155-Mbps to 4.25-Gbps LASER DRIVER

Check for Samples: ONET4201LD

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**
- **Active Back-Termination at the Output**
- **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 ONET4201LD 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.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DETAILED DESCRIPTION

BLOCK DIAGRAM

A simplified block diagram of the ONET4201LD 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 below.

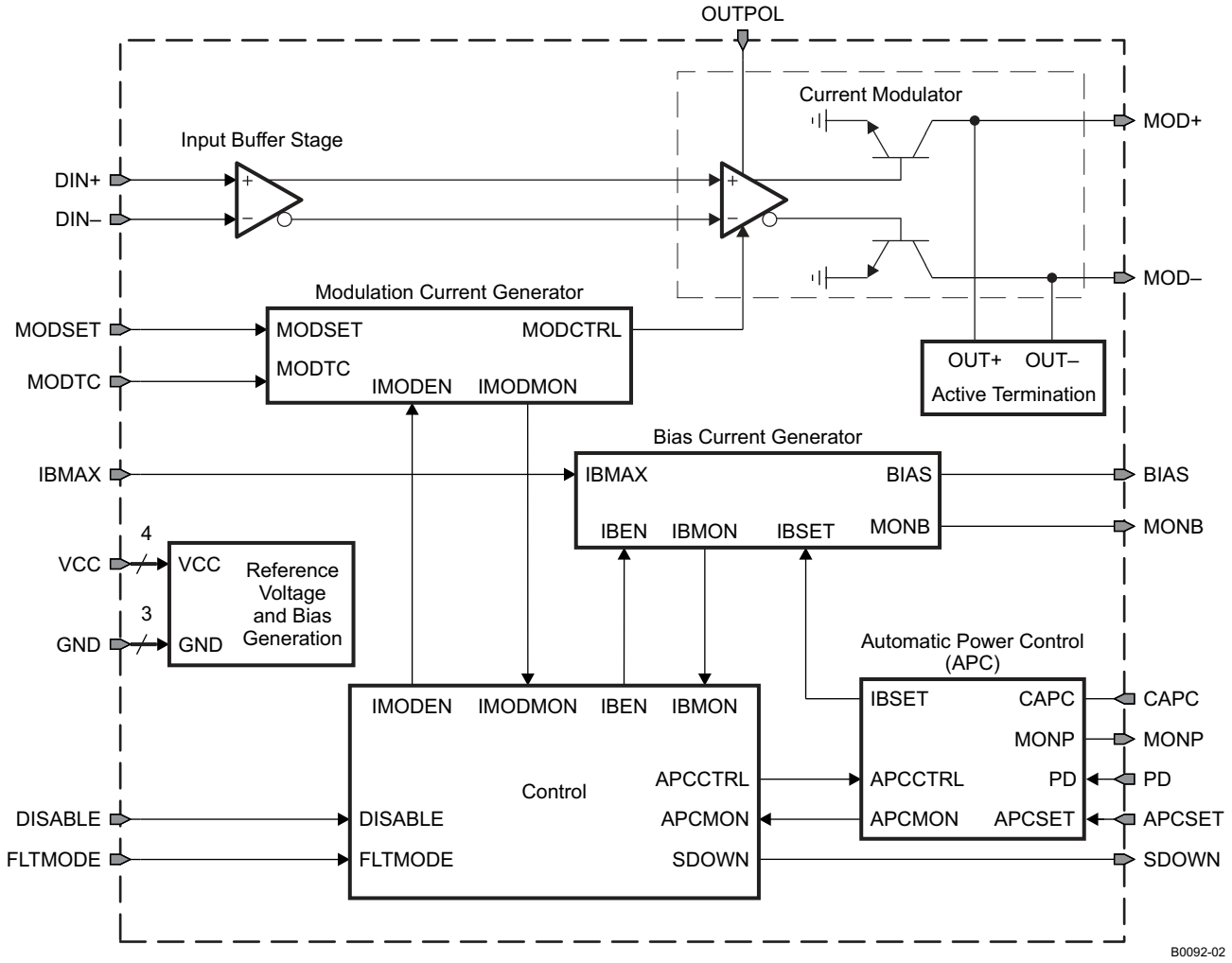


Figure 1. Simplified Block Diagram of the ONET4201LD

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 mainly consists of two common-emitter output transistors and the required driver circuitry. Depending on 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 both cases, the maximum modulation current is 85 mA. The modulation output is optimized for driving a 20-Ω load.

