

Method for the Control of Extinction Ratio in Optical Transceivers

Introduction

Extinction Ratio (ER) is directly related to Laser Signal Power and Bit Error Rate (BER) in an optical communications channel, and is a key parameter used to specify the reliability of signal transmission in optical transceivers. There have been a variety of methods used to control ER. Most methods have shown significant limitations, especially when the laser experiences changing temperature and aging conditions.

Purpose

CEYX utilizes a proprietary method for ER control that yields superior performance over other methods. This brief discusses the method CEYX has developed and compares laser performance using the CEYX method to more traditional methods.

Extinction Ratio Defined

ER is defined as follows:

$$\text{Equation 1: } ER = 10 \log (P_H/P_L)$$

Where:

P_H = Laser Power level for logic high

P_L = Laser Power level for logic low

Discussion of how Laser Power changes with Temperature

Laser power levels can drift as a function of its temperature and aging. Changes in laser power levels makes distinguishing between a logic low (power level low) and a logic high (power level high) more difficult. Misinterpretation of signal low and signal high results in data errors (as measured by BER). A measurement of the distinction between power logic levels is the extinction ratio, which is defined as 10 times the logarithm of the ratio of power level high or logic high, to the power level low or logic low.

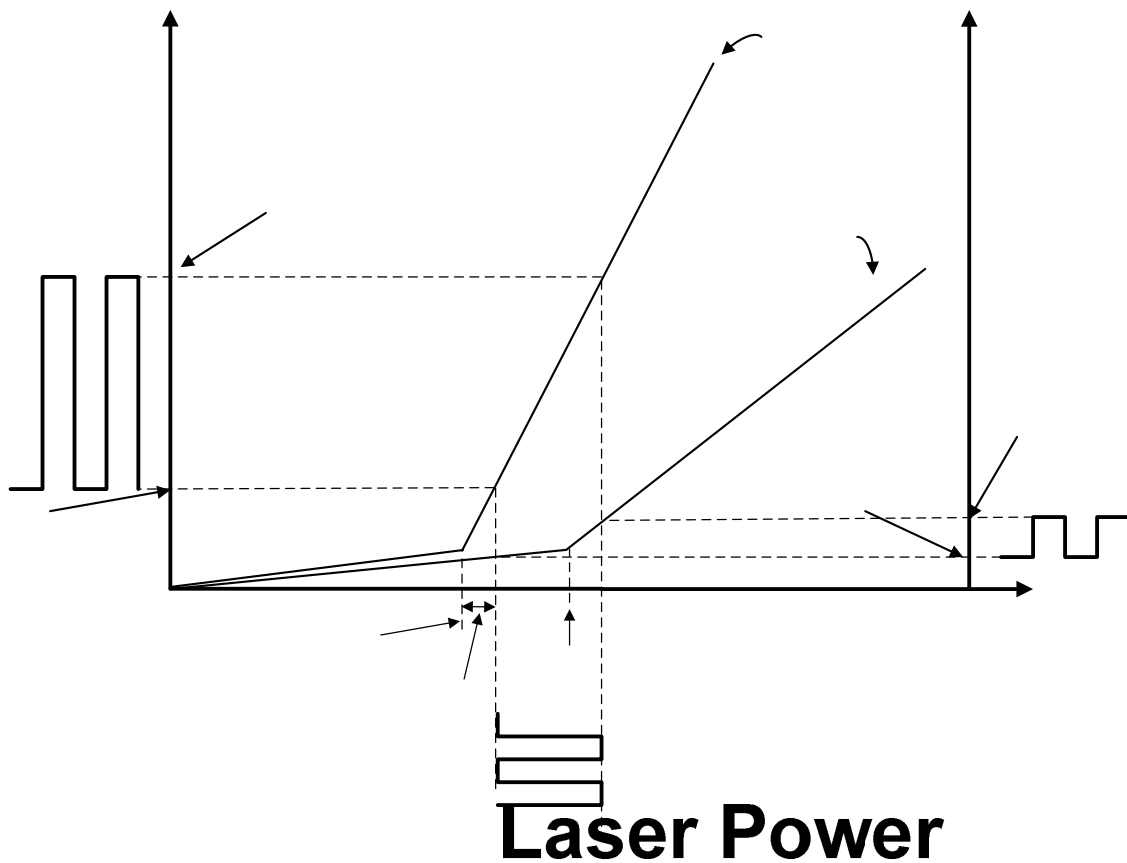
To illustrate the issue with laser power output as a function of current input, Figure 1 shows a typical set of characteristics of Laser power versus laser current, over a temperature range. During optical transceiver set up, sufficient current must be applied to the laser in order to reach the laser threshold I_{TH1} . To ensure adequate margin for the laser to achieve full lasing, additional current over the threshold current is added $\Delta_{BIAS 1}$. Full lasing current is represented as laser bias current I_{B1} shown in Equation 2.

