-and-ground, or both, to activate. Note that the third overvoltage protector shown for grounded systems in Figure 3 is optional, but if included can provide increased protection in the case of tip-ring faults.

When an overvoltage is applied between tip-and-ring at the input, the voltage across the overvoltage protection device will increase until the overvoltage device begins to operate (clamp or fold back). With the overvoltage protection device in the activated state, current is conducted through the overcurrent devices, and diverted around the circuit to be protected. For short surges such as lightning, the overcurrent devices should be selected such that they do not interrupt current, so the circuit can immediately return to normal operation when the overvoltage event passes. For longer overvoltage events such as AC power cross or power induction, the overcurrent protector operates, protecting the end equipment, wiring, and overvoltage devices.

For voltages below the threshold of the overvoltage device, or when faults in the circuit to be protected occur, an excessive amount of current could be drawn from the power source. In this case, the overcurrent protection operates to prevent damage to the wiring or circuit.

## Designing Resettable Solutions

PolySwitch resettable devices are positive temperature coefficient (PTC) devices that increase significantly in resistance (“trip”) in response to an overcurrent surge. SiBar TSP devices are silicon crowbar devices that shunt from a high to a low impedance in response to

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**Figure 2. Ungrounded CPE Design**

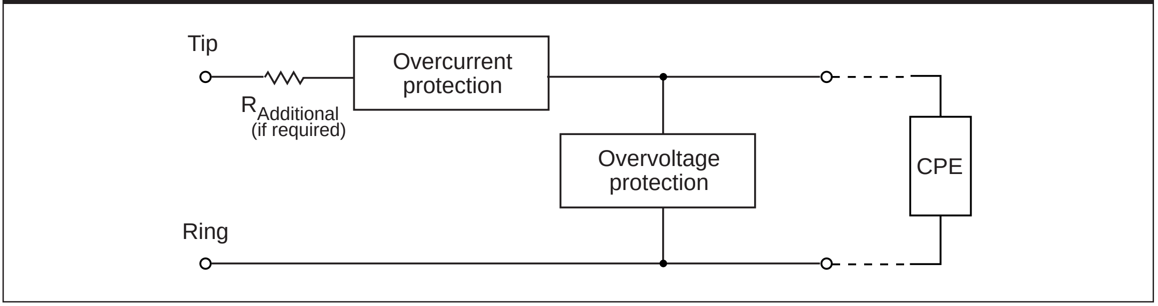
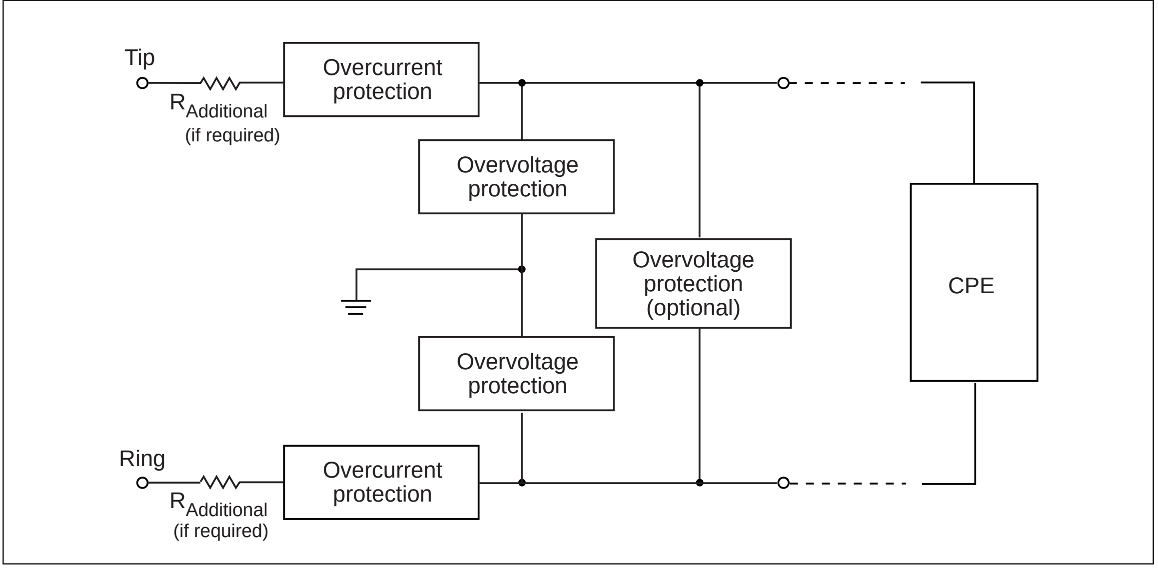