For optimum performance when driving a laser diode over a 20-Ω transmission line, the ONET4201LD provides active 20-Ω back-termination, which minimizes jitter caused by reflections.

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 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 ONET4201LD 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}, which 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:

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

This current limit establishes the maximum bias current available in closed loop mode, as well as in transient fault conditions such as shorts at the PD pin to ground or delayed laser power up.

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.

The 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:

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

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

As with any negative-feedback system design, care must be taken to assure 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 modulation 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 functions of this block are 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 that 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 ONET4201LD. 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 V_{CC}.

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.

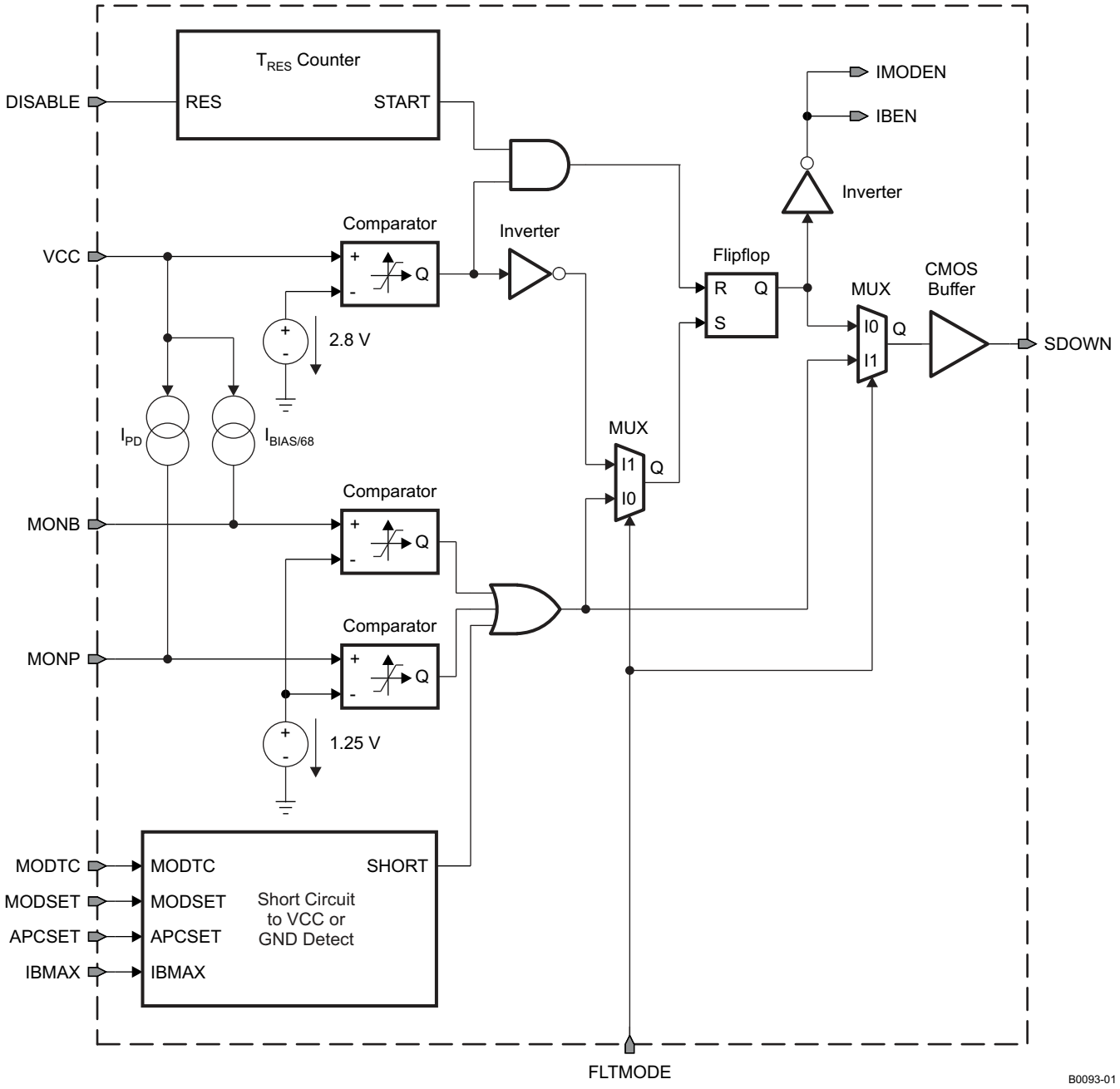


Figure 2. Functional Representation of the Fault Detection Circuitry

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 photodiode current 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 V_{CC} or GND) and the monitor voltages exceed their programmed threshold (see Table 1).

