Application Note:

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Thermistor Compensation for Temperature-Induced Slope Efficiency Variations in PON Burst-Mode Laser Drivers

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1 Overview

The optical network terminal (ONT) in any passive optical network (PON) system requires a burst-mode laser diode driver. This laser driver must be capable of quickly turning on a laser diode, modulating the laser to send a burst of data, and then quickly shutting down to allow another user to transmit. Since the ONT may be mounted on the outside of a building, it must be capable of robust operation over the full -40° to +85°C temperature range. There are several integrated circuit burst-mode laser drivers commercially available today. In most cases these burst-mode laser drivers include very effective closed-loop temperature compensation for variations in laser diode threshold current caused by temperature and aging. Unfortunately they generally do not include internal methods for changing their output modulation current to compensate for temperature induced variations in laser diode slope efficiency.

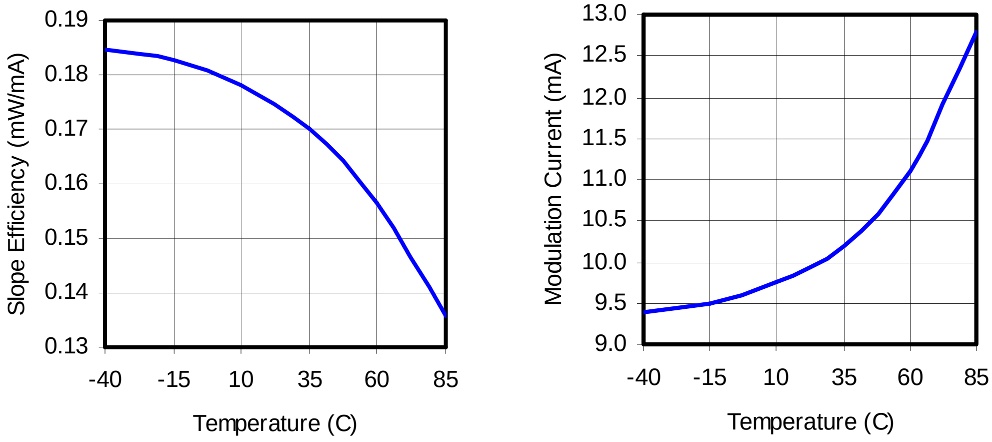
In a typical PON system, the average optical power and extinction ratio for the burst-mode upstream signal must be maintained at stable levels under all temperature conditions. In most cases the minimum average optical power is 0dBm or more and the specified extinction ratio is greater than 10. For a typical laser diode the slope efficiency (peak-to-peak optical output power divided by peak-to-peak input current) decreases as the temperature increases, causing the extinction ratio to decline. There are several methods to deal with this problem, including: (a) set the initial extinction ratio much higher than the specified minimum so that even at the maximum temperature, the extinction ratio will never decline below this level, (b) use a commercially available programmable temperature compensated potentiometer to change the laser driver modulation current as a function of temperature, (c) implement external circuitry for closed-loop control of the laser driver modulation current, or (d) use a network of fixed resistors and thermistors to change the laser driver modulation current as a function of temperature. Method (a) seems simple, but setting a very high extinction ratio on a burst-mode laser driver causes a number of complications that make it impractical in most systems. Method (b) works well, but it is moderately expensive. Method (c) is impractical due to difficulties in reliable implementation. This leaves method (d), which is less capable than methods (b) and (c), but provides a low-cost practical solution with “good enough” performance.

2 Measured Slope Efficiency Variation of a Typical PON Laser Diode

In order to design a suitable compensation circuit, it is first necessary to obtain data on temperature-induced slope efficiency variation for the specific laser diode that is being used in the PON system. Using this data we can determine the corresponding changes in modulation current that would be necessary to keep the output power and extinction ratio constant. As an example, Figure 1(a) shows the measured average slope efficiency for laser diodes in a number of PON triplexers. The measured data for these commercially available triplexers was obtained from Maxim reference design boards[1]. From the measured slope efficiency variation, we can calculate the modulation current necessary to maintain the desired average output power and extinction ratio using

$$I_{MOD} = (P_1 - P_0)/S_e = 2P_{AVE}[(r_e - 1)/(r_e + 1)]/S_e \qquad (1)$$

where I_{MOD} is the peak-to-peak modulation current, $(P_1 - P_0)$ is the peak-to-peak optical output power, S_e is the slope efficiency, P_{AVE} is the average optical output power, and r_e is the extinction ratio. The modulation current shown in Figure 1(b) is calculated from the slope efficiency of Figure 1(a) using equation (1) with P_{AVE} = 0dBm and r_e = 11.5dB.



(a) (b)

Figure 1. (a) Measured average slope efficiency and (b) Calculated modulation current profile necessary to compensate for slope efficiency variation (assumes 0dBm average optical power and 11.5dB extinction ratio).

