BOURNS®

Highly Effective Microsecond-Response Surge Protection for Telecommunication Lines

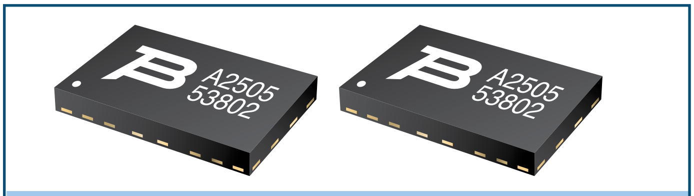
WHITE PAPER

Introduction

Telecommunication lines have one of the most electrically-exposed interfaces in modern electronic systems. Copper subscriber lines, Digital Subscriber Line (DSL) loops, Private Branch Exchange (PBX) trunks, and Voice over Internet Protocol (VoIP) gateway ports are all routinely subjected to high-energy electrical disturbances that can originate from lightning strikes, power-cross events, inductive switching, and electrostatic discharge. Adding to protection challenges are today's telecom interface ICs that operate at low voltage levels and possess reduced tolerance to transient overstress. Even brief surge currents can exceed semiconductor Safe Operating Area (SOA) limits, resulting in junction breakdown, thermal damage, latch-up, or catastrophic failure.

This white paper presents the advantages of incorporating Bourns® TBU® High-Speed Protectors (HSPs) for effective surge protection in telecom systems. These high-speed, solid-state overcurrent protection solutions are specifically designed to protect sensitive electronics from transient events. As a helpful resource for telecom designs, the white paper explains the surge threat environment in telecom systems, theoretical protection principles, the advanced operating technology used in TBU® HSPs, their coordinated design methodology, and the resulting performance advantages designers can expect when employing TBU® High-Speed Protectors.

TBU® HSP Surge Protection Benefits



Bourns® TBU® High-Speed Protectors (HSPs)

Unlike traditional voltage clamping devices, TBU® HSPs are able to cut off harmful currents in sub-microsecond response time and automatically reset once the fault condition is removed, similar to a resettable fuse. TBU® HSPs can be also be implemented in a coordinated protection architecture with Gas Discharge Tubes (GDTs), TISP® Thyristor Surge Protectors and Transient Voltage Suppressor (TVS) Diodes or Metal Oxide Varistors (MOVs), enabling designers to meet stringent regulatory standards such as: ITU-T K.20, ITU-T K.21, GR-1089-CORE, IEC 61000-4-5.

The primary benefits are as follows:

Standards-based Surge Survivability: Employing TBU® HSPs in telecom designs enables compliance with 1-6 kV lightning surges, supports both 8/20 µs and 10/700 µs waveform requirements, and meets GR 1089 power cross test standards.
Cost-effective Resettable Protection: Unlike fuses, TBU® HSPs require no replacement, so maintenance requirements can be reduced and operating costs lowered. This results in increased equipment uptime, and enhanced overall system reliability.
These benefits result from minimizing both thermal and electrical overstress, which improves MTBF, reduces field returns, and increases compliance margins.
Compact and Scalable Implementation: TBU® HSP devices support high density designs by offering a ultra-small footprint that helps reduce component count and simplifies PCB routing.

Telecom System Surge Environment

Exposed telecommunication equipment includes:

- **Central office line cards**
- **DSL modems**
- **VoIP gateways**
- **Enterprise PBX systems**
- **Remote subscriber terminals**

This equipment is typically connected directly to outside plant copper lines that may extend several kilometers. These lines many times act as large antennas for electromagnetic disturbances. Telecommunication equipment deployed in carrier and enterprise networks include a range of systems designed to interface with outside plant lines while maintaining signal integrity and regulatory compliance.

Central office line cards are interface modules installed in switching systems at the service provider's central office. Line cards provide necessary battery feed, signalling, supervision, and surge protection for multiple subscriber loops terminating at the network.

