155 Mbps to 4.25 Gbps LASER DRIVER

FEATURES

- **Multirate Operation From 155 Mbps up to 4.25 Gbps**
- **Bias Current Programmable From 1 mA to 100 mA**
- **Modulation Current Programmable From 5 mA to 85 mA**
- **APC and Fault Detection**
- **Fault Mode Selection**
- **Bias and Photodiode Current Monitors**
- **CML Data Inputs**
- **Temperature Compensation of Modulation Current**
- **Single 3.3-V Supply**
- **Surface-Mount, Small-Footprint, 4 mm × 4 mm 24-Lead QFN Package**

APPLICATIONS

- **SONET/SDH Transmission Systems**
- **Fibre Channel Optical Modules**
- **Fiber Optic Data Links**
- **Digital Cross-Connects**
- **Optical Transmitters**

DESCRIPTION

The ONET4211LD is a laser driver for multiple fiber optic applications up to 4.25 Gbps. The device accepts CML input data and provides bias and modulation currents for driving a laser diode. Also provided are automatic power control (APC), temperature compensation of modulation current, fault detection, and current monitor features.

The device is available in a small-footprint, 4 mm × 4 mm 24-pin QFN package. The circuit requires a single 3.3-V supply.

This power-efficient laser driver is characterized for operation from –40°C to 85°C.

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

DETAILED DESCRIPTION

BLOCK DIAGRAM

A simplified block diagram of the ONET4211LD is shown in Figure 1.

This compact, low-power, 4.25-Gbps laser driver circuit consists of a high-speed data path and a bias-and-control block.

The function of the data path is to buffer the input data and then modulate the laser diode current according to the input data stream.

The bias-and-control block generates the laser diode bias current, contains automatic power control (APC) to maintain constant optical output power, generates a modulation current that can be temperature compensated, and controls power on during start-up and shutdown after failure detection. The circuit design is optimized for high-speed and low-voltage operation (3.3 V).

The main circuit blocks are described in detail in the following paragraphs.

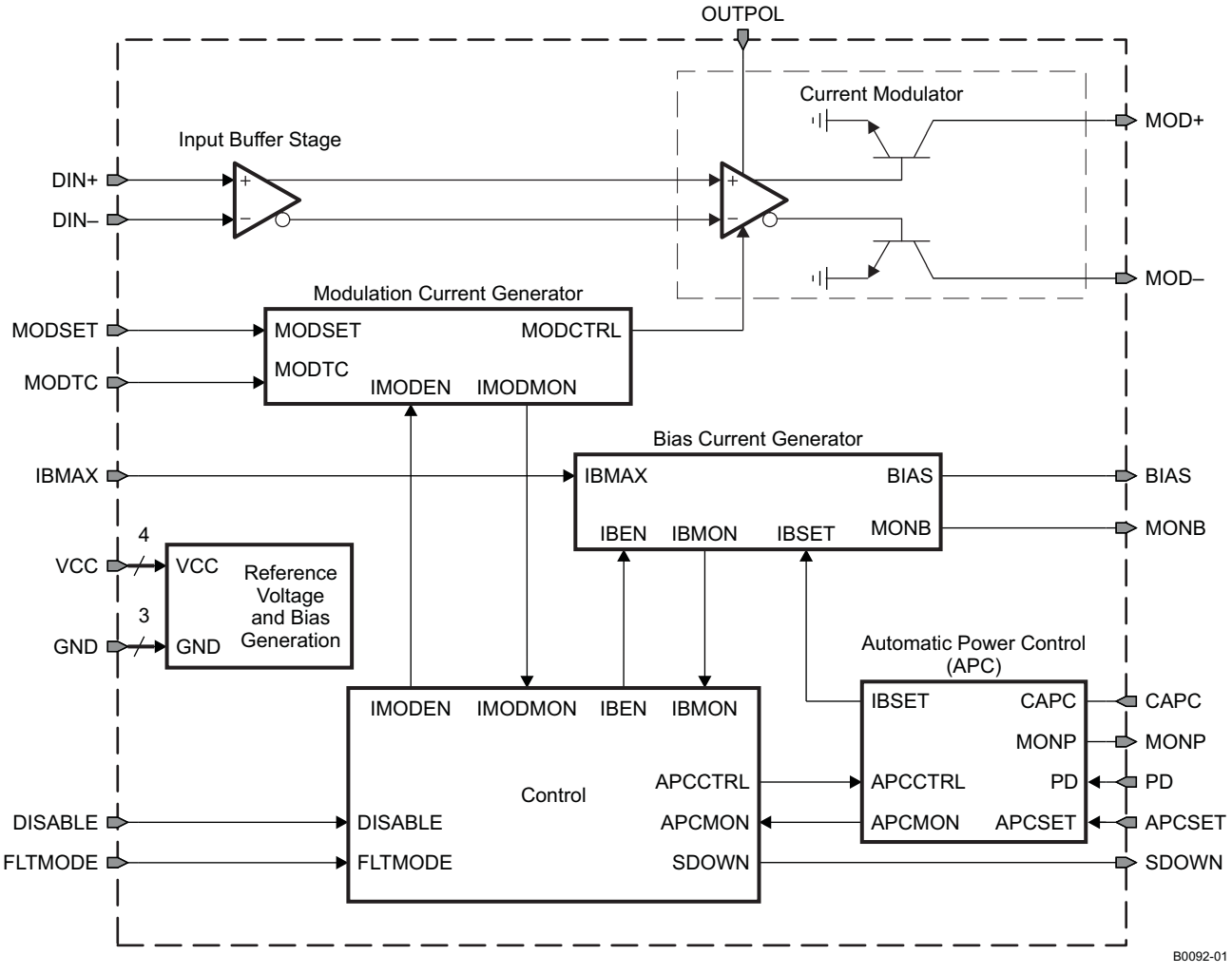

Figure 1. Simplified Block Diagram of the ONET4211LD

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HIGH-SPEED DATA PATH

The high-speed data path consists of an input buffer stage and a current modulator.

The input buffer stage takes CML-compatible differential signals. It provides on-chip, 50-Ω termination to VCC. AC-coupling may be used at the DIN+ and DIN- inputs.

The laser diode current modulator consists mainly of two common-emitter output transistors and the required driver circuitry. According to the input data stream, the modulation current is sunk at the MOD+ or the MOD– pin.

Modulation current setting is performed by means of the modulation current generator block, which is supervised by the control circuit block.

The laser diode can be either ac- or dc-coupled. In either case, the maximum modulation current is 85 mA. The modulation output is optimized for driving a 20-Ω load.

For optimum power efficiency, the laser driver does not provide any on-chip back-termination.

BIAS AND CONTROL

The bias-and-control circuitry consists of the bandgap voltage and bias generation block, the bias current generator, the automatic power control block, and the supervising control circuitry.

BANDGAP VOLTAGE AND BIAS GENERATION

The bandgap voltage reference provides the process- and temperature-independent reference voltages needed to set bias current, modulation current, and photodiode reference current. Additionally, this block provides the biasing for all internal circuits.

AUTOMATIC POWER CONTROL

The ONET4211LD laser driver incorporates an APC loop to compensate for the changes in laser threshold current over temperature and lifetime. The internal APC is enabled when resistors are connected to the IBMAX and APCSET pins. A back-facet photodiode mounted in the laser package is used to detect the average laser output power. The photodiode current I_{PD} that is proportional to the average laser power can be calculated by using the laser-to-monitor transfer ratio, ρ_{MON} and the average power, P_{AVG}:

$$I_{PD}\,[A] = P_{AVG}\,[W] \times \rho_{MON}[A/W] \tag{1}$$

In closed-loop operation, the APC modifies the laser diode bias current by comparing I_{PD} with a reference current I_{APCSET} and generates a bias compensation current. I_{PD} can be programmed by selecting the external resistor R_{APCSET} according to:

$$R_{APCSET}[\Omega] = \frac{4.69\ V}{I_{PD}\,[A]} = \frac{4.69\ V}{P_{AVG}[W] \times \rho_{MON}[A/W]} \tag{2}$$

The bias compensation current subtracts from the maximum bias current to maintain the monitor photodiode current. The maximum bias current is programmed by the resistor connected to IBMAX:

$$I_{BIASMAX}[A] = \frac{343\ V}{R_{BIASMAX}[\Omega]} \tag{3}$$

An external pin, MONB, is provided as a bias current monitor output. A fraction of the bias current (1/68) is mirrored and develops a voltage drop across an external resistor to ground, R_{MONB}. The voltage at MONB is given as:

$$V_{MONB}[V] = \frac{R_{MONB}[\Omega] \times I_{BIAS}[A]}{68} \tag{4}$$

If the voltage at MONB is greater than the programmed threshold, a fault mode occurs.

MONP is also provided as a photocurrent monitor output. The photodiode current, I_{PD}, is mirrored and develops a voltage across an external resistor to ground, R_{MONP}. The voltage at MONP is given as:

$$V_{MONP}[V] = R_{MONP}[\Omega] \times I_{PD}[A] \tag{5}$$

If the voltage at MONP is greater than the programmed threshold, a fault mode occurs.

