

10.7Gbps, +3.3V, Compact VCSEL Driver

General Description

The MAX3975 is a +3.3V driver designed to directly modulate common-anode vertical cavity surface emitting lasers (VCSELs) at data rates up to 10.7Gbps. The driver output can be connected directly to the VCSEL, requiring no external components for biasing. With a 2.5mm x 2.5mm chip-scale package (UCSP™), transmit disable, output-current monitor, and 0°C to +85°C operation, the MAX3975 is ideal for 850nm XFP/XENPAK transceivers.

The MAX3975 delivers 3mA to 12mA of modulation current, with 1.5mA to 10mA of bias current (peak current 22mA). Typical switching time is 28ps (20% to 80%) with 8ps of deterministic jitter.

Applications

10 Gigabit Ethernet Transceivers
XFP/XENPAK/X2/XPAK Optical Transceivers
SONET VSR Optical Transmitters
10 Gigabit Fibre-Channel Transceivers

Ordering Information

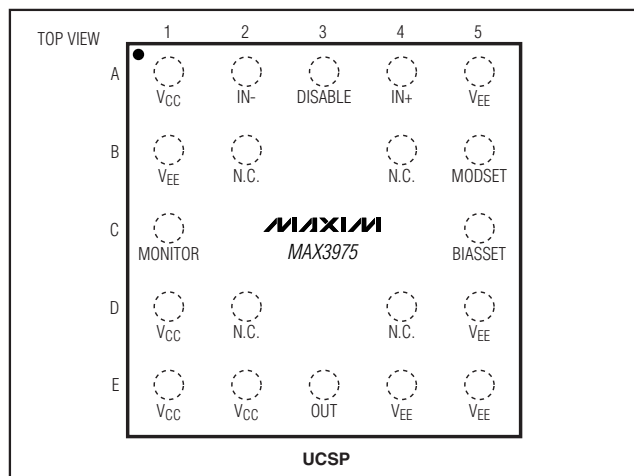
PART	TEMP RANGE	PIN-PACKAGE	PKG CODE
MAX3975UBA-T	0°C to +85°C	20 UCSP-20 (2.5mm x 2.5mm)	B25-4

UCSP is a trademark of Maxim Integrated Products, Inc.

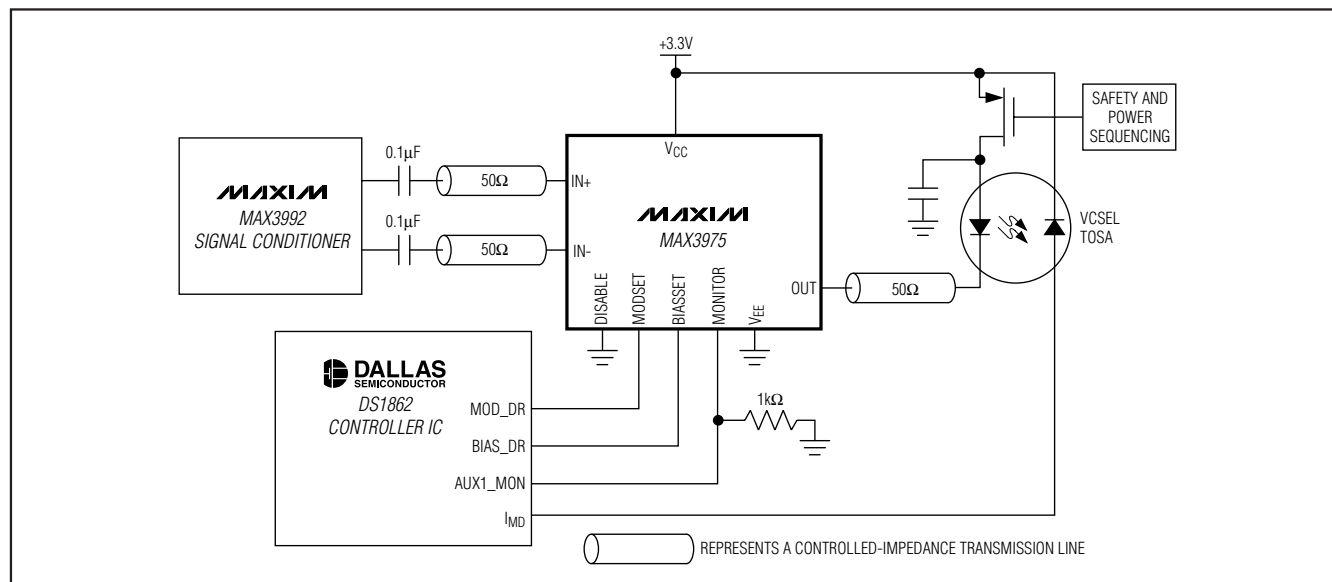
Features

- ◆ 2.5mm x 2.5mm Chip-Scale Package (5 x 5 Array UCSP)
- ◆ Single +2.97V to +3.63V Supply Voltage
- ◆ 28ps Switching Time
- ◆ DC-Coupled Output
- ◆ 3mA to 12mA Modulation Current
- ◆ 1.5mA to 10mA Bias Current
- ◆ Output Disable Circuit
- ◆ Output-Current Monitor

