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Application Note

Applying the Optobus™ I Multichannel Optical Data Link to High-Performance Communication Systems: SCI, Fibre Channel, and ATM

OPTOBUS I

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This application note discusses the applicability of Optobus I for communication systems, focusing on SCI, Fibre Channel and ATM. A detailed description of the Optobus technology is included.

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Abstract

This paper describes sample communication applications with the Optobus™ I data link. Optobus I is a multichannel optical data link which has an aggregate bandwidth of 4 Gb/sec bidirectional and a distance of 300 meters, with plenty of headroom for future expansion. Such capability might be required for shelf–to–shelf or rack–to–rack data movement in high–performance routers, switches, file servers, and public telecommunication equipment. Because Optobus I is a purely physical link, it can operate in a variety of protocol environments. Fibre Channel and the Scalable Coherent Interface (SCI) are selected to represent high–performance serial and parallel interconnects respectively. An analysis of each shows the situations in which Optobus I might be selected to work with such protocols. Because Optobus I offers higher bandwidth and lower cost, it can replace serial physical links for reduced distances. In an interconnect environment which is already parallel, Optobus I offers increased distance over copper cables.

Introduction

High–speed networks require physical links capable of handling multi–gigabit data rates. To date, the only viable options have been serial copper or fiber, and parallel copper. The former requires expensive mux/demux circuitry and has limited headroom for bandwidth improvements, while the latter requires bulky cabling and has limited distance. This paper takes a brief look at a sample from each methodology — Fibre Channel and the Scalable Coherent Interface — and shows how the Optobus I data link might operate in each environment.

Optobus is a multichannel link technology capable of multi–gigabit data rates. Designed for high–volume manufacturing, Optobus offers a combination of distance and bandwidth which is unattainable with previous solutions. Because Optobus I is a physical link which imposes virtually no restrictions on the designer, it can be easily integrated into any communication system.

This paper is divided into six sections. First, a review of the physical interconnect options available today shows the need for Optobus. Second, the fundamentals of the Optobus I data link are introduced. This first Optobus implementation has an aggregate throughput of 4 Gb/sec in each direction and a distance of up to 300 meters, with a high–volume price target of < $100/Gb for a complete link (two transceiver modules and two connectorized fiber ribbons). By outlining the characteristics of the main functional blocks and their implementation we show how Optobus I simultaneously achieves its design targets for cost, performance, and ease of use. This first link is an entry product; the underlying technology can support far more bandwidth and distance.[1]

Third, Fibre Channel is selected as a representative serial optical interconnect. Fibre Channel is capable of 1.0625 Gbaud operation. Because Optobus transfers data in parallel vs. serial, it can replace the physical portion of such serial standards in certain situations. The key word here is “certain”: a standard such as Fibre Channel has advantages today, including interoperability (for interconnects to equipment from other vendors) and distance. An examination of the logic required to implement a serial physical link shows its complexity and lack of headroom, and presents an argument for a technology such as Optobus in lower–distance applications.

Fourth, the Scalable Coherent Interface (SCI) is discussed. SCI is a parallel communication standard with a maximum defined speed of 1 GByte/sec. With copper cable, SCI is limited to approximately 10 meters for lower–speed implementations and 3 meters for the top speed. Because it is parallel, Optobus is virtually a drop–in replacement for the copper cable used to date, and can yield immediate distance increases.

Fifth, a brief application example is presented in which multiple ATM signals are transferred in parallel. Finally, summary and conclusions are presented. The applications shown in this paper are representative of what is available today and of what is under development for tomorrow, given the physical interconnects previously available. The most exciting applications are the ones which haven’t even been thought of yet because system designers have never had a tool like Optobus with which to work.

Physical Interconnect Options

The two main interconnect methodologies available today are parallel copper, and serial copper or fiber. Parallel implementations have the potential for higher bandwidth than serial ones, but many problems have limited their widespread use in high–speed applications. Noise is a concern, although noise can be somewhat alleviated by differential signaling. The bulk and weight of high–performance copper are also awkward: gigabit bandwidth requires thick, individually shielded cable. The primary limitation, however, is skew. Copper cabling is mechanically drawn, and reducing cable–to–cable skew is extremely difficult. Today, connectorized shielded cabling with 4–5 ns cable–to–cable skew over 25 meters can cost hundreds of dollars in volume.

