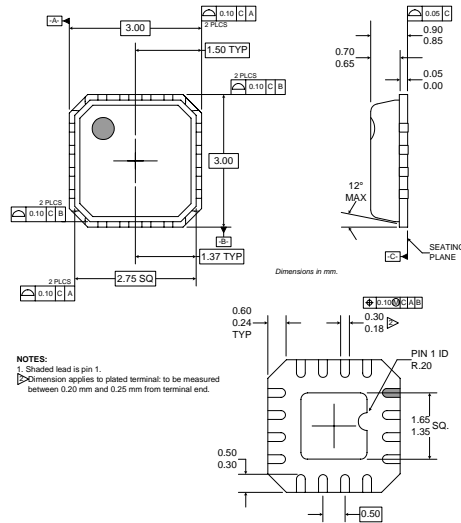


Typical Applications

- Gigabit and 10Gigabit Ethernet Optical Transceivers
- Fiber-Channel Optical Transceivers (1X,2X)
- SONET VSR & System Interconnect
- All Fiber Optic Transceiver Applications up to 3.125Gbps Serial Data Rate

Product Description

The RF3760 is a laser driver intended for 1310nm Edge Emitting Lasers (EEL) based light sources. The device operates at 3.3V, 25mA quiescent, while supplying laser bias in 2mA to 100mA range and modulating currents from 3mA to 50mA range. Features include a differential input with single-ended output design optimized for 2.5Gbps to 3.125Gbps operation. Each device contains a bias generator, laser modulator, and failure alarm. Automatic power control (APC) maintains a constant average optical output power by adjusting the laser bias current to offset temperature effects and laser aging. Features include TX\_DISABLE input and failure alarm.



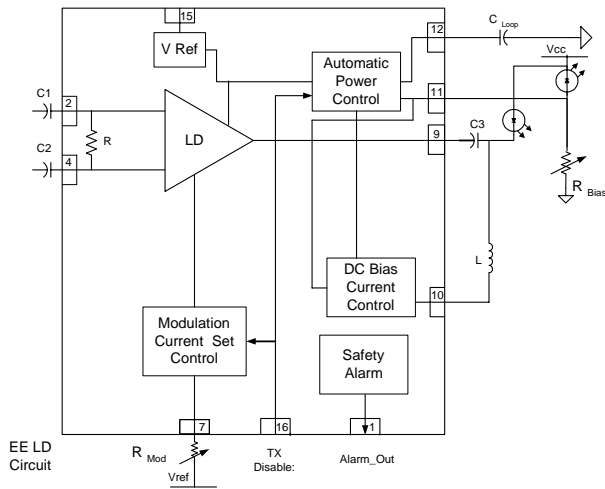
Package Style: LCC, 16-pin, 3x3

Optimum Technology Matching® Applied

- |                                     |                                   |  |
|-------------------------------------|-----------------------------------|--|
| <input type="checkbox"/> Si BJT     | <input type="checkbox"/> GaAs HBT | <input type="checkbox"/> GaAs MESFET             |
| <input type="checkbox"/> Si Bi-CMOS | <input type="checkbox"/> SiGe HBT | <input type="checkbox"/> Si CMOS                 |
| <input type="checkbox"/> InGaP/HBT  | <input type="checkbox"/> GaN HEMT | <input checked="" type="checkbox"/> SiGe Bi-CMOS |

Features

- +3.3V Supply Voltage/25mA Quiescent Current
- Common Anode Laser Driver
- 3mA to 50mA Laser Modulation Current
- 2mA to 100mA Laser Bias Current Control Range



Functional Block Diagram

Ordering Information

RF3760 Edge Emitting Laser Driver at 3.125Gbps  
RF3760 PCBA Fully Assembled Evaluation Board

RF Micro Devices, Inc.  
7628 Thorndike Road  
Greensboro, NC 27409, USA

Tel (336) 664 1233  
Fax (336) 664 0454  
<http://www.rfmd.com>

## Absolute Maximum Ratings

| Parameter                   | Rating      | Unit             |
|-----------------------------|-------------|------------------|
| Supply Voltage              | 4           | V                |
| Input Voltage               | 4           | V <sub>P-P</sub> |
| Operating Temperature Range | -40 to +85  | °C               |
| Storage Temperature Range   | -65 to +125 | °C               |
| Junction Temperature Max    | +125        | °C               |



**Caution!** ESD sensitive device.

RF Micro Devices believes the furnished information is correct and accurate at the time of this printing. However, RF Micro Devices reserves the right to make changes to its products without notice. RF Micro Devices does not assume responsibility for the use of the described product(s).

Note: TA=+25°C unless otherwise noted. Functional operation near or above Maximum Ratings is not implied. Exposure to stress levels at or near maximum ratings for any period of time may affect reliability or cause permanent damage to the devices.