**Figure 3. Grounded CPE Design**



an overvoltage surge, such as those caused by lightning, power cross, and power surge.

For *lightning surges*, the SiBar device will crowbar to a low impedance, diverting current around the protected circuit and preventing excessive voltages from appearing at the terminals of the device to be protected. The surge current capability of the SiBar device must be considered when designing to protect against a lightning surge. Four waveforms are specified by TIA-968-A and detailed in Table 1. The 10/160µs and 10/560µs waveforms apply to both opencircuit and short-circuit conditions. For these two surges, the TIA-968-A requires only that a hazardous failure not occur. The equipment does not have to be operational after these tests.

In addition, to comply with the TIA-968-A specification, the equipment must be operational after the tests.

The most robust design addresses the worst-case fault currents and waveforms, with the equipment surviving all tests operationally. To survive operationally, the surge current that passes through the SiBar device must be less than or equal to its surge rating. The TVBxxxSA devices are rated at 70A for the 10/560 waveform and 100A for the 10/160 waveform, thus additional line impedance is needed to reduce the surge current to below the SiBar TVBxxxSA rating. The total amount of resistance required can be calculated by first looking at the impedance of the surge generator. An 800V open circuit voltage and 100A shortcircuit current implies a source impedance of:

$$R_{source} = V_{open\ circuit}/I_{short\ circuit} = 800V/100A = 8\Omega$$

To reduce the 10/560 current to 70A, the completed circuit must have a total impedance of:

$$R_{total} = V_{open\ circuit}/I_{rating} = 800V/70A = 11.5\Omega$$

The additional resistance necessary is:

$$R_{additional} = R_{total} - R_{source} = 11.5\Omega - 8\Omega = 3.5\Omega$$

A 1500V open-circuit voltage and 200A short-circuit current implies a source impedance of:

$$R_{source} = V_{open\ circuit}/I_{short\ circuit} = 1500V/200A = 7.5\Omega$$

To reduce the 10/160 current to 100A the completed circuit must have a total impedance of:

$$R_{total} = V_{open\ circuit}/I_{rating} = 1500V/100A = 15\Omega$$

The additional resistance necessary is:

$$R_{additional} = R_{total} - R_{source} = 15\Omega - 7.5\Omega = 7.5\Omega$$

A grounded system must pass both tests operationally; therefore, a minimum of 7.5Ω must be inserted in the line to reduce the current to within the SiBar device rating.

For ungrounded systems, only a metallic test applies; therefore, a minimum of 3.5Ω is required.

For applications which require low series impedance, the higher-surge-rated TVBxxxSC family can be used with no additional series resistance.

For *ungrounded systems*, the additional resistance can be put in either the tip or ring line as shown in Figure 2.

As shown in Figure 4, a PolySwitch TRF600-150 or TS600-170 device provides the necessary resistance.

For *grounded systems*, the current path can be between tip-and-ring, tip-and-ground, or ring-and-ground. To protect the overvoltage device from failure in a grounded system, the additional resistance needs to be placed in both tip and ring as shown in Figure 3. As shown in Figure 5, a TRF600-150 with resistance greater than 7.5Ω provides the necessary resistance.

As discussed, the use of a PolySwitch device may provide some or all of the necessary resistance. Refer to the latest PolySwitch datasheets for the available resistance range to reduce the lightning surges as defined by TIA-968-A to within the SiBar device rating. Using less or no resistance will allow higher currents to pass through the SiBar TVBxxxSA device which may damage the device and cause it to fail short. This failure mode is not allowed by the TIA; therefore, a higher current rated TVBxxxSC thyristor should be used in these designs.

