A Novel Automatic Power Control Method for Multichannel VCSEL Driver

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Abstract

We present a novel method of automatic power control (APC) for multichannel VCSEL driver ICs. The APC function is achieved by monitoring the junction voltage change of VCSEL with temperature variations. It demonstrates the designed VCSEL driver IC can control the optical power without an additional monitoring-photodiode (M-PD) and operates up to 2.5 Gb/s using 0.18-µm CMOS technology.

I. Introduction

High-speed direct coupled parallel optical data transmissions commonly use vertical-cavity surface-emitting lasers (VCSELs) in one-dimensional or two-dimensional arrays as their light sources.

These VCSELs are required to compensate the performance degradations due to temperature variations. To alleviate the thermal effect of VCSEL at transmission system, various papers have been reported on this study over a long period to time. Two kinds of solutions are available for the above purpose. One is the development of a temperature-insensitive VCSEL device [1] and the other is the use of an automatic power control circuit in VCSEL driver IC [2]-[3]. Since the technology for temperature-insensitive VCSEL device is still immature, APC has been used commercially to compensate the temperature characteristics of VCSEL.

APC architecture of most VCSEL driver ICs includes a photodiode that is used to monitor the output power from the VCSEL as shown in Fig.1. This monitoring-photodiode (M-PD) provides a current output proportional to the total light output from the VCSEL. The proportionality of M-PD output current is associated with the package configuration to focus on M-PD a part of output power from VCSEL [4]. This conventional APC is difficult to apply to 1 × N or N × N multichannel VCSEL.

In this paper, we describe VCSEL driver IC with a novel automatic power control method, which is implemented by 0.18-µm CMOS technology. The proposed APC technique does not require an M-PD to adjust the output power of VCSEL with changing temperature.

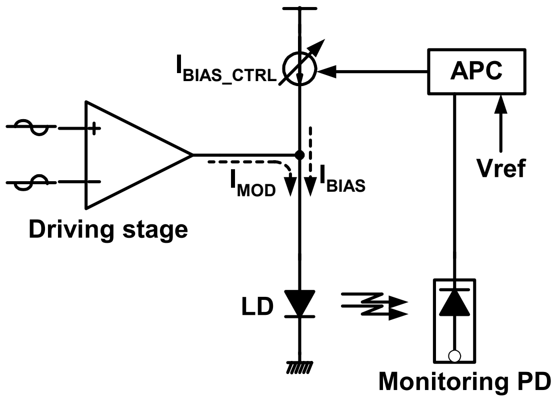


Fig.1. Conventional driver IC with automatic power control function.

II. VCSEL Characteristic

For most semiconductor diodes, the junction voltage at fixed current decreases as the temperature increases. VCSELs are no exception, with approximately a -2 mV/°C variation. Figure 2 shows the voltage variation of a specified node of the VCSEL at fixed injection current (I_{INJ}=4 mA) with changing temperature. From this experimental result, the specified node voltage of VCSEL changes from 1.87 V to 1.65 V as temperature changes from 27 °C to 110 °C. Sensing the specified node voltage of VCSEL can be applied to automatic power control method for multichannel VCSEL driver IC.

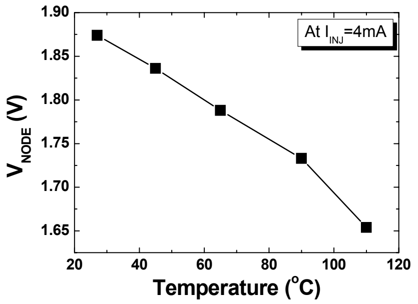
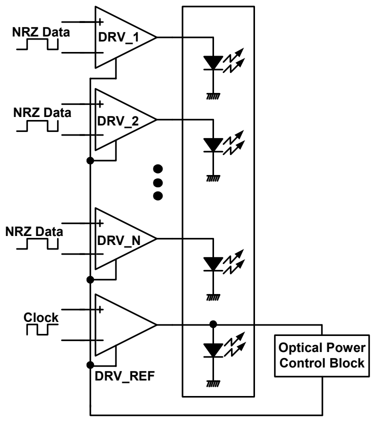


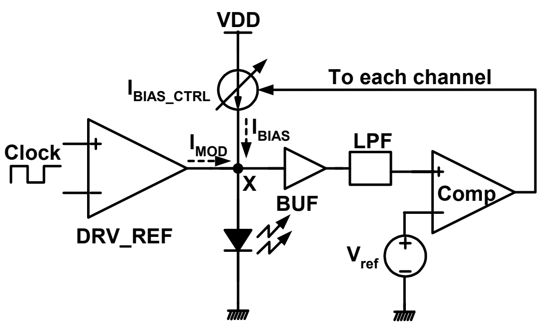
Fig.2. The voltage variation of the specified node of VCSEL as temperature changes.

III. The Proposed APC Method

In order to maintain a constant optical power in the presence of temperature variations, most VCSEL driver ICs are required to control the bias current of VCSEL in the ambient temperature variations and have adjusted the optical power by feedback circuit including M-PD. The proposed APC method, however, adjusts the optical power of VCSEL array without externally additional M-PD.



(a)



(b)

Fig.3. (a) Block diagram of multichannel optical transmitter with the proposed APC method and (b) the detailed block of reference channel with APC.

Figure3 (a) shows the simplified block diagram of multi-channel optical transmitter with the proposed APC using reference channel. As shown in Fig.3. (a), the optical power of all channels can be adjusted by monitoring the specified node of reference-channel VCSEL. The clock signal is applied to this reference channel for extracting DC level of the specified node.

