19-1550; Rev 2; 3/01

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

General Description

The MAX3286/MAX3296 series of products are high-speed laser drivers for fiber optic LAN transmitters, optimized for Gigabit Ethernet applications. Each device contains a bias generator, laser modulator, and comprehensive safety features. Automatic power control (APC) adjusts the laser bias current to maintain average optical power at a constant level, regardless of changes in temperature or laser properties. For lasers without a monitor photodiode, these products offer a constant-current mode. The circuit can be configured for use with conventional shortwave (780nm to 850nm) or longwave (1300nm) laser diodes, as well as vertical-cavity surface-emitting lasers (VCSELs).

The MAX3286 series (MAX3286–MAX3289) is optimized for operation at 1.25Gbps, and the MAX3296 series (MAX3296–MAX3299) is optimized for 2.5Gbps operation. Each device can switch 30mA of laser modulation current at the specified data rate. Adjustable temperature compensation is provided to keep the optical extinction ratio within specifications over the operating temperature range. This series of devices is optimized to drive lasers packaged in low-cost TO-46 headers. Deterministic jitter (DJ) for the MAX3286 is typically 22ps, allowing a 72% margin to Gigabit Ethernet DJ specifications.

These laser drivers provide extensive safety features to guarantee single-point fault tolerance. Safety features include dual enable inputs, dual shutdown circuits, and a laser-power monitor. The safety circuit detects faults that could cause dangerous light output levels. A programmable power-on reset pulse initializes the laser driver at startup.

The MAX3286/MAX3296 are available in a compact, 5mm × 5mm, 28-pin QFN package; a 5mm × 5mm, 32-pin TQFP package; or in die form. The MAX3287/MAX3288/MAX3289 and MAX3297/MAX3298/MAX3299 are available in a 16-pin TSSOP-EP package.

Applications

Gigabit Ethernet Optical Transmitter

Fibre Channel Optical Transmitter

ATM LAN Optical Transmitter

Typical Application Circuits and Selector Guide appear at end of data sheet.

Features

- ♦ **7ps Deterministic Jitter (MAX3296)**
  22ps Deterministic Jitter (MAX3286)
- ♦ **+3.0V to +5.5V Supply Voltage**
- ♦ **Selectable Laser Pinning (Common Cathode or Common Anode) (MAX3286/MAX3296)**
- ♦ **30mA Laser Modulation Current**
- ♦ **Temperature Compensation of Modulation Current**
- ♦ **Automatic Laser Power Control or Constant Bias Current**
- ♦ **Integrated Safety Circuits**
- ♦ **Power-On Reset Signal**
- ♦ **QFN Package Available**

Ordering Information

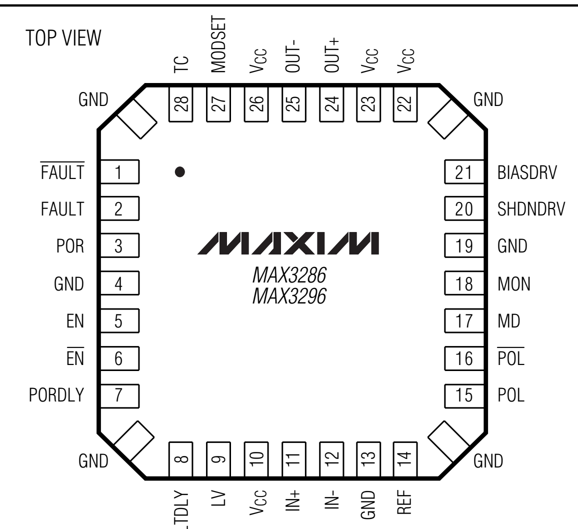
PART	TEMP. RANGE	PIN-PACKAGE
MAX3286CGI	0°C to +70°C	28 QFN (5mm × 5mm)**
MAX3286CHJ	0°C to +70°C	32 TQFP (5mm × 5mm)
MAX3286C/D	0°C to +70°C	Dice*

Ordering Information continued at end of data sheet.

**Dice are designed to operate from T_J = 0°C to +110°C, but are tested and guaranteed only at T_A = +25°C.*

***Exposed pad.*

Pin Configurations



QFN*

**Exposed pad is connected to GND.*

Pin Configurations continued at end of data sheet.

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

ABSOLUTE MAXIMUM RATINGS

Supply Voltage at V_{CC} ....-0.5V to +7.0V
Voltage at $\overline{EN}$, EN, PORDLY, FLTDLY, LV, IN+, IN-, REF, POL, $\overline{POL}$, MD, MON, BIASDRV, MODSET, TC..-0.5V to (V_{CC} + 0.5V)
Voltage at OUT+, OUT-.........................(V_{CC} - 2V) to (V_{CC} + 2V)
Current into FAULT, $\overline{FAULT}$, POR, SHDNDRV....-1mA to +25mA
Current into OUT+, OUT- 60mA
Continuous Power Dissipation (T_A = +70°C)
32-Pin TQFP (derate 14.3mW/°C above +70°C).........1100mW
28-Pin QFN (derate 28.7mW/°C above +70°C) 2300mW
16-Pin TSSOP (derate 27mW/°C above +70°C) 2162mW
Operating Temperature Range...............................0°C to +70°C
Operating Junction Temperature Range ....0°C to +150°C
Processing Temperature (die) ....+400°C
Storage Temperature Range ....-55°C to +150°C
Lead Temperature (soldering, 10s) ....+300°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

(V_{CC} = +3.0V to +5.5V, T_A = 0°C to +70°C, unless otherwise noted. Typical values are at V_{CC} = +3.3V and T_A = +25°C, R_{TC} = open; see Figure 1a.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	I_{CC}	Figure 1a, R_{MOD} = 1.82kΩ		52	75	mA
Data Input Voltage Swing	V_{ID}	Total differential signal, peak-to-peak, Figure	200		1660	mV
TTL Input Current		$0 \le V_{PIN} \le V_{CC}$	-100		100	µA
TTL Input High Voltage	V_{IH}		2.0			V
TTL Input Low Voltage	V_{IL}				0.8	V
FAULT, $\overline{FAULT}$ Output High Voltage	V_{OH}	I_{OH} = -100µA	2.4			V
FAULT, $\overline{FAULT}$ Output Low Voltage	V_{OL}	I_{OL} = 1mA			0.4	V
BIAS GENERATOR (Note 1)						
BIASDRV Current, Shutdown		EN = GND	-1		1	µA
BIASDRV Current Sink		FAULT = low, $V_{BIASDRV} \ge 0.6V$	0.8			mA
BIASDRV Current Source		FAULT = low, $V_{BIASDRV} \le V_{CC}$ - 1V	0.8			
REF Voltage		$I_{REF} \le$ 2mA, MON = V_{CC}	2.45	2.65	2.85	V
MD Nominal Voltage	V_{MD}	APC loop is closed	1.55	1.7	1.85	V
MD Voltage During Fault		Common-cathode configuration		0.4	1.2	V
		Common-anode configuration	2	V_{CC} - 0.8		
MD Input Current		Normal operation (FAULT = low)	-2	0.16	2	µA
MON Input Current		V_{MON} = V_{CC}		0.44	6	µA
POWER-ON RESET						
POR Threshold		LV = GND	3.9		4.5	V
		LV = open	2.65		3.0	
POR Hysteresis				150		mV
FAULT DETECTION						
REF Fault Threshold					2.95	V
MD High Fault Threshold			V_{MD} + 5%		V_{MD} + 20%	
MD Low Fault Threshold			V_{MD} - 20%		V_{MD} - 5%	
MON Fault Threshold		MAX3286/MAX3288/MAX3296/MAX3298	V_{CC} - 600		V_{CC} - 480	mV
MODSET, TC Fault Threshold					0.9	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +3.0V to +5.5V, T_A = 0°C to +70°C, unless otherwise noted. Typical values are at V_{CC} = +3.3V and T_A = +25°C, R_{TC} = open; see Figure 1a.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
SHUTDOWN							
Voltage at SHDNDRV		$I_{SHDNDRV}$ = 10µA, FAULT asserted		V_{CC} - 0.4			V
		$I_{SHDNDRV}$ = 15mA, FAULT not asserted		0		V_{CC} - 1.2	
		$I_{SHDNDRV}$ = 1mA, FAULT not asserted		0		V_{CC} - 2.4	
LASER MODULATOR							
Data Rate		MAX3286 series			1.25		Gbps
		MAX3296 series			2.5		
Minimum Laser Modulation Current						2	mA
Maximum Laser Modulation Current		R_L ≤ 25Ω		30			mA
Tolerance of Modulation Current		R_{MOD} = 1.9kΩ (i_{MOD} = 30mA)		-10		10	%
		R_{MOD} = 13kΩ (i_{MOD} = 5mA)		-15		15	
Modulation-Current Edge Speed		20% to 80%	MAX3286 series		130	220	ps
			MAX3296 series		90	150	
Deterministic Jitter (Note 2)		MAX3286 series	R_{MOD} = 13kΩ (i_{MOD} = 5mA)		46	65	ps
			R_{MOD} = 4.1kΩ (i_{MOD} = 15mA)		29	45	
			R_{MOD} = 1.9kΩ (i_{MOD} = 30mA)		22	35	
		MAX3296 series	R_{MOD} = 13kΩ (i_{MOD} = 5mA)		14	35	
			R_{MOD} = 4.1kΩ (i_{MOD} = 15mA)		8	22	
			R_{MOD} = 1.9kΩ (i_{MOD} = 30mA)		7	20	
Random Jitter, RMS (Note 3)		MAX3286 series			2	8	ps
		MAX3296 series			2	4	
Shutdown Modulation Current					15	200	µA
Modulation-Current Temperature Coefficient		Tempco = max, R_{MOD} = open; Figure 5			4000		ppm/°C
		Tempco = min, R_{TC} = open; Figure 5			50		
Differential Input Resistance				620	800	980	Ω
Output Resistance		Single ended		42	50	58	Ω
Input Bias Voltage					V_{CC} - 0.3		V
LASER SAFETY CIRCUIT							
POR Delay	t_{PORDLY}	PORDLY = open		0.3	1.25		µs
		C_{PORDLY} = 0.01µF, MAX3286/MAX3296 only		3	5.5		ms
Fault Time	t_{FAULT}	(Note 4)			22		µs
Glitch Rejection at MD				10	20		µs

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +3.0V to +5.5V, T_A = 0°C to +70°C, unless otherwise noted. Typical values are at V_{CC} = +3.3V and T_A = +25°C, R_{TC} = open; see Figure 1a.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
FLTDLY Duration	t_{FLTDLY}	C_{FLTDLY} = 0	0.2	1		µs
		C_{FLTDLY} = 270pF	100	140		
EN or $\overline{EN}$ Minimum Pulse Width Required to Reset a Latched Fault	t_{EN_RESET}	MAX3286/MAX3296 only, Figure 1b		6	10	ns
FAULT Reset After EN, $\overline{EN}$, or POR Transition	t_{RESET}	MAX3286/MAX3296 only, Figure 1b		1	2	µs
SHDNDRV Asserted After EN = Low or $\overline{EN}$ = High	t_{SHUTDN}	MAX3286/MAX3296 only, Figure 1b		3.5	5.5	µs

Note 1: Common-anode configuration refers to a configuration where POL = GND, $\overline{POL}$ = V_{CC}, and an NPN device is used to set the laser bias current. Common-cathode configuration refers to a configuration where POL = V_{CC}, $\overline{POL}$ = GND, and a PNP device is used to set the laser bias current.

Note 2: Deterministic jitter measured with a repeating K28.5 bit pattern 00111110101100000101. Deterministic jitter is the peak-to-peak deviation from the ideal time crossings per ANSI X3.230, Annex A.

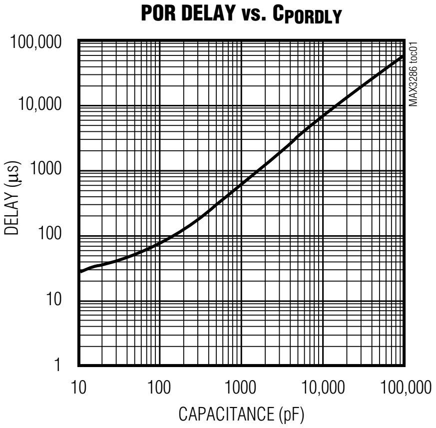
Note 3: For Fibre Channel and Gigabit Ethernet applications, the peak-to-peak random jitter is 14.1 times the RMS jitter.

Note 4: Delay from a fault on MD until FAULT is asserted high.

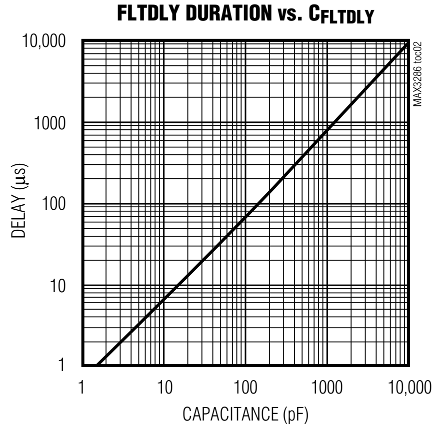
Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted.)

