Optical Datalinks

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This paper discusses optical datalinks, the electro-optic devices that are the interfaces between electrical circuits and fiber optic cables. To meet the market-driven requirements of cost, performance, and early availability, datalinks must be designed and manufactured using Design for X (DFX) techniques, and well-controlled processes and easily incorporated improvements from research. These datalinks are used in both multimode and single mode systems, depending on the demands of physical distance and desired data rates. This paper will present an overview of the currently available products and technologies, including optical switches that can be used in local area networks.

Introduction

Optical datalinks are electro-optical devices that form the interfaces between electrical circuits and fiber optic cables. These units are subject to increasingly stringent performance requirements, must be rapidly introduced into production, and compete on the basis of price in many markets. To simultaneously meet these diverse requirements, it is necessary to use design and manufacturing approaches that include modularity; material and process reuse, and consistent testing approaches. Furthermore, tight coupling among the design, research, and manufacturing communities ensures a seamless and timely information flow from the laboratory to the manufacturing floor and the transformation of lightwave technology into products that meet the demands of data communications customers. Datalink designs reflect a unique blend of technologies and disciplines, including materials science, chemistry, and device physics research; the traditional design engineering fields; and high volume, low cost manufacture. Successfully integrating these apparently disparate fields has resulted in the products described here.

Datalinks provide users with the traditional advantages of fiber optics [data capacity, electromagnetic interference (EMI) immunity, minimal radiated power] combined with small size, reliability, low cost, and an easy interface to existing circuitry. This last feature frees the system designer from having to provide and integrate the electronics necessary for this interface function.

A datalink serving as a transmitter consists of the following:

- An optical receptacle (i.e., a connector) and its housing. These often are integrated.
- An emitter, electrical circuitry, and means to mechanically and electrically interconnect to a circuit board.

At the other end of an optical cable, a receiver has similar components, except a detector replaces the emitter. Traditionally, optical datalinks are used in multimode systems that use light emitting diodes (LEDs) and 50 or 62.5 micrometers (μm) core fiber. These optical subsystems are suitable for data rates up to 300 megabits per second (Mb/s) and typical distances of 3 kilometers (Km). Systems with more demanding distance or data rate requirements require a single mode fiber with a core about 7μm in diameter; lasers are used as the emitter. Increasingly, however, design and manufacturing philosophies are converging for LED and laser-based subsystems.

Components for Multimode Systems

This section presents specific characteristics of AT&T's ODL® Series II, ODL 50 Series II, ODL 125 Series II, and ODL 250H optical datalink packages. It also presents the

Panel 1. Terms and Acronyms in This Paper

AC	alternating current
ANSI	American National Standards Institute
CBIC-U	complementary bipolar integrated circuit
CMOS	complementary metal-oxide semiconductor
DC	direct current
DIP	dual in-line packaging
ECL	emitter coupled logic
EMI	electromagnetic interference
ESCON	Enterprise Systems Connection Architecture
FDDI	Fiber Distributed Data Interface
FIT	one failure in 10^9 hours
IC	integrated circuit
ISO	International Standards Organization
LAN	local area network
LCP	liquid crystal polymer
LED	light-emitting diode
ODL	optical datalink
OSA	optical subassembly
PC	personal computer
PES	polyether sulfone
PIN	positive-intrinsic-negative diode
SEM	standard electronic module
SONET	synchronous optical network
ST	straight tip
TTL	transistor-transistor logic

Fiber Distributed Data Interface (FDDI) standard of the American National Standards Institute (ANSI), FDDI transceivers (including the 1402U and 1403A), an FDDI optical bypass switch; and the 200 Mb/s transceiver.

ODL Series II Packaging. As optical datalink volumes increase and prices drop, the need for high performance at low cost becomes critical. The previous generation of ODL packages, ODL 50 and ODL 200, provided high performance and small size. To meet today's market demands, however, a less expensive solution is needed.

