

M02063/6/7/8/9

Application Note: Designing a Burst Mode Laser Driver with Open Loop APC Control¹

This application note provides recommendations on how specific MindSpeed laser drivers (M02063, M02069, M02066, CX02067, and CX02068) can be used in open loop² burst-mode applications.

Passive Optical Networks (PON) are currently being installed in several countries. IEEE and ITU standards exist for PON networks and many networks are designed to these standards and proprietary standards.

In all PON applications, the ONU (client side) laser driver must operate in burst mode. Some of the variables in ONU laser driver requirements are enable/disable time, re-clocking, and bias current control.

The burst enable/disable time requirements vary from 10ns to 512ns, the data may or may not need to be re-clocked, and the bias current may be controlled in an open loop or closed loop fashion.

This application note will address enable/disable times of less than 10ns, with or without re-clocking of the data, and with open loop control of the bias current.

Open Loop vs. Closed Loop laser bias current control

Deciding whether to use open loop or closed loop bias current control involves many system level factors unrelated to circuit design. It is not the intent of this application note to recommend open loop operation or closed loop operation.

1. Patent Pending
2. "Open Loop" in this application means that the bias current is not controlled by a monitor photodiode. In open loop bias current control, the bias current will either be controlled in a digital fashion by a temperature sensor, look-up table, and digital potentiometer or in an analog fashion by a thermistor circuit. Closed loop bias current control uses a monitor photodiode in the laser package in conjunction with an APC (average power control) circuit in the laser driver.

Deciding whether to use the M02063, M02069, M02066, CX02067, or the CX02068

	Re-Clocking	Max Bias Current	Max Modulation Current	Package
M02063	No	50mA	50mA	MLF-24
M02069	No	50mA	50mA	MLF-24
M02066	Yes	100mA	85mA	TQFP32
CX02067	No	100mA	85mA	TQFP32 or BCC+24L
CX02068	No	100mA	85mA	BCC+24L

Four parameters determine which Mindspeed part you select for your ONU/ONT application: clocking, maximum bias current, maximum modulation current, and package style.

If re-clocking of the data is needed, you will need to use the M02066-82. The M02066 is the only one of the 5 parts available with clock inputs. The TQFP package (-82) will be needed because it provides the $BIAS_{MON}$ output which is needed for open loop control. The M02066 can supply up to 100mA of bias current and 85mA of modulation current which should be adequate for almost all ONU applications.

If re-clocking is not needed, the M02063 or M02069 is the first choice if the maximum modulation current¹ and bias current are each less than 50mA. These parts are part of Mindspeed's newest laser driver family with extensive laser safety and DDMI compatible outputs. They are fabricated with a high speed silicon germanium process that gives excellent transient response and very low jitter. Open loop control of the M02063 and M02069 bias current is available with no extra parts, (simply connect $BIAS_{MON}$ to APC_{SET}). The M02063 and M02069 are available in the MLF24 package. The M02063 is useful for applications up to 2 Gbps. The M02069 should be used for ONU applications with bit rates above 2 Gbps.

If re-clocking is not needed, but laser bias or modulation currents are greater than 50mA then the CX02068 or the CX02067 should be selected. At data rates of 622 Mbps and below, the CX02068 is adequate and it is available in either the TQFP32 or the BCC+24L package. At data rates above 622 Mbps the CX02067 should be selected and it is available only in the BCC+24L package.

OPEN LOOP OPERATION

Open loop control of the bias current requires the generation of an adjustable DC current.

Controlling the bias current of the M02063 or M02069 can easily be accomplished by feeding current from the $BIAS_{MON}$ pin directly to the APC_{SET} pin as described in the datasheet. The current out of the $BIAS_{MON}$ pin is 1/50th of the current sunk at the BIAS output. The APC circuitry will increase the BIAS current (hence the $BIAS_{MON}$ current) until the voltage at APC_{SET} is 1.3V. The bias current will then be $50 \times 1.3V / R_{APCSET}$.

