

EVALUATION KIT  
AVAILABLE

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

MAX3766

## General Description

The MAX3766 is a complete, easy-to-program laser driver for fiber optic LAN transmitters, optimized for operation at 622Mbps. It includes a laser modulator, automatic power control (APC), and a failure indicator with latched shutdown.

Laser modulation current can be programmed up to 60mA at 622Mbps. A programmable modulation temperature coefficient can be used to keep the transmitted extinction ratio nearly constant over a wide temperature range. The modulator operates at data rates up to 1.25Gbps at reduced modulation current. APC circuitry uses feedback from the laser's monitor photodiode to adjust the laser bias current, producing constant output power regardless of laser temperature or age. The MAX3766 supports laser bias currents up to 80mA.

The MAX3766 provides extensive laser safety features, including a failure indicator with latched shutdown and a smooth start-up bias generator. These features help ensure that the transmitter output does not reach hazardous levels. The MAX3766 is available in a compact 20-pin QSOP and dice.

## Applications

622Mbps ATM Transmitters

1.25Gbps Fiber Optic LAN Transmitters

1.25Gbps Ethernet Transmitters

*Typical Application Circuits appear at end of data sheet.*

## Features

- ◆ 60mA Modulation Current
- ◆ 80mA Bias Current
- ◆ 200ps Edge Speed
- ◆ Modulation-Current Temperature Compensation
- ◆ Automatic Power Control
- ◆ Laser-Fail Indicator with Latched Shutdown
- ◆ Smooth Laser Start-Up

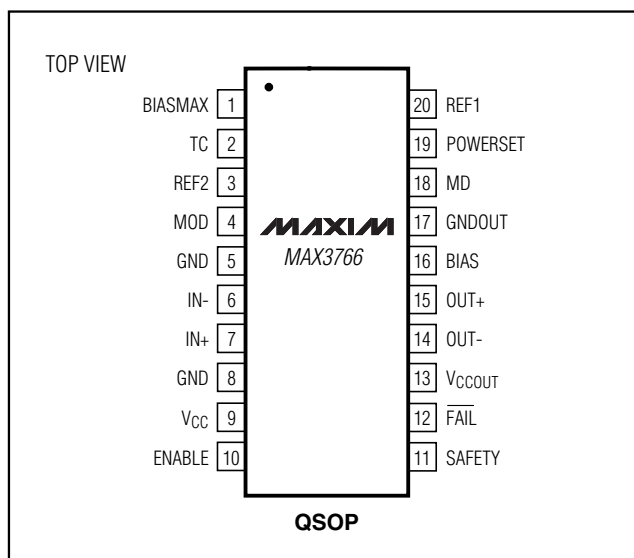
## Ordering Information

| PART        | TEMP RANGE     | PIN-PACKAGE |
|-------------|----------------|-------------|
| MAX3766EEP  | -40°C to +85°C | 20 QSOP     |
| MAX3766EEP+ | -40°C to +85°C | 20 QSOP     |
| MAX3766E/D  | -40°C to +85°C | Dice*       |

\*Dice are designed to operate over this range, but are tested and guaranteed at  $T_A = +25^\circ\text{C}$  only. Contact factory for availability.

+Denotes lead-free package.

## Pin Configuration



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage,  $V_{CC}$ ,  $V_{CCOUT}$  ..... -0.5V to 7.0V  
 Voltage at IN+, IN-, ENABLE, SAFETY,  $\overline{FAIL}$  ..... -0.5V to ( $V_{CC} + 0.5V$ )  
 Voltage at MOD, BIASMAX, POWERSET, TC ..... -0.5V to 4.0V  
 Current out of REF1, REF2 ..... -0.1mA to 10mA  
 Current into OUT+, OUT- ..... -5mA to 100mA  
 Current into BIAS ..... -5mA to 130mA  
 Current into MD ..... -5mA to 5mA

Current into  $\overline{FAIL}$  ..... -5mA to 30mA  
 Current into SAFETY ..... -5mA to 10mA  
 Continuous Power Dissipation ( $T_A = +85^\circ\text{C}$ )  
     QSOP (derate 9.1mW/ $^\circ\text{C}$  above  $+85^\circ\text{C}$ ) ..... 590mW  
 Operating Junction Temperature Range .....  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Processing Temperature (dice) .....  $+400^\circ\text{C}$   
 Storage Temperature Range .....  $-55^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Lead Temperature (soldering, 10sec) .....  $+300^\circ\text{C}$

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

| PARAMETER                                               | CONDITIONS                                                           | MIN            | TYP          | MAX   | UNITS                 |
|---------------------------------------------------------|----------------------------------------------------------------------|----------------|--------------|-------|-----------------------|
| <b>RECOMMENDED OPERATING CONDITIONS</b>                 |                                                                      |                |              |       |                       |
| Supply Voltage, $V_{CC}$                                |                                                                      | 4.5            | 5.0          | 5.5   | V                     |
| Ambient Operating Temperature                           | (Note 1)                                                             | -40            | 25           | 85    | $^\circ\text{C}$      |
| Differential Input Signal Amplitude                     | $V_{IN+} - V_{IN-}$ , common-mode input = $V_{CC} - 1.3V$ , Figure 1 | 500            | 1000         | 1800  | mV                    |
| Input Common-Mode Voltage                               | Referenced to $V_{CC}$                                               | -1.4           | -1.3         | -1.19 | V                     |
| Enable Input High                                       |                                                                      | 2.0            |              |       | V                     |
| Enable Input Low                                        |                                                                      |                |              | 0.8   | V                     |
| Voltage at OUT+, OUT-                                   |                                                                      | $V_{CC} - 2.5$ |              |       | V                     |
| Voltage at BIAS                                         |                                                                      | $V_{CC} - 2.5$ |              |       | V                     |
| $\overline{FAIL}$ Load                                  | All DC testing uses 5.1k $\Omega$ load                               |                | 2.7 to 20    |       | k $\Omega$            |
| Data Rate                                               |                                                                      |                | DC to 1.25   |       | Gbps                  |
| Data Duty Cycle                                         | While using APC                                                      |                | 50           |       | %                     |
| Laser to PIN Coupling                                   | Not tested                                                           |                | 0.001 to 0.1 |       | mA/mA                 |
| <b>DC PARAMETERS</b>                                    |                                                                      |                |              |       |                       |
| Supply Current                                          | $I_{CC}$ (Note 2)                                                    | 21             | 25           | 32    | mA                    |
| $\overline{FAIL}$ Output High                           | $R_{\overline{FAIL}} = 5.1k\Omega$                                   | 4.3            |              |       | V                     |
| $\overline{FAIL}$ Output Low                            | $I_{MD} > 15\mu\text{A}$ , $R_{\overline{FAIL}} = 5.1k\Omega$        |                | 0.33         | 0.44  | V                     |
| Bias-Current Range                                      | (Note 3)                                                             | 0.5            |              | 80    | mA                    |
| Bias Current when Driver is Disabled or Shut Down       |                                                                      |                | 0.1          | 10    | $\mu\text{A}$         |
| Modulation-Current Programmable Range                   | Input data high (Note 3)                                             | 2              |              | 60    | mA                    |
| Modulation Current                                      | Input data low (Note 2)                                              |                | 1            | 200   | $\mu\text{A}$         |
| Modulation Current when Driver is Disabled or Shut Down |                                                                      |                |              | 10    | $\mu\text{A}$         |
| Minimum Modulation-Current Temperature Compensation     | $R_{TC} = 0\Omega$                                                   |                | -50          |       | ppm/ $^\circ\text{C}$ |
| Maximum Modulation-Current Temperature Compensation     | $R_{TC} = \text{open}$                                               |                | 5600         |       | ppm/ $^\circ\text{C}$ |

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## ELECTRICAL CHARACTERISTICS (continued)

| PARAMETER                                | CONDITIONS                                                                       | MIN  | TYP | MAX  | UNITS         |
|------------------------------------------|----------------------------------------------------------------------------------|------|-----|------|---------------|
| Monitor-Diode Current Programmable Range |                                                                                  | 15   |     | 2000 | $\mu\text{A}$ |
| Monitor-Diode Bias Voltage               | $V_{CC} - V_{MD}$                                                                | 1.5  | 2.1 | 2.3  | V             |
| Upper MD Voltage for Failure             | Referenced to $V_{CC}$                                                           | -1.2 |     |      | V             |
| Lower MD Voltage for Failure             | Referenced to $V_{CC}$                                                           |      |     | -2.8 | V             |
| Range of MD for No Failure               | Width of operating window, centered at nominal $V_{MD}$                          |      | 300 |      | mV            |
| REF1 Voltage for Failure                 | Referenced to nominal $V_{REF1}$                                                 | 0.5  |     |      | V             |
| REF1 Reference Voltage                   | $T_A = +25^\circ\text{C}$ , $V_{REF1}$                                           | 2.8  | 3.1 | 3.4  | V             |
| REF2 Reference Voltage                   | $T_A = +25^\circ\text{C}$ , $V_{REF2}$                                           | 2.1  | 2.4 | 2.7  | V             |
| <b>AC PARAMETERS</b> (Notes 4, 5, and 6) |                                                                                  |      |     |      |               |
| Output Edge Speed (20% to 80%)           | $I_{MOD} = 60\text{mA}$                                                          |      | 210 | 400  | ps            |
|                                          | $I_{MOD} = 30\text{mA}$                                                          |      | 160 | 300  |               |
|                                          | $I_{MOD} = 10\text{mA}$                                                          |      | 125 | 250  |               |
| Output Aberrations                       | $I_{MOD} = 30\text{mA}$                                                          |      | 10  |      | %             |
| Pulse-Width Distortion                   | $I_{MOD} = 60\text{mA}$                                                          |      | 5   | 80   | ps            |
|                                          | $I_{MOD} = 30\text{mA}$                                                          |      | 20  | 80   |               |
|                                          | $I_{MOD} = 10\text{mA}$                                                          |      | 80  | 120  |               |
| Random Jitter                            | RMS, $T_A = +25^\circ\text{C}$ , $V_{CC} = +5\text{V}$ , $I_{MOD} = 30\text{mA}$ |      | 2   | 3    | ps            |

**Note 1:** Dice are tested at room temperature only ( $T_A = +25^\circ\text{C}$ ).

**Note 2:**  $V_{CC} = +5.5\text{V}$ ,  $R_{BIASMAX} = 887\Omega$ ,  $R_{MOD} = 887\Omega$ ,  $R_{POWERSET} = 287\Omega$ ,  $R_{TC} = 0\Omega$ ,  $V_{BIAS} = V_{OUT+} = V_{OUT-} = 3.0\text{V}$ . Supply current excludes  $I_{BIAS}$ ,  $I_{OUT+}$ ,  $I_{OUT-}$ , and  $I_{FAIL}$ .