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As with any negative-feedback system design, care must be taken to ensure stability of the loop. The loop bandwidth must not be too high, in order to minimize pattern-dependent jitter. The dominant pole is determined by the capacitor C_{APC}. The recommended value for C_{APC} is 200 nF. The capacitance of the monitor photodiode C_{PD} adds another pole to the system, and thus it must be small enough to maintain stability. The recommended value for this capacitance is $C_{PD} \leq 50$ pF.

The internal APC loop can be disabled by connecting a 100-kΩ resistor from APCSET to VCC and leaving PD open. In open-loop operation, the laser diode current is set by $I_{BIASMAX}$ and I_{MODSET}.

MODULATION CURRENT GENERATOR

The modulation current generator defines the tail current of the modulator, which is sunk from either MOD+ or MOD–, depending on the data pattern. The modulation current consists of a current I_{MOD0} at a reference temperature T_0 = 60°C (set by the resistor R_{MODSET}) and a temperature-dependent modulation current defined by the resistor R_{MODTC}. The modulation current can be estimated as follows:

$$I_{MOD}[A] = \frac{265\ V}{R_{MODSET}[\Omega]} \times \left[1 + \left(\frac{24\ \Omega}{R_{MODTC}[\Omega]} + 630\ ppm\right) \times \left(T[^oC] - T_0[^oC]\right)\right] \quad (6)$$

Note that the reference temperature, T_0, and the temperature compensation set by R_{MODTC} vary from part to part. To reduce the variation, I_{MOD} can be calibrated over temperature and set with a microcontroller DAC or digital potentiometer.

CONTROL

The function of this block is to control the start-up sequence, detect faults, detect tracking failure of the APC loop, and provide disable control. The laser driver has a controlled start-up sequence which helps prevent transient glitches from being applied to the laser during power on. At start-up, the laser diode is off, SDOWN is low, and the APC loop is open. Once V_{CC} reaches ~2.8 V, the laser diode bias generator and modulation current generator circuitry are activated (if DISABLE is low). The slow-start circuitry gradually brings up the current delivered to the laser diode. From the time when V_{CC} reaches ~2.8 V until the modulation current and bias current reach 95% of their steady state value, is considered the initialization time. If DISABLE is asserted during power on, the slow-start circuitry does not activate until DISABLE is negated.

FAULT DETECTION

The fault detection circuitry monitors the operation of the ONET4211LD. If FLTMODE is set to a low level, (hard-fault mode) this circuitry disables the bias and modulation circuits and latches the SDOWN output on detection of a fault. The fault mode is reset by toggling DISABLE (for a minimum time of T_{RES}) or by toggling VCC.

Once DISABLE is toggled, SDOWN is set low and the circuit is re-initialized.

If FLTMODE is set to a high level (soft-fault mode), a fault is indicated at the SDOWN output; however, the bias and modulation circuits are not disabled. The SDOWN output is reset once the fault-causing condition disappears. Toggling DISABLE or VCC is not required.

A functional representation of the fault-detection circuitry is shown in Figure 2.

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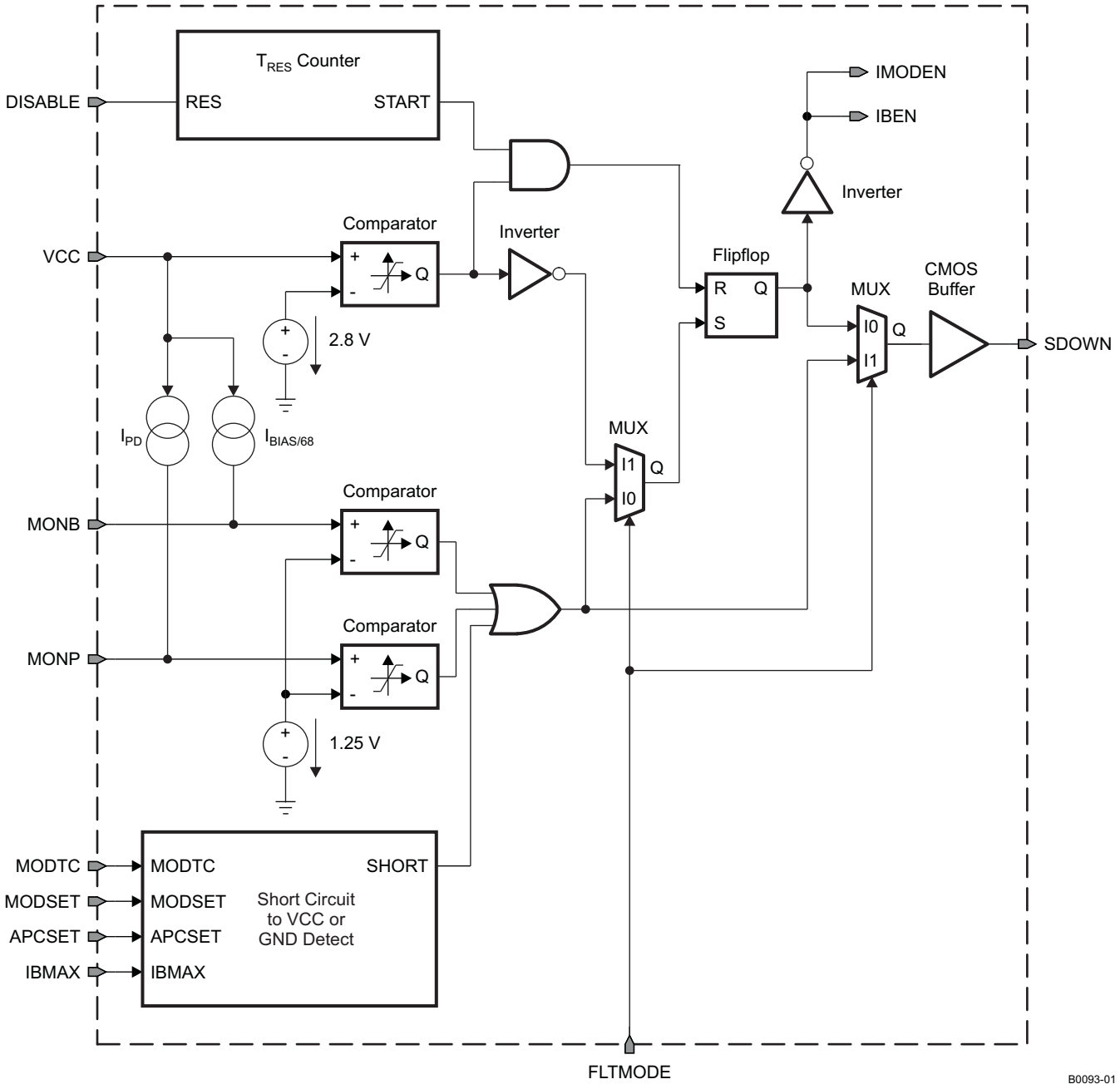

Figure 2. Functional Representation of the Fault Detection Circuitry

A fault mode is produced if the laser cathode is grounded and the photocurrent causes MONP to exceed its programmed threshold. Another fault mode can be produced if the laser diode end-of-life condition causes excessive bias current and photocurrent that results in monitor voltages (MONP, MONB) being greater than their programmed threshold. Other fault modes can occur if there are any I/O pin single-point failures (short to VCC or GND) and the monitor voltages exceed their programmed threshold (see Table 1).

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Table 1. Response to I/O-Pin Shorts to VCC or GND

PIN	FLTMODE = LOW		FLTMODE = HIGH	
	Response to Short to GND	Response to Short to V_{CC}	Response to Short to GND	Response to Short to V_{CC}
APCSET	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault, I_{MOD} unaffected	SDOWN high, I_{BIAS} and I_{MOD} unaffected	No fault
BIAS	SDOWN latched high, I_{MOD} disabled	No fault, I_{BIAS} goes to zero	SDOWN high, I_{MOD} unaffected	No fault, I_{MOD} unaffected
CAPC	No fault	No fault, I_{BIAS} goes to zero	No fault, I_{MOD} unaffected	No fault, I_{BIAS} goes to zero
DIN+	No fault, I_{MOD} disabled	No fault	No fault, I_{MOD} disabled	No fault
DIN–	No fault, I_{MOD} disabled	No fault	No fault, I_{MOD} disabled	No fault
DISABLE	Normal circuit operation	Normal circuit operation	Normal circuit operation	Normal circuit operation
IBMAX	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	SDOWN high, I_{MOD} unaffected	SDOWN high, I_{MOD} unaffected
MOD+	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault	SDOWN high, I_{BIAS} unaffected	No fault
MOD–	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault	SDOWN high, I_{BIAS} unaffected	No fault
MODSET	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault, I_{MOD} disabled	SDOWN high, I_{BIAS} unaffected	No fault, I_{MOD} disabled
MODTC	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault	SDOWN high, I_{BIAS} and I_{MOD} unaffected	No fault
MONB	No fault	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault	SDOWN high, I_{BIAS} and I_{MOD} unaffected
MONP	No fault	SDOWN latched high, I_{BIAS} and I_{MOD} disabled	No fault	SDOWN high, I_{BIAS} and I_{MOD} unaffected
OUTPOL	No fault, polarity reverses	No fault	No fault, polarity reverses	No fault
PD	No fault, I_{MOD} unaffected	No fault, I_{BIAS} goes to zero	No fault, I_{MOD} unaffected	No fault, I_{BIAS} goes to zero
SDOWN	No fault	No fault	No fault	No fault

PACKAGE

For the ONET4211LD, a small-footprint, 4-mm × 4-mm, 24-lead QFN package is used, with a lead pitch of 0,5 mm. The pinout is shown in Figure 3.