Since TRF600,TS600, and TSM600 devices are designed to pass the TIA-968-A requirements

**Figure 4. Suggested Arrangement to Meet TIA-968-A for an Ungrounded CPE Design**

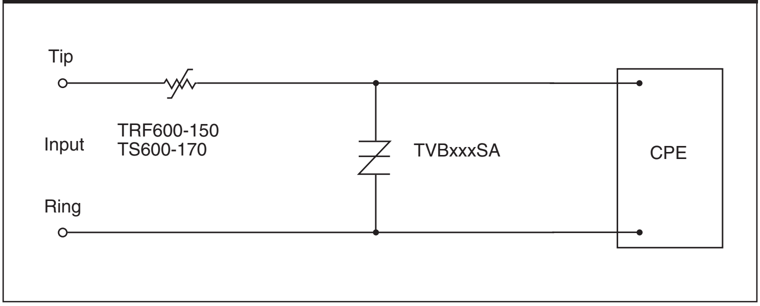
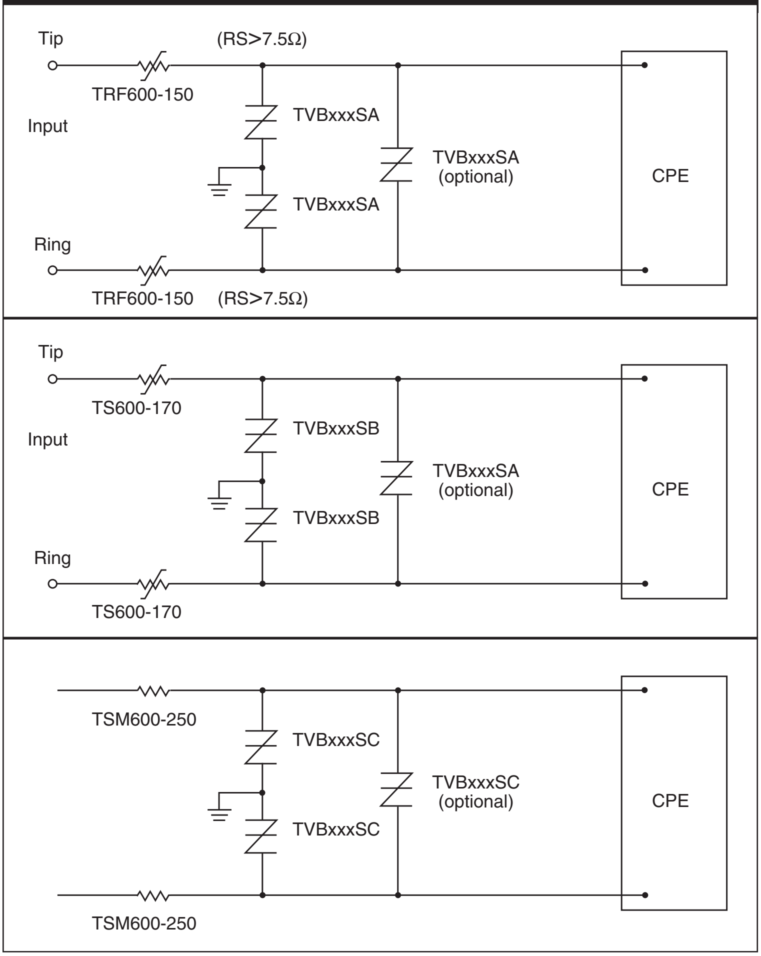



**Figure 5. Suggested Arrangement to Meet TIA-968-A for a Grounded CPE Design**




without tripping, the use of a PolySwitch device with the appropriately rated SiBar device can provide a fully resettable solution for ungrounded and grounded systems as shown in Figures 4 and 5.

## Device Selection

Choose the SiBar TVBxxxSA or TVBxxxSC series and PolySwitch TRF600,TS600, or TSM600 devices for a coordinated, resettable solution to assist CPE manufacturers in meeting the specification requirements of UL60950 and TIA-968-A. Select a SiBar device with a rated off-state voltage $V_{DM}$ closest to but greater than the system's peak operating voltage.