The Series II package is a low cost, high performance optical datalink with an integral straight tip (ST) connector (Figure 1). Transmitters and receivers are housed in fundamentally identical packages consisting of an injection-molded housing and optical sub-assembly (OSA), transistor outline (TO) type header, a 16-pin dual in-line package (DIP), and stamped metal cover, all of which are mature, high volume packaging technologies. This reuse of piecepart designs and appropriate manufacturing technologies enabled the rapid introduction of new datalinks at a low cost, and with minimal additional manufacturing capital; without reuse, price and availability of these products could not meet customer demands. The DIP includes specialized end leads connecting directly to the OSA. This provides low lead parasitics for high-speed performance. In addition, ceramic chip capacitors are molded directly into the DIP to improve power supply filtering. The injection-molded housing uses liquid crystal polymer (LCP), a high temperature engineering plastic.

ODL 50 Series II. The ODL 50 II product family operates at data rates of 0 to 70 Mb/s at distances up to 3 km. These devices use short wavelength optics operating at 0.87μm; the technology is mature and low cost. The 1261 transmitter uses a single-chip LED driver as a constant current source, with temperature compensation and an optional scrambler to provide a 50 percent duty cycle. Transistor-transistor logic (TTL) and emitter coupled logic (ECL) inputs are available using 1.75 complementary metal-oxide semiconductors (CMOS). Receivers have been developed for burst mode applications, as well as applications requiring alternating current (AC) coupling. The first type can be configured in several ways. It can operate as a burst mode receiver at data rates up to 50 Mb/s, or can operate in the AC mode at rates up to 70 Mb/s. Both configurations use the same complementary bipolar integrated circuit (CBIC-U) chip. The ODL 50 Series II products are in high volume production at AT&T Microelectronics in Reading, Pennsylvania.

ODL 125 Series II. The ODL 125 Series II datalink operates at 125 Mb/s and uses long wavelength optics operating at 1.3μm to allow longer transmission distances. Based on the ODL 50 Series II package design, this device offers a low cost, high performance solution for local area network (LAN) applications. By reusing this packaging, fully functional, low cost models have been made available quickly. Adding a silicon potting compound inside the package allows wave soldering and the aqueous cleaning that follows. The transmitter consists of a single fully integrated CBIC-U LED driver and a high speed LED; the typical output power is -16.0 dBm (decibels relative to one milliwatt). The receiver uses a high speed front-illuminated positive-intrinsic-negative diode (PIN) and a single-chip receiver integrated circuit (IC) with signal detect circuitry. Typical sensitivity is -35.6 dBm at 2.5×10^{-8} bit error rate.

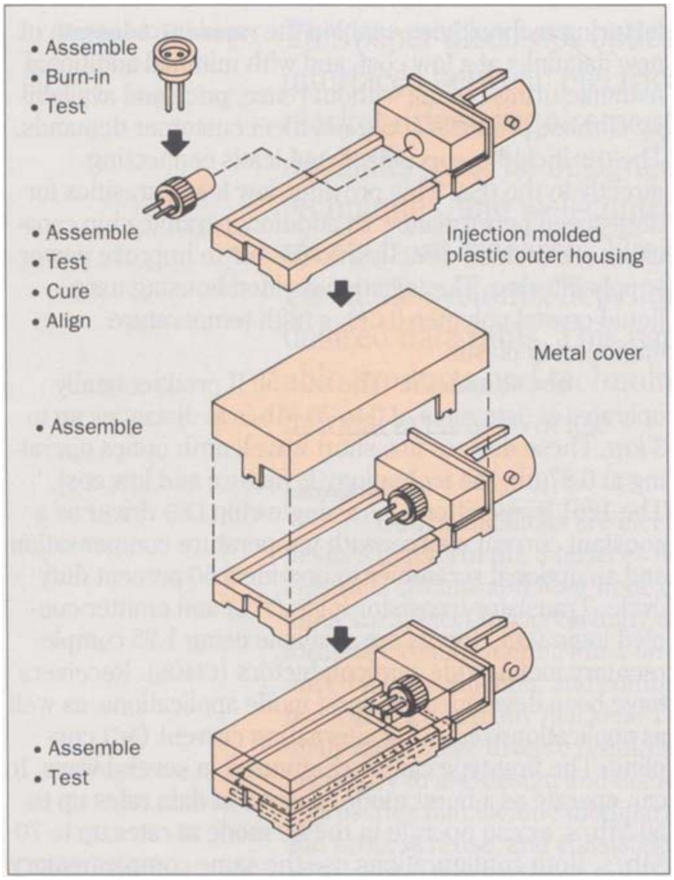


Figure 1. The ODL Series II optical datalink package with an integral ST connector.