APC block is consisted of buffer, low-pass filter (LPF), and comparator as shown in Fig.3. (b). The buffer isolates the X node and LPF. The LPF extracts the DC voltage level of X node. The comparator compares the extracted DC voltage level with the external reference voltage (V_{ref}) and generates the relevant voltage level to control the bias current of VCSEL. In this architecture, point which special attention should be paid is the design of bias current control circuit that provides a fixed current independent of X-node voltage.

For the given external reference voltage, as temperature increases, the DC level of the X node is lowering. This DC level extracted by LPF is compared with the reference voltage at comparator. And then the relevant voltage of comparator increases the bias current to VCSEL until the X-node voltage and reference voltage reach a same level.

In this principle, the proposed APC method for multichannel VCSEL driver IC makes it possible to provide stable optical power over temperature variations without externally additional M-PD.

IV. Results

The performance of driver IC with the proposed APC method has been simulated using the parameters of the 0.18-μm CMOS technology.

Figure 4 shows changes of bias current with the voltage variations at X node in Fig. 3(b). This simulation results indicate that the proposed APC method adjusts the bias current of VCSEL at several node voltages corresponding to temperature variations.

Figure 5 depicts the output transient responses for 2.5-Gb/s modulation. In the input pattern, 1,0,1,0 patterns are for reference channel and PRBS pattern is for data channels.

Figure 6 illustrates the layout for four-channel VCSEL driver IC array, in which the chip area is 0.6 × 1.7 mm^2.

V. Conclusions

VCSEL driver IC with the proposed APC method is implemented by 0.18-µm CMOS technology. The APC function is achieved by monitoring the junction voltage change of VCSEL with temperature variations. Therefore, this work can adjust the optical power of VCSEL without externally additional M-PD.

An improved version is currently in development and focused on one and two-dimensional VCSEL driver IC without a sacrificed channel, which is reference channel in this version.

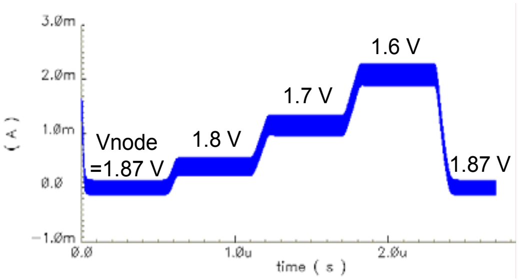
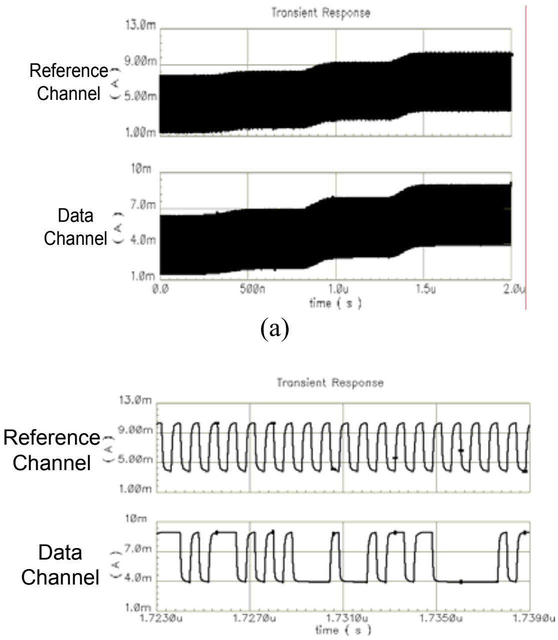


Fig. 4. Bias current adjustment as the node voltage of VCSEL changes.



(a)

(b)

Fig.5. Transient responses of reference and data channel simulated for 2.5-Gb/s modulation.

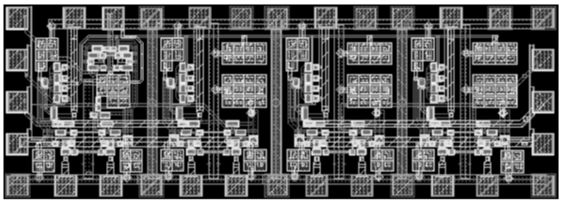


Fig. 6. Chip layout for 4-channel VCSEL driver IC array.

Acknowledgement

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References

[1] Chida, H., Fukagai, K., Miyazaki, T., Ishikawa, S., "25-100°C automatic power control free 600 Mbit/s modulation of 0.98 µm InGaAs/AlGaAs laser for high-speed data link," Electronics Letters, vol. 31, issue 23, pp. 2006-2008, 1995.

[2] Ohtomo, Y., Yoshida, T., Nishisaka, M., Nishimura, K., Shimaya, M., "A single-chip 3.5 Gb/s CMOS/SIMOX transceiver with automatic-gain-control and automatic-power-control circuits," in IEEE ISSCC, pp. 58-59, Feb. 2000.

[3] Yong-Hun Oh, Quan Le, Sang-Gug Lee, Nguyen Duy Bien Yen, Ho-Yong Kang, Tae-Whan Yoo, "Burst-mode transmitter for 1.25Gb/s Ethernet PON applications passive optical networks," Proc. of ESSCIRC, pp. 283-286, Sept. 2004.

[4] Claisse, P.R., Jiang, W., Kiely, P.A., Roll, M.; Boughter, L., Sanchez, P., Cotney, D., Lebby, M., Webb, B., Lawrence, B., "Automatic power control of a VCSEL using an angled lid TO56 package," ECTC, pp. 203-209, May 1998.