10Gbps Transceivers Slim Down
for the Data Center

Intel® enables a new generation of 10Gbps XFP Optical Transceivers

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Introduction

Today's data centers are connected at Gigabit speeds to support 100 Megabit connections to the desktop. As Gigabit connectivity to the desktop becomes more pervasive, 10Gbps optical technology will move into server, storage and workgroup switch applications in the Enterprise data center to meet the growing demand for bandwidth.

As these short reach applications put a pressure on high port density, they need optical transceivers that consume less power, are smaller in size and lower in cost, and XFP optical transceivers have been designed to satisfy these requirements. The emerging XFP Multi-Source Agreement (MSA) is focused around reducing the size, power and cost of implementing high density switching and routing equipment for 10Gbps networks. An MSA defines electrical interfaces, physical characteristics, signaling schemes and other essential characteristics that enable companies to provide system original equipment manufacturers (OEMs) with a reliable supply of standard products.

In just a few short years, we have seen the packaging of 10Gbps optical transceivers shrink from a 4" x 3.5" footprint, to a slim 2.3" x 0.68" package. Similarly, optical transceiver power consumption has dropped from 10W to under 3W. Price is also coming down as manufacturers refine their designs and improve their manufacturing process technologies.

The key to all of this optimization has been silicon integration. Intel's latest family of optical components are enabling the development of a new generation of XFP optical transceivers that simplify the functionality and optimize the features to address shorter reach Enterprise and Metro networking applications. These solutions are tools that will help enable 10G in the Enterprise, as prices are expected to erode over time in line with the historical trend of moving from 10M to 100M, and ultimately to 1G.

Does size really matter?

The driving force behind the XFP optical transceiver has been port density. Data centers are built around multiple racks of high-speed switching equipment, that aggregate channels from content servers and storage appliances. In a switch or router chassis, there is a fixed cost associated with the switching fabric and control processors. The best way for an OEM to reduce the cost of their system is to increase the port density on the line cards that plug into the chassis.

With a body width that is half the size of its predecessors, XFP optical transceivers enable up to 16 channels to be implemented within a chassis that would plug into a standard 22" equipment rack. Of course, with such high port density, cooling and heat dissipation become crucial. The small form factor and limited surface area makes it difficult to dissipate heat from the transceiver. Thus, the XFP MSA has specified the package at 2.5 W when used in a system that provides 100 linear feet per minute of airflow. For Local Area Network (LAN) and Metropolitan Area Network (MAN) applications, this power requirement can easily be met using the latest silicon and VCSEL technology. For Wide Area Network (WAN) applications where the optical transmit power is higher, meeting the 2.5W power rating becomes more of a challenge.

Over the past several months, the XFP MSA for 10Gbps optical transceivers has greatly accelerated and converged development efforts towards serial data path implementation for 10Gbps optical communication ports. At the same time, XFP also offers convenient system implementation with simpler printed circuit board (PCB) choices and other advantages such as protocol agnostic optical transceivers that result in lower overall system cost. More than 70 companies have signed up behind this MSA including Intel, who was actively involved in the MSA ratification process.

Usage environments & attributes

In general, the XFP optical transceiver has been designed to conform to the performance and distance requirements of 10Gbps Ethernet. The transmission rate and encoding used for SONET OC-192 are slightly different, yet well within the capabilities of an XFP optical transceiver. In fact, since the serializer/deserializer (SerDes) and encoding functions are now performed by the digital controller, the XFP optical transceiver is protocol agnostic and can therefore be used for many different applications such as Storage Area Networks (SANs) and Ethernet switches, giving OEMs a clear cost advantage in terms of re-usability across multiple platforms.

As indicated in Figure 1, the XFP optical transceiver is merely responsible for driving the laser and amplifying the signal from the photodiode. The media access controller used to drive the XFP optical transceiver essentially determines the application protocol that creates advantages such as a protocol agnostic optical transceiver. This allows the system manufacturer to qualify one optical transceiver and then use it in various applications. Additionally, moving the digital functions out of the transceiver and into the digital application specific integrated circuit (ASIC) helps the silicon designers introduce efficiencies through Moore's Law. Moore's Law states that that the number of transistors per square inch on integrated circuits will double every year. Stated differently, with each shrink in process technology, it is easier to drive down power and cost with a digital process, as compared to an analog process. Thus, consolidating the digital functions helps silicon designers optimize these functions.