DSL modems are customer-premises devices that enable high-speed digital data transmission over traditional copper telephone pairs by modulating data onto higher-frequency bands while coexisting with voice service.
VoIP gateways convert voice traffic between traditional circuit-switched telephony and IP-based packet networks, enabling interoperability between legacy Public Switched Telephone Network (PSTN) infrastructure and modern broadband networks.
Enterprise PBX systems serve as private telephone exchanges within organizations, managing internal call routing, external trunk connections, and deliver advanced features such as call forwarding, conferencing, and voicemail.
Remote subscriber terminals are field-deployed access nodes located closer to end users. These extend network reach by aggregating multiple subscriber lines and backhauling traffic to the central office, improving loop-length performance and broadband service availability.

Electrical Surge Threat Environment

Typical disturbances include:

Disturbance Type	Typical Magnitude	Duration
Lightning Surge	1-6 kV	µs range
Power Cross	110-600 VAC	Seconds
Ringing Voltage	70-150 VAC	20-25 Hz
ESD	±8 to ±15 kV	ns range

Lightning-induced surges are commonly simulated using:

- 10/700 µs waveform, which is the telecom standard.
- On a 1.2/50 µs open circuit voltage and 8/20 µs short circuit current waveforms from a combination wave generator.

For example, ITU-T enhanced level testing may require:

- 6 kV, 40 Ω, 10/700 µs surge

In telecommunications surge-immunity testing, lightning-induced transients are reproduced using standardized impulse waveforms that reflect real-world coupling mechanisms on outside plant cabling. The 10/700 µs waveform, widely defined in ITU-T recommendations such as ITU-T K.21, represents a voltage surge that rises to its peak in ten microseconds and decays to half of that value in 700 microseconds.

This longer-duration impulse is intended to simulate a lightning-induced overvoltage that usually appears on twisted-pair telecom lines, where the source impedance is relatively high and the stress is primarily voltage-driven.

In contrast, the 8/20 µs waveform, commonly referenced in surge standards including IEC 61000-4-5, characterizes a high-current impulse with an eight microsecond rise time and 20 microsecond half-value decay. It is often used in combination-wave generators to evaluate both voltage and current stress, particularly for power ports and low-impedance interfaces. Under enhanced test levels defined by ITU-T, equipment may be required to withstand surges as high as 6 kV using a 10/700 µs waveform with a 40 ohm (Ω) source impedance. This condition represents a severe lightning-induced event and ensures that telecommunications equipment, especially its ports connected to external cabling, can tolerate high-energy transients without damage, fire hazard, or loss of service. Without current limiting, such events can inject tens to hundreds of amperes into sensitive IC pins.

With these fast-acting surge threats in mind, an effective telecom protection device must be able to: respond in microseconds, limit fault current precisely, withstand repeated surge events, avoid degrading signal bandwidth, and automatically reset. Bourns designed its TBU® HSP technology to address these requirements directly.

Physics of Surge Coupling in Telecom Lines

Telecom cables are long conductors exposed to electromagnetic fields. According to Faraday's Law:

$$V_{induced} = -\frac{d\Phi}{dt}$$

Rapidly changing magnetic flux during lightning events induces voltage in telecom loops. Additionally, capacitive coupling from adjacent power lines contributes to overvoltage conditions. Because telecom pairs typically have characteristic impedance near 100 Ω, high surge currents can result when exposed to kilovolt-level impulses. There are several known semiconductor failure mechanisms in telecom ICs. These include: PN junction avalanche breakdown, thermal bond wire melting, CMOS latch-up, and gate oxide rupture.

The critical factor is energy:

$$E = \int V(t) \cdot I(t)\, dt$$

If current is not limited, instantaneous power is significantly amplified:

$$P = V \times I$$

These conditions can exceed device limits within microseconds. Therefore, limiting current rapidly is more effective at reducing total energy stress than voltage clamping alone and this is where TBU® HSPs truly excel.

Limitations of Conventional Protection

Device	Protection Mode	Limitation
Fuse	Thermal interruption	Slow, single use
MOV	Voltage clamping	Degrades over time
TVS	Avalanche clamp	Does not prevent high surge current
Series resistor	Passive limiting	Degrades signal quality

Traditional protection often allows high surge current to momentarily flow through the protected IC before clamping stabilizes. A current-triggered protection device, such as a Bourns® TBU® HSP protector, provides a more controlled and effective solution.