Pin Configuration



Typical Application Circuit



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ABSOLUTE MAXIMUM RATINGS

Power-Supply Voltage (V _{CC}).....	-0.5V to +4.5V	Continuous Current at OUT.....	30mA
Voltage at IN+, IN-	(V _{CC} - 1.75V) to (V _{CC} + 0.5V)	Voltage at OUT	4V
Differential Input Voltage (IN+ - IN-)	±1.5V	Continuous Power Dissipation (T _A = +85°C)	
Voltage at DISABLE.....	-0.5V to (V _{CC} + 0.5V)	20-Bump UCSP (derate 10.0mW/°C above +85°C) ...	650mW
Voltage at MODSET, BIASSET	-0.5V to +2.0V	Operating Junction Temperature.....	+150°C
Voltage at MONITOR.....	-0.5V to V _{CC}	Storage Temperature Range.....	-55°C to +150°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} = +2.97V to +3.63V, R_{LOAD} = 50Ω, I_{MOD} + I_{BIAS} ≤ $\frac{(V_{CC} - V_{OUT-MIN} - 1.2V)}{50}$, T_A = 0°C to +85°C. Typical values are at V_{CC} = +3.3V, I_{BIAS} = 6.0mA, I_{MOD} = 6.0mA, and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Power-Supply Current (Includes Bias and Modulation Currents)	I _{CC}	I _{BIAS} = 10mA, I _{MOD} = 12mAp-p, DISABLE = low		106	135	mA
		I _{BIAS} = 1.5mA, I _{MOD} = 3mAp-p, DISABLE = low		55	70	
		DISABLE = high		34	50	
SIGNAL INPUT						
Input Impedance		Single ended	42	50	58	Ω
Input Sensitivity	V _{IN-MIN}	(Figure 2)			250	mV _{P-P}
Input Overload	V _{IN-MAX}	(Figure 2)	1000			mV _{P-P}
LASER MODULATION						
Output Resistance	R _T		42	50	58	Ω
Minimum Modulation	I _{MOD-MIN}				3	mA
Maximum Modulation	I _{MOD-MAX}		12			mA
Modulation Current When DISABLE = High		V _{IN} = 1000mV _{P-P} (Note 1)		100	250	μAp-p
Voltage at OUT	V _{OUT}	(Note 2)	0.7			V
Deterministic Jitter	DJ	(Notes 1, 3)		8	18	psp-p
Random Jitter	RJ	(Note 1)		0.35	0.8	psRMS
Output Switching Time	t _R , t _F	20% to 80% (Notes 1, 4)		28	36	ps
Current Gain from MODSET to OUT				10		mA/mA
LASER BIAS						
Minimum Bias Current	I _{BIAS-MIN}				1.5	mA
Maximum Bias Current	I _{BIAS-MAX}		10			mA
Current Gain from BIASSET to OUT				10		mA/mA
Bias-Set Current Threshold for Disable		(Note 5)	10	25		μA
Output Current when Disabled		I _{BIASSET} ≤ 10μA or DISABLE = high			250	μA

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ELECTRICAL CHARACTERISTICS (continued)

($V_{CC} = +2.97V$ to $+3.63V$, $R_{LOAD} = 50\Omega$, $I_{MOD} + I_{BIAS} \leq \frac{(V_{CC} - V_{OUT-MIN} - 1.2V)}{50}$, $T_A = 0^\circ C$ to $+85^\circ C$. Typical values are at $V_{CC} = +3.3V$, $I_{BIAS} = 6.0mA$, $I_{MOD} = 6.0mA$, and $T_A = +25^\circ C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MONITOR OUTPUT						
MONITOR Gain		$R_{MONITOR} = 1k\Omega$		16		mA/mA
MONITOR Offset Error			-25		+25	μA
MONITOR Gain Variation			-30		+30	%
		V_{CC} and temperature only		± 8		
DISABLE INPUT						
Input High Voltage			2.0			V
Input Low Voltage					0.8	V
Input Resistance	R_{DIS}		50	76	100	$k\Omega$
Input Current		$-0.3V < V_{DISABLE} < (V_{CC} + 0.3V)$	-100		+100	μA
LASER CURRENT PROGRAMMING						
Reference Voltage at BIASSET and MODSET	V_{BG}			1.2		V
Gain Matching of I_{BIAS} and I_{MOD}		(Note 6)	-25		+25	%

Note 1: Guaranteed by design and characterization using the circuit shown in Figure 1.

Note 2: V_{OUT} is the minimum instantaneous voltage at the output (not the average voltage).

Note 3: Measured at 10.7Gbps with a pattern equivalent to $2^{23} - 1$ PRBS.

Note 4: Measured at 2.5Gbps with a 0101 repeating pattern.

Note 5: Programming a bias set current ($I_{BIASSET}$) below the threshold disables the output currents.

Note 6: Gain Matching = $100 \times \left(\frac{\text{Bias Gain}}{\text{Modulation Gain}} - 1 \right)$

Measured under the following conditions:

$I_{MOD} = 12mA$, $I_{BIAS} = 4mA$

$I_{MOD} = 3mA$, $I_{BIAS} = 4mA$

$I_{MOD} = I_{BIAS} = 4mA$

$I_{MOD} = I_{BIAS} = 8mA$.

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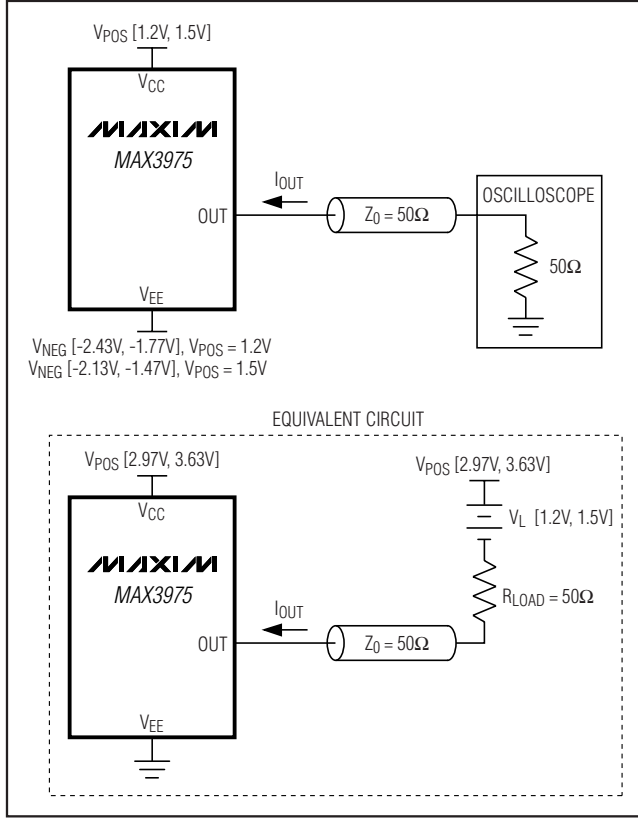