**Note 3:** Total output current must be reduced at high temperatures with packaged product to maintain maximum junction temperature of  $T_j = +150^\circ\text{C}$ . See the *Design Procedure* section.

**Note 4:** All AC parameters are measured with a  $25\Omega$  load.  $I_{MOD}$  is the AC current amplitude at either OUT pin. The AC voltage at OUT is greater than  $V_{CC} - 2.5\text{V}$ .

**Note 5:** Pulse-width distortion is measured at the 50% crossing point. Data input is a 155MHz square wave, with  $t_R \approx 300\text{ps}$ .

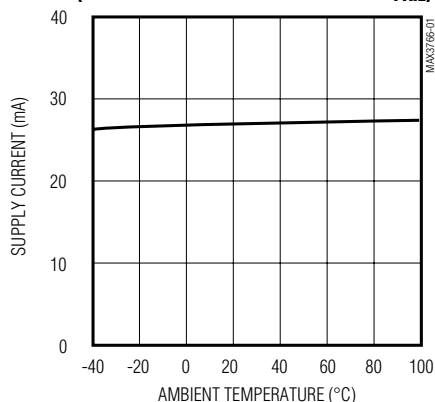
**Note 6:** AC specifications are guaranteed by design and characterization.

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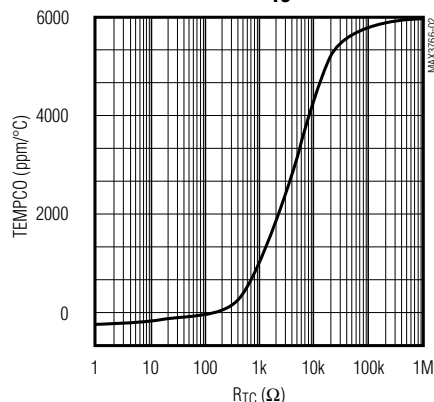
## Typical Operating Characteristics

(Typical Operating Characteristics are measured on the MAX3766 evaluation kit,  $V_{CC} = +5.0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

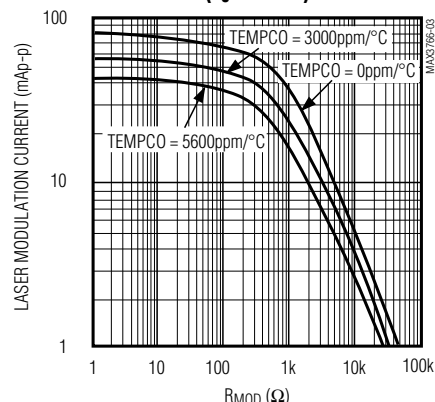
**SUPPLY CURRENT vs. TEMPERATURE  
(EXCLUDES OUTPUT CURRENTS AND  $I_{FAIL}$ )**



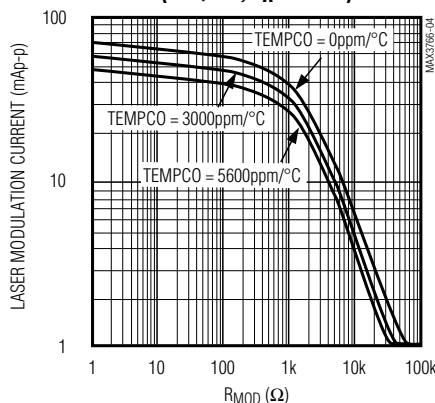
**MODULATION CURRENT TEMP CO  
vs.  $R_{TC}$**



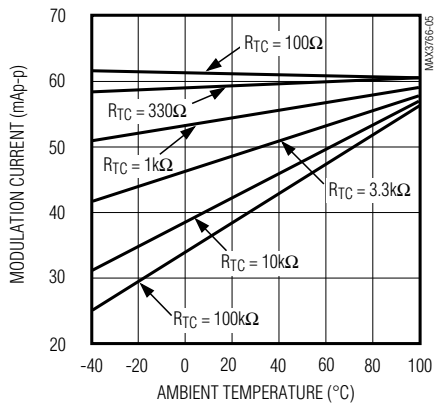
**DIE MODULATION CURRENT vs.  $R_{MOD}$   
( $T_J = +25^\circ C$ )**



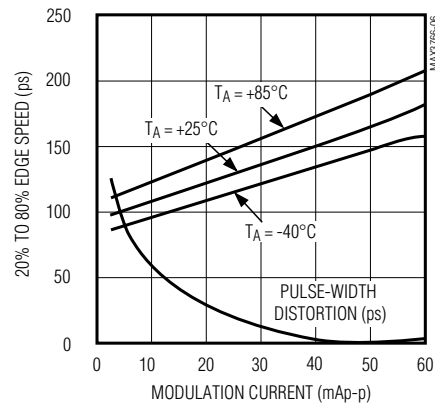
**MODULATION CURRENT vs.  $R_{MOD}$   
(20 QSOP,  $T_A = +25^\circ C$ )**



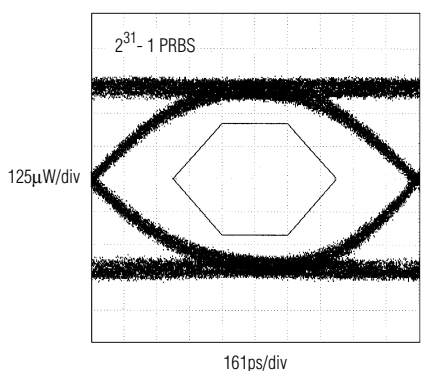
**MODULATION CURRENT  
vs. TEMPERATURE**



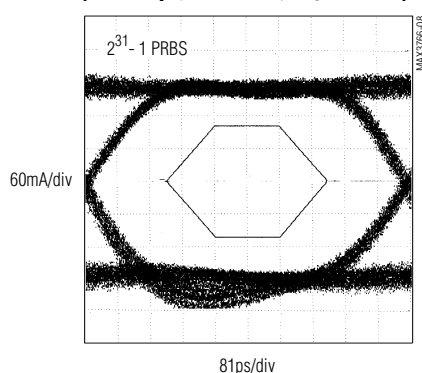
**MODULATION EDGE SPEED AND  
PWD vs. AMPLITUDE**



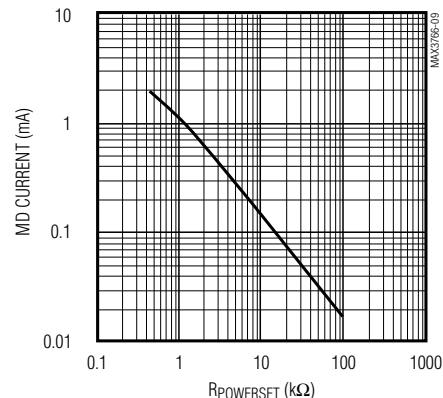
**EYE DIAGRAM  
(622Mbps, 1300nm LASER, 470MHz FILTER)**