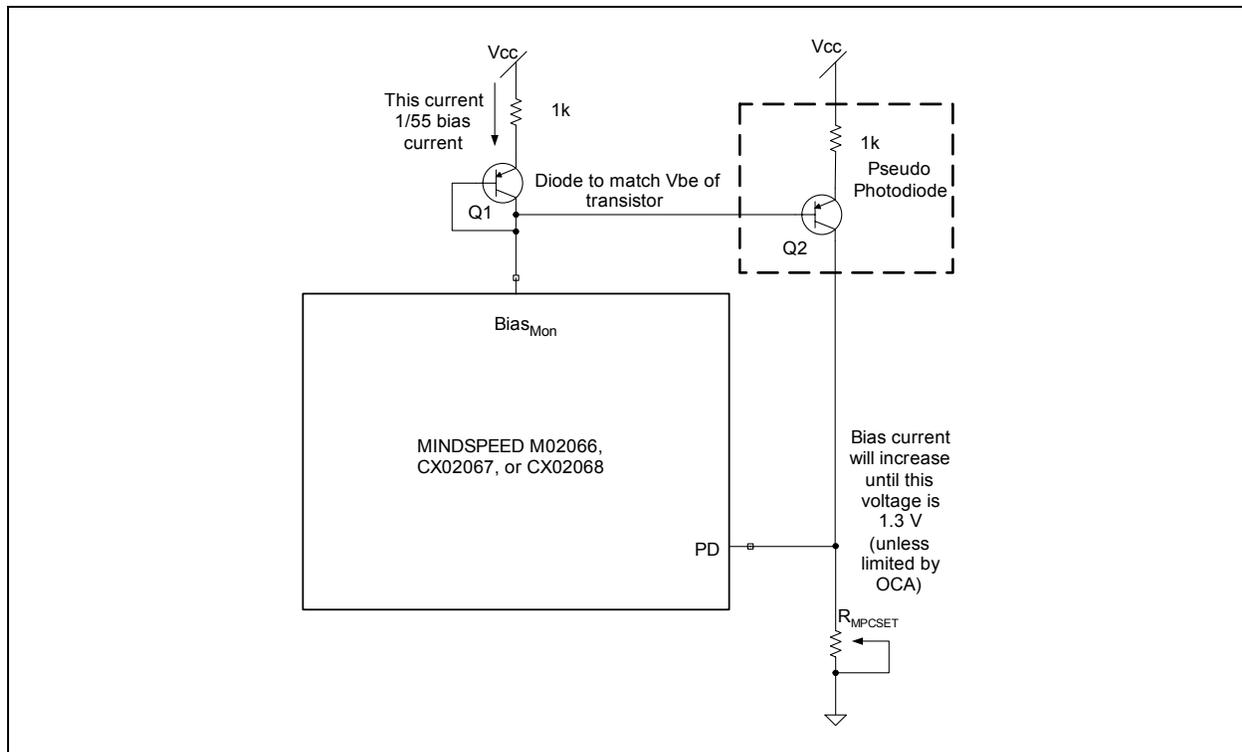
1. The maximum modulation current for the M02063 and M02069 is specified at 45mA over the operating temperature range of -40C to +85C. However, at high temperatures higher modulation currents are available and above 50°C 50mA of modulation current is available.

Controlling the bias current of the M02066, CX02067, or CX02068 is accomplished in a similar fashion, but requires a few external components. For these parts, the $BIAS_{MON}$ current is referenced to V_{CC} and the PD^1 voltage is referenced to ground. So the $BIAS_{MON}$ current will need to be mirrored and referenced to ground as shown in Figure 1. In this case the bias current will be approximately $55 \times 1.3V / R_{MPCSET}$.

Most open loop applications use a digitally controlled potentiometer to control the bias and modulation currents. In this case, R_{MODSET} and R_{MPCSET} (R_{APCSET} on the M02063 and M02069) should be replaced with digital potentiometers.

Designs can be accomplished without digital pots by controlling the modulation current using a fixed resistor at R_{MODSET} and adjustment of the modulation current over temperature with the internal compensation of the laser driver at TC_{SLOPE} . A thermistor network can be placed at R_{MPCSET} to control the bias current over temperature to avoid the use of a digital potentiometer.

Figure 1. Configuration of M02066/CX02067/CX02068 for open-loop bias control



Enable/Disable Time

The Mindspeed M02063, M02069, M02066, CX02067, and CX02068 laser drivers were not designed for burst mode switching times of less than 10ns, but with a small amount of external circuitry they can achieve this.

In this section we will first discuss switching the modulation and bias current independently, then we will discuss switching them jointly.

1. The operation of the PD pin is similar to the operation of the APC_{SET} pin on the M02063 and M02069. The Bias current will increase until the voltage at PD is $\sim 1.3V$.

