BY PHILLIP HAVENS • LITTELFUSE LP

Designing protective circuitry for DSL loops: Beware of pitfalls

DSL EQUIPMENT REQUIRES PROTECTION FROM A VARIETY OF OVERVOLTAGE CONDITIONS, BUT THE NEED TO AVOID UNDULY DEGRADING CIRCUIT OPERATION COMPLICATES CIRCUIT DESIGN.

The appropriate protective-circuit design for DSL (digital-subscriber-line) loops depends on the type of loop: Loops vary in voltage conditions and in susceptibility to attenuation and degradation in signal integrity. Therefore, protective circuitry that works well in one application may be completely inappropriate in another. A "normal" signal ranges from 2.5V in an HDSL (high-bit-rate DSL) to 260V in an DSL system (see **sidebar** "Normal signals"). The circuit design and choice of circuit-protection devices must take these differences into account. You should also consider the design with respect to effects of varying capacitance.

BASIC PROTECTIVE CIRCUITS

Designers have a number of devices to choose from—GDTs (gas-discharge tubes), thyristors, MOVs (metal-oxide varistors), and TVS (transient-voltage-suppression) diodes for overvoltage, and fuses and PTC (positive-temperature-coefficient) devices for overcurrent. The challenge is to use them effectively without unduly degrading normal circuit operation.

HDSL circuits require longitudinal protection at both the HTU-C (HDSL-transceiver-unit-central-office) and HTU-R (HDSL-transceiver-unit-remote) interfaces because of the ground connection HDSL uses with loop powering. One approach is to use a pair of TSPDs (transient-surge-protection devices) from tip to ground and ring to ground to provide overvoltage protection, preceding them with a pair of fuses—one on the tip and one on the ring—to provide overcurrent protection (**Figure 1**). For the transceiver side of the coupling transformer, another TSPD can provide overvoltage protection.

The ATU-C (ADSL [asymmetric-DSL]-transceiver-unit-central-office) interface and the ATU-R (ADSL-transceiver-unit-remote) interface typically use longitudinal protection;

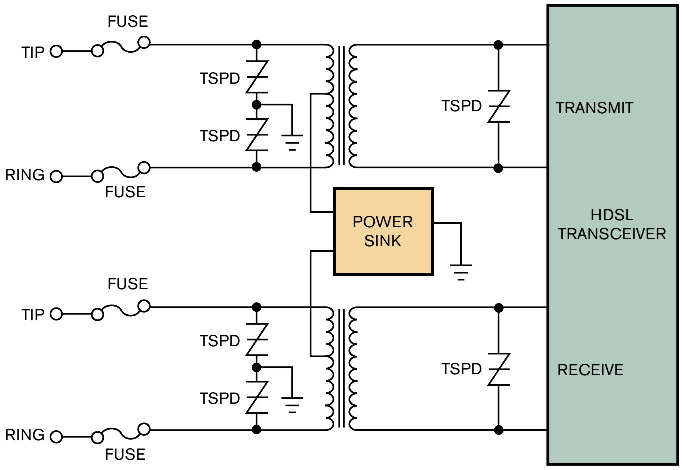

Figure 1 A pair of TSPDs and a pair of fuses can provide overvoltage and overcurrent protection for an HTU-C interface and an HTU-R interface.