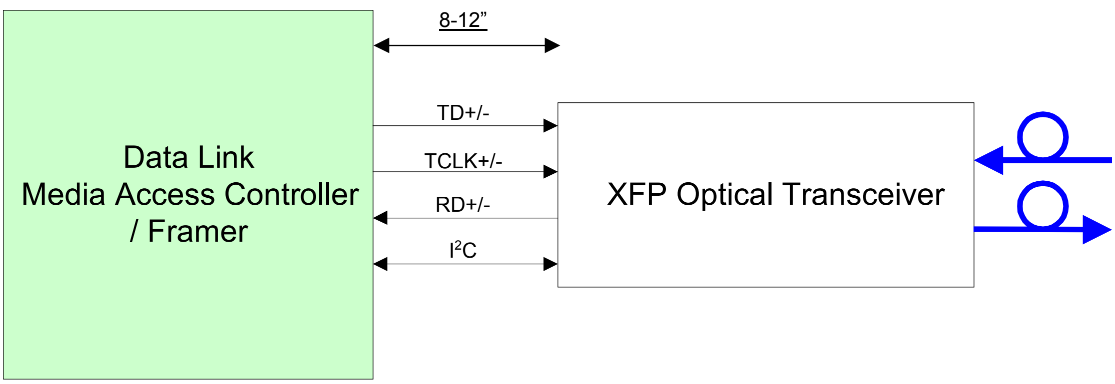

Figure 1. XFP Optical Transceiver Application Diagram

In addition to lower power and a smaller footprint, the other salient feature of the XFP optical transceiver is the XFI serial electrical interface. Only one differential pair is used for the transmit channel and another pair for the receiver. There is also a differential clock line into the transceiver. This 6-wire interface simplifies signal routing. It also keeps the electrical connector small, which is key to reducing the body width and enabling the small form factor. If the interconnect traces are properly laid out using stripline structure, the interface allows up to 8" transmission distance over standard FR-4 PCB material and up to 12" with Rogers PCB material.

Not as easy as it sounds

While it may all sound simple, be assured there are significant challenges in implementing 10Gbps XFP optical transceivers. Overcoming the loss of the FR-4 PCB material is the primary challenge, but definitely doable with today's technology. At 10Gbps, an 8" length of FR-4 exhibits approximately –15 dB of loss. Since crosstalk is a major concern, transmit pre-emphasis is not a viable tool for offsetting the channel attenuation. In fact, the transmit signal is kept below 500mVpp in order to reduce radiated emissions and Electro-Magnetic Interference (EMI). To overcome the attenuation and distortion, a signal conditioner is required at the input to the electrical receiver. But adding a signal conditioner will still not solve the EMI issue, thus being difficult to guarantee Class II FCC compliance.

The signal conditioner equalizes the incoming data stream and retimes the signal. Even with a reconditioned circuit, the board designer must be careful to minimize discontinuities in the transmission path. Signal lines should be buried in a stripline configuration in order to maintain constant 100 Ohm differential impedance and reduce radiated emissions and noise susceptibility. If the layout is done carefully, the connector will probably be the most vulnerable element in the transmission path. Fortunately, connector manufacturers are addressing the problem and have developed a 30-pin edge connector that maintains controlled impedance and provides shielding to minimize crosstalk and radiated emissions.

The small XFP optical transceiver package size effectively allows the designer about 0.5" x 0.2" on the internal substrate, for placement of the signal conditioning laser drivers, receive amplifier, and clock and data recovery (CDR) components. With such a small working space, it has been up to silicon designers to optimize component functions for low heat dissipation and reduce the device count through silicon integration.

