

# Application Note

## Protecting VDSL Line Drivers with Bourns® TBU® High-Speed Protector Solutions

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TBU-CA-050-500-WH



TBU-CA-085-500-WH

### Introduction

It is a challenging task to protect VDSL drivers while still maintaining signal integrity and bandwidth. VDSL protection is more difficult to achieve than ADSL protection for several reasons:

1. The high bandwidth requirements dictate lower loss and tightly coupled transformers with lower leakage inductance. This also increases the efficiency with which surge energy is transferred from the line side back to the driver.
2. Output transistor structures used in the driver must be capable of higher speed, which typically results in higher sensitivity to damage.
3. The capacitance of protection devices becomes a major consideration in achieving the bandwidth. Non-linear capacitance creates frequency and voltage bias dependent distortions which degrade signal data rate capability.

Consequently, it has been found that many tried and tested protection solutions previously used for ADSL no longer work well for VDSL. Fortunately, the Bourns® TBU® High-Speed Protector provides a means of protecting VDSL applications without compromising signal integrity or data rates. This document describes a number of different TBU® device protection topologies for use in VDSL. Each topology has different capabilities and cost points. Naturally, the simplest forms of protection are limited to applications operating in more benign environments, such as where primary protection can be guaranteed. The more comprehensive solutions cater to the most demanding surge testing, yet still offer fully resettable protection and unsurpassed data rates.



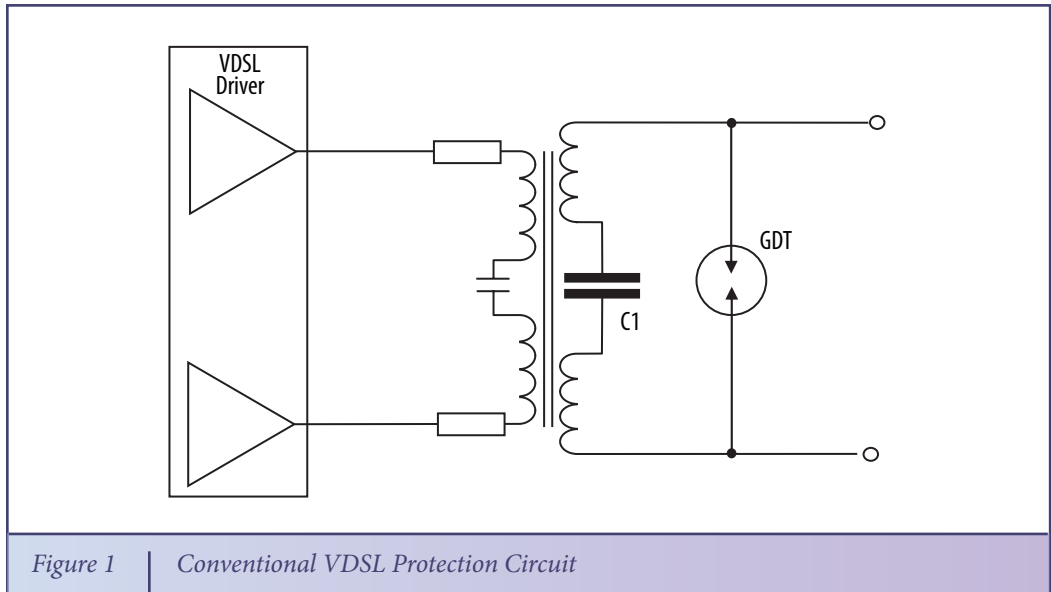
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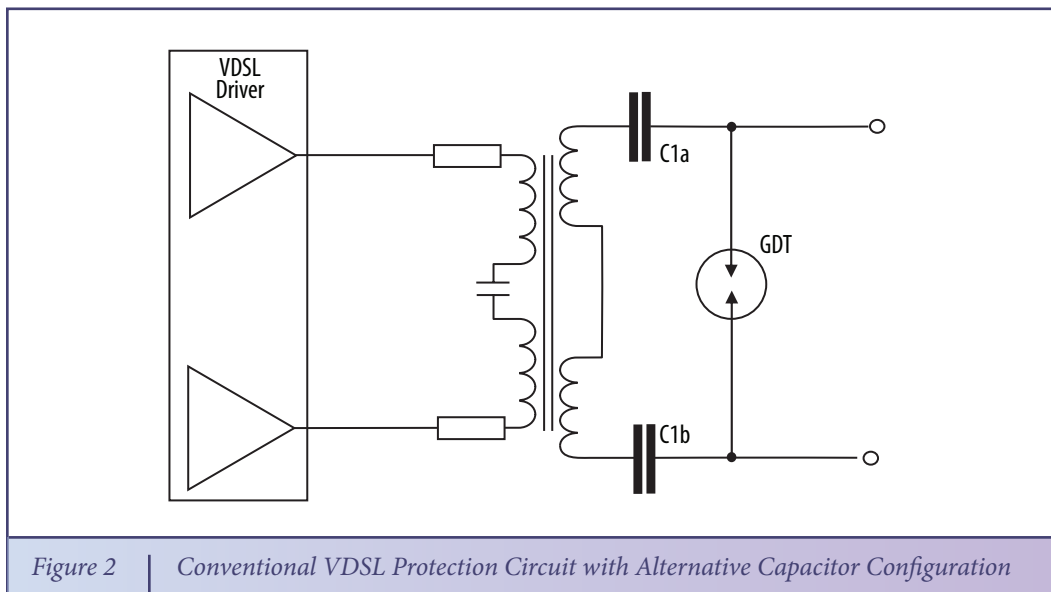
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## Conventional Protection

