Burst-Mode Transmitter for 1.25Gb/s Ethernet PON Applications

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ABSTRACT

This paper presents a burst-mode 1.25Gb/s transmitter suitable for use in Ethernet PON (E-PON) applications. With burst enable signal the transmitter proposed in this paper allows fast responses from the beginning of high-speed burst data while a conventional APC circuits based on feedback from a monitor photodiode was used. The chip was implemented in 0.18μm CMOS technology and occupies an area of 0.9 × 0.75 mm² with about 260mW power dissipation under 3.3V supply. Measurement shows a stable transmitted optical power over a wide temperature range (-40℃ to 80℃) with above 10dB extinction ratio.

1. INTRODUCTION

As motivated by the huge data transmission capacity for multimedia communications, PON (Passive Optical Network) based on FTTH (Fiber-To-The-Home) is considered as an emerging access network technology to solve the last mile problem of communications. As illustrated in Figure 1, typical PON system consists of OLT (Optical Line Terminal), ONUs (Optical Network Units) and passive optical splitter connecting these two parts. As can be seen Figure 1, PON system is a PtMP (Point-to-Multipoint) optical network with no active elements in the signal path from source to destination. This passive PtMP ability sharing a single optical fiber makes it feasible to implement a cost effective solution for subscriber line that supports broadband voice, data, and even video services [1-2]. A key component of such PON systems is the burst-mode up-stream transmitter located inside the ONUs at the subscriber end. Its crucial performance characteristics are careful control of the transmitted power over a wide temperature range.

This paper describes 1.25Gb/s optical transmitter for E-PON (Ethernet PON) applications using a standard CMOS technology. Though the ATM-PON was developed and first standardized from FSAN (Full Service Access Network) in the middle of 1990s as an optical network transport protocol, the E-PON based on IP technology tends to be thought as a much attractive communication protocol because of its lower cost and higher speed compares on ATM-PON [3-4]. Furthermore, in this paper, the increasing demands for the lower cost and higher integration can be sufficiently satisfied with CMOS based implementation of high-speed circuits.

The fully integrated 1.25Gb/s transmitter with 0.18μm CMOS process was accomplished for the "The study of core technology of IP-based optical access network", which is supported by the Ministry of Information and Communications of Korea. This work also contributes the development of E-PON in a foreseeable future.

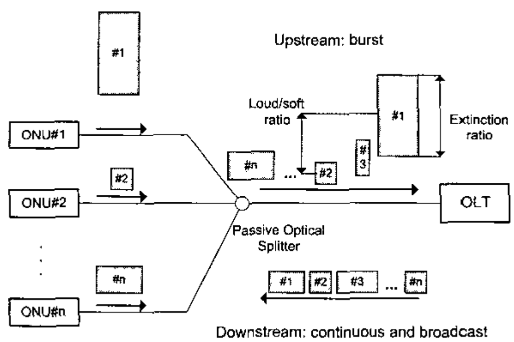

Figure 1. Architecture of general PON system

2. Transmitter Architecture and Circuits

Most optical transmitters are required to stably maintain system performances such as average optical power and extinction ratio over a wide temperature range (-40°C to 80°C). In order to obtain reliable and constant transmitted optical power over this wide temperature, the characteristics of laser diode should be confirmed as a function of temperature.

Figure 2 shows general transmitted optical power versus laser current characteristics of a laser-diode. Although the transmitted power is roughly proportional to the current through the laser above threshold (I_{th}), as illustrated in Figure 2, this relationship varies greatly

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with temperature of the laser. The increased temperature results the decreased optical gain, which is normally defined as the slop efficiency (η). As the gain decreases, more laser current should be driven into the laser in order to get a coherent optical power from the laser. Therefore, these inherent temperature dependencies of laser diode make it essential optical transmitter to adopt some temperature compensation circuits.

For controlling the transmitted power, the designed burst-mode transmitter, in this paper, uses a conventional feedback technique, which is composed of high-speed transimpedance amplifier (TIA) and peak detection circuits. With burst enable signal (BEN) the transmitter proposed in this paper allows fast responses from the beginning of high-speed burst data while a conventional APC circuits based on feedback from a monitor photodiode was used [5].