**EYE DIAGRAM  
(1.244Gbps, 25Ω LOAD,  $I_{MOD} = 60mA$ )**



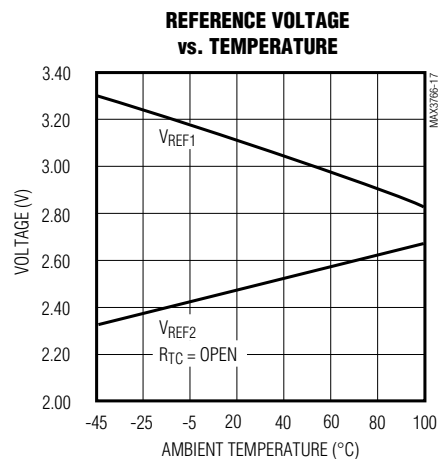
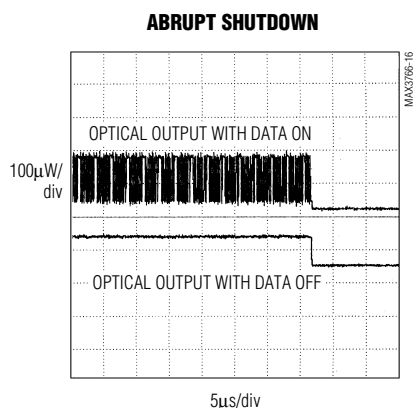
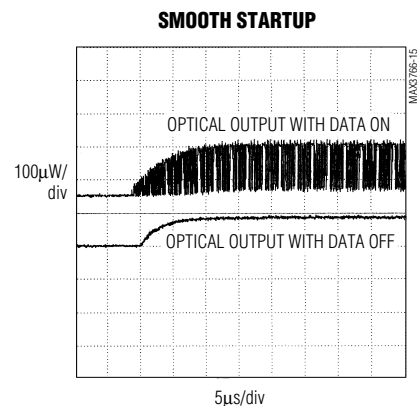
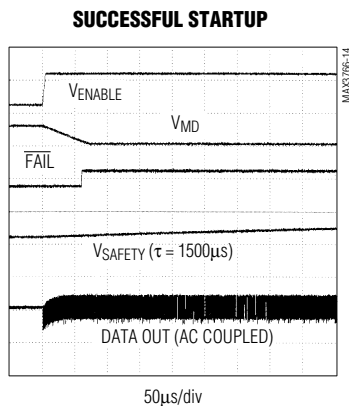
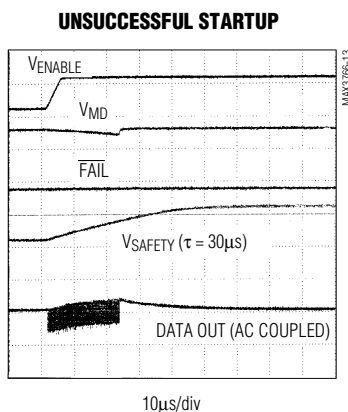
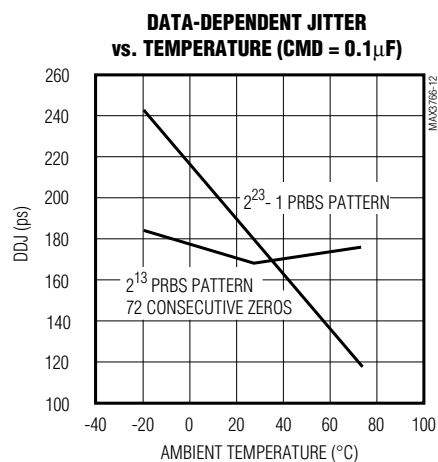
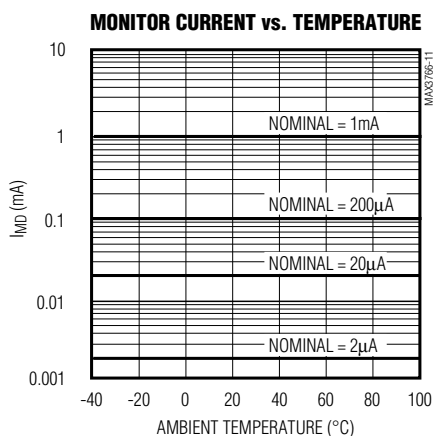
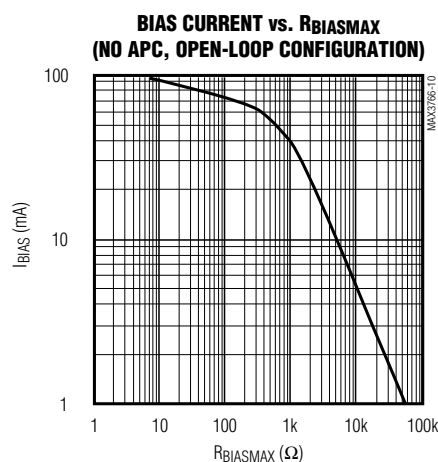
**MONITOR CURRENT vs.  $R_{POWERSET}$**



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Typical Operating Characteristics (continued)

(Typical Operating Characteristics are measured on the MAX3766 evaluation kit,  $V_{CC} = +5.0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Pin Description

| PIN  | NAME                     | FUNCTION                                                                                                                                                                                                                                                       |
|------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1    | BIASMAX                  | The current into BIASMAX sets the maximum laser bias current. Connecting BIASMAX directly to REF1 allows the largest possible bias current.                                                                                                                    |
| 2    | TC                       | The resistance ( $R_{TC}$ ) between TC and REF1 programs the temperature coefficient of REF2. Connecting TC directly to REF1 produces the minimum tempco. Leaving TC unconnected produces the maximum tempco.                                                  |
| 3    | REF2                     | REF2 is the reference voltage used to program the modulation current. The tempco of REF2 is programmed by $R_{TC}$ .                                                                                                                                           |
| 4    | MOD                      | The current into MOD programs the laser modulation current. Connect MOD to REF2 with a resistor or potentiometer.                                                                                                                                              |
| 5, 8 | GND                      | Ground. All grounds must be connected.                                                                                                                                                                                                                         |
| 6    | IN-                      | Inverting Data Input                                                                                                                                                                                                                                           |
| 7    | IN+                      | Noninverting Data Input                                                                                                                                                                                                                                        |
| 9    | V <sub>CC</sub>          | Positive Supply Voltage. All V <sub>CC</sub> pins must be connected.                                                                                                                                                                                           |
| 10   | ENABLE                   | ENABLE is a TTL-compatible input. When low or open, this pin disables the output modulation and bias current.                                                                                                                                                  |
| 11   | SAFETY                   | A capacitor to ground at SAFETY determines the turn-on delay for the safety circuits. If SAFETY is grounded or TTL low, internal safety shutdown features are disabled. A TTL high at SAFETY enables the internal safety shutdown features.                    |
| 12   | $\overline{\text{FAIL}}$ | The $\overline{\text{FAIL}}$ output asserts low if the voltage at MD is above or below nominal. $\overline{\text{FAIL}}$ also asserts if REF1 is inadvertently tied to the positive supply. $\overline{\text{FAIL}}$ has TTL-compatible output voltage levels. |
| 13   | V <sub>CCOUT</sub>       | Supply Voltage for the Output Current Drivers                                                                                                                                                                                                                  |
| 14   | OUT-                     | Inverting Modulation-Current Output                                                                                                                                                                                                                            |
| 15   | OUT+                     | Noninverting Modulation-Current Output                                                                                                                                                                                                                         |
| 16   | BIAS                     | Connection for the DC Laser Bias Current                                                                                                                                                                                                                       |
| 17   | GNDOUT                   | Ground for the Output Current Drivers                                                                                                                                                                                                                          |
| 18   | MD                       | Input for the laser monitor photodiode current.                                                                                                                                                                                                                |
| 19   | POWERSET                 | The current into POWERSET programs the average optical output power when automatic power control is used.                                                                                                                                                      |
| 20   | REF1                     | REF1 is a voltage reference used to program laser bias current and average power.                                                                                                                                                                              |

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

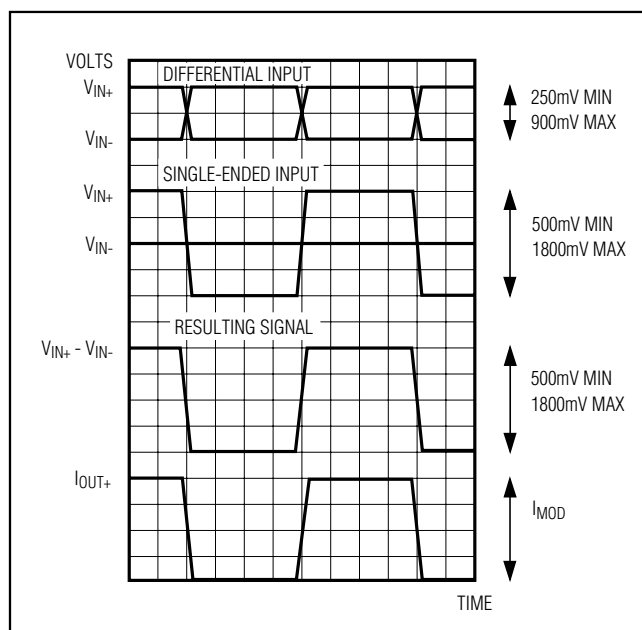


Figure 1. Required Input Signal and Output Polarity

## Detailed Description

Figure 2 is a functional block diagram of the MAX3766 laser driver. The major functional blocks are the reference generator, PECL input buffer, laser-bias circuit, modulation-current driver, automatic power control (APC), failure detection, and safety circuit.

### Reference Generator

The MAX3766 provides adjustments for maximum laser-bias current, laser modulation current, and average laser power. To program these adjustments, simply use the currents obtained by inserting a resistor in series with integrated voltage references REF1 and REF2. The temperature coefficient (tempco) of REF1 compensates for the tempco of the bias, modulation, and APC current mirrors. Therefore, a programming current derived from REF1 is constant with temperature. REF2 provides a positive tempco, which can be applied to the modulation current. A positive modulation-current tempco will compensate for the thermal characteristics of typical laser diodes. The modulation-current tempco is programmed by an external resistor ( $R_{TC}$ ), which is connected from REF1 to TC.  $R_{TC}$  and an internal  $2k\Omega$  resistor form a weighted sum of the temperature-compensated reference (REF1) and the temperature-increasing reference, which is buffered and output at REF2. REF1 and REF2 are stable with no bypass capacitance. Bypass filtering REF1 or REF2 is not required.

### PECL Input Buffer

The differential PECL input signals are connected to the high-speed PECL input buffer at IN+ and IN-. The input impedance at IN+ and IN- is greater than  $100k\Omega$ , and the input bias current is less than  $10\mu A$ . The MAX3766's data inputs are not self-biasing. The common-mode input should be set by the external PECL termination circuitry. To obtain good AC performance, inputs should always be greater than  $2.2V$  and less than  $V_{CC}$ .

### Laser Modulation-Current Driver

The laser modulation-current driver consists of a current mirror and an emitter coupled pair. The mirror has a gain of  $+30mA/mA$ . Modulation-current amplitude is programmed with external resistor  $R_{MOD}$  connected from REF2 to MOD.  $R_{MOD}$  can be estimated as follows:

$$R_{MOD} = \frac{1.55V(30)}{I_{MOD}} - 520\Omega$$

with  $R_{TC} = 0\Omega$ .

The MAX3766 AC output drives up to  $60mA$  of laser current. Pulse-width distortion and overshoot are lowest between  $30mA$  and  $60mA$ . However, output edge speed increases at lower currents. When the output current is between  $2mA$  and  $60mA$ , the edge speed is suitable for communications up to  $622Mbps$ . Edge speeds below  $30mA$  are suitable for communications up to  $1.25Gbps$  (see *Typical Operating Characteristics*).

