

Circuit Protection Application Note

TBU™ Electronic Current Limiter GR-1089 Port Type 2 and 4 Ethernet Protection



About the Protection

This application note details the TBU device protection in an Ethernet application. The I-V and surge characteristics of the TBU device are described. The lightning surge and power fault standards that are applicable to Ethernet protection are listed and can be used as a reference when reviewing the design and bench measurements section of this application note.

Scope

This application note describes the:

- Lightning surge and power fault levels of GR-1089 for Ethernet protection
- Lightning surge and power fault protection characteristics of the TBU device
- Recommended TBU device protection solution
- Bench measurements using the TBU device solution

Introduction

Ethernet technology is a common interface technology used in local area networking in the corporate business, industrial, and home environments. There are several variations of Ethernet, the most common types being the 10 BaseT at 10 Mbps data rate, fast Ethernet at 100 Mbps and a growing trend toward GbE at 1000 Mbps. The IEEE 802.3 is the Ethernet standard for millions of Ethernet lines. Over the next 10 years, GbE will continue to adhere to this standard, which leads to fast and easy deployment while promising higher bandwidth performance LAN capabilities.

As communications networks increase in presence both inside and outside the home or office there is an increasing likelihood that Ethernet cabling and ports will be exposed to electrical overstress due to lightning surge, power line induction and power cross resulting in damaged network interface components and increased system costs due to hardware problems.

Bourns provides solutions for Ethernet with protection against AC power cross, induction, and lightning surges.



Protection Standards

GR-1089-CORE Issue 4, Section 4.6 defines the criteria for equipment interfacing with telecommunications ports and states that “telecommunications ports shall be tested regardless of what type of traffic they carry or what function they perform. For example, 10 BaseT and 100 BaseT Ethernet and other similar ports are considered telecommunications ports and shall be tested.”

Lightning transient or AC power cross exposure can be longitudinal (line-to-line), also known as common-mode or can be metallic (line-to-ground), also known as transverse or differential-mode. Both types of surges are potential threats to the telephone network infrastructure. A common-mode transient occurs when the tip conductor and ring conductor are exposed to the same voltage potential above earth ground. A differential-mode case occurs when there is a difference of potential between the tip conductor and the ring conductor. Common-mode surges can be converted to differential-mode surges by way of an imbalance between the conductors of the telecommunications equipment circuit, such as an imbalanced resistive path between the tip and ring conductors.

Lightning surge and AC power fault surge tests for Ethernet applications are categorized based by port types in GR-1089-CORE Issue 4. Port Type 4, aka intra-building requirements, is the requirement for Ethernet port protection. The tables below list the electrical requirements for the intra-building standards.

In GR-1089, criteria for equipment interfacing with telecommunications ports is referred to as first-level or second-level criteria. First-level compliance requires that the EUT (equipment under test) shall not be damaged and continues to operate after the application of the tests.

Lightning Surge Test	Voltages	Minimum Peak Current per Conductor (Amperes)	Maximum Rise/Minimum Decay Time for Voltage and Current ¹ (µs)	Repetitions, Each Polarity
1	+/-800	100	2/10	1
2	+/-1500	100	2/10	1

In customer premises equipment, telecommunications lines may come into contact with power lines. GR-1089 defines second-level criteria as more destructive than first-level. Second-level criteria ensures that the EUT shall not become a fire, fragmentation hazard, or electrical safety hazard as a result of the applied test. The EUT may be damaged during the test.

Power Cross Test	Voltage (V _{rms})	Current (Amperes)	Time (Minutes)
1a	120V _{rms}	25 A	15



Transient Blocking Unit Protection

The TBU (Transient Blocking Unit) device is an effective method for protecting Ethernet transmit and receive pairs, for 10 Base-T, fast Ethernet, and gigabit Ethernet. The TBU device blocks the surge current by switching to a high-impedance state. The TBU device is a normally low-resistance semiconductor device that is triggered to the high-impedance state when the current flowing through it reaches a preset trigger level.