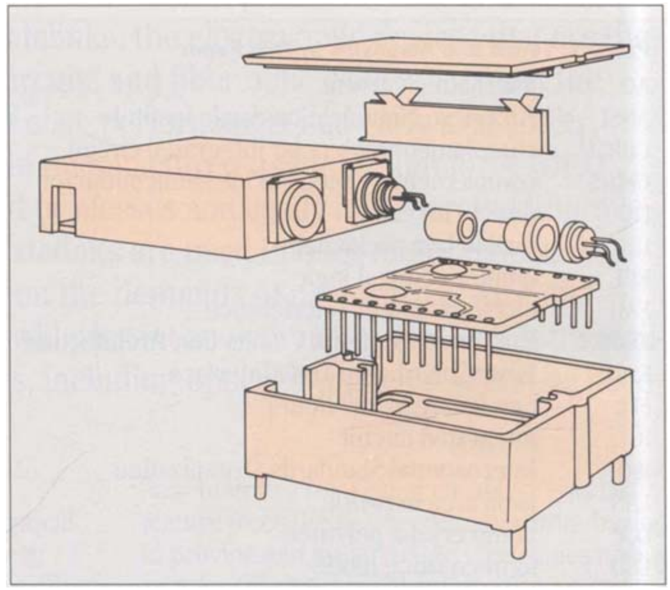


Figure 2. The 1402U transceiver. This device uses a plastic receptacle and gold-plated aluminum housing to improve EMI performance and isolate circuit and chassis grounds. One multilayer circuit board is the substrate for the receiver and transmitter circuitry, with one IC for the transmitter and one for the receiver.

Fiber Distributed Data Interface (FDDI). The American National Standard Institute (ANSI) developed the first fiber optic LAN standard. This standard, known as FDDI, has been submitted to the International Standards Organization (ISO) as a candidate for the first worldwide standard for an optical LAN. This LAN, based on the IEEE 802.5 standard, uses token-passing, dual counter-rotating fiber rings. The physical layer calls for long wavelength (1.3μm), 62.5/125 50/125μm optional) fiber cable, a polarized duplex connector, 11 dB (worst case) power budget, and an optional bypass switch. The line rate is 125 Mb/s; the use of a 4B5B block encoding reduces the user data rate to 100 Mb/s.

We describe several products that have been developed to meet FDDI requirements.

FDDI Transceivers. The 1402U and 1403A transceivers are high performance, FDDI-compliant units. The 1402U conforms to the multi-sourced industry-standard package with a 2 by 11 pin configuration. The 1403A replaces the original 1404A transceiver. Both versions accept the standard FDDI duplex connector. Four receptacle keys are available to ensure proper interconnection.

The 1402U transceiver (Figure 2) uses a plastic receptacle and gold-plated aluminum housing to provide superior EMI performance and isolation of circuit and chassis grounds. One multilayer circuit board is the substrate for the receiver and transmitter circuitry, with one IC for the transmitter and one for the receiver. The LED and PIN are mounted on TO headers that are compatible with high volume manufacture. Fiber stubs in ceramic ferrules provide optical alignment (to well below 10μm) between the LED (or PIN) and the optical connector; and ceramic alignment sleeves align the fiber stub ferrule to the connector ferrule. Thus this product, as well as others described here, must meet the conflicting requirements of high precision and low cost, suggesting easy manufacturability. The typical (average) transmitter output power is -16.4 dBm; the typical sensitivity is -35.4 dBm at 2.5×10^{-10} bit error rate.

Optical Bypass Switch. In FDDI dual counter-rotating rings, a single node failure will cause the system to electronically bridge the two rings. Thus, the failure effectively creates one continuous ring from the two original rings. This mode results in a 50 percent decrease in maximum transmission capacity. If the network contains only one fiber ring, a node failure will cause the entire ring to fail. The FDDI standard allows an optical bypass switch to prevent ring failure in both the single and dual ring configurations. For this application, a compact, low cost, high performance 2 by 2 optical bypass switch is in development. If a node fails, the switch bypasses the failed node and keeps the ring operational without degrading the transmission rate.