The modulation-current tempco can be programmed with an external resistor  $R_{TC}$ , as described in the *Reference Generator* section. An internal  $520\Omega$  resistor is included to limit the maximum modulation current if MOD is connected directly to REF2.

If the MAX3766 is shut down or disabled, the modulation programming current is shunted to ground. Any remaining modulation current is switched to OUT-.

For optimum performance, the voltage at OUT+ and OUT- must always exceed  $V_{CC} - 2.5V$ .

### Laser Bias Circuit

The laser bias circuit is a current mirror with a gain of  $+40mA/mA$ . Redundant controls disable the bias current during a shutdown or disable event: the programming current is switched off, and any remaining bias output current is switched away from the laser. Ensure that the voltage at BIAS always remains above  $V_{CC} - 2.5V$ . If the bias circuit is not used, connect BIAS to  $V_{CC}$ .

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

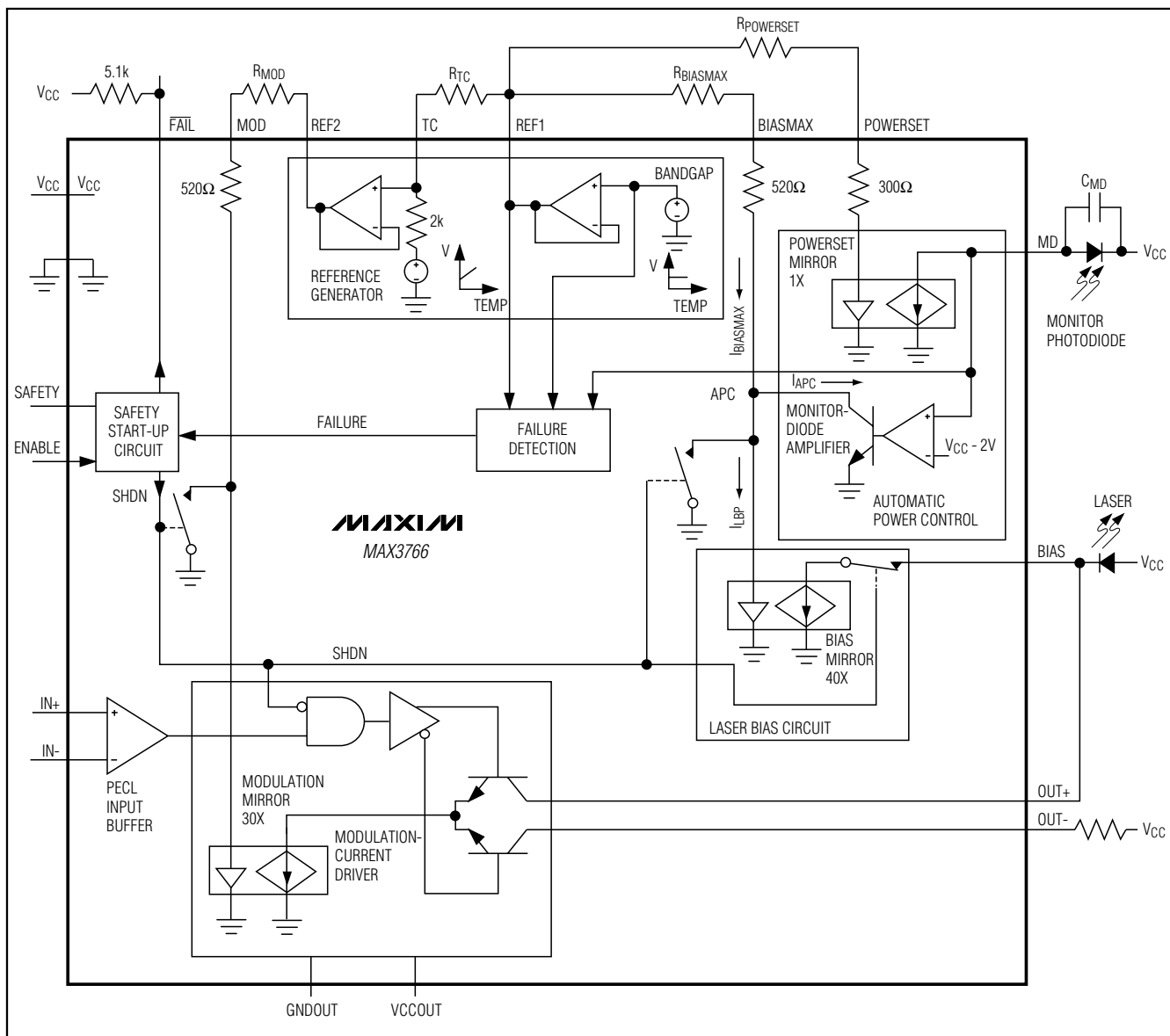


Figure 2. Functional Diagram

The available laser bias current is programmed by connecting external resistor  $R_{BIASMAX}$  from REF1 to BIASMAX. The BIASMAX programming current is adjusted by the APC circuit and amplified by the laser bias circuit.

An internal  $520\Omega$  resistor between BIASMAX and the mirror input at internal node APC limits the maximum laser bias current when BIASMAX is connected directly to REF1. BIASMAX can be directly connected to REF1 in space-constrained designs, causing the maximum

programming current (about 2.5mA) to flow into BIASMAX. Selecting a BIASMAX resistor saves power and limits the transmitter's maximum light output.  $R_{BIASMAX}$  can be estimated as follows:

$$R_{BIASMAX} = \frac{1.55V(40)}{I_{BIASMAX}} - 520\Omega$$

This equation applies to maximum bias currents above 10mA.



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Automatic Power Control

Transmitters employing a laser with monitor photodiode can use the APC circuit to maintain constant power, regardless of laser threshold changes due to temperature and aging. The APC circuit consists of the POWERSET current mirror and the monitor diode amplifier.

The POWERSET current mirror provides an accurate method of programming the back facet monitor photodiode current, which is assumed to be proportional to laser output power. An external resistor from REF1 to POWERSET programs the current in the unity-gain current mirror. RPOWERSET can be estimated as follows:

$$R_{\text{POWERSET}} = \frac{1.55\text{V}}{I_{\text{MOD}}} - 300\Omega$$

The monitor-diode amplifier senses the current from the monitor photodiode at MD, provides gain, and adjusts the laser bias programming current (ILBP). The monitor-diode amplifier forces the monitor-diode current to equal the current programmed at POWERSET. The monitor-diode amplifier can reduce the laser bias programming current, but cannot increase it. Therefore, the APC circuit can adjust laser bias current between 0 and the setting determined by RBIASMAX.

When the APC feedback loop is closed, the voltage at MD is approximately 2V below VCC. If the loop cannot close due to excess or insufficient photocurrent, a failure is detected by the failure-detection circuit. Internal circuitry prevents the voltage at MD from dropping below VCC - 3.2V.

The stability and time constant of the APC feedback loop is determined by an external compensation capacitor (CMD) of at least 0.1μF. Connect the compensation capacitor from VCC to MD, as shown in *Typical Application Circuits*, to ensure a smooth start-up at power-on or transmitter enable.

If a monitor diode is not available, the APC feature can be disabled by connecting RPOWERSET to GND and leaving MD unconnected.

## Failure Detection

Figure 3 shows a simplified schematic of the failure-detection circuit. The failure-detection circuit senses two conditions. First, if the APC control loop cannot control the monitor current due to laser undercurrent, overcurrent, or a fault condition, a window comparator detects that VMD is above or below VCC - 2V and asserts the failure signal. Second, if REF1 is shorted to the positive supply (or any another voltage above the normal operating level), a comparator detects this condition and asserts the failure signal. If left undetected,

the reference voltage would rise, the current at POWERSET would increase, and the APC loop would attempt to add laser current beyond the intended value.

Either failure condition causes the  $\overline{\text{FAIL}}$  output to assert TTL low. The  $\overline{\text{FAIL}}$  output buffer is an open-collector output and is designed to operate with a 5.1kΩ external pull-up resistor.

## Safety/Start-Up Circuit

The safety circuit includes the digital logic needed to provide a latched internal shutdown signal (SHDN) for disabling the laser if a failure condition exists. The MAX3766 produces less than 20μA of total laser current when disabled by safety features or by the ENABLE input. Figure 4 is a simplified schematic of the safety circuit.

If ENABLE is low or open, the laser bias and modulation outputs are disabled by SHDN, regardless of the state of the safety logic. The TTL-compatible ENABLE input is internally pulled low with a 100kΩ resistor.

There are two useful safety configurations: failure indication and latched shutdown.

## Failure-Indication Configuration

Select the failure-indication configuration by connecting SAFETY to ground. In this configuration, a failure condition is reported at  $\overline{\text{FAIL}}$ , but does not cause a latched shutdown. This configuration requires no additional circuitry for start-up.