Figure 1 shows a basic VDSL circuit. The line side capacitor C1 must be rated to withstand the peak voltage let-through by the GDT. In many applications, the capacitor is split as shown in figure 2. This is simply a matter of a trade-off of cost versus size: it is sometimes preferable to use two lower voltage rated capacitors than one single larger capacitor of twice the voltage rating. There is no electrical difference to the application from a signal perspective.



The GDT may be one that is used directly on the board, or may be a primary protection GDT. In either case, the presence of a GDT in the system has a very significant effect.



### Conventional Protection (Continued)

During a surge, the capacitor C1 charges during the rising edge of the waveform, as shown in figure 3.



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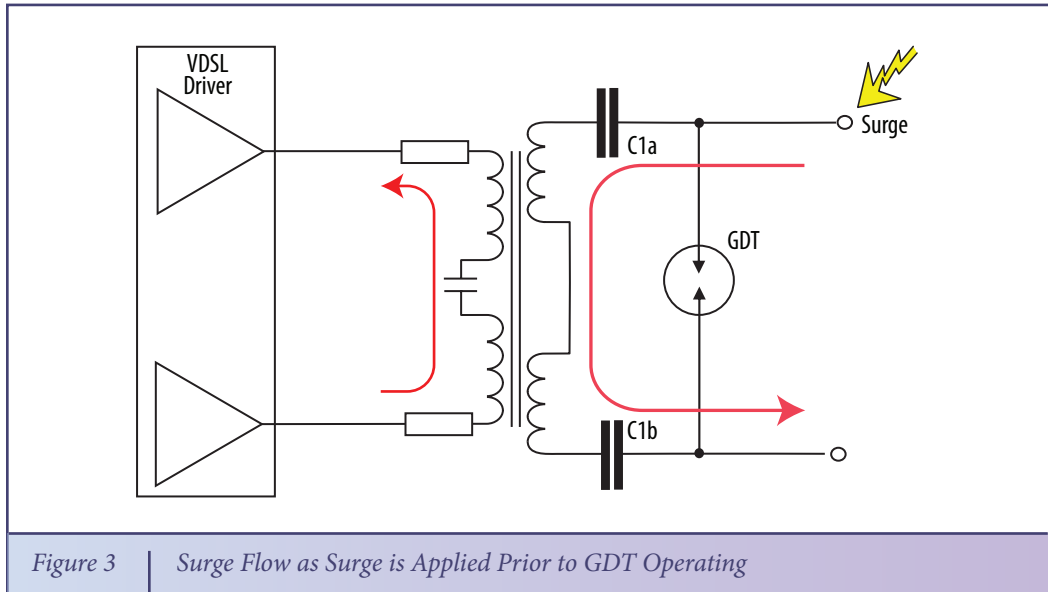


Figure 3 | Surge Flow as Surge is Applied Prior to GDT Operating

The charge current flows through the primary side of the transformer and is coupled to the secondary side, resulting in surge current flowing into the driver output stage. At this point the current is relatively low in level.

