0206X-APP-001-A
February 6, 2003

Using MindSpeed Laser Drivers in PON Burst-Mode Applications

Application Note

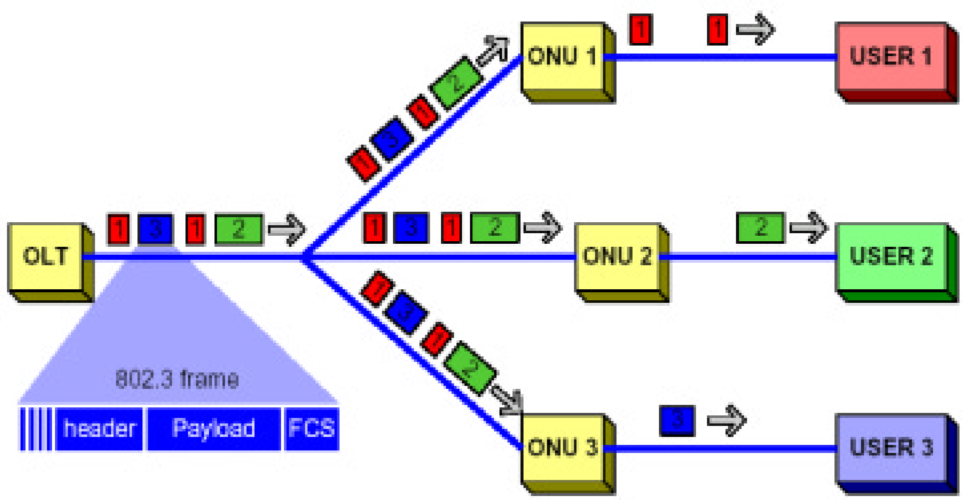
Introduction

This application note provides recommendations on how specific MindSpeed laser driver devices (M02060, CX02066, CX02067, and CX02068) can be used in burst-mode applications.

Passive Optical Networks (PON) may be an effective solution for Fiber to the Home (FTTH) and for many consumers they could become the primary data path for existing and new multimedia services. As a consumer level application, FTTH design must be extremely economical and robust. However, because a PON design requires burst-mode operation, new technical challenges and risks are present. Bias and modulation current must be enabled quickly and accurately (and be disabled just as quickly) after long delays. “Slow-start” circuitry, which protects lasers from turn-on transients, must be bypassed to some degree.

In this application note, turn-on and turn-off of the modulation current and bias current as well as external component selection will be addressed. Suggestions will be provided on required precautions to insure the transmitter does not generate transients that may generate an over current or reverse bias condition that might damage the laser.

Figure 1. Ethernet-Based Passive Optical Network [(1)]



1. Diagram from Ethernet PON presentation by JC Kuo and Glen Kramer, Alloptic, at the IEEE 802.3 EFM Study Group, Portland, OR, July 10-12, 2001.

New System Performance Requirements

Just prior to the creation of this application note, the IEEE 802.3ah Optical PMD STF voted to set minimum turn-on and turn-off times of 600 nanoseconds for the transmitter of the PON ONU (Optical Network Unit).

Later implementations of the standard may require turn-on times of 50 nanoseconds or 20 nanoseconds or less. In this application note we will describe how to achieve turn-on and turn-off times of 20 nanoseconds or less.

Lasers must be fully off during the disable period, (currently specified at less than -45 dBm). This means both modulation and bias current must be on the order of 10 uA or less when disabled. The off current of MindSpeed laser drivers is most commonly specified at 300 uA. Benchtop measurements show less than 1 uA of off current for both modulation and bias current. However, at this time there are no plans to lower the specified current or guarantee other specifications. A 1 Kohm or greater resistor can be added in parallel with the laser to shunt any residual currents in the off state.

In burst-mode applications, designers will no longer be able to rely completely on slow-start circuitry in the laser drivers to protect lasers from turn-on transients and other power supply transients. In the design recommendations in this application note, most of the slow-start circuitry is left intact and we discuss how to maintain an underdamped response at the turn-on and turn-off of the burst-mode.

In burst mode applications, the laser driver internal temperature compensation cannot be used and must be disabled. Large temperature transients are present on the die because of the significant change in current between the burst on and burst off condition.