To achieve the required low thermal resistance of about 38 K/W, which keeps the maximum junction temperature below 115°C, a good thermal connection of the exposed die pad is mandatory.

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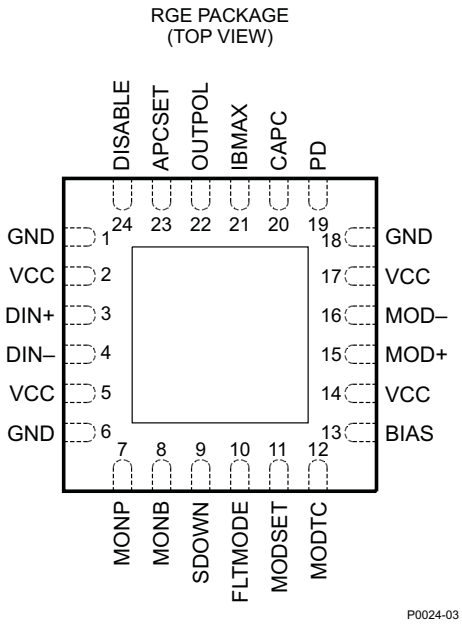

Figure 3. Pinout of the ONET4211LD in a 4-mm × 4-mm, 24-Lead QFN Package (Top View)

TERMINAL FUNCTIONS

TERMINAL		TYPE	DESCRIPTION
NAME	NO.		
APCSET	23	Analog-in	Set photodiode reference current with resistor to GND.
BIAS	13	Analog-out	Laser-diode bias-current sink. Connect to laser cathode.
CAPC	20	Analog	APC loop capacitor
DIN+	3	CML-in	Non-inverted data input. On-chip, 50-Ω terminated to VCC.
DIN–	4	CML-in	Inverted data input. On-chip, 50-Ω terminated to VCC.
DISABLE	24	LVTTL-in	Disable modulation and bias-current outputs.
FLTMODE	10	CMOS-in	Fault mode selection input. If a low level is applied to this pin, any fault event is latched and the bias and modulation currents are disabled in a fault condition. Toggling of DISABLE or VCC resets the fault condition. If pin is set to a high level, fault events are flagged at the SDOWN output but not latched. The bias and modulation currents are not disabled. SDOWN is reset once the fault condition disappears.
GND	1, 6, 18, EP	Supply	Circuit ground. The exposed die pad (EP) must be grounded.
IBMAX	21	Analog-in	Set maximum laser diode current with resistor to GND.
MOD+	15	Analog-out	Laser modulation current output. Connect to laser cathode. Avoid usage of vias on board.
MOD–	16	Analog-out	Complementary laser modulation current output. Connect to VCC adjacent to anode of laser diode. Avoid usage of vias on board.
MODSET	11	Analog-in	Set temperature-independent modulation current with resistor to GND.
MODTC	12	Analog-in	Set modulation-current temperature compensation with resistor to GND.
MONB	8	Analog-out	Bias current monitor. Sources 1/68 of the bias current.
MONP	7	Analog-out	Photodiode current monitor. Sources a current identical to the photodiode current.
OUTPOL	22	LVTTL-in	Alters modulation current output polarity. Open or high: normal polarity; low: inverted polarity. OUTPOL is pulled up internally. Normal polarity: when DIN+ is high, current is sunk into MOD+.
PD	19	Analog-in	Monitor photodiode input. Connect to photodiode anode for APC. Sinks the photodiode current to GND.
SDOWN	9	LVTTL-out	Fault detection flag
VCC	2, 5, 14, 17	Supply	3.3-V, ±10% supply voltage

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ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)(1)

V_{CC}	Supply voltage(2)	–0.3 V to 4 V
I_{IBIAS}	Current into BIAS	–20 mA to 120 mA
I_{IMOD+}, $I_{IMOD–}$	Current into MOD+, MOD–	–20 mA to 120 mA
I_{PD}	Current into PD	–5 mA to 5 mA
V_{DIN+}, $V_{DIN–}$, $V_{DISABLE}$, V_{MONB}, V_{MONP}, $V_{FLTMODE}$, V_{SDOWN}	Voltage at DIN+, DIN–, DISABLE, MONB, MONP, FLTMODE, SDOWN(2)	–0.3 V to 4 V
V_{CAPC}, V_{IBMAX}, V_{MODSET}, V_{APCSET}, V_{MODTC}	Voltage at CAPC, IBMAX, MODSET, APCSET, MODTC(2)	–0.3 V to 3 V
V_{MOD+}, $V_{MOD–}$	Voltage at MOD+, MOD–(2)	0.6 V to VCC + 1.5 V
V_{BIAS}	Voltage at BIAS(2)	1 V to 3.5 V
ESD	ESD rating at all pins except MOD+, MOD–	2 kV (HBM)
	ESD rating at MOD+, MOD-	1 kV (HBM)
$T_{J,max}$	Maximum junction temperature	150°C
T_{STG}	Storage temperature range	–65°C to 150°C
T_A	Characterized free-air operating temperature range	–40°C to 85°C
T_{LEAD}	Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

(1) 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 under *recommended operating conditions* is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

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RECOMMENDED OPERATING CONDITIONS

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	3	3.3	3.6	V
T_A	Operating free-air temperature	–40		85	°C

DC ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC}	Supply voltage		3	3.3	3.6	V
I_{VCC}	Supply current	I_{MOD} = 30 mA, I_{BIAS} = 20 mA (excluding I_{MOD}, I_{BIAS})		22		mA
		I_{MOD} = 60 mA, I_{BIAS} = 100 mA (excluding I_{MOD}, I_{BIAS})			45	mA
I_{BIAS}	Bias current range				100	mA
$I_{BIAS-OFF}$	Bias off-current	DISABLE = high or hard-fault mode; V_{BIAS} ≤ 3.5 V			25	µA
	Bias overshoot	During module hot plugging. V_{CC} turnon time must be ≤ 0.8 s			10%	
	Bias current temperature stability	APC open loop	–480		480	ppm/°C
	Bias current absolute accuracy(1)	I_{BIAS} ≥ 1 mA	–15%		15%	
		I_{BIAS} = 1 mA, T_A = 25°C		±15%		
	Bias current monitor gain, I_{BIAS}/I_{MONB}			68		mA/ mA
	MONB and MONP threshold range	A fault is never detected for $V_{MONB/P}$ ≤ 1 V and a fault always occurs for $V_{MONB/P}$ ≥ 1.35 V	1	1.25	1.35	V
	PD current monitor gain, I_{PD}/I_{MONP}			1		mA/mA
V_{ID}	Differential input signal		200		1600	mV_{PP}
	SDOWN output high voltage	I_{OH} = 100 µA sourcing	2.4			V
	SDOWN output low voltage	I_{OL} = 1 mA sinking			0.4	V
	DISABLE input impedance		4.7	7.4	10	kΩ
	DISABLE input high voltage		2			V
	DISABLE input low voltage				0.8	V
V_{PD}	Monitor diode voltage				1.6	V
	Monitor diode dc current range		18		1500	µA

(1) Absolute accuracy refers to part-to-part variation.

AC ELECTRICAL CHARACTERISTICS

Typical operating condition is at V_{CC} = 3.3 V, I_{MOD} = 30 mA, I_{BIAS} = 20 mA and T_A = 25°C.
over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Data rate		4.25			Gbps
I_{MOD}	Modulation current range	Current into MOD+/MOD– pin; V_{MOD+}, $V_{MOD–}$ ≥ 0.6 V	5		85	mA
$I_{MOD-OFF}$	Modulation off-current	DISABLE = high or hard-fault occurred			25	µA
	Modulation current stability		–600		600	ppm/°C
	Modulation current absolute accuracy(1)	I_{MOD} = 10 mA		±40%		
		I_{MOD} = 80 mA		±25%		

(1) Absolute accuracy refers to part-to-part variation.