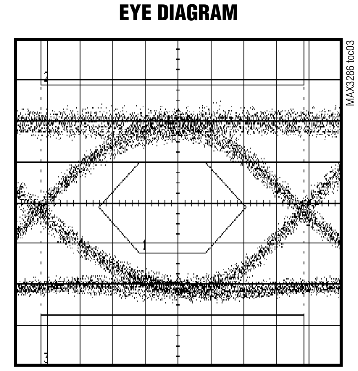
POR DELAY vs. C_{PORDLY}



FLTDLY DURATION vs. C_{FLTDLY}



EYE DIAGRAM

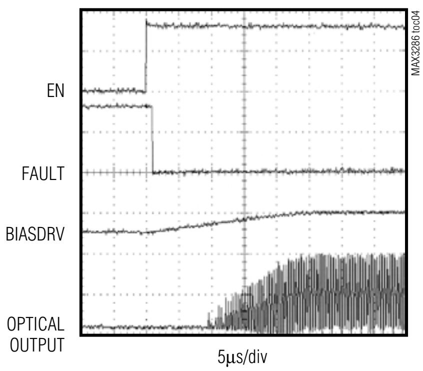


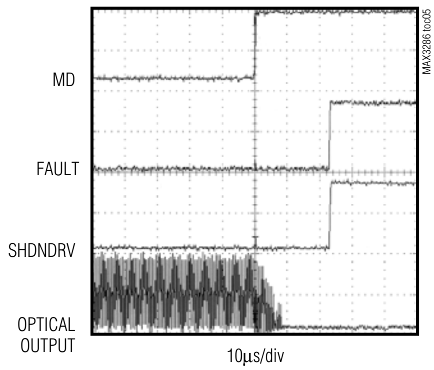
50ps/div

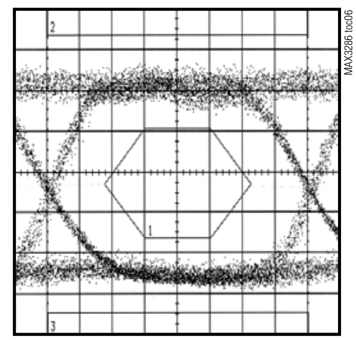
2.5Gbps, 1310nm LASER, 2^7 - 1 PRBS, i_{MOD} = 15mA

Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)







Pin Description

PIN				NAME	FUNCTION
QFN MAX3286 MAX3296	TQFP MAX3286 MAX3296	TSSOP-EP MAX3287 MAX3297 MAX3289 MAX3299	TSSOP-EP MAX3288 MAX3298		
1	1	—	—	$\overline{FAULT}$	Inverting Fault Indicator. See Table 1.
—	2, 16, 19	—	—	N.C.	No Connect
2	3	—	—	FAULT	Noninverting Fault Indicator. See Table 1.
3	4	2	2	POR	Power-On Reset. POR is a TTL-compatible output. See Figure 14.
4, 13, 19	5, 14, 22, 30	1, 6	1, 6	GND	Ground
5	6	—	—	EN	Enable TTL Input. Laser output is enabled only when EN is high and $\overline{EN}$ is low. If EN is left unconnected, the laser is disabled.
6	7	—	—	$\overline{EN}$	Inverting Enable TTL Input. Laser output is enabled only when $\overline{EN}$ is low or grounded and EN is high. If $\overline{EN}$ is left unconnected, the laser is disabled.
7	8	—	—	PORDLY	Power-On Reset Delay. To extend the delay for the power-on reset circuit, connect a capacitor to PORDLY. See *Design Procedure*.

Pin Description (continued)

PIN				NAME	FUNCTION
QFN MAX3286 MAX3296	TQFP MAX3286 MAX3296	TSSOP-EP MAX3287 MAX3297 MAX3289 MAX3299	TSSOP-EP MAX3288 MAX3298		
8	9	—	—	FLTDLY	Fault Delay Input. Determines the delay of the FAULT and $\overline{\text{FAULT}}$ outputs. A capacitor attached to FLTDLY ensures proper startup. (See *Typical Operating Characteristics*.) FLTDLY = GND: holds FAULT low and $\overline{\text{FAULT}}$ high. When FLTDLY = GND, EN = high, $\overline{\text{EN}}$ = low, and V_{CC} is within the operational range, the safety circuitry is inactive.
9	10	—	—	LV	Low-Voltage Operation. Connect to GND for 4.5V to 5.5V operation. Leave open for 3.0V to 5.5V operation (Table 2).
10, 22, 23, 26	11, 25, 26, 29	3, 11, 14	3, 11, 14	V_{CC}	Supply Voltage
11	12	4	4	IN+	Noninverting Data Input
12	13	5	5	IN-	Inverting Data Input
14	15	7	7	REF	Reference Voltage. A resistor connected at REF to MD determines the laser power when APC is used with common-cathode lasers.
15	17	—	—	POL	Polarity Input. POL is used for programming the laser-pinning polarity (Table 4).
16	18	—	—	$\overline{\text{POL}}$	Inverting Polarity Input. $\overline{\text{POL}}$ is used for programming the laser-pinning polarity (Table 4).
17	20	8	8	MD	Monitor Diode Connection. MD is used for automatic power control.
18	21	—	9	MON	Laser Bias Current Monitor. Used for programming laser bias current in VCSEL applications.
20	23	9	—	SHDNDRV	Shutdown Driver Output. Provides a redundant laser shutdown.
21	24	10	10	BIASDRV	Bias-Controlling Transistor Driver. Connects to the base of an external PNP or NPN transistor.

Pin Description (continued)

PIN				NAME	FUNCTION
QFN MAX3286 MAX3296	TQFP MAX3286 MAX3296	TSSOP-EP MAX3287 MAX3297 MAX3289 MAX3299	TSSOP-EP MAX3288 MAX3298		
24	27	12	12	OUT+	Modulation-Current Output. See *Typical Application Circuits*.
25	28	13	13	OUT-	Modulation-Current Output. See *Typical Application Circuits*.
27	31	15	15	MODSET	Modulation-Current Set. The resistor at MODSET programs the temperature-stable component of the laser modulation current.
28	32	16	16	TC	Temperature-Compensation Set. The resistor at TC programs the temperature-increasing component of the laser modulation current.
EP	—	EP	EP	Exposed Pad	Ground. This must be soldered to the circuit board ground for proper thermal performance. See *Layout Considerations*.

Table 1. Typical Fault Conditions

PIN	FAULT CONDITION
V_{CC}	LV = open and V_{CC} < 3V; LV = GND and V_{CC} < 4.5V
REF	V_{REF} > 2.95V
POL and $\overline{POL}$	POL = $\overline{POL}$
MON	$V_{MON} < V_{CC}$ - 540mV
MD	$V_{MD} > 1.15 \times V_{MD(nom)}$, $V_{MD} < 0.85 \times V_{MD(nom)}$
EN and $\overline{EN}$	EN = low or open, $\overline{EN}$ = high or open
MODSET and TC	V_{MODSET} and $V_{TC} \leq 0.8V$

Table 2. LV Operating Range

LV	OPERATING VOLTAGE RANGE (V)
Open	>3.0
Grounded	>4.5

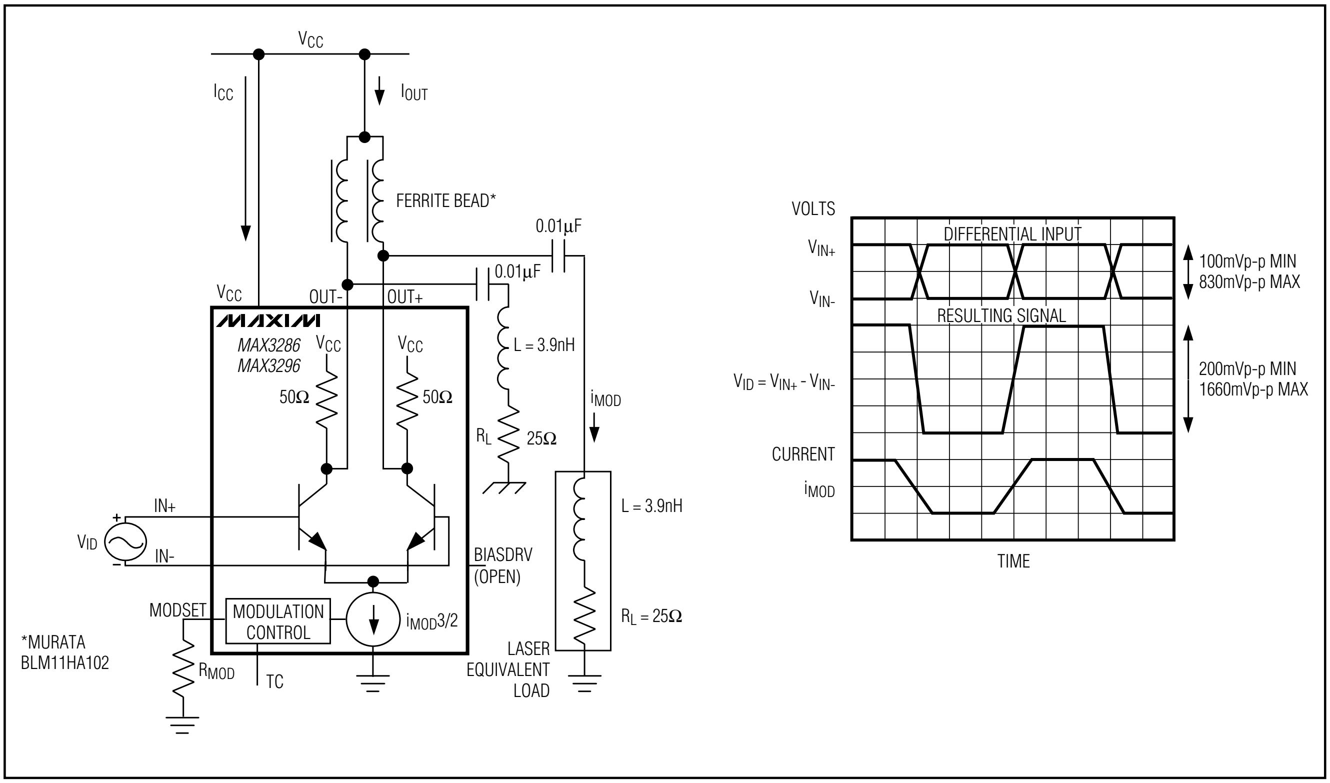


Figure 1a. Output Load for AC Specification

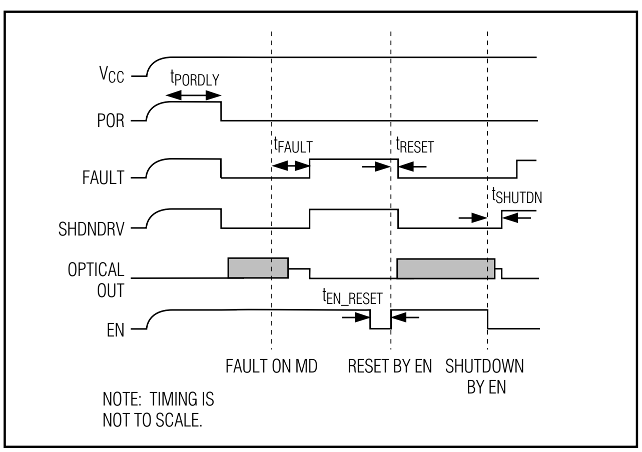


Figure 1b. Fault Timing

Detailed Description

The MAX3286/MAX3296 series of laser drivers contain a bias generator with APC, laser modulator, power-on reset (POR) circuit, and safety circuitry (Figures 2a and 2b).

Bias Generator

Figure 3 shows the bias generator circuitry containing a power-control amplifier, controlled reference voltage, smooth-start circuit, and window comparator. The bias generator combined with an external PNP or NPN transistor provides DC laser current to bias the laser in a light-emitting state. When there is a monitor diode (MD) in the laser package, the APC circuitry adjusts the laser-bias current to maintain average power over tem-

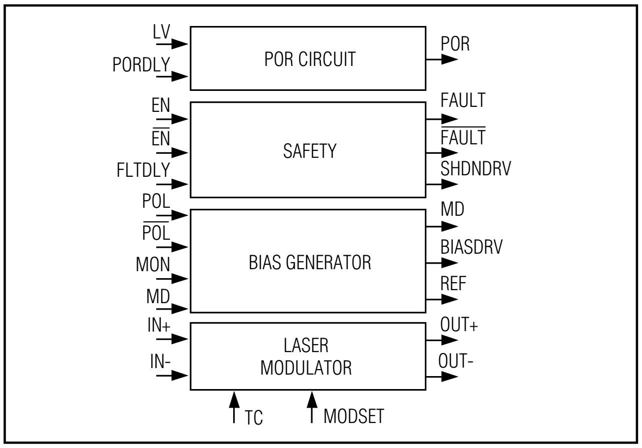


Figure 2a. Simplified Laser Driver Functional Diagram

perature and changing laser properties. The MD input is connected to the anode or cathode of a monitor photodiode or to a resistor-divider, depending on the specific application circuit. Three application circuits are supported: common-cathode laser with photodiode, common-cathode laser without photodiode, and common-anode laser with photodiode (as shown in the *Design Procedure*). The POL and $\overline{POL}$ inputs determine the laser pinning (common cathode, common anode) (Table 4).

The smooth-start circuitry prevents current spikes to the laser during power-up or enable; this ensures compliance with safety requirements and extends the life of the laser.

