Optimizing I/O protection for ADSL modems

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By employing advanced modulation techniques to transmit data at 8Mbps rates while keeping regular phone service undisturbed, ADSL technology offers simultaneous channels for data and voice services through continuous connectivity–freeing users from having to dial up every time they want to connect to the network. And because ADSL is not circuit-switched, it is unaffected by congestion at the service provider, making possible a lot of applications like real-time videoconferencing, Web hosting, video streaming, distance learning, telemedicine and video-on-demand.

Exploiting ordinary phone lines, ADSL equipment has to undergo electrical hazards such as lightning stresses, ESDs and power crossing. Hence, it requires adequate protection against damaging over-voltages.

From a hardware point of view, ADSL can be considered as a superimposed digital service that runs over the subscriber line while reusing the existing telecom network. A major operation that must be achieved before data reaches the modem is the separation of the digital broadband signal from the analog voice channel–this is done by adding a splitter.

The ADSL modem–also referenced as ADSL Terminal Unit at Central Office side (ATU-C) or ADSL Terminal Unit at Customer Premises side (ATU-R)–handles the upstream and downstream signals of the ADSL communication between the service provider and the end user interface, commonly a PC at the subscriber side (**Figure 1**).

Four main functional blocks compose an ADSL modem:

- The line interface, generally a hybrid circuit based on a line transformer;
- The internal circuit which includes the ASIC chipset and the memory;
- The data lines interface;
- The power supply.

Typical protection requirements

Electrical overstresses in the form of over-voltage and over-current can occur in telecom systems due to lightning effects or from interaction with the AC power network and may destroy valuable network equipment.

To prevent these malfunctions, major regulation authorities such as ITU-T, Core and FCC have described in specific standards or recommendations the various tests that any telecom equipment must undergo to be qualified. These recommendations depend on the considered country and the location of the equipment (**Table 1**), and whether it is installed in a Central Office (CO) or at the Customer Premises (CPE).

The standards presented in **Table 1** are applicable to the equipment itself, and the protection devices' role is to put the equipment in compliance with the standards. A parallel protection element is generally used to withstand the lightning over-voltages as defined by the standards. This protection device is generally based on "crowbar" characteristics as those offered by a Trisil device, which switches on when an overstress occurs on the line, while keeping idle in normal operating mode.

	North America					Rest of the world				
	GR-974 Core	GR-1089 Core	FCC Part 68	UL497	UL1459	ITU-T K17	ITU-T K20	ITU-T K21	ITU-T K28	ITU-T K45
Customer Premises Equipt										
Primary protection										
Terminal equipment										
Central Office										
Primary protection										
CO equipment										
Network equipment										

Table 1: Specific standards depend on the country and the location of the equipment.