This switch (Figure 3) is made from chemically micro-machined silicon parts. The silicon base aligns spherical micro-lenses to input and output fibers, and positions the switching element—a pivoting silicon mirror—in the optical path. A 5 volt (V), 30 milliamp (mA) electro-magnetic actuator activates the switch from the bypass mode (power off) to the active mode (power on). A wire spring holds the silicon mirror in the bypass state. The silicon optical subassembly and actuator are aligned by the injection-molded plastic housing. The small footprint, equal to that of an 18-pin DIP, allows the switch to be board-mounted or embedded in the FDDI cable plant. This switch offers optimal fiber routing, low loss (typically 0.7 dB), and a self-test feature that incorporates 10 dB of loss to ensure that the node has enough power margin before insertion into the ring. The switch meets or exceeds all FDDI performance requirements.

200 Mb/s Transceiver (ESCON-Compatible.) The 1401AA transceiver (Figure 4) is designed for the physical medium-dependent layer of systems that use the Enterprise Systems Connection Architecture (ESCON). It provides an optical-fiber communications link between channels and control units, and offers enhanced radiated and conducted noise immunity, high reliability, operation from a single +5 V power supply, and built-in signal detect indicator. With 62.5/125μm multimode fiber, operating distances are at least 3 Km. The transmitter, operating at 1.3μm, has a typical output power of -17.2 dBm. The receiver has a typical sensitivity of -35.5 dBm at a 1×10^{-12} bit error rate.

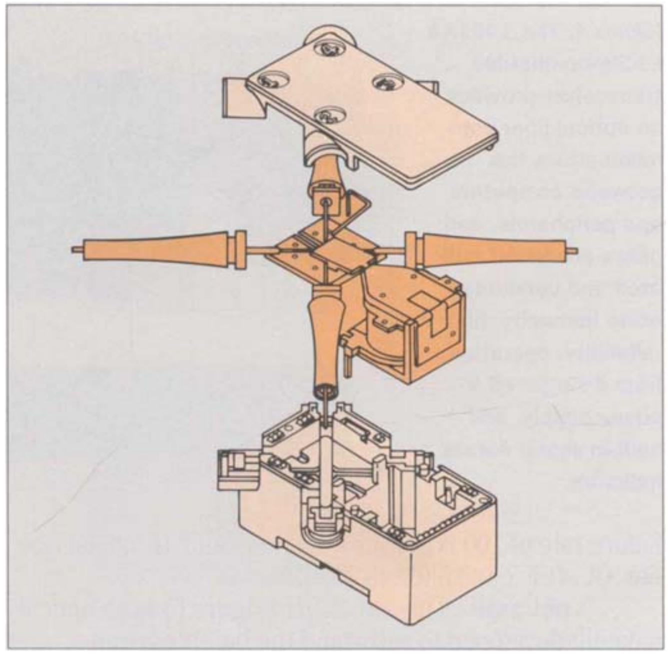
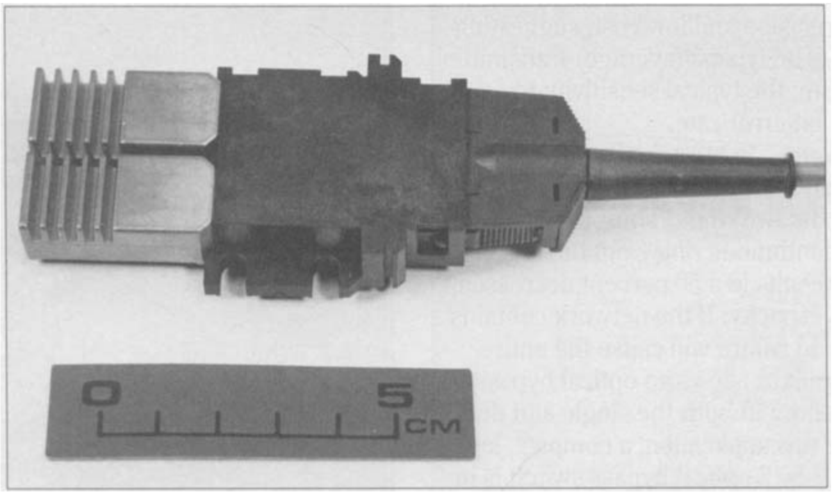


Figure 3. The optical bypass switch that prevents ring failure in single and dual ring configurations. It is made from chemically micro-machined silicon parts. It offers optimal fiber routing, low loss, and a self-test feature that incorporates 10 dB of loss to ensure the node has sufficient power margin before insertion into the ring.