When the voltage reaches the GDT operating level, the GDT immediately 'crowbars' and produces a short across the line, preventing any further surge energy from being applied to the system. However, the short circuit rapidly discharges the output capacitors which have charged to the GDT strike voltage, resulting in a brief but very high amplitude capacitive discharge current pulse.

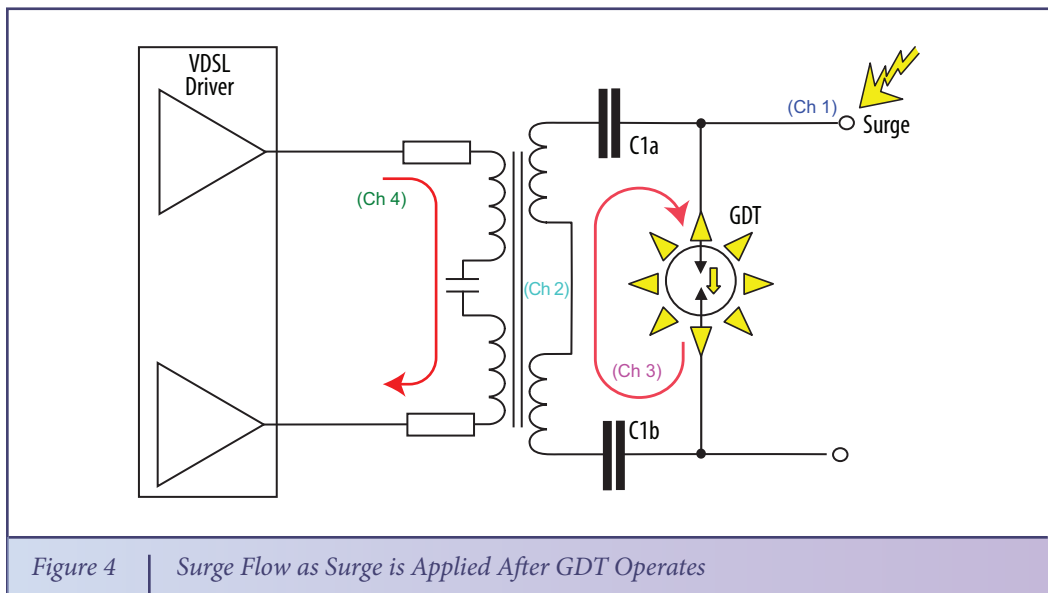


Figure 4 | Surge Flow as Surge is Applied After GDT Operates



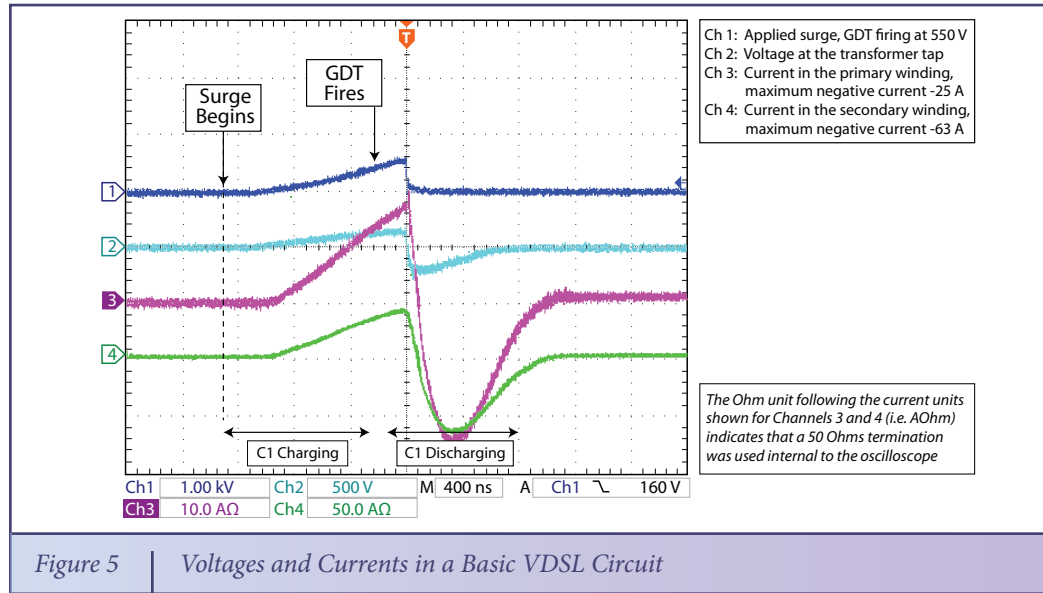
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## Conventional Protection (Continued)

This effect is shown in figure 5 which depicts the voltages and currents that flow during a surge using a 2.5:1 transformer:



Note that the secondary side current is 2.5 times the primary discharge current, due to the step-up ratio of the windings.