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, disables I_{MOD}	SDOWN high, I_{BIAS} unaffected	No fault, disables I_{MOD}
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 ONET4201LD, 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.

In order 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.

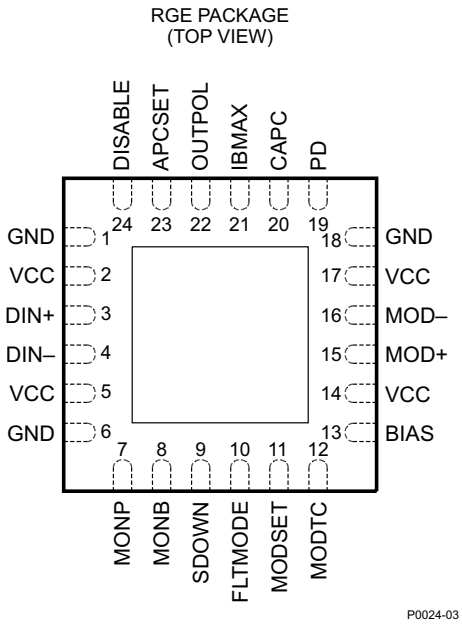


Figure 3. Pinout of the ONET4201LD in a 4-mm × 4-mm, 24-Lead QFN Package (Top View)

TERMINAL FUNCTIONS

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
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	Noninverted 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

ABSOLUTE MAXIMUM RATINGS

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

		VALUE	UNIT
V_{CC}	Supply voltage(2)	–0.3 to 4	V
I_{IBIAS}	Current into BIAS	–20 to 120	mA
I_{IMOD+}, $I_{IMOD–}$	Current into MOD+, MOD–	–20 to 120	mA
I_{PD}	Current into PD	–5 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 to 4	V
V_{CAPC}, V_{IBMAX}, V_{MODSET}, V_{APCSET}, V_{MODTC}	Voltage at CAPC, IBMAX, MODSET, APCSET, MODTC(2)	–0.3 to 3	V
V_{MOD+}, V_{MOD-}	Voltage at MOD+, MOD–(2)	0.6 to VCC+1.5	V
V_{BIAS}	Voltage at BIAS(2)	1 to 3.5	V
ESD	ESD rating at all pins except MOD+, MOD–	2	kV (HBM)
	ESD rating at MOD+, MOD-	1	
$T_{J,max}$	Maximum junction temperature	150	°C
T_{stg}	Storage temperature range	–65 to 150	°C
T_A	Characterized free-air operating temperature range	–40 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.

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})		32		mA
		I_{MOD} = 60 mA, I_{BIAS} = 100 mA (excluding I_{MOD}, I_{BIAS})			55	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} turn on 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	mVp-p
	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