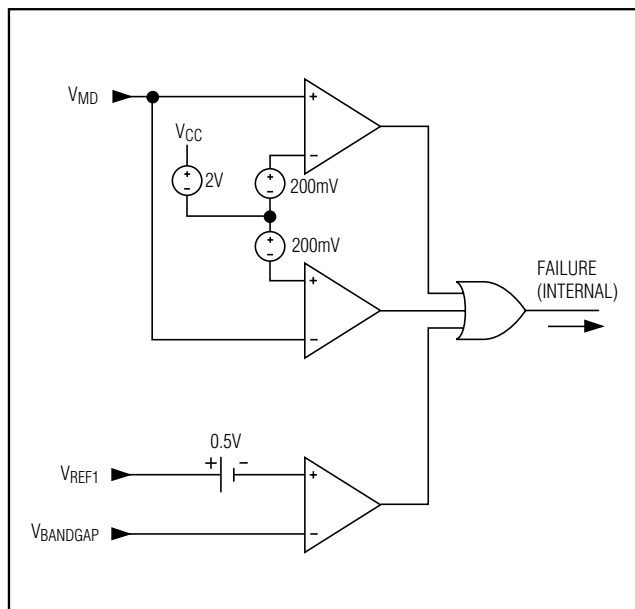


Figure 3. Failure-Detection Circuit (Simplified)

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

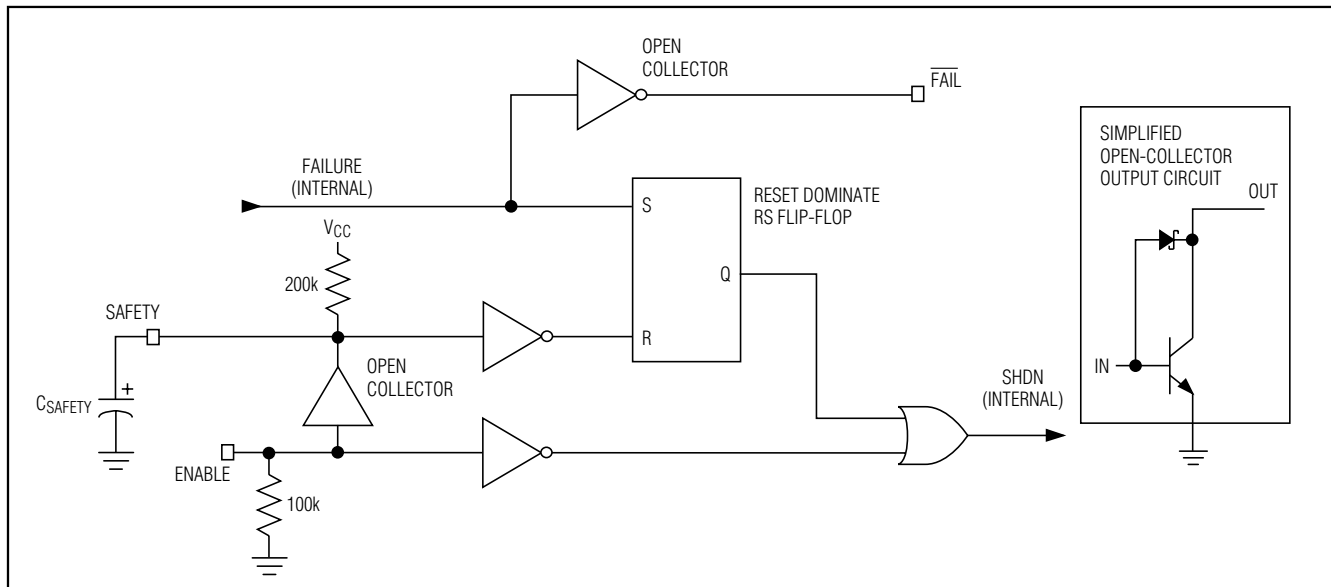


Figure 4. Simplified Safety Circuit Schematic

## Latched Shutdown Configuration

This configuration is shown in the *Typical Application Circuits* (configured for best performance), and can be selected by connecting a capacitor ( $C_{SAFETY}$ ) to ground at SAFETY. In this configuration, the transmitter is shut down when a failure is detected. It can be restarted only by a power-on cycle or a toggle of the ENABLE input.

During start-up,  $\overline{FAIL}$  is asserted until laser power reaches the programmed level. The safety circuit must be disabled at power-on or at transmitter enable, providing enough time for the APC circuit to reach the programmed laser power level.

In space-constrained designs,  $C_{SAFETY}$  can be selected to provide a shutdown delay. When power is initially applied, or when the ENABLE signal is toggled from a logic 0 to a logic 1, the voltage at SAFETY is low, and rises with a time constant set by  $C_{SAFETY}$  and an internal  $200k\Omega$  pull-up resistor. The SAFETY signal is inverted and resets the input of a reset-dominant RS flip-flop. The internal signal FAILURE from the failure-detection circuit is connected to the set input of the flip-flop. After SAFETY has gone high (allowing time for the APC feedback loop to settle) and if internal signal FAILURE is low, the flip-flop output is low, and the bias and modulation outputs are allowed to remain on. Refer to Figure 5 for a timing diagram of start-up in the latched shutdown configuration.

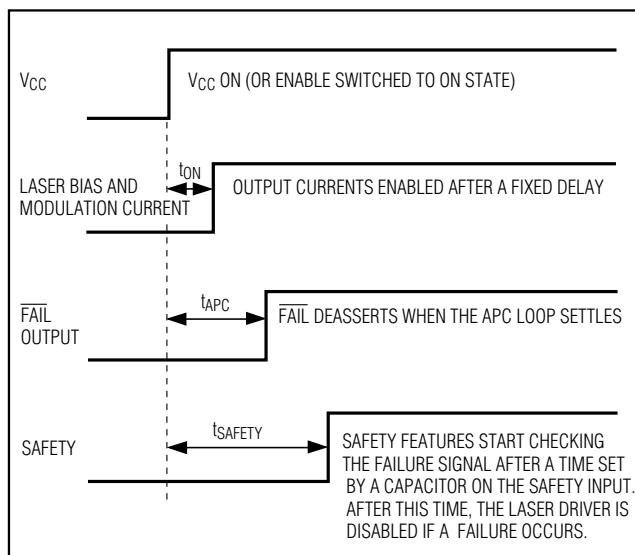


Figure 5. Start-Up Sequence Timing

The duration of  $t_{SAFETY}$  must be about 10 times  $t_{APC}$  for a successful start-up. After start-up, the transmitter operates normally until a failure is detected, causing the output currents to be shut down. The laser-current outputs remain off until the failure condition is eliminated and the ENABLE input is toggled, or until the power is cycled. A potential problem with this transmitter-enable method is that a slow-rising power supply may not enable the transmitter.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

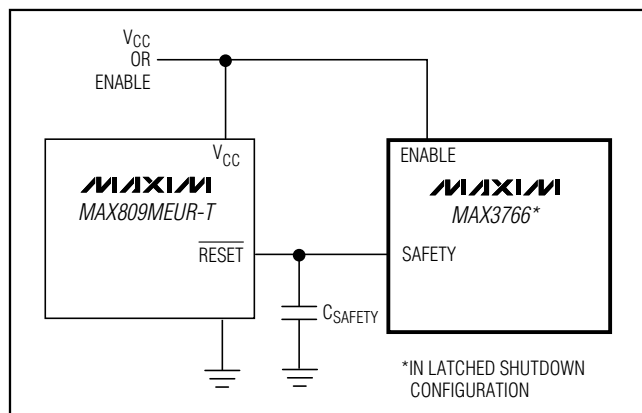


Figure 6. Reset Pulse Generator

If PC board space is not a constraint, Maxim recommends enabling the transmitter with a reset-pulse generator, such as the MAX809, which generates a reset signal after VCC reaches 4.5V (Figure 6). This method ensures that the transmitter starts correctly, even if the supply ramps very slowly.

## Design Procedure

### Select Laser

Select a communications-grade laser with a rise time of 0.5ns or better for 622Mbps applications. The voltage swing at the OUT+ pin affects the output waveform, and is largely determined by the laser resistance, inductance, and modulation current. To obtain the MAX3766's AC specifications, the output voltage at OUT+ must remain above VCC - 2.5V at all times.

An approximation for the minimum voltage at OUT+ is given by the following equation (Table 1):

$$V_{OUT(MIN)} = V_{CC(MIN)} - V_{LASER} - (I_{MOD}) \left( R_L + R_D + \frac{L}{t_r} \right)$$

Select a laser that meets the output voltage criteria. A high-efficiency laser requires low modulation current and generates low voltage swing at OUT+. Laser package inductance can be reduced by trimming leads. Typical package leads have inductance of 25nH per inch (1nH/mm). A compensation filter network can also be used to reduce ringing, edge speed, and voltage swing.

Table 1. Output Voltage Approximation

| VARIABLE              | DESCRIPTION                                                                                       | TYPICAL VALUE         |
|-----------------------|---------------------------------------------------------------------------------------------------|-----------------------|
| V <sub>OUT(MIN)</sub> | Approximation for the lowest voltage at the OUT+ pin                                              | 2.2V                  |
| V <sub>CC(MIN)</sub>  | Minimum power supply                                                                              | 4.5V                  |
| V <sub>LASER</sub>    | Laser forward voltage at operating power                                                          | 1.3V                  |
| R <sub>L</sub>        | Laser dynamic resistance                                                                          | 3Ω                    |
| I <sub>OUT</sub>      | Laser modulation current                                                                          | 30mA                  |
| R <sub>D</sub>        | Any damping resistance or line termination in series with the laser (but not in series with BIAS) | 10Ω                   |
| L                     | Total series inductance of laser, laser package, and board traces to the MAX3766                  | 6nH                   |
| t <sub>r</sub>        | 20% to 80% rise time of the laser modulation current, filtered by a compensation network          | 300ps<br>(20% to 80%) |

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Set Modulation-Current Tempco

Compute the required modulation tempco from the slope efficiency of the laser at  $T_A = +25^\circ\text{C}$  and at a hot temperature. Then select the value of  $R_{TC}$  from the *Typical Operating Characteristics*.

For example, suppose a laser has a slope efficiency (SE) of 0.021mW/mA at  $+25^\circ\text{C}$ , which reduces to 0.018mW/mA at  $+85^\circ\text{C}$ . The temperature coefficient is given by the following:

$$\begin{aligned}\text{Laser tempco} &= \frac{(SE_{85} - SE_{25})}{SE_{25} \cdot (85 - 25)} \cdot 10^6 \\ &= -2380\text{ppm}/^\circ\text{C}\end{aligned}$$

From the *Typical Operating Characteristics*, the value for  $R_{TC}$ , which offsets the tempco of the laser, is  $3\text{k}\Omega$ . If modulation temperature compensation is not desired, connect TC directly to REF1.

