



## GDT Application Note

*GDT Protection Solutions for ADSL and ADSL2+ Solution*

*By Tim Ardley*

High-speed broadband applications require low capacitance protection solutions to ensure adequate performance. Protectors used in traditional POTS (Plain Old Telephone Service) are not capacitance critical due to the low frequency spectrum (3 kHz) used for voice. The performance of ADSL2+ chipsets is affected by voltage dependent capacitance variation between the TIP and RING conductors. The capacitance variation with DC and ADSL signal voltage causes harmonic and intermodulation distortion. GDT (Gas Discharge Tube) capacitance is not sensitive to voltage variation and has a maximum capacitance of 1 pF. This ensures the overvoltage protection solution is transparent to the ADSL circuit of the resistor side of the bridge.

### **Designing with a 2035-35-SM GDT**

The US TIA-968-A for CPE (Customer Premises Equipment) modems that utilize the same copper twisted pair with voice need to comply with a type B ringer requirement. This defines the minimum stand-off voltage to be 269 V (150 Vrms with a -56.5 V battery). The Bourns® 2-electrode surface mount 2035-35-SM has a DC sparkover voltage of 350 V with a 15 % tolerance is designed to ensure the GDT will not be operated under this condition while providing additional head-room for the ADSL signal. For example, applications with line feed voltages of -190 V will require a 2035-25-SM type GDT.

A GDT has a higher dynamic protection voltage (sparkover voltage) compared to a TISP® thyristor. This sparkover voltage may allow a higher energy spike to transfer to the secondary side (ADSL chipset) of the transformer that needs to be considered. For example, the 2035-35-SM 350 V GDT has a typical dynamic impulse voltage of 750 V for 1000 V/μs compared to an impulse voltage of 413 V for a 300 V<sub>DRM</sub> thyristor. The effect of higher impulse voltages are discussed later in this technical article.

### **US TIA-968-A and UL 60950 Requirements**

The TIA-968-A standard has two types of lightning surge tests, A and B. Type A test allows equipment to fail, but only in a “safe” mode that is not harmful to the network. Any protection failure must be an open circuit condition making the CPE noticeably unusable after the surge. Type A metallic (transverse) testing applies two surges (one of each polarity) between any pair of lines on which lightning surges may occur. This test will be applied between Tip to Ring connections. The impulse voltage and current waveform is a 10/560 μs with an open circuit voltage of 800 V and current of 100 A.

TIA-968-A Specifications	Wave Shape (t1/t2 μs)	Open Circuit voltage (V)	Short Circuit current (A)	Surge Type
Longitudinal	10/160	1500	200	A
Metallic	10/560	800	100	
Longitudinal	9/720, (4/245)	1500	37.5	B
Metallic	9/720, (5/320)	1000	25	

For longitudinal applications, the equipment is surged between the conductors and earth grounding connections. This test will also be done on all non-registered equipment leads. Longitudinal testing uses a different 10/160 μs test waveform with a peak open-circuit voltage of 1500 V and short circuit current of 200 A.

Table 1 - TIA-968-A impulse requirements



Type B surges reflect normal lightning surge exposure and the CPE must not degrade or fail during these tests. The metallic test (one of each polarity between Tip to Ring) uses a 9/720  $\mu$ s, 1000 V open-circuit voltage with 5/320  $\mu$ s, 25 A short circuit current. Longitudinal tests use the same generator, but with an open-circuit voltage of 1500 V and short circuit current of 37.5 A (for single outputs only). *Table 1* shows type A and B impulse requirements for US customer premises equipment. The 2035-35-SM has an impulse rating capability of 100 A 10/700  $\mu$ s which ensures it passes type A surges. The 10/700  $\mu$ s impulse shape is longer by 140  $\mu$ s compared to the 10/560 impulse and is therefore adequate for the protection design, see *Figure 1*.