Figure 1. AC Characterization Circuit

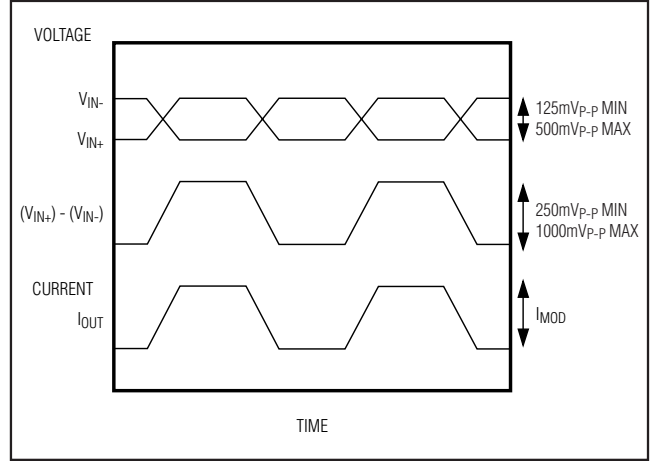
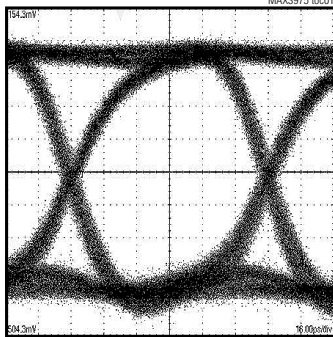


Figure 2. Required Input Signal and Output Polarity

Typical Operating Characteristics

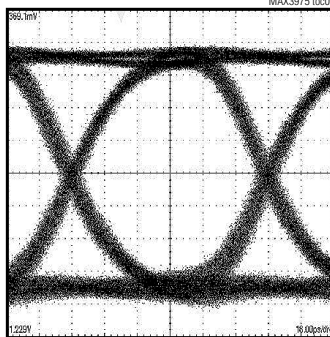
(VCC = +2.97V to +3.63V, RLOAD = 50Ω, TA = 0°C to +85°C. Typical values are at VCC = +3.3V, IBIAS = 6.0mA, IMOD = 6.0mA, and TA = +25°C, unless otherwise noted.)

10.3Gbps ELECTRICAL EYE DIAGRAM
(IBIAS = 4mA, IMOD = 5mA, 2²³ - 1 PRBS)



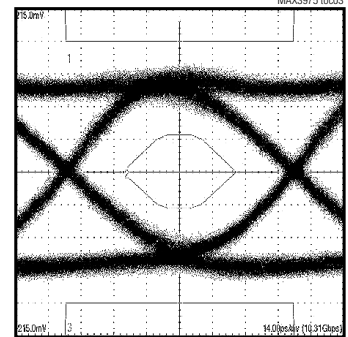
16ps/div

10.3Gbps ELECTRICAL EYE DIAGRAM
(IBIAS = 10mA, IMOD = 12mA, 2²³ - 1 PRBS)



16ps/div

10.3Gbps OPTICAL EYE DIAGRAM
(PAVG = -2.0dBm, OMA = 471μWp-p, 2²³ - 1 PRBS)
(ADVANCED OPTICAL COMPONENTS VCSEL
TOSA HFE6190-561)



14ps/div

8GHz FILTER, 24% 10GbE MASK MARGIN

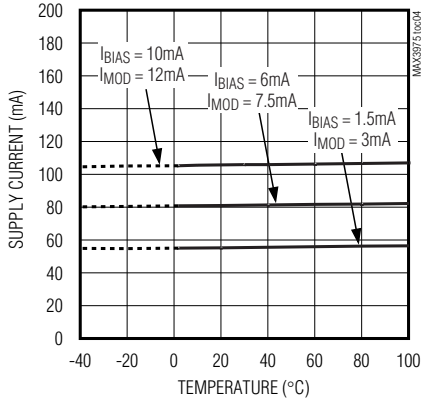
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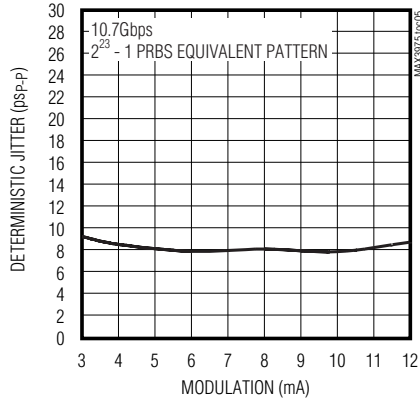
Typical Operating Characteristics (continued)

($V_{CC} = +2.97V$ to $+3.63V$, $R_{LOAD} = 50\Omega$, $T_A = 0^\circ C$ to $+85^\circ C$. Typical values are at $V_{CC} = +3.3V$, $I_{BIAS} = 6.0mA$, $I_{MOD} = 6.0mA$, and $T_A = +25^\circ C$, unless otherwise noted.)

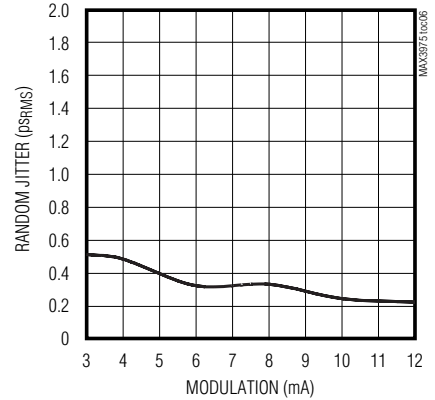
**SUPPLY CURRENT vs. TEMPERATURE
(INCLUDES I_{BIAS} AND I_{MOD})**



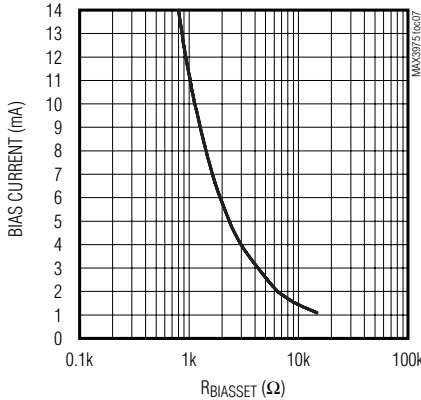
DETERMINISTIC JITTER vs. MODULATION CURRENT



