PROTECTING THE HIGHWAY TO THE CLOUD

Author: Phillip Havens

Introduction

Because a growing percentage of both business and personal information is stored "in the cloud," it becomes more important than ever to ensure fast, reliable access to this information. Telephone-service providers have a strong financial incentive to offer packages of services that can compete with those once available only through cable companies. In other words, they want to deliver voice, data, video and Internet connectivity to customers simultaneously and seamlessly.

Fiber networks have begun bringing high-speed connectivity to neighborhoods across the country, but for telecom providers to reach into customers' premises, they need to use the copper wiring they already have in place. Doing so will require G.fast technology, which allows customers to obtain fiber-like access speeds as telecom providers phase in their fiber deployments. Because of the enormous potential for expanding broadband coverage more economically, some industry experts are forecasting that the global market for G.fast chips will grow to $2.9 billion annually.[1]

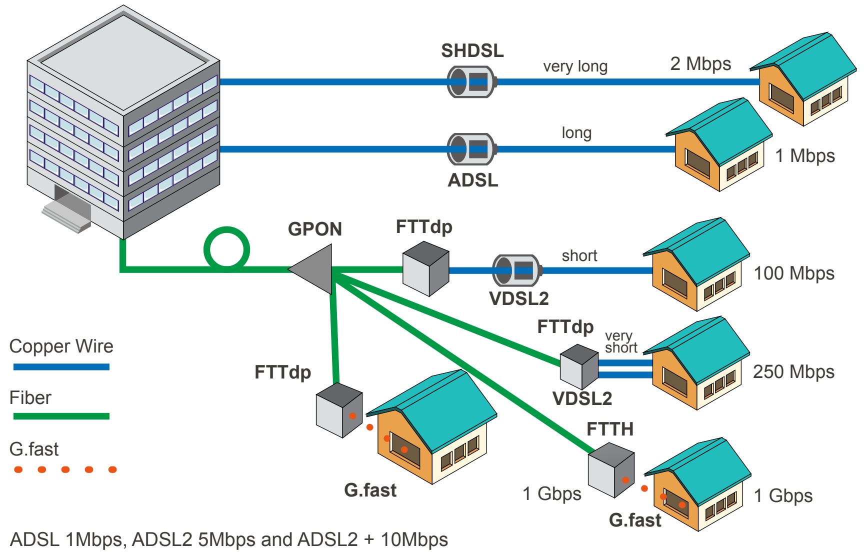

Figure 1: FTTdp access network.

Here is how G.fast makes economical high-speed connectivity possible: the telecom company installs fiber to a remote terminal (also known as fiber to the node, or FTTN) then branches out through the neighborhood over "the last mile" to the customer premises using the copper-wire infrastructure that's already in place. G.fast technology employs a wide frequency bandwidth (up to 106 MHz, with the potential of going as high as 212 MHz) to deliver the voice/data/video/Internet to the subscriber. Multipoint FTTN offers telecom companies a far more economical way to deliver high-speed data to the customer. There's no need to "roll trucks" to the neighborhood for every new subscriber; subscribers self-install the new G.fast modem in minutes and plug it into their own power system.

G.fast technology is complementary to FTTdp (fiber to the distribution point), multiport FTTdp, FTTC (fiber to the curb) and FTTH (fiber to the home), offering the advantage of not restricting the available fiber bandwidth nearly as much as previous xDSL technologies did. For example, although VDSL2 tops out at 100 Mbps, reaching that speed requires bonding (i.e., the use of two twisted-wire pairs) and vectoring to cancel out crosstalk. Similarly, ADSL2+ has a top speed of 10 Mbps, the maximum for ADSL2 is 5 Mbps and ADSL is limited to 1 Mbps. In contrast, G.fast has a targeted data rate of 1 Gbps over 100 meters of single twisted-pair (24 AWG/0.5 mm) cable; ongoing improvements to the technology offer the chance for still faster data speeds, making it even more promising. Research underway at Sckipio, the pioneer in G.fast chipset technology, also suggests that distances up to 500 meters may be possible while providing speeds of up to hundreds of megabits/second.