Switching the modulation current

The M02063, M02069, M02066, CX02067, and CX02068 have PECL compatible inputs that can be DC coupled¹. If the laser driver interface can be DC coupled, the modulation current can be switched off simply by putting the data inputs in a logic 0 state (Din+ low and Din-high). There is a constant modulation current sourced to the outputs OUT+ and OUT- and it is switched between them depending on the state of the data inputs. When the inputs are in a logic 1 state the current is sunk by OUT+, when the inputs are in a logic 0 state the current is sunk by OUT-. Holding the inputs in a logic 0 state directs the modulation current away from the laser (away from OUT+) and holds it in the OUT- leg of the output circuitry. The switching time to achieve this is the rated rise time of the part which will be on the order of 100ps.

For the M02066, there is a second alternative to stop the modulation signal that uses the clock enable (CEN) pin if the clock inputs are not used. In this case the data inputs only need to be held in the logic 0 state while CEN transitions high. If CEN is high and there is no clock signal at the clock inputs CLK+ and CLK-, the modulation signal will “latch” with all the modulation current directed to either the OUT+ or the OUT- output. Whether the modulation signal will be latched in the OUT+ or OUT- output is determined by the data inputs when CEN transitions high. If CEN goes high when the data inputs are in a logic 1 state the modulation current will be latched with the current through the laser and the OUT+ output. If CEN goes high when the data inputs are in a logic 0 state the modulation current will be latched with the current diverted away from the laser through the OUT- output.

If the data inputs cannot be DC coupled or if the data inputs cannot be held in a known state, the modulation current will have to be switched with the bias current as discussed in the next section of this note.

Switching the Bias Current (see Figure 2)

To switch the bias current in less than 10ns, an external switch is added in parallel with the laser.

Similar to the switching of the modulation current through and around the laser by the OUT+ and OUT- outputs, this external switch will allow the bias current to either be passed through the laser or shunted around it depending on whether the external switch is open or closed.

As noted above, this external switch can be used to switch the modulation current as well as the bias current, but it becomes more difficult to do this for the bias and modulation current simultaneously without degrading the optical eye.

Three performance criteria are critical to the operation of the switch in parallel with the laser; speed, capacitive loading of the modulation signal, and voltage drop at the required switching current.

The capacitive loading of the modulation current will be considered first. An easy way to minimize the capacitance of the switch is to add a diode in series with the switch. A schottky diode will need to be used because the forward voltage of the switch in series with the diode must always be less than the forward voltage of the laser. The Agilent HBAT-540B is a possible choice. It has a forward voltage less than 0.6V at 100mA of forward current and a $C_{J0} = 3\text{pF}$. The forward voltage of this diode and the switch must be less than the forward voltage of the laser². The capacitance of the schottky diode may be used as part of the snubbing network to compensate for the inductance of the laser TO can.

1. The M02063 and M02069 data inputs can only be DC coupled for $V_{CC} = 3.3\text{V}$. They do not support DC coupled PECL signalling levels with $V_{CC} = 5\text{V}$.
2. This laser forward voltage must be at the current which gives the maximum allowable optical power when the burst is off.

Two different types of components are recommended for switching the bias current around the laser: either an inverting logic gate or a PMOS FET. It is not difficult to find logic gates with propagation delays and risetimes that easily meet the 10ns switching time, the Toshiba TC7PAU04FU and the Fairchild NC7WZ04 are examples of such parts. Multiple gates will be needed depending on the maximum bias current to be switched.

It is also possible to find discrete PMOS FETs¹ that will give fast switching times (as seen in [Figure 3](#)), but the characteristics must be carefully examined. The advantage of using a transistor over a logic gate is that a series diode may not be needed to minimize the capacitive load at low data rates. An example is the Fairchild FDV302P. Initial examination of the datasheet for the FDV302P shows it to be too slow to switch the bias current, and it may not be reasonable to expect 10ns switching. The maximum turn-on delay time is specified as 12ns, however, this is when the gate is driven with a 50Ω source impedance. Using gates such as those specified above will result in a driving impedance 1/2 that of a 50Ω source and switching times proportionally faster.

Switching the Modulation Current with the Bias Current

If the state of the data inputs cannot be controlled, the modulation current can be switched with the bias current. The major change to the schematic on the following page is that more logic gates or transistors in parallel may need to be used to switch the laser current. A second change is that if only the bias current is being switched, the capacitance of the switch can be isolated from the modulation signal by putting the switch on the other side of the bias current resistor. If the modulation current is being switched as well as the bias current, the switch must be at the laser cathode.