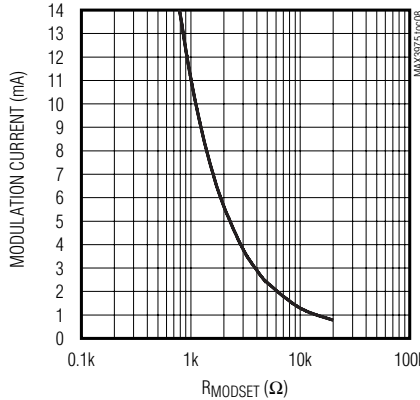
RANDOM JITTER vs. MODULATION CURRENT



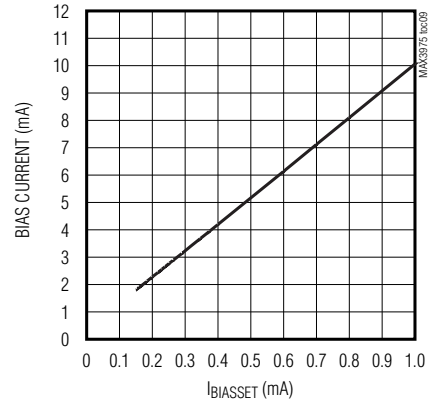
BIAS CURRENT vs. $R_{BIASSET}$



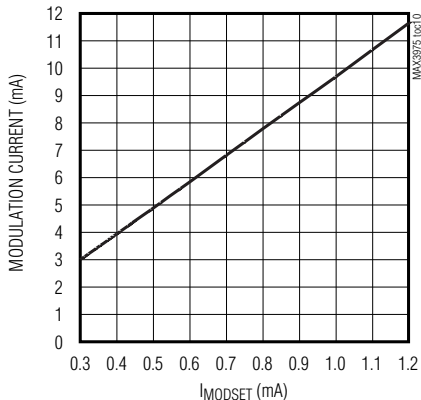
MODULATION CURRENT vs. R_{MODSET}



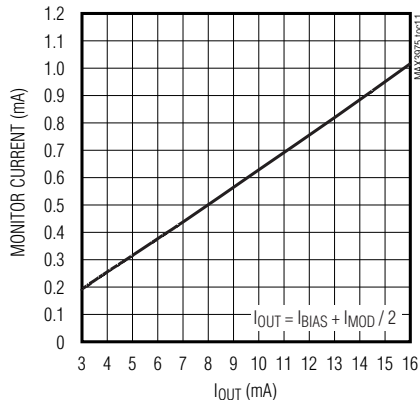
BIAS CURRENT vs. $I_{BIASSET}$



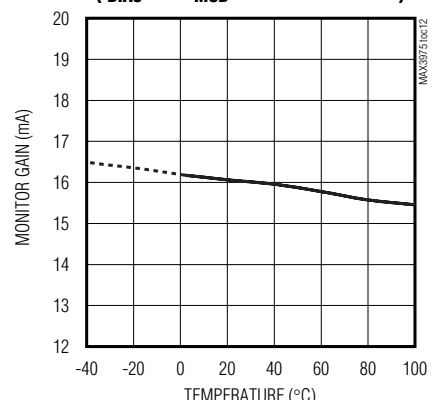
MODULATION CURRENT vs. I_{MODSET}



MONITOR CURRENT vs. I_{OUT}



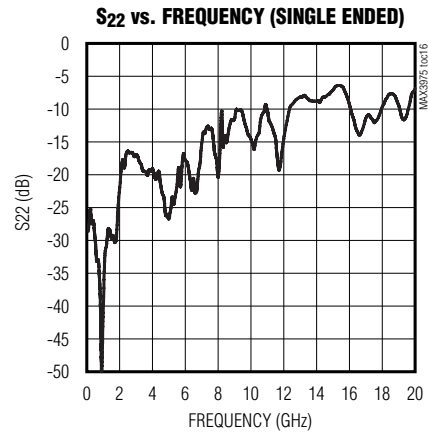
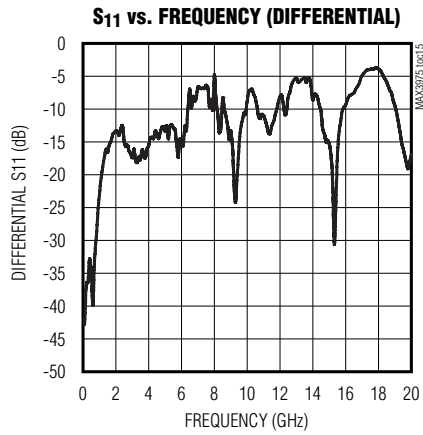
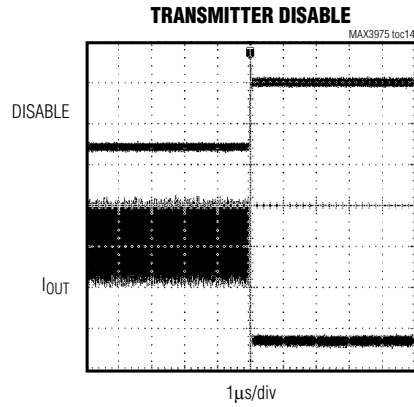
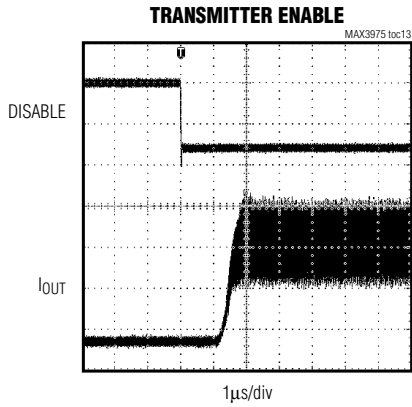
**MONITOR GAIN vs. TEMPERATURE
(I_{BIAS} AND I_{MOD} REMAIN CONSTANT)**



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Typical Operating Characteristics (continued)

($V_{CC} = +2.97V$ to $+3.63V$, $R_{LOAD} = 50\Omega$, $T_A = 0^\circ C$ to $+85^\circ C$. Typical values are at $V_{CC} = +3.3V$, $I_{BIAS} = 6.0mA$, $I_{MOD} = 6.0mA$, and $T_A = +25^\circ C$, unless otherwise noted.)



