Short Wavelength Optical Transceiver using VCSEL

Akiyoshi Iguchi, *Kenyo* Tobita, *Yoshiharu* Unami, *Katsuyuki* Arai, *Yoshiya* Isono, *Tsutomu* Watanabe, *Tuyoshi* Sugawara[*1], Robert P. Dahlgren[*2], Hari Naidu[*2], James Oby[*2], Reginald Conley[*2] and Hirokazu Hashimoto[*2]

*1 Tohoku Fujikura Ltd.

*2 Fujikura Technology America Corp.

Gigabit Ethernet and Fibre Channel are new technological standards which enable high speed data transmission at long distances. Modular transceivers are required to convert transmission media easily.

We have developed a 1.25 Gbps short wavelength optical transceiver using a Vertical Cavity Surface Emitting Laser (VCSEL) for Gigabit Ethernet and Fibre Channel applications. The modular transceiver is hot-pluggable. The operating distance is 2 to 500 m with multimode 50/125 μm GI fiber. The power supply is a single +5V. The input and output serial data are AC coupled differential PECL. The transceiver described in this paper satisfies the 1000BASE-SX classification in IEEE 802.3z and 100-M5-SN-I class in FC-PH-2 standards.

1. Introduction

Fibre Channel and Gigabit Ethernet are very attractive technologies to realize high speed data communication with low cost and high reliability.

Fibre Channel was originally standardized by the American National Standard Institute (ANSI) and is expected to be used for serial interface of computers and peripheral equipment such as storage systems. There are three documents which define the physical layer of Fibre Channel, which are referred to as FC-PH (Fibre Channel Physical and Signaling Interface) 1), FC-PH-2 2), and FC-PH-3 3). A network that is constructed using Fibre Channel point-to-point, arbitrated loop hubs, or switches may be connected to a super-computer, mainframe, or workstation, along with mass-storage devices, to enable high-speed processing of data.

Gigabit Ethernet enables a bandwidth that is 10 times larger than Fast Ethernet in LAN. The IEEE P802.3z Draft 5 of Gigabit Ethernet has been approved by the IEEE Standards Board in June 1998 4) and is now officially a standard. The IEEE 802.3z working group employed Fibre Channel technology for its physical layer, because optical transceivers for Fibre Channel had already been developed

In these technologies, hot-pluggable transceivers are required to change the media easily such as single mode optical fiber cable, multimode optical fiber cable, and copper cable. HUBs and switches used for Fibre Channel Arbitrated Loop (FC-AL) and Gigabit Ethernet require such modular transceivers which are also hot-pluggable.

We have successfully developed a short wavelength optical transceiver for Fibre Channel 5) and a long-wavelength transceiver for Fibre Channel and Gigabit Ethernet 6). At this time, we have developed a short-wavelength optical transceiver using Vertical Cavity Surface Emitting Laser (VCSEL) at the transmission data rate of 1.25 Gbps that is defined by 1000BASE-SX of IEEE P802.3z clause 38. We have confirmed that this transceiver meets the standard's requirement for Gigabit Ethernet at environmental temperatures between 0 and 60 °C. This report summarizes the evaluation results of the transceiver.

2. Outline of the Transceiver

We designed a transceiver based on the Gigabit Interface Converter (GBIC) standard 7), optical specifications of which meets the standards for 1000BASE-SX of IEEE Draft P802.3z/D5.0 clause 38 and 100-M5-SN-I class of FC-PH-2. Table 1 shows the specifications for the transceiver. Fig. 1 shows the appearance of the transceiver. The transceiver has external dimensions of 33 mm × 65 mm × 12 mm. The optical receptacle is a duplex SC connector. The electrical interface connector has 20 pins.

Fig. 2 shows a block diagram of the transceiver functions. The transceiver is composed of a transmitter, a receiver, and control circuits.