The peak current in an application will depend on factors such as the turns ratio, the leakage inductance and the amount of effective series resistance in the discharge path, but can in some applications reach over 200 A. Generally, the designs with the highest performance have the least amount of loss and leakage inductance, and the effect is to make the discharge of the line side capacitors faster and higher in magnitude.

Such high peak currents in the driver side of the transformer are very difficult to clamp effectively. The high peak current and stray inductance in the PCB trace connections limit practical clamping effectiveness, and severe stress to the driver can result. Larger devices often introduce prohibitively high non-linear capacitance. Clamping, either in the form of the line side GDT or additional driver side clamp devices can therefore be seen to be at best only part of the solution for VDSL protection.





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## Bourns® TBU® High-Speed Protector-Based Solutions

Solutions based upon TBU® device protection products address limitations of existing solutions by significantly reducing the surge current reaching the line drivers and increasing the linearity and rate-reach of the system. The following circuits illustrate TBU® device protection topologies that can be used for effective protection of VDSL circuits in a variety of configurations. The difference in the solutions is the presence of a primary protector.

### Option 1

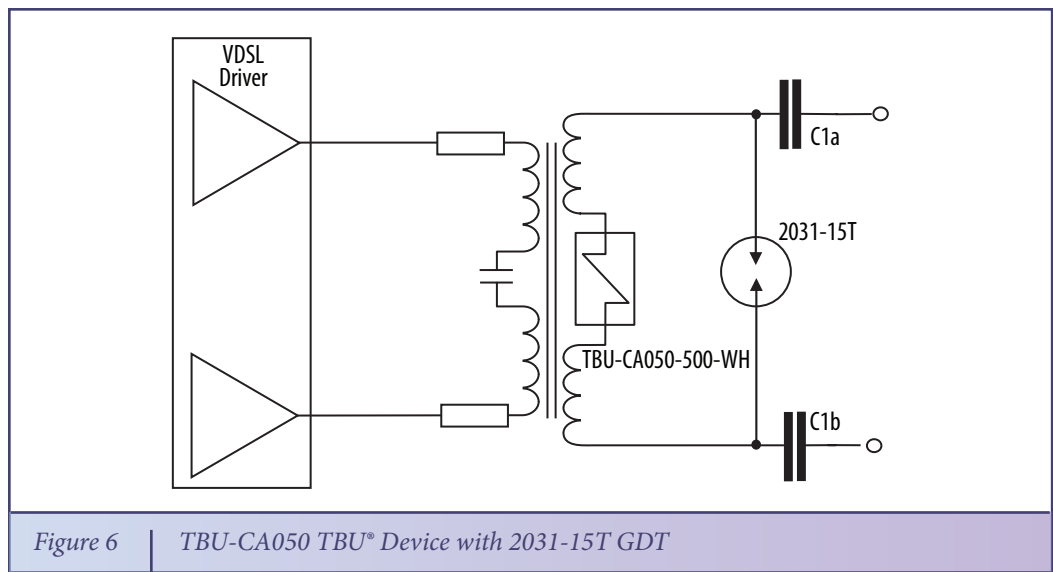


Figure 6 | TBU-CA050 TBU® Device with 2031-15T GDT

Bourns® TBU-CA050-500 is a low resistance 500 V TBU® device with a minimum trip current of 500 mA. If there is no primary protector, the TBU-CA050 TBU® device requires capacitors and transformers that can withstand the maximum voltage, for example 5 kV for GR-1089 or 4 kV/6 kV for ITU protection tests. The operation of the circuit is shown in figures 7 and 8.