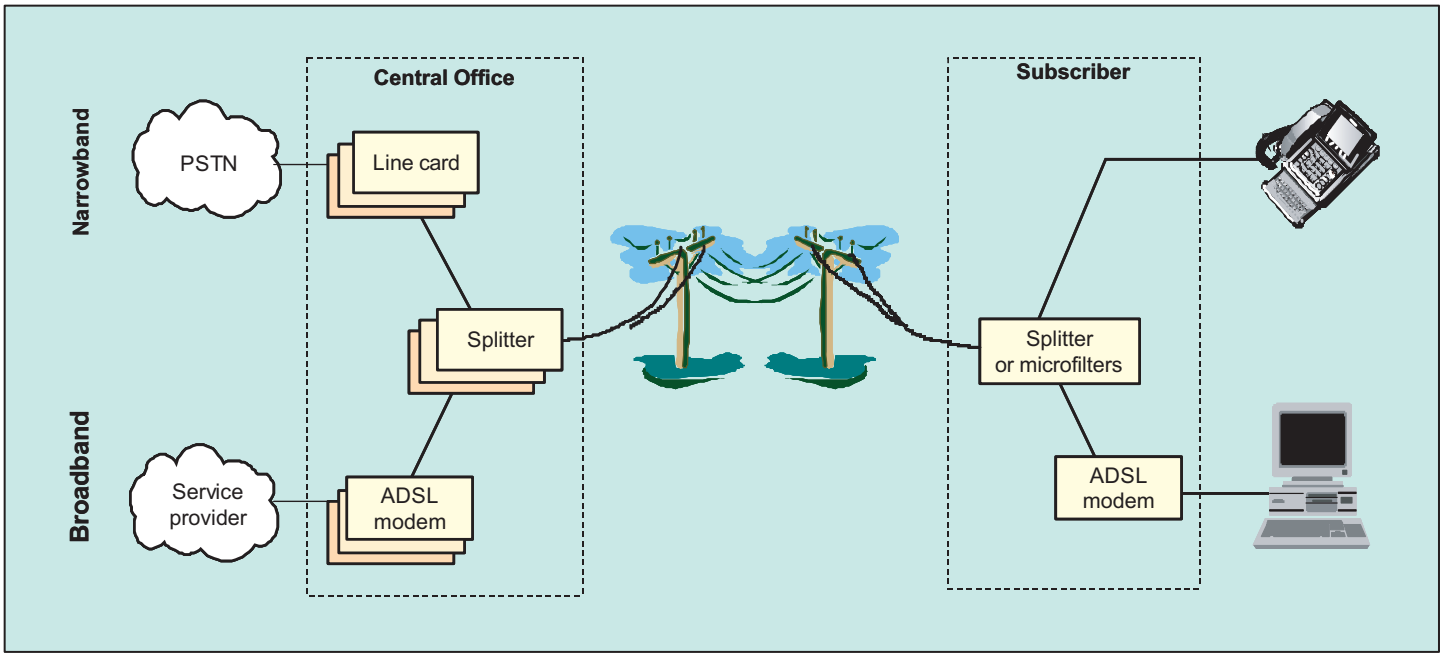

Figure 1: The ADSL modem handles the upstream and downstream signals of the ADSL communication between the service provider and the end-user interface.

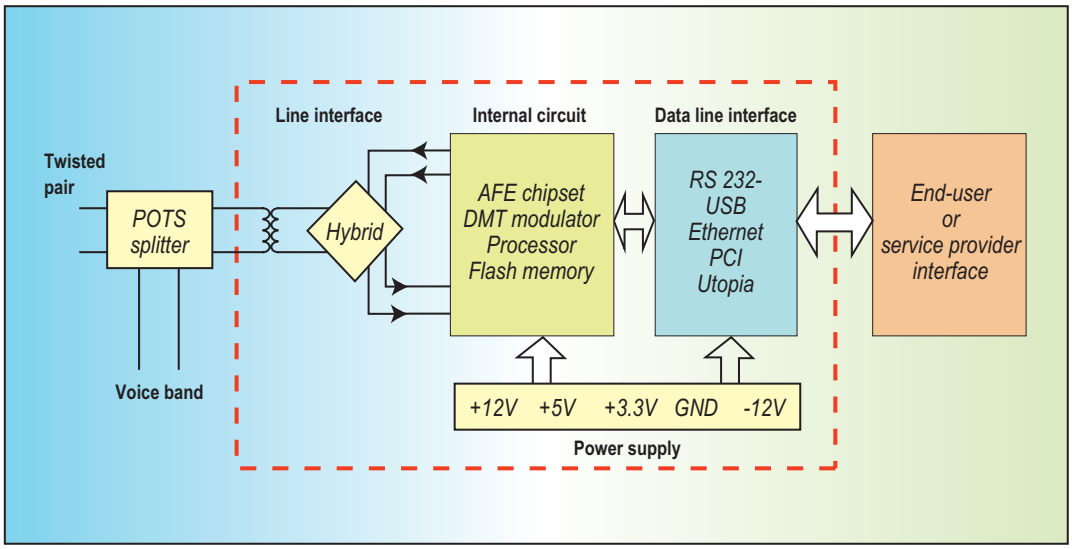

Figure 2: Four main functional blocks compose an ADSL modem.