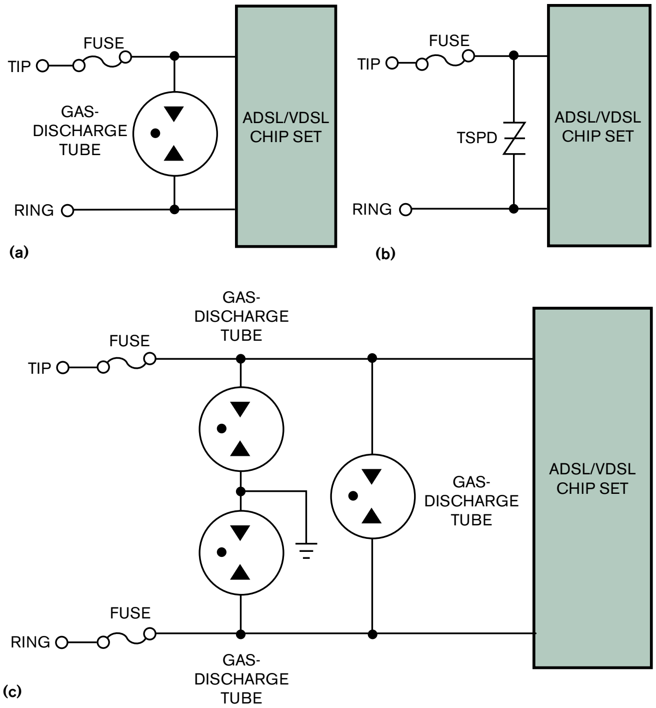

Figure 2 One way to provide metallic protection for an ATU-C interface and an ATU-R interface is to use a simple GDT and a fuse (a). An alternative is to replace the GDT with a TSPD (b). Yet a third method is to connect GDTs in a delta configuration to provide tip-to-ground, ring-to-ground (longitudinal), and tip-to-ring (metallic) protection.

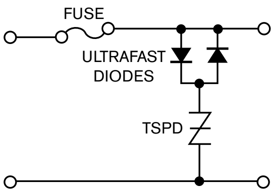

Figure 3 When microcapacitance TSPDs do not sufficiently reduce capacitive effects, a pair of ultrafast-switching diodes in an inverse-parallel arrangement can help in some circuits.

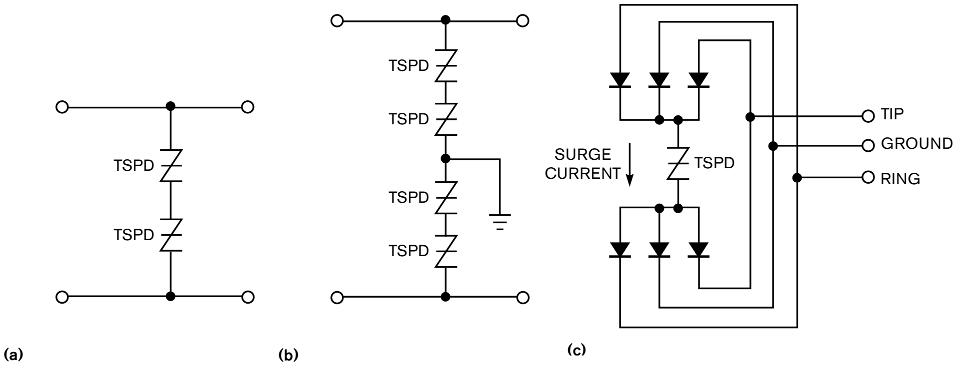

Figure 4 A circuit with two TSPDs (a) works well for metallic transients on CPE. A configuration with four TSPDs works well to protect against the longitudinal surges on ADSL2+ (b). Another useful circuit is a balanced-bridge topology (c).

an ADSL modem at the customer premises does not, due to the absence of earth-ground connections. You may consider a GDT if the design uses a 0.5A fuse (**Figure 2**). A TSPD and a surge-tolerant fuse can provide metallic protection. An alternative method, with GDTs connected in the delta configuration, provides tip-to-ground, ring-to-ground (longitudinal), and tip-to-ring (metallic) protection.

MINIMIZING CAPACITIVE EFFECTS

One of the drawbacks of some solid-state protective devices—TSPDs, for example—is their high, voltage-dependent capacitance, which can cause problems in three areas. Capacitance imbalance due to different biasing voltages on the tip and the ring may cause longitudinal, or common-mode, signal distortion. On-hook/off-hook/ringing transitions can cause sudden transient events to occur on the phone line, possibly changing the capacitance of the channel. Equalization established during modem training becomes suboptimal when the capacitance of the channel shifts. The capacitance of the channel changes instantaneously during the transmission of 30V-p-p signals; these nonlinear channel characteristics may lead to IM (intermodulation) distortion.

The object is to design a protective circuit that will minimize the effects of varying capacitance yet still provide protection compliant with the appropriate regulatory and standards requirements or recommendations.