## Set Modulation Current

The modulation-current amplitude can be programmed with a fixed resistor or adjusted with a potentiometer. A small internal resistance is provided to prevent damage if the potentiometer is adjusted to the end of its range. The value of  $R_{MOD}$  can be selected from the *Typical Operating Characteristics*.

Example: A transmitter requires average power of -8dBm (160μW), with an extinction ratio of 15. The optical signal output is 280μW (see *Optical Power Relations*). If the slope efficiency is 0.021mW/mA at  $+25^\circ\text{C}$ , then the required modulation current is  $0.280\text{mW} / 0.021\text{mW/mA} = 13.3\text{mA}$ . From the *Typical Operating Characteristics*, the value of  $R_{MOD}$  is selected to be  $3\text{k}\Omega$ .

## Set Average Laser Power and Maximum Bias Current

When APC is used, the average power control is programmed by  $R_{POWERSET}$ , which is typically a potentiometer. The value of  $R_{POWERSET}$  can be estimated from the *Typical Operating Characteristics*.

Example: Suppose a transmitter's output power will be adjusted to -8dBm (160μW) average power during manufacturing. The coupling efficiency from laser to monitor photodiode varies from 0.4A/W to 0.8A/W for the selected laser, causing monitor current to vary between 64μA and 128μA. From the *Typical Operating Characteristics*,  $R_{POWERSET}$  should be adjustable between  $12\text{k}\Omega$  and  $24\text{k}\Omega$ .

Select  $R_{BIASMAX}$  to provide sufficient current for a hot laser at its end of life. For example, if the expected laser threshold at  $+85^\circ\text{C}$  and end of life is 40mA, then from the *Typical Operating Characteristics*,  $R_{BIASMAX}$  should be  $1\text{k}\Omega$  or less.

If APC is not used, the laser bias current is programmed by  $R_{BIASMAX}$ . Select  $R_{BIASMAX}$  from the *Typical Operating Characteristics*.

## Set APC Time Constant

Capacitor  $C_{MD}$  determines the APC time constant, and must be large enough not to cause data-dependent jitter. For 622Mbps SONET/ATM applications, Maxim recommends selecting  $C_{MD} \geq 0.1\mu\text{F}$ .

## Select CSAFETY

When using the latched shutdown configuration, determine the minimum value of  $C_{SAFETY}$  from the *Typical Operating Characteristics*. Calculate  $C_{SAFETY}$  as follows:

$$C_{SAFETY} = \frac{C_{MD}}{20\text{k}\Omega \cdot I_{MD}}$$

For example: If  $C_{MD}$  is  $0.1\mu\text{F}$  and typical monitor current ( $I_{MD}$ ) is  $100\mu\text{A}$ , then the value of  $C_{SAFETY}$  should be  $50\text{nF}$  or larger. This ensures that  $t_{SAFETY}$  is at least 10 times the  $t_{APC}$ .

## Design Bias Filter

To reduce data-dependent jitter, add a filter at BIAS (see *Typical Operating Circuit*). Maxim recommends a  $1\mu\text{H}$  inductor or ferrite bead with a self-resonance frequency of 200MHz or more.

## Design Laser-Compensation Filter Network

Laser package lead inductance causes the laser impedance to increase at high frequencies, which leads to ringing, overshoot, and degradation of the output eye. A laser-compensation filter network can be used to reduce the output load seen by the MAX3766 at high frequencies, thereby reducing output ringing and overshoot.

The compensation components ( $R_{COMP}$  and  $C_{COMP}$ ) are most easily determined by experimentation. Begin with a no-compensation network, and observe the ring frequency ( $f_n$ ) of the laser and laser driver (Figure 7). Begin with  $R_{COMP} = 25\Omega$  and  $C_{COMP} = 1/(2\pi f_n R_{COMP})$ . Increase  $C_{COMP}$  until the desired transmitter eye is obtained.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

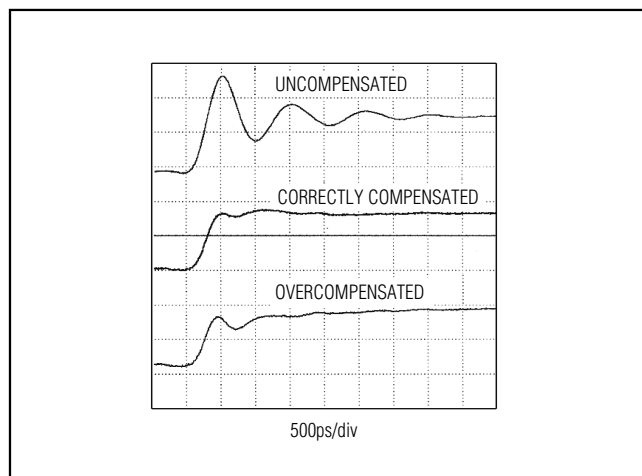


Figure 7. Example Laser Compensation

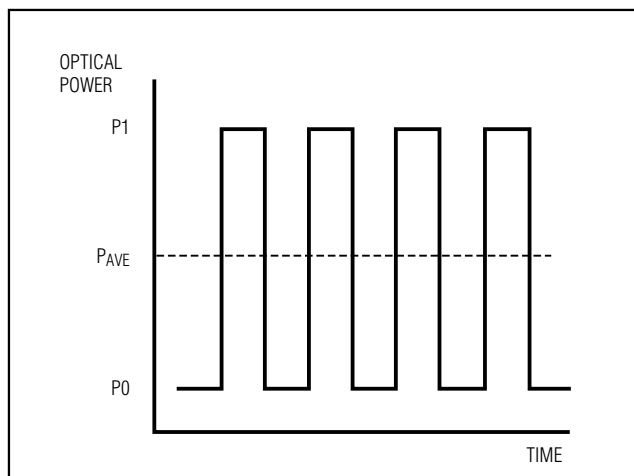


Figure 8. Optical Power Relations

## Calculate Power Consumption

The MAX3766's junction temperature must be kept below +150°C at all times. Calculate total power dissipated on the MAX3766 by laser power as follows:

$$\text{Power} = V_{CC} (I_{CC} + I_{BIAS} + I_{MOD}) - (I_{MOD} / 2 + I_{BIAS}) V_{LASER}$$

where  $I_{BIAS}$  is the maximum bias current allowed by  $R_{BIASMAX}$ ,  $I_{MOD}$  is the AC modulation current,  $V_{LASER}$  is the typical laser forward voltage.

$$\text{Junction temperature} = \text{power (Watts)} \cdot 110 (^{\circ}\text{C/W}).$$

## Applications Information

### Optical Power Relations

Many MAX3766 specifications relate to output current amplitude. When working with fiber optic transmitters, the output is normally expressed in terms of average optical power and extinction ratio (Figure 8). Table 2 lists relations that are helpful in converting optical power to output signal amplitude when designing with the MAX3766. The relations are true if the average duty cycle of the input data is 50%.

### Input Terminations

The MAX3766's data inputs must be biased externally. Refer to Figure 9 for common input terminations.

### Laser Safety and IEC 825

The International Electrotechnical Commission (IEC) determines standards for hazardous light emissions from fiber optic transmitters. Specification IEC 825 defines the maximum light output for various hazard levels. The MAX3766 provides features that aid compliance with IEC 825.

Table 2. Optical Power Definitions

| PARAMETER              | SYMBOL      | RELATION                                                   |
|------------------------|-------------|------------------------------------------------------------|
| Average Power          | $P_{AVE}$   | $P_{AVE} = (P_0 + P_1) / 2$                                |
| Extinction Ratio       | $r_e$       | $r_e = P_1 / P_0$                                          |
| Optical Power of a "1" | $P_1$       | $P_1 = 2P_{AVE} \frac{r_e}{r_e + 1}$                       |
| Optical Power of a "0" | $P_0$       | $P_0 = 2P_{AVE} / (r_e + 1)$                               |
| Signal Amplitude       | $P_{INPUT}$ | $P_{INPUT} = P_1 - P_0 = 2P_{AVE} \frac{r_e - 1}{r_e + 1}$ |

A common safety requirement is single-point fault tolerance, whereby one unplanned short, open, or resistive connection does not cause excess light output. When the MAX3766 is used in the latched shutdown configuration, as shown in *Typical Application Circuits*, the circuit responds as shown in Table 3.

Using the MAX3766 laser driver alone does not ensure that a transmitter design is compliant with IEC 825. The entire transmitter circuit and component selections must be considered. Each customer must determine the level of fault tolerance required by their application, recognizing that Maxim products are not designed or authorized for use as components in systems intended for surgical implant into the body, for applications intended to support or sustain life, or for any other application where the failure of a Maxim product could create a situation where personal injury or death may occur.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