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Pin Description

PIN	NAME	FUNCTION
A1, D1, E1, E2	V _{CC}	+3.3V Supply Voltage. All V _{CC} pins must be connected to the supply voltage.
A2	IN-	Negative Data Input. Includes 50Ω to V _{CC} on-chip termination resistor.
A3	DISABLE	Transmitter Disable, TTL Compatible. Total VCSEL current is low when this pin is set to a TTL high (asserted) or left open. VCSEL current is enabled when this input is set to a TTL low (deasserted).
A4	IN+	Positive Data Input. Includes 50Ω to V _{CC} on-chip termination resistor.
A5, B1, D5, E4, E5	V _{EE}	Supply Ground. All V _{EE} pins must be connected to the supply ground.
B2, B4, D2, D4	N.C.	No Connection. These pins must be soldered to the circuit board but should not be electrically connected to any circuit nodes (left floating).
B5	MODSET	Modulation Current Set Pin, Analog. A resistor connected from this pin to V _{EE} sets the desired modulation current. Modulation current can also be programmed with a current-sinking digital-to-analog converter (DAC) or voltage DAC with series resistor. See Figure 4.
C1	MONITOR	VCSEL DC Current Monitor, Analog. Current from this output is proportional to the VCSEL DC current. Connect to V _{EE} if not required in the application.
C5	BIASSET	Bias Current Set Pin, Analog. A resistor connected from this pin to ground sets the desired bias current. Bias current can also be programmed with a current-sinking DAC or voltage DAC with series resistor. See Figure 4. Programming a current below the bias-set current threshold disables the driver output.
E3	OUT	Modulation and Bias Current Output (Current Flows from VCSEL to OUT). Connect to VCSEL cathode.

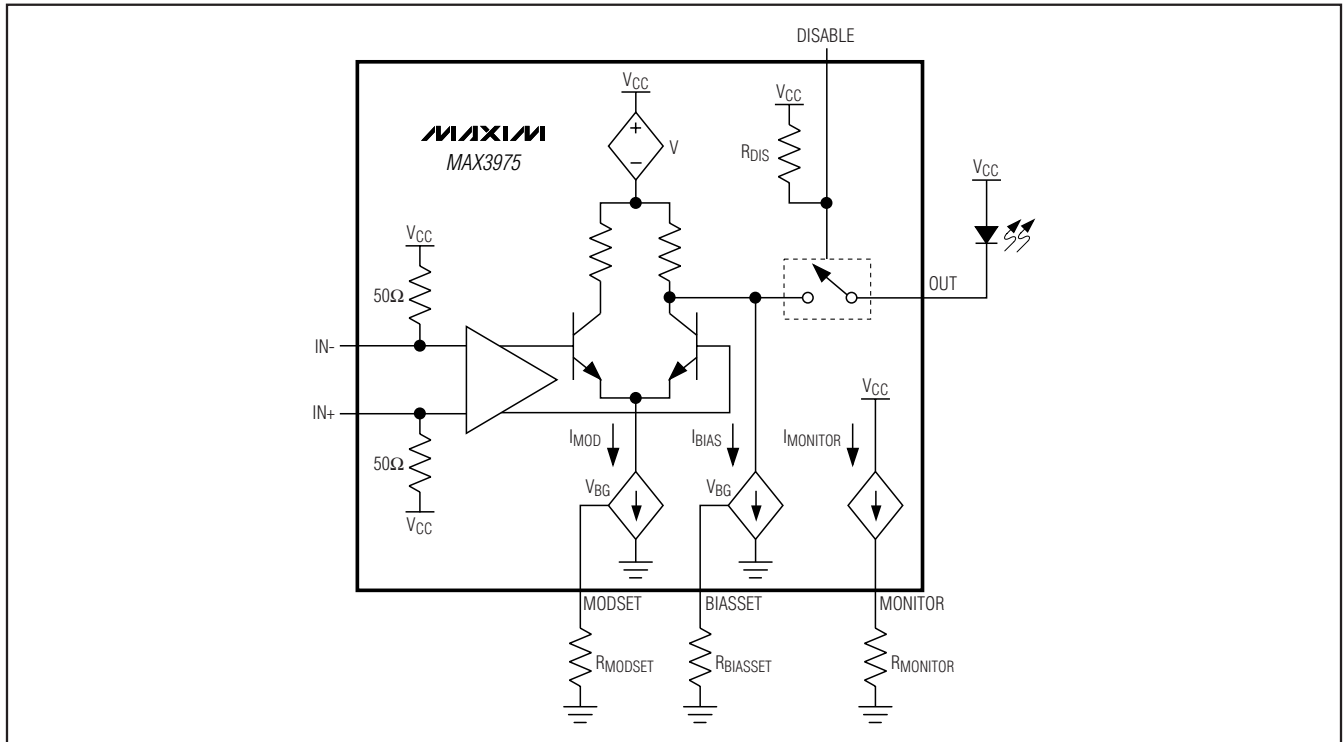


Figure 3. Functional Diagram

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Detailed Description

The MAX3975 VCSEL driver consists of a high-speed modulator with programmable modulation and bias currents, transmitter disable circuit, and output-current monitor (Figure 3). The MAX3975 operates from a +3.3V supply and provides a 50Ω output termination, 3mA to 12mA of modulation, and 1.5mA to 10mA of bias current, allowing operation with a variety of 10Gbps VCSELs.

Modulation Circuit

The modulation circuitry consists of an input buffer, a current mirror, and a high-speed current switch. The modulator drives up to 12mA of modulation with a 50Ω VCSEL load.