	Europe / Asia	USA
Lightning	**ITU-T K20 /K21** 6000V 10/700µs 150A 5/310µs	**GR-1089 core** 2500V 2/10µs 500A 2/10µs
Power contact	230V up to 1.44A during 15mn 600V @ 1A during 5 x 0.2s 1500V @ 7.5A during 5 x 2s	600V, 1000V @ 1A during 60 x 1s

Table 2: The requirements for the main CO standards for equipment protection differ from those of the CPE requirements.

The standards also impose to withstand the AC power fault, also called "power crossing." The protection in this case is achieved by the combination of the parallel protection of the crowbar type and a serial protection opening the circuit under over-current.

Aside from these typical telecom protection requirements, some standards also include the protection against ESD that require tolerance without damage for the equipment to ESD events.

Line interface protection: This protection stage is generally found before the splitter to protect the complete system.

To select the right protection component, several parameters have to be defined according to the application:

- The stand-off voltage must be at least equal to the maximum voltage value in the normal operating mode of the line (ringing mode).
- The surge current capability corresponding to the relevant lightning standard.
- The capacitance, because of the high data rate used, must be minimized to lower the bit-error rate (BER)

These parameters differ for the CO and for the CPE.

CO requirements: Since the twisted pair is coming from outdoors, the protection has to comply with the GR-1089 Core 500A 2/10µs for America and with ITU-T K20/K21 for the rest of the world.

The SMP100LC Trisil family has been specifically developed to meet all these requirements. It is compliant with lightning standards and features a low parasitic capacitance value to prevent distortion of the ADSL signal in normal operating conditions. Two SMP100LC-270 (with 270V break-over voltage between TIP and Ground and RING and Ground) achieve efficient protection.

Due to the fast turn-on of silicon crowbar protections, some spikes may occur on the secondary side of the transformer. A low-power Transil device like the SMAJ15CA-TR perfectly fits to suppress them (**Figure 3**).

	Europe / Asia	USA
Lightning	**ITU-T K21** 1500V 10/700µs 37.5A 5/310µs	**FCC part 68 part B** 25A 5/320µs 37.5A 5/320µs
Power contact	230V up to 1.44A during 15mn 600V 1A during 5 x 0.2s 1500V 7.5A during 5 x 2s	Not required

Table 3: Telecom equipment must comply with the standards of the country where it is used.

