10 Gb/s optical transceiver with MUX and DEMUX

Hideki Takagi　Takeo Horio
Tomokazu Takahashi　Masaaki Umezawa

In recent years, the Internet has spread into offices and homes (domestic subscribers) at an explosive rate, all around the world. Alongside this, electronic commerce systems, and multimedia services for sound and image distribution, are already up and running. Access networks are being introduced based on PON (Passive Optical Network) setups capable of handling larger volumes of communications traffic than current xDSL or CATV networks which use existing telephone circuits. In PON systems, couplers are inserted into fibre-optic networks and a single optical fibre is fed to a number of subscribers, which means that optical fibres can be introduced into subscribers' homes in a cost effective way. A system of this kind enables information transmission suitable for all kinds of multimedia services, from telephone to data communications.

As access networks get faster and faster, higher capacity architecture is becoming necessary in the metropolitan area networks spanning major cities, and the backbone area networks which link these together.

The creation of high-capacity backbone network systems like that shown in Fig. 1 is generating increasing demands for highly compact, low-power optical interfaces between transmission devices. In response to this situation, at Oki, we have developed the 10Gb/s optical transceiver which integrates signal multiplexing (MUX) and demultiplexing (DEMUX) functions, as a key device for optical interfaces between backbone fibre-optic networks and metropolitan area networks. Our transceiver is compatible with 40 km spans, and complies with the international standards for trunk transmission networks, SONET (Synchronous Optical Network) standard OC-192 IR-2 1) and SDH (Synchronous Digital Hierarchy) standard STM-64 S-64.2b 2). The features and performance characteristics of this 10 Gb/s optical transceiver are described in this paper.

Features of the 10 Gb/s optical transceiver

The main features of our 10 Gb/s optical

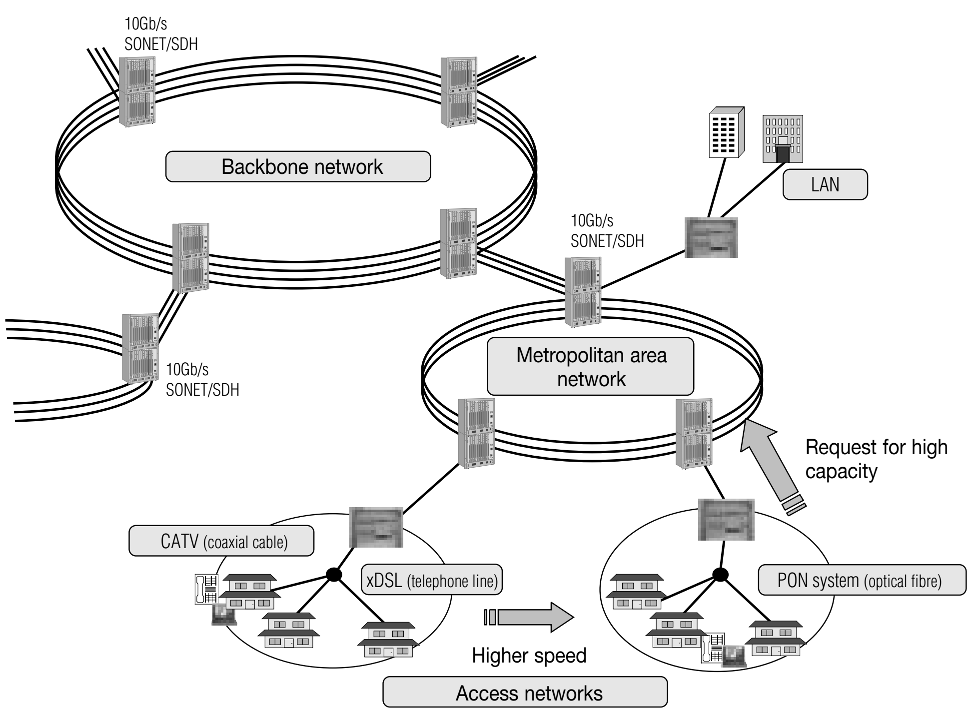


Fig. 1 Overview of optical network

transceiver are listed below.

(1) The optical signal interface complies with OC-192 IR-2 and STM-64 S-64.2b. The transmitter uses a 1.55 μm band laser module and is compatible with 40 km-long transmission paths using 1.3 μm single-mode optical fiber.

(2) The electrical signal interface uses 622.08 Mb/s x 16bit @ LVDS (Low Voltage Differential Signalling), due to the integrated MUX and DEMUX functions, and is based on OIF (Optical Internetworking Forum) standards (1999.102.8 SFI-4)3). Furthermore, since the electrical signal runs at 622.08 Mb/s, signals can be handled very easily when mounted on a mother board.

(3) The transceiver detachable 300-pin electrical connectors with industry-standard terminal functions and terminal layout.

The transceiver operates at supply voltages of +5V, +3.3V, and -5.2V, each with ±5% margin, and has an operational temperature range of 0 – 65°C. Under these conditions, the maximum power consumption is 13 W. The external dimensions are 88.9 x 114.3 x18 mm^3 (including heat sink).

Structure of the 10 Gb/s optical transceiver

Fig. 2 shows the structure of the 10 Gb/s optical transceiver. Since the signal MUX and DEMUX functions, and so on, are integrated, the optical signal interface operates at 10 Gb/s (serial signal), and the electrical signal interface operates at 622 Mb/s (16-bit parallel signal).

The transmitter section is made up of a DFB-LD (Distributed Feedback Laser Diode) module with integrated EA (Electroabsorption) modulator (“EA-DFB laser module”), an EA driver IC, signal multiplexing IC (“MUX IC”), Automatic Power Control (APC) circuit, and Automatic Temperature Control (ATC) circuit. The 622 Mb/s x 16-bit parallel signal is converted to a 10 Gb/s serial signal by the MUX IC, and the EA-DFB laser module is driven by the EA driver IC. If jitter (temporal fluctuation in the phase direction) is in the transmitter reference clock input to the MUX IC, then jitter will occur in the optical output waveform. This jitter may cause degradation of the optical output waveform specifications (eye mask specifications), and the transmission characteristics, which are described later in this article. Therefore, to avoid this problem, the jitter is reduced by means of a jitter clearance circuit before the transmission reference clock is input to the MUX IC. The operation of the EA-DFB laser module is stabilized by the APC circuit, which ensures a uniform optical output from the laser, and the ATC circuit, which maintains a constant temperature in the module.

The receiver section is constituted by a photoreceptor element module4) which is integrated with a PIN –PD (PIN-Photodiode) and a pre-amplifier circuit, (hereafter, “PIN-AMP module”), a post-amplifier, and a signal demultiplexing IC (“DEMUX IC”). The 10 Gb/s optical signal is converted to an electrical signal by the PIN-AMP module, amplified by the post-amplifier, and then input to the DEMUX IC. This IC has a clock recovery function based on a PLL (Phase Locked Loop) circuit for regenerating the data and clock signals, and then converts to a 622 Mb/s x

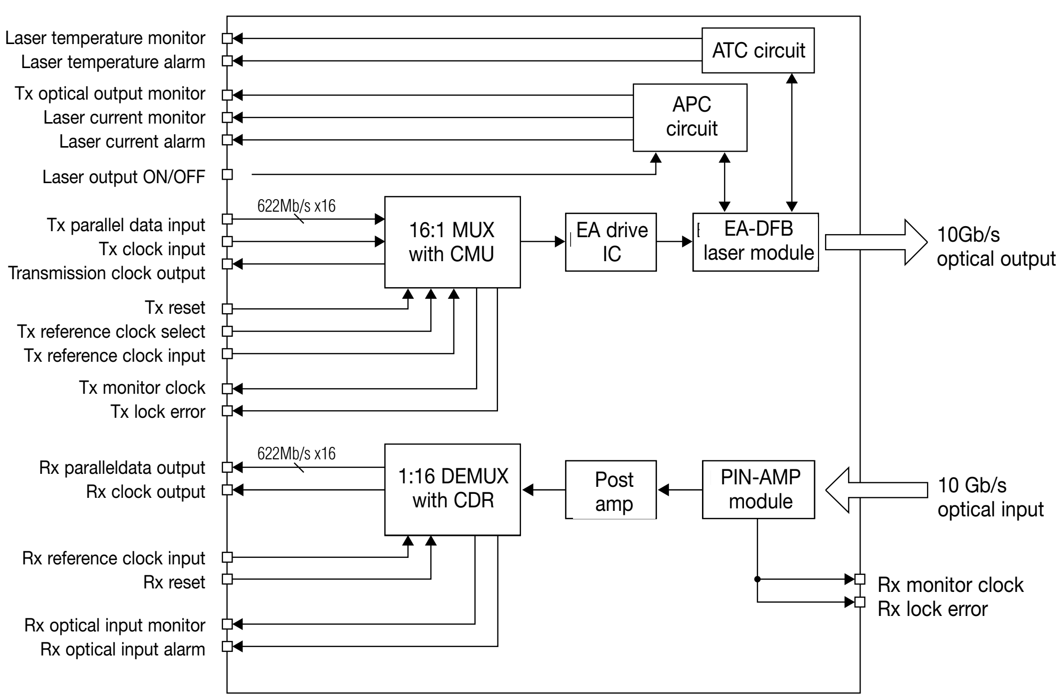


Fig. 2 10 Gb/s optical transceiver

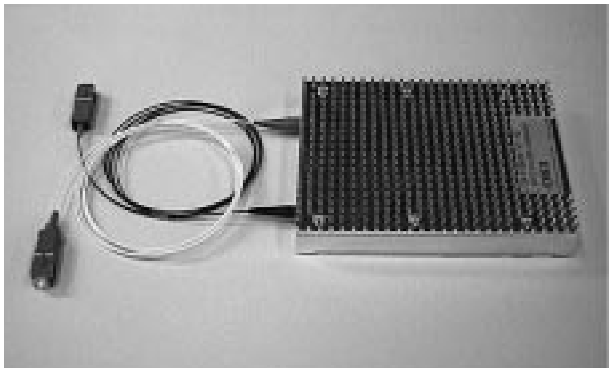


Fig. 3 External photograph of 10 Gb/s optical transceiver

16-bit parallel signal by means of a DEMUX circuit.

The transmitter section has monitoring functions, such as an optical output monitor, LD current monitor, LD temperature monitor, LD bias current increase detector function, and LD temperature shift detector function, whilst the receiver comprises an optical input monitor, and optical input detector, and the bit-rate shift of the optical input data signal, or the like.

Fig. 3 shows an external photograph of this transceiver.

Features

The 10 Gb/s optical transceiver was evaluated using a 31-stage pseudo-random binary sequence (PRBS) 2^{31} –1). Table 1 lists the results of this evaluation.

(1) Bit error ratio characteristics

Fig. 4 shows the bit error ratio characteristics for a 10 Gb/s optical transceiver. The minimum sensitivity which satisfies an error ratio of 1 x 10^{-12} or less is –18 dBm, and the overload is guaranteed to be at least +1 dBm. In this way, the transceiver has sufficient margin against the specifications, when temperature and supply voltage change.

Moreover, since there is a maximum signal level difference of about 50 dB between the receiver and

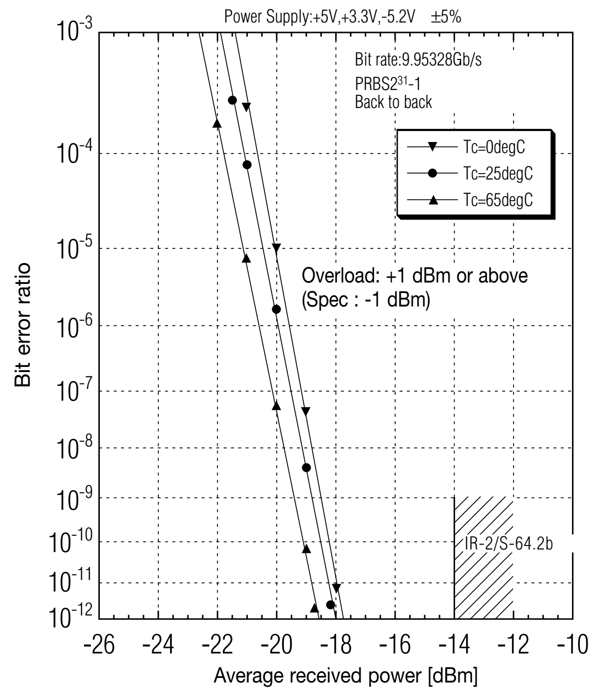


Fig. 4 Bit error ratio characteristics

transmitter, it is necessary to restrict degradation of characteristics due to cross-talk. This is done by optimizing the mounting structure.

(2) Optical output waveform

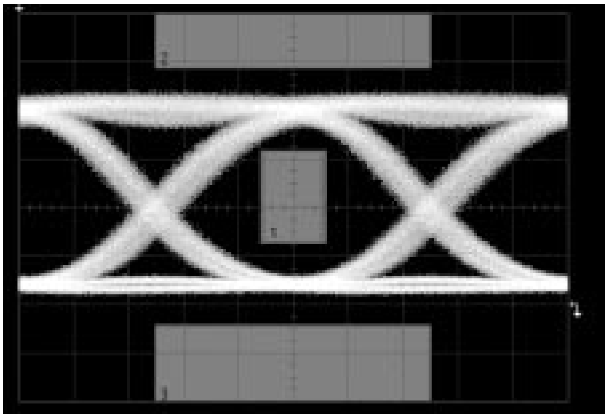
Fig. 5 shows the optical output waveform after passing the 4th order Bessel Thompson filter. The extinction ratio is 10 dB, and a good waveform is obtained which easily meets the eye mask standards in OC-192/STM-64. The characteristics are also stable with respect to temperature variation and power voltage variation.

(3) Transmission characteristics

The above-mentioned optical output waveform was input to 1.3 μm single-mode optical fibre, and we

Table 1 Evaluation of 10 Gb/s optical transceiver

Item	Unit	Specification	Evaluation result	
			min.	max.
Optical output power	dBm	-1 ~ +2	0.23	0.84
Central wavelength	nm	1530 ~ 1565	1550	
Optical output waveform	—	Eye mask specification	Passed	
Extinction ratio	dB	≥ 8.2	9.72	—
Sensitivity	dBm	≤ -14	—	-17.8
Overload	dBm	≥ -1	1	—
Jitter generation, tolerance, transfer	—	GR-253 standard	GR-253 passed	
Path penalty (50 km transmission in 1.3 μm single-mode optical fibre)	dB	≤ 2	—	1.5
Power consumption	W	≤ 14	—	12.5



(20ps/div)

Fig. 5 Optical output waveform

carried out a 50 km transmission test with dispersion exceeding 800 ps/nm. Any distortion of the transmitted waveform due to dispersion inside the optical fibre will result in a significant degradation of the bit error ratio at the receiver end. This problem was minimized as far as possible, by optimizing the design of the EA-DFB laser module and driving the EA-DFB module at optimum bias. When received sensitivity after 50 km transmission was compared with a Back to Back system (signal not transmitted along the optical fibre), the degradation (transmission penalty) due to fibre dispersion was 1.2 dB. Even if the degradation included temperature fluctuation and supply voltage variation, it was 1.5 dB, which mean that the module has stable transmission characteristics.

(4) Jitter characteristics

This section looks at the jitter characteristics of the 10 Gb/s optical transceiver, and one aspect of these, the jitter transfer, are illustrated in Fig. 6. Since the jitter clean-up circuit restricts the jitter transfer band,

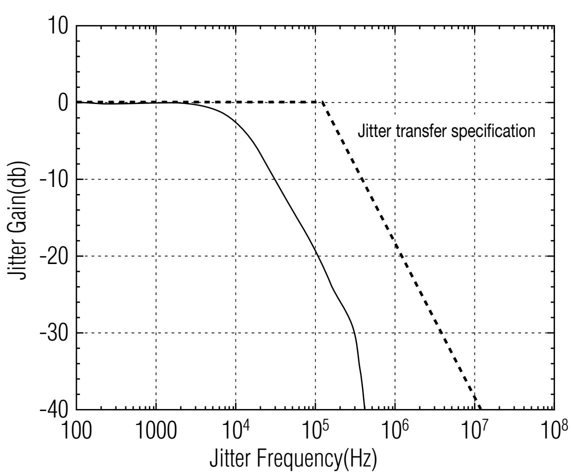


Fig. 6 Jitter transfer characteristics

the module easily complies with the cut-off frequency standard of 120 kHz, and the jitter gain within bandwidth is restricted to 0.1 dB or less. Therefore, even if the transmitter reference clock contains a jitter component, this jitter can be suppressed. Moreover, jitter generation is 0.088 UIpp compared to the standard of 0.1 UIpp, and the jitter tolerance also is filling the standard mask enough. In this way, the module has stable jitter characteristics with respect to temperature or voltage changes.

Conclusion

At Oki, we have developed a 10 Gb/s optical transceiver with MUX and DEMUX circuits. It has the characteristics which sufficient margin to the specifications. Here, we have presented a 10 Gb/s optical transceiver which complies with the OC-192 IR-2 / STM-64 S-64.2b standards specified for SONET/SDH, and we already have a transceiver which is compatible with SR-2/I-64.2 (transmission distance 25 km). From here on, we plan to have product line-up with the miniaturization of size, and power consumption reduction, and transmission distances (0.6, 2, 80 km), as well as developing products compatible with DWDM (Dense Wavelength Division Multiplexing) systems which are valuable in expanding transmission capacity.

References

1) Telecordia GR-253-CORE Issue 3
2) ITU-T G691
3) OIF 1999, 102.8 SFI-4
4) Okuda, et. al. : “Development of surface mount-type 10 Gb/s PIN-AMP module”, IEICE, Proceedings of 2001 General Conference, C-3-91

Authors

Hideki Takagi: Optical Components Company, Photonic Products Dept.
Takeo Horio: Optical Components Company, Photonic Products Dept.
Tomokazu Takahashi: Optical Components Company, Photonic Products Dept.
Masaaki Umezawa: Optical Components Company, Photonic Products Dept.