Evaluating the LC SFF Interface for Single-Mode and Multimode Applications

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Small-form-factor (SFF) fiber-optic interfaces offer several benefits to both original equipment manufacturers (OEMs) and premises applications. As a result, the industry is seeing incredible growth in the use of SFF interfaces in systems to acquire 2.5-Gb/s speeds in applications such as ATM, Gigabit Ethernet, and SONET/SDH.

One of the most attractive benefits of SFF interfaces is the space savings they offer in equipment designs and patch panels. These interfaces are approximately the size of copper modular plugs, so that densities are not sacrificed in either network equipment or premises cabling applications. This may translate into lower cost for a fiber system for the OEM, since an equal number of fiber ports or copper ports are possible for the same area.

For example, suppose an OEM offers a chassis-based switch with a plug-in card that accommodates 24 copper ports. When introducing a fiber-based switch that uses ST or SC connectors and transceivers, designers would find that the connector and transceiver size only allowed for 12 fiber ports, effectively cutting port capacity in half. Today's transceivers are half the size of ST and SC transceivers, simplifying redesign. This also lowers equipment cost, by enabling the OEM to use the same panels as the copper-based design. The same density advantage holds true for patch panels and similar devices, saving space in equipment rooms. Figure 1 compares the port density of RJ-45, SC, and LC SFF interfaces.

In addition, installation of fiber optic connectors for premises applications has become a much easier process. Many suppliers now offer no-epoxy, no-polishing SFF connectors. These connectors also use a latching mechanism that is much like that used in the RJ-45 connectors.

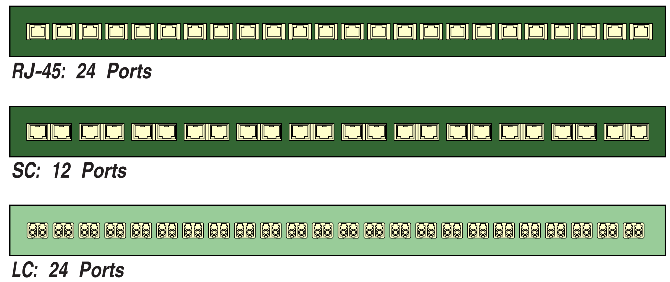

Figure 1. SFF interfaces, such as the LC, offer higher port densities than older ST or SC interfaces—and achieve densities equivalent to copper RJ-45s.

Because of the importance of SFF interfaces to future equipment designs, several manufacturers have offered an interface of their own design. Today, there are at least six different versions vying for market acceptance. In 1997, many designers hoped that the TIA/EIA committee would specify a particular SFF interface when it began to draft new premises cabling standards. Instead, the committee elected to let the market decide, requiring only that optical connectors meet specified optical and mechanical performance levels.

However, while the SFF interfaces now available may meet the TIA/EIA 568B requirements, gigabit-speed applications have shown that there are quantifiable differences between SFF connectors and transceivers, in terms of both performance and flexibility. Whether examining premises cabling or network equipment applications, the fast adoption of Gigabit Ethernet and other gigabit technologies are causing many designers to re-examine the SFF issue. With some gigabit products, the differences between SFF interfaces becomes more apparent. This is because gigabit systems offer lower power budgets, which in turn put a premium on optical performance, and complicate transceiver design.

Performance and Power Budgets

Link power was not a major issue with 10-Mb/s Ethernet, with a power budget of about 12.5 dB. However, because of the increased speeds, the power budget for Gigabit Ethernet is about 2.5 dB. The TIA/EIA-568A specification outlines an insertion loss of 0.75 dB maximum. Most SFF connectors achieve losses under 0.4 dB, but Gigabit Ethernet typically requires designers to count the number of connections in the channel. SFF connectors that provide insertion loss averaging 0.2 or 0.3 dB will occasionally exhibit losses of 0.5 dB or higher based on statistical variation. As a result, designers will frequently only provide two connections in the path: one at the equipment patch panel, and one at the telecommunications outlet, equipment room or riser closet. When three or more connections are required, as is often the case in high-speed cross connect links, designers find that they cannot use these connectors.

The LC connector (shown in Figure 2 along with a companion transceiver), introduced as early as 1997, is based on a 1.25-mm-diameter single-fiber ceramic ferrule, the same proven technology used with nearly every version of the previous generation of fiber-optic connectors. While most SFF connectors offer 0.2 to 0.4 dB performance, the LC connector generally offers performance of 0.1 dB or better. As a result, the LC connector allows ample margin for installations using cross connect architectures, providing more flexibility for rapid moves and rearrangements.

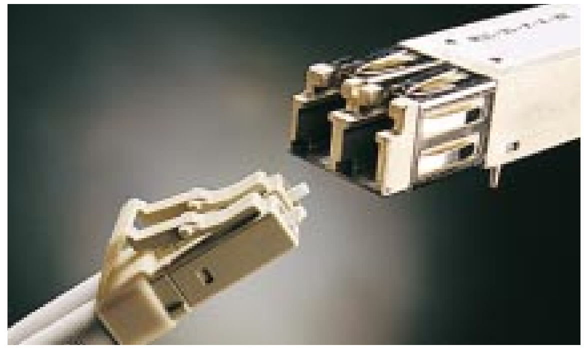

Figure 2. LC small-form-factor connectors combine the proven ceramic ferrule with a mod-jack style latching mechanism. LC transceivers are shipping today in version to cover applications needs from 10 Mb/s to 2.5 Gb/s.