Modulation Current – Burst Mode Operation

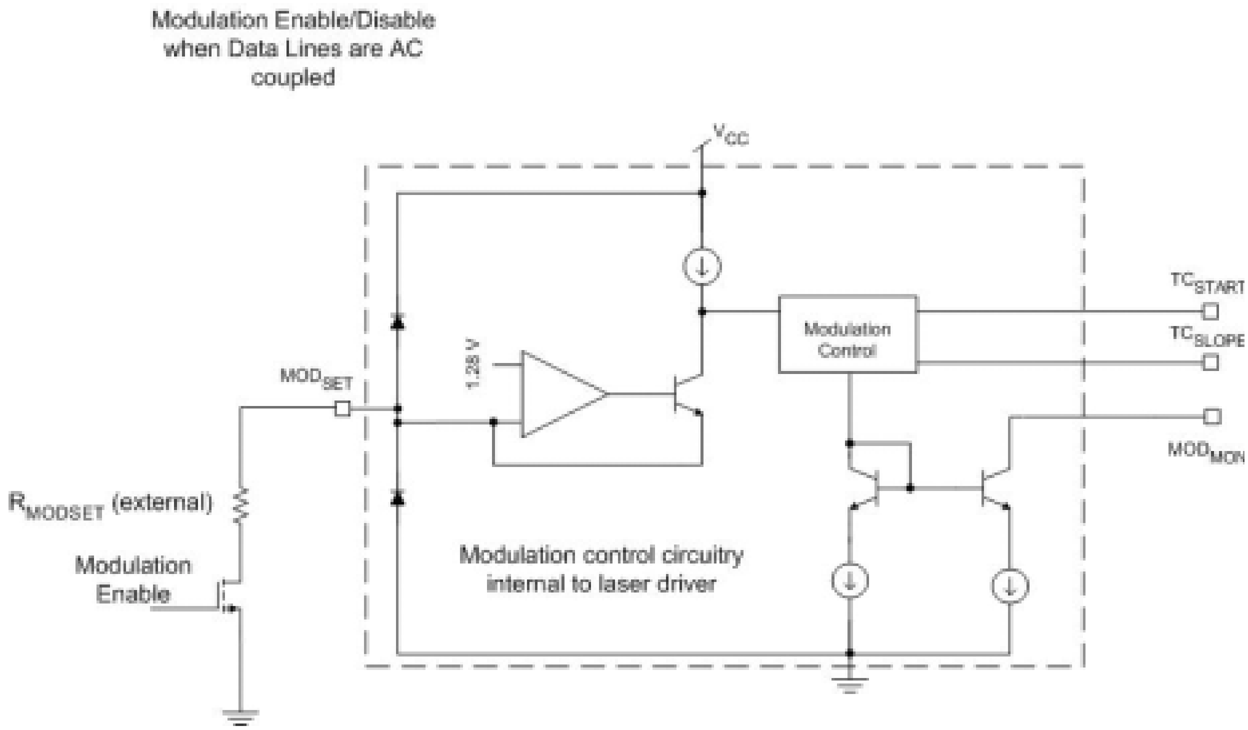
The modulation current should be enabled and disabled simply by DC coupling the data input lines. Disabling of the modulation current will occur when Din+ low and Din- high. Circuitry in the M02060, CX02066, CX02067, and CX02068 allow the data inputs to be held in one state for long periods and when modulation is restarted the modulation current will still be at the level programmed by RMODSET.

The benefits of DC coupling the data lines are virtually instantaneous (much less than 5 nanoseconds) for enabling and disabling of the modulation current. It also avoids the potential problem of the voltage drift on the AC coupling capacitors during the disable time, which could cause duty cycle distortion (DCD) errors for some time after enabling modulation.

DC coupling of the data lines is the (t.b.d. preferred?) practice in PON system designs. When the transmitter is disabled, it is dependent on the IC driving the MindSpeed laser driver to hold the data input lines in the logic 0 condition.

If AC coupling of the data lines is required, the modulation current can be disabled by driving RMODSET high through a diode switch or by opening a transistor switch (see figure below). Internal capacitors in the laser driver IC and loop time constants will result in modulation current turn-on and turn-off times of approximately 450 nanoseconds.

Figure 2. Modulation Enable/Disable when Data Lines are AC Coupled



Bias Current – Burst Mode Operation

Enabling and disabling the bias current requires additional circuitry for holding the “mean power control” level during the disable period.