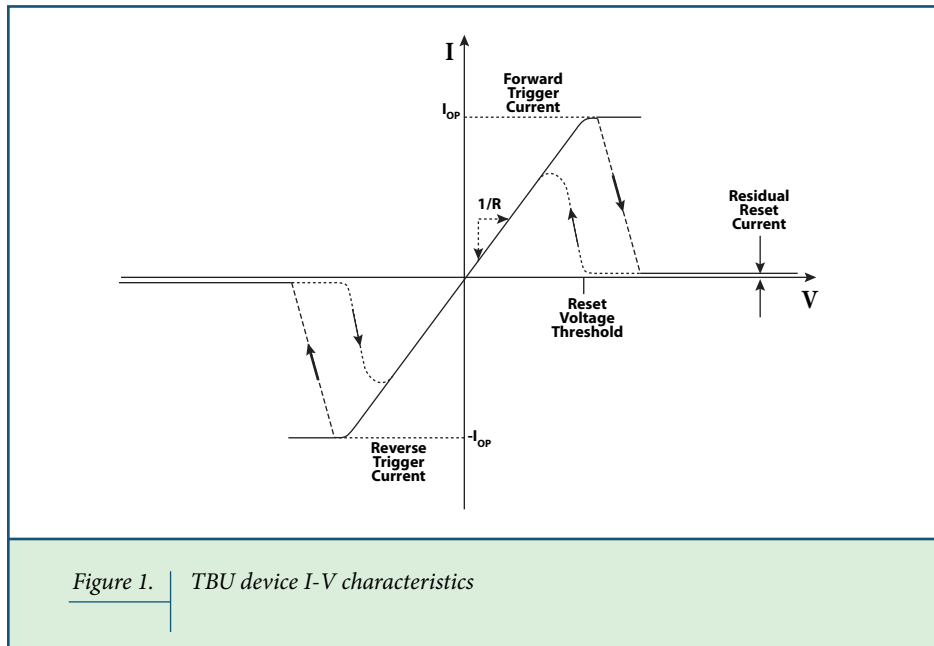


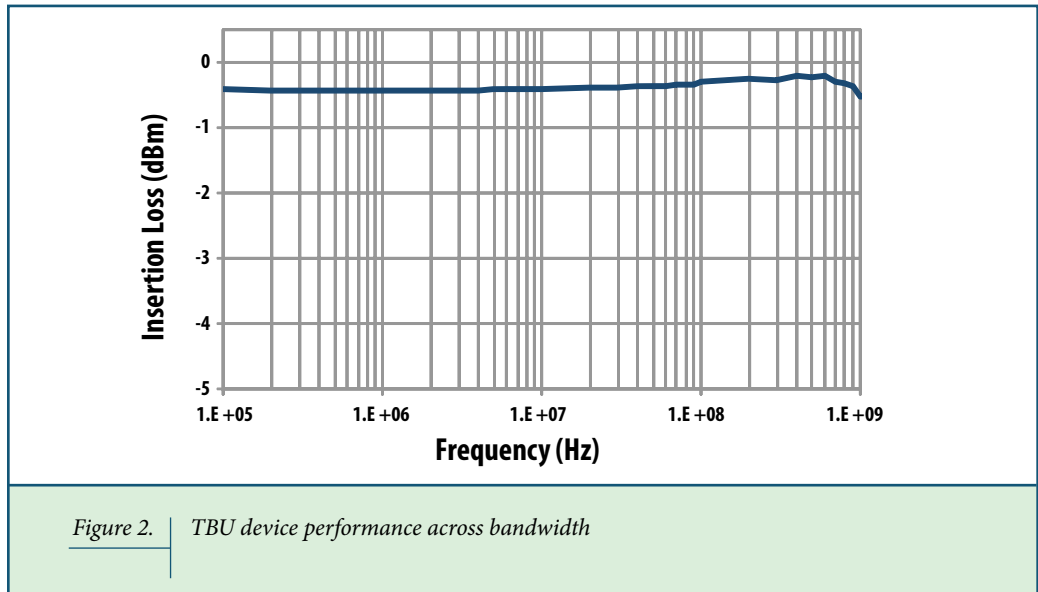
Figure 1 shows the I-V characteristics of a TBU device. In normal operation, the TBU device appears as a resistor in the circuit: it is a two terminal device, and requires no connection to a supply or ground. Consequently, the only capacitance it introduces into the circuit is that of stray capacitance to surrounding traces – no more than a typical surface mount resistor. The TBU device is extremely fast to react to transients typically limiting current within 100 ns. Similarly, it is quick to reset, returning to the low-resistance state within 100 μs of the applied voltage dropping below the reset threshold.