The amplitude of the modulation current at OUT (I_{MOD}) is linearly proportional to the control current at MODSET and is given by the relationship:

$$I_{MOD} = I_{MODSET} \times 10$$

The control current is programmed with a resistor from MODSET to VEE. The control current can also be programmed with a current-sinking DAC or voltage DAC with series resistor as shown in Figure 4.

Biasing Circuit

The biasing circuitry consists of a current mirror that is connected to the driver output. Bias and modulation currents are combined internally, eliminating the need for an external bias inductor. The biasing circuit provides up to 10mA of bias current with a 50Ω VCSEL load.

The bias current at OUT (I_{BIAS}) is linearly proportional to the control current at BIASSET and is given by the relationship:

$$I_{BIAS} = I_{BIASSET} \times 10$$

The control current is programmed with a resistor from BIASSET to VEE. The control current can also be programmed with a current-sinking DAC or voltage DAC with series resistor as shown in Figure 4. Programming a set current below the bias-set current threshold disables the driver output.

Transmitter Disable

The MAX3975 is equipped with a transmitter disable control (DISABLE). The DISABLE input is a TTL-compatible, low-current digital input. When DISABLE is set to TTL high (asserted) or left open, both the modulation and bias currents are disabled. The modulation and bias currents are enabled when DISABLE is set to TTL low (deasserted), and $I_{BIASSET}$ is above the disable threshold.

Output Current Monitor

The MONITOR is a current output that provides an indication of the VCSEL DC current. Connecting a resistor ($R_{MONITOR}$) from the MONITOR output to VEE gives the following relationship:

$$V_{MONITOR} = (1/16) \times (I_{BIAS} + (I_{MOD} / 2)) \times R_{MONITOR}$$

where, $(I_{BIAS} + (I_{MOD} / 2)) =$ VCSEL DC current.

The voltage at the monitor output must be less than 2.18V for compliance. The recommended range for $R_{MONITOR}$ is 500Ω to 1.2kΩ, with 1kΩ being typical. MONITOR must be connected to VEE if not required in the application.

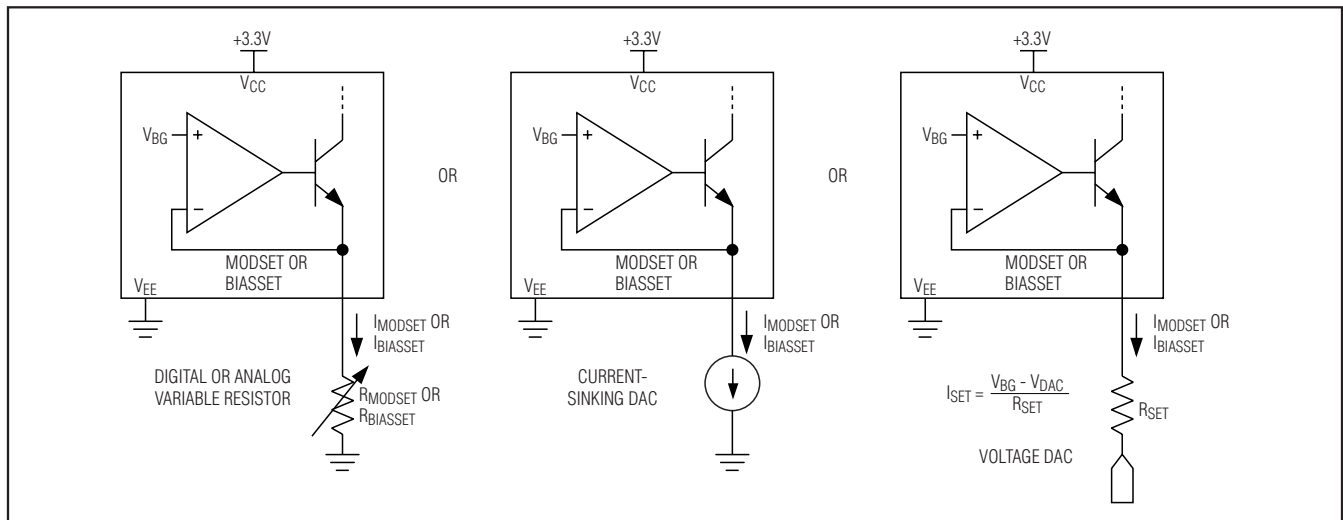


Figure 4. Bias and Modulation Current Controls

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Table 1. Optical Power Relations

PARAMETER	SYMBOL	RELATION
Average Power	P_{AVG}	$P_{AVG} = (P_0 + P_1) / 2$
Extinction Ratio	E_r	$E_r = P_1 / P_0$ $E_r = (2P_{AVG} + OMA) / (2P_{AVG} - OMA)$
Optical Power of a 1	P_1	$P_1 = 2P_{AVG} E_r / (E_r + 1)$
Optical Power of a 0	P_0	$P_0 = 2P_{AVG} / (E_r + 1)$
Optical Modulation Amplitude	OMA	$OMA = P_1 - P_0 = 2P_{AVG} (E_r - 1) / (E_r + 1)$
Laser Slope Efficiency	η	$\eta = OMA / I_{MOD}$
Modulation Current	I_{MOD}	$I_{MOD} = OMA / \eta$
Bias Current	I_{BIAS}	$I_{BIAS} = I_{TH} + (P_0 \times \eta)$

Note: Assuming a 50% average input duty cycle and mark density.

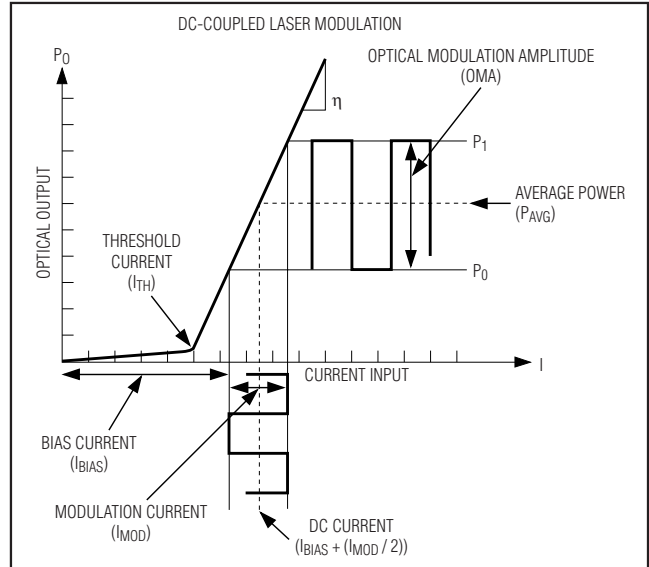


Figure 5. Optical Power Relations

Design Procedure

Interfacing with VCSELs

The MAX3975 modulating output (OUT) is optimized to interface directly to the cathode of a common-anode VCSEL. No external components are required between the VCSEL cathode and the driver output.