The 1401AA transceiver consists of transmitter, receiver, and shell (i.e., receptacle) modules. It uses many of the same components and technologies as other datalinks, a critical strategy in meeting reliability requirements of the ESCON system. The transmitter and receiver modules use plated zinc die-cast housings, and the shell is injection-molded polyether sulfone (PES). The transmitter and receiver are constructed with an OSA and circuit assembly; both have a single CBIC-U chip for all electronic functions. Enhanced radiated and conducted noise immunity come from careful electrical bypassing and layout of the multi-layer printed wiring board, a complete metal enclosure, low resistance connection of all grounds, and no floating conductors in the receiver module. At a cooling air velocity of 200 ft/min and a temperature of 50° C, the 1401AA should have an average

Figure 4. The 1401AA ESCON-compatible transceiver provides an optical-fiber communications link between computers and peripherals, and offers enhanced radiated and conducted noise immunity, high reliability, operation from a single +5 V power supply, and built-in signal detect indicator.



failure rate of 100 FITs over a 100,000-hour (Khr) service life. (A FIT is one failure in 10^9 hours.)

ODL 250H. The ODL 250H (Figure 5) is an optical datalink developed to withstand the harsh environments typically encountered by military systems. It is designed to the custom hybrid requirements of MIL-H-38534 Class H. Besides providing immunity to environmental extremes (including EMI), this device provides, reduced weight, high data capacity, and good radiation tolerance. As its name implies, the ODL 250H operates at 250 Mb/s. Screening and quality conformance test procedures use a version of Method 5008 of MIL-STD-883, modified for fiber optic custom microcircuits. Production units will be assembled on a MIL-STD-1772 certified line.

The ODL 250H evolved from optical datalinks intended mainly for commercial applications, e.g, ODL 200-ESCON-compatible, and from an earlier 16-pin DIP-style hermetic pigtailed datalink (ODL 200H) intended primarily for the military. In addition, experience gained in developing and manufacturing high reliability undersea lightwave systems was used to design the ODL 250H. The transmitter and receiver are self-contained in a compact surface-mount package with 16 gull-wing leads. The package is 0.12 inches high and requires 0.86 square inches of area (with leads) so it can be used on both sides of standard electronic module (SEM) circuit boards. Silicon integrated circuits, chip capacitors, and optical devices are hermetically enclosed to eliminate humidity-related failures. Materials used inside the package assure low levels of ionic contamination and moisture. The datalink operates at 1.3µm. A 100/140µm optical fiber pigtail provides the fiber optic interface to the edge of the SEM card. A transmitter-receiver pair typically provides 20 dB of link margin over a temperature range of -55° C to 125° C.

Single Mode Products

This section discusses single-mode products. These are used primarily for telecommunications applications, and include the 1227 laser-based transmitter, and 1310 synchronous optical network (SONET) compatible products. These types of transmitters and receivers are representative of those now beginning to be widely deployed in SONET standards-driven applications. These laser-based subsystems require the same design and manufacturing philosophy as the LED-based communications products previously described.

1227 Transmitter. The 1227 is a laser-based transmitter designed for data rates up to 650 Mb/s. It is suitable for applications requiring a small, low-profile uncooled device operating in an office or loop environment. The 1227 consists of a laser with an integral back-facet detector, thin film hybrid circuit with CMOS driver, a 20 pin DIP-style package, and a pigtail terminated in an ST connector. A future version will have an integral connector. The optical output power is typically -7 dBm.

The laser driver consists of one 0.9µm CMOS chip and associated components on the hybrid. It provides high speed current switching for laser modulation, and a low speed optical power control circuit with stable voltage and current references. A temperaturecontrolling circuit also allows compensation for the laser slope efficiency. The transmitter package is an iron-nickel-cobalt alloy with a welded cover to provide EMI immunity and thermal dissipation.