The power-control amplifier drives an external transistor to control the laser bias current. In a fault condition, the power-control amplifier's output is disabled (high

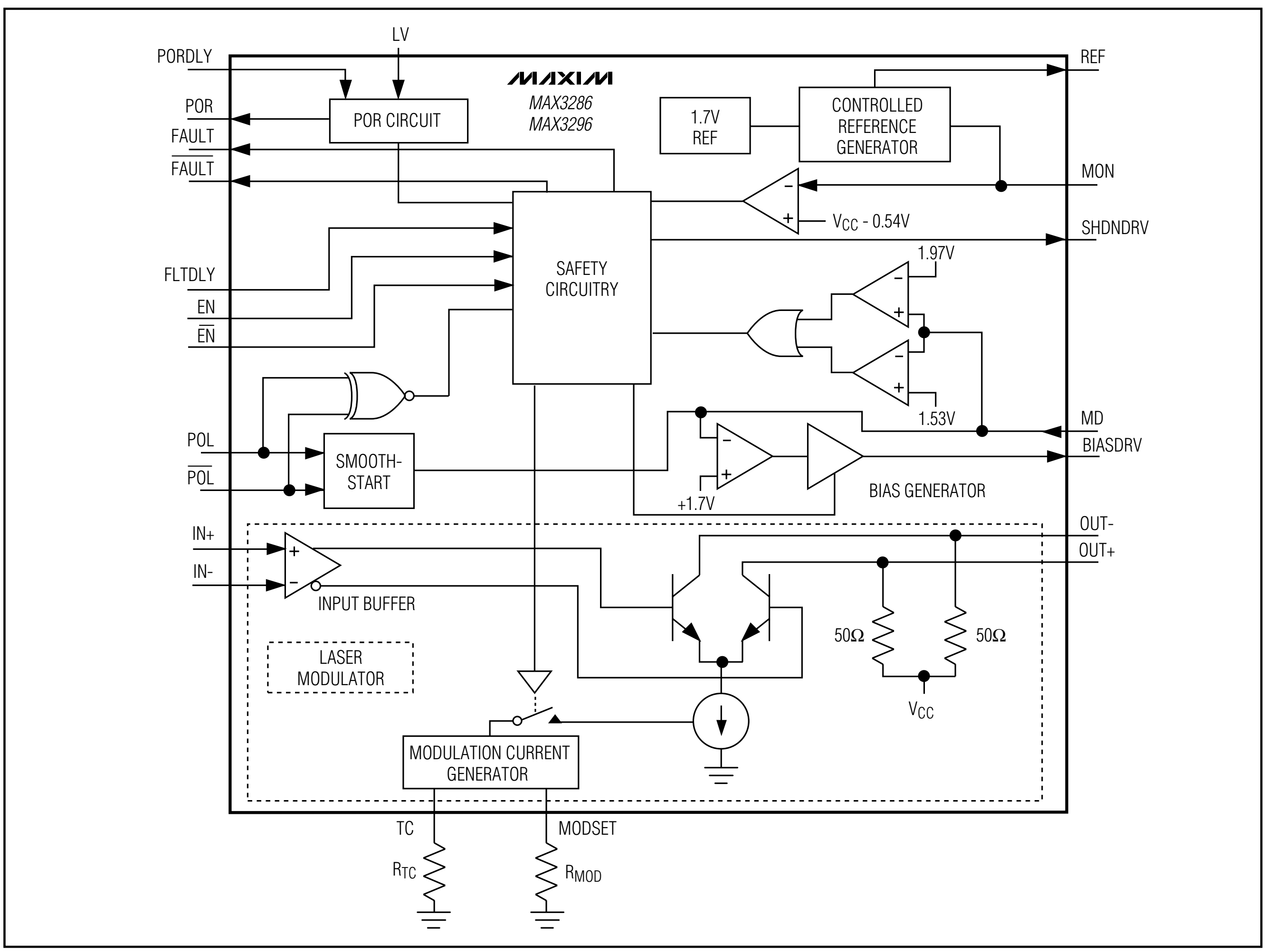


Figure 2b. Laser Driver Functional Diagram

impedance). This ensures that the PNP or NPN transistor is turned off, removing the laser-bias current. (See *Applications Information*.)

The REF pin provides a controlled reference voltage dependent upon the voltage at MON. The voltage at REF is V_{REF} = 2.65 - 2.25(V_{CC} - V_{MON}). A resistor connected at REF determines the laser power when APC is used with common-cathode lasers. See *Design Procedure* for setting the laser power.

Modulation Circuitry

The modulator circuitry consists of an input buffer, current generator, and high-speed current switch (Figure 4). The modulator drives up to 30mA of modulation current into a 25Ω load.

Many of the modulator performance specifications depend on the total modulator current (I_{OUT}) (Figure 1a). To ensure good driver performance, the voltage at OUT+ and OUT- must not be less than V_{CC} - 1V.

The amplitude of the modulation current is set with resistors at the MODSET and temperature coefficient (TC) pins. The resistor at MODSET (R_{MOD}) programs the temperature-stable portion of modulation current, while the resistor at TC (R_{TC}) programs the temperature-increasing portion of the modulation current. Figure 5 shows modulation current as a function of temperature for two extremes: R_{TC} is open (the modulation current has zero temperature coefficient) and R_{MOD} is open (the modulation temperature coefficient is 4000ppm). Intermediate tempco values of modulation current can be obtained as described in the *Design Procedure*. Table 3 is the R_{TC} and R_{MOD} selection table.

Safety Circuitry

The laser driver can be used with two popular safety systems. APC maintains laser safety using local feedback. Safety features monitor laser driver operation and

Table 3. R_{TC} and R_{MOD} Selection Table

TEMPCO (ppm/°C)	i_{MOD} = 30mA		i_{MOD} = 15mA		i_{MOD} = 5mA	
	R_{MOD} (kΩ)	R_{TC} (kΩ)	R_{MOD} (kΩ)	R_{TC} (kΩ)	R_{MOD} (kΩ)	R_{TC} (kΩ)
3500	26.7	1.69	53.6	3.65	162	11.5
3000	9.53	2.0	18.7	4.32	57.6	13.3
2500	5.76	2.49	11.3	5.23	34.8	16.2
2000	4.12	3.16	8.06	6.49	24.9	20.0
1500	3.24	4.32	6.19	8.87	19.1	26.7
1000	2.67	6.49	5.11	13.3	15.8	40.2
500	2.26	13.3	4.22	26.7	13.3	80.6

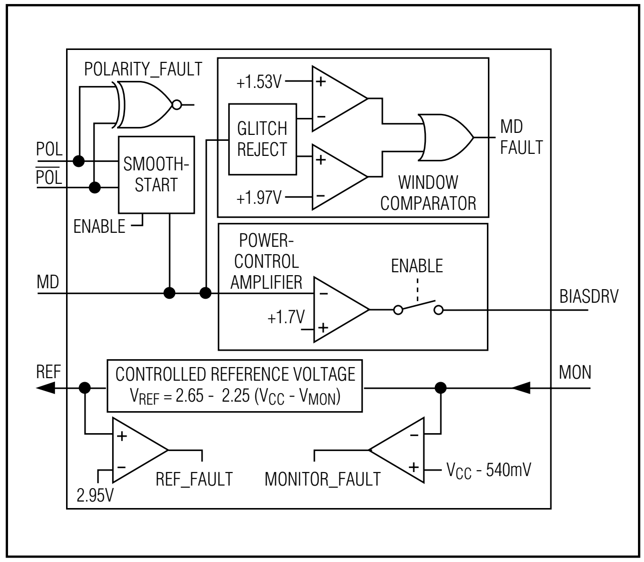


Figure 3. Bias Generator Circuitry

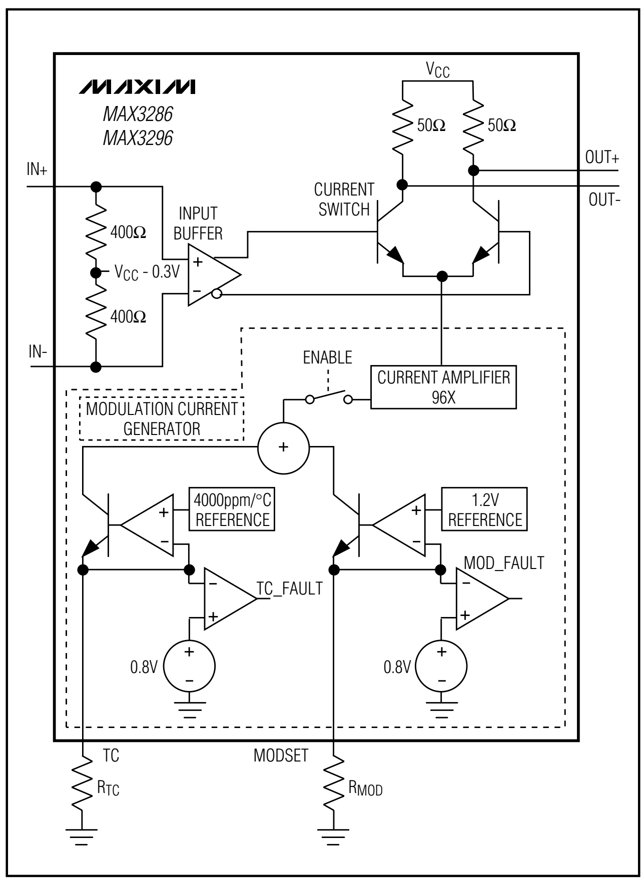


Figure 4. Laser Modulator Circuitry

force a shutdown if a fault is detected. The shutdown condition is latched until reset by a toggle of EN, $\overline{EN}$, or power.

Another safety system, Open Fiber Control (OFC), uses safety interlocks to prevent eye hazards. To accommodate the OFC standard, the MAX3286/MAX3296 series provide dual enable inputs and dual fault outputs.

The safety circuitry contains fault detection, dual enable inputs, latched fault outputs, and a pulse generator (Figure 6).

Safety circuitry monitors the APC circuit to detect unsafe levels of laser emission during single-point failures. A single-point failure can be a short to V_{CC} or GND, or between any two IC pins.

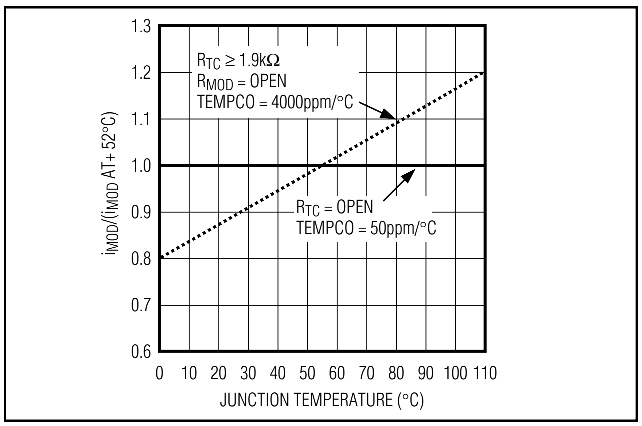


Figure 5. Modulation Current vs. Temperature for Maximum and Minimum Temperature Coefficient

Pulse Generator

During startup, the laser is not emitting light and the APC loop is not closed, triggering a fault signal. To allow startup, an internal fault-delay pulse disables the safety system for a programmable period of time, allowing the driver to begin operation. The length of the pulse is determined by the capacitor connected at FLTDLY and should be set 5 to 10 times longer than the APC time constant. The internal safety features can be disabled by connecting FLTDLY to GND. Note that EN must be high, $\overline{EN}$ must be low, and V_{CC} must be in the operational range for laser operation.

Fault Detection

The MAX3286/MAX3296 series has extensive and comprehensive fault-detection features. All critical nodes are monitored for safety faults, and any node voltage that differs significantly from its expected value results in a fault (Table 1). When a fault condition is detected, the laser is shut down. See *Applications Information* for more information on laser safety.

Shutdown

The laser drivers offer dual redundant bias shutdown mechanisms. The SHDNDRV output drives an optional external MOSFET semiconductor. The bias and modulation drivers have separate, internal disable signals.

Latched Fault Output

Two complementary FAULT outputs are provided with the MAX3286/MAX3296 series. In the event of a fault, these outputs latch until one of three events occurs:

1) The power is switched off, then on.