A 50Ω controlled-impedance transmission line with minimal length should be used between the VCSEL and the driver output. The VCSEL should be a high-speed, high-efficiency laser that requires low modulation current and generates a low voltage swing. Use a broadband supply filter at the VCSEL anode.

The minimum instantaneous voltage at OUT is 0.7V. To obtain fast edge transitions and low jitter, a VCSEL, supply voltage, and packaging technology must be selected that ensures V_{OUT} is within the operating range of the driver output.

Programming the Modulation Current

For a desired optical modulation amplitude (OMA), the required modulation current can be calculated based on the laser slope efficiency (η) using the equations in Table 1. To program the desired modulation current, connect a resistor from MODSET to V_{EE} . See the Modulation Current vs. RMODSET graph in the *Typical Operating Characteristics* to select the value of RMODSET that corresponds to the required modulation current. When using an external DAC as shown in Figure 4, see the Modulation Current vs. I_{MODSET} graph in the *Typical Operating Characteristics*.

Programming the Bias Current

For a desired laser average optical power, P_{AVG} , the required bias current can be calculated based on the laser slope efficiency (η) and threshold current (I_{TH}) using the equations in Table 1. To program the desired bias current, connect a resistor from BIASSET to V_{EE} . See the Bias Current vs. RBIASSET graph in the *Typical Operating Characteristics* to select the value of RBIASSET that corresponds to the required bias current. When using an external DAC as shown in Figure 4, see the Bias Current vs. I_{BIASSET} graph in the *Typical Operating Characteristics*.

Closed-Loop Operation

Closed-loop power control can be implemented by using a controller IC as shown in the *Typical Application Circuit* on page 1. The controller IC monitors the photodiode current then adjusts the resistance/current seen by the BIASSET pin to maintain average power of the optical output over temperature and laser lifetime. Optical modulation amplitude (OMA) control is achieved by using a temperature indexed lookup table to control the resistance/current seen by the MODSET pin. The time constant from MODSET/BIASSET to OUT is typically 175ns.

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Safety and Power Sequencing

For safety fault protection and proper power sequencing, use a low on-resistance MOSFET between the VCSEL power supply and the VCSEL anode, as shown in the *Typical Application Circuit*. A power-on-reset circuit and the safety fault signal of the controller IC (if applicable) should control the MOSFET gate.

The power-on-reset circuit should be designed to disable the VCSEL when the driver supply voltage is below 2.9V. This prevents the VCSEL from producing excessive optical output while the driver powers up/down.

UCSP Assembly Considerations

The MAX3975 is packaged in a 2.5mm x 2.5mm, chip-scale package (5 x 5 UCSP). Five of the solder ball positions (B3, C2, C3, C4, D3) are not populated (package code B25-4). For the latest application details on UCSP construction, dimensions, tape carrier information, PC board techniques, bump-pad layout, and rec-

ommended reflow temperature profile, as well as the latest information on reliability testing results, refer to the Application Note: UCSP—A *Wafer-Level Chip-Scale Package* available on Maxim's website at www.maxim-ic.com/ucsp.

Applications Information

Interface Models

Figures 6, 7, 8, and 9 show simplified input and output circuits.

