SFP optical modules: Legacy compatibility vs. improved performance

Nathan Tracy - October 17, 2017

Communication and datacenter equipment manufacturers are looking to deploy 50 Gbps or 100 Gbps data links. These links, based on high-density connections with single or double 50 Gbps electrical channels, need I/O connections that go beyond the traditional small form-factor pluggable (SFP) port. Two new approaches have emerged that enhance SFP: micro quad SFP (microQSFP) and SFP-double density (SFP-DD). The one you select will depend on your design priorities.

The defining characteristics on an I/O connector are data rate, signal integrity, and form factor. Signal integrity directly affects data rate. Form factor affects density and power dissipation.

Pluggable optics standardization

Most pluggable form factor optics come out of Multi-Source Agreements (MSAs) among connector, optics, cable and equipment manufacturers rather than standards bodies. A group of manufacturers get together and decide to support a particular type of form factor to address a market need. As a small group of like-minded companies, an MSA group can move faster in defining a new type of solution because everyone generally understands and agrees on what they intend to accomplish. A totally open standards forum like IEEE or ISO, on the other hand, includes companies that may have strong biases against a new form factor because of other potentially competing ideas or directions.

One of the basic features of any I/O configuration is that it creates a common form factor upon which manufacturers and users standardize. With pluggable optics and direct-attach copper cables, a
manufacturer could produce equipment at minimal cost by installing only the capacity a customer needs. The customer can plug in different transceiver modules as needed, paying as needs grow. If that pluggable form factor is long-lived, then as the customer needs to support different reaches, for example, having modules initially installed that are good for 2 km but later need new modules that support 10 km, they can use a module that delivers longer reach. This plug-and-play ability to upgrade reach and throughput has made modular I/O devices very successful in the market.

**The SFP Interface**

SFP has been an industry workhorse for over 15 years. Originally specified for 1 Gbps, the connector and optical industries have found ways to make this form factor work for 25 Gbps and 50 Gbps speeds. But, SFP has a single channel (one transmit lane and one receive lane) operating at these rates.

Because it has been so widely adopted, SFP has established a reference point for density and usability. Whether through plan or accident, an SFP module is about the size of your thumb and a finger you'd use to insert or remove it. If the module were smaller, insertion and removal would require a special tool and would be more difficult. As for density, 48 ports of SFP fit in 1 rack unit (RU) high equipment designed for a standard 19-in. rack, which is the same number of ports as RJ45 (Figure 1).

[Why are 19-in. racks that size?]

**Figure 1. SFP ports accept both optical modules and copper cables.**

**microQSFP**

microQSFP is a recent pluggable module form factor developed by an MSA group consisting of over 20 industry-leading companies and initially published in March 2016 with parts available now (See "Pluggable Optics Standardization."). The microQSFP MDI was recently adopted into the IEEE P802.3cd draft specification for 1x50G, 2x50G and 4x50G applications. The microQSFP form factor is the same width as SFP, but with the functionality of a QSFP module because it has four electrical channels (Figure 2). microQSFP quadruples the bandwidth density over SFP, and specific design efforts were made to enhance the thermal and EMI performance. As a new form factor, there was significant design freedom to solve these issues because the form factor was not burdened by legacy design choices. This has resulted in an I/O system that offers significant enhancements in thermal management capacity (greater than 7 W per module), which is required because of higher optical module power dissipations for current and future data rates. These benefits apply equally to
switching, server, storage and wireless applications.

**Figure 2.** microQSFP form factor modules can insert into single-height or double-height cages.

microQSFP modules can match the port density of SFP because they have the same width, but microQSFP can also be used for optical module and copper cable applications that use one, two, or four channels of electrical connectivity. Therefore, microQSFP modules can support a wide range of applications, including the developing requirements for 2x50 Gbps ports in switches and server network interface cards.

The thermal benefits of microQSFP also enable higher port count than SFP due to its airflow properties. In fact, up to 72 ports can be used in a 1RU enclosure with both front-panel and system thermal margin. microQSFP connectors offer improved signal integrity performance at 25 Gbps NRZ and 50 Gbps PAM4, along with a road map to 100 Gbps.