The low loss also better enables a centralized network architecture, in which electronics can be consolidated at a central point and cable runs from equipment room to work area are up to 300 meters. For network architects, a centralized architecture can help to reduce costs, as well as simplify cable and network management. In addition, the ability to put more connectors in the centralized channel enables a more robust and flexible cable plant.

The LC interface at a glance . . .

Design		1.25-mm ceramic ferrules
Fiber Spacing		6.25 mm
Single-Fiber Version		Yes
Color-Coded Housing (single mode/multimode)		Yes
Insertion Loss (typical)	Single Mode	0.1 dB
	Multimode	0.1 dB
Return Loss (min)	Single Mode	50 dB
	Multimode	20 dB
Field Termination		Epoxy/polish No-epoxy/no-polish
Transceiver Availability	10 Mb/s	√
	125 Mb/s	√
	156 Mb/s	√
	622 Mb/s	√
	1.25 Gb/s	√
	2.5 Gb/s	√
Installed Base (connectors)		2 million +

Transceiver Designs

There has been widespread agreement between providers of SFF transceivers to adopt common mechanical dimensions and pinouts for their traditional through-hole devices and pluggable transceivers. The pluggables are much like GBIC devices, which enable the transceiver to be plugged into boards as needed, allowing end users to add capacity as needed or to change transceivers to meet various needs. Because of these agreements, most SFF transceiver packages are dimensionally identical. This simplifies the design process, since a single circuit board design can accommodate transceivers from many sources, regardless of the interface.

As with any electronic circuit, high-speed design presents new challenges to transceiver packages. Eliminating EMI and maintaining signal integrity at high speeds is, of course, more challenging at higher frequencies than lower. Some of the most basic parts of the transceiver design can make the task simpler or more difficult.

Some competitive transceiver designs have fiber spacing as close as 0.75 mm, which complicates the circuit design and packaging (Figure 3). The design does not accommodate hermetically sealed TO cans, which help to prevent electrical and optical crosstalk. Direct chip-on-board approaches to transceiver design require component-level separation to prevent coupling between active components and fibers. This separation is usually done requires a polymer waveguide or other mechanism between device and output port, which both complicates the packaging and assembly of the device and reduces optical power to the fiber by as much as 2 dB.

Figure 3

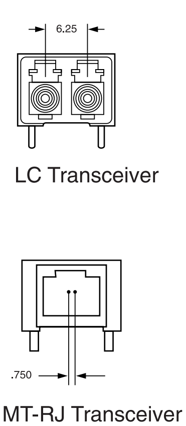

Figure 3. The wider fiber spacing of the LC interface simplifies transceiver design.

The LC duplex interface transceiver offers 6.25-mm fiber-to-fiber spacing. This permits direct coupling between the electro-optic interface and the fiber, which in turn reduces optical and electrical crosstalk, reduces power consumption, and simplifies manufacturing. Because there is no need for a waveguide, LC transceivers require less power to deliver a given amount of optical power into the fiber. Conversely, optical losses into the receiver port are reduced, thus allowing for higher receiver sensitivity.

Single-Mode and Multimode Applications

Most SFF connectors were designed originally to meet fiber-to-the-desk applications over multimode fiber, where primary concerns were low cost and rapid installation. Later, as fiber for telecommunications became more widely adopted and applications such as security and video systems became more prevalent, demand for single-mode SFF connectors grew.

The LC connector, on the other hand, was designed as a high-performance connector for both single-mode and multimode applications. In both applications, the LC connector meets stringent performance demands, with typical values of 0.1 dB for insertion loss and 55 dB for return loss in single-mode designs.

Single-mode connectors have tighter tolerance requirements in terms of concentricity, bore diameter, and other mechanical dimensions, so that single-fiber designs are optimized for performance. Achieving such tight tolerances in a two-fiber ferrule is difficult, since the tolerances between fiber bores must also be controlled. The best performing single-mode duplex connectors use ganged single fiber connectors, rather than single ferrules containing two fibers. The ganging allows the individual connectors to float so that each is free to move independently and align more accurately.

Ease of Use

To succeed in premises wiring, the SFF connectors must be not only high-performance, but also easy to install. The LC connector is available in both field-polished and factory pre-polished versions. The field polished LC is mounted with a quicker version of the familiar polishing technique widely employed for the ST and SC. The smaller diameter of the LC endface reduces polishing time by about 40 percent, compared to conventional connectors. For labor-cost-sensitive customers requiring high-performance SFF connectors, the LC will soon be available in a quick mountable, pre-polished version.

Conclusion

There is no de facto standard for an SFF interface. Many industry analysts are predicting that there will be room for more than one interface, depending on individual applications. Market acceptance of the LC continues to grow, with a large and growing range of suppliers now offering LC interface products. Today, the LC is the most widely used SFF connector, with over 2 million in the field.

From the standpoint of transceivers, the complexity of designing gigabit transceivers with closely spaced fibers has hindered widespread availability. On the other hand, LC transceivers are readily available from several sources for Ethernet, Fibre Channel, ATM, SONET, and other high-speed applications—as well as 10Base-FL, Fast Ethernet, and 155- and 622-Mb/s ATM. In fact, more transceiver manufacturers support the LC interface than any other SFF interface.