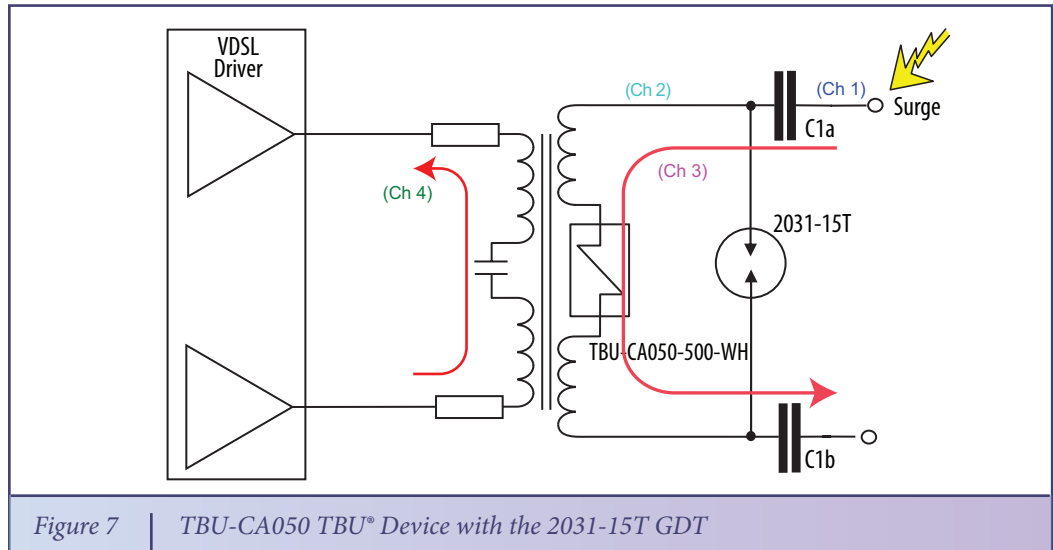


Figure 7 | TBU-CA050 TBU® Device with the 2031-15T GDT

## Bourns® TBU® High-Speed Protector-Based Solutions (Continued)

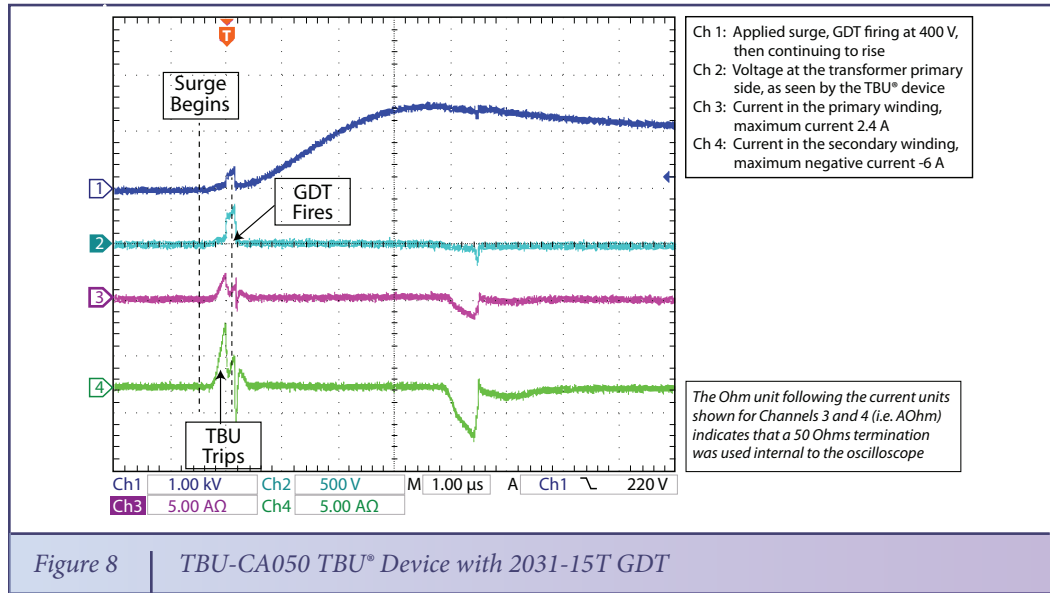
During a lightning surge, the TBU® device becomes high impedance almost immediately, preventing energy from being coupled to the driver side, as can be seen in the figure below.



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As the voltage rises, the 2031-15T GDT activates, protecting the TBU® device from transients above 500 V.

### Key Points

- It is important to note the change in scale of the current waveforms in figure 8 compared to figure 5. The peak driver side current is reduced from -63 A to 6 A, greater than a factor of 10 reduction in peak current.
- Also, the combined duration of the secondary current transients is around 200 μs, compared to around 2 μs in figure 5, again, a factor of 10 reduction.
- The total let-through energy is proportional to the I<sup>2</sup>t product. It can therefore be seen that the total energy is reduced by a factor of approximately 1000.