Adopting a High-Reliability Protection Strategy

TBU® High-Speed Protector Operating Principles

Bourns® TBU® HSP devices provide a high-speed solid-state current limiting solution optimized for telecom applications. When used in coordinated architectures with GDTs, TVS diodes and MOV devices, they enable compliance with standards such as ITU-T K.20, ITU-T K.21, GR-1089-CORE, and IEC 61000-4-5. The result is a robust, resettable, high-reliability protection strategy that enhances telecom system durability while preserving signal integrity.

To implement, the TBU® HSP is placed in series with the signal line. Its behavior consists of three states:

- First, normal $I < I_{trigger}$ - low impedance, minimal insertion loss;
- Second, triggered $I > I_{trigger}$ - switches to blocking mode (high impedance);
- Third, reset fault removed automatically returns to normal (low impedance).

The typical operating characteristics from these devices provide a response time of less than 1 µs, a trigger current range of 50-500 mA (some headroom or tolerance is there), an impulse voltage rating up to 850 V, and a RMS voltage rating up to 425 V plus they are resettable. Examples of applicable TBU® HSP Series include:

- TBU-CA Series: Offers broad versatility as a general-purpose solution for industrial controls, medical electronics*, and data communication ports.
- TBU-PL Series: Excellent solution for telecom because the series is specifically tailored to protect Subscriber Line Interface Cards (SLICs) from surges such as lightning and AC power cross.

Both of these series are optimized for telecom interface protection.

The TBU-PL Series high-speed protectors are optimized for voice and VoIP SLIC applications. To ensure proper operation on these telecom lines, the maximum voltage rating of the TBU® device must never be exceeded. When line conditions may surpass this limit, an appropriate Overvoltage Protection (OVP) device should be added to clamp excessive voltage before it reaches the TBU®.

A cost effective general protection approach—used across many telecom interfaces, not just VoIP—pairs a Bourns® TBU® device with two Bourns® MOVs. For bandwidth sensitive applications, a Bourns® GDT may be used instead of MOVs due to its very low capacitance. In designs requiring EN55024 EMC compliance, the TBU® device may also be used with capacitors connected between the Tip and Ring lines and ground to ensure proper electromagnetic performance.

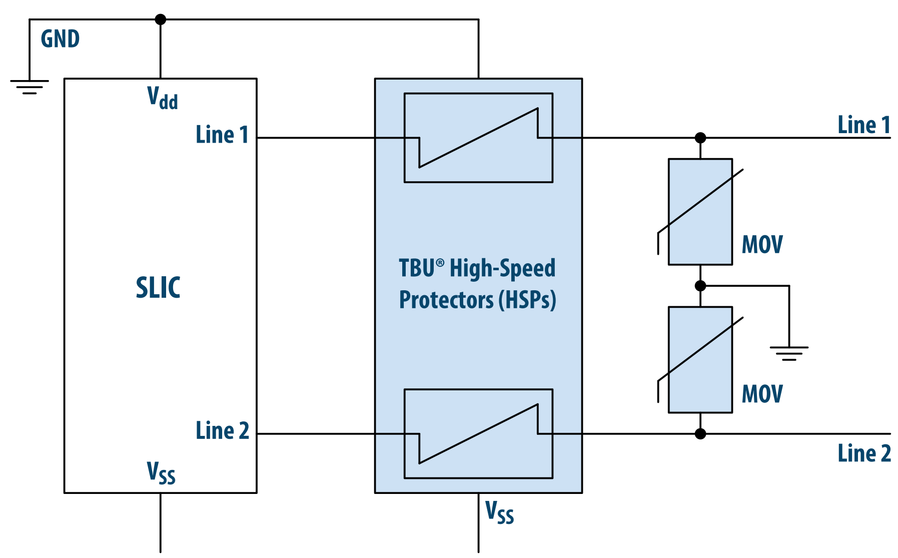


Figure 1. VoIP SLIC application schematic utilizing a TBU® HSP protection device and a pair of MOVs.

The schematic above illustrates the application protection and does not constitute the complete circuit design. Customers should verify actual device performance in their specific applications.