UL 60950 covers a wide range of safety and protection topics such as isolation, creepage, transient protection and AC power fault conditions. The protection circuit needs to conform to these requirements. The simplest method to pass UL 60950 is to ensure the equipment either limits the  $I^2T$  to less than 100 A<sup>2</sup>s or has a fuse that operates below 1.3 A DC. Equipment operationally passing type A surge will tend to use a fuse such as 1.25 A Bourns® B1250T or 0.5 A B0500T and line to ground separation is required.

The  $I^2T$  rating of the fuse needs to be considered with TIA-968-A type A and B surges. The TIA-968-A has a type A surge of 200 A, 10/160  $\mu$ s for longitudinal applications where the equipment can fail safely. Bourns® B1250T will not open under this impulse and therefore the overvoltage protector needs to be rated for this impulse current. Type A criteria allows the equipment to fail, but the fuse will need to open before the overvoltage protector fails. The Bourns® B0500T 0.5 A fuse has an  $I^2T$  rating of 1.4 and therefore will fail open under this impulse test to reduce the stresses on the overvoltage protector. Fuses with ratings of 2 A and above may not operate before the UL 60950 wiring simulator opens and the equipment fails.

Failure coordination between the overvoltage protector and the single fuse also needs to be considered under the AC power fault contact tests. If the equipment is not in a fire enclosure, the equipment is tested to 600 Vrms, 2.2 A for 30 minutes and 600 Vrms, 7 A for 5 seconds. The overvoltage protector needs to sustain the test until the fuse fails. The GDT has higher power losses compared to the Bourns® TISP® thyristor as the GDT conducting voltage is five times larger. The 0.5 A B0500T fuse coordinates with the 2035-xx-SM GDT family.

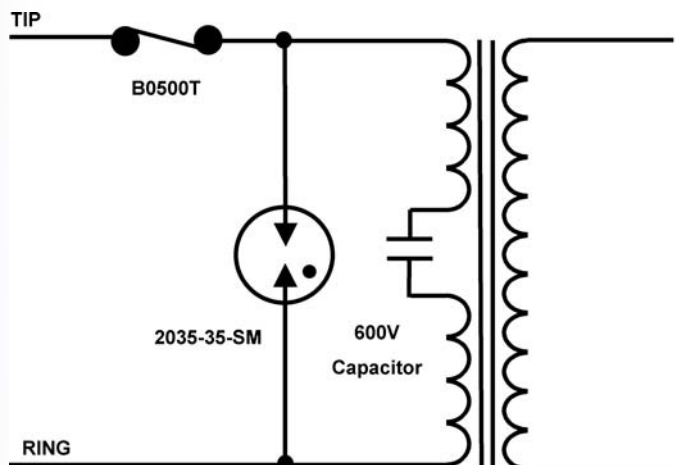


Figure 1 - ADSL for CPE applications

The 2035-xx-SM will be tested for 30 minutes at 135% of the fuse current rating at 600 V rms. During this test, the 2035-xx-SM will dissipate approximately 5 W. Therefore the PCB layout for the GDT needs to be considered in this solution.

**Note:** The Bourns® B0500T fuse with 2035-35-SM GDT solution is not suitable for Telcordia GR-1089-CORE type applications. A TISP4C395H3BJR thyristor overvoltage protector with a Bourns® B1250T fuse is recommended for this telecom requirement.



## Protecting Transformer Isolation

Transformers provide a high level of inherent protection, but do have limitations in isolation properties. Designing to TIA-968-A, the isolation rating needs to be higher than 1500 V longitudinal (TIP/RING to GND) for the impulse tests. Hi-POT tests are done to telecom equipment to ensure adequate insulation between the telephone line and ground terminals where resistance is commonly measured at 1500 Vrms. Flashover of the primary winding, printed circuit board wiring or connector pins should also be considered at these high voltages. The protection applied to the transformer secondary must also be able to withstand the ac coupled impulse currents. A common method to prevent isolation breakdown is to reference the overvoltage circuit protection to Earth as shown in Figure 2. The system ground used on the secondary side of the transformer is