### Design Hints:

- The coupling capacitors prevent low frequency AC voltage during power cross. Both the capacitors and the transformer must have sufficient breakdown voltage capability to withstand the lightning surge or power cross requirements of the application.
- If there is primary protection, the capacitors must have a sufficient transient rating to withstand the let-through voltage of the primary protector. The transformer must have a sufficient primary to secondary rating to withstand any common mode transients that may pass through the primary protector. In this way, this solution is suitable for both ITU and GR-1089 type applications, and is particularly useful for applications falling into the category of Equipment with Agreed Primary Protection.

## Bourns® TBU® High-Speed Protector-Based Solutions (Continued)

### Option 2



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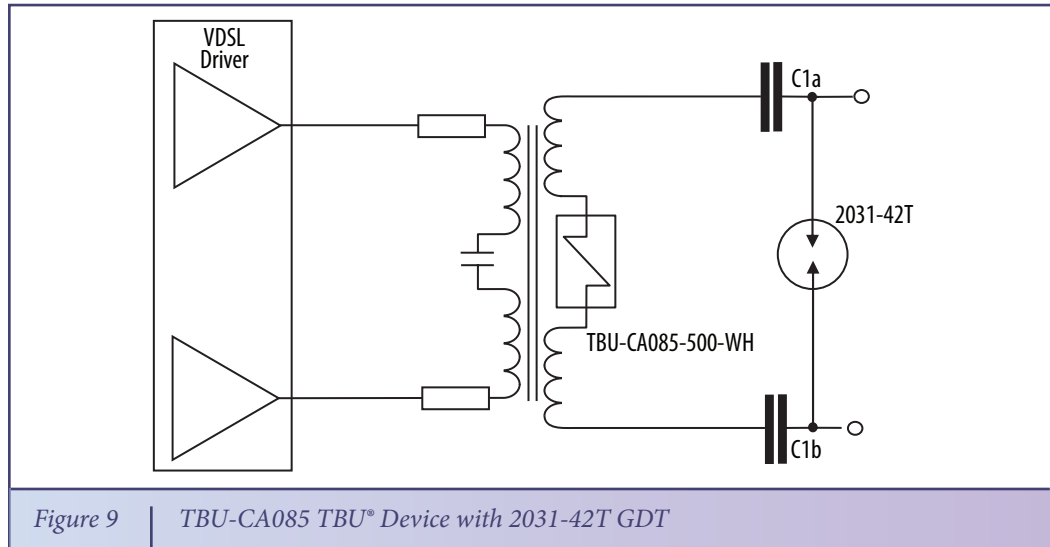


Figure 9 | TBU-CA085 TBU® Device with 2031-42T GDT

The TBU-CA085-500 is an 850 V TBU® High-Speed Protector with a minimum trip current of 500 mA. As with the previous TBU® device solution, this solution also assumes there is no primary protection. The GDT placement in this example will protect the capacitors. During a lightning surge, the TBU® device becomes high impedance almost immediately, preventing energy from being coupled to the driver side. As the surge voltage increases, the 2031-42T activates, preventing any voltages above the rating of the TBU® device. The GDT will not activate during a 230 VAC power cross and can withstand ITU-T K.20/21 type power cross testing. It is not usually suitable for use in GR-1089, as the lower power GDT cannot handle the power cross requirements; the 2020-42T should be used as a substitute. The waveforms in the circuit are shown figure 10.