The additional circuitry consists of a high speed SPDT switch such as the STMicroelectronics STG3157 (2). As shown in the Figure above, the single-pole side of the SPDT should be connected to the CMPC pin of the laser driver and the double throw side should be connected to the CMPC capacitor on one side and to Vcc on the other.

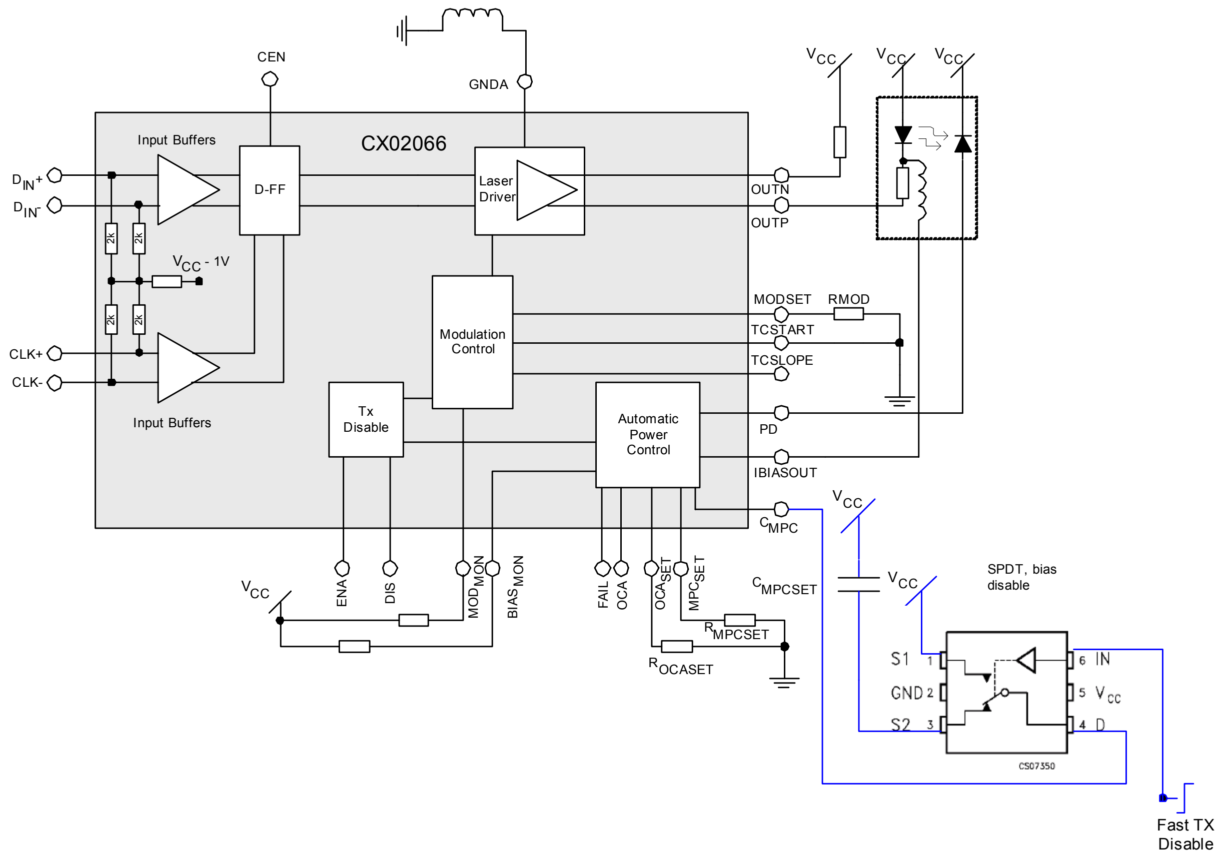
The bias current is enabled when the double throw leg is switched to the CMPC capacitor and the laser driver immediately applies a bias current to the laser according to the amount of charge stored on CMPC.

The bias current is disabled when the double throw leg is switched to Vcc.

The enable and disable time for bias current switching is dominated by the switching time of the analog switch or other external circuits. Analog switches are available with switching delays of less than 10 nanoseconds. Following the switching of the analog switch, there will be a propagation delay internal to the laser driver of less than 5 nanoseconds. The turn-on of the bias current will be strongly affected by the external componentry and layout. If an inductor is used to isolate the laser from the bias circuitry, risetime of the bias current will be dominated by the inductor time constant.