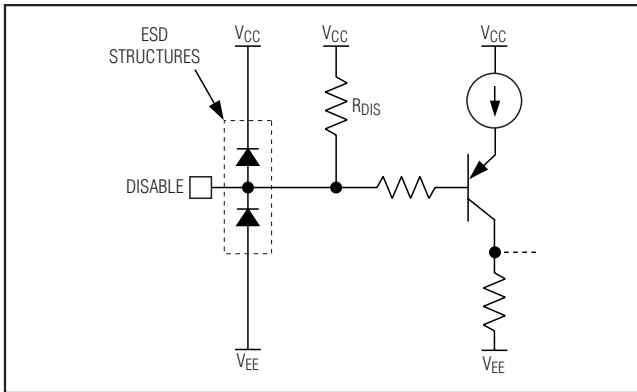


Figure 6. Simplified DISABLE Input Structure

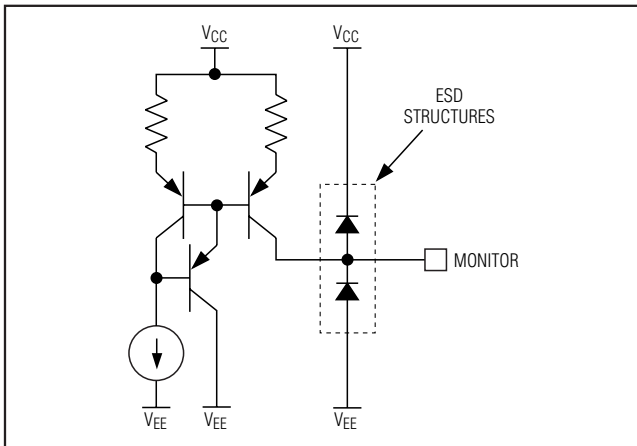


Figure 7. Simplified MONITOR Output Structure

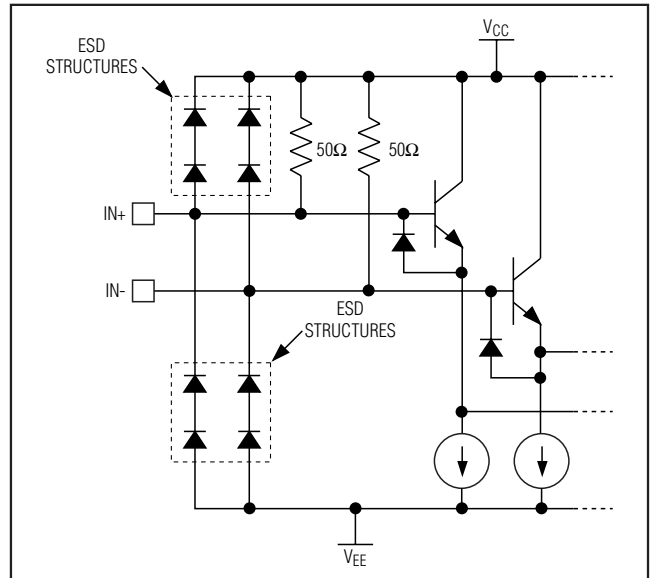


Figure 8. Simplified Data Input Structure

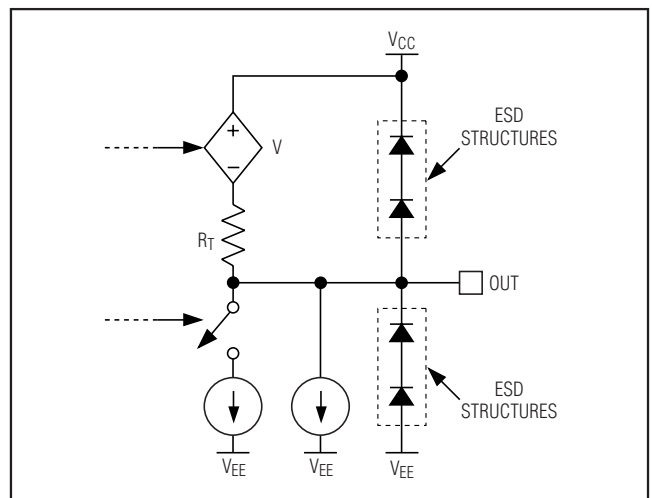


Figure 9. Simplified Data Output Structure

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Layout Considerations

Design a broadband supply filter that provides low impedance between 10kHz and 15GHz. Use controlled-impedance transmission lines to interface to the high-speed input and output of the MAX3975. The parasitic capacitance at BIASSET and MODSET must be less than 20pF to ensure stability of the current controls.

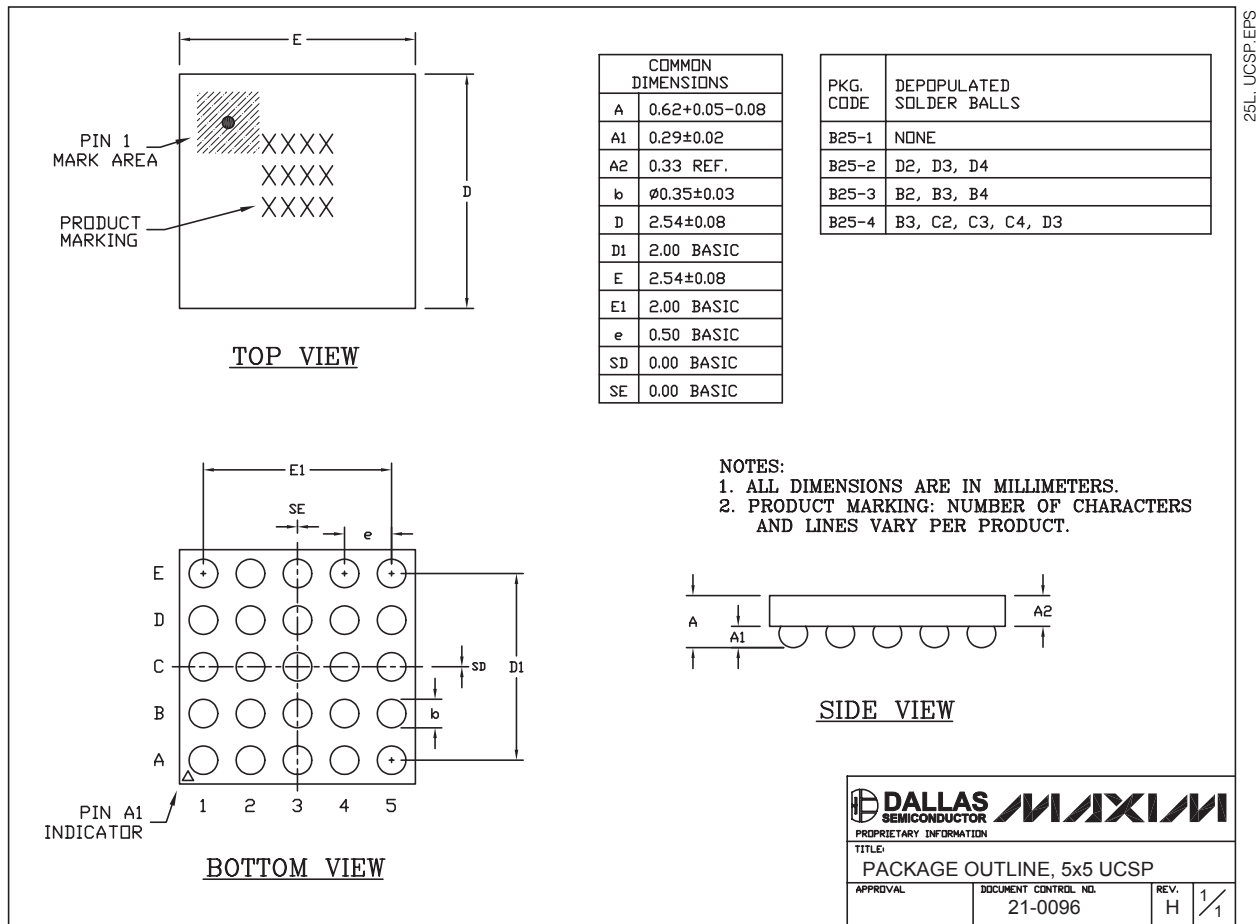
Chip Information

TRANSISTOR COUNT: 1387

PROCESS: SiGe Bipolar

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)



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