One method is to use microcapacitance TSPDs, which can have a typical capacitance of 60 pF, or 40% less than a standard TSPD part. When 60 pF is still too much, a good alternative is to put the TSPD in series with a pair of ultrafast-switching diodes in an inverse-parallel arrangement (**Figure 3**). Because the diodes have capacitances of about 10 pF each, the total capacitance across the loop is approximately 15 pF. The fuse is necessary for safety and to guard against power-fault events. Although this approach works well in

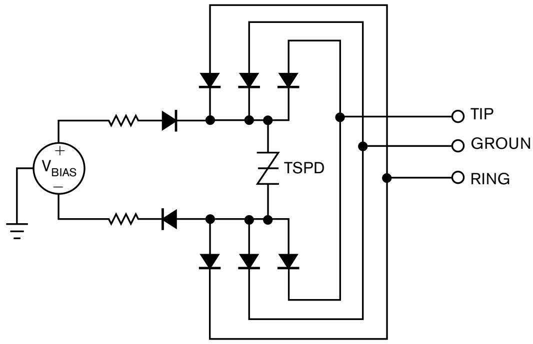

Figure 5 The application of a minimum line bias can reduce and linearize capacitance. A 5V bias applied through two 1-MΩ resistors can serve a circuit with a POTS overlay; a 24V bias works for a circuit without a POTS overlay.

T3 and Ethernet applications, the high peak voltages of VDSL2 (very-high-speed DSL 2) cause the diodes to conduct sufficient current to cause linearity problems that will corrupt the coding constellations.

Figure 4a shows a circuit with two TSPDs that works well for metallic transients on CPE (customer-premises equipment); **Figure 4b** shows a circuit for longitudinal surges on ADSL2+. Another useful circuit is the balanced-bridge topology in **Figure 4c**. Yet another alternative is to apply a minimum line bias to reduce and linearize capacitance. **Figure 5** shows the general topology; a 5V bias applied through two 1-MΩ resistors can serve a circuit with a POTS (plain-old-telephone-service) overlay, and a 24V bias works for a circuit without a POTS overlay.

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Although there are multiple factors to consider when designing protective circuits for DSL, there are multiple useful approaches. Because of the complexities involved, designers may wish to seek advice from suppliers that offer all the circuit-protection technologies and are therefore not biased toward any one type of protective device.EDN

AUTHOR'S BIOGRAPHY

Phillip Havens is telecom-sector technical manager at Littelfuse. He represents the company at many telecom-related industry meetings and helps define, direct, and support new silicon-based protection products. Havens also interfaces with customers' technical teams to develop the most cost-effective protection for their various applications.

NORMAL SIGNALS

Though at times it's unintentional, DSLs (digital-subscriber lines) can experience a number of voltage conditions. One important consideration is whether the loop provides POTS (plain-old-telephone service) as well as DSL. POTS involves battery and ringing voltages. Battery voltage is nominally −48V dc, or 56.6V maximum. Ringing voltage is nominally 90V at 20 Hz in the United States and 25 Hz in Europe, but it can reach 150V rms at 16 to 40 Hz. Therefore, the maximum expected voltage under normal conditions is the peak value of the maximum operating ring voltage, 150V rms, plus the maximum dc bias of the central-office battery, for a total of approximately 269V in the worst-case situation.

HDSLs (high-bit-rate DSLs), on the other hand, use a 1.544-Mbps, T1-equivalent transmission rate but with half the bandwidth of a comparable T1/E1 link. The signaling levels are a maximum of ±2.5V, and loop powering for regenerators is typically less than 190V.

ADSLs (asymmetric DSLs) employ transmission rates that reach 6.144 Mbps from the COT (central-office terminal) to the RT (remote terminal) and as much as 640 kbps from the RT to the COT, whereas VDSL2 (very-high-speed DSL 2) employs symmetrical data rates to 100 Mbps on short loops.

Telephone engineers define overvoltages as metallic (differential mode), between the tip and the ring, or longitudinal (common mode), between the tip and ground or between the ring and ground. Overvoltages can exceed 2500V, and surge currents can reach 500A. Surges can come from nearby lightning strikes or either inductive or direct-contact ac-powerline interactions.

Longitudinal overvoltages are more frequent and are attributable to power induction, power crosses, and nearby lightning strikes, provided that the line is referenced to ground. You can convert one-way longitudinal transients to metallic transients if both the tip and the ring have protective devices to ground and one device conducts before the other.