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Adopting a High-Reliability Protection Strategy (Continued)

Designing a Coordinated Protection Architecture

Bourns® TBU® HSP devices are used within a layered protection topology. For example, in a SLIC, the device provides the full set of BORSCHT functions—battery feed (B), overvoltage protection (O), ringing (R), signaling (S), coding (C), hybrid (H), and test (T). These functions support key operations such as delivering battery power, generating ring signals, and managing the supervision between the codec and the telephone handset.

The design shown in Figure 2 complies with ITU T Enhanced K.20, K.21, and K.45 requirements and can withstand 230 V_{rms}, 23 A for 900 seconds, as well as an increased surge level of 10/700 µs at 6 kV. This is accomplished all without the use of a primary protector. In comparison, the configuration in Figure 3 meets ITU T Basic K.20, K.21, and K.45 requirements and withstands 600 V_{rms}, 1 A for 0.2 seconds, along with an increased surge level of 10/700 µs at 4 kV, also without requiring a primary protector.

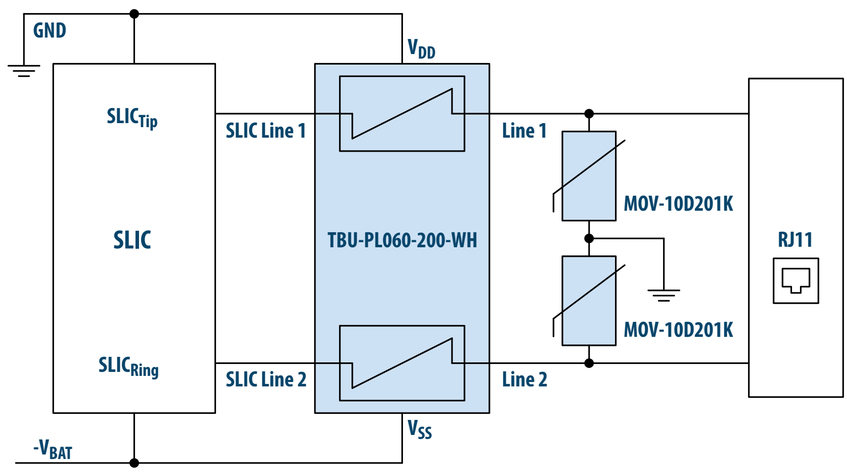

Figure 2. ITU-T 6 kV Solution, Negative Voltage Tracking

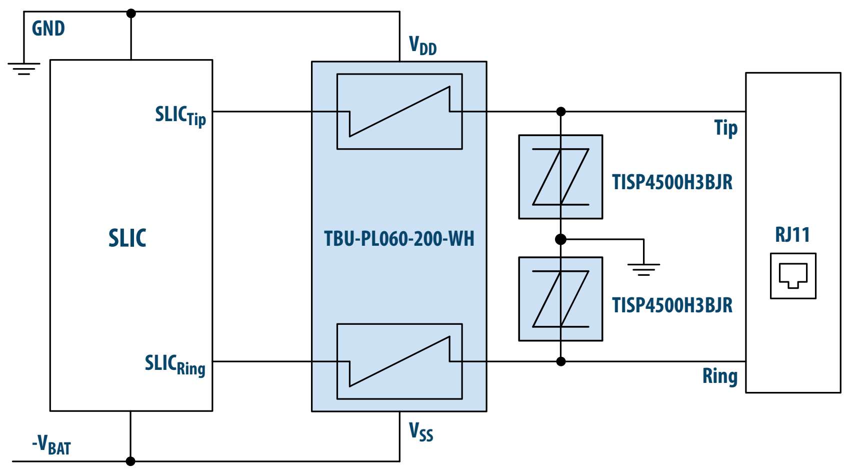

Figure 3. ITU-T 4 kV Solution, Negative Voltage Tracking

In Figures 2 and 3, the Bourns components used are : TISP® Thyristor Surge Protectors , TBU® High-Speed Protectors, and Metal Oxide Varistors (MOVs).

The schematics above illustrate the application protection and do not constitute the complete circuit designs. Customers should verify actual device performance in their specific applications.