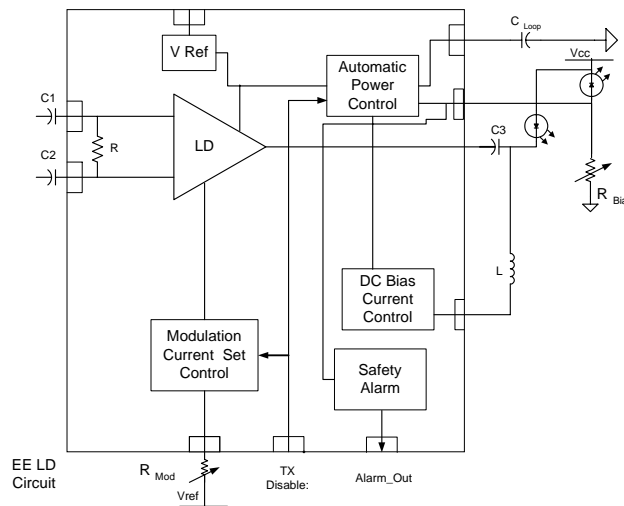
| Parameter  | Specification |                 |        | Unit              | Condition  |
|--|---------------|-----------------|--------|-------------------|--|
|  | Min.          | Typ.            | Max.   |                   |  |
| <b>Inputs</b>  |               |                 |        |                   |  |
| Data Rate (BR)   | 0.100         | 3.125           | 3.500  | Gbps              | T=25 °C, V <sub>CC</sub> =3.3V, V <sub>IN</sub> =500mV <sub>P-P</sub><br>Data Rate=3.125Gbps |
| Supply Voltage (V)   | 3.0           | 3.3             | 3.6    | V                 |  |
| Quiescent Current (I <sub>Q</sub> )                                |               | 25              | 30     | mA                |  |
| Total Current (I <sub>TOT</sub> )                                  | 25            |                 | 180    | mA                | I <sub>TOT</sub> =I <sub>Q</sub> +I <sub>BIAS</sub> +I <sub>MOD</sub>                        |
| Differential Input Impedance (R <sub>IN</sub> )                    | 90            | 100             | 110    | Ω                 |  |
| Differential Input V Swing   | 100           |                 | 1500   | mV <sub>P-P</sub> | Ac-coupled   |
| Input Rise/Fall Time (t <sub>RI</sub> , t <sub>FI</sub> )          |               |                 | 100    | pS                |  |
| TX Disable High (TX_Dis_h)   |               | V <sub>CC</sub> |        |                   |  |
| TX Disable Low (TX_Dis_l)  |               | GND             |        |                   |  |
| <b>Outputs</b>   |               |                 |        |                   |  |
| Laser Bias Current (I <sub>BIAS</sub> )                            | 2             |                 | 100    | mA                | Ext R Bias   |
| Laser Modulation Current (I <sub>MOD</sub> )                       | 3             |                 | 50     | mA                | Ext R Mod  |
| Output Rise/<br>Fall Time (t <sub>ROUT</sub> , t <sub>FOUT</sub> ) | 40            | 50              | 70     | pS                | Electrical rise and fall time at 20%/80%   |
| Output Skew (dt <sub>Latency</sub> )                               |               | 15              | 20     | pS                |  |
| Output Random Jitter (RJ <sub>P-P</sub> )                          |               | 30              | 40     | pS                |  |
| Output Undershoot/Overshoot  |               |                 | 20     | %                 |  |
| Alarm Out High (Alrm)  |               | V <sub>CC</sub> |        |                   |  |
| Alarm Out Low (Alrm)   |               | GND             |        |                   |  |
| Time to Enable (T <sub>ON</sub> )                                  |               | 0.001           | 1.0    | mS                |  |
| Time to Disable (T <sub>OFF</sub> )                                |               | 1.0             | 10.0   | μS                |  |
| Time to Fault (T <sub>FAULT</sub> )                                |               |                 | 100.0  | μS                |  |
| <b>Current Control</b>   |               |                 |        |                   |  |
| Laser Bias Current Control Range (R <sub>BIAS</sub> )              |               | 2,000           | 10,000 | Ω                 | Ext R Bias set   |
| Laser Modulation Current Control Range (R <sub>MOD</sub> )         |               |                 | 10,000 | Ω                 | Ext R Modset   |

## Laser Alarm Table

| TX Disable              | System State                    | Alarm Out       |
|-------------------------|---------------------------------|-----------------|
| 0V to 1.3V              | Normal                          | Gnd             |
| 0V to 1.3V              | Failure of Photo or Laser Diode | V <sub>CC</sub> |
| 1.4V to V <sub>CC</sub> | N/A                             | V <sub>CC</sub> |

| Pin                 | Function              | Description  | Interface Schematic |
|---------------------|-----------------------|--|---------------------|
| 1                   | <b>ALARM<br/>OUT</b>  | Alarm signal.  |                     |
| 2                   | <b>INPUT+</b>         | Input pin, positive polarity of differential pair.   |                     |
| 3                   | <b>NC</b>             | DC voltage is present on this pin. If it is necessary to ground this pin, then a DC-blocking capacitor must be used. |                     |
| 4                   | <b>INPUT-</b>         | Input pin, negative polarity of differential pair.   |                     |
| 5                   | <b>GND</b>            | Ground connection. For best results, keep traces physically short and connect immediately to ground plane.           |                     |
| 6                   | <b>GND</b>            | Ground connection. For best results, keep traces physically short and connect immediately to ground plane.           |                     |
| 7                   | <b>MOD SET</b>        | Sets laser modulation current by external resistor or potentiometer.   |                     |
| 8                   | <b>NC</b>             | Not connected.   |                     |
| 9                   | <b>LASER<br/>MOD</b>  | Laser modulation current output.   |                     |
| 10                  | <b>LASER DC</b>       | DC laser bias current output.  |                     |
| 11                  | <b>PD IN</b>          | Input from anode of photodiode for control loop.   |                     |
| 12                  | <b>LOOP C</b>         | Control loop capacitor, maintain loop stability.   |                     |
| 13                  | <b>VCC</b>            |  |                     |
| 14                  | <b>VCC</b>            |  |                     |
| 15                  | <b>VREF</b>           | On-chip reference voltage.   |                     |
| 16                  | <b>TX<br/>DISABLE</b> | Disables laser driver.   |                     |
| <b>Pkg<br/>Base</b> | <b>GND</b>            | Ground connection. For best results, keep traces physically short and connect immediately to ground plane.           |                     |

## Theory of Operation and Application Information



**Figure 1. Functional Block Diagram**

### General Description of IC

#### *Bias and Modulation Current Settings*

Bias current supply to the laser diode is generated on-chip and controlled by an Automatic Power Control (APC) loop. The APC loop uses the photodiode current in the feedback loop to adjust the laser bias current. This maintains average optical power over temperature and aging of the laser.