Serial interconnects dominate in the LAN environment and are emerging as system level interconnects due to the limitations of parallel copper. The cables are of course less bulky than parallel copper but the mux and demux electronics

1”Low–Cost, High–Speed Parallel Optical Data Transfer Using OPTOBUS™ Technology;” Jerry Grula, Rich Parks, and Daniel Schwartz; High–Performance System Design Conference, Design SuperCon ’95.

can be expensive. Examples such as Fibre Channel will probably provide cost effective solutions out to a few hundred Mb/sec, but the cost and difficulty of serial solutions escalates as the data rates approach 1 Gbit/sec. These problems are related to the fundamental difficulty of fabricating and packaging ICs that support gigabit clock rates as well as to the difficulty of providing a clean electromagnetic environment on the required boards.

Because serial interconnects are not keeping up with the bandwidth requirements of shared memory/distributed processing systems, high–performance parallel protocols are beginning to emerge. The Scalable Coherent Interface (SCI) allows up to 8 Gb/sec with an 18–bit width, and the High–Performance Parallel Interface (HiPPI) allows up to 1.6 Gb/sec with a 64–bit width[2]. Because of the skew and noise problems of copper mentioned earlier, however, the specifications for these protocols severely limit the maximum interconnect distance.

Figure 1 illustrates the performance of Optobus I as compared to traditional serial and parallel interconnects. Recently, serial solutions have entered the gigabaud region, and distances in the kilometers are available. To some extent, the designer implementing serial interconnects can trade off cost vs. distance and bandwidth, but improvements in bandwidth will become increasingly cost–prohibitive. Alternatively, parallel copper offers the higher bandwidth but is severely limited by distance.

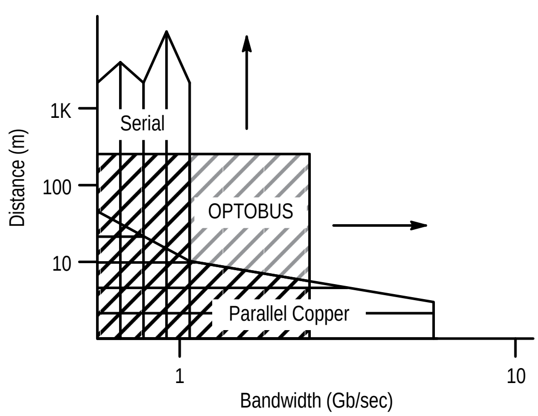

Figure 1. Distance vs. Bandwidth

Applications requiring distances of 10–300 meters and multi–gigabit speeds are represented by the shaded area. For such applications, Optobus I is an excellent fit. Follow–on performance increases will expand this region. This does not mean, however, that Optobus I should not be considered for the shared regions: its price, performance, and ease of use may make it an attractive alternative.

Optobus I Technology

The Optobus I optical link is a 10–bit wide bidirectional data interconnect solution for point–to–point applications (see Figure 2). The link is totally asynchronous and DC coupled with a timing accuracy better than 1 ns. The user can treat it as a cable with extremely low skew and no losses.

2 The ANSI X3TII Committee is currently working on a 6.4Gb/sec version of HiPPI (HiPPI–6400).

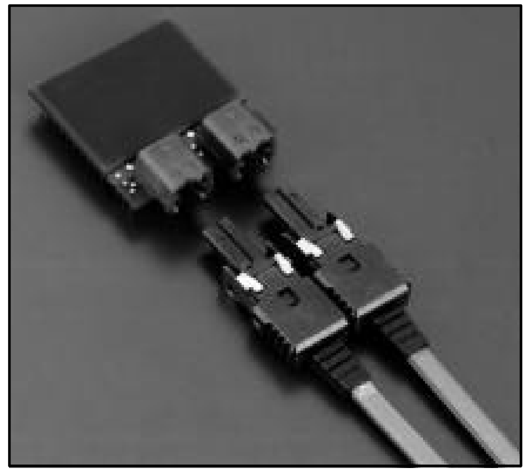

Figure 2. Optobus I Data Link

This next–generation link represents the enabling breakthrough technology required to utilize opto–electronics in a low–cost environment. The optical link consists of two identical transceiver modules and two separate connectorized 10–fiber ribbon cables, providing bidirectional capability at 4 Gb/sec in each direction (400 Mb/sec per channel).

The design goal was to provide clean data transfer at multi–gigabit speeds cost–effectively. Note that labeling Optobus I as a 400 Mb/sec per channel link is based on defining “clean data transfer” as a 1.5 ns eye opening for data sampling. Advanced users may select to use a smaller opening (i.e., higher frequency), provided that the rise/fall times, jitter, and skew are accounted for. Motorola will work with customers on a case–by–case basis to determine the performance limitations of Optobus I within their specific systems.