Protection Role Distribution

Surge Protection Sequence

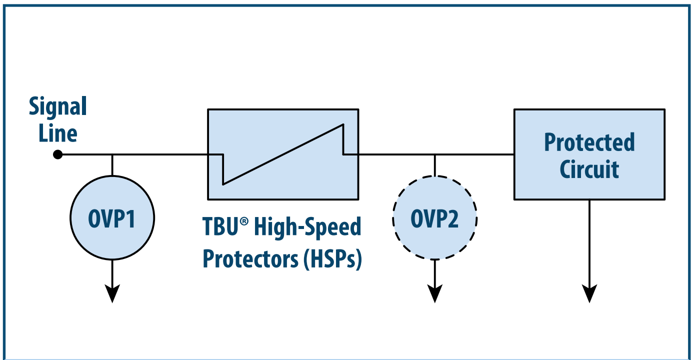

Figure 4. Surge Sequence

In Figure 4, the surge protection sequence is as follows:

1. Surge appears online
2. TVS (OVP2) clamps voltage and forces the TBU to detect overcurrent
3. TBU® HSP device switches to blocking state (~1 µs)
4. TVS (OVP2) continues to clamp remaining residual voltage
5. GDT (OVP1) absorbs bulk energy
6. System resets automatically when voltage drops below V_{reset}

Compliance-Based Device Selection

Below, Table 3, lists the representative protection mapping for telecom standards:

Standard Requirement	Surge Level	Example TBU® HSP	Example Clamp Device
ITU-T K.20 Basic	1 kV, 10/700 µs	TBU-PL075-200	MOV 10D361K
ITU-T K.21 Enhanced	6 kV, 40 Ω	TBU-PL085-200	MOV 10D391K
GR-1089 Port Type 4	1000 V, 100 A	TBU-PL060-200	MOV 10D201K
IEC 61000-4-5	1-4 kV	TBU-CA Series	TVS 400-600 W

Proper coordination ensures that telecom equipment meets required surge resistibility standards without sustaining damage.

Power Cross Protection:

During sustained AC power cross faults, such as exposure to 230 VAC, where the peak voltage reaches V_{peak} = 325 V unrestricted current flow can lead to destructive heating. Using a TBU® HSP configured with a 200 mA trigger threshold sharply limits the transferred energy, significantly reducing the risk of fire hazards and PCB carbonization.

Signal Integrity Performance:

Unlike MOV-based protection approaches, TBU® devices provide additional design benefits:

- Low insertion loss
- Low inductance
- Minimal added capacitance
- Symmetrical bidirectional protection
- No distortion of DSL frequency bands

This makes them suitable for: xDSL, VoIP analog front ends, RS-485, and industrial telecom interfaces.

The schematic above illustrates the application protection and does not constitute the complete circuit designs. Customers should verify actual device performance in their specific applications.

Result and Benefits

Surge Survivability

Coordinated TBU® HSP-based protection enables telecom interfaces to meet industry surge immunity requirements, including:

- 1-6 kV lightning surges
- 8/20 µs high-current and 10/700 µs high-voltage waveforms
- GR 1089 power cross tests

In these events, primary protectors (MOVs, GDTs, TVS diodes) clamp the overvoltage, while the TBU® HSP device limits current within microseconds, transitioning to a high impedance state to block follow-on surge energy. This prevents excessive current from reaching downstream ICs and secondary protectors, significantly reducing thermal stress and improving equipment survivability.

During longer duration power cross faults, the TBU® device limits fault current to a controlled level, reducing the risk of PCB damage or overheating. Once the fault is removed and normal line voltage returns, the TBU® HSP automatically resets, supporting system uptime.

Resettable Protection

Because TBU® HSP devices reset automatically and require no replacement, they reduce maintenance, lower operating costs, increase availability, and improve MTBF and compliance margins.

Compact and Scalable Implementation

Their small footprint, low insertion loss, and minimal added capacitance support high density layouts, simplified routing, and compatibility with bandwidth sensitive applications such as xDSL, VoIP analog front ends, and industrial telecom interfaces.

Conclusion

When paired with appropriate clamping devices, TBU® HSPs provide a fast, resettable, standards compliant current limiting solution for both lightning surges and power cross conditions.

This coordinated architecture minimizes electrical and thermal overstress, improves long term reliability, and delivers a compact, cost-effective protection strategy for modern telecom system designs.