The bias current is fed to the anode of the laser diode through a ferrite inductor (L). This current level is tuned via an external resistor,  $R_{BIAS}$ , which is connected between the anode of the monitor photodiode and ground. The potential at the anode is fixed at 0.8V at normal operation. So, the photocurrent is related to  $R_{BIAS}$  as,

$$I_{PH} = \frac{0.8}{R_{BIAS}}$$

From the photo diode's responsivity and laser diode's L-I (light versus current) curves, the appropriate level of laser diode bias current ( $I_{BIAS}$ ), or average optical power, can be adjusted. The chip design allows a maximum bias current of 100mA to allow for thermal extremes.

An external resistor,  $R_{MOD}$ , programs the amplitude of the laser diode's modulation current. The voltage supply of this resistor is generated by an on-chip band-gap circuitry to stabilize the output over temperature. The  $I_{MOD}$  range is from 3mA to 50mA. Figure 2 will aid in selection of  $R_{MOD}$  for temperatures.

When using AC-coupling, the transient LD current is swinging between  $I_{BIAS} + (I_{MOD}/2)$  and  $I_{BIAS} - (I_{MOD}/2)$  (see Figure 3). When using DC coupling, the transient LD current is swinging between  $I_{BIAS}$  and  $(I_{BIAS} + I_{MOD})$  (see Figure 4).

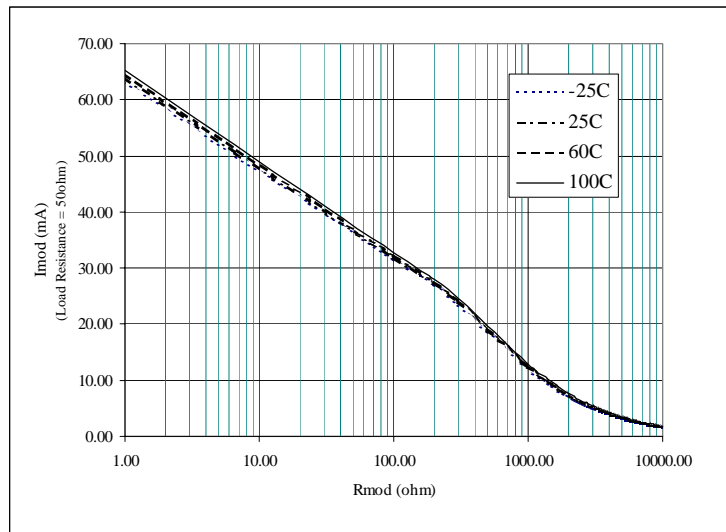


Figure 2.  $I_{MOD}$  versus  $R_{MOD}$  versus Temperature

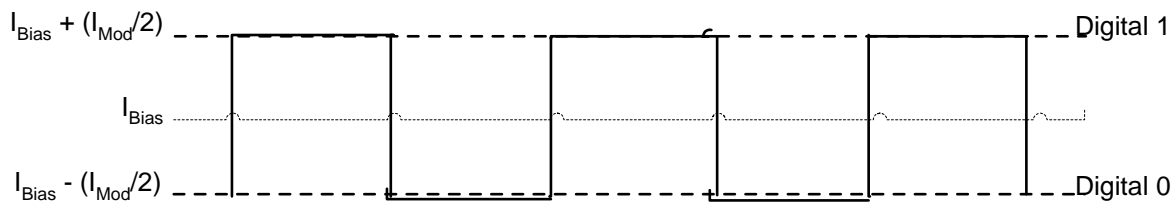


Figure 3. Transient Current of Laser Diode Using AC-Coupling

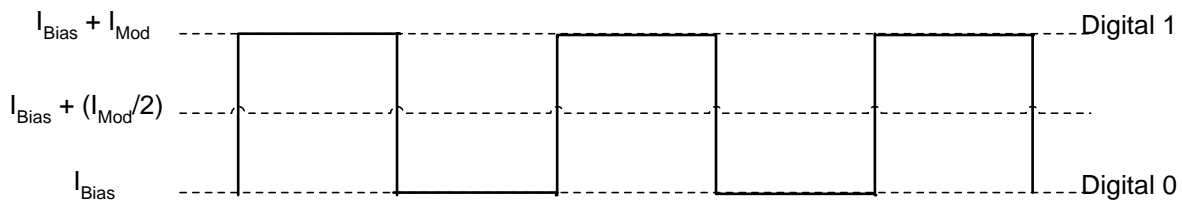


Figure 4. Transient Current of Laser Diode Using DC-Coupling

*Automatic Power Control Loop (APC)*

The APC loop works to maintain an average optical power over temperature by forcing the laser diode to generate a constant photocurrent through the photodiode. The user selects  $R_{BIAS}$  to set the appropriate output optical power. The loop constant capacitor ( $C_{LOOP}$ ) is required to set the loop bandwidth.

*Alarm/Fault Detection*

A voltage reading is taken from the anode side of the photodiode and compared within a window comparator. If this voltage varies outside of the window, then the alarm will go 'high'. This can be caused by the laser or photodiode being shorted or open.