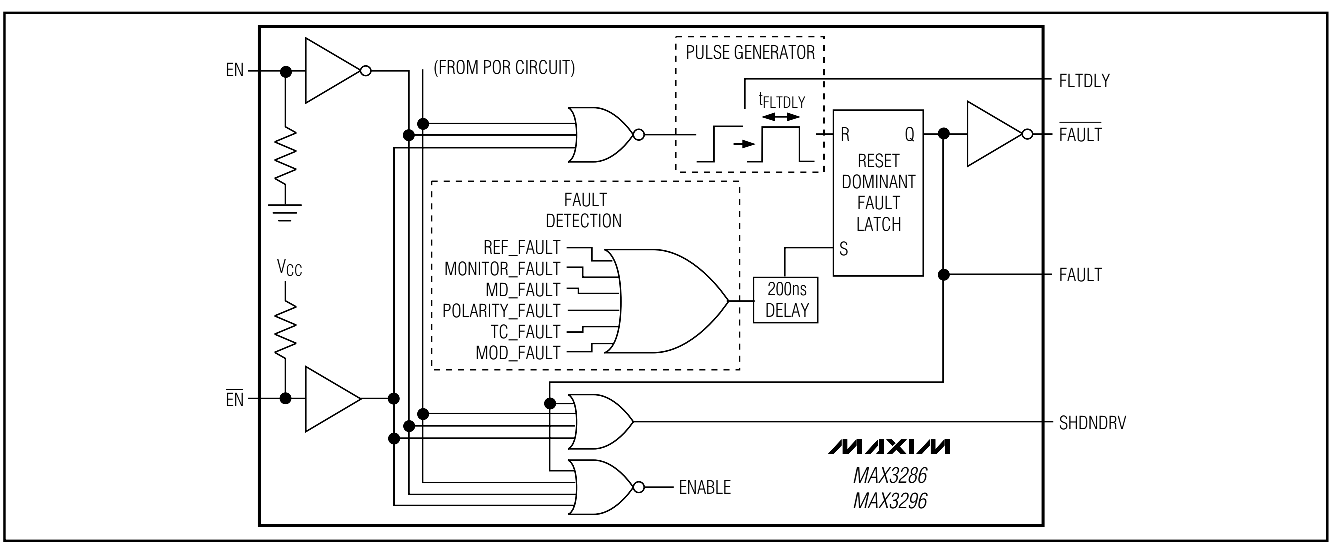


Figure 6. Simplified Safety Circuit Schematic

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

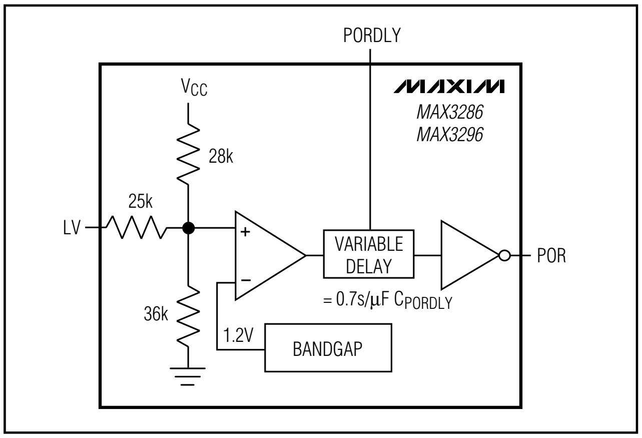


Figure 7. Power-On Reset Circuit

2) EN is switched low, then high.

3) $\overline{EN}$ is switched to high, then low.

Power-On Reset (POR)

Figure 7 shows the POR circuit for the MAX3286/MAX3296 series devices. A POR signal asserts low when V_{CC} is in the operating range. The voltage operating range is determined by the LV pin, as shown in Table 2. POR contains an internal delay to reject noise on V_{CC} during power-on or hot-plugging. The delay can be extended by adding capacitance to the PORDLY pin. The POR comparator includes hysteresis to improve noise rejection. The laser driver is shut down while V_{CC} is out of the operating range.

Design Procedure

Select Laser

Select a communications-grade laser with a rise time of 260ps or better for 1.25Gbps, or 130ps or better for 2.5Gbps applications. To obtain the MAX3286/MAX3296s' AC specifications, the instantaneous output voltage at OUT+ must remain above V_{CC} - 1V at all times. Select a high-efficiency laser that requires low modulation current and generates low-voltage swing at OUT+. Laser package inductance can be reduced by trimming the leads. Typical package leads have inductance of 25nH/in (1nH/mm); this inductance causes a larger voltage swing across the laser. A compensation filter network can also be used to reduce ringing, edge speed, and voltage swing.

Programming the Modulation Current

Resistors at the MODSET and TC pins set the amplitude of the modulation current. The resistor R_{MOD} sets the temperature-stable portion of the modulation current while the resistor R_{TC} sets the temperature-increasing portion of the modulation current.

To determine the appropriate temperature coefficient from the slope efficiency (α) of the laser, use the following equation:

$$\text{Laser Tempco} = \frac{\alpha_{70} - \alpha_{25}}{\alpha_{25}(70°C - 25°C)} \times 10^{+6}\ [\text{ppm/°C}]$$

where α is the slope of the laser output power to the laser current.

For example, suppose a laser has a slope efficiency α_{25} of 0.021mW/mA at +25°C, which reduces to 0.018mW/mA at +70°C. Using the above equation will produce a laser tempco of -3175ppm/°C.

To obtain the desired modulation current and tempco for the device, the following two equations can be used to determine the required values of R_{MOD} and R_{TC}:

$$R_{TC} = \frac{0.21}{\text{Tempco}\left(i_{MOD}\right)} - 250\Omega$$

$$R_{MOD} = \frac{(R_{TC} + 250\Omega)52 \times \text{Tempco}}{(0.19 - 48 \times \text{Tempco})} - 250\Omega$$

where Tempco = -Laser Tempco.

Figure 8a shows a family of curves derived from these equations. The straight diagonal lines depict constant tempcos. The curved lines represent constant modulation currents. If no temperature compensation is desired, Figure 8b displays a series of curves that show laser modulation current with respect to R_{MOD} for different loads.

The following useful equations were used to derive Figure 8a and the equations at the beginning of this section. The first assumes $R_L = 25\Omega$.

$$i_{MOD} = 51 \times \left[\frac{1.15}{R_{MOD} + 250\Omega} + \frac{1.06}{R_{TC} + 250\Omega} \times \left(1 + 4.0 \times 10^{-3}\left(T - 25°C\right)\right)\right][A]$$

$$i_{MOD(70°C)} = i_{MOD(25°C)} + i_{MOD(25°C)}(\text{TEMPCO})(70°C – 25°C)[A]$$

Programming the Bias Current/APC

Three application circuits are described below: common-cathode laser with photodiode, common-cathode laser without photodiode, and common-anode laser

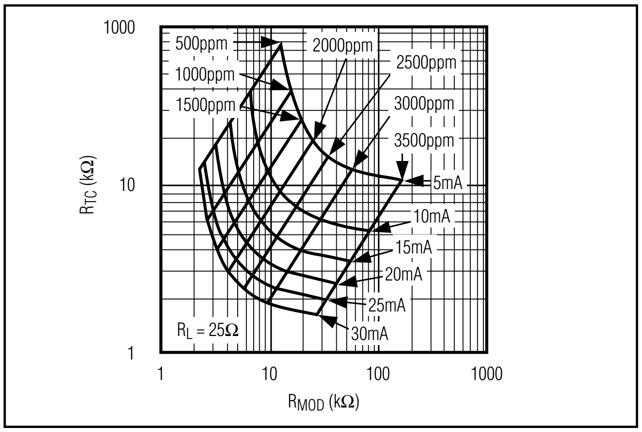


Figure 8a. R_{TC} vs. R_{MOD} for Various Conditions

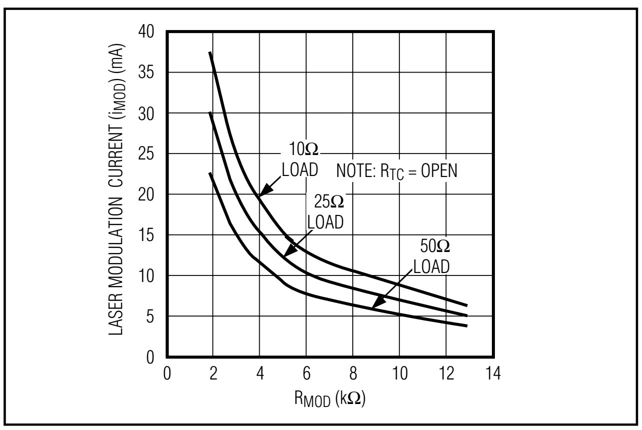


Figure 8b. Laser-Modulation Current vs. R_{MOD}

with photodiode. The POL and $\overline{POL}$ inputs determine the laser pinning (common cathode, common anode) and affect the smooth-start circuits (Table 4).

Common Cathode with Photodiode (Optical Feedback)

In the common cathode with photodiode configuration, a servo control loop is formed by external PNP Q1, the laser diode, the monitor diode, R_{SET}, and the power-control amplifier (Figure 9). The voltage at MD is stabilized to 1.7V. The monitor photodiode current (I_D) is set by (V_{REF} - V_{MD}) / R_{SET} = 0.95 / R_{SET}. Determine the desired monitor current (I_D), then select R_{SET} = 0.95 / I_D.

The APC loop is compensated by $C_{BIASDRV}$. A capacitor must be placed from BIASDRV to V_{CC} to ensure low-noise operation and to reject power-supply noise. The time constant governs how quickly the laser bias current reacts to a change in the average total laser current ($I_{BIASDRV}$ + i_{MOD}). A capacitance of 0.1µF is sufficient to obtain a loop time constant in excess of 1µs, provided that R_{DEG} is chosen appropriately. Resistor R_{DEG} may be necessary to ensure the APC loop's stability when low bias currents are desired.

The voltage across R_{DEG} should not be any larger than 250mV at maximum bias current.

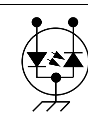
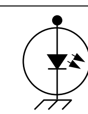
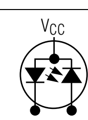
The discrete components used with the common cathode with photodiode configuration are as follows:

R_{SET} = 0.88 / I_D

$C_{BIASDRV}$ = 0.1µF (typ)

R_{DEG} = 0.25 / $I_{BIAS(MAX)}$

Table 4. POL Pin Setup for Each Laser Configuration Type

DEVICE	POL	$\overline{POL}$	DESCRIPTION	LASER PINNING
MAX3286/MAX3296	V_{CC}	GND	Common cathode with photodiode	
MAX3287/MAX3297	—	—		
MAX3286/MAX3296	V_{CC}	GND	Common cathode without photodiode	
MAX3288/MAX3298	—	—		
MAX3286/MAX3296	GND	V_{CC}	Common anode with photodiode	
MAX3289/MAX3299	—	—		
MAX3286/MAX3296	V_{CC}	V_{CC}	Not allowed; fault occurs	—
MAX3286/MAX3296	GND	GND	Not allowed; fault occurs	—

Q1 = general-purpose PNP, β >100, f_t > 5MHz

B1 = ferrite bead (see *Bias Filter* section)

M1 = general-purpose PMOS device (optional)

Common Cathode with Current Feedback

In the common-cathode configuration with current feedback, a servo control loop is formed by an external PNP transistor (Q1), R_{MON}, the controlled-reference voltage block, R_{SET}, R_{MD}, and the power-control amplifier (Figure 10). The voltage at MD is stabilized to 1.7V. The voltage at MON is set by the resistors R_{SET} and R_{MD}. As in the short-wavelength configuration, a 0.1µF $C_{BIASDRV}$ connected between BIASDRV and V_{CC} is sufficient to obtain approximately a 1µs APC loop time constant. This improves power-supply noise rejection.

To select the external components:

1) Determine the required laser bias current:

$$I_{BIAS} = I_{TH} + i_{MOD} / 2$$

2) Select R_{MD} and R_{SET}.

   Maxim recommends R_{SET} = 1kΩ, R_{MD} = 5kΩ, which results in $V_{CC} - V_{MON} \approx$ 250mV.

3) Select R_{MON} where R_{MON} = 250mV / I_{BIAS}, assuming R_{SET} = 1kΩ and R_{MD} = 5kΩ.

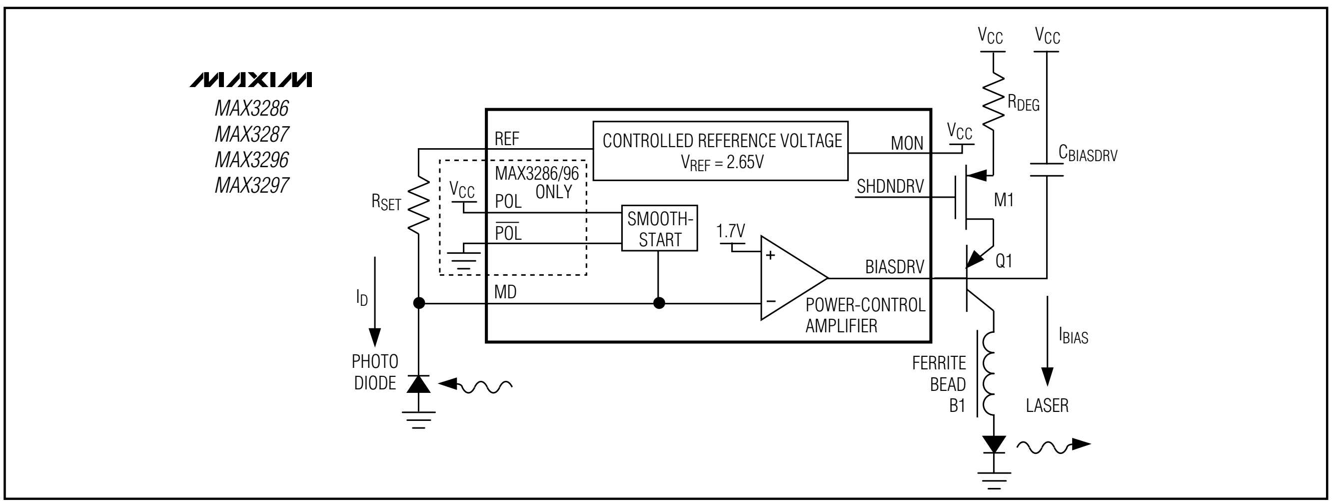


Figure 9. Common-Cathode Laser with Photodiode

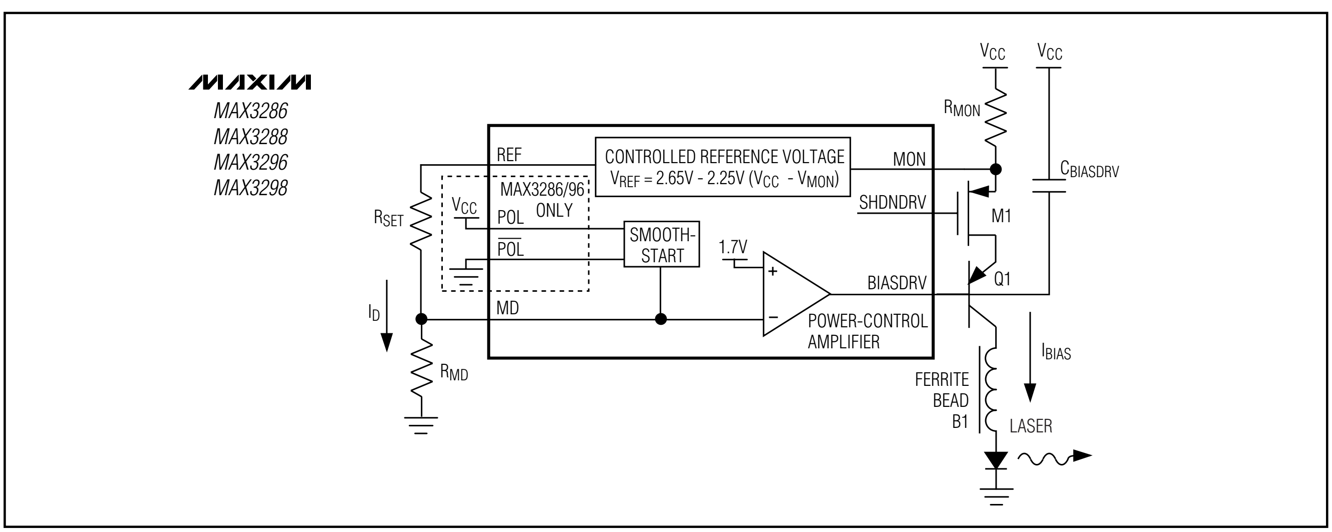


Figure 10. Common Cathode with Current Feedback (PNP Configuration)