**Table 3. MAX3766 Fault Response in Latched Shutdown Configuration**

| PIN                      | CIRCUIT RESPONSE TO OVERVOLTAGE OR SHORT TO V <sub>CC</sub>                                                                                                                | CIRCUIT RESPONSE TO UNDERVOLTAGE OR SHORT TO GROUND                                                                                                                                                                                                                                            |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BIASMAX                  | Depending upon the setting of RPOWERSET, there is either no effect, or a latched shutdown.                                                                                 | Bias current reduction causes a low laser output, resulting in a latched shutdown.                                                                                                                                                                                                             |
| REF1                     | High voltage on REF1 causes a failure and latched shutdown.                                                                                                                | Modulation and bias currents are reduced or off; no hazard exists.                                                                                                                                                                                                                             |
| REF2, TC, MOD            | Modulation current is increased. Either the APC circuit will reduce power levels, or an overcurrent will be detected at MD, causing a failure signal and latched shutdown. | Modulation current is reduced; no hazard exists.                                                                                                                                                                                                                                               |
| ENABLE                   | Normal condition for circuit operation.                                                                                                                                    | Modulation and bias currents are shut down.                                                                                                                                                                                                                                                    |
| IN+, IN-                 | Forces output to either constant 1 or 0. APC maintains the power level at the programmed level.                                                                            | Forces output to either constant 1 or 0. APC maintains the power level at the programmed level.                                                                                                                                                                                                |
| SAFETY                   | Normal condition for circuit operation.                                                                                                                                    | Safety shutdown features are disabled, but a hazard is not created.                                                                                                                                                                                                                            |
| $\overline{\text{FAIL}}$ | No effect on circuit.                                                                                                                                                      | No effect on circuit.                                                                                                                                                                                                                                                                          |
| OUT+, BIAS               | Voltage increase at these pins will turn off the laser.                                                                                                                    | High laser output asserts $\overline{\text{FAIL}}$ . A complete short will destroy the laser, eliminating the hazard. A resistive short may cause a hazard. External circuitry combined with the $\overline{\text{FAIL}}$ signal may be used to protect against a resistive short (Figure 10). |
| OUT-                     | Normal condition for circuit operation.                                                                                                                                    | Forces output to be logic 1. APC maintains the power level at the programmed level.                                                                                                                                                                                                            |
| MD                       | Voltage increase at MD causes a failure and output current shutdown.                                                                                                       | Voltage decrease at MD causes a failure and output current shutdown.                                                                                                                                                                                                                           |
| POWERSET                 | Laser output increases, but is limited by the setting of RBIASMAX.                                                                                                         | Laser output decreases.                                                                                                                                                                                                                                                                        |



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

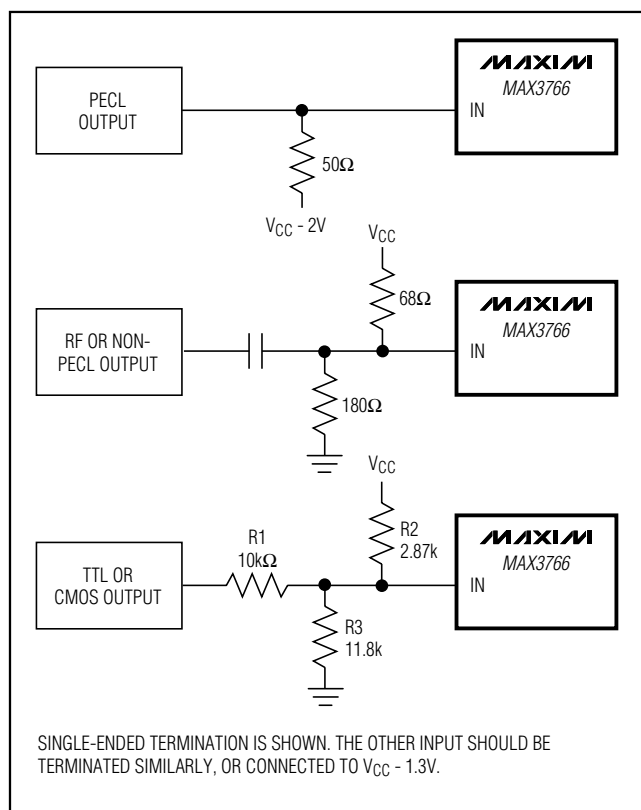


Figure 9. Input Terminations

## Layout Considerations

The MAX3766 is a high-frequency product. The performance of the circuit is largely dependent upon the layout of the circuit board.

Use a multilayer circuit board with a dedicated ground plane. Use short laser package leads placed close to OUT+ and OUT- to keep output inductance low. Power supplies should be capacitively bypassed to the ground plane with surface-mount capacitors placed near the power-supply pins.

## Solutions to Common Problems

### 1) Laser output is ringing and contains overshoot.

This is often caused by inductive laser packaging. Try reducing the lead length of the laser pins. Modify the compensation network to reduce the driver's output edge speed (see *Design Procedure*). This problem can also occur if the voltage at OUT+, OUT-, or BIAS is below  $V_{CC} - 2.5V$ . Test this by increasing the supply voltage, or reducing the modulation current.

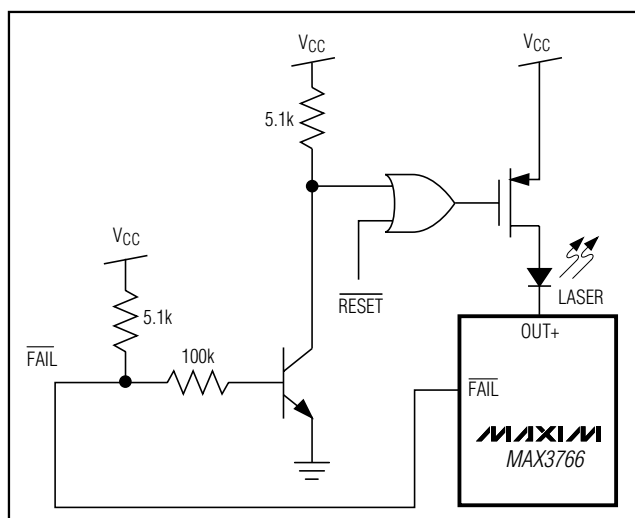


Figure 10. External Laser Shutdown Circuit

### 2) Low-frequency oscillation on the bias-current output.

Ensure  $C_{MD} \geq 0.1\mu F$ .

### 3) Modulation driver is not needed.

If only the bias-current driver and safety circuits are needed, connect IN+ to  $V_{CC}$ , and leave IN- unconnected. Connect OUT+ and OUT- to the supply. Leave MOD, TC, and REF2 unconnected.

### 4) APC is not needed.

If only the high-speed modulation driver is used, connect BIAS to  $V_{CC}$ , and leave POWERSET, MD, FAIL, and BIASMAX unconnected. Connect SAFETY to ground.

### 5) Laser edge switching speed is low.

Refer to the *Design Bias Filter* section. It may be necessary to select LBIAS with a higher self-resonating frequency.

## Wire Bonding Die

The MAX3766 uses bondpads with gold metalization. Make connections to the die with gold wire only, using ball bonding techniques. Wedge bonding is not recommended. Pad size is 4 mils (0.1mm) square. Die thickness is typically 15 mils (0.38mm).

## Interface Models

Figure 11 shows typical models for the inputs and outputs of the MAX3766, including package parasitics. If dice are used, replace the package parasitic elements with bondwire parasitic elements.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