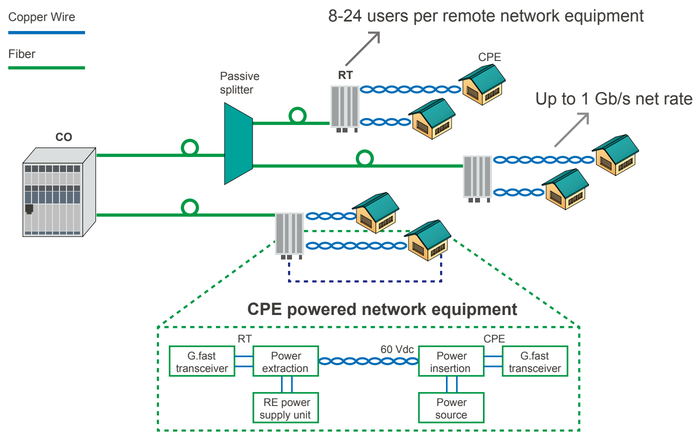

Figure 2: FTTdp G.fast architecture.

G.fast Circuit-Protection Challenges

For high-bandwidth lines such as G.fast, the capacitance of any circuit-protection components placed on the line can degrade the signal, reducing its rate and reach. But G.fast modems and circuitry in the node can't be left unprotected from lightning-induced surges. Although customer-premises equipment (CPE) designers have three basic circuit-protection options—gas discharge tubes (GDTs), transient-voltage suppressor (TVS) diode arrays and protection thryristors—whatever they choose must allow their design to comply minimally with the surge requirements of TIA-968B (formerly known as FCC Part 68). This capability is required for any communication equipment in the United States that connects to the public switched telephone network (PSTN). Other countries have similar requirements, which are outlined in Table 1. Some G.fast vendors may favor a more robust design complying with GR-1089-Core for the U.S. market.

GDTs, TVS diode arrays and protection thyristors each have their advantages and disadvantages for G.fast circuit protection:

- The advantages of GDTs include surge-current ratings as high as 20 kA and capacitance ratings as low as 1 pF with a 0 V bias. They are typically used for primary protection thanks to their high surge rating, but their low interference for high-frequency components sometimes make them a possibility for high-speed data links. But they also have some disadvantages for G.fast applications, including an excessively high initial voltage threshold (which means they may fail to activate at a threshold low enough to protect the circuit when a surge that exceeds the system's normal operating voltage occurs), GDT performance characteristics that can change when installed in dark places, a relatively large footprint and thermal accumulation during power faults.

- TVS diode arrays are clamping-type components that offer a low voltage threshold turn-on values. Because of their clamping characteristics, however, they dissipate higher power levels and therefore must be physically larger to achieve surge ratings that are similar to those of the thyristor crowbarring components. This physically larger silicon package results in higher off-state capacitance values that could be incompatible with high bandwidth signaling.

- A protection thyristor is a PNPN component that can be thought of as a thyristor without a gate. When it exceeds its peak off-state voltage (V_{DRM}), it will clamp a transient voltage to within the device's switching voltage (V_S) rating. Then, once the current flowing through it exceeds its switching current, it will crowbar and simulate a short-circuit condition. When the current flowing through it is less than its holding current (I_H), it will reset and return to its high off-state impedance. The advantages of next-generation protection thyristors for this application include a fast response time, stable electrical characteristics, long-term reliability and low capacitance. And because they are crowbar devices, voltage cannot damage them.

In the United States, circuit protection for the equipment that telecommunications companies install on their side of the network (for example, in the cabinet that houses the optical network termination unit—or ONT—in the neighborhood) must comply with NEBS (Network Equipment Building System) design guidelines, which in turn may require compliance with GR-1089 Issue 6 Port Type 3 surges. [2] Because these loops are short, the port type may be designated as Type 3a/5a. Each provider will define its own lightning resistibility requirements. Port Type 3 is the most severe case for this type of equipment. See Table 2 for more information on port types.