$$\text{Equation 2: } I_{B1} = I_{TH1} + \Delta_{BIAS 1}$$

Laser current settings are generally done at a default temperature T_1 , which is usually manufacturing ambient. As seen in Figure 1, I_{B1} corresponds to the laser power output low P_{LOW1} or logic low at T_1 .

A second current source is introduced into the laser I_{MOD1} , which establishes the laser power output high P_{HIGH1} or logic high also at T_1 . As represented in Figure 1, the difference between P_{LOW1} and P_{HIGH1} is distinct and well defined, resulting in an acceptable ER value.

The problem of laser output power shift begins to show up when the temperature changes from the original T_1 setting. For example, when the temperature of the laser changes to T_2 , the result is LI Characteristic Temperature T_2 . The right vertical axis in Figure 1 shows the new laser output power, where P_{HIGH2} and P_{LOW2} are significantly closer together. The result is increased chance for bit errors in data transmission. Further complicating laser performance is the P_{LOW2} point now operates below the shifted laser threshold current I_{TH2} . In cases where P_{LOW2} is below the new laser threshold I_{TH2} , output signals will become unstable at the logic low. An additional complicating factor when P_{LOW2} is below the new laser threshold I_{TH2} is sluggish transition times between logic low and logic high, resulting in further erosion of signal quality.



The CEYX Solution for Extinction Ratio

CEYX's solution uses its proprietary firmware called the Infinite-loop Extinction Ratio Stabilizer (ILERS). The ILERS program maintains P_{HIGH} and P_{LOW} be separate, coordinated firmware programs, which independently and simultaneously monitor and control the output operating parameters. The objective of the ILERS program is to maintain stability for P_{HIGH} and P_{LOW} regardless of temperature and aging.

The ILERS program contains several elements described in more detail below:

Monitor and control programs:

- Automatic threshold detector
- Dynamic Servo

Compensating programs:

- Temperature compensator
- Aging compensator

**Power Out
at temperature T_1**

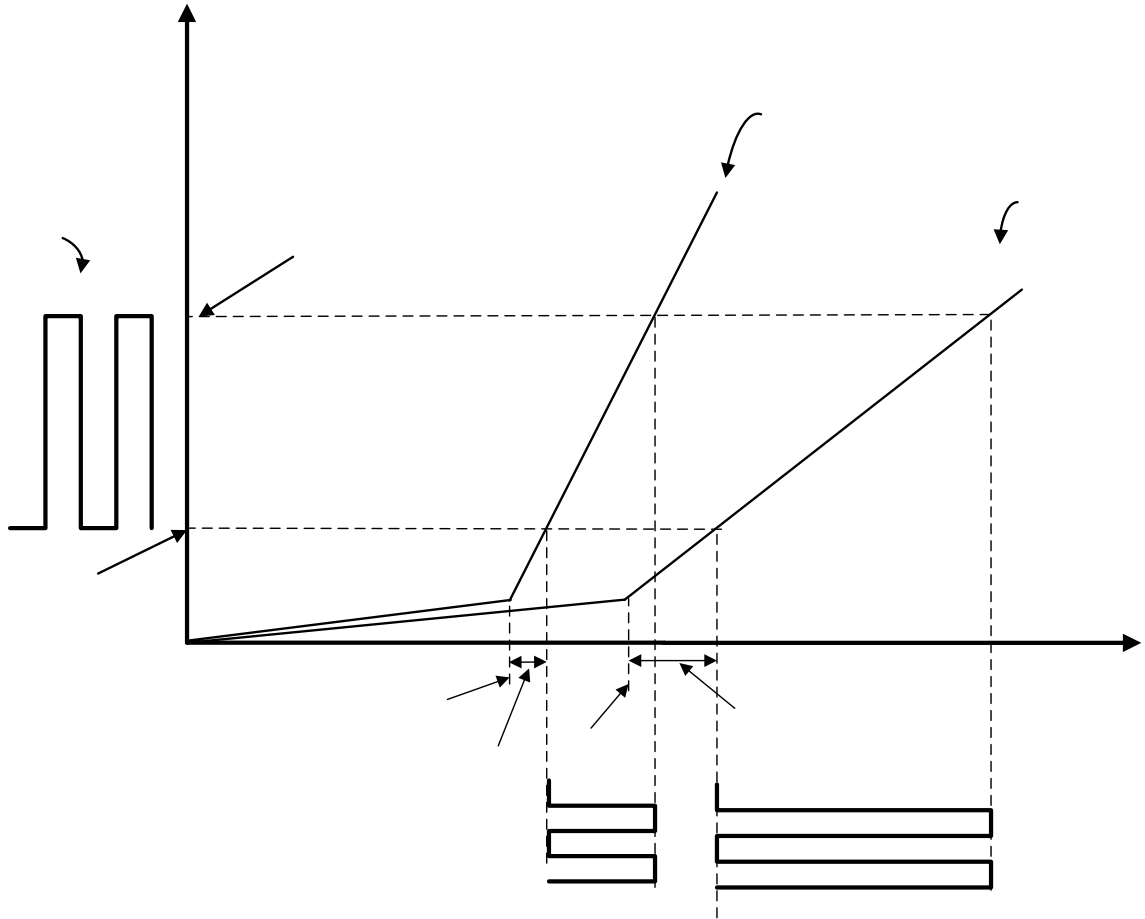
CEYX Extinction Ratio Stabilizer Approach

The Control and Monitor Programs

1. The CEYX approach begins at initial transceiver power up. To set P_{LOW} at initial power up, the ILERS program uses the **Automatic Threshold Detector** program which:
 - a. Determines the laser threshold current I_{TH1} during power up initialization

- b. Automatically determines Δ_{BIAS1} , the bias margin, which is the additional amount of bias current applied by the system to set the operating point P_{LOW} to the desired level. The bias margin guarantees operation above threshold in presence of system noise.

The result is that I_{B1} is set according to Eq.2 (see Figure 2). The output value of I_{B1} is stored in the Controls Configuration database for future reference.



2. The parametric values now available to the ILERS program are the automatically determined I_{B1} , the measured P_{LOW} , and the target ER value (which was previously stored in the Configuration database as part of the operation parametric value set.) Using Equation 1, the desired P_{HIGH} is calculated and the result is stored in the Configuration database.
3. The **Dynamic Servo** is then activated in order to maintain the P_{HIGH} set point during the tranceiver's useful lifetime. Shown in Figure 3 is a diagram of the portion of the Dynamic servo that is used to maintain P_{HIGH} .