TBU Device Protection Solution

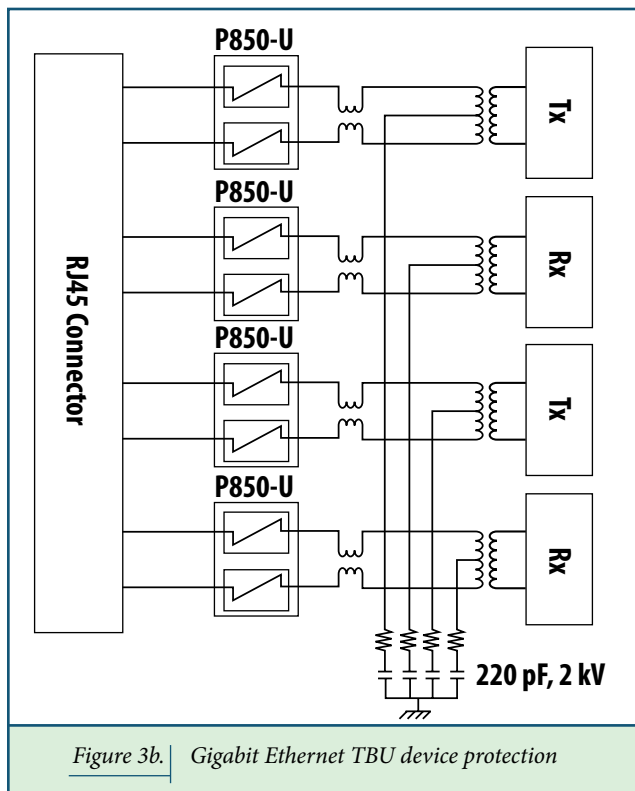
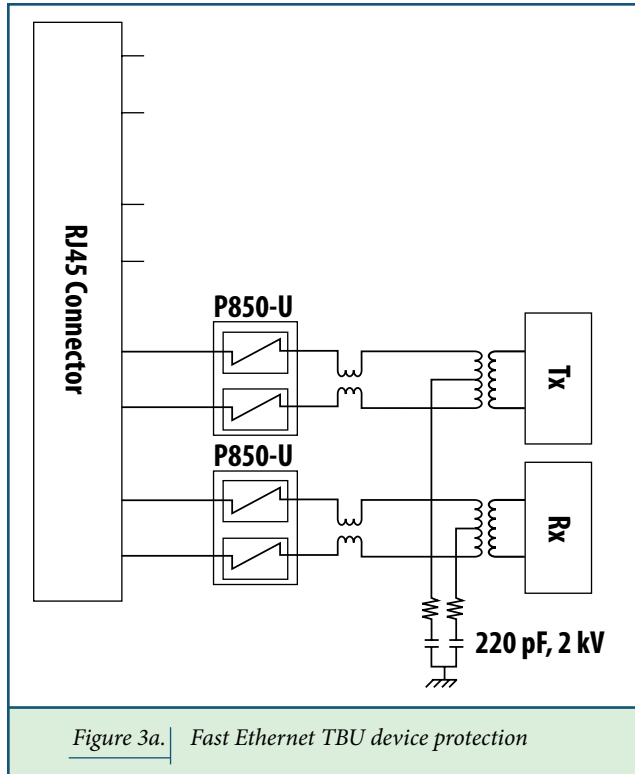
Ethernet applications include an isolation transformer between the Ethernet drivers/receivers and the line interface. The Bourns® P850-U TBU device is used to block the input of the Ethernet magnetics from high-voltages and currents due to a transient event or an AC power cross. The “-U” in the TBU device part number refers to the unidirectional nature of this specific TBU device, which takes advantage of the galvanic isolation of the Ethernet transformer.

In high-frequency applications, bandwidth should be analyzed. During normal operation, the TBU device acts like a series resistor with approximately 500 pF in parallel, meaning that there will be a slight insertion loss at low-frequencies which will rise at around 100 MHz due to the bypass effect of the capacitance. This is typically the case up to around 2 GHz, at which point layout will have the most effect on bandwidth (see figure 3). The capacitance drops very rapidly to about 50 pF when the voltage across the TBU device is greater than about 10 V, thus limiting any capacitively-coupled energy effect which is a key design characteristic in any high-speed system.





Figures 3a and 3b show the protection implementations for fast Ethernet and gigabit Ethernet respectively.