3 Obtaining the Desired MODSET Resistance

Once we know the desired modulation current at each temperature, we can use this data to calculate the necessary modulation current setting resistance, R_{MODSET}, for the burst-mode laser driver. For this example, we use a Maxim burst-mode laser driver[2] , where the relationship between R_{MODSET} and I_{MOD} is given by

$$R_{MODSET} = 1.2/(I_{MOD}/250) \qquad (2)$$

The curve with markers in Figure 2 represents the desired MODSET resistance and it was calculated using equation (2) along with the values of I_{MOD} from Figure 1(b).

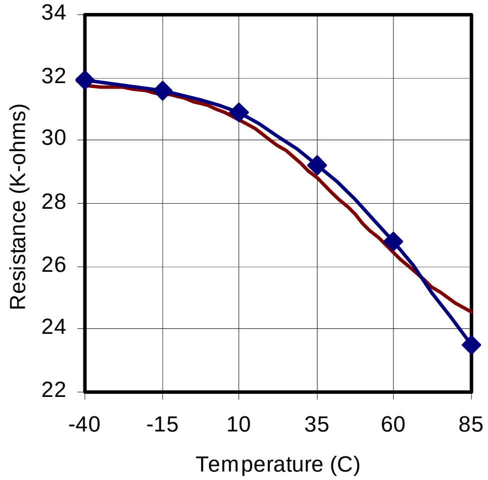


Figure 2. Desired modulation setting resistance (curve with markers) and actual resistance from thermistor network (curve without markers).

The simple resistor/thermistor network shown in Figure 3 can be used to quite effectively approximate the desired modulation setting resistance. In this figure, R_{Therm} represents the thermistor, while R_{series} and $R_{parallel}$ are standard value fixed resistors. Various combinations of thermistors and parallel resistance values can be used to create a resistance curve that approximates the desired shape. Once the curve shape is determined, it can be offset vertically by changing the value of the series resistor. The actual thermistor network curve plotted in Figure 2 was generated using a Panasonic ERT-J0ER333J thermistor along with a 9.5k parallel resistor and a 22.5k series resistor. Initial design values for these components can be determined empirically using a spreadsheet program to graph different combinations of resistance values and compare them to the desired curve (as in Figure 2). Final resistance values are then refined for optimal performance after construction and testing of the actual circuit.

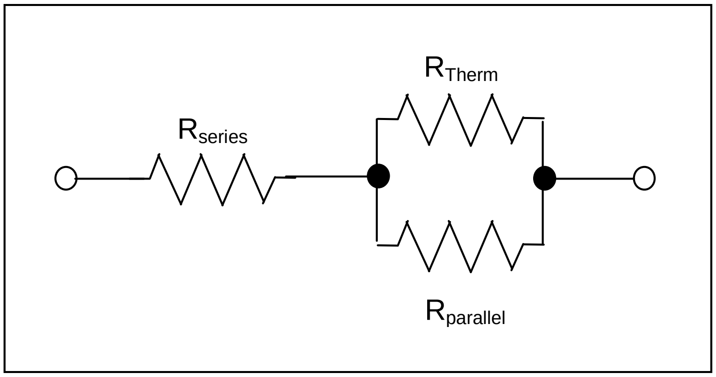


Figure 3. Thermistor network used to approximate desired modulation setting resistance.

4 Results

Actual extinction ratio measurement results using the thermistor network above are shown in Figure 4 and demonstrate that the extinction ratio variation over temperature is approximately 1dB.

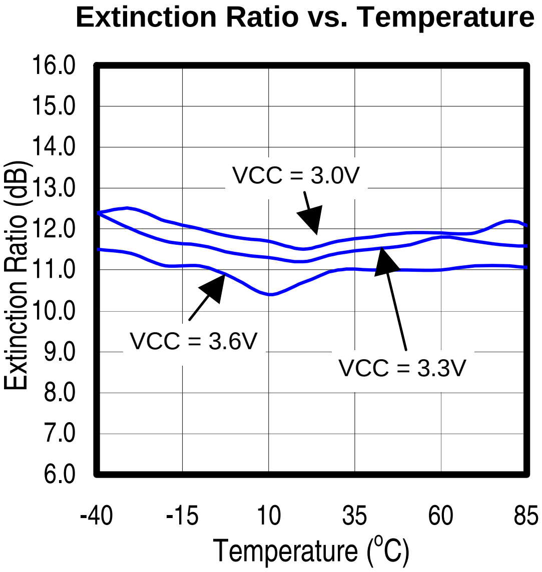


Figure 4. Lab measurement results of extinction ratio versus temperature using the thermistor network of Figure 3.

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[1] Maxim Integrated Products, HFRD 10.4 - 1244Mbps/1244Mbps GPON ONT Reference Design (datasheet), www.maxim-ic.com

[2] Maxim Integrated Products, MAX3656 155Mbps to 2.5Gbps Burst-Mode Laser Driver (datasheet), www.maxim-ic.com