The basic Optobus link presented herein only begins to tap the potential of the underlying technology’s capability. Since the module is a low cost MCM and the limiting factor on performance is the speed of the electronics, new products with more capacity or higher levels of functionality could follow quickly. For example, a follow–on to the existing module is in development which will double the speed with no change in either the form factor or pinout of the part. The goal of this family of interconnect solutions is to minimize the effort required to design in or upgrade the interconnect.

Key attributes include the following:

- Current Mode Logic (CML), a low–voltage differential I/O that provides for easy interface. As a transitional solution, it can drive and be driven by differential PECL I/Os. Due to the wide margin characteristic of differential I/Os, it is also very easy to design into ASICs of any technology. CML style I/Os have been used for years in high performance systems to support clock rates up to a Gb/sec.

- The link is transparent, it can accept an NRZ data stream (i.e., no encoding is required), and each channel is asynchronous (i.e., no timing requirements are stipulated). The result is a “perfect cable,” with < 1 ns channel–to–channel timing accuracy for distances up to 300 meters and with no electrical loss.

- All of the traditional advantages of fiber are available. These include light weight, compact size, and freedom from electro–magnetic interference issues. Mechanically, Optobus provides clear advantages over existing copper solutions. Copper solutions are inevitably heavier, bulkier, and require massive connectors to support the cable.

Figure 3 shows the major components of an Optobus I module. Two 10–bit multimode fiber ribbons interface the transmit and receive subsections to the second module (not shown). Because the core of this multimode fiber (62.5 μm) is eight times larger than that of single mode fiber, the alignment tolerances are relaxed from those of traditional fiber optic solutions.

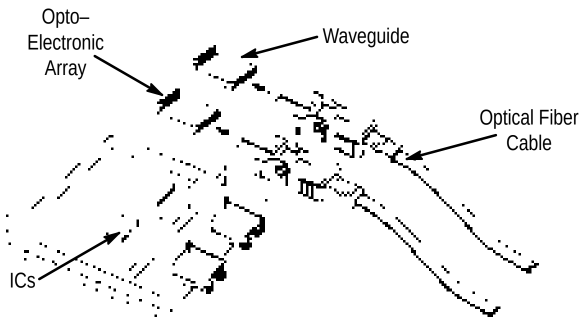

Figure 3. Optobus I Exploded View

The optical wave guide is one of the breakthrough enabling technologies of Optobus I. These wave guides, manufactured by standard molding techniques, provide a convenient and manufacturable optical interface for the transceiver module. The module assembly cost is kept low by restricting optical alignment tolerances to the mating of the lasers and photo–detectors to the corresponding wave guide. This passive alignment is performed simultaneously with the electrical connection by a flip chip attachment process.

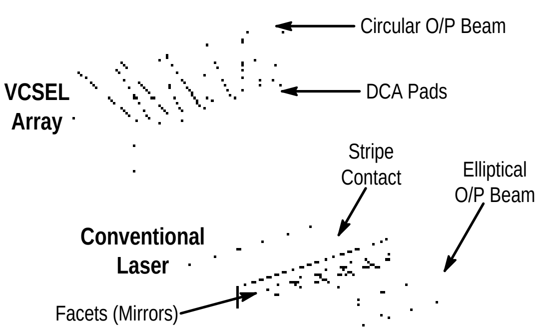

Figure 4. VCSEL versus Edge–Emitting Laser

Another breakthrough enabling technology, shown in Figure 4, is the x10 array of Vertical Cavity Surface Emitting Lasers (VCSELs). VCSELs have several advantages over traditional lasers. First, edge–emitting lasers must be cleaved and packaged prior to testing, whereas the laser output of VCSELs is perpendicular to the substrate, allowing probe testing at the wafer level. Thus, the lasers are known to be good prior to further assembly. Second, VCSELs can be modulated directly from an NRZ data stream with fixed bias and drive currents, simplifying both the packaging and electronics as compared to traditional lasers. Third, a VCSEL output beam is virtually circular, whereas an edge–emitter output beam is highly elliptical. This makes coupling simple and soen not require lensing.

Although the opto–electronic devices are compound semiconductors, the IC content of an Optobus I module is exclusively silicon: 12 GHz f_T bipolar in the receiver subsystem and 1 μm CMOS in the transmitter subsystem. Both processes have been qualified for years within Motorola. These processes were selected over newer, faster ones for a reason: by not pushing the limits of silicon technology, risk is minimized while still providing a high–performance interconnect. Follow–on products which significantly improve performance will simply require a re–design into newer silicon technologies.