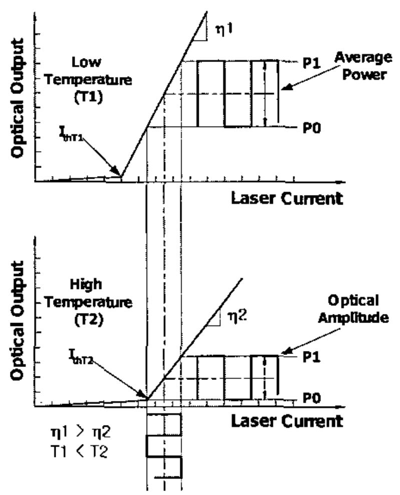


Figure 2. Temperature characteristics of a laser-diode as an optical output vs. laser current.

Figure 3 shows the simplified block diagram of the burst-mode optical transmitter architecture proposed in this work. As discussed above, in order to compensate the strong temperature dependency of the laser diode, peak comparator circuits (AMC and APC) based on feedback from a monitoring photodiode are implemented. DC coupling between circuits is required for burst-mode operation. As can be seen in Figure 3, together with Top/Bottom peak detection circuits, the APC and AMC circuits control bias and modulation currents of the laser diode respectively for the given external references. Therefore, in this architecture, once the reference voltages of the AMC and APC circuits are determined at the outside, the initial bias and modulation currents for the stable optical power of the laser diode are automatically installed. Here the initial bias current is usually around the threshold in order to reduce the turn-on delay of the laser.

For the given reference voltages, as temperature increases the lower monitoring photodiode current (i_{PD}) is fed into the high-speed TIA due to the decreased transmitted optical power of the laser. And then this feedback current generates higher voltage at the output of peak detection circuits, which results in increasing bias and modulation currents of the laser diode. In the next turn, the increased bias and modulation currents rather decrease the output voltage level of the peak detection circuits so that the reliable and constant optical power is transmitted.

In this principle, the proposed optical transmitter can provide stable performances over a wide temperature without any kinds of additional adjustments. The detailed circuits for each block are explained below.

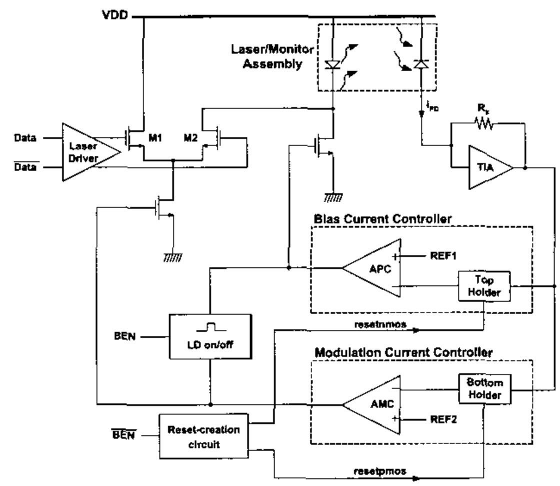


Figure 3. Block diagram of the proposed transmitter architecture with temperature compensation for laser-diode.

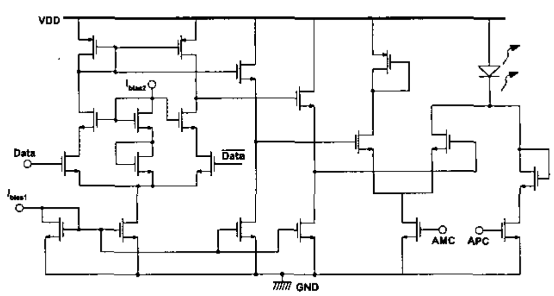
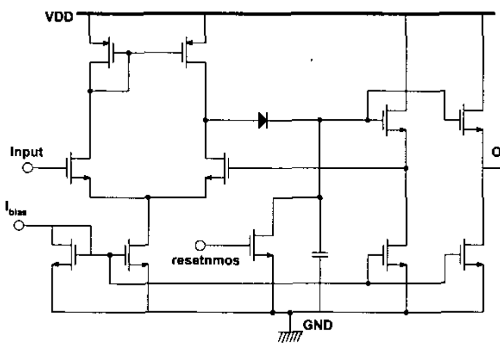


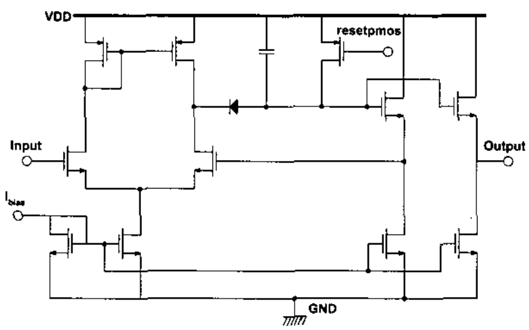
Figure 4. Simplified Laser driver schematic.