**SFP-DD**

SFP-DD is a newly formed MSA group, leveraging the SFP interface to forward-address new requirements. The SFP-DD interface (**Figure 3**) employs two channels that operate up to 25 Gbps NRZ modulation or 56 Gbps PAM4 modulation. The premise with SFP-DD is that customers will sometimes plug legacy cables and optics into new 50 Gbps switches they’re going to buy for the next generation. For example, a new switch might be 50 Gbps per channel, and they might want to plug their old 10 Gbps or 25 Gbps per channel modules into that switch. Ethernet auto-negotiates speeds, so the switch silicon would downshift to support these older modules and cables if required.
Figure 3. SFP-DD form factor modules insert into a SFP-DD receptacles only.

The idea behind SFP-DD is that reusing legacy cables and optics is important to mitigate the risk of next-generation optical module production ramps, whereas the premise with microQSFP (which uses an adapter for backward compatibility) is that the user will buy new 50 Gbps modules and cables to fully utilize the capabilities of a new switch. And while the receptacles are backward-compatible, SFP-DD modules can't be used in old equipment; the design requires an entirely new PCB layout.

With SFP or microQSFP, a module mates with all the contacts (a row of lower contacts and a row of upper contacts) in the receptacle at once. With SFP-DD, designers added a second row of contacts that's recessed inward on the pluggable module and on the connector, so when it inserts into the cage, it passes over the first row of contacts and mates with both the first and second rows of contacts. A legacy module only connects to the first row of contacts.

This double-row concept complicates connector design and thus impacts signal integrity. SFP-DD has a more difficult time supporting 56 Gbps because signal integrity isn't quite as good as it would be with a single row of contacts (Table 1).

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<th>microQSFP</th>
<th>SFP-DD</th>
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<tbody>
<tr>
<td>Insertion loss</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Return Loss</td>
<td>Good</td>
<td>fair</td>
</tr>
<tr>
<td>Noise</td>
<td>Good</td>
<td>fair</td>
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<tr>
<td>Integrated crosstalk noise (ICN)</td>
<td>Good</td>
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Thermal management

Thermal management
microQSFP was developed because of the premise that datacenters needed more density in their switches. The roadmaps for switch silicon show growth in port count with each new generation. Therefore, the switch chassis will need more ports; the motivation behind microQSFP was to increase bandwidth density without impacting the chassis size. microQSFP designers targeted the
general SFP size because it was a widely accepted density and was easy to use, and they targeted four lanes because that demonstrated a very convenient building block for existing and new networking architectures.

Unfortunately, increasing module density exacerbated the thermal management dilemma for the modules at both the face plate and for the switch ICs inside the chassis. With more modules in the face plate of a switch’s chassis, there was less room for perforations that admit air into the interior. To solve this problem, microQSFP incorporates thermal management design that integrates cooling fins into the module. Fins also direct the air past the module and into the switch or NIC IC’s location. With microQSFP, system air flow improves as you add more ports and temperatures decrease in high density systems (Figure 4).

Figure 4. Airflow comparison between SFP (top) and microQSFP (bottom) shows how microQSFP can maintain thermal integrity even with 50% more ports than SFP.

microQSFP has been demonstrated to be capable of at least 7 W of power capacity. In contrast, SFP-DD modules are the same size as SFP modules and can be cooled with riding heat sinks. These limit maximum port density and have a harder time efficiently cooling lower row SFP-DD ports in stacked 2-row applications. The stated goal of the SFP-DD MSA is to achieve 3.5 W of thermal capacity.

Figure 5. microQSFP modules use integrated heat sinks for thermal management.

Technical maturity
The microQSFP MSA group, currently consisting of more than 20 members, launched the MSA specification at OFC in March 2016. Since that time, optical modules have been built and demonstrated, SMT and stacked connectors and cages have been production-tooled with fully measured and validated signal integrity and EMI performance levels, and copper cable assemblies have been delivered. Thermal system level testing has been demonstrated. The SFP-DD MSA group published its specification at ECOC in September 2017 and looks forward to validation of signal integrity, EMI and thermal in the future when first parts become available.

**Conclusion**

The SFP form factor has been a workhorse in the optical transceiver and module marketplace for many years, but its limit of one channel means it cannot meet the needs of vendors who want to deliver devices that support hundreds of gigabits of throughput. microQSFP and SFP-DD are two approaches to enhancing the SFP size/density so as to address the needs of switches and NICs that will begin appearing soon.

The choice between the two approaches comes down to this: if you need higher density, excellent signal integrity, improved thermal capacity, all with proven performance, as well as a path to 400 Gigabit Ethernet and don't require backward compatibility, then consider microQSFP. If, however, you need backward compatibility with legacy “plugs,” then SFP-DD is also an option.

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