Finally, the ICs, optical interface units and bypass capacitors reside on a laminate multichip module (MCM–L) substrate. The substrate is carefully designed to provide a clean electrical environment and to eliminate interactions between the receiver and transmitter subsystems. Because of the tight integration of the separate components as a multichip module, the user can treat the link as a black box without any knowledge of optics or the internal features of the module.

Figure 6 contains a logic block diagram of one–half of an Optobus I link (i.e., one direction of transmit and receive). All user interface with the link is electrical, so no optical expertise is required. The next several paragraphs describe the electrical functionality of Optobus I.

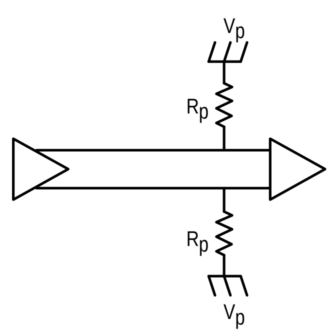

Figure 5. I/O Description

In order to control the amount of electrical noise inside the module and to ensure signal integrity on the customer's boards, the module uses Current Mode Logic (CML), a form of low voltage differential I/O. The design philosophy of the electrical I/Os is that the high output impedance differential output stage will be terminated by the customer at the line receiver with pull up resistors matched to the transmission line impedance as shown in Figure 5.

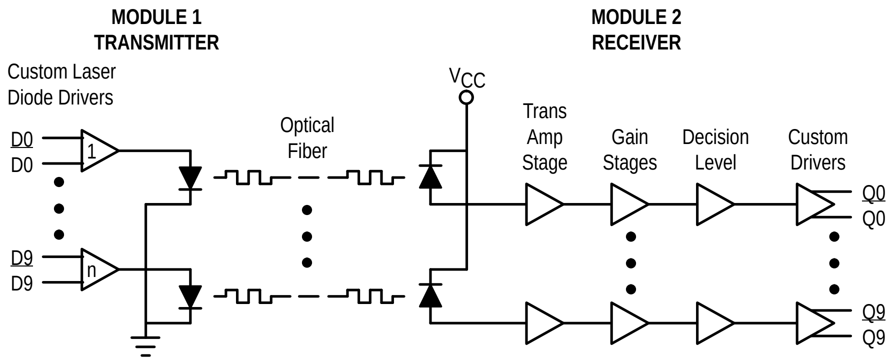

Figure 6. Logic Block Diagram –– One–Half of the Optobus I Link

The transmitter subsystem consists of a transmitter wave guide unit with ten optical outputs plus a single 10–channel CMOS laser driver IC. A block diagram of a single channel is shown in Figure 7. Several of the functions of the laser driver are invisible to the user of the module. In particular, both the laser modulation current I_{drive} and pre–bias current $I_{pre–bias}$ are digitally programmed in 0.5 mA steps as determined by package bonding options. The differential inputs require a minimum swing of 0.25V and support a common mode range from V_{CC}–2.25V to V_{CC}.

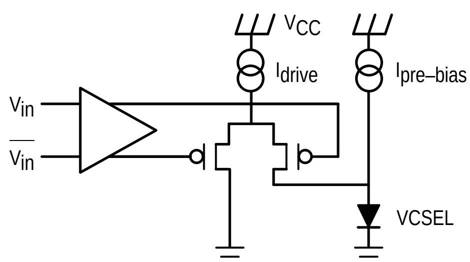

Figure 7. Transmitter Subsection

The receiver subsystem in Figure 8 is based on the ten photo–diodes in conjunction with a fixed decision threshold, DC coupled receiver IC. The line drivers at the output of the receiver subsystem are always sinking 5 mA of current through one pin of the differential pair while the other complementary pin sits in the high impedance state. Hence, the logic high state is just the pull–up voltage V_P and the logic low is V_P–0.005*R_P. For a 50Ω system, this corresponds to 250 mV swings. The line drivers have been designed to accommodate 3V<V_P<V_{CC} and thus can easily drive ECL differential receivers such as Motorola's MC100E416. While the module today requires a 5V supply, it can easily be interfaced to a 3V system by using the 3V rail as the pull up voltage. Because of this flexibility, compatible I/Os can be produced in any device technology.