Figure 4 shows simplified laser driver schematic. In order to provide proper DC bias and 50Ω matching of the input, the designed laser driver uses simple LVPECL interface. As can be seen in Figure 4, in order to increase saturation regions of the differential pair, the first differential stage adopts a simple DC feedback topology.

The peak detection circuits are given in Figure 5. The principle and concern on the operation of the holding circuits was fully discussed in [6]. As can be seen in Figure 5, for burst-mode operation, the designed Top/Bottom hold circuits are reset before each input burst. The reset created from burst enable signal provides a fast response time for the laser on/off operation as well.



(a)



(b)

Figure 5. Peak detection circuits (a) top hold circuit and (b) bottom hold circuit.

3. Measurement Results

The proposed optical transmitter shown in Figure 3 is being realized with 0.18μm CMOS technology and dissipates are about 260mW with 3.3V supply voltage and an area of 0.9 × 0.75 mm^2. The chip microphotograph is shown in Figure 6. Now, for the system integration, small form factor (SFF) package of the implemented chip is currently in development.

In order to evaluate the performances of the proposed transmitter, we uses HP Parallel BER Tester, which can generates up to 3Gb/s PRBS burst signal.

Figure 7 shows the measured waveforms for 1.25Gb/s burst mode with $2^{-9} - 1$ PRBS data. As can be seen in Figure 7, the proposed transmitter quickly responses with the reset signal. For giving more insights, Figure 8 provides more detailed description of the eye diagram of one of the two bursts shown in Figure 7. As shown in Figure 8, the eye is clearly opened with the patterned preamble and PRBS payload data. And it shows above 10-dB extinction ratio with the averaged transmitted power of about 0-dBm.

In order to simply test the APC/AMC functions in a wide temperature range (–40°C to 80°C), a hot blow heater is used to directly increase the temperature of the laser. As a result, Figure 9 compares the eye diagram under two extreme temperatures of the laser with/without the feedback. Based on these measurements, the feedback proposed in this paper is confirmed to be working properly but the feedback loop gain is not enough to satisfy the constant transmitted optical power. However, in case of without feedback, the optical power is severely distorted as temperature increases.

Table 1 summarizes the overall performances of this work.

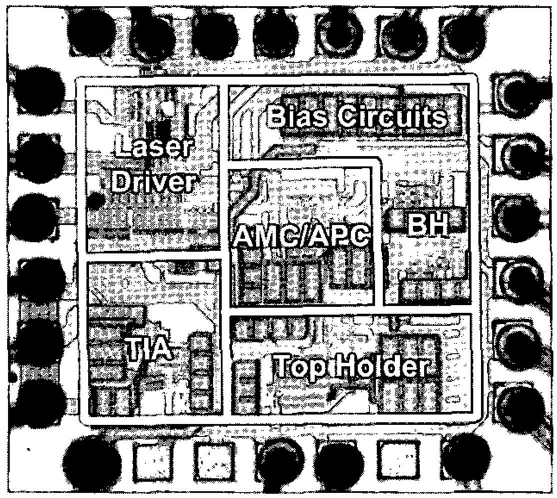


Figure 6. Chip microphotograph.

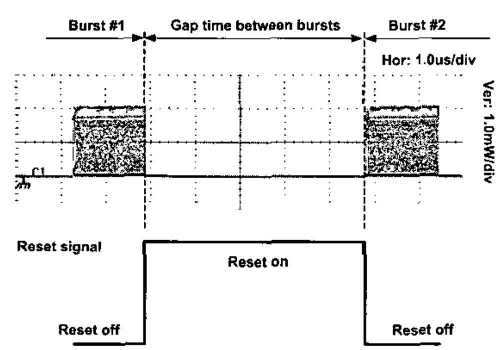


Figure 7. Measured waveforms for 1.25Gb/s burst mode with $2^{-9} - 1$ PRBS data

4. Conclusions

A burst-mode optical transmitter for 1.25Gb/s E-PON applications has been integrated in a standard 0.18μm CMOS technology. To achieve reliable and constant operation over a wide range of ambient temperature, the designed transmitter uses dual-loop feedback realized with peak comparator circuits. Based on measurements, the proposed feedback can be used for the burst-mode application. An improved version is currently in development and focused on increasing feedback loop gain and ESD protection circuits.