### Disable Functionality

When the TX\_DISABLE pin is high, it turns off both the  $I_{MOD}$  and  $I_{BIAS}$  so there is no light output from the laser, and the alarm will go 'high'. When TX\_DISABLE is set low, the IC will start normal operation.

| TX_DISABLE            | Laser Current | Alarm           |
|-----------------------|---------------|-----------------|
| 0V~1.3V               | Enabled       | GND             |
| 1.4V ~V <sub>CC</sub> | Off           | V <sub>CC</sub> |

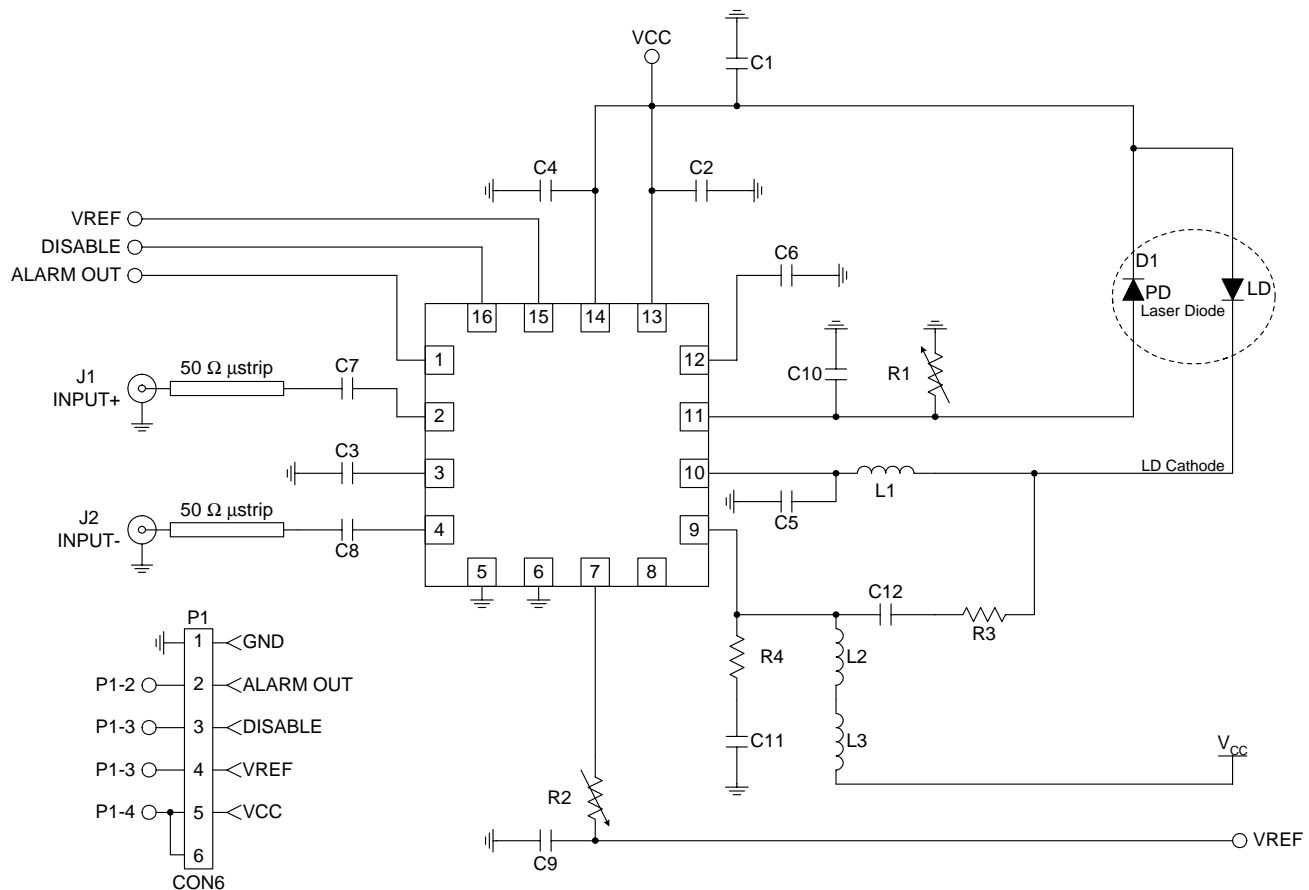
### Laser Diode Selection

The chip is configured for a common anode type of laser with AC-coupling of  $I_{MOD}$ . If  $I_{MOD} < 20\text{mA}$  is required, then DC-coupling is allowed. For 3.125Gb/s operation, the rise/fall time of the laser diode itself should be less than 100ps. The AC modulation current is in the range of 3mA to 50mA. The bias current ranges from 2mA to 100mA. The photodiode is assumed to output 0.08mA to 0.8mA photocurrent within the laser diodes normal operating range.

The Edge-Emitting laser driver can interface with most packaged common anode and bare die lasers.

### General Description of Application Schematic

The differential inputs of the RF3760 are internally balanced 50Ω to ground, 100Ω from pin to pin, the single-ended output is 50Ω. Additional circuitry surrounding the RF3760 requires judicious selection regarding component value. Please refer to the Evaluation Schematic (Figure 5) and the Bill of Materials for the Evaluation Board (Table 1) and the recommended values.