Laser Power

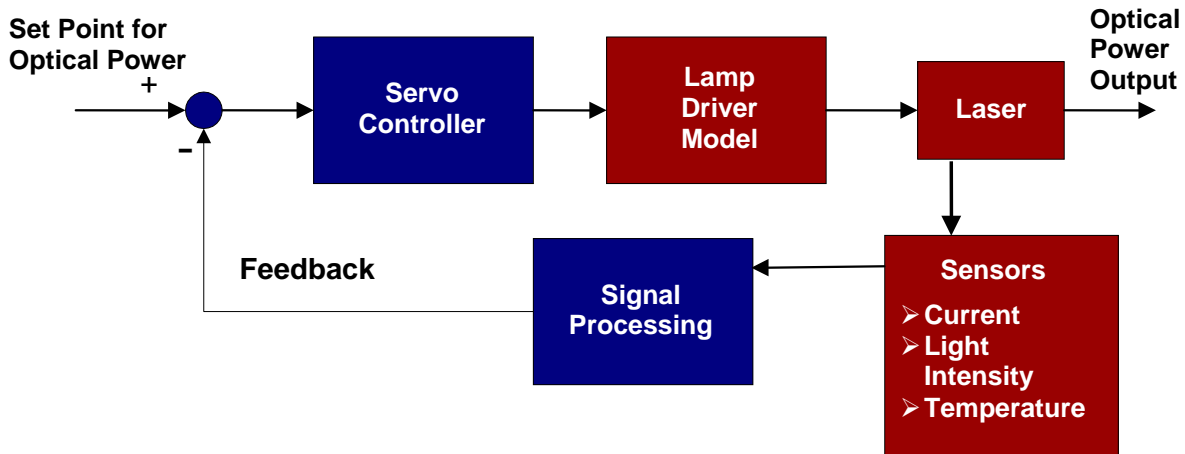


Figure 3: Dynamic Servo Control for Laser Power

The Compensator Programs

1. Temperature Compensator

The Temperature Compensator program is activated to constantly monitor temperature effect of P_{LOW} through the use of models and temperature feedback. Whenever a temperature change is detected by the Temperature Compensator, the compensator firmware calculates new factors (see Eqs. 3 and 4) for the threshold current I_{TH1} and for the bias margin current Δ_{BIAS1} . The result is that the original laser power output for the logic low P_{LOW} is maintained as it was originally set.

Two of the models used to compensate for the temperature drift of the laser are:

- Laser threshold current versus temperature function is described by Eq. 3 and shows the relationship of temperature changes to changes in the original threshold I_{TH1} . As temperature changes, the function f is adjusted to ensure $I_{TH2} = I_{TH1}$:

$$\text{Equation 3: } I_{TH2} = I_{TH1} * (T, T_1)$$

Where I_{TH1} is the threshold current measured by the system at the time when the transceiver is calibrated, T_1 is the temperature of the laser when the transceiver is calibrated.

Slope efficiency versus temperature function is described by Eq. 4 and shows the relationship of temperature changes to changes in the original LI Characteristic at T_1 slope S_{L1} . As temperature changes the function g is adjusted to ensure $S_{L2} = S_{L1}$:

$$\text{Equation 4: } S_{L2} = S_{L1} * (T, T_1)$$

Where S_{L1} is the slope efficiency at the time when the transceiver is calibrated, T_1 is the temperature of the laser when the transceiver is calibrated. As seen in Figure 2 the Temperature Compensator allows the change of LI Characteristic at T_1 ; shift to LI Characteristic T_2 , with no resulting change in P_{LOW2} (where $P_{LOW1} = P_{LOW2}$).

2. Aging Compensator

The Age Compensator program is activated to constantly monitor laser-aging effects on P_{LOW} through the use of models and age feedback. The laser will exhibit age effects in threshold current and slope efficiency. Since threshold current aging is directly related to P_{LOW} , the threshold current must be adjusted to compensate.

To compensate, the Aging Compensator program keeps track of laser operational time. In an optical transceiver application, the program will set a flag in Controller memory in order to notify the network host computer a recalibration of the threshold current is required. Due to the nature of the typical laser age profile, the need to recalibrate the threshold current is only occasional, and is related to the transceiver application requirements.

If the network host grants permission to recalibrate, the firmware will run the Automatic Threshold Detector program, which will then recalibrate the threshold current I_{TH} . The newly calibrated threshold current I_{TH} is subsequently retrieved and used in all relevant controls programs.

As an option, some systems will rely on setting and maintaining average laser power. This approach is also used by the Temperature Compensator Module to produce stable ER over temperature.

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