Intel's solution

The Transmit Path. Figure 2 shows Intel's components solution for XFP optical transceivers. In the transmit path, the solution consists of the Intel® LXT16714 10Gbps 1:1 Re-timer and the Intel® LXT17001/11 Laser Driver. The re-timer is used for jitter suppression, which is currently an optional feature in the XFP MSA, also known as the Clock Multiplier Unit (CMU) mode. The benefit of a re-timer is to eliminate jitter that is being applied to the signal from the system side and the contribution of Inter-Symbol-Interference (ISI) from the PCB trace. This feature enables OEMs to build a true SONET compliant module, which conforms to ITU/Telcordia jitter recommendations. Today the optional CMU mode is not widely adopted and traditional signal conditioning devices are used instead, making it difficult to develop true SONET compliant optical transceivers as the total jitter budget comes from the contribution from the host, ISI from the PCB, and from the transceiver itself. As the total budget is tight, one can imagine that the portion from the optical transceiver has to be even tighter. If the optional CMU mode is supported only the jitter generated by the XFP optical transceiver itself will be passed to the optical fiber.

As described, today's architectures are typically built up with a CDR device in the transmit path. In addition to the CMU mode device described above, Intel has several CDR solutions available today. The Intel®LXT16723 is a low power, low form factor CDR, whereas the Intel® LXT16715 is a signal conditioning transceiver holding a bi-direction CDR.

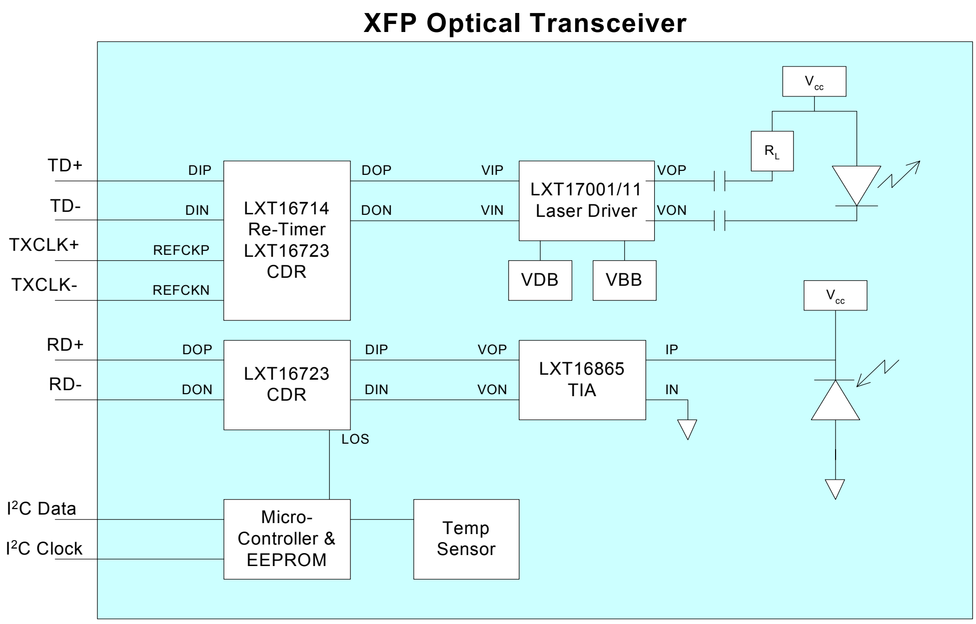

Figure 2. Intel® Components Solution for XFP Optical Transceiver Applications

One of the challenging but exciting features of the XFP optical transceiver is hot-plug-ability, which is not an easy task. The user must be able to insert the transceiver during normal operation of the host application. There is no training sequence and the receiver must synchronize to the incoming data stream within 300ns. The electrical interface is AC coupled, yet the incoming signal can exhibit significant overshoot during the hot-plug event. The Intel LXT16714 10Gbps 1:1 Re-timer has the required overshoot protection to withstand the hot-plug event.

The Intel LXT16714 is a Phase Lock Loop (PLL) and encompasses the associated Voltage Controlled Oscillator (VCO), phase and frequency detectors that are required to implement the re-timer function. Depending on the clock reference and external loop filter, the device can be configured to address bit rates ranging form 9.95 to 11.1Gbps. A Current Mode Logic (CML) output is provided to directly drive the Intel LXT17001/11 Laser Driver.