2. The STMicroelectronics STG3157 worked well in prototyping, but does not have a low enough leakage specification to guarantee operation over temperature.

Figure 3. Using the CX2066/68 or M02060 in Burst Mode Applications



Selecting C_{MPC}

The C_{MPC} capacitor should be chosen in the fashion recommended by the respective laser driver datasheet, except the capacitor must be at least 6.8 nF. This is because there is a 60 pF internal capacitance in the laser driver IC that will be fully depleted when the SPDT is shorted to Vcc. The C_{MPC} capacitor must be much larger than this 60 pF capacitance plus the charge injection from the analog switch, Qinjected, because there will be an error in the bias current each time the laser driver is enabled.

The loop time constant to correct this bias current error is quite long (~10 microseconds) so this error must be kept to a minimum by assuring that C_{MPC} is large.

Selecting An Analog Switch

Selecting the wrong analog switch can have detrimental consequences. If a switch has excessive capacitance or excessive charge injection of the wrong polarity, a high current transient may be placed on the bias current line. If a switch has excessive leakage, the C_{MPC} capacitor will droop during the disable period and it will take several microseconds for the bias current to return to the correct level after the transmit is enabled. The choice of an analog switch will also largely determine the enable/disable time.

Following are critical parameters to verify when selecting an SPDT analog switch, and recommended performance minimums.

Parameter	Minimum Performance
Switch ON resistance at Vcc=3.3V	< 20 ohms
Charge injection at Vcc=3.3V	< 40 pC
OFF state leakage current (at all operating temperatures)	<30 nanoamps [3]
Output enable/disable time (at all operating temperatures)	<15 nanoseconds (for 20 nanosecond performance)
Break before make switching	Required

Slow-Start Circuitry

The modulation current controller and bias current controller in MindSpeed laser drivers have independent slow start circuits to prevent exposing the laser to potentially damaging transients. The modulation slow-start circuit uses internal capacitors and a feedback loop to control the rise in modulation current to the level set by the external resistor R_{MODSET}. If the data lines are DC coupled, the modifications described in this application note do not affect the modulation slow start circuitry. It will operate once at power-up and the modulation current will be controlled to the level set by R_{MODSET} regardless of whether the transmitter is enabled or disabled [4].

If the data lines are AC coupled and the modulation current is disabled at the R_{MODSET} pin, the modulation slow start circuitry will operate every time the transmitter is enabled. After the transmitter is enabled, the modulation current will rise from 0 mA to the level set by R_{MODSET} in approximately 450 nanoseconds.

The bias current controller slow-start circuit uses the C_{MPC} capacitor as part of its control loop. At power-up, the SPDT switch should default to the state where the C_{MPC} capacitor is connected to the laser driver IC. Otherwise, the C_{MPC} capacitor will have an unknown bias, which may result in bias current levels that could damage the laser.

At initial power-up of the module, the C_{MPC} capacitor needs several hundred microseconds for the slow-start circuitry to charge the C_{MPC} capacitor to the correct level. During this initialization period the bias current needs to be enabled.

3. Manufacturing processes also cause leakage currents. Care should be taken to insure circuit boards are kept clean throughout the manufacturing process. A Vcc guard ring around the switched C_{MPC} node can help insure that leakage does not draw towards ground which might result in excess charge on the C_{MPC} capacitor and destructive bias current levels when the transmitter is enabled.
4. The modulation current will be constant. It will either be directed to the laser or the load resistor. When the transmitter is disabled the modulation current will continue at the programmed amplitude through the load resistor.

Other Considerations

The temperature compensation of the laser driver should be disabled. As shown in Figure 3, TC_{SLOPE} should be left open and TC_{START} should be shorted to ground.

If the burst period is less than 100 microseconds (for a 10 nF cap), the C_{MPC} capacitor may eventually discharge and the bias current will be low and erratic unless the period is lengthened and its control loop allowed to settle. Ideally, the burst period will be increased to be several hundred microseconds long every few seconds.

It is important to choose an appropriate value for OCA_{SET} to counteract failure of the SPDT switch or board leakage problems. If C_{MPC} is pulled towards ground by board leakage or switch failure, the laser driver will try to provide excessive bias current. OCA will counteract this if it has been set appropriately.