The relationship between laser bias current and R_{MON} is shown in Figure 11. The remaining discrete components used with the common cathode without photodiode configuration are as follows:

Q1 = general-purpose PNP, β >100, f_t > 5MHz

B1 = ferrite bead (see *Bias Filter* section)

M1 = general-purpose PMOS device (optional)

$C_{BIASDRV}$ = 0.1µF (typ)

Common Anode with Photodiode

In the common-anode configuration with photodiode, a servo control loop is formed by an external NPN transistor (Q1), the laser diode, the monitor diode, R_{SET}, and the power-control amplifier. The voltage at MD is stabilized to 1.7V. The monitor photodiode current is set by $I_D = V_{MD} / R_{SET}$ (Figure 12). Determine the desired monitor current (I_D), then select R_{SET} = 1.7V / I_D.

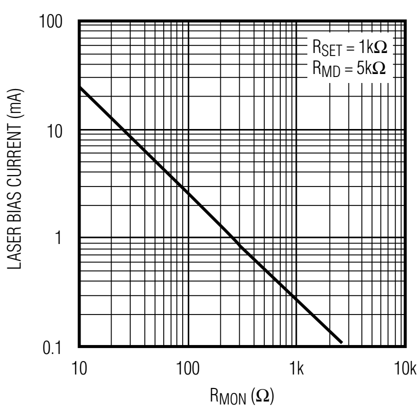


Figure 11. Common Cathode without Photodiode Laser

$C_{BIASDRV}$ and a degeneration resistor (R_{DEG}) must be connected to the bias transistor (in this case NPN) to obtain the desired APC loop time constant. This improves power-supply (and ground) noise rejection. A capacitance of 0.1µF is sufficient to obtain time constants of up to 5µs in most cases. The voltage across R_{DEG} should not be larger than 250mV at maximum bias current.

The discrete components used with the common anode with photodiode configuration are summarized as follows:

R_{SET} = 1.7 / I_D

$C_{BIASDRV}$ = 0.1µF (typ)

R_{DEG} = 0.25 / $I_{BIAS(MAX)}$

Q1 = general-purpose NPN, β > 100, f_t > 5MHz

B1 = ferrite bead (see *Bias Filter* section)

M1 = general-purpose PMOS (optional)

Programming POR Delay

A capacitor may be added to PORDLY to increase the delay for which POR will be asserted low (meaning that V_{CC} is within the operational range) when powering up the part.

The delay will be approximately:

$$t = \frac{C_{PORDLY}}{(1.4)10^{-6}} [s]$$

See *Typical Operating Characteristics.*

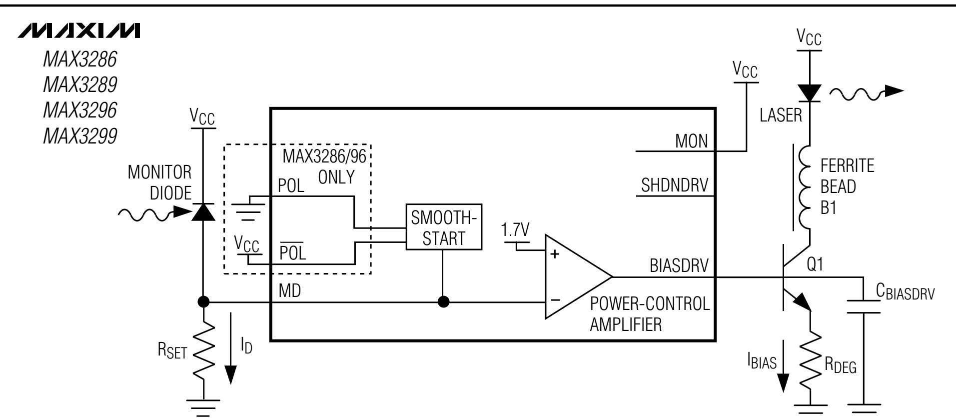


Figure 12. Common Anode with Photodiode

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

Designing the Bias Filter and Output Pullup Beads

To reduce deterministic jitter, add a ferrite-bead inductor between the collector of the biasing transistor and either the anode or cathode of the laser, depending on type (see *Typical Operating Characteristics*). Use a ferrite-bead inductor with an impedance >100Ω between f = 10MHz and f = 2GHz, and a DC resistance < 3Ω. Maxim recommends the Murata BLM11HA102SG. These inductors are also desirable for tying the OUT+ and OUT- pins to V_{CC}.

Designing the Laser-Compensation Filter Network

Laser package inductance causes the laser impedance to increase at high frequencies, leading to ringing, overshoot, and degradation of the output eye pattern. A laser-compensation filter network can be used to reduce the output load seen by the laser driver 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 R_{COMP} = 25Ω and C_{COMP} = 2pF. Increase C_{COMP} until the desired transmitter eye is obtained (Figure 13).

Quick Shutdown

To reduce laser shutdown time, a FET device can be attached to SHDNDRV as shown in Figure 10. This will provide a typical laser power shutdown time of less than 10µs.

Applications Information

Laser Safety and IEC 825

The International Electrotechnical Commission (IEC) determines standards for hazardous light emissions from fiber optic transmitters. IEC 825 defines the maximum light output for various hazard levels. The MAX3286/MAX3296 series provides features that facilitate compliance with IEC 825.

A common safety requirement is single-point fault tolerance, whereby one unplanned short, open, or resistive connection does not cause excess light output. When these laser drivers are used, as shown in the *Typical Operating Circuits*, the circuits respond to faults as listed in Table 5.

Using these laser drivers alone does not ensure that a transmitter design is compliant with IEC 825. The entire transmitter circuit and component selections must be considered. Customers must determine the level of fault tolerance required by their applications, 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.

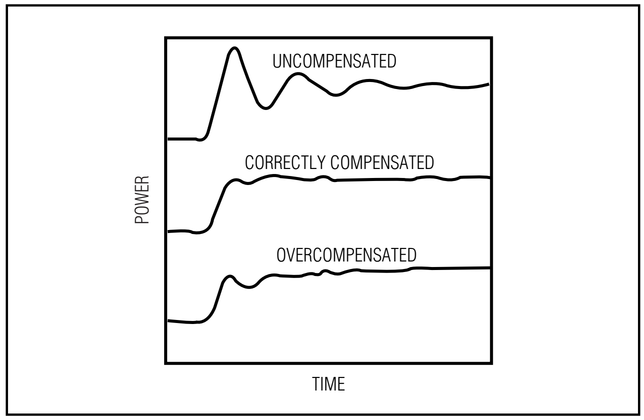


Figure 13. Laser Compensation

Layout Considerations

The MAX3286/MAX3296 series comprises high-frequency products. Their performance largely depends upon the circuit board layout.

Use a multilayer circuit board with a dedicated ground plane. Use short laser package leads placed close to the modulator outputs. Power supplies must be capacitively bypassed to the ground plane with surface-mount capacitors placed near the power-supply pins.

The dominant pole of the APC circuit is normally located at BIASDRV. To prevent a second pole in the APC (that can lead to oscillations), ensure that parasitic capacitance at MD is minimized.

Common Questions

Laser output is ringing or contains overshoot. This is often caused by inductive laser packaging. Try reducing the length of the laser leads. Modify the compensation components to reduce the driver's output edge speed (see *Design Procedure*). Extreme ringing can be caused by low voltage at the OUT± pins. This may indicate that pullup beads or a lower modulation current are needed.

Low-frequency oscillation on the laser output. This is more prevalent at low temperatures. The APC may be oscillating. Try increasing the value of $C_{BIASDRV}$ or increasing the value of R_{DEG}. Ensure that the parasitic capacitance at the MD node is kept very small (<10pF).

The APC is not needed. Connect FLTDLY to ground to disable fault detection. Connect MD to REF and MON to V_{CC}. BIASDRV and SHDNDRV can be left open.

Table 5. Circuit Response to Various Single-Point Faults

PIN NAME	CIRCUIT RESPONSE TO OVERVOLTAGE OR SHORT TO V_{CC}	CIRCUIT RESPONSE TO UNDERVOLTAGE OR SHORT TO GROUND
$\overline{\text{FAULT}}$	Does not affect laser power.	Does not affect laser power.
FAULT	Does not affect laser power.	Does not affect laser power.
POR	Does not affect laser power.	Does not affect laser power.
PORDLY	Does not affect laser power.	Fault state* occurs.
EN	Normal condition for circuit operation.	Fault state* occurs.
$\overline{\text{EN}}$	Fault state* occurs.	Normal condition for circuit operation.
LV	Does not affect laser power.	Fault state* occurs if V_{CC} is less than +4.5V.
POL	If $\overline{\text{POL}}$ is a TTL HIGH, a fault state* occurs; otherwise, the circuit is in normal operation.	If $\overline{\text{POL}}$ is a TTL LOW, a fault state* occurs; otherwise, the circuit is in normal operation.
$\overline{\text{POL}}$	If POL is a TTL HIGH, a fault state* occurs; otherwise, the circuit is in normal operation.	If POL is a TTL LOW, a fault state* occurs; otherwise, the circuit is in normal operation.
MON (also MAX3288/98)	In common cathode without photodiode configuration, a fault state* occurs; otherwise, does not affect laser power.	Fault state* occurs.
SHDNDRV (also MAX3287/97/89/99)	Does not affect laser power. If optional FET is used, the laser output is shut off.	Does not affect laser power.
FLTDLY	Any fault that occurs cannot be reset. Does not affect laser power.	Does not affect laser power.
IN+, IN-	Does not affect laser power.	Does not affect laser power.
REF	Fault state* occurs.	In common-cathode configurations, a fault state* occurs; otherwise, does not affect laser power.
MD	Fault state* occurs.	Fault state* occurs.
BIASDRV	In common-cathode configurations, the laser bias current is shut off. In common anode, high laser power triggers a fault state.* Shutdown occurs if a shutdown FET (M1) is used. If shutdown FET is not used, other means must be used to prevent high laser power.	In common-anode configurations, the laser bias current is shut off. In common cathode, high laser power triggers a fault state.* Shutdown occurs if a shutdown FET (M1) is used (Figures 9, 10).
OUT+, OUT-	Does not affect laser power.	Does not affect laser power.
MODSET	Does not affect laser power.	Fault state* occurs.
TC	Does not affect laser power.	Fault state* occurs.

** A fault state will assert the FAULT pins, disable the modulator outputs, disable the bias output, and assert the SHDNDRV pin.*

3.0V to 5.5V, 1.25Gbps/2.5Gbps LAN Laser Drivers

The modulator is not needed. Leave TC and MODSET open. Connect IN+ to VCC, IN- to REF, and leave OUT+ and OUT– open.

Wirebonding Die

The MAX3286/MAX3296 series uses bondpads with gold metalization. Make connections to the die with gold wire only, using ball-bonding techniques. Wedge bonding is not recommended. Bondpad size is 4mil square. Die thickness is typically 15mils (0.38mm).

Interface Models

Figures 14–18 show typical input/output models for the MAX3286/MAX3296 series of laser drivers. If dice are used, replace the package parasitic elements with bondwire parasitic elements.