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AC ELECTRICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V, I_{MOD} = 30 mA, I_{BIAS} = 20 mA and T_A = 25°C.
over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Modulation current temperature compensation (2)	R_{MODTC} = 3.125 kΩ		8300		ppm/°C
		R_{MODTC} open		630		
t_r	Output rise time (20% to 80%)	V_{MOD+} ≥ 1 V, $V_{MOD–}$ ≥ 1 V, I_{MOD} = 30 mA		35	55	ps
t_f	Output fall time (80% to 20%)	V_{MOD+} ≥ 1 V, $V_{MOD–}$ ≥ 1 V, I_{MOD} = 30 mA		35	55	ps
t_{OFF}	Disable assert time (see Figure 4)	Time from rising edge of DISABLE until output currents fall below the maximum limits of $I_{MOD-OFF}$ and $I_{BIAS-OFF}$		0.06	5	µs
t_{ON}	Disable negate time (see Figure 5)	Time from falling edge of DISABLE until output is 90% of nominal		80		µs
t_{INIT}	Time to initialize	From power on or negation of SDOWN using DISABLE		80		µs
t_{FAULT}	Fault assert time	Time from fault to SDOWN rising edge		3.3	50	µs
t_{RESET}	DISABLE reset (see Figure 6)	Maximum spike pulse duration at DISABLE being ignored			0.8	µs
		DISABLE high time required to reset SDOWN			6	µs
	Output overshoot/undershoot		–29%		29%	
	Random jitter	I_{MOD} = 60 mA		0.6	0.9	ps_{RMS}
DJ	Deterministic jitter (3)	10 mA ≤ I_{MOD} ≤ 60 mA, with K28.5 pattern at 4.25 Gbps		15	30	ps_{p-p}
		10 mA ≤ I_{MOD} ≤ 60 mA, with 2^{23} –1 PRBS or equivalent pattern at 2.67 Gbps		13	32	ps_{p-p}
		K28.5 pattern at 1.06 Gbps		5		ps_{p-p}
		2^{23} – 1 PRBS or equivalent pattern at 155 Mbps		10		ps_{p-p}

(2) For a given external resistor connected to the MODTC pin, the modulation-current temperature compensation varies due to part-to-part variations.
(3) Jitter measured at positive edge and negative edge crossing of eye diagram.

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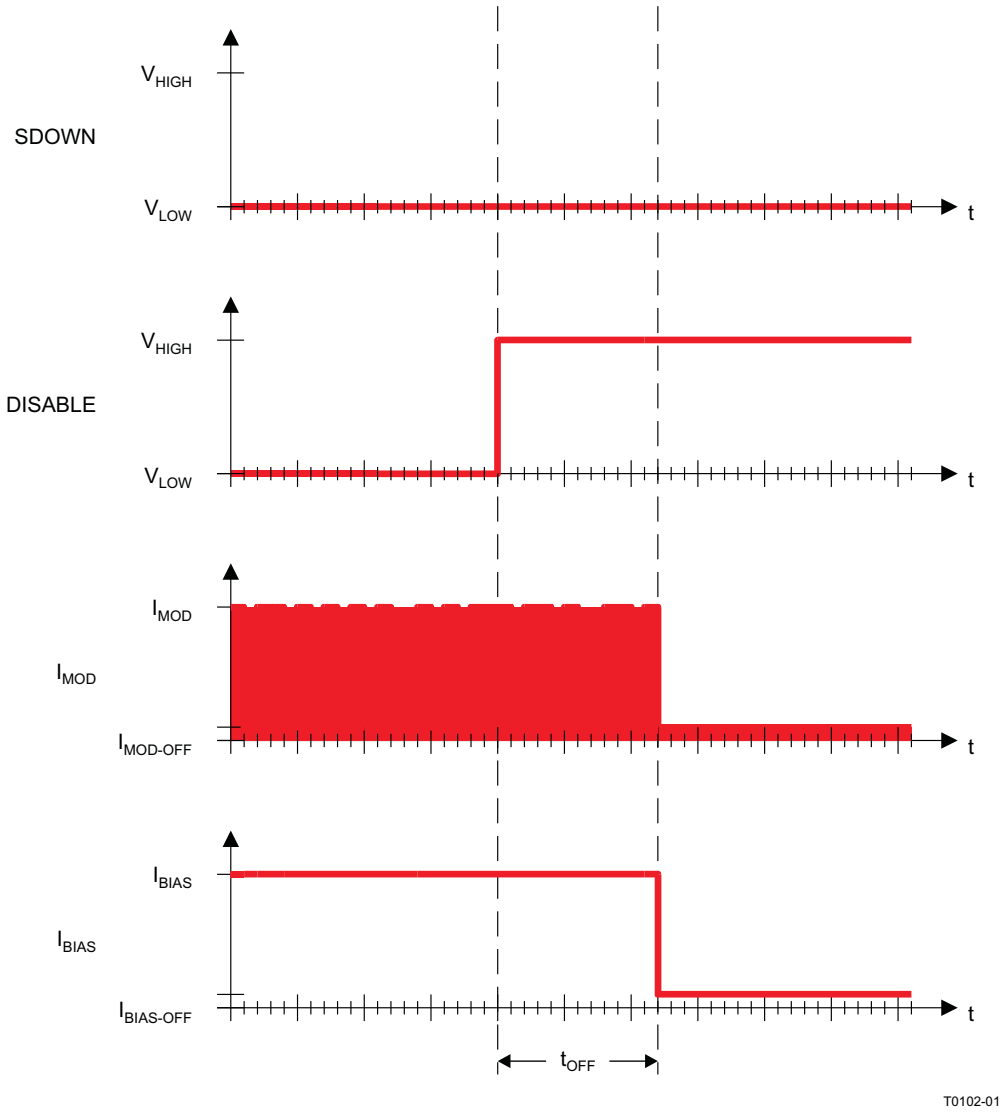