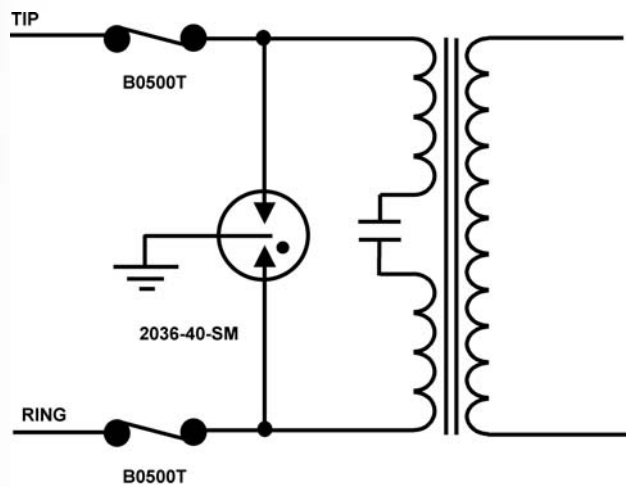


Figure 2 – Protection against isolation breakdown

isolated through the power supply windings to ensure isolation. Breakdown protection can be achieved by using the 3-electrode surface mount solution, 2036-xx-SM. This arrangement will limit the isolation stress to the sparkover voltage rating of the GDT. The TIP-RING protection will have a higher sparkover voltage due to the longer chamber distance, but cannot be guaranteed. The 2036-xx-SM DC sparkover voltage has a 20 % tolerance on its rating. Therefore, to accommodate the ADSL voltage with a type B ringer requirement, a 400 V 2036-40-SM should be considered in the design.

The B0500T fuse is used to protect the GDT during the 600 Vrms under UL 60950 tests. The transformer capacitor must be voltage rated to withstand the GDT sparkover voltage. The low capacitance values indicate that only small 60 Hz currents flow during testing. To remove the need for fusing, the sparkover voltage needs to be at least 850 V to ensure the GDT does not operate. This can be achieved as shown in Figure 3, by placing a second 600 V GDT in series with a 2036-60-SM. The 600 V GDT is selected due to the 20 % tolerance of the DC sparkover voltage. This provides a maximum working voltage window of 960 V before the GDT operates.

The 3-electrode 2036-60-SM GDT can be replaced with two 2035-60-SM GDTs connected in series to keep device ordering to a minimum. This layout is commonly known as a “star” or “Y” configuration.

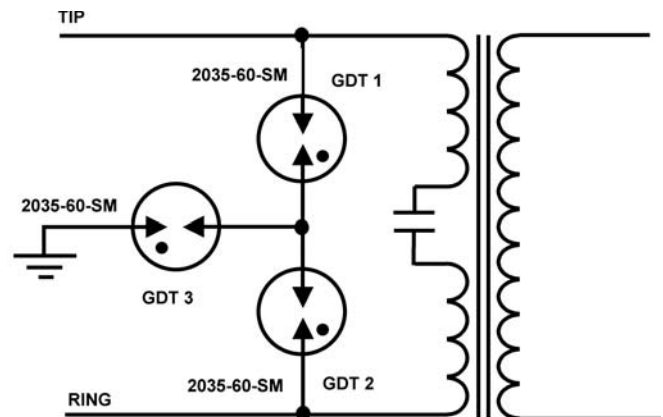


Figure 3 – Removing single blow fuses

**Note:** This application solution is dependent upon transformer performance and additional secondary protection. Each application should be tested to verify its suitability.