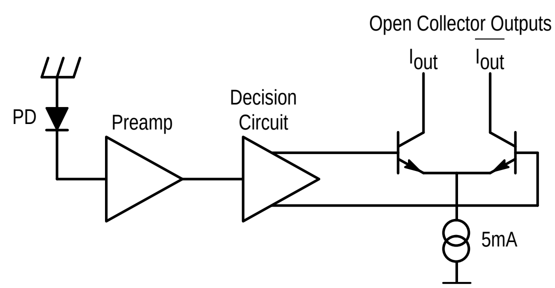

Figure 8. Receiver Subsection

Laser safety is an important factor when considering optical interconnects. The Optobus I product is certified by Motorola to be a Class I Laser product to the requirements of the DHHS Federal Product Performance Standard for Laser Products, 21 CFR Subchapter J, Part 1040.10. Class I levels of laser radiation are not considered to be hazardous.

The laser wavelength is nominally 850 nanometers. Maximum laser output power from each port is 0.8 milliwatts. The output beam diverges in a large angle cone. It is the large angle of divergence that permits classifying Optobus I as a Class I laser product even though no shutdown circuitry exists on the module.

Overview of Fibre Channel

Fibre Channel was developed to provide a practical and expandable method for high–speed data transfer among workstations, mainframes, supercomputers, desktop computers, storage devices, and display devices.[3] Among its capabilities are the following:

- Performance from 133 Mbaud to 1.0625 Gbaud. Higher bit rates may be added as faster serial physical transport mechanisms become available.
- Support to distance up to 10 km. This maximum distance is achievable using longwave lasers (e.g., 1300 nm.) and single–mode fiber.
- Small connectors.
- Support for multiple cost/performance levels.

3 *Fibre Channel: Connection to the Future*, Fibre Channel Association, 1994.

- Ability to carry multiple existing interface command sets, including but not limited to Internet Protocol (IP), Small Computer System Interface (SCSI), High Performance Parallel Interface (HiPPI), and Asynchronous Transfer Mode (ATM).

Figure 9 shows the five layers defined for Fibre Channel. FC–0, the lowest layer, specifies the physical link, including the cables, connectors, drivers, transmitters, and receivers. FC–1 (Transmission Protocol) defines the 8B/10B encoding/decoding and transmission protocol used to integrate the data with the clock information required by serial transmission techniques. FC–2 (Signaling Protocol) defines the rules for the signaling protocol and such transport “building blocks” as ordered sets, frames, sequences, and exchanges. FC–3 provides common services such as striping, which parallels multiple Fibre Channel ports for higher bandwidth. Finally, FC–4 provides mapping of the above listed upper layer protocols to the layers below.

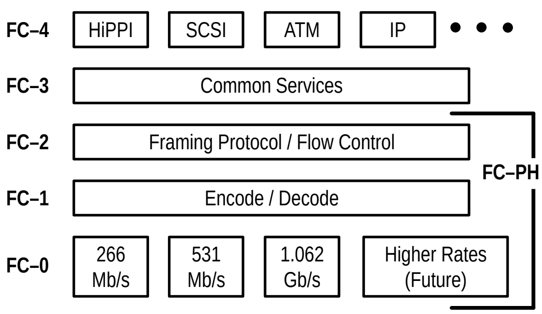

Figure 9. Fibre Channel Layers

The three lowest layers comprise the physical standard (FC–PH). The rest of this section shows how Optobus I can be used in this environment. Unless otherwise noted, it is assumed that the transmission speed is the highest defined to date (1.0625 Gbaud), as this provides the best match for Optobus I.

FC–2 defines the transport mechanism used by Fibre Channel. Several of the functions, such as link initialization and shutdown, are unnecessary with Optobus I: such information will simply be transmitted as data. Since Fibre Channel frames always contain an integral multiple of bytes, all Fibre Channel data and control information passes through the 10–bit Optobus I link using eight channels for byte data and one channel for clock.

Figure 10 contains a functional diagram of the two lowest Fibre Channel layers.[4] On the transmit side, a byte of data is provided with a clock to generate the IBM–patented 8B/10B encoded data. This encoding scheme is required with serial transmission methodologies to maintain consistent laser operation (traditional optical solutions only) and for clock recovery. These 10 bits are provided with the transmit clock to a parallel to serial converter, which provides a 1.0625 Gbaud serial signal to the laser circuitry. Note that because of the encoding and transmission overhead, the data rate is actually 100 MB/sec (800 Mb/sec).

On the receive side, the serial data is provided to clock generation circuitry and to a serial to parallel converter which, with the extracted clock, generates the 10 parallel bits of encoded data. These bits are then decoded to generate the byte of data.