Figure 4. DISABLE Assert Time TOFF

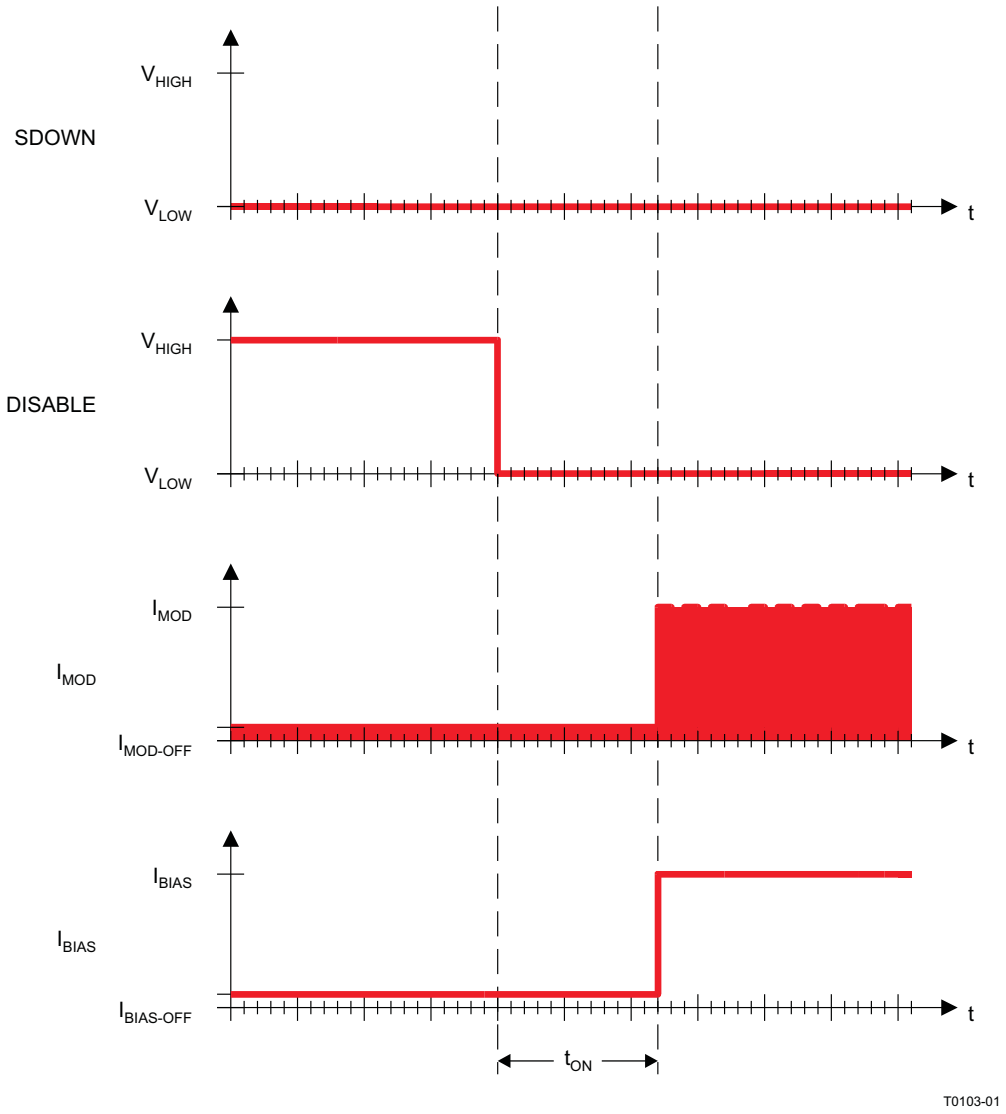

Figure 5. DISABLE Negate Time TON

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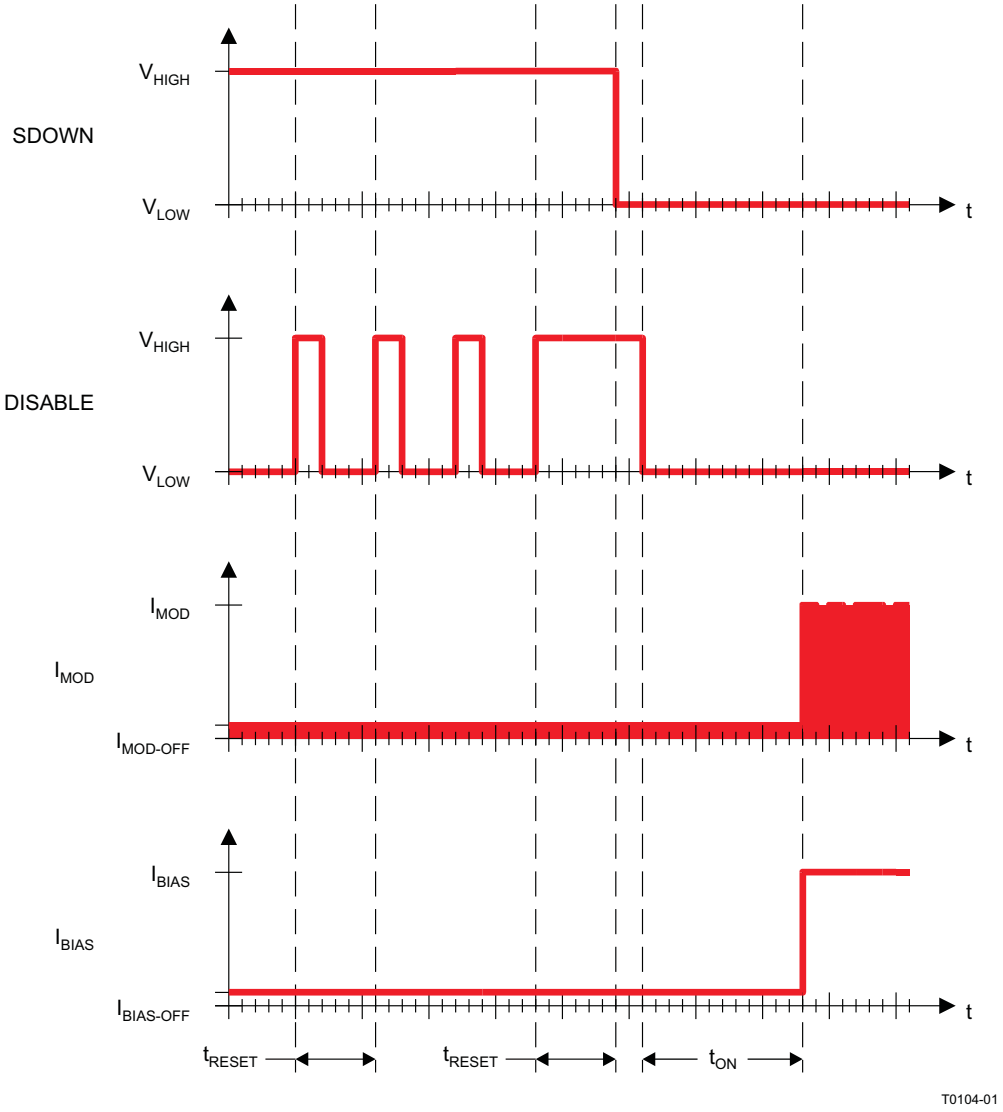

Figure 6. SDOWN Reset Time TRESET

TYPICAL CHARACTERISTICS

Typical operating condition is at V_{CC} = 3.3 V, I_{MOD} = 30 mA, I_{BIAS} = 20 mA and T_A = 25°C (unless otherwise noted)

ELECTRICAL EYE-DIAGRAM AT 4.25 Gbps WITH K28.5 PATTERN

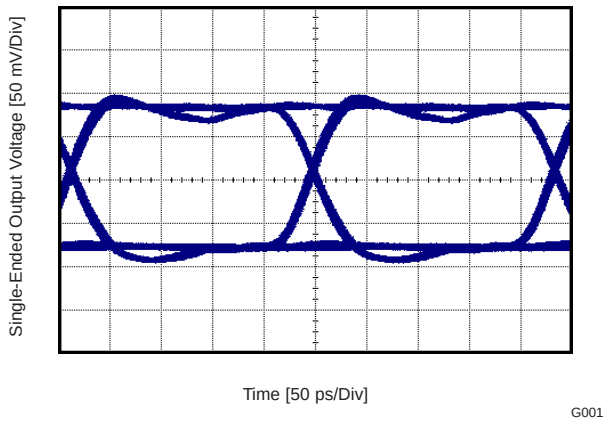

Figure 7.

ELECTRICAL EYE-DIAGRAM AT 2.125 Gbps WITH K28.5 PATTERN

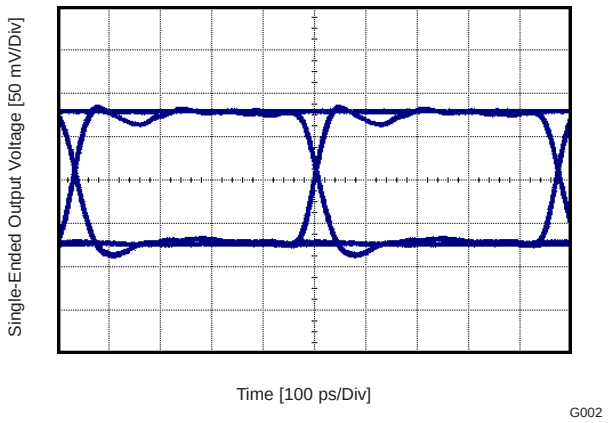

Figure 8.

ELECTRICAL EYE-DIAGRAM AT 1.0625 Gbps WITH K28.5 PATTERN

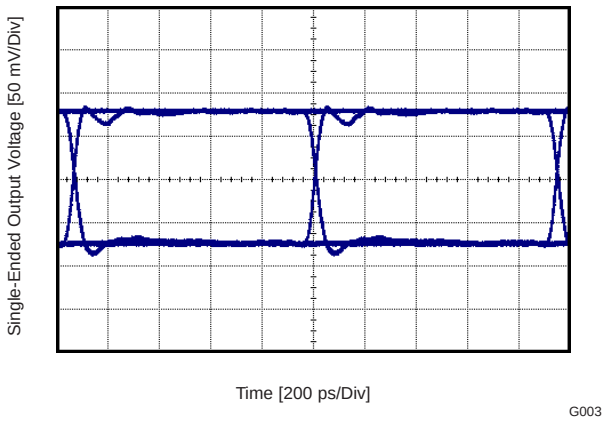

Figure 9.

DETERMINISTIC JITTER vs MODULATION CURRENT

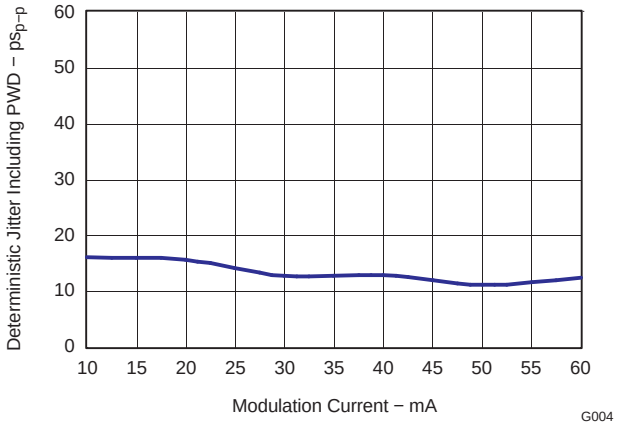

Figure 10.

RANDOM JITTER vs MODULATION CURRENT

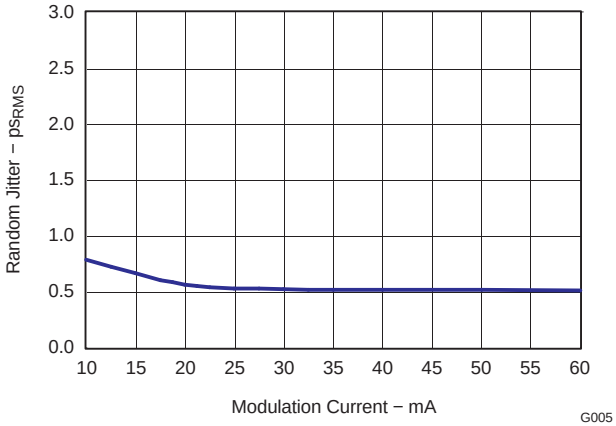

Figure 11.

RANDOM JITTER vs TEMPERATURE

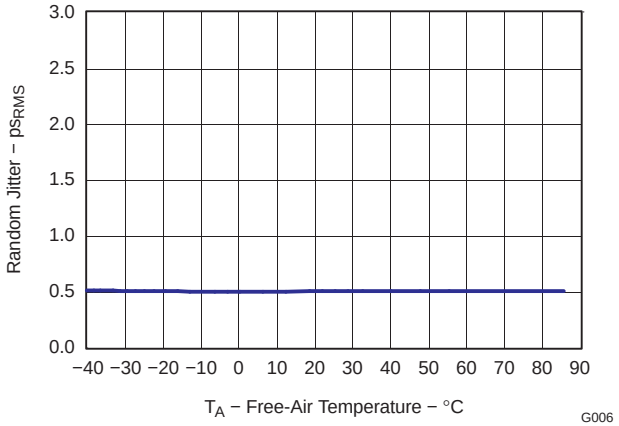

Figure 12.