The Intel LXT17011 Laser Driver is capable of delivering up to 90 mA of bias current and 60 mA of modulation current to the laser source. These drive levels make the device suitable for use with VCSEL, FP, and DFB style lasers. Applying the proper voltage reference to the VBB and VMB pins sets the modulation and bias current. Once configured, the device provides sufficient optimum driver current with minimal overshoot (<10%). Rise and fall times are under 30 ps, providing reliable signal integrity.

<u>The Receive Path</u>. The receive path is made-up of the Intel® LXT16865 High Gain Transimpedance Amplifier (TIA) and the Intel LXT16723 10Gbps 1:1 CDR. The Intel LXT16865 operates from a 3.3 V power supply, whereas the Intel LXT16723 operates from a dual 1.8V/3.3V power supply, and both devices are designed in CMOS or BiCMOS technology that is key to driving down the power and cost of the implementation. The devices are also available in either chip scale packaging or die form, that ensure short interconnects and reliable signal integrity.

In the receive path, the photodiode converts light energy into an electrical signal. Output from the photodiode can range from 20 μA to 20 mA, depending on the light energy of the incoming signal. The Intel LXT16865 TIA converts this input current into manageable voltages. The Intel LXT16865 TIA is also a current mode amplifier. Negative feedback is implemented internally to stabilize the device and set the transimpedance gain. Transimpedance gain is best when the feedback resistor (R_f) is large. However, too much feedback resistance can also cause stability problems. The LXT16865 provides transimpedance gain of 12 kohms, which is sufficient to produce a voltage large enough for detection by the Intel LXT16723 10Gbps 1:1 CDR or the Intel LXT16715 10Gbps 1:1 Signal Conditioning Transceiver. Input noise is less than 10 pA/sqrt(Hz), which is below the noise floor of most photodiodes.

Similar to the Intel LXT16714 10Gbps 1:1 Re-timer in the transmit path, the Intel LXT16723 10Gbps 1:1 CDR is a PLL device. However, both the Intel LXT16723 and the Intel LXT16715 10Gbps 1:1 Signal Conditioning Transceiver qualify for the transmit path if the CMU mode is not supported. The CDR features an integrated limiting amplifier, which quantifies the signal levels so they can be presented to the subsequent phase detector. Incoming data is sampled to determine the optimum bit period. The device also determines the optimal sampling point, resulting in low jitter and an open eye.

Conclusion

To meet growing demands for bandwidth, 10Gbps speeds will soon move from the backbone to server, storage and workgroup switch applications in the Enterprise. This will require optical transceivers that consume less power, are smaller in size, and are lower in cost.

Increasing port density in switching and routing equipment is one of the best means for driving down the cost of implementing a network. XFP is all about increasing port density and driving down cost of the optical transceivers. While it ultimately brings simplicity to the system, implementation can be challenging. Intel's 10Gbps XFP component solution addresses many of the challenges and facilitates the design and implementation of the XFP optical transceiver.

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For specific information on the Intel products mentioned herein, refer to the links below:

Intel® LXT16714 10Gbps 1:1 Re-timer

Intel® LXT16715 10Gbps 1:1 Signal Conditioning Transceiver

Intel® LXT16723 10Gbps 1:1 CDR

Intel® LXT16865 High Gain Transimpedance Amplifier

Intel® LXT17001/11 Laser Driver

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Intel around the world

United States and Canada
Intel Corporation
Robert Noyce Building
2200 Mission College Blvd.
P.O. Box 58119
Santa Clara, CA 95052-8119
USA

Europe
Intel Corporation (UK) Ltd.
Pipers Way
Swindon
Wiltshire SN3 1RJ
UK

Asia-Pacific
Intel Semiconductor Ltd.
32/F Two Pacific Place
88 Queensway, Central
Hong Kong, SAR

Japan
Intel Kabushiki Kaisha
P.O. Box 300-8603 Tsukuba-gakuen
5-6 Tokodai, Tsukuba-shi
Ibaraki-ken 300-2635
Japan

South America
Intel Semicondutores do Brasil
Av. Dr Chucri Zaidan, 940-10th floor
Market Place Tower II
04583-906
Sao Paulo-SP-Brasil

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