**NOTES:**

1. Transmission lines are to be precision 50 Ω microstrip lines on INPUT+, INPUT- and LASERMOD.

**Figure 5. Evaluation Board for TO Packaged Laser**

Table 1. Evaluation Board Component List

| Designator | Value                | Footprint   | Description   |
|------------|----------------------|-------------|---|
| C1         | 0.1 $\mu$ F          | 0402        | Bypass capacitor for $V_{CC}$ , should be as close to IC as possible.   |
| C2         | 0.1 $\mu$ F          | 0603        | Bypass capacitor, should be along the same line as the laser diode pin.   |
| C3         | 0.1 $\mu$ F          | 0402        | AC ground for chip. Due to DC being present here, a capacitor is necessary to connect to ground.                          |
| C4         | 0.1 $\mu$ F          | 0402        | Bypass capacitor.   |
| C5         | 50 pF                | 0402        | Bypass capacitor.   |
| C6         | 4.7 $\mu$ F          | Tantalum-B  | Loop constant capacitor, should be as close to IC as possible.  |
| C7, C8     | 0.1 $\mu$ F          | 0402        | DC-blocking capacitor of Input+ and Input-.   |
| C9         | 10 nF                | 0402        | Bypass capacitor.   |
| C10        | 100 pF               | 0402        | Bypass capacitor.   |
| C11        | 6 pF                 | 0402        | Capacitor used for output match.  |
| C12        | 0.1 $\mu$ F          | 0402        | DC-blocking capacitor for laser input, should be as close to IC as possible.  |
| D1         | N/A                  | TO-46       | Mitsubishi ML725B11F Edge-Emitting laser diode.   |
| J1, J2     | N/A                  | N/A         | SMA connector for data inputs.  |
| L1         | 600 $\Omega$ Ferrite | 0603        | RF choke, should be as close to the laser diode pin as possible.  |
| L2         | 600 $\Omega$ Ferrite | 0603        | RF choke.   |
| L3         | 20 $\mu$ H           | 0603        | RF choke.   |
| P1         | N/A                  | N/A         | 6 pin DC connector.   |
| R1         | 10 k $\Omega$        |             | Adjusting this potentiometer will adjust the modulation current to the laser.   |
| R2         | 10 k $\Omega$        |             | Adjusting this potentiometer will adjust the bias current to the laser.   |
| R3         | 20 $\Omega$          | 0402        | Series resistor to set the impedance of the laser to 25 $\Omega$ . Should be as close to the laser diode pin as possible. |
| R4         | 75 $\Omega$          | 0402        | Resistor used for output match.   |
| U1         | RF3760               | 3mmx3mm LCC | RF Micro Devices' Serial EEL Laser Driver.  |

Because there is a DC voltage present on the input of the amplifier, external DC-blocking capacitors are required (C7 and C8). Since this device is optimized for use at 0.1 Gbps to 4.0 Gbps, a value of 0.1  $\mu$ F was chosen to provide the best coupling across all data rates.

If AC-coupling of the laser diode is used, then the value chosen for the DC-blocking capacitor must also be chosen to have the least affect on the intended data rate. Choosing a value too low will cause a high frequency cut-off in the circuit response (see Equation 1).

$$f_c = \frac{1}{(R \cdot C)} = \frac{1}{(50\Omega \cdot 10nF)} = 2MHz \quad \text{Eq. 1}$$

An RF Choke is used when applying DC bias in order to present constant high impedance to the diode. The frequency response and parasitic capacitance of the choke must be taken into account when making this choice. Because of the wide bandwidth of the laser driver, the choke could cause roll-off at high or low frequencies. Large value inductors (on the order of 870 nH) will achieve better low frequency response, but can have large parasitic capacitances that can cause a high frequency roll-off. There is a negative impact on circuit density as large values are typically only available in very large footprints (0805 or larger). Choosing a ferrite bead instead of an inductor can help minimize the high frequency impact since these typically have high impedance at higher frequencies. Ferrites are also available in smaller package sizes minimizing circuit density.

Because the dynamic resistance of the edge-emitting laser is approximately 5  $\Omega$ , a 20  $\Omega$  resistor (R3) is added in series with the laser input. This brings the impedance of the laser closer to 50  $\Omega$ . Larger values for this series resistor will present too large of a voltage drop and not allow for proper operation of the laser driver.

The magnitude of the modulation and bias currents supplied to the laser diode can be adjusted using external variable resistors. The RF3760 evaluation board is populated with two potentiometers, a 10 k $\Omega$  pot for bias control and a 10 k $\Omega$  pot for modulation control. In production, fixed resistor values would program  $I_{MOD}$  and  $I_{BIAS}$ .

### Setting APC Loop Bandwidth

The Loop Capacitor (C6) sets the APC loop bandwidth. Increasing the value of C6 will increase the time constant of the APC loop, causing the loop lock at a longer time period. Decreasing the value of C6 will cause the loop to turn on faster, but could cause the circuit to oscillate. To achieve loop stability and maintain reasonable turn on times, a value in the 5 $\mu$ F range will achieve a time constant of 0.2mS.

### Laser Diode Selection Criteria

When testing the functionality of the RF3760 driver, it is also necessary to examine the performance of the laser diode. Specifications such as rise and fall time should be measured, as this could be a limiting factor in the overall system design.

Previous discussions have assumed the use of a laser and a monitor photodiode contained in a TO package (see Figure 5 for application schematic). This allows the photocurrent to be monitored for the internal APC loop. For applications using a laser and no photodiode, the APC loop will not be functional. For this application, the photocurrent can be controlled externally via the LoopC pin (see Figure 6 for application schematic). *When using this set-up, the 2k $\Omega$  potentiometer needs to be initially set to 0k $\Omega$ .*

Along with the input V<sub>CC</sub> and TX\_DISABLE pin, an Alarm output pin is also available to monitor any deviations from normal operation. The TX\_DISABLE pin is an active high circuit and should be tied to ground. If the driver is disabled or the laser diode or photodiode cease to function, the alarm signal will go HI (V<sub>CC</sub>).

| Disable               | System State                    | Alarm State     |
|-----------------------|---------------------------------|-----------------|
| 0V~1.3V               | Normal                          | Ground          |
| 0V~1.3V               | Failure of Photo or Laser Diode | V <sub>CC</sub> |
| 1.4V ~V <sub>CC</sub> | N/A                             | V <sub>CC</sub> |