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TYPICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V, I_{MOD} = 30 mA, I_{BIAS} = 20 mA and T_A = 25°C (unless otherwise noted)

RISE TIME AND FALL TIME vs MODULATION CURRENT

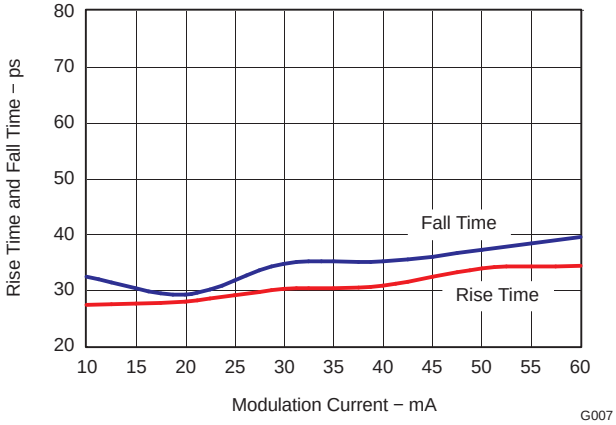

Figure 13.

BIAS-MONITOR CURRENT GAIN I_{MONB}/I_{BIAS} vs BIAS CURRENT I_{BIAS}

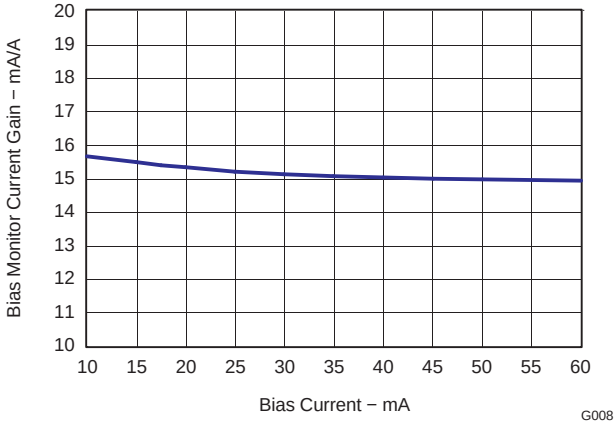

Figure 14.

BIAS CURRENT I_{BIAS} IN OPEN-LOOP MODE vs EXTERNAL RESISTOR $R_{BIASMAX}$

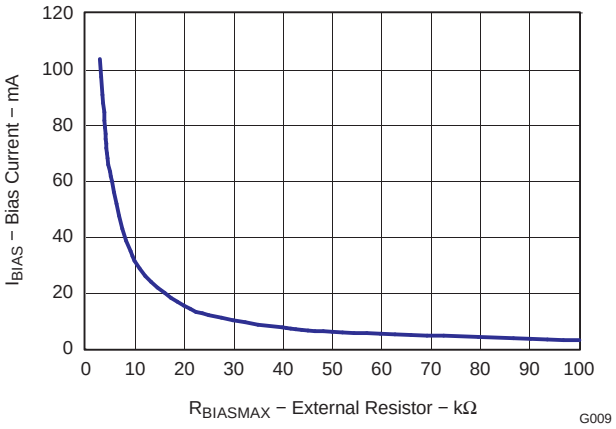

Figure 15.

MODULATION CURRENT I_{MOD} vs EXTERNAL RESISTOR R_{MODSET}

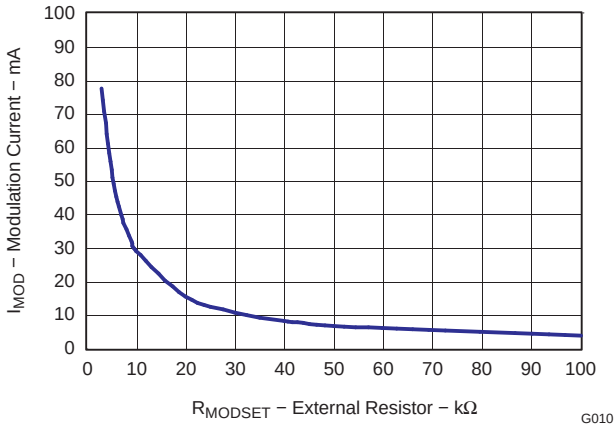

Figure 16.

MONITOR DIODE CURRENT I_{PD} vs EXTERNAL RESISTOR R_{APCSET}

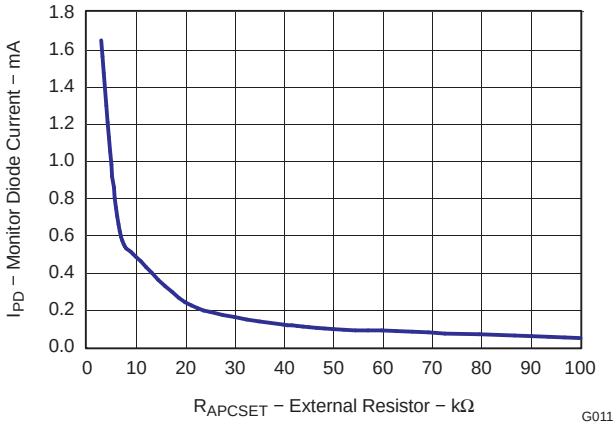

Figure 17.

PHOTODIODE MONITOR GAIN I_{MONP}/I_{PD} vs TEMPERATURE

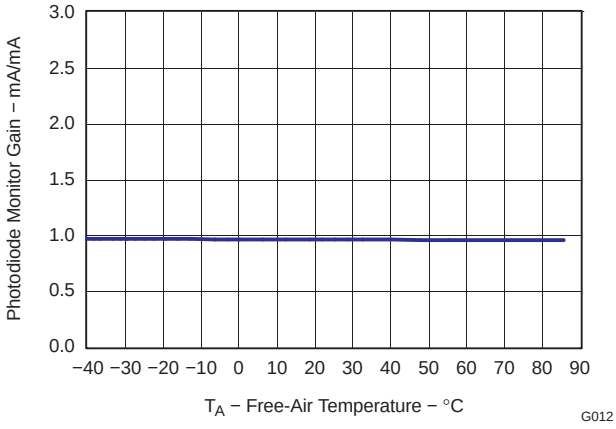

Figure 18.

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TYPICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V, I_{MOD} = 30 mA, I_{BIAS} = 20 mA and T_A = 25°C (unless otherwise noted)

BIAS CURRENT MONITOR GAIN I_{MONB}/I_{BIAS} vs TEMPERATURE

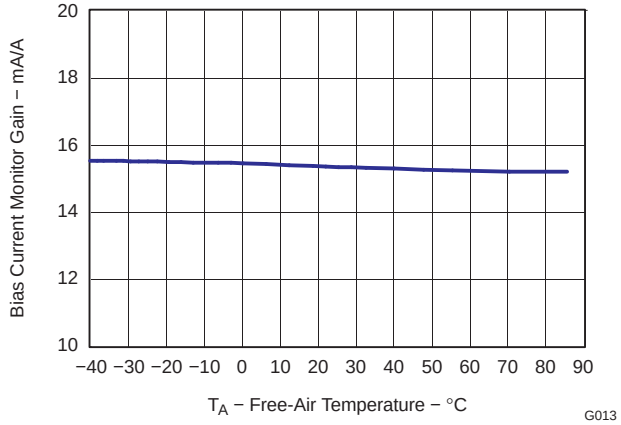

Figure 19.

SUPPLY CURRENT (excl. I_{MOD} and I_{BIAS}) vs TEMPERATURE

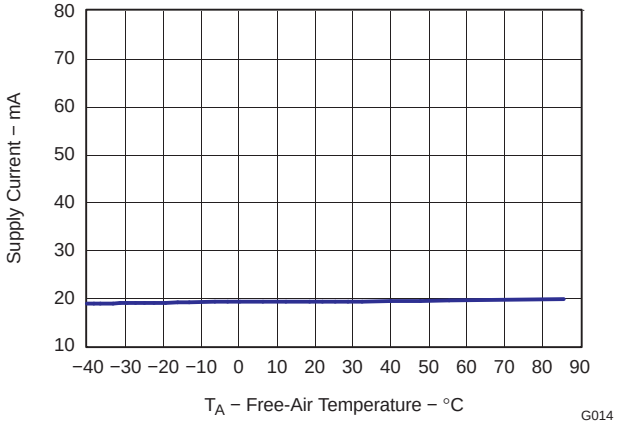

Figure 20.

MODULATION CURRENT vs TEMPERATURE FOR DIFFERENT SETTINGS OF R_{MODTC}

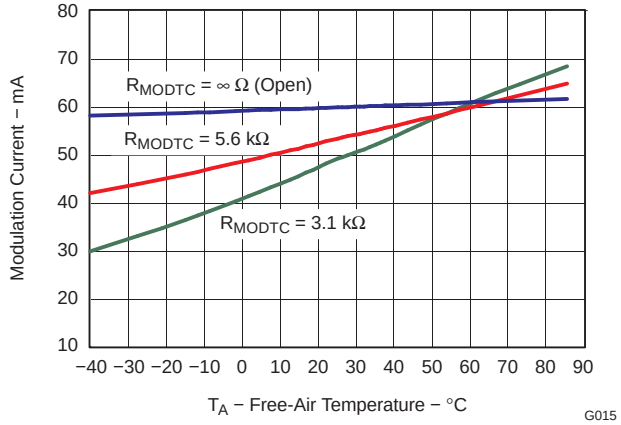

Figure 21.