If possible, the laser should be DC coupled to the laser driver because AC coupling will add additional transients and lengthen the settling time following enable or disable. Similarly, if the bias current is sourced to the laser through an inductor, the lowest reasonable inductance should be used.

Measurements

On a CX02066 electrical evaluation board, an SPDT switch was added between the C_{MPC} pin on the IC and the C_{MPC} capacitor and Vcc (the evaluation board schematic follows).

The measurement below was taken with C_{MPC} = 10 nF and the bias current set to 40 mA. This measurement was taken across R18 (R18=10 ohms).

Figure 4. Burst Mode, BIAS Current Disabled

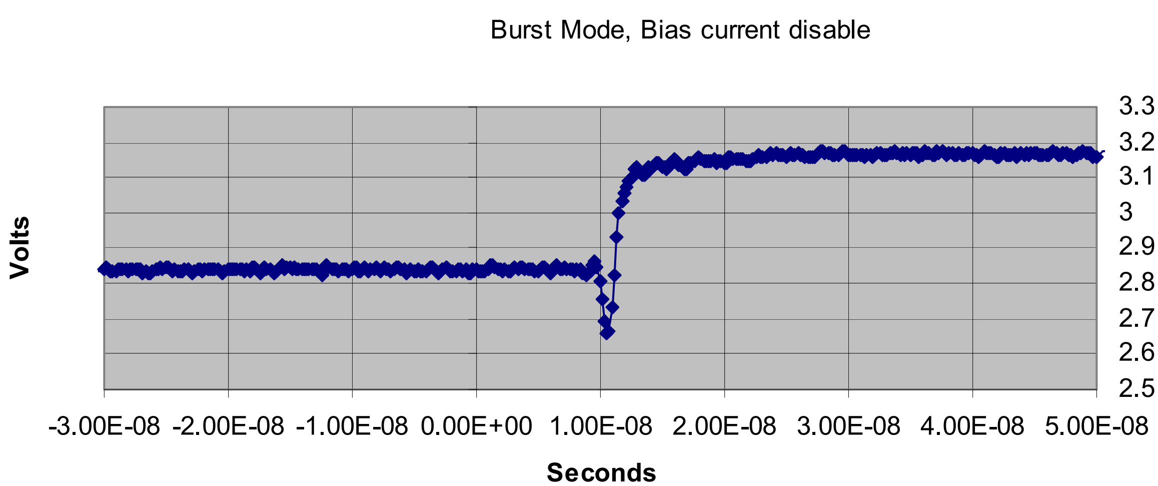


Figure 5. Burst Mode, BIAS Current Enabled

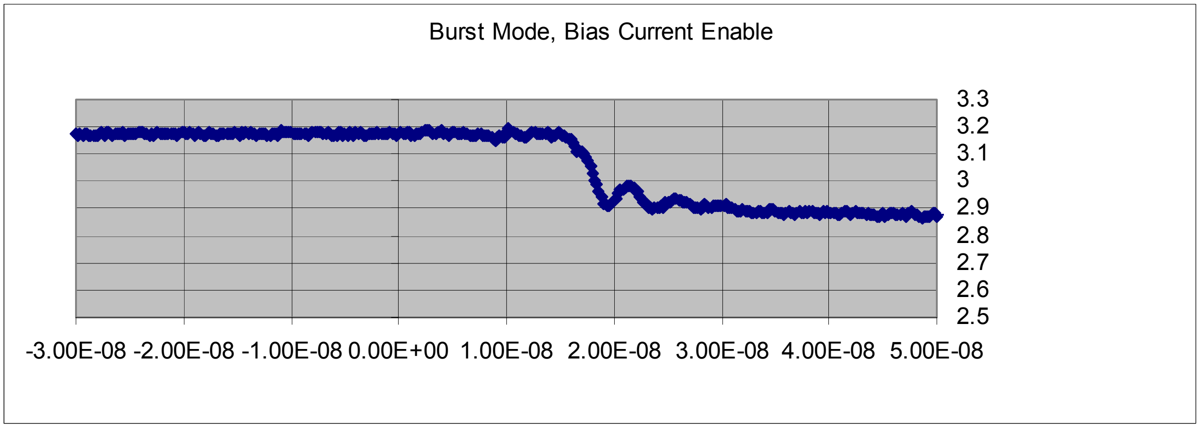


Figure 6. Burst Mode, BIAS Current Enabled