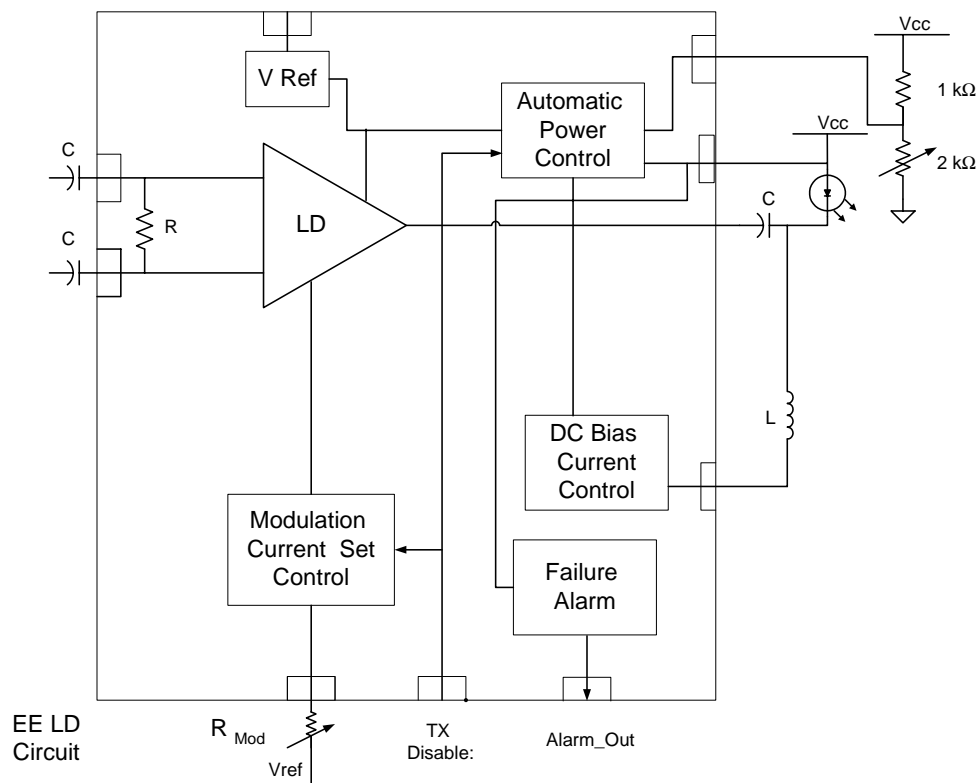


Figure 6. Evaluation Board Schematic for External Bias Current Control with No Photodiode

### Evaluation Board Layout Considerations

In order to achieve circuit density and have isolation between signal paths and RF paths, a multilayer evaluation board is used (see Table 2). For the evaluation board provided by RFMD, an 18mil microstrip line on 8mil Rogers RO4003 material will achieve the desired  $50\Omega$  impedance. For this application, the Rogers RO4003 material was used due to the tightly toleranced dielectric constant. Another common board material used, FR-4, can vary its dielectric constant by as much as  $\pm 10\%$  depending on the manufacturer. The line width and core material thickness and dielectric constant are critical to maintain controlled line impedances.

**Table 2. Evaluation Board Layer Stack Up**

|                             |                            |                  |                       |
|-----------------------------|----------------------------|------------------|-----------------------|
| Lyr 1 (Signal)              | -----                      | 0.5oz CU+Plating | 0.002"                |
|                             | Core Rogers RO4003         |                  | 0.008" $\pm 0.0015$ " |
| Lyr 2 (Solid Ground Plane)  | -----                      | 1.0oz CU         | 0.0014"               |
|                             | PrePreg FR4 or Alternative |                  | 0.020"                |
| Lyr 3 (Solid Plane, unused) | -----                      | 1.0oz CU         | 0.0014"               |
|                             | Core FR4 or Alternative    |                  | 0.008"                |
| Lyr 4 (Signal)              | -----                      | 0.5oz CU+Plating | 0.002"                |

It is also necessary to match the electrical lengths of the balanced inputs and outputs as closely as possible. Having unbalanced path lengths can cause the output eye diagram to have slower rise and/or fall times, increased jitter, and ripple on the one or zero.

Also, transitions from the connector to the trace and from the trace to the package pin are critical when considering high frequency evaluation board design. Any changes in the trace width can cause a mismatch, thus affecting performance. In order to avoid this, the pad for the SMA center pin and the package pads have the same width as the microstrip traces. If the package pins, SMA pins, and microstrip traces cannot be the same width, then tapering, or other compensation techniques, should be used at all transitions to minimize mismatch.