The diagram also contains circuitry to perform Open Fibre Control Laser Safety protection. Such circuitry is generally required in longwave laser/single–mode fiber systems to maintain Class 1 safety certification. The Light Emitting Diode (LED) and shortwave laser media currently defined for lower bandwidth (≤ 531 Mbaud) Fibre Channel implementation do not need such circuitry.[5]

Fibre Channel transceiver operation can contain additional circuitry not shown in Figure 9. First, internal PECL receivers and transmitters provide an alternative electrical serial interface. This circuitry is muxed with the serial/parallel blocks at the optical interface. Second, internal ID Generator circuitry provides a two–bit indication of the speed of the specific module. Third, external state machines work with the modules to provide the necessary ordered sets for functions such as initialization and shutdown.

4 FCSI–301–Revision 1.0: *Gigabaud Link Module Family: Physical, Electrical, and Link Level Specification*, printed 02/16/94.

5 FC–PH REV 4.1, *Fibre Channel Physical Specification*, August 12, 1993.

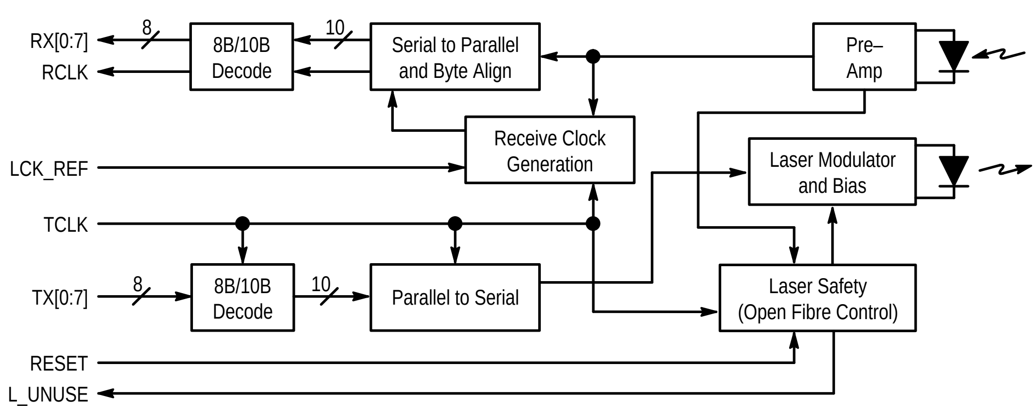

Figure 10. Functional Diagram of FC–1 and FC–0 Layers, Longwave Laser and Single–Mode Fiber

Fibre Channel and Optobus

The above functionality succeeds in meeting the gigabaud goals of Fibre Channel, but the circuitry is complex, expensive, and provides interface challenges. Essentially, a single Optobus I transceiver module provides 4X higher bandwidth. Optobus I can accept an NRZ data stream, so no encoding is required. Because Optobus I transmits data in parallel, equivalent or higher data rates are achieved with an order of magnitude lower per–channel speed than that of serial solutions. As a result, no expensive, powerful drivers and receivers are required for the optical interface. The inherent laser safety of Optobus I eliminates the need for shutdown circuitry. Because every channel of Optobus I is asynchronous and independent with respect to each other, no timing requirements are imposed on the designer other than the < 1 ns timing accuracy of the link. And because higher speed links will be available in the future, system performance improvements will require few additional design changes.

As a result, Optobus I is well suited for those applications in which Fibre Channel is being considered for distances up to 300 meters. Optobus I will not, however, operate as a direct “drop in” replacement of the Fibre Channel transceiver for reasons outlined in the following paragraphs.

The form factor of Optobus I differs from that defined by Fibre Channel. Optobus I is approximately 1.45 in. square. Fibre Channel Gigabaud Link Module (GLM) transceivers are approximately 1.4 in. wide by 3.25 in. long (approximately 2X larger). Also, Optobus I uses PGA pins at a 100 mil pitch, while Fibre Channel uses a pin connector with 50 mil pitch.

Fibre Channel transceiver modules operate in the FC–0 layer only; i.e., they accept data which is already 8B/10B encoded (and clock), and they provide the encoded receive data and clock. Thus, the interface to such modules is 11 bits bidirectional, one more bit than is available in the Optobus I link. A liberty has been taken here: Fibre Channel defines 10–bit words as nominal but not exclusive to speeds up to 531 Mb/sec, and 20–bit words as nominal but not exclusive for 1.0625 Gb/sec. If a system had been designed to provide such 20–bit words (16 bits of encoded data), 2–to–1 multiplexers and demultiplexers would be required. Alternatively, two Optobus I links could be used in parallel, although such an approach would not take full advantage of the bandwidth available.