DISABLE ASSERT TIME T_{OFF}

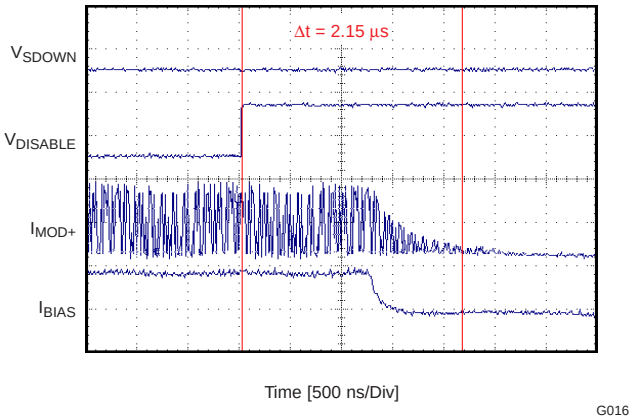

Figure 22.

DISABLE NEGATE TIME T_{ON}

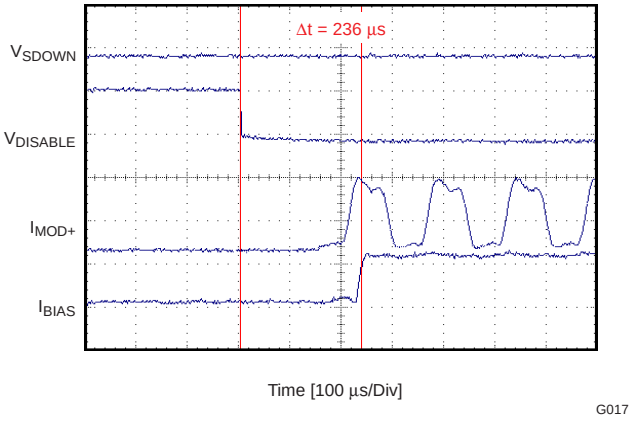

Figure 23.

SHUTDOWN RESET TIME T_{RESET}

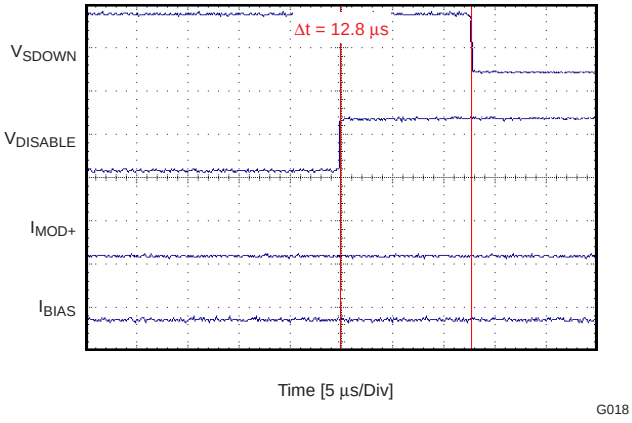

Figure 24.

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APPLICATION INFORMATION

Figure 25 shows the ONET4211LD connected with a dc-coupled interface to the laser diode; alternatively, the ONET4211LD laser driver can be ac-coupled.

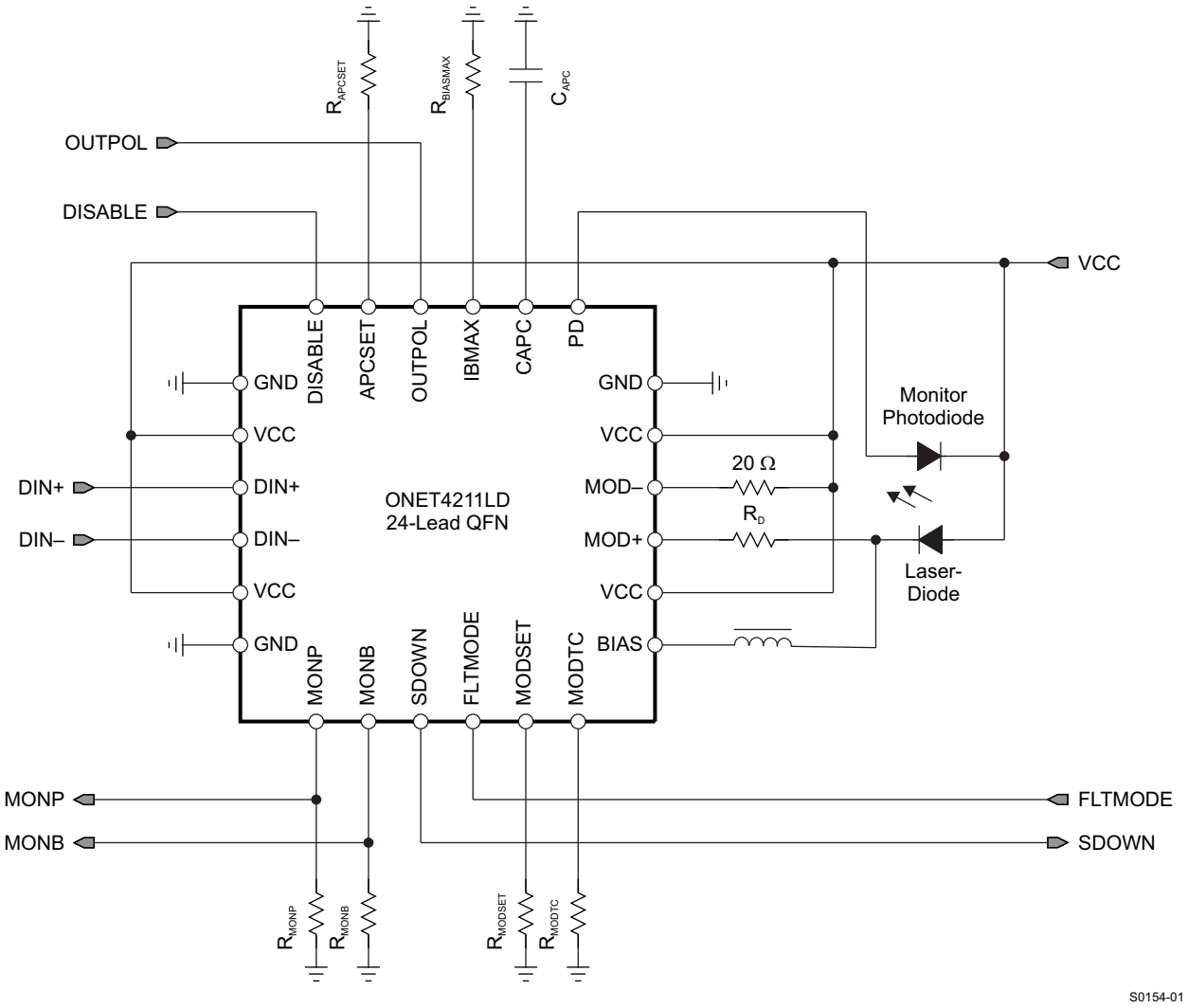

Figure 25. Basic Application Circuit With DC-Coupled Interface Between the ONET4211LD and the Laser Diode

APC loop instability can occur with large inductive loading on the BIAS pin. To ensure loop stability in this case, it is recommended to connect a 1-nF capacitor to ground at the BIAS pin.

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SELECT A LASER

In the design example according to Figure 25, the ONET4211LD is dc-coupled to a typical communication-grade laser diode capable of operating at 4.25 Gb/s with the following specifications shown in Table 2.

Table 2. Laser Diode Specifications

PARAMETER		VALUE	UNITS
λ	Wavelength	1310	nm
P_{AVG}	Average Optical Output Power	5	mW
I_{TH}	Threshold current	10	mA
ρ_{MON}	Laser-to-monitor transfer	0.05	mA/mW
η	Laser slope efficiency	0.2	mW/mA

SELECT APCSET RESISTOR

When the APC loop is activated, the desired average optical output power P_{AVG} is defined by characteristics of the monitor diode and by the APCSET resistor R_{APCSET}. The relation between the monitor photodiode current I_{PD} and the average optical output power P_{AVG} is given by Equation 7:

$$I_{PD}\,[A] = P_{AVG}\,[W] \times \rho_{MON}[A/W] \tag{7}$$

The R_{APCSET} resistor is calculated by Equation 8:

$$R_{APCSET}[\Omega] = \frac{4.69\ V}{I_{PD}\,[A]} = \frac{4.69\ V}{P_{AVG}[W] \times \rho_{MON}[A/W]} \tag{8}$$

For the laser diode specified in Table 2 and the desired average optical output power of 5 mW, R_{APCSET} is calculated as in Equation 9:

$$R_{APCSET}[\Omega] = \frac{4.69\ V}{P_{AVG}[W] \times \rho_{MON}[A/W]} = \frac{4.69\ V}{5\ mW \times 0.05\ mA/mW} = 18.75\ k\Omega \tag{9}$$

Note that the monitor photodiode current I_{PD} must not exceed 1.5 mA, corresponding to a minimum APCSET resistor $R_{APCSET,MIN}$ = 3.1 kΩ.