The latest protection thyristors are designed to protect telecommunications equipment to the high surge-level requirements of GR-1089 functionally, as long as it is correctly located in the circuit between the transformer and the DSL driver. The transformer attenuates the surge. The component can also be placed on the line side of the transformer if there is sufficient impedance between it and the entry point (typically an RJ11 connector), such as the high-pass filters implemented in these types of applications.

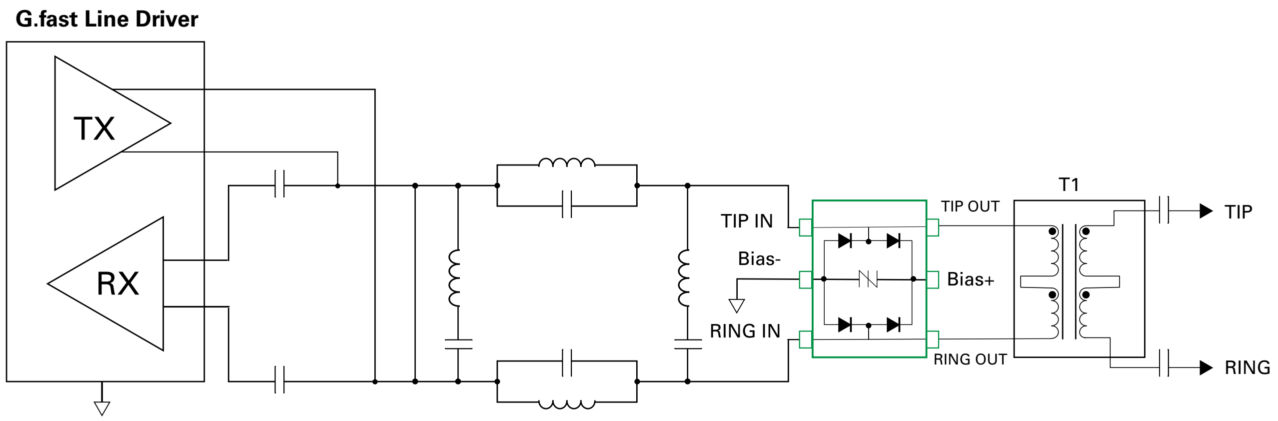

Figure 3: The amplitude of G.fast signals is much lower than those of existing xDSL services, so the varying voltage across the protection thyristor is also very low. The result is an imperceptible variation in capacitance. With the component in the tertiary position (as shown above), rate and reach testing has shown an acceptable loss of less than 0.2 dB.

G.fast Design and Worldwide Standards

When designing G.fast equipment, most companies want to design circuitry that will be compatible with worldwide standards. For international locations such as Europe, Asia, the Middle East and some South American countries, equipment must comply with either the Basic or Enhanced surge-withstand levels outlined in the recommendations shown in Table 1.

Table 1: Worldwide surge-protection standards relevant to the design of G.fast equipment

Standards	Descriptions
ITU-T K.20	Resistibility of telecommunication equipment installed in a telecommunications center to overvoltages and overcurrents
ITU-T K.21	Resistibility of telecommunication equipment installed in a customer premisis to overvoltages and overcurrents
ITU-T K.45	Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents
YD/T 950-1998	(Similar to ITU-T K.20)
YD/T 993-1998	(Similar to ITU-T K.21)
YD/T 1082-2000	(Similar to K.20 and K.45)
IEC 6100-4-5 (Level 5)	The highest level of this standard. (Testing and measurement techniques) - Surge immunity (lightning surge effects) test 3rd Edition), which is required in other European and Asian countries

Table 2: GR-1089 contains First Level and Second Level inter-building and intra-building test conditions for lightning immunity. The specific surge condition depends on the port type. More information on the requirements of these standards is in the "Ethernet Protection Design Guide," available free of charge from Littelfuse.