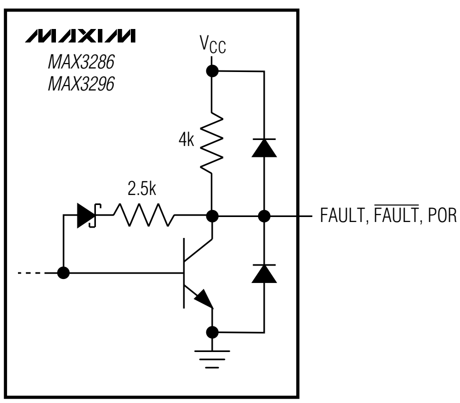


Figure 14. Logic Outputs

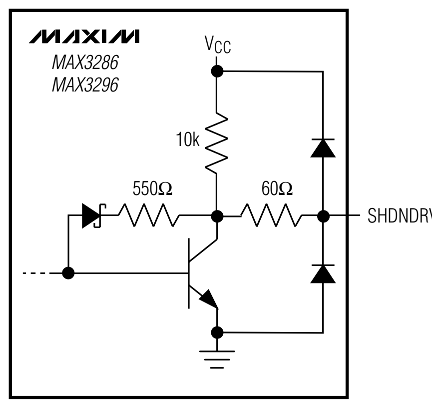


Figure 15. SHDNDRV Output

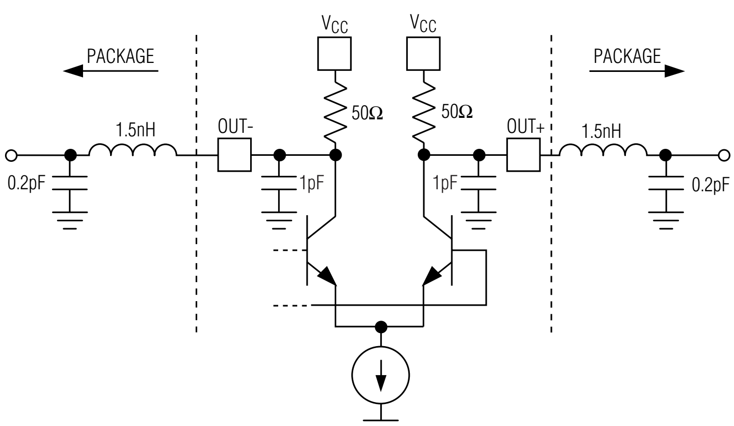


Figure 16. Modulator Outputs

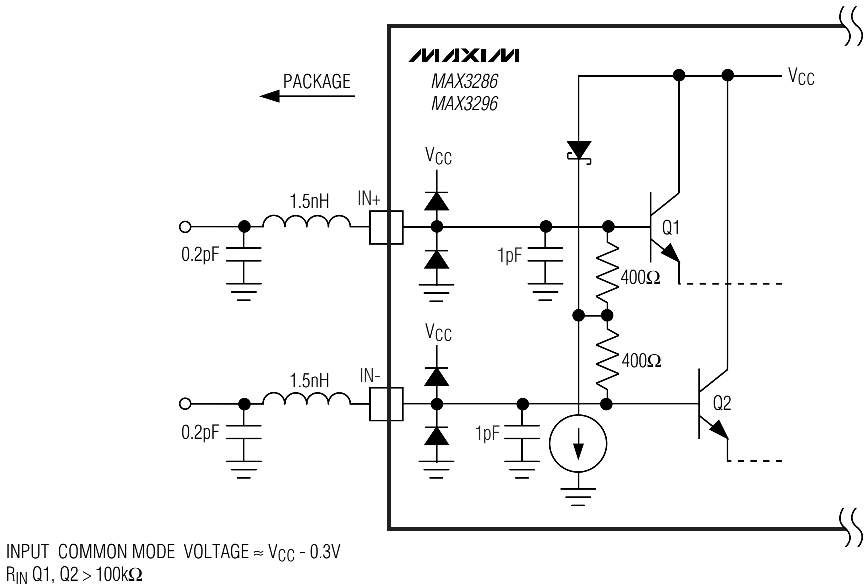


Figure 17. Data Inputs

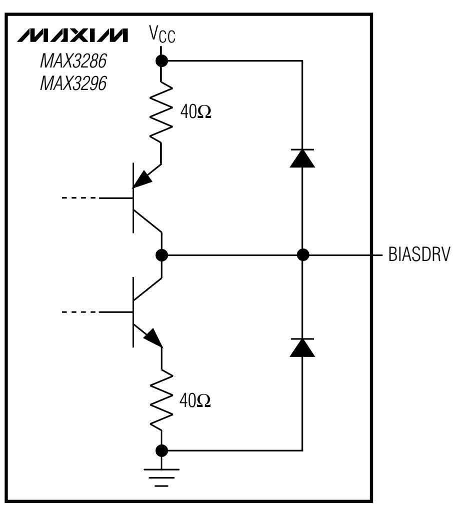
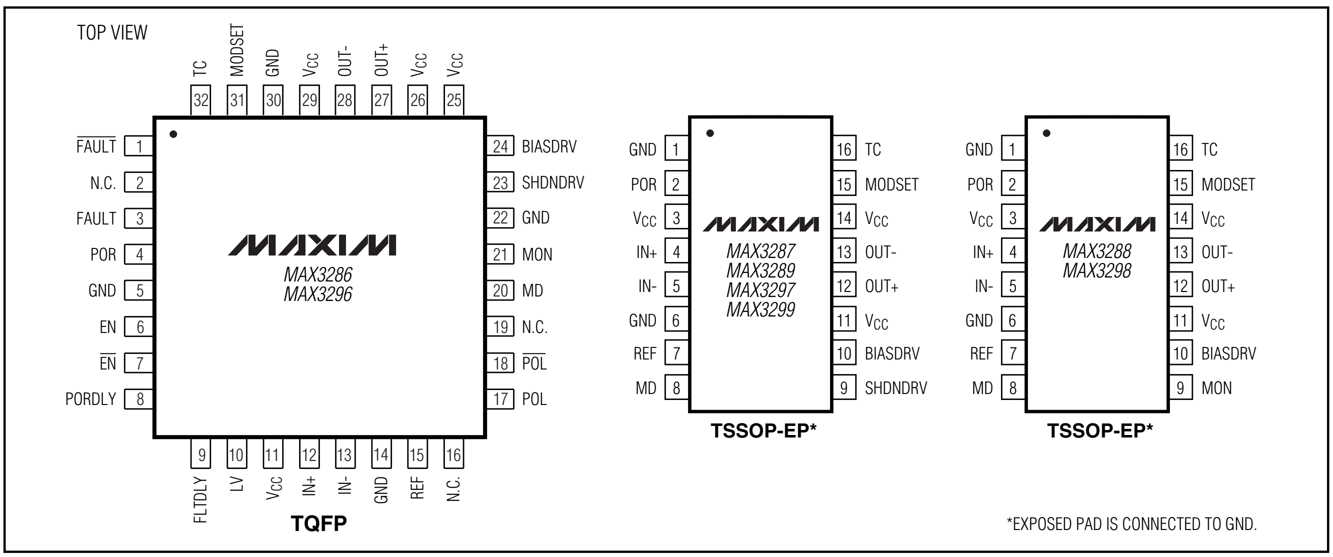


Figure 18. BIASDRV Output

Selector Guide

DATA RATE/DEVICE		LASER CONFIGURATION			PACKAGE
1.25Gbps	2.5Gbps	COMMON ANODE WITH PHOTODIODE	COMMON CATHODE WITH PHOTODIODE	COMMON CATHODE WITH PHOTODIODE	
		Longwave	Shortwave or VCSEL	VCSEL	
MAX3286	MAX3296	✓	✓	✓	32 TQFP/28 QFN/dice
MAX3287	MAX3297		✓		16 TSSOP-EP
MAX3288	MAX3298			✓	16 TSSOP-EP
MAX3289	MAX3299	✓			16 TSSOP-EP

Pin Configurations (continued)

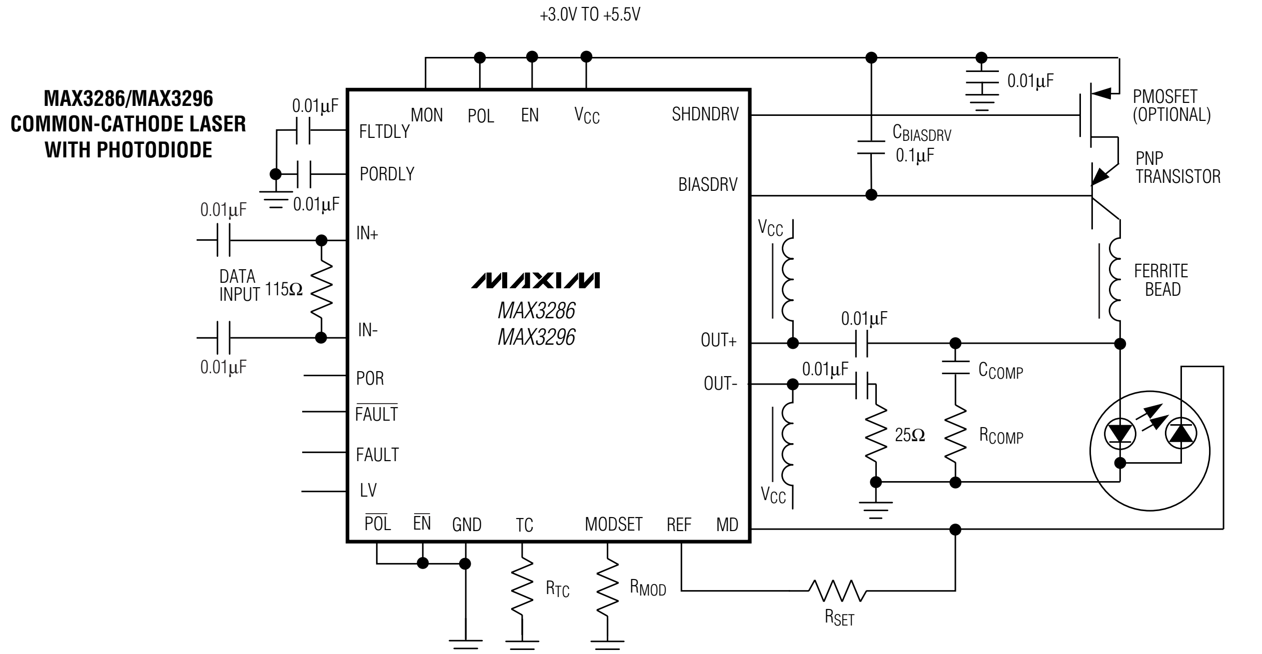


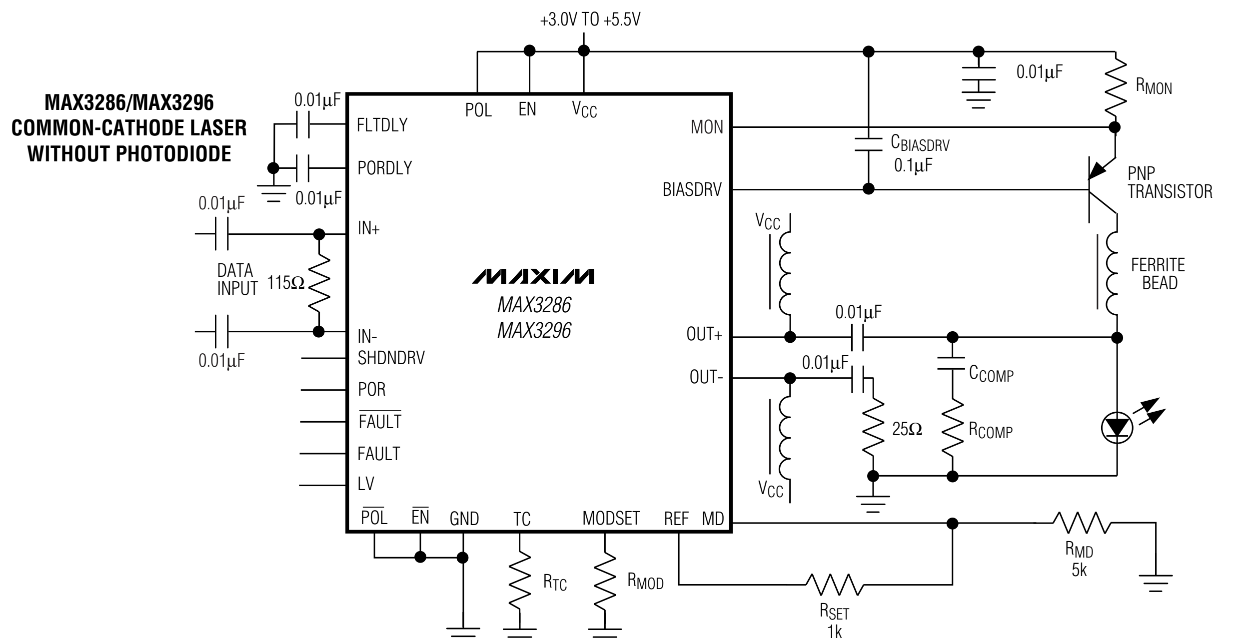
Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
MAX3287CUE	0°C to +70°C	16 TSSOP-EP**
MAX3288CUE	0°C to +70°C	16 TSSOP-EP**
MAX3289CUE	0°C to +70°C	16 TSSOP-EP**
MAX3296CGI	0°C to +70°C	28 QFN (5mm × 5mm)**
MAX3296CHJ	0°C to +70°C	32 TQFP (5mm × 5mm)
MAX3296C/D	0°C to +70°C	Dice*
MAX3297CUE	0°C to +70°C	16 TSSOP-EP**
MAX3298CUE	0°C to +70°C	16 TSSOP-EP**
MAX3299CUE	0°C to +70°C	16 TSSOP-EP**