SELECT MODSET RESISTOR

Modulation current I_{MOD} is dependent on the required optical output peak-to-peak power P_{p-p} or the average optical power P_{AVG}. I_{MOD} can be calculated using the laser slope efficiency η and the desired extinction ratio r_e:

$$I_{MOD}[A] = \frac{P_{p-p}[W]}{\eta[W/A]} = \frac{2 \times P_{AVG}[W] \times \frac{r_e - 1}{r_e + 1}}{\eta[W/A]} \tag{10}$$

Using the laser diode parameters from Table 2 and assuming an extinction ratio r_e = 8 dB (X6.3) for an average optical power P_{AVG} = 5 mW, the required modulation current results as:

$$I_{MOD} = \frac{2 \times 5\ mW \times \frac{6.3 - 1}{6.3 + 1}}{0.2\ mW/mA} = 36.3\ mA \tag{11}$$

The modulation current is adjustable, with a selectable temperature coefficient TC according to the relation:

$$I_{MOD}[A] = I_{MOD0}[A] \times \left(1 + TC \times \left(T[^oC] - T_0[^oC]\right)\right) \tag{12}$$

where T is the ambient temperature in °C and T_0 is the reference temperature (T_0 = 60°C).

The temperature coefficient TC of the modulation current is typically adjustable between 630 ppm/°C and 8300 ppm/°C.

For calculation of the required external resistor R_{MODSET} for a given modulation current and a given temperature, the formula can be modified as follows:

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$$R_{MODSET}[\Omega] = \frac{265\ V}{I_{MOD}[A]} \times \left(1 + TC \times \left(T[^oC] - T_0[^oC]\right)\right) \quad (13)$$

If 4000 ppm/°C is the desired temperature coefficient and the modulation current from the preceding example, 36.3 mA, is required at a temperature of 25°C, the MODSET resistor R_{MODSET} is given by Equation 14.

$$R_{MODSET}[\Omega] = \frac{265\ V}{36.3\ mA} \times \left(1 + \frac{4000\ ppm}{^oC} \times (25^oC - 60^oC)\right) = 6.3\ k\Omega \quad (14)$$

Note that the modulation current I_{MOD} must not exceed 85 mA over the complete temperature range, corresponding to a minimum MODSET resistor $R_{MODSET,MIN}$ = 3.1 kΩ.

SELECT MODTC RESISTOR

The R_{MODTC} resistor is used to program a modulation temperature coefficient that can be used to compensate for the decreased slope efficiency of the laser at a higher temperature. The temperature coefficient TC_{LD} of the laser can be calculated using the slope efficiency η_1 at temperature T_1 and η_2 at temperature T_2 as shown in Equation 15:

$$TC_{LD}\left[\frac{1}{^oC}\right] = \frac{\eta_2[W/A] - \eta_1[W/A]}{\eta_1[W/A] \times \left(T_2[^oC] - T_1[^oC]\right)} \times 10^6 \quad (15)$$

As an example, for the laser in Table 2, the slope efficiency at temperature T_1 = 25°C is η_1 = 0.2 mW/mA. At temperature T_2 = 85°C, the slope efficiency is η_2 = 0.15 mW/mA. The corresponding temperature coefficient TC_{LD} of the laser can be calculated:

$$TC_{LD} = \frac{0.15\ mW/mA - 0.2\ mW/mA}{0.2\ mW/mA \times (85^oC - 25^oC)} \times 10^6 = -4167\frac{1}{^oC} \quad (16)$$

The MODTC resistor R_{MODTC} can be used to compensate the laser temperature coefficient TC_{LD} in order to maintain the same optical output swing within a range of 630 ppm up to 8300 ppm. For this, R_{MODTC} may be programmed as follows:

$$R_{MODTC} = \frac{24\ \Omega}{(TC - 630\ ppm) \times \left[\frac{1}{^oC}\right] \times {}^oC} \quad (17)$$

To compensate for the decreased slope efficiency of the laser in Table 2, TC must be 4167 ppm/°C.

This leads to the following MODTC resistor R_{MODTC}:

$$R_{MODTC} = \frac{24\ \Omega}{\frac{4167\ ppm - 630\ ppm}{^oC}\ {}^oC} = 6.8\ k\Omega \quad (18)$$

SELECT BIASMAX RESISTOR

The BIASMAX resistor $R_{BIASMAX}$ is used to limit the bias current applied to the laser diode.

To calculate $R_{BIASMAX}$, the maximum threshold current at 85°C and end of life must be determined. The maximum bias current for the dc-coupled interface can be approximated by Equation 19.

$$I_{BIASMAX}[A] = I_{THMAX}[A] \quad (19)$$

$R_{BIASMAX}$ can be set by Equation 20.

$$R_{BIASMAX}[\Omega] = \frac{343\ V}{I_{BIASMAX}[A]} = \frac{343\ V}{I_{THMAX}[A]} \quad (20)$$

For the example laser diode, the maximum threshold current is 40 mA at 85°C. Therefore, $R_{BIASMAX}$ can be approximated by Equation 21.

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$$R_{BIASMAX} = \frac{343\ V}{40\ mA} = 8.6\ k\Omega \quad (21)$$

SELECT V_{MONB} AND V_{MONP} RANGE

Monitoring the bias current is achieved by taking the fractional (1/68) bias current and developing a voltage across an external resistor to ground. Equation 22 provides the value for V_{MONB} for a resistor value equal to 768 Ω.

$$V_{MONB}[V] = \frac{R_{MONB}[\Omega] \times I_{BIAS}[A]}{68} = \frac{768\ \Omega \times I_{BIAS}[A]}{68} = 11.29\ \Omega \times I_{BIAS}[A] \quad (22)$$

Monitoring of the photo current is achieved by taking a mirror of I_{PD} and developing a voltage across an external resistor to ground. Equation 23 provides the value for V_{MONP} for a resistor equal to 200 Ω.

$$V_{MONP}[V] = R_{MONP}[\Omega] \times I_{PD}[A] = 200\ \Omega \times I_{PD}[A] \quad (23)$$

LASER DIODE INTERFACE

The output stage of the ONET4211LD is optimized for driving a 20-Ω load. The combination of a damping resistor, R_D, along with the resistance of the laser diode, must be 20 Ω for impedance matching. The suggested typical value for R_D is 6 Ω to 15 Ω. A bypass capacitor of 10 nF placed close to the laser anode also helps to optimize performance.

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Revision History

Changes from Original (November 2006) to Revision A **Page**

- Changed Disable negate time From: Typ = 200 To: Typ = 80 10
- Changed Time to initialize From: Typ = 200 To: Typ = 80 10
- Changed DISABLE reset Maximum spike pulse From: Max = 10 To: Max = 0.8 10
- Changed DISABLE high time From: Min = 20 To: Max = 6 10

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
ONET4211LDRGER	Obsolete	Production	VQFN (RGE) | 24	-	-	Call TI	Call TI	-40 to 85	ONET 4211L
ONET4211LDRGET	Obsolete	Production	VQFN (RGE) | 24	-	-	Call TI	Call TI	-40 to 85	ONET 4211L

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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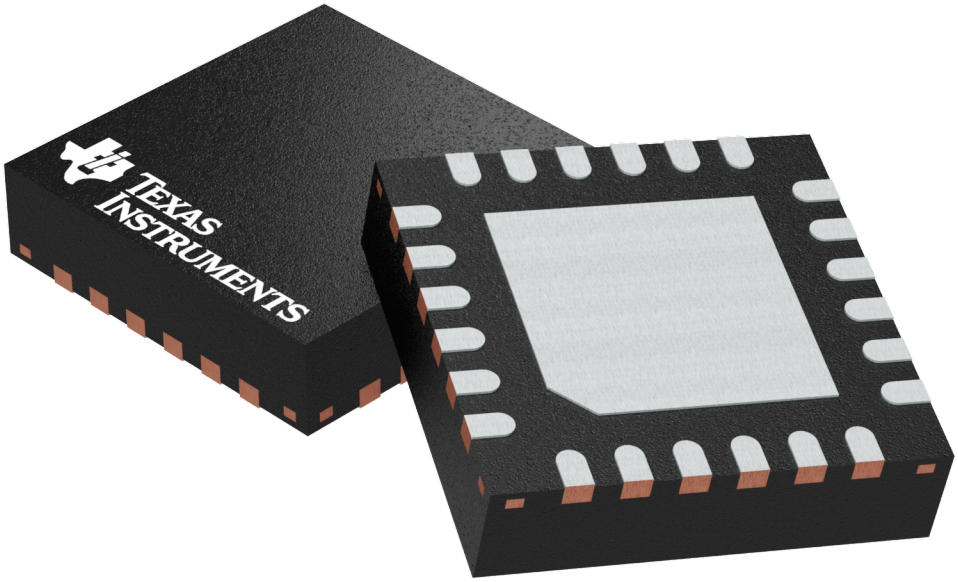
RGE 24

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



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