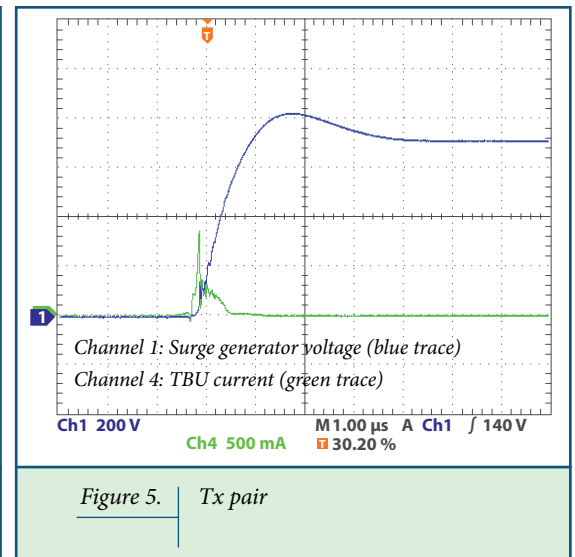
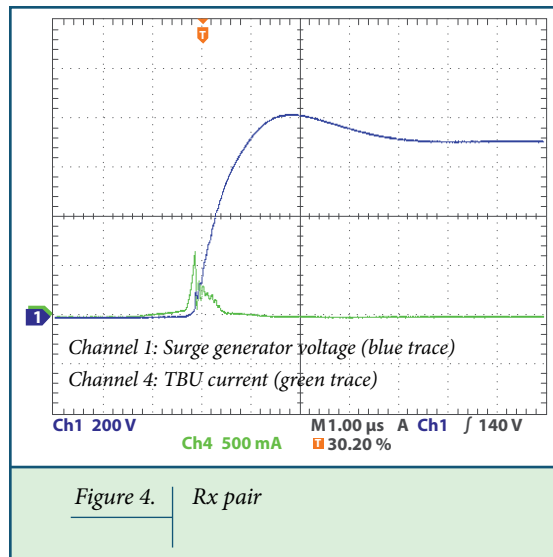


Bench Measurements

The following test results are shown to demonstrate the protection capabilities of the circuits previously described. The P850-U TBU device has an impulse voltage rating of 850 V, which means that peak surge voltages lower than 850 V are blocked by the TBU device and the circuit will pass the surge requirements described in the standards section of this application note. For voltages higher than 850 V, a GDT is used to lower the peak voltages, thus allowing the TBU device to protect by blocking high currents through the TBU device, while the GDT protects the TBU device from exceeding its breakdown voltage level. The power fault voltage rating of the P850-U TBU device is 425 V_{rms}.

The Ethernet line transformer provides high-voltage isolation between the line and the protected side of the transformer. Primary to secondary voltage isolation is typically rated for 1500 V or higher. The termination capacitor is rated to withstand longitudinal-mode voltage conditions. The center-tapped virtual AC ground capacitor is present on the primary side of the Ethernet transformer to reduce emission levels due to EMI. The capacitor value is 220 pF, 2 KV.

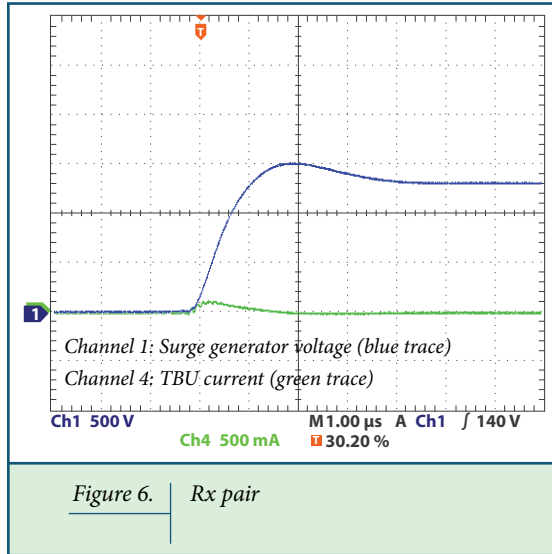
Port Type 4: ±800 V Lightning Surge Testing



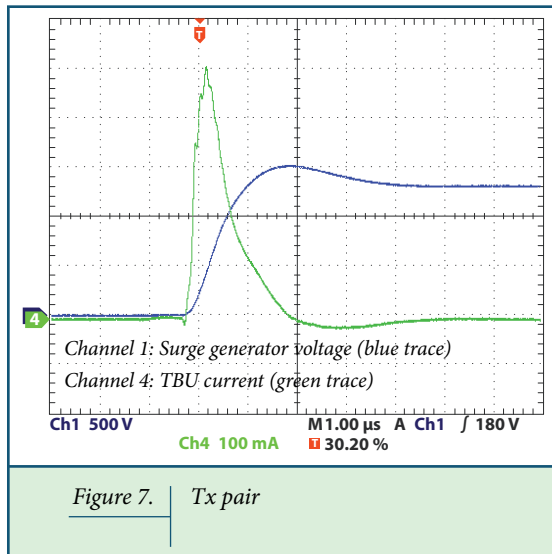
In figures 4 and 5, the generator voltage increased and the current through the TBU device caused the TBU device to trigger. The port is protected and no damage or stress occurred to the Ethernet and protection circuits; the port remains functional after the test.