## Voltage Between TIP and RING

Voltage between the TIP and RING should be limited as much as possible. When the protection operates and effectively shorts the TIP and RING together, a resonance occurs between the capacitor and transformer inductance. The capacitive energy is converted into inductive energy and transferred to the secondary winding. Ignoring the effects of any secondary winding overvoltage protection circuitry, the peak circulating current  $I_{PK}$  will be where  $L$  is the transformer

$$I_{PK} = V_{PEAK} \cdot \left(\frac{C}{L}\right)^{\frac{1}{2}}$$

leakage inductance and  $C$  is the coupling capacitor value. As the inductance and capacitance are fixed values, the peak current will depend on the peak voltage,  $V_{PEAK}$ . The peak voltage is dictated by the overvoltage protection device. Higher values of protection voltage referenced will cause higher currents and therefore increases the protection requirement needed for the secondary winding. This needs to be especially considered if a GDT is deployed for the primary-side protection due to their high sparkover voltages under fast  $dV/dT$  conditions. The 2035-35-SM GDT has a DC sparkover voltage of 350 V with 100 V/s which can be approximately 750 V (114 % increase) with a 1000 V/ $\mu$ s impulse. The protection voltage,  $V_{(BO)}$  value of a TISP® thyristor may change 7-10 %.

ADSL2+ applications require low capacitance protection solutions where a GDT solution discussed previously will provide less than 1 pF. Bourns® TISP® products provide low impulse voltages to limit energy on the secondary-side of the transformer, but have higher values of capacitance. A TISP4350T3BJ has 20 pF at -50 V bias and is ideally suited to voice and ADSL modems for CPE applications. Implementing a TISP3200T3BJ as shown in *Figure 4* will further reduce the TIP to RING capacitance to 15 pF with -50 V bias voltage specification. The TISP3200T3BJ connected in series will provide at least a 310 V stand-off voltage before the thyristors start to conduct. The thyristor selection will also keep the maximum voltage across the transformer to 400 V due to the 200 V  $V_{(BO)}$  thyristor specification. This allows the coupling capacitance voltage rating to be 400 V.

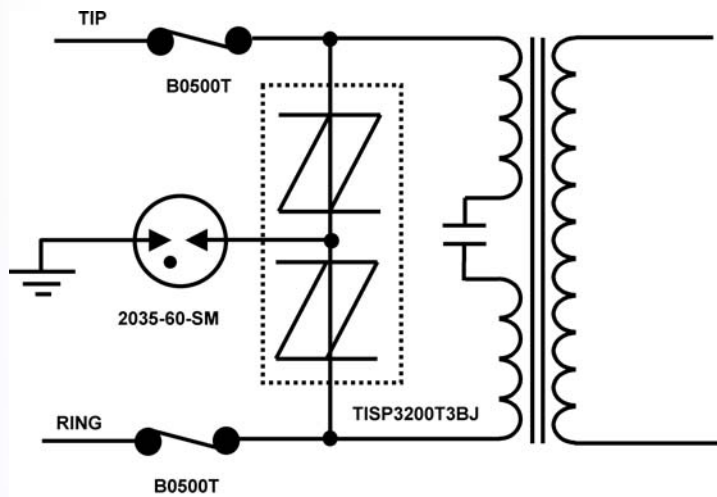


Figure 4- Low capacitance and overshoot solution



ADSL applications share the standard POTS lines and therefore require a minimum stand-off voltage of 275 V to meet TIA-968-A type “B” ringer requirements. A TISP4145J1BJ can be used from the center star connection to ground where the circuit capacitance will be approximately 27 pF with the isolation stress on the transformer limited to 345 V. A GDT in the ground return line as shown in *Figure 4* reduces the TIP/RING to GND capacitance to less than 1 pF for ADSL2+ applications. The isolation stress on the transformer will be limited to 800 V (1400 V under fast 1000 V/ $\mu$ s transients).

Replacing the TISP3200T3BJ with two TISP4520H3BJ thyristors in series as shown in *Figure 4* will ensure the protection will not operate during the 600 Vrms standards tests. This removes the requirement for two additional fuses in the application. Please contact your local Bourns Applications Engineer to discuss your circuit protection needs.

Please contact your local Bourns Sales Representative for more information.

**Asia-Pacific:** Tel +886-2 256 241 17  
Fax +886-2 256 241 16

**Europe:** Tel +41-(0)41 768 55 55  
Fax +41-(0)41 768 55 10

**Americas:** Tel +1-951-781-5500  
Fax +1-951-781-5700