1. A npn bipolar transistor may also work as long as a schottky catch diode is used from the collector to base to limit saturation.

Figure 2. Using logic gates for shunting laser current

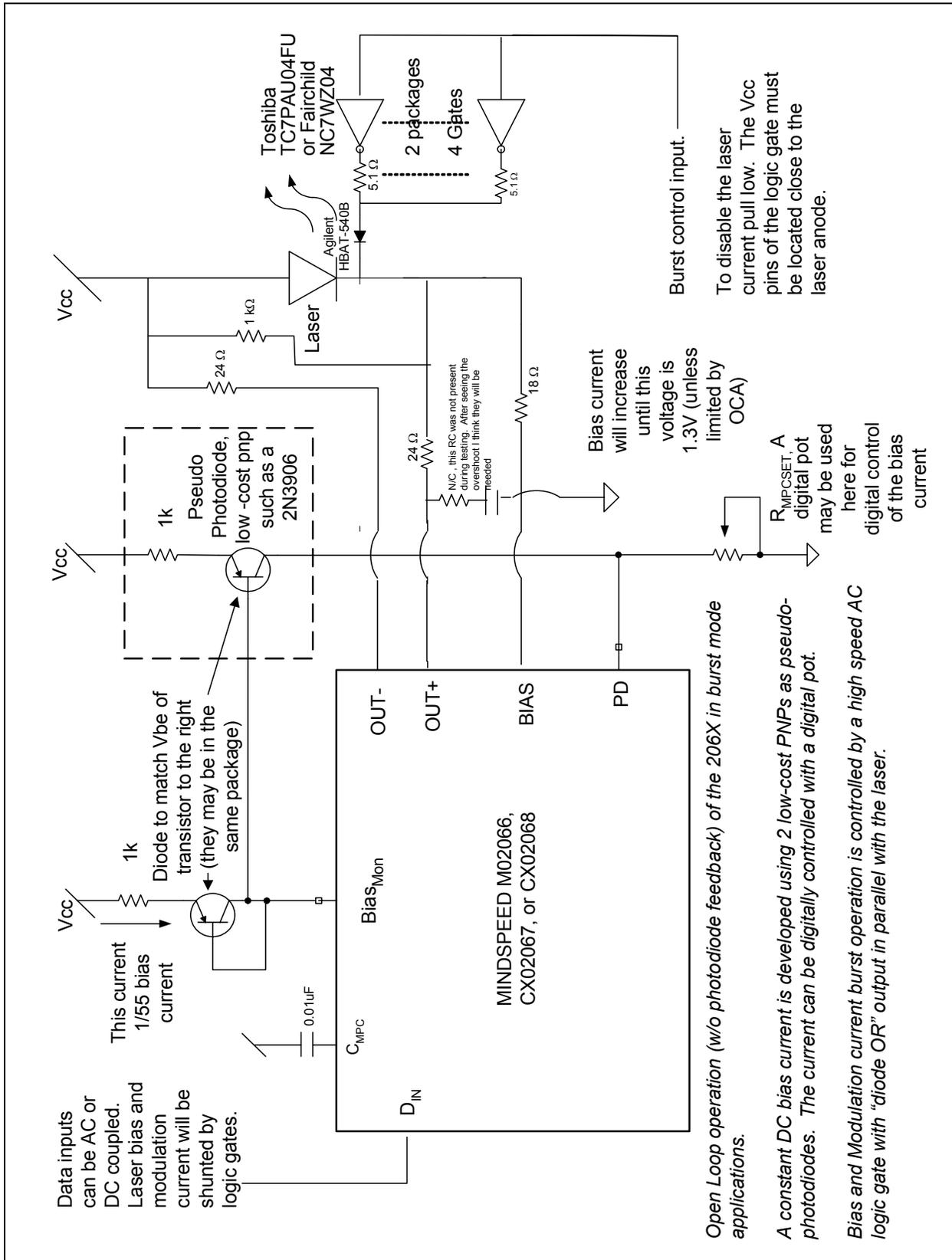
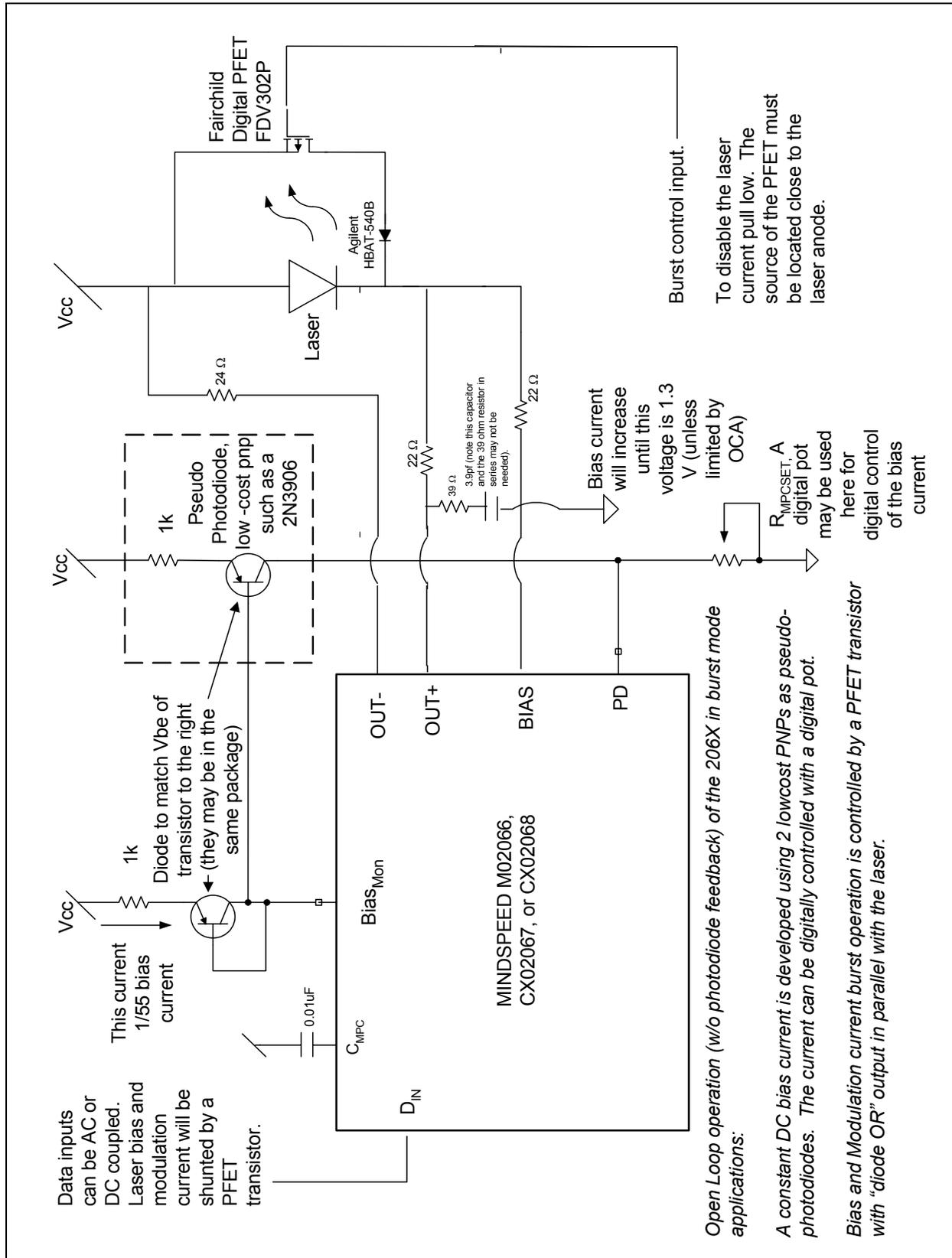