Port Type 4: ±1500 V Lightning Surge Testing



In figure 6, the common-mode surge does not generate enough current to trigger the TBU device; there is no capacitance-to-ground in the receive pair. In figure 7, a capacitor-to-ground is present. The current is a result of the capacitor inrush current during the common-mode surge test. However, the current is insufficient to trigger the TBU device. The transformer is rated to 1500 V or greater and the TBU device will not trigger during and common-mode surge. The current scale for figure 7 is zoomed in more than figure 6 which makes the current waveform peak level appear larger than that of figure 6. The Ethernet circuit is protected and remains functional.





Port Type 4: 120 Vrms Power Fault Test

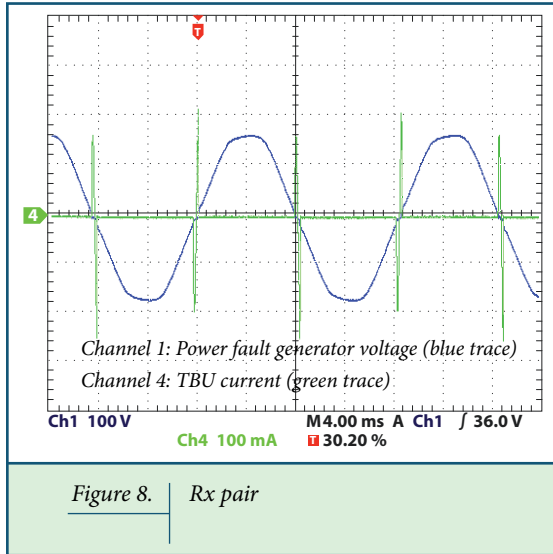
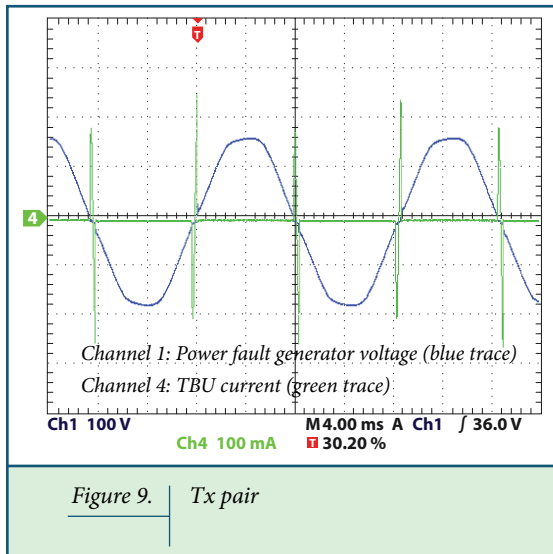


Figure 8 and figure 9 show the P850-U triggering during the power fault test. When the TBU device triggers due to a positive-going AC power fault, it protects the Ethernet port. Once the surge voltage reduces, the TBU device resets until it triggers and protects against the negative-going AC power fault. This cycle repeats for the duration of the test, fifteen minutes. No damage or stress occurred to the circuits; the port remains functional after the test.





Integrated RJ45 Connector

A number of third-party vendors have integrated the TBU device and magnetics into RJ45 connectors for Ethernet applications, such as 10/100/1000-Base-T connectors. Refer to Bourns' sales or applications teams for details.

Layout Considerations

To pass the surge requirements, careful attention must be paid to the clearance between the TBU device pads and the surrounding electrical pads, vias, or shields. Standard clearances will help ensure that the Ethernet port passes the surge requirements. Refer to the Bourns P-U Series data sheet for TBU device orientation and PCB layout recommendations.

Conclusion

TBU devices are designed to provide superior protection for Ethernet applications. Furthermore, TBU device bandwidth allows for very high data rates to pass without interference to the signals. Lastly, no damage or stress is made to the Ethernet circuit or the protection devices; the circuit is fully functional after the surge tests within rated limits of the TBU device.

Bourns® products are available through an extensive network of manufacturer's representatives, agents and distributors. To obtain technical applications assistance, a quotation, or to place an order, contact a Bourns representative in your area.

Specifications subject to change without notice. Actual performance in specific customer applications may differ due to the influence of other variables. Customers should verify actual device performance in their specific applications.

For more information on TBU devices and other circuit protection products from Bourns, please visit

www.bourns.com

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