1310 Receivers. The 1310 family of receivers are designed for the SONET rates of 52, 156, and 622 Mb/s; typical sensitivities are -42, -38, and -30 dBm, respectively. The maximum input power is typically -7 dBm. The units are fabricated in a hermetic, pigtailed, DIP-style enclosure containing a planar InGaAs PIN photodetector, a GaAs preamplifier, and a silicon comparator. The receivers require +5 and -5.2 V supplies and operate over a case temperature range of -40° C to 85° C. As with the 1227 transmitter, the future version of the 1310 will have an integral connector. Both the 1227 and 1310 share design and packaging approaches with the LED-based subsystem.

Future Products Trends

There are two trends in lightwave datacom products: lower prices and higher performance. Market pressure will continue to drive prices down; this is particularly apparent at data rates of 125 Mb/s and lower. These products are increasingly competing with copper-based systems. Photonic systems have the advantages of high capacity, long transmission distances, EMI immunity, and negligible radiated power. Also, because products of this type will be mounted on the motherboard in PCs and workstations, reliability and size will be highly significant. This market, which includes FDDI, will be driven less by performance than by cost, and will spur developing low cost components, subassemblies, and effective assembly and test procedures. The key building blocks of low cost design are optical subassemblies (including the LEDs and PINs), electronic packaging, electrical and optical interconnects, and overall packaging design.

At speeds of 200 Mb/s and above, additional factors apply. Price will be important, but additional functionality also will be required. Integrating multiplex/demultiplex (mux/demux) and clock recovery will be needed so the electrical system designer can interface to the optical subsystem at low data rates (< 20 Mb/s). Even at these speeds, however, design modularity and reuse, and design for manufacture, will be critical to meet customer price and availability demands.

An interesting issue arises in choosing either an

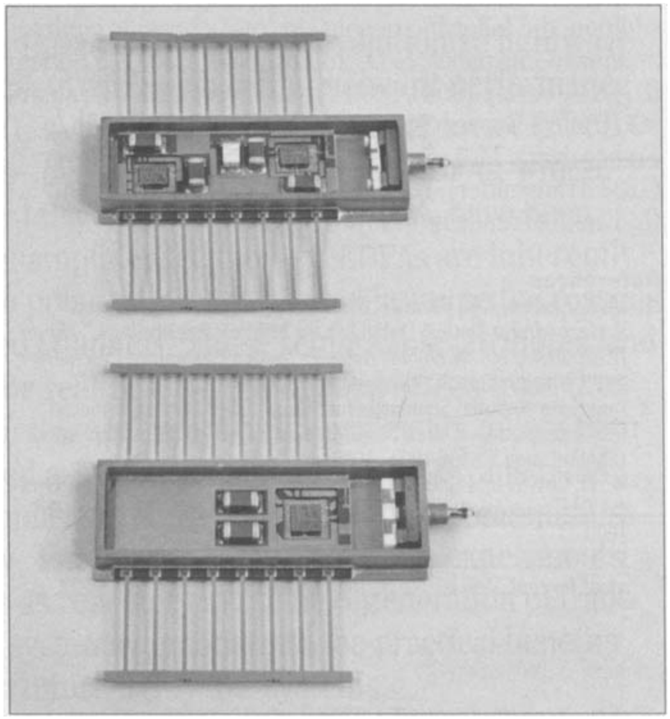


Figure 5. The ODL 250H optical datalink provides immunity to environmental extremes, increased security, reduced weight, increased bandwidth, and good radiation tolerance. It operates at 250 Mb/s, and is designed to the custom hybrid requirements of MIL-H-38534 Class H.

LED or laser as the emitter in datacom systems. For short distances, connector-intensive applications, and data rates below 300 Mb/s, both could use multimode fiber. High data rates (>500 Mb/s) and longer distances call for the lasers and single mode fiber. Given the progress being made in developing inexpensive, uncooled lasers, it will not be long before they begin to compete with LEDs by providing more power, which will permit the use of less expensive, higher loss components in the cable plant. LEDs will likely continue to require less complicated drive circuits and be usable over a wider temperature range.

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