Also required is a translation from the TTL defined in Fibre Channel to the CML/PECL of Optobus I. In fact, the above preference of 20 bits for gigabaud links is driven by the desire to allow TTL interfaces at higher speeds. TTL <—> PECL translators are readily available if necessary. Also, note that 20 TTL (single–ended) I/O can be replaced with 10 PECL (differential) I/O in the user’s interface circuitry, and that differential I/O require fewer supply pins, so pin count can actually be reduced by designing the interface circuitry with PECL I/O.

Finally, the multichannel connector used by Optobus is not specified by Fibre Channel. All of the differences listed above are important only where interoperability is a concern.

It is obvious that the Optobus I link is not a drop–in replacement for Fibre Channel, although it is possible that future Optobus products might be compliant. The Fibre Channel Enhanced Physical (FC–EP) effort is aimed at additional physical layer implementations. But the main point of this section was to show how Optobus I might fit in an application where a serial interconnect had previously been considered. For high–speed internal communications, Optobus I has the advantages of increased bandwidth at lower distances, with headroom for increases in both areas.

Overview of the Scalable Coherent Interface (SCI)

The Scalable Coherent Interface (SCI) evolved from the increasing need for shared data and multiprocessing in distributed systems. SCI defines a system architecture which supports shared memory, where every processor has access to every memory location regardless of physical location. Thus, all shared memory in the system, although physically distributed, appears to reside in a single large address space, and normal load and store instructions can access it.[6] Because SCI already uses a parallel interconnect methodology, it is an excellent candidate for use with Optobus.

The following list contains some of the key goals considered by the SCI developers:

- High Bandwidth: Maximum defined speed is 1 GByte/sec via 16 data bit channels at 500 Mb/sec/ch. Clock and frame signals are also sent for a total of 18 bits in parallel.
- Scalability: Broad applicability to a wide range of application sizes, speeds, and costs. For example, in addition to the nominal 16–bit word described above, words of 1 (serial), 4, 8, 32, 64, and 128 bits have also been defined.
- Low Latency: The delay between data request and receipt must be minimized so that a local processor is not unduly penalized for requesting distant data vs. local data.
- Coherence: Cache memory is used to store a local copy of data obtained from a distant source. If data from a shared memory location is modified while in the cache, such modifications must be provided to other processors requesting the same location. Such cache coherence must be maintained in a shared memory system.
- Interconnect Independence: Daisy chain, ring, and switch topologies are all supported. Note that these all use point–to–point interconnects between nodes. True buses are not supported, although bus bridges and some bus–like services are supported.

In SCI, the clock is sent at one–half frequency, and both edges of the clock are used for data sampling. For example, at 500 Mb/sec/ch the clock frequency is actually 250 MHz, so the “bit rate” of the clock is 500 Mb/sec (one high and one low transition in a 4 ns period). While this places added constraints on the duty cycle of the clock, it eliminates the problems of a special ultra–high 1 Gb/sec channel.

With its high bandwidth, low latency, and shared memory, SCI is well–suited for use in high–performance networked workstation clusters, distributed databases/file servers, video–on–demand, etc. For example, in video–on–demand, loading digitized video from optical storage components and then queuing it for broadcast requires massive bandwidth.

6 “Local–Area MultiProcessor: the Scalable Coherent Interface,” David B. Gustavson and Qiang Li, SCIzzL, Santa Clara University, 1994.

SCI and Optobus

Because of SCI's bandwidth goals, the interconnect methodology had to be optimized for extremely high performance. By using point–to–point interconnects, the transmission line problems associated with the multiple stubs of traditional buses are eliminated. Low voltage swings reduce drive currents and enable higher frequencies. Differential signaling reduces noise sensitivity, especially important for these low voltage swings. Finally, different paths are used for transmit and receive, which maintains a constant driver current and thus reduces noise.

While the SCI specification allows for operation up to 1 GByte/sec, practical implementations at that speed are not yet available. LSI Logic offers a CMOS "NodeChip," developed with Dolphin Interconnect Solutions, which currently provides 125 MByte/sec of data transfer (62.5 Mb/sec/ch with 16 data channels, plus clock and frame). The device operates from 0V to +5V and provides PECL–compatible I/O. Since the top rail is +5V, the differential driver is terminated with a resistor pulldown to +3V. A diagram of an SCI interconnect with such a device is shown in Figure 10.