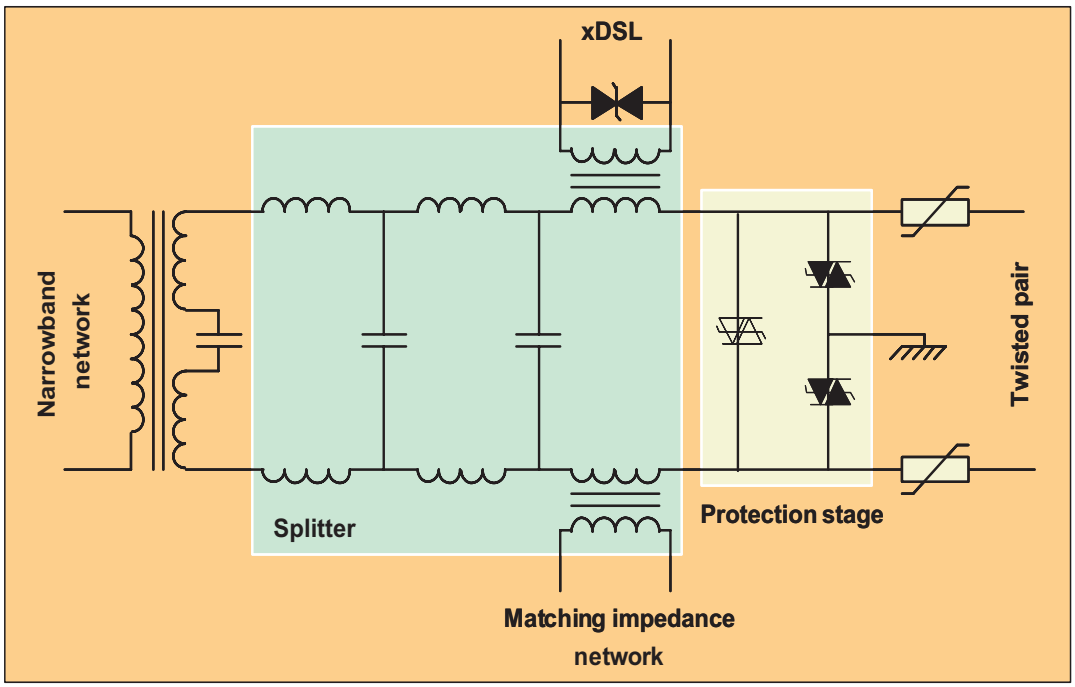

Figure 3: Some spikes may occur on the secondary side of the transformer due to the fast turn-on of silicon crowbar protections.

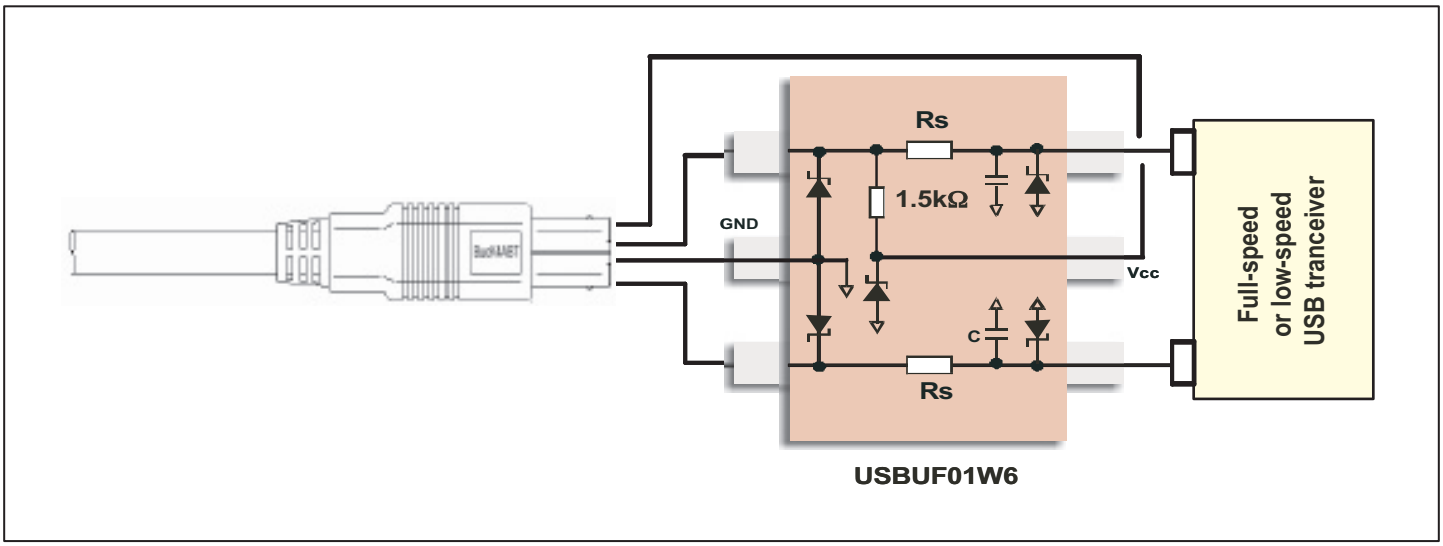

Figure 4: EMI filtering and ESD protection is achieved with the USBUF01W6 device.

	Europe / Asia	USA
Lightning	ITU-T K20 6000V 10/700µs 150A 5/310µs	GR-1089 core intra-building 1500V 2/10µs 100A 2/10µs
Power contact	230V up to 1.44A during 15mn 600V @ 1A during 5 x 0.2s 1500V @ 7.5A during 5 x 2s	Not required

Table 4: Though mainly used for intra-building communication, Ethernet ports must also comply with specific standards.