Figure 3. Using a PFET transistor to shunt the laser current



Experimental Results

The following results use the schematic in [Figure 2](#) with an NEC NX7315U laser (using the modulation current to switch both the bias and modulation current. The modulation current is adjusted to 50mA peak to peak and the bias current is 50mA¹.

Trace 2 is the burst on/burst off trigger from a signal generator. It is asynchronous to the data signal.

Trace 1 is the optical input from a Tektonix P6713 optical probe. The trace 1 signal is delayed by 6 meters of optical fibre used to connect to the laser, then connect to a remote optical attenuator and return to the optical probe at the oscilloscope. This delay is approximately 6 meters x 5ns/meter = 30 ns. However, trace 1 has an additional 4 ft. of coax to the scope which adds 4ns of delay on the Trace 2 path. **The final delay of trace 2 with respect to trace 1 is 26ns.**

Three characteristics in trace 1 should be observed in figures 5 and 6.

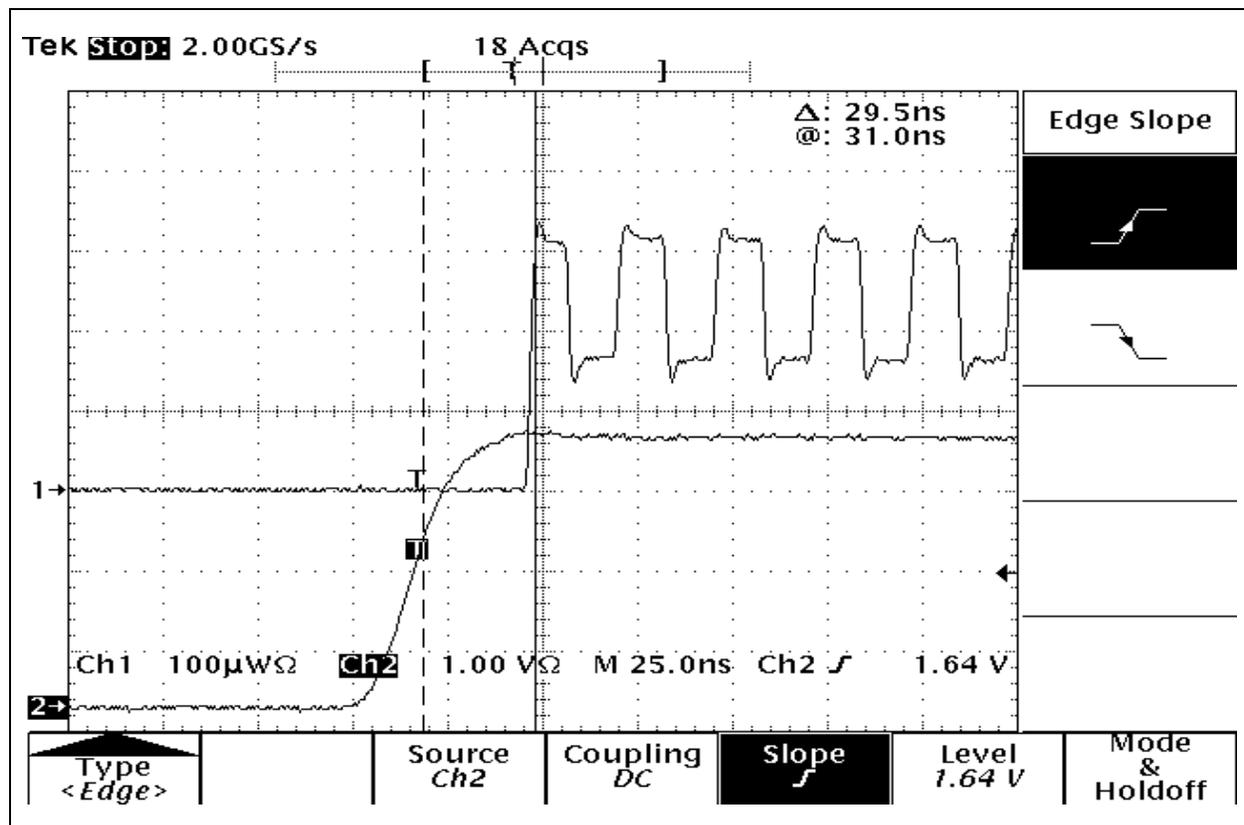
On the left axis the ground levels for traces 1 and 2 are shown by the trace number with an arrow. The optical signal is fully off when Trace 1 is at the level "1->".

When the optical signal is on and modulating, the extinction ratio is small. This is because the bias current is high (50mA) to demonstrate the ability of the circuit to shunt large amounts of bias current.

The optical turn-on delay of this circuit as shown by figure 5 is 31ns - 26ns = 5ns.

The turn-off delay of this circuit as shown by figure 6 is 34.5ns - 26ns = 8.5ns.

Figure 4. Burst On Performance



1. The 50 ohm resistor was placed in parallel with the laser so it would not exceed its current rating.

Figure 5. Burst Off Performance