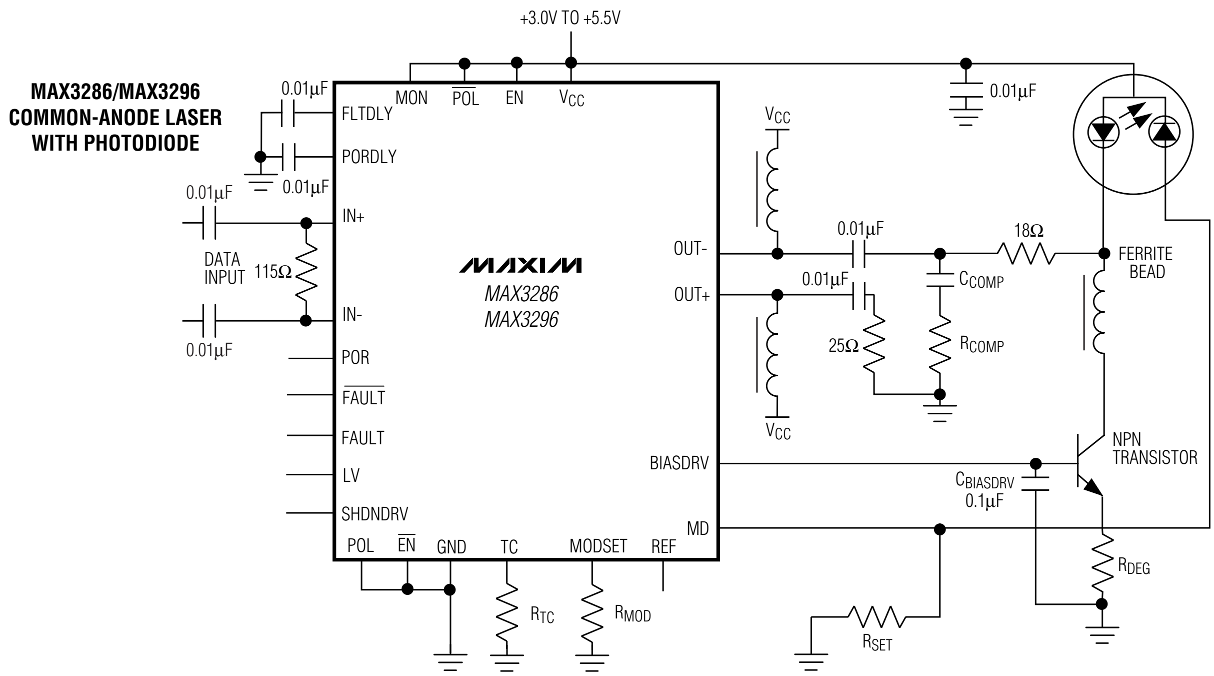
**Dice are designed to operate from T_J = 0°C to +110°C, but are tested and guaranteed only at T_A = +25°C.*
***Exposed pad.*

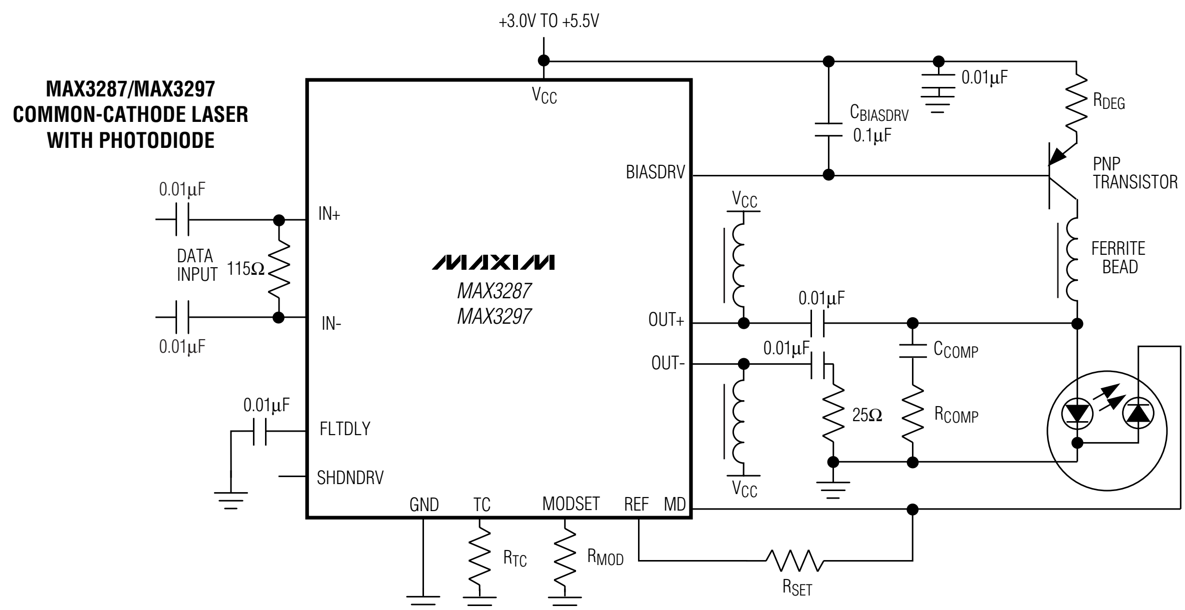
Typical Application Circuits



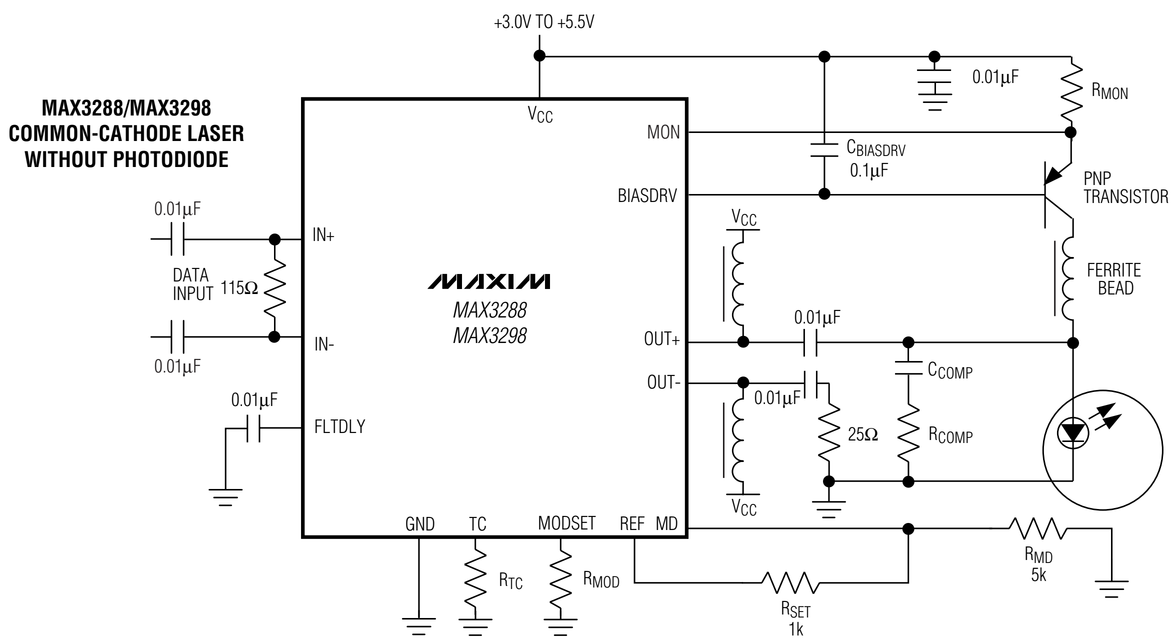


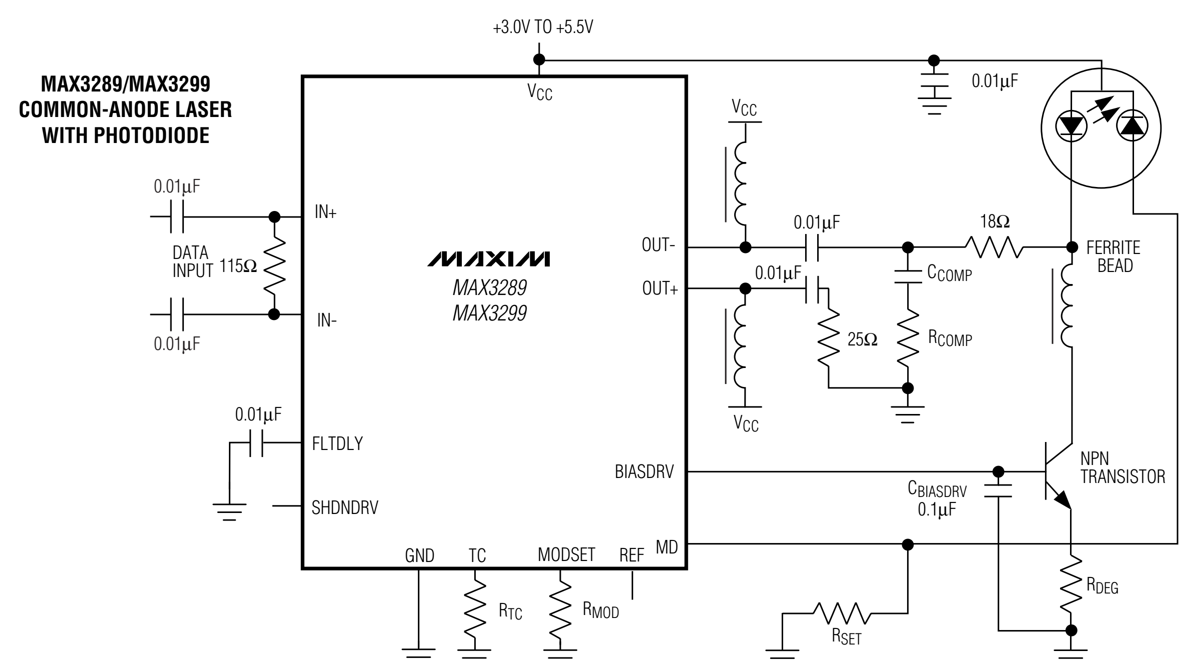
Typical Application Circuits (continued)





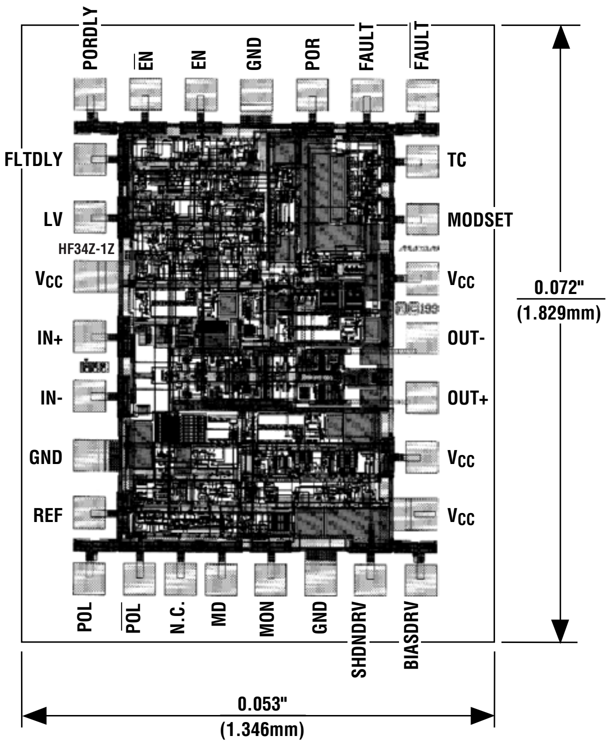
Typical Application Circuits (continued)