CPE requirements: Any telecom equipment must comply with the standards of the country where it is used. **Table 3** lists the main requirements found in the world with this respect.

The topology of the splitter on the CPE side is similar to the CO side, but as the standards are less severe, the protection devices can be of a lower caliber.

The SMP30 or SMP50 Trisil families comply with worldwide telecom standards for CPE and have low parasitic capacitances compatible with ADSL debit rate. For the same reason as for the CO, the SMAJ15CA-TR remains the most efficient device after the transformer (**Figure 3**).

Serial PTC or resistors are mostly used to withstand the power crossing tests.

Interfaces

Data lines Interfaces: On the data lines side, three main interfaces are commonly used: USB port, Ethernet link and PCI interface.

The USB and Ethernet ports are used for external modem connections. They may face disturbances coming from the outside environment and therefore, they have to comply with specific protection standards.

As for the PCI interface, it is generally implemented with built-in modems and as this link is totally internal to the end user equipment–it does not face the same electrical stresses from the environment.

USB interface: The most popular home data line is probably the USB. The USB1.1 technology transmits data at two different rates: low-speed (1.5Mbps) or full-speed (12Mbps). These high frequencies have imposed new design regulations to meet EMI and RFI requirements such as those of the FCC or the International Special Committee on Radio Interference (CISPR). This is in addition to the ESD standards like the IEC61000-4-2 level 4 (8kV contact, 15kV air discharge) or the MIL STD883E, Method 3015-7 (25kV).

Application	Product	Protection type	Standard compliance
Telecom line at CO	SMP100LC-270	270V - 60pF @ 2V crowbar	GR-1089 core ITU-T K20/K21
Telecom line at CPE	SMP30-270	270V - 25pF @ 2V crowbar	FCC part 68 type B ITU-T K21
	SMP50-270	270V - 30pF @ 2V crowbar	
ADSL modem secondary side	SMAJ15CA-TR	15V clamping diode	-
USB protection (upstream)	USBUF01W6	ESD protection RFI suppression Baud rate selection	FCC part 15 CISPR publication 22 IEC61000-4-2 level 4 MIL-STD 883E method 3015-7
Ethernet primary side	TPN3021	28V - 16pF @ 1V crowbar	GR-1089 core intra-building
	SMP100LC-8	8V - 75pF @ 2V crowbar	GR-1089 core ITU-T K20/21
	SMP100LC-35	35V - 55pF @ 2V crowbar	
Secondary line at service provider or 10Base-T protection	DALC208SC6	4 line rail-to-rail protection array	IEC61000-4-2 level 4 MIL-STD 883E method 3015-7

Table 5: STMicroelectronics have various products with different protection types.

The USBUF01W6 device has been specifically designed for upstream ports and has been developed in compliance with the above standards. The USB speed choice is made by the connection of the 1.5Ω resistor to D+ or D-. **Figure 4** shows the implementation of the USBUF01W6 device.

The USBUF01W6 does not only achieve protection against ESD, but also behaves as an EMI/RFI noise suppressor and supplies the pull-up or pull down resistors.

Ethernet interface: Ethernet is a LAN technology that transmits information between computers at speeds of 10Mbps and 100 million Mbps. The 10Mbps variety, or 10Base-T system, operates over two pairs of wires, one pair is used for receiving data signals and the other pair is used for transmitting data signals. Each pair is connected to the Ethernet transceiver IC through a line-transformer that isolates the system.

The Ethernet link generally requires similar line protection as for a standard telecom line. Therefore, the same lightning standards as for telecom lines apply, and a parallel protection device with crowbar characteristics must be placed before the line transformer for the following purpose:

- Ensure correct signal transmission with low capacitance to avoid possible distortion at the high data rate used.
- Keep idle while in normal operating mode. As Ethernet is based on low signal voltage, a low voltage protection device is required.
- Withstand the lightning currents and allow the system to comply with the related standards.

Mainly used for intra-building communication, Ethernet ports must comply with the standards presented in **Table 4**.