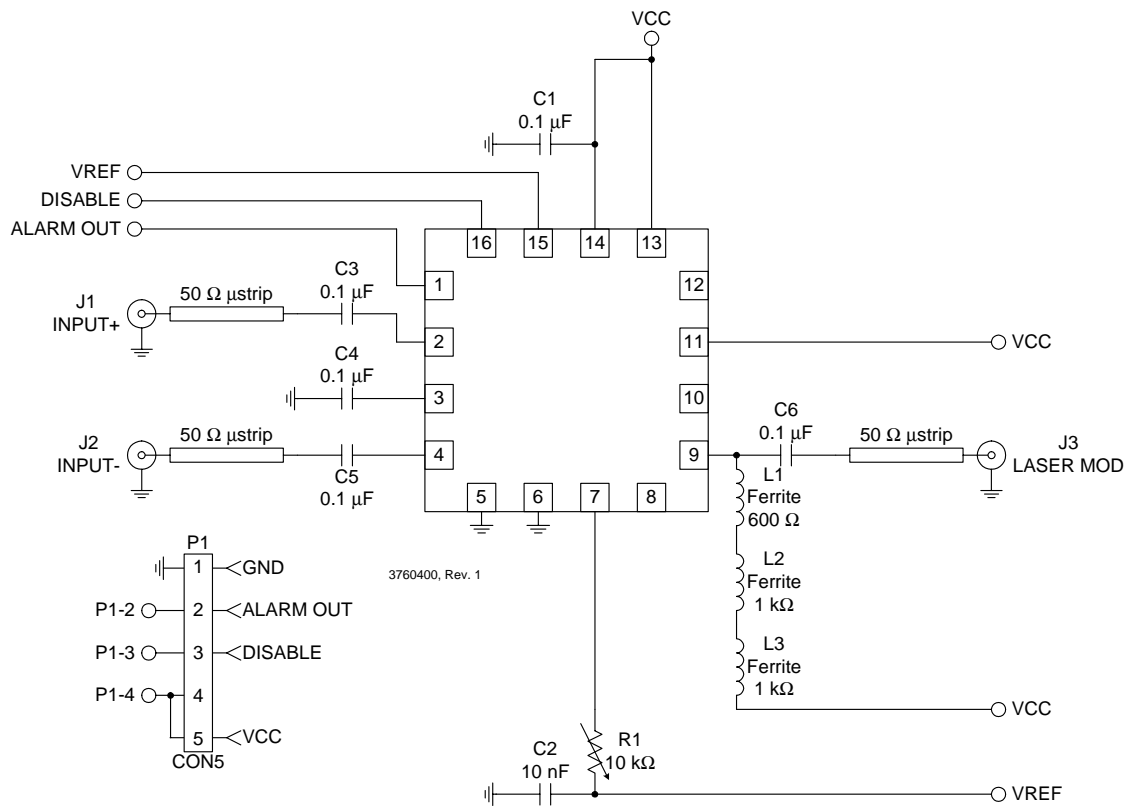
In order to minimize the amount of noise on the  $V_{CC}$  circuitry, it is important to place any bypass capacitors as close to the IC as possible.

The most critical microstrip line on the entire board is the output trace on the 'Laser Mod' pin. This path provides the modulated current to the LASER diode; therefore any errors introduced in this path will directly affect the quality of the output eye diagram. This trace needs to be as physically short as possible and  $50\Omega$ . Keeping an electrically short distance will alleviate the negative effects of a non-perfectly matched transmission line. The DC-blocking capacitor should be placed close to the package, and the bias choke should be close to the laser. It may be necessary to use broadband capacitors on for the DC block if the performance is not satisfactory at all frequencies.

On the RFMD evaluation board, the LASER used is in a TO-46 can package. In order to place this close to the RF3760, the TO package is on it's side and 'slid' over the side of the PCB. The pins of the Mitsubishi ML725B11F diode are approximately 12.5mm, but have been cut down to 1.5mm.



Evaluation Board Schematic - Electrical

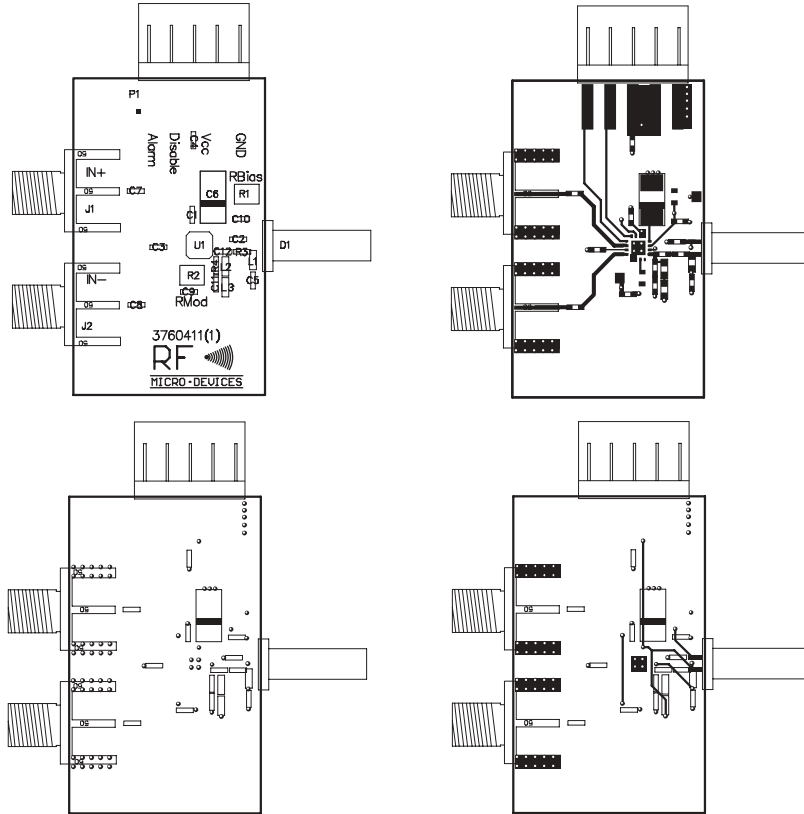


NOTES:

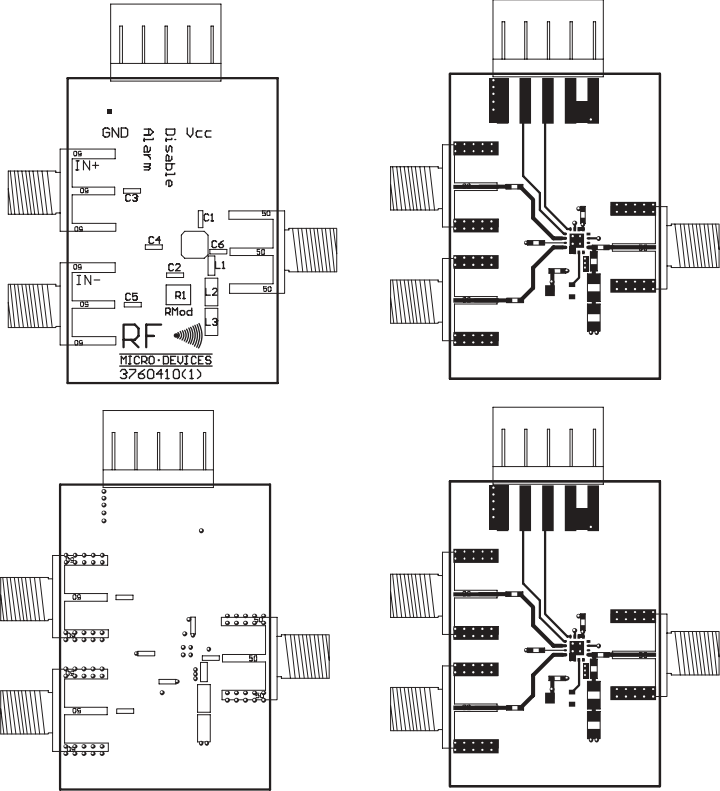
1. Transmission lines are to be precision 50 Ω microstrip lines on INPUT+, INPUT- and LASERMOD.

Evaluation Board Layout - Optical  
Board Size 21.5mm x 35.5mm

Board Thickness 0.042", Board Material Rogers RO4003 and FR-4, Multi-Layer

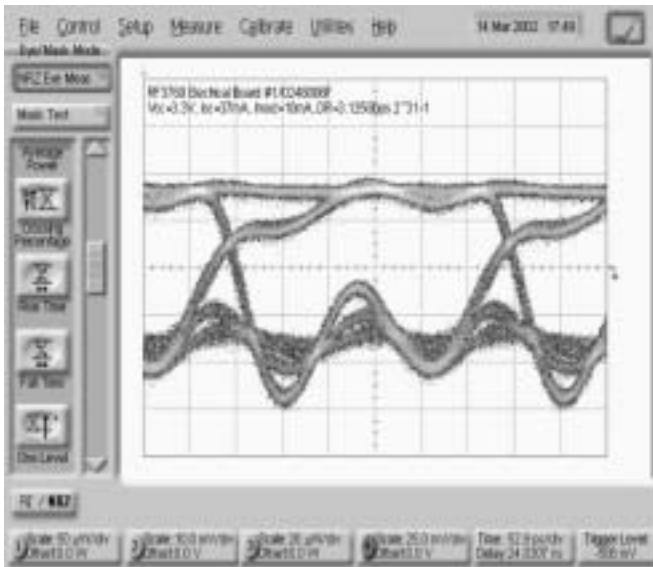


Evaluation Board Layout - Electrical  
Board Size 23.5mm x 34.2mm  
Board Thickness 0.042", Board Material Rogers RO4003 and FR-4, Multi-Layer

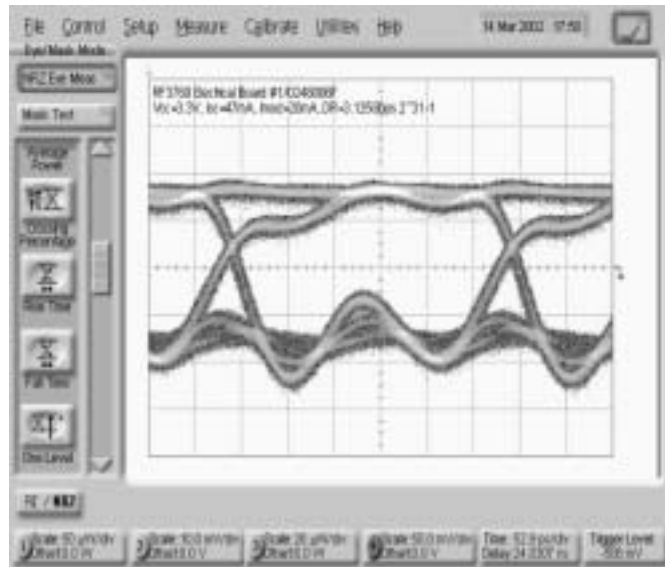


## Electrical Evaluation Board Data

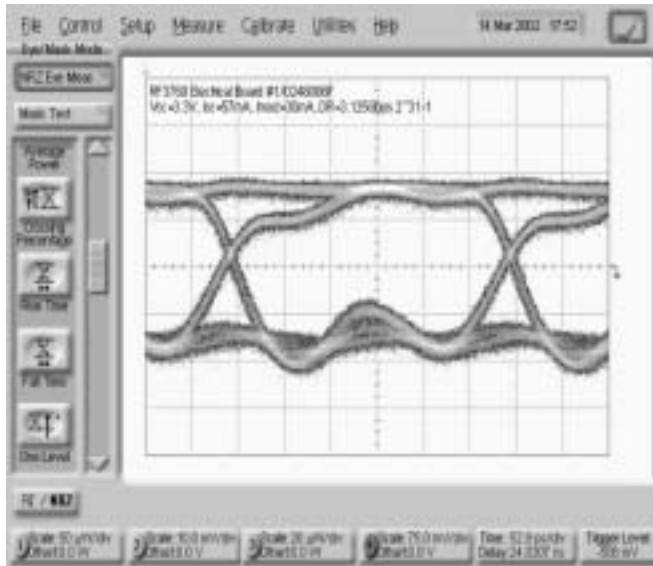
$I_{MOD}=10\text{mA}$



$I_{MOD}=20\text{mA}$



$I_{MOD}=30\text{mA}$



$I_{MOD}=50\text{mA}$