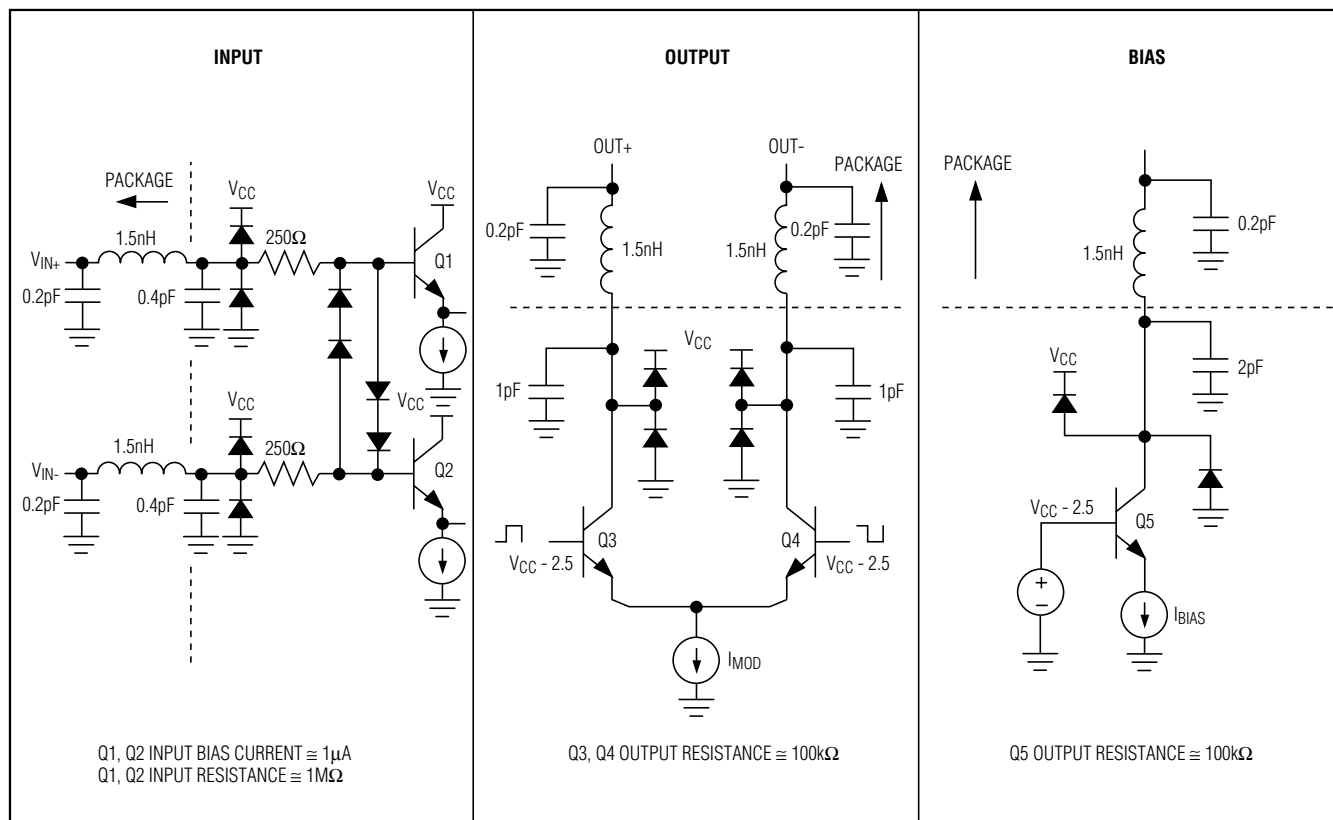


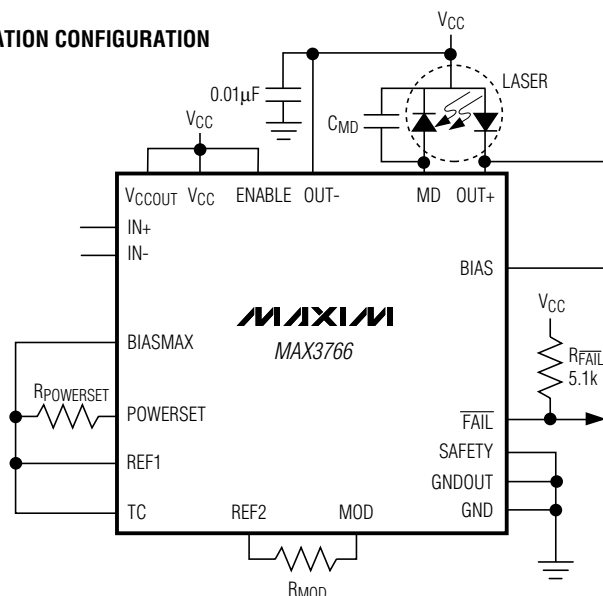
Figure 11. Interface Models



# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

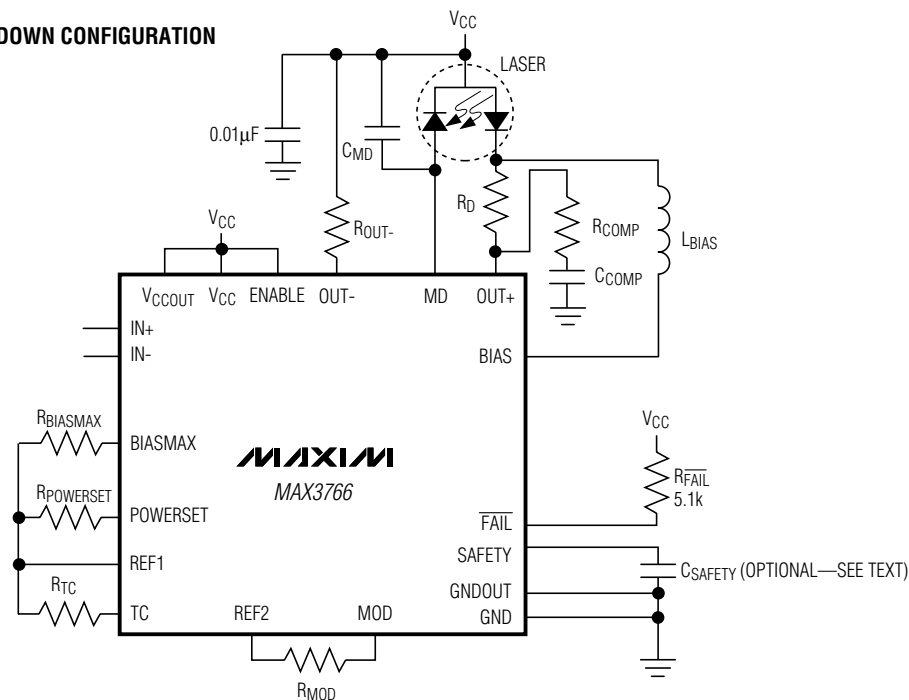
## Typical Application Circuits

### FAILURE-INDICATION CONFIGURATION



CONFIGURED FOR MINIMUM COMPONENT COUNT.

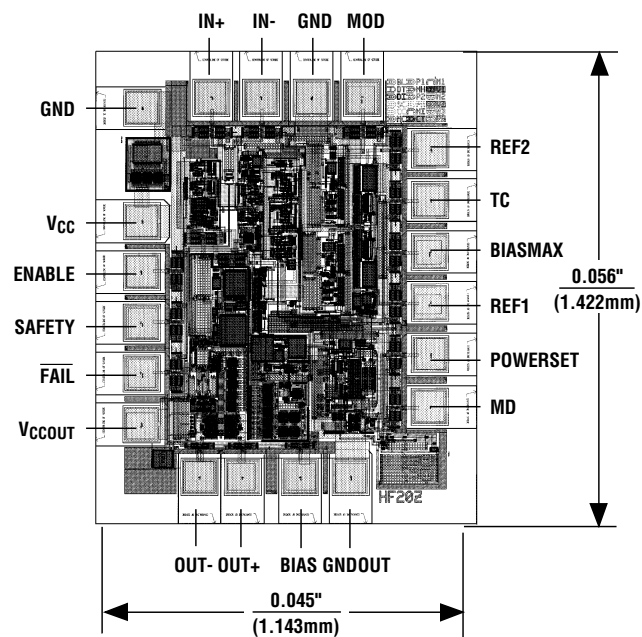
### LATCHED SHUTDOWN CONFIGURATION



CONFIGURED FOR BEST PERFORMANCE.  
R<sub>TC</sub> SETS THE TEMPERATURE COEFFICIENT OF THE MODULATION CURRENT.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Chip Topography



TRANSISTOR COUNT: 725

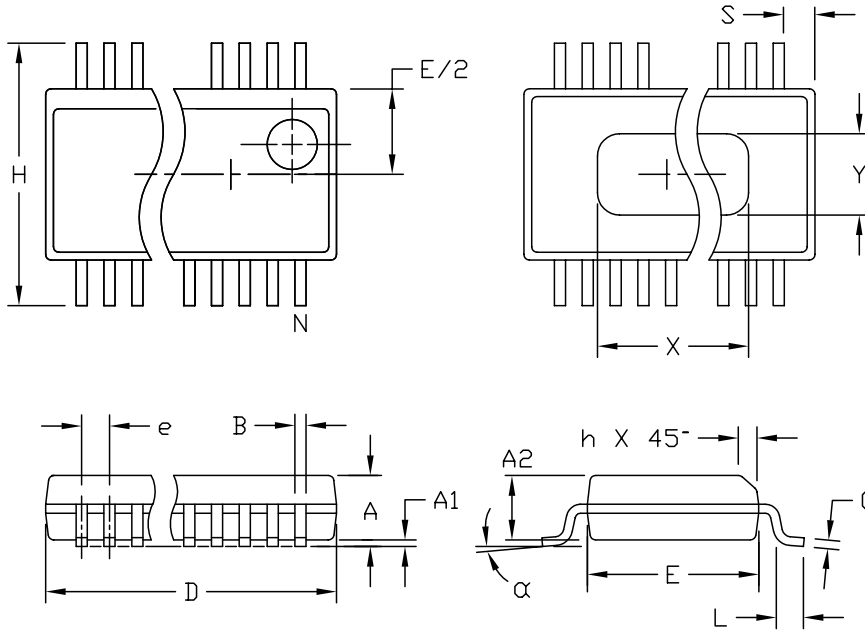
SUBSTRATE CONNECTED TO GND AND GNDOUT.

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

## Package Information

MAX3766

QSOP-EPS



### NOTES:

1. D & E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .006" PER SIDE.
3. HEAT SLUG DIMENSIONS X AND Y APPLY ONLY TO 16 AND 28 LEAD POWER-QSOP PACKAGES.
4. CONTROLLING DIMENSIONS: INCHES.
5. MEETS JEDEC MO137.

| DIM | INCHES         |       | MILLIMETERS |       |
|-----|----------------|-------|-------------|-------|
|     | MIN            | MAX   | MIN         | MAX   |
| A   | .061           | .068  | 1.55        | 1.73  |
| A1  | .004           | .0098 | 0.102       | 0.249 |
| A2  | .055           | .061  | 1.40        | 1.55  |
| B   | .008           | .012  | 0.20        | 0.31  |
| C   | .0075          | .0098 | 0.191       | 0.249 |
| D   | SEE VARIATIONS |       |             |       |
| E   | .150           | .157  | 3.81        | 3.99  |
| e   | .025 BSC       |       | 0.635 BSC   |       |
| H   | .230           | .244  | 5.84        | 6.20  |
| h   | .010           | .016  | 0.25        | 0.41  |
| L   | .016           | .035  | 0.41        | 0.89  |
| N   | SEE VARIATIONS |       |             |       |
| X   | SEE VARIATIONS |       |             |       |
| Y   | .071           | .087  | 1.803       | 2.209 |
| α   | 0°             | 8°    | 0°          | 8°    |

### VARIATIONS:

|   | INCHES |       | MILLIMETERS |       | N     |
|---|--------|-------|-------------|-------|-------|
|   | MIN.   | MAX.  | MIN.        | MAX.  |       |
| D | .189   | .196  | 4.80        | 4.98  | 16 AA |
| S | .0020  | .0070 | 0.05        | 0.18  |       |
| X | .107   | .123  | 2.72        | 3.12  |       |
| D | .337   | .344  | 8.56        | 8.74  | 20 AB |
| S | .0500  | .0550 | 1.270       | 1.397 |       |
| D | .337   | .344  | 8.56        | 8.74  | 24 AC |
| S | .0250  | .0300 | 0.635       | 0.762 |       |
| D | .386   | .393  | 9.80        | 9.98  | 28 AD |
| S | .0250  | .0300 | 0.635       | 0.762 |       |
| X | .271   | .287  | 6.88        | 7.29  |       |

|                                                |                      |     |     |
|------------------------------------------------|----------------------|-----|-----|
| <b>MAXIM</b>                                   |                      |     |     |
| PROPRIETARY INFORMATION                        |                      |     |     |
| TITLE:                                         |                      |     |     |
| PACKAGE OUTLINE, QSOP, .150", .025" LEAD PITCH |                      |     |     |
| APPROVAL                                       | DOCUMENT CONTROL NO. | REV | 1/1 |
|                                                | 21-0055              | C   |     |

# 622Mbps LAN/WAN Laser Driver with Automatic Power Control and Safety Shutdown

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