Acknowledgement

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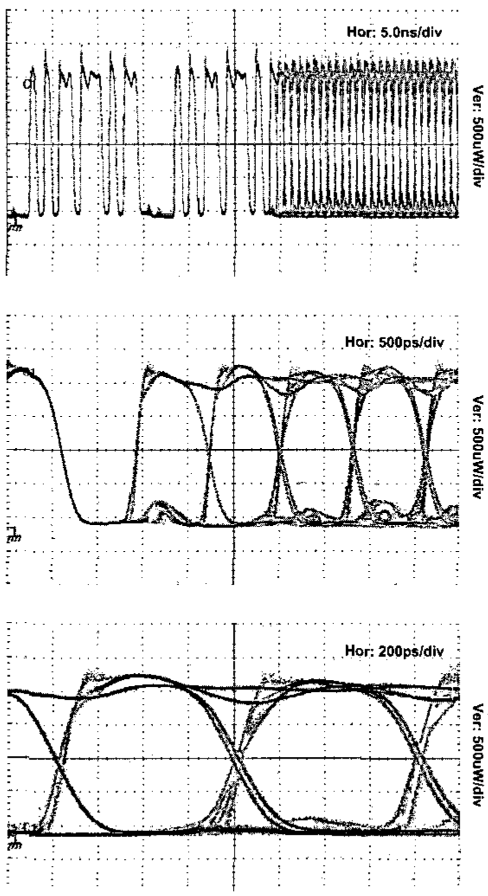

Figure 8. Eye diagrams of one of the two bursts shown in Figure 7t the room temperature.

Table 1. Summary of the proposed work

Specifications	This work	Conditions
Data rate	1.25 Gb/s	Burst-mode
Averaged power	About 0-dBm	At room temp.
-3-dB Bandwidth	1.3 GHz	Not optimized
Extinction ratio	> 12 dB (w/) > 8 dB (w/o)	Feedback
Power dissipation	About 260 mW	3.3 V supply
Chip size	0.9×0.75 mm^2	0.18μm CMOS

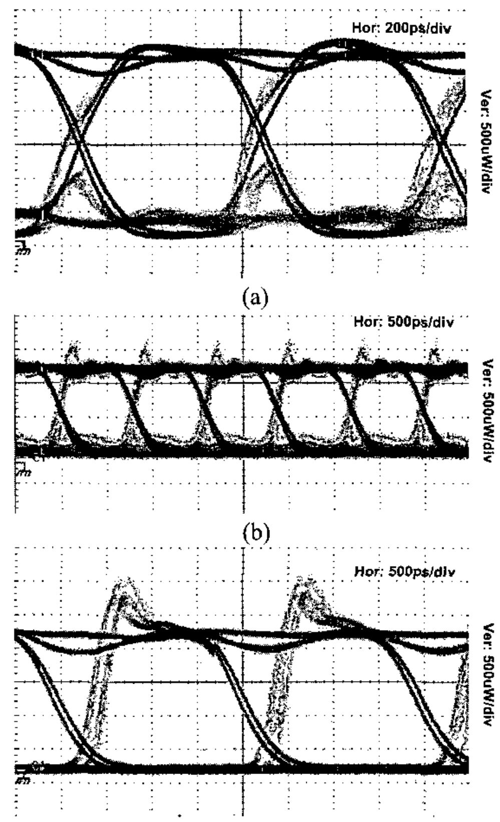

Figure 9. Eye diagrams of the transmitted power over temperature with/without the feedback. (a) and (b) are lower and higher temperature with the feedback, respectively, and (c) is without the feedback.

References

[1] IEEE 802.3 ah Ethernet in the First Mile Task Force, March 2002.

[2] Toru Matsuyama et al., "A 156Mbps CMOS Laser Diode Driver for Optical Burst-Mode Transmission," *IEEE Simposium on VLSI Circuits Digest of Technical Papers*, 2000.

[3] Recommendation ITU-T G.983.

[4] Afshin Momtaz et al., "A Fully Integrated SONET OC-48 Transceiver in Standard CMOS," *IEEE Journal of Solid-State Circuits*, December 2001.

[5] Quan Le et al., "Burst-Mode Receiver for 1.25Gb/s Ethernet PON with AGC and Internally Created Reset Signal," *IEEE International Solide-State Circuits Conforence, Dig. of Tech. Papers, pp. 474-540,* Feb. 2004.

[6] M. Nakamura et al., "156-Mbit/s CMOS Optical Receiver for Burst-mode transmission", *IEEE Journal of Solid-State Circuits*, August 1998.