The light source is a short wavelength VCSEL with a central wavelength of 850 nm and packaged in a TO can. VCSELs are relatively new lasers which have the following characteristics:

(1)Small threshold current, which is typically less than 10 mA
(2)Higher modulation bandwidth than the CD laser
(3)Optical spectral width which is well-suited to reduce modal noise
(4)Higher reliability than the CD laser

The photo detector element has a built-in pre-amplifier and is also packaged in a TO can. Each optical device is built into an Optical Subassembly (OSA) using a lens and a plastic receptacle.

The transmission medium is multimode GI optical fibers 50/125-μm, and the transmission distance is between 2 to 500 meters. These multimode fibers have large core diameters that allow easier optical coupling of an OSA than single-mode fibers.

The main signal interfaces of both +/-TX_DATA and +/-RX_DATA are AC coupled positive referenced ECL or pseudo ECL (PECL).

The transmitter is composed of a VCSEL drive circuit and FAULT detection circuit. The VCSEL drive circuit has an auto power control (APC) feature to maintain a stable optical output against aging, fluctuations in the ambient temperature and supply voltage. When the FAULT detection circuit detects abnormalities in the VCSEL drive circuit that may lead to increases in optical output power, it asserts High to TX_FAULT output, and then automatically turns off the laser output. This function meets laser safety Class 1 requirements in a single failure condition.

The receiver is composed of the above-mentioned photo-detector/pre-amplifier and a post-amplifier.

The function of each control signals (TX_DISABLE, TX_FAULT, RX_LOS) are as follows:

(1) TX_FAULT is an active High open collector compatible output signal. When the control circuit detects failure of the VCSEL drive circuit, end of life, low power supply voltage, or over power supply voltage, the control circuit turns off the VCSEL output and asserts High to TX_FAULT output.

(2) TX_DISABLE is an active High TTL input signal. This is an external signal from outside of the transceiver, to turn the laser output on/off.

(3) RX_LOS is an active High open collector compatible output signal, which is generated by the receiver. This indicates that the optical received power is below a predetermined level, caused by events such as unplugged fiber cable, broken fiber cable or disabled transmitter at the

other end of the fiber.

The transceiver is equipped with serial identification specified in Annex D of the GBIC specification using the 2-wire serial CMOS E2PROM. The information it provides are type of serial transceiver, nominal bit rate, connector type, link length, GBIC vendor, part number and so on.

The power supply voltage is single +5 V. The transceiver corresponds to hot plugging and un-plugging enabled by the pin connection sequence shown in Table 2. In this hot plugging procedure, a special circuit limits the inrush current to less than +30 mA above the steady state current. To protect the VCSEL from damaging current surges in this case, the power source circuit utilizes a slow start circuit.

3. Characteristics of the transceiver

3. 1 Characteristics of the transmitter

Fig. 3 shows the temperature characteristics of the average optical output power from the transmitter. The APC circuit ensures the optical output power fluctuation as small as 0.4 dB for the ambient temperature range of 0 to 60 °C.

Fig. 4 shows a typical eye pattern of the optical output from the transmitter. In this figure, the eye mask is the one specified in the IEEE 802.3z document. The eye pattern satisfies the specified mask, which indicates that the optical signal waveform was favorable with respect to the rise/fall time, jitter, and overshoot/undershoot. This feature was sustained in a supply voltage range from 4.75 to 5.25 V and an ambient temperature range from 0 to 60 °C.

Fig. 5 shows the extinction ratio versus the ambient temperature. The value was at least 13.3 dB for the entire range of the power supply voltage of 4.75 to 5.25 V and the ambient temperature of 0 to 60 °C, which meets the minimum value specified in the 1000BASE-SX specification of 9 dB.

The optical jitter characteristics are shown in Fig. 6 and Fig. 7. Fig. 6 shows the eye opening. For the entire range of ambient temperature and power supply voltage, the value was well above the 57 % minimum specified in the standard. Fig. 7 shows the deterministic jitter. The value was well below the 20 %p-p maximum specified in the standard, for the entire range of ambient temperature and power supply voltage.