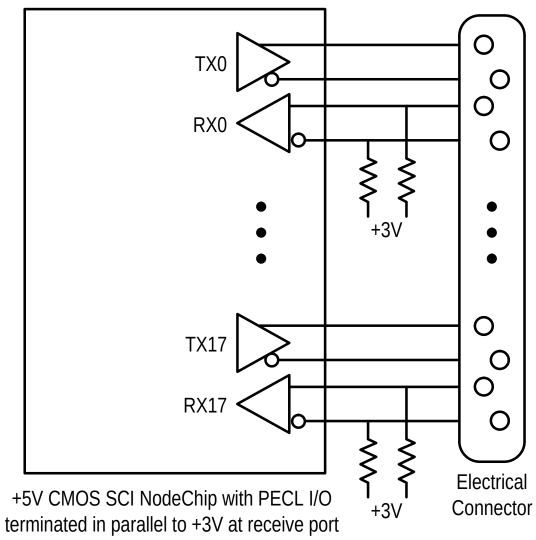

Figure 10: SCI Interconnect (PECL)

At these speeds, practical SCI copper connections are limited to about 10 meters. Optobus I is virtually a plug–in replacement for the copper cable and extends the distance to 300 meters. Since the parallel connection is 18 bits, two of the 10–bit Optobus I links replace the copper cable. Alternatively, 2–to–1 multiplexer/demultiplexer circuitry can be used to transfer the data over a single Optobus I link. The inputs to the Optobus I transmit block remain unchanged, since it accepts PECL levels. The common mode range of the outputs of the Optobus I receiver is such that it will operate with the +3V termination (as a CML pullup instead of an emitter follower pulldown), but the differential outputs would swing from 2.75V to 3V, assuming 50Ω termination. The termination may have to be switched to +5V to accommodate the common mode range of the NodeChip receiver.

Development is underway to provide SCI solutions which provide the maximum defined bandwidth. Vitesse Semiconductor, for example, is currently developing a GaAs NodeChip to operate at 1 GByte/sec.

Note that while today's solutions are PECL–compatible, the preferred technology is the Low Voltage Differential Signal (LVDS) standard developed for SCI.[7] PECL has been used to date because of its wide availability and familiarity within the industry. Future Optobus products will meet the bandwidth needs of full–speed SCI interconnects with LVDS interfaces.

Application Example: ATM and Multiple Serial Channels

Asynchronous Transfer Mode (ATM) is being heralded as the next great networking standard. Its cell–based switching can be used for a variety of traffic types — data, voice, and video. Because the cell size is relatively small (53 bytes comprised of a 5–byte header and 48 bytes of data), it is not optimized for high–performance data movement, but a large cell would inhibit the isochronous transfer of voice and video, so some compromise was necessary.[8]

At the OC–3/STM–1 rate of 155 Mb/sec, an Optobus I link has more bandwidth than is required for a single ATM channel. However, some applications may require the passing of multiple ATM channels in parallel. Because the Optobus I link provides 10 independent, asynchronous channels, it can carry 10 separate 155 Mb/sec channels plus overhead, regardless of whether or not those channels are synchronized. Such capability might be required for shelf–to–shelf or rack–to–rack data movement in high–performance routers, switches, file servers, and public telecommunication equipment.

7 *IEEE Standard for Low–Voltage Differential Signals for SCI (LVDS)*, Draft 1.00 IEEE Std 1596.3–1994.

8 *Gigabit Networking*, Craig Partridge, Addison–Wesley Publishing Company, Reading, MA, 1994.

Conclusions

Optobus is a breakthrough in cost–effective high–speed interconnects. The first product is a 10–bit wide bidirectional optical data interconnect solution for point–to–point applications. The link is totally asynchronous and DC coupled with a timing accuracy better than 1 ns. The user can treat it as a cable with extremely low skew and no losses. Optobus I provides an aggregate bandwidth of 4 Gb/sec at a distance of 300 meters, with tremendous room for performance increases.

To date, the only viable options for high–performance physical interconnects have been serial fiber or copper, and parallel copper. The former requires expensive mux/demux circuitry and has limited headroom for bandwidth increases, while the latter requires bulky cabling and has limited distance. Examples of each are shown, with how Optobus I can help the different applications in different ways. If a serial interconnect is considered, Optobus I can improve bandwidth and cost at reduced distances. If a parallel interconnect is considered, Optobus I can increase distance at a cost comparable to shorter high–performance copper cables.

High–performance communications equipment can find uses for such capability in today's systems and in their current plans for tomorrow's systems. However, the most exciting applications are the ones which haven't even been thought of yet because system designers have never had a tool like Optobus with which to work. Optobus can potentially erase the traditional boundaries between digital systems and thus allow the designer to partition systems in new ways that until now were not viable. At Motorola, we look forward to working with the design community to revolutionize systems level interconnects.

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