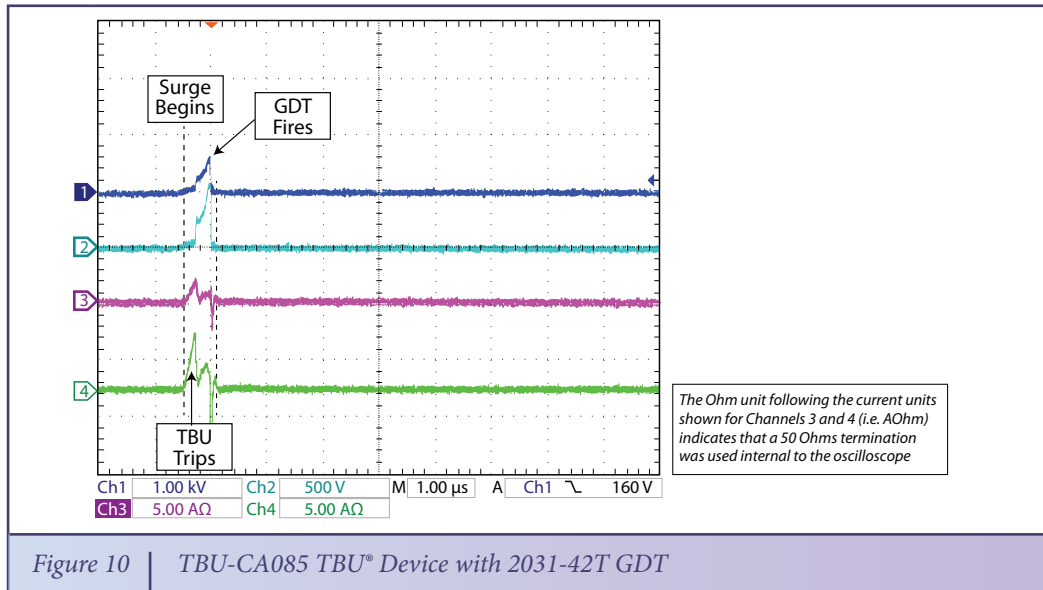


Figure 10 | TBU-CA085 TBU® Device with 2031-42T GDT

## Bourns® TBU® High-Speed Protector-Based Solutions (Continued)

### Option 3



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TBU-CA-085-500-WH

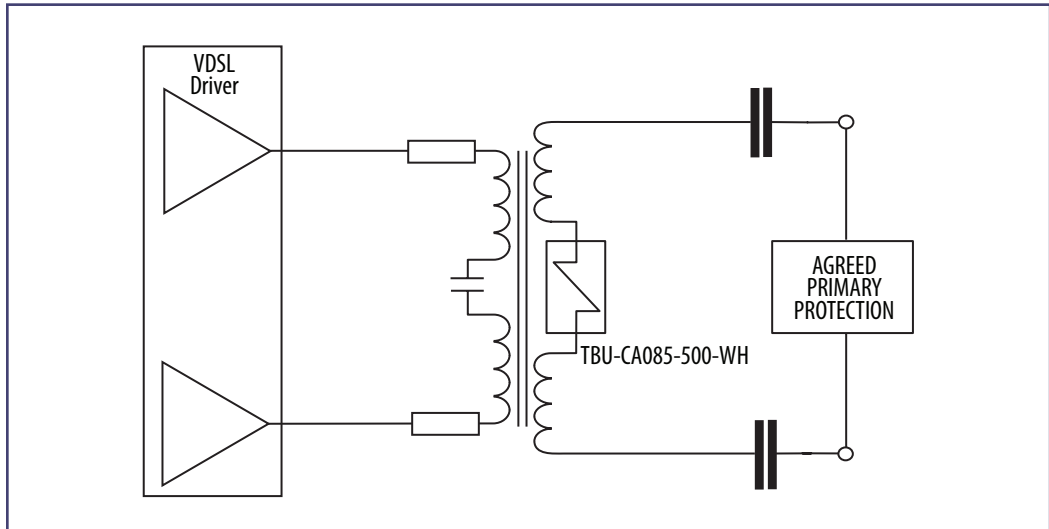


Figure 11 | TBU-CA085 TBU® Device with Agreed Primary Protection

In equipment that has known primary protection, the protector can be chosen to limit the peak voltage to less than the 850 V rating of the TBU® device. In that case, with suitable selection of the capacitor and transformer breakdown voltages, the circuit shown in figure 11 can be used.

The TBU® device trips as the surge begins, protecting the driver. As the surge voltage increases, the primary protection limits the peak voltage to below the maximum limits of the TBU® device, capacitor and transformer.





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## Conclusion

The basic conventional DSL solution no longer is effective in meeting design requirements to operate with all of today's new line drivers, to reduce the surge current to low levels, and to meet the rate-reach requirements of today's VDSL systems. Several design options illustrate how to implement the TBU® device into an effective VDSL protection solution. The solutions can reduce current seen by the line drivers by a factor of up to 1000 times and meet the transmission requirements rate-reach requirements.

Refer to the following documentation for additional information:

- TBU-CA data sheet
- 2031-xxT data sheet

For further technical support and for complete circuit protection solutions,  
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