3. 2 Characteristics of the receiver

Fig. 8 shows the minimum sensitivity of received optical power versus the ambient temperature when the bit error rate of 1E-12. The measured minimum sensitivity was –18.7 dBm, which is considerably smaller than the minimum value of -17 dBm specified in the 1000BASE-SX.

3. 3 General Characteristics

Table 3 shows the major characteristics of the transceiver. The results satisfy the target values given in Table 1.

4. Conclusions

We have developed a short-wavelength optical transceiver using VCSEL for the optical transmitter with a data rate of 1.25 Gbps that is defined by

Class 1000BASE-SX of IEEE802.3z. In a range of supply voltages from 4.75 to 5.25 V and of ambient temperature from 0 to 60 °C, the transceiver meets the required specification.

Lastly, we would like to extend our sincere thanks to those who instructed and assisted us in the development of this transceiver.

References

1) ANSI X3.230: FC-PH

2) ANSI X3.297: FC-PH-2

3) ANSI X3T11/Project 1119D/Rev 9.4: FC-PH-3

4) IEEE P802.3z

5) K. Tobita, et al.: Short Wavelength Optical Transceiver for 1.063-Gbps Fibre Channel, Fujikura Technical Review, No.27, pp22-26, 1998

6) K. Dohmoto, et al.: Long Wavelength Optical Transceiver for Fibre Channel and Gigabit Ethernet, Fujikura Giho, No.94, pp15-19, 1998

7) SMCC, Vixel, Compaq, AMP: Gigabit Interface Converter (GBIC) Rev. 5.1

Table 1. Specifications of Transceiver

Item	Unit	Min.	Max.
Nominal bit rate	Gbps	1.0625 and 1.25	
Tolerance	ppm	±100	
Media		Multimode fiber GI 50/125 μm	
Operating range (typ)	m	2	500
Bit error rate			1E−12
Optical connector		Duplex SC	
Outside size	mm	33 × 65 × 12	
Power supply voltage	V	4.75	5.25
Data signal level		AC coupled PECL	
Operating temperature	℃	0	50
Transmitter			
Spectral center wavelength	nm	770	860
RMS Spectral width	nm		0.85
Launched power	dBm	−9.5	−5.0
Extinction ratio	dB	9	
Eye opening @BER= 1×10^{-12}	%	57	
Deterministic jitter	% (p-p)		20
Receiver			
Optical received power	dBm	−17	0

Table 2. Transceiver to Host Connector Pin Assignment

Pin Name	Pin #	Description	Sequence
RX_LOS	1	Receiver Loss of Signal, logic High	2
TX_DISABLE	7	Transmitter Disable, logic High	2
TX_FAULT	10	Transmitter Fault, logic High	2
MOD_DEF(0)	4	Transceiver definition and presence	2
MOD_DEF(1)	5		2
MOD_DEF(2)	6		2
$V_{DD}T$	16	Transmitter +5 volts	2
$V_{DD}R$	15	Receiver +5 volts	2
TGND	8	Transmitter Ground	2
TGND	9		2
TGND	17		1
TGND	20		1
RGND	2	Receiver Ground	2
RGND	3		2
RGND	11		1
RGND	14		1
+TX_DATA	18	Transmit Data, Differential PECL	1
-TX_DATA	19	Transmit Data, Differential PECL	1
+RX_DATA	13	Receive Data, Differential PECL	1
-RX_DATA	12	Receive Data, Differential PECL	1

Table 3. Characteristics of Transceiver

Item		Unit	Measured value
Transmitter	Spectral center wavelength	nm	839 (Typ)
	Spectral width	nm RMS	0.31 (Typ)
	Optical output power	dBm	−7.0 ～ −6.6
	Extinction ratio	dB	> 12
	Eye opening @BER=1×10^{-12}	%	> 77
	Deterministic jitter	% p-p	< 15
Minimum received power		dBm	< −18
Consumption power		W	< 1.0

Fig. 1. Appearance of Transceiver.

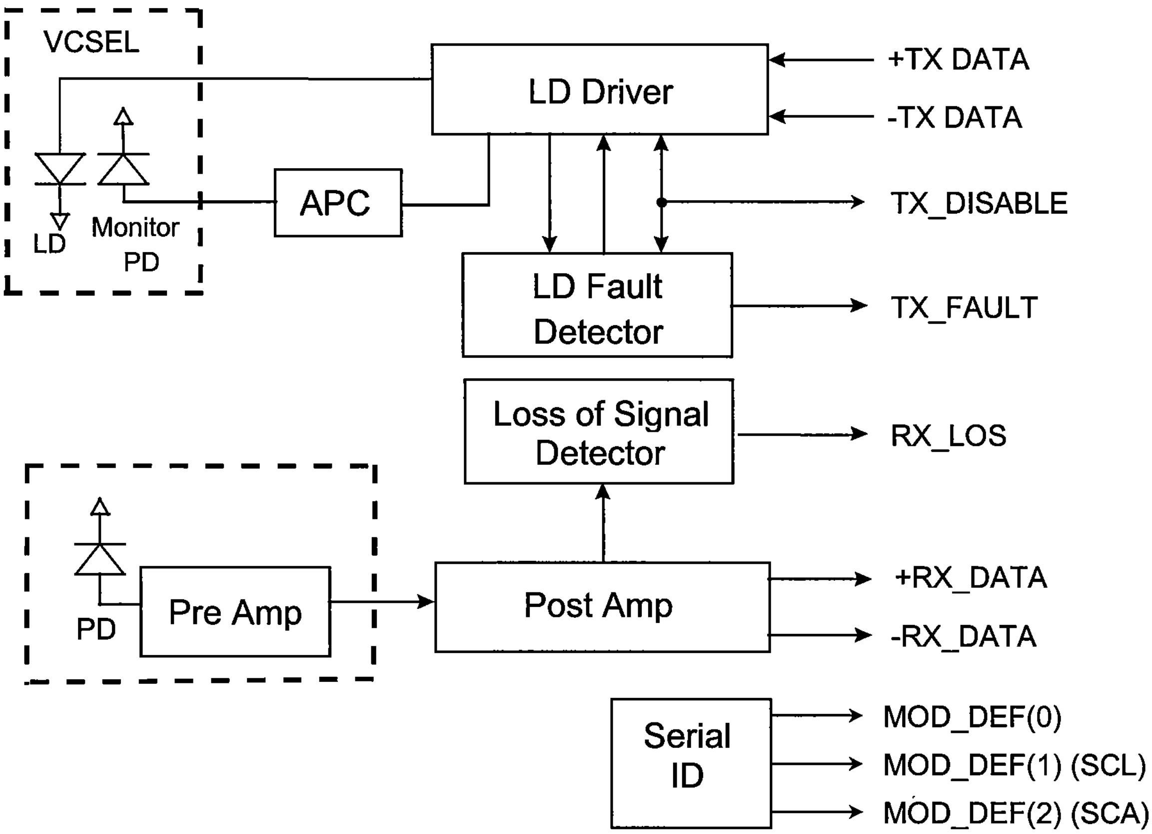

Fig. 2. Block Diagram of Transceiver.

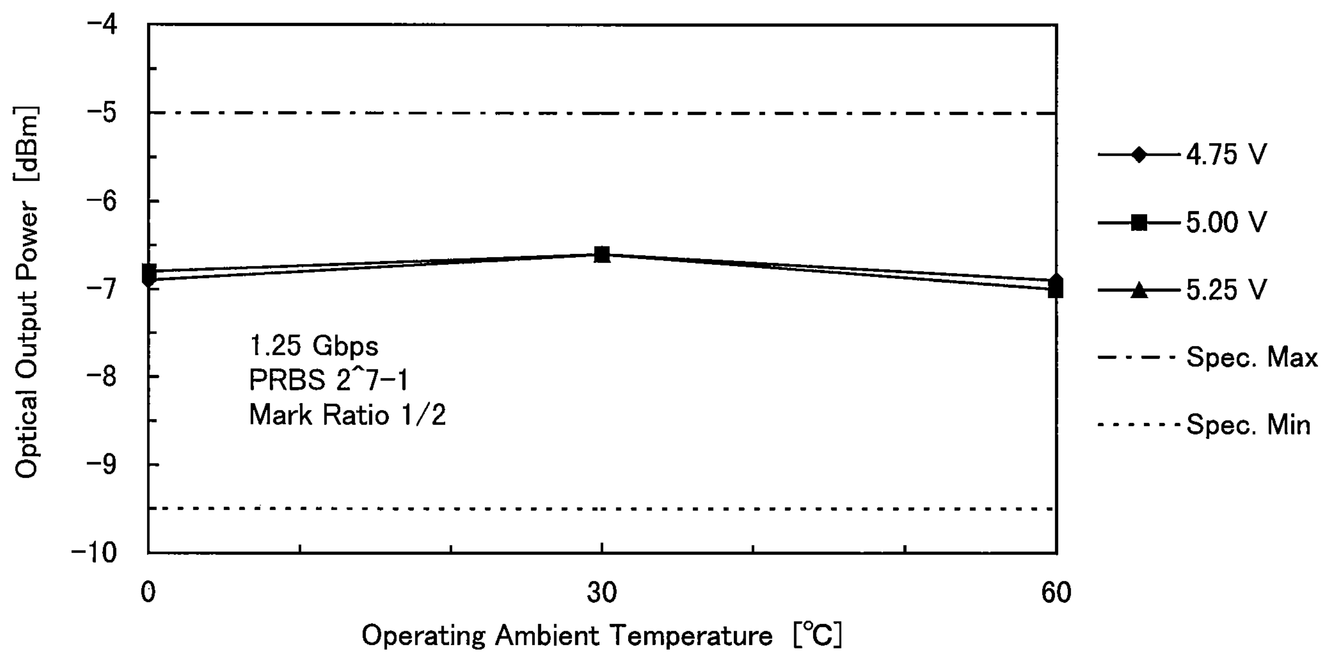

Fig. 3 Optical output power versus Operating Ambient Temperature

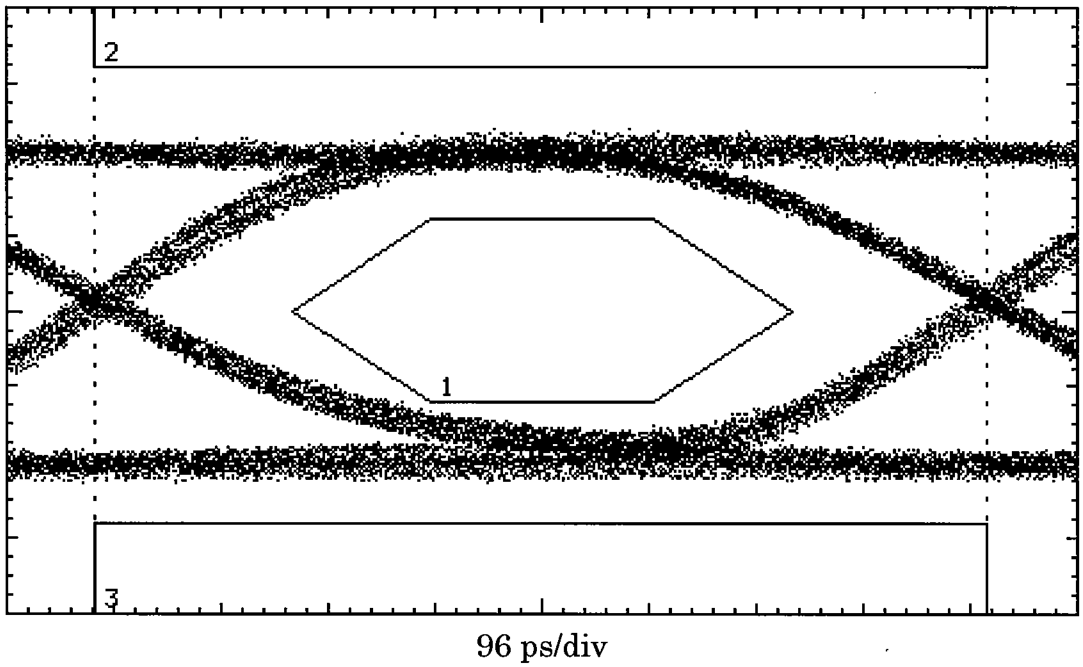

Fig. 4 Eye Pattern of Optical Output (1.25 Gbps, PRBS 2^7-1, Mark Ratio 1/2)