Port Type Number	Descriptions
1	Network Inter-Building
2	Network Intra-Building
3	Customer premises (CP) inter-building and cell site locations
3a	Intra-building cell site CP ports
3b	Short reach Outside Plant (OSP) CP ports*
4	CP Intra-building
4a	Customer side ONT intra-building
5	OSP inter-building
5a	Intra-cell site
5b	Short reach OSP ports
6	Antenna ports
7	AC power ports
8	Local DC power ports
8a	DC power to antenna
8b	Intra-cell DC power

*Typically less than 500 feet

Advantages of the Latest Protection Thyristors for G.fast Designers

The latest generation of protection thyristors offers circuit designers developing G.fast hardware a variety of advantages:

- When properly incorporated into the printed circuit board (PCB) layout, it provides lightning surge protection for both G.fast modems installed at the customer premises and G.fast drivers located in the optical-network termination (ONT) unit, where the optical fiber terminates and the signal is translated into analog. (See the line driver reference design in Figure 3. For more information on this reference design, see the "G.fast Line Driver Tertiary Overvoltage Protection Application Brief."

- Also useful for protecting a variety of telecommunications equipment to the high surge-level requirements of GR-1089, the latest protection thyristors can prevent signal degradation. This capability is the result of initial low off-state capacitance (just 2.0 pF max) and its extremely low variance in capacitance over voltage swings, so it avoids interfering with the steady-state signals (variations in capacitance demodulate the DSL signal). Together, the extremely low capacitance and ultra-low variation in capacitance allow for maximum rate and reach capabilities for G.fast services.

- By offering various stand-off voltages, it's compatible with the G.fast power-spectrum density (PSD) limits, but it can also serve in G.fast chipsets that are backward compatible with VDSL2. In these cases, many of the line drivers will increase their output voltage range to meet the VDSL2 PSD limits if they "fall back" to a VDSL2 mode. The higher stand-off voltages that this new design offers are compatible with the higher steady-state voltages typical of VDSL2. PCB signal degradation is lower because the SOT-23-6 footprint offers a flow-through design that simplifies the board-layout process. When the PCB designer lays out the board, this component allows that designer to keep the PCB traces parallel and eliminates the need for a stub connection—both conditions that could create an impedance mismatch on the line.

- A high surge rating (minimum 30 A) provides excellent protection for the G.fast modem when a lightning-induced surge races down or across the tip and ring pair. The crowbarring-type component will look like a short circuit that diverts the surge current away from the G.fast line driver, preventing it from being damaged. The thyristor automatically resets once the surge event has passed, and the modem continues to run. A surge rating of 15 to 16 amps typically won't provide enough protection and will prove insufficient for G.fast applications that experience more severe exposure, including GR-1089 Issue 6 inter-building requirements and ITU K20/21/45 Enhanced external-line recommendations.

Conclusion

Compared with the advantages and disadvantages of current GDTs and TVS diode arrays, the latest protection thyristors offering the most advanced crow-barring circuit protection, combined with G.fast technology, are on the way to making access to the cloud faster, easier and more reliable for both telecom companies and their business and residential customers.

1. "Global G.fast Chips Market 2016-2021: Industry Growth, Demands and Research Report." Posted April 20, 2016. www.sbwire.com/press-releases/global-gfast-chips-market-2016-2021-industry-growth-demands-and-research report-682101.htm

2. "GR-1089 Issue 6 Review" offers a short summary of some of the changes made in GR-1089 when Issue 6 was released. Many small individual tables focus on the ESD, surge and power fault testing per specific application types. Readers are advised to review the official GR-1089 Issue 6 document to ensure a comprehensive understanding of all requirements. www.littelfuse.com/~/media/electronics/application_notes/sidactors/littelfuse_sidactor_gr_1089_issue_6_review_application_note.pdf.pdf

About the Author

Phillip Havens is Principal Engineer of Standards and Applications at Littelfuse. He has a BSEE and MSEE from Louisiana Tech University and is a licensed professional engineer (PE). He represents Littelfuse at electronics-safety, circuit-protection and telecom-related industry associations such as the ITU, TIA, ATIS, IEC, IEEE, PEG and UL497/60950-1/62368-1 STPs. He also helps define, direct and support the company's silicon-based protection products.