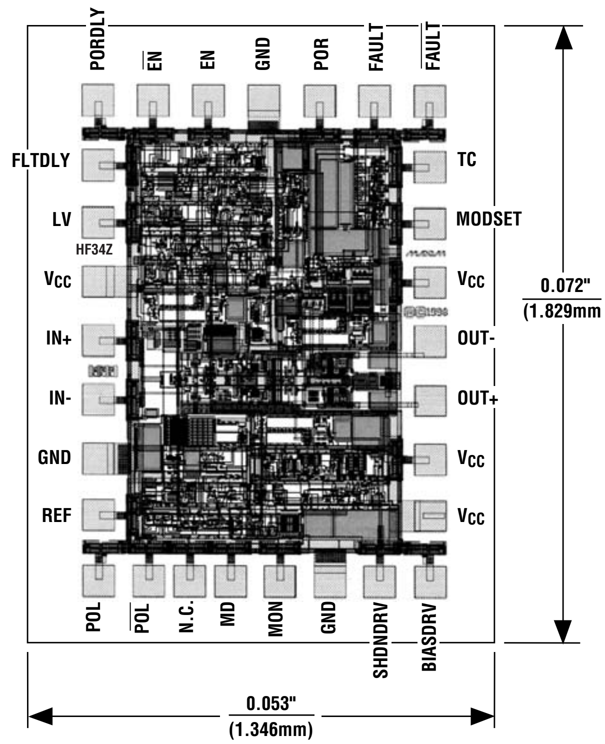
Chip Topographies

MAX3286



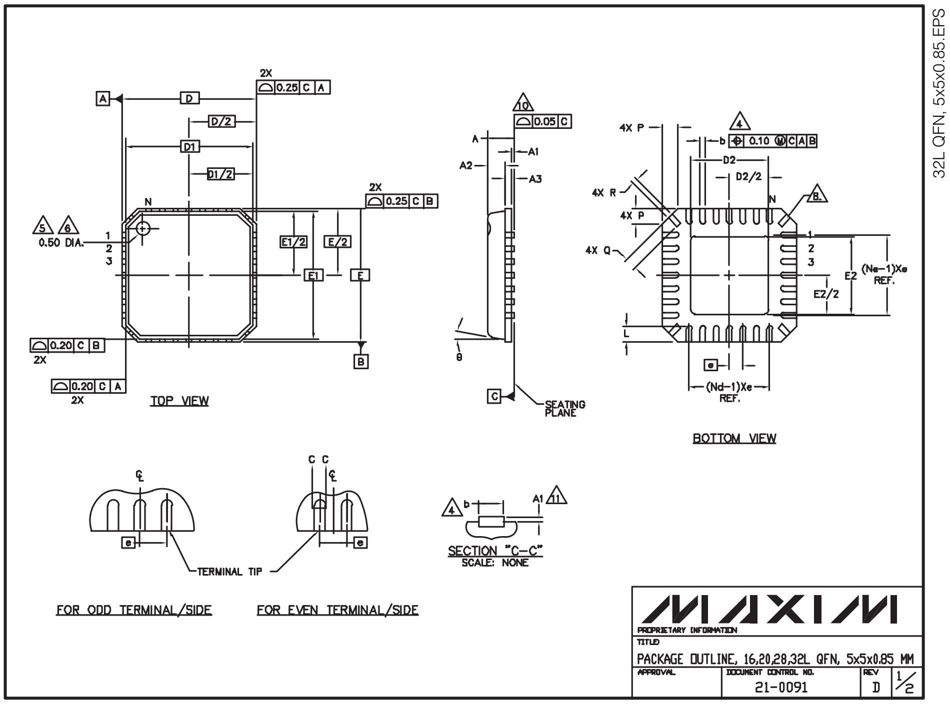
TRANSISTOR COUNT: 1154
SUBSTRATE CONNECTED TO GND

MAX3296



TRANSISTOR COUNT: 1154
SUBSTRATE CONNECTED TO GND

Package Information



NOTES:

1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM)
2. DIMENSIONING & TOLERANCES CONFORM TO ASME Y14.5M. – 1994.
3. N IS THE NUMBER OF TERMINALS.
   Nd IS THE NUMBER OF TERMINALS IN X-DIRECTION &
   Ne IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
4. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25mm FROM TERMINAL TIP.
5. THE PIN #1 IDENTIFIER MUST BE EXISTED ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR OTHER FEATURE OF PACKAGE BODY.
6. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
7. ALL DIMENSIONS ARE IN MILLIMETERS.
8. THE SHAPE SHOWN ON FOUR CORNERS ARE NOT ACTUAL I/O.
9. PACKAGE WARPAGE MAX 0.05mm.
10. APPLIED FOR EXPOSED PAD AND TERMINALS. EXCLUDE EMBEDDING PART OF EXPOSED PAD FROM MEASURING.
11. APPLIED ONLY FOR TERMINALS.

SYMBOL	COMMON DIMENSIONS			NOTE
	MIN.	NOM.	MAX.	
A	–	0.85	1.00	
A1	0.00	0.01	0.05	11
A2	–	0.65	0.80	
A3	0.20 REF.			
D	5.00 BSC			
D1	4.75 BSC			
E	5.00 BSC			
E1	4.75 BSC			
θ			12°	
P	0.24	0.42	0.60	
R	0.13	0.17	0.23	

SYMBOL	PITCH VARIATION A			NOTE
	MIN.	NOM.	MAX.	
e	0.80 BSC			
N	16			3
Nd	4			3
Ne	4			3
L	0.50	0.60	0.75	
b	0.28	0.33	0.40	4
Q	0.30	0.40	0.65	
D2	SEE EXPOSED PAD VARIATION: B			
E2	SEE EXPOSED PAD VARIATION: B			

SYMBOL	PITCH VARIATION B			NOTE
	MIN.	NOM.	MAX.	
e	0.65 BSC			
N	20			3
Nd	5			3
Ne	5			3
L	0.50	0.60	0.75	
b	0.23	0.28	0.35	4
Q	0.30	0.40	0.65	
D2	SEE EXPOSED PAD VARIATION: B			
E2	SEE EXPOSED PAD VARIATION: B			

SYMBOL	PITCH VARIATION C			NOTE
	MIN.	NOM.	MAX.	
e	0.50 BSC			
N	28			3
Nd	7			3
Ne	7			3
L	0.50	0.60	0.75	
b	0.18	0.23	0.30	4
Q	0.30	0.40	0.65	
D2	SEE EXPOSED PAD VARIATION: A,B			
E2	SEE EXPOSED PAD VARIATION: A,B			

SYMBOL	PITCH VARIATION D			NOTE
	MIN.	NOM.	MAX.	
e	0.50 BSC			
N	32			3
Nd	8			3
Ne	8			3
L	0.30	0.40	0.55	
b	0.18	0.23	0.30	4
Q	0.00	0.20	0.45	
D2	SEE EXPOSED PAD VARIATION: A			
E2	SEE EXPOSED PAD VARIATION: A			

SYMBOLS		D2			E2			NOTE
		MIN	NOM	MAX	MIN	NOM	MAX	
EXPOSED PAD VARIATIONS	A	2.95	3.10	3.25	2.95	3.10	3.25	
	B	2.55	2.70	2.85	2.55	2.70	2.85	

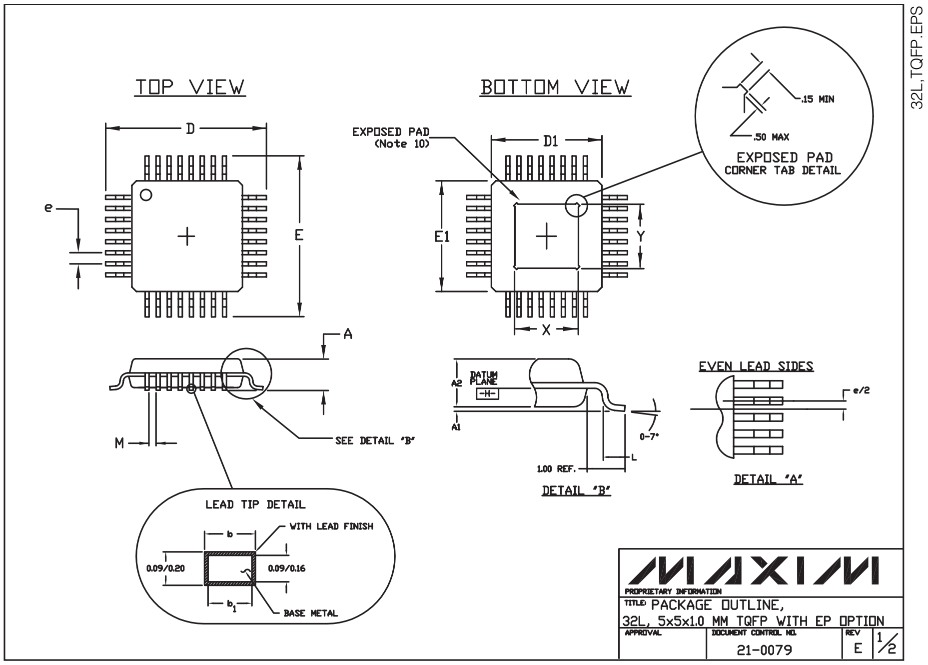
EXAMPLE: WE CAN CALL VARIATION "BB" FOR 20 TERMINAL QFN WITH 2.70mm X 2.70mm NOMINAL EXPOSED PAD DIMENSION. THE FORMER ONE IN VARIATION IS FOR PITCH VARIATION AND THE LETTER ONE IS FOR EXPOSED PAD VARIATION.

PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, 16,20,28,32L QFN, 5x5x0.85 MM

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0091	D	2/2

Package Information



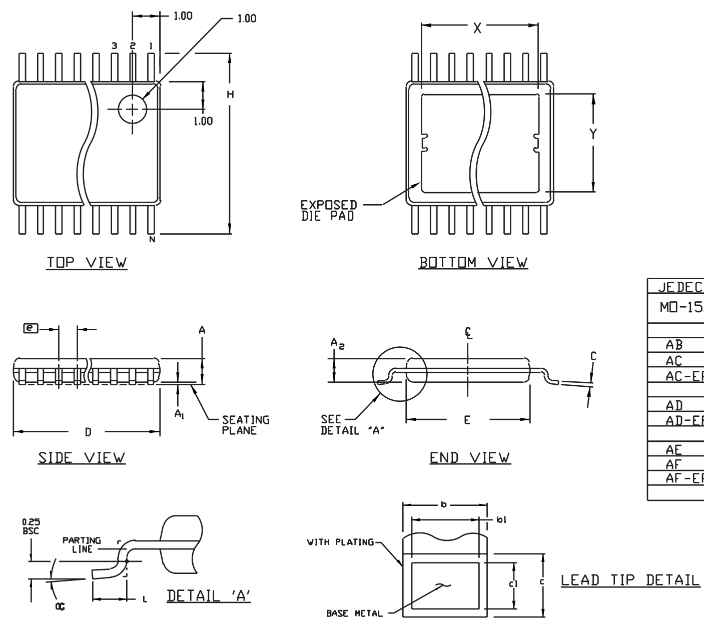
NOTES:
1. ALL DIMENSIONING AND TOLERANCING CONFORM TO ANSI Y14.5-1982.
2. DATUM PLANE -H- IS LOCATED AT MOLD PARTING LINE AND COINCIDENT WITH LEAD, WHERE LEAD EXITS PLASTIC BODY AT BOTTOM OF PARTING LINE.
3. DIMENSIONS D1 AND E1 DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE MOLD PROTRUSION IS 0.254 MM ON D1 AND E1 DIMENSIONS.
4. THE TOP OF PACKAGE IS SMALLER THAN THE BOTTOM OF PACKAGE BY 0.15 MILLIMETERS.
5. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 MM TOTAL IN EXCESS OF THE b DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. CONTROLLING DIMENSION: MILLIMETER.
7. THIS OUTLINE CONFORMS TO JEDEC PUBLICATION 95, REGISTRATION MO-136.
8. LEADS SHALL BE COPLANAR WITHIN .004 INCH.
9. EXPOSED DIE PAD SHALL BE COPLANAR WITH BOTTOM OF PACKAGE WITHIN 2 MILS (.05 MM).
10. DIMENSIONS X AND Y APPLY TO EXPOSED PAD (EP) VERSIONS ONLY. SEE INDIVIDUAL PRODUCT DATASHEET TO DETERMINE IF A PRODUCT USES EXPOSED PAD PACKAGE.

	JEDEC VARIATIONS DIMENSIONS IN MILLIMETERS			
	AA		AA-EP*	
	5x5x1.0 MM		5x5x1.0 MM	
	MIN.	MAX.	MIN.	MAX.
A	—	1.20	—	1.20
A_1	0.05	0.15	0.05	0.15
A_2	0.95	1.05	0.95	1.05
D	7.00 BSC.		7.00 BSC.	
D_1	5.00 BSC.		5.00 BSC.	
E	7.00 BSC.		7.00 BSC.	
E_1	5.00 BSC.		5.00 BSC.	
L	0.45	0.75	0.45	0.75
M	0.15	—	0.15	—
N	32		32	
e	0.50 BSC.		0.50 BSC.	
b	0.17	0.27	0.17	0.27
b1	0.17	0.23	0.17	0.23
*X	N/A	N/A	2.70	3.30
*Y	N/A	N/A	2.70	3.30

* EXPOSED PAD (Note 10)

MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE,
32L, 5x5x1.0 MM TQFP WITH EP OPTION
APPROVAL | DOCUMENT CONTROL NO. 21-0079 | REV E | 2/2

Package Information (continued)



TSSOP.EPS

SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	—	1.10		.043
A_1	0.05	0.15	.002	.006
A_2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b1	0.19	0.25	.007	.010
c	0.090	0.20	.0035	.008
c1	0.090	0.135	.0035	.0053
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.50	.246	.256
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
Y	2.85	3.15	.112	.124
α	0°	8°	0°	8°

JEDEC			VARIATIONS			
MO-153	N		MILLIMETERS		INCHES	
			MIN.	MAX.	MIN.	MAX.
AB	14	D	4.90	5.10	.193	.201
AC	16	D	4.90	5.10	.193	.201
AC-EP	16	D	4.90	5.10	.193	.201
		X	2.85	3.15	.112	.124
AD	20	D	6.40	6.60	.252	.260
AD-EP	20	D	6.40	6.60	.252	.260
		X	4.00	4.34	.157	.171
AE	24	D	7.70	7.90	.303	.311
AF	28	D	9.60	9.80	.378	.386
AF-EP		D	9.60	9.80	.378	.386
		X	5.35	5.65	.211	.222

NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15 mm PER SIDE.
3. CONTROLLING DIMENSION: MILLIMETER.
4. MEETS JEDEC OUTLINE MO-153 VARIATIONS AB, AC, AD, AE, AF.
5. DIMENSIONS X AND Y APPLY TO EXPOSED PAD (EP) VERSIONS ONLY.
6. EXPOSED PAD FLUSH WITH BOTTOM OF PACKAGE WITHIN .002".

MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE, TSSOP, 4.40mm BODY, 0.65mm PITCH
APPROVAL | DOCUMENT CONTROL NO. 21-0066 | REV C | 1/1