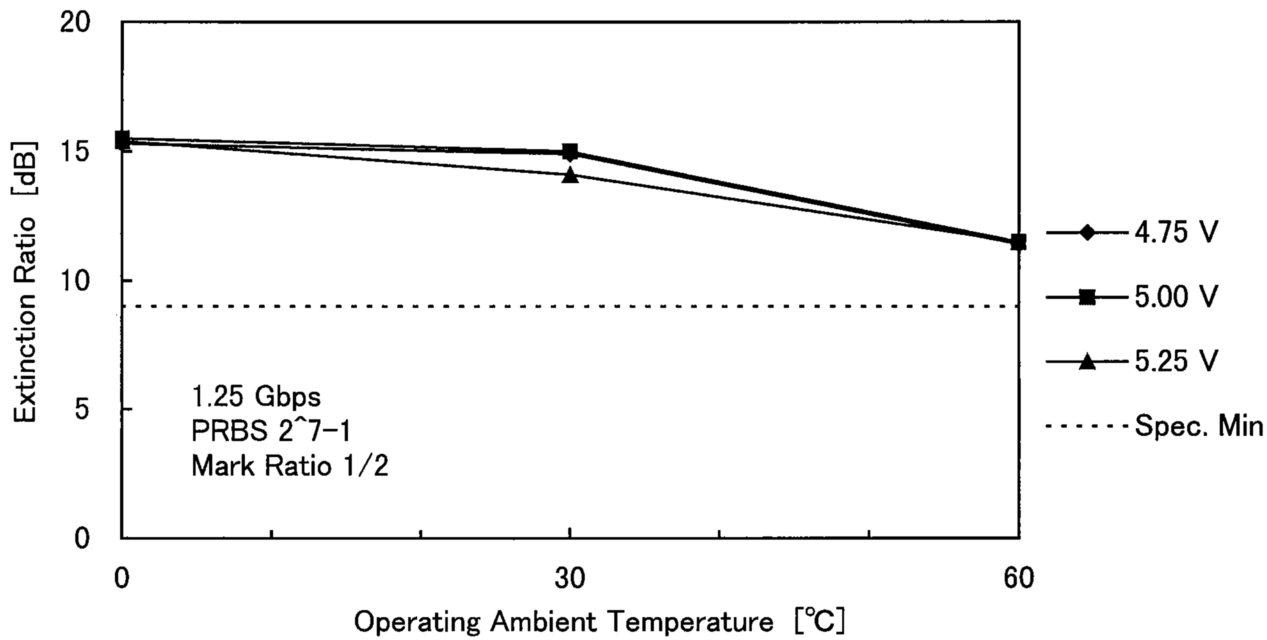

Fig. 5 Extinction Ratio versus Operating Ambient Temperature

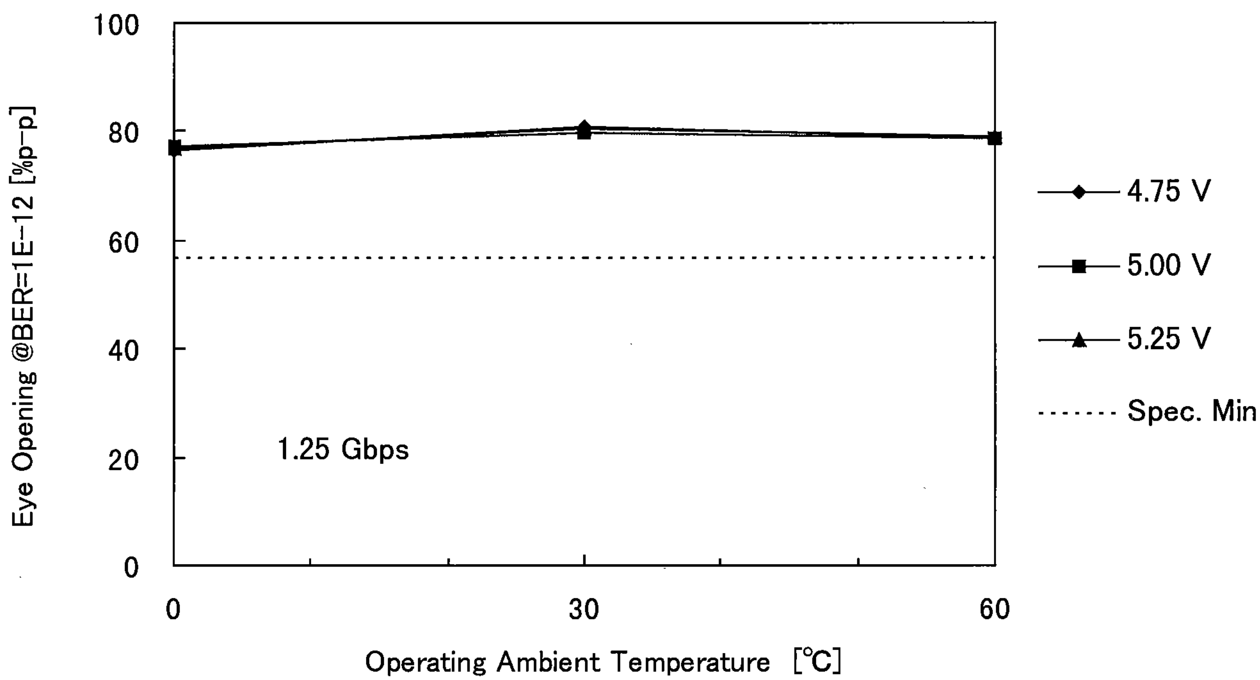

Fig. 6 Eye Opening versus Operating Ambient Temperature

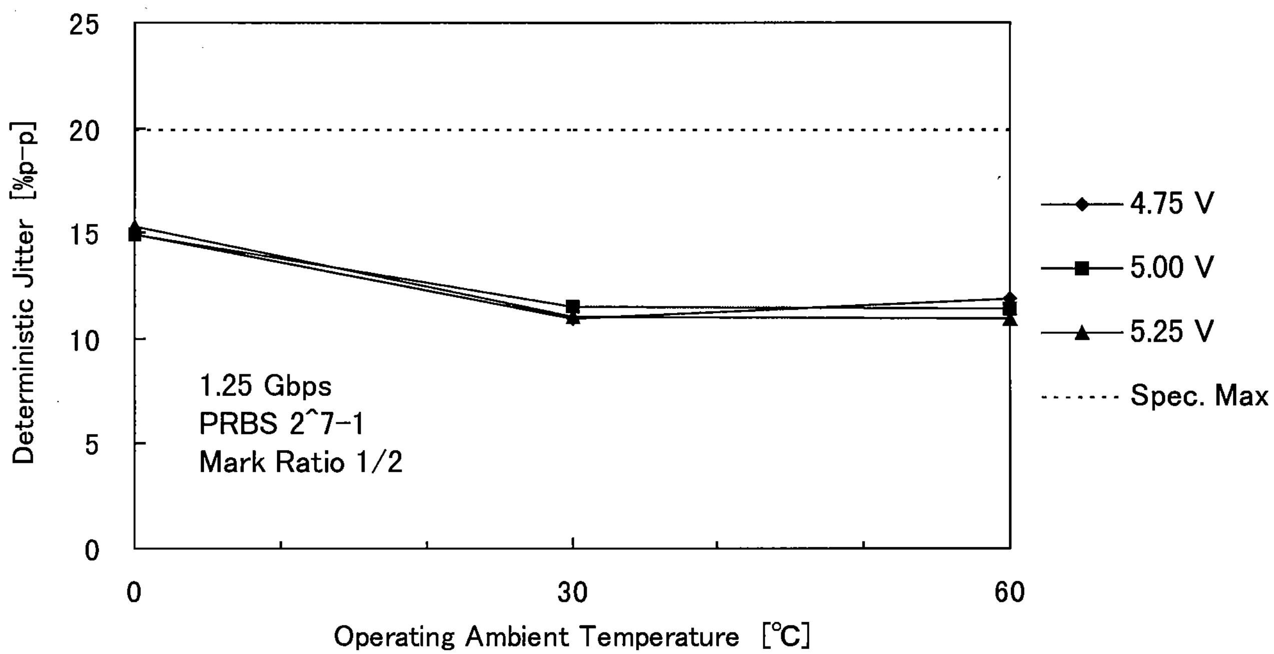

Fig. 7 Deterministic Jitter versus Operating Ambient Temperature

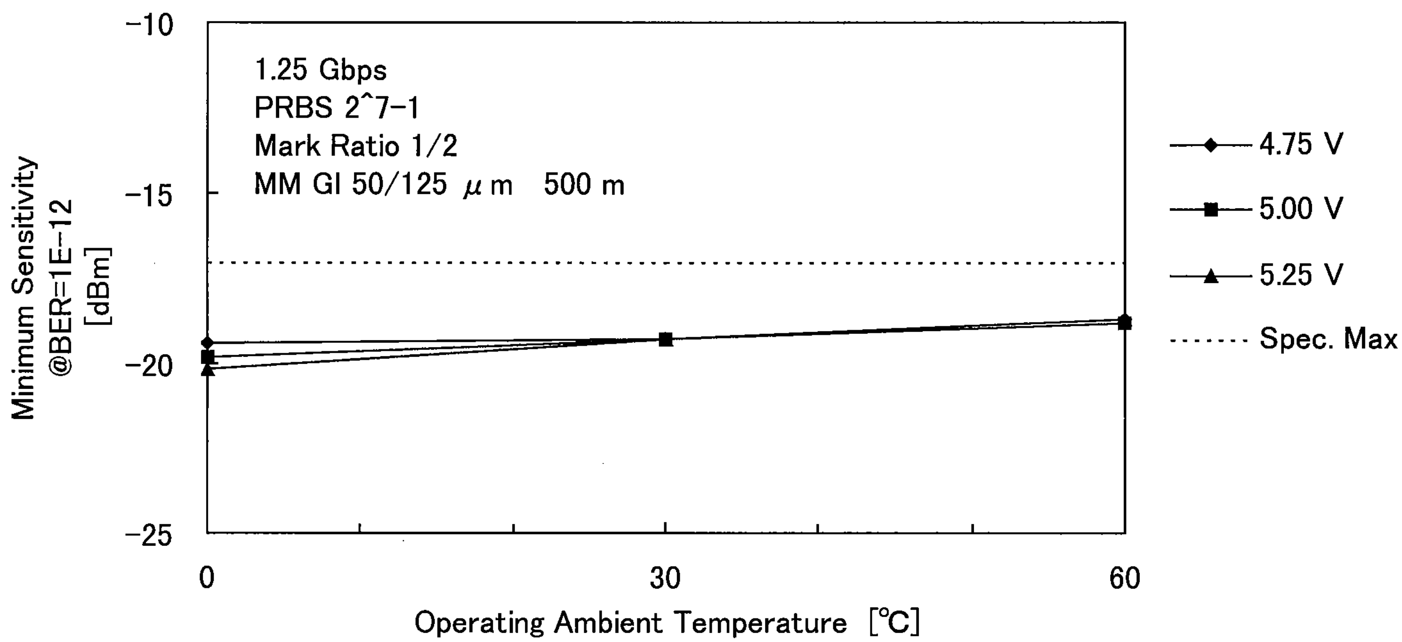

Fig. 8 Minimum Sensitivity versus Operating Ambient Temperatutre