Primary protection is commonly achieved either with a tripolar crowbar device such as the TPN3021 crowbar protection or with two SMP100LC type devices, with low breakover voltage. The TPN3021 includes three Trisil. In the case of a surge, the Trisil serves as short-circuit and turns itself off again when the over-voltage has passed. After the transformer, a secondary protection is generally ensured using small diodes in a single package.

Specifically designed for protecting four lines simultaneously, the DALC208SC6 diode array provides rail-to-rail clamping feature with low capacitance. Housed in a compact SOT23-6L package, the device includes eight diodes used to connect four wires to V_{CC} rail and GND. Its low capacitance of 7pF per diode makes it particularly suitable to prevent significant signal distortion. It is a cost-effective solution in comparison with pure discrete solutions and allows easy PCB layout for the designer. □

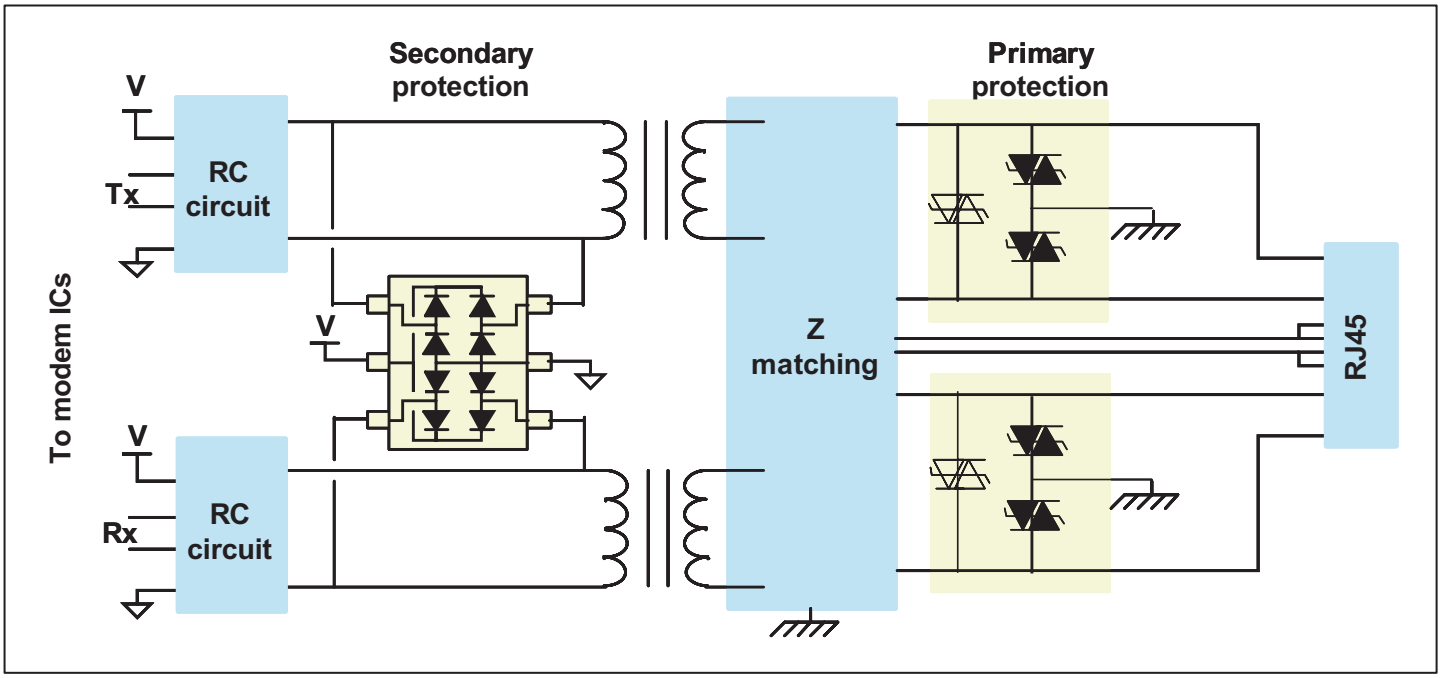

Figure 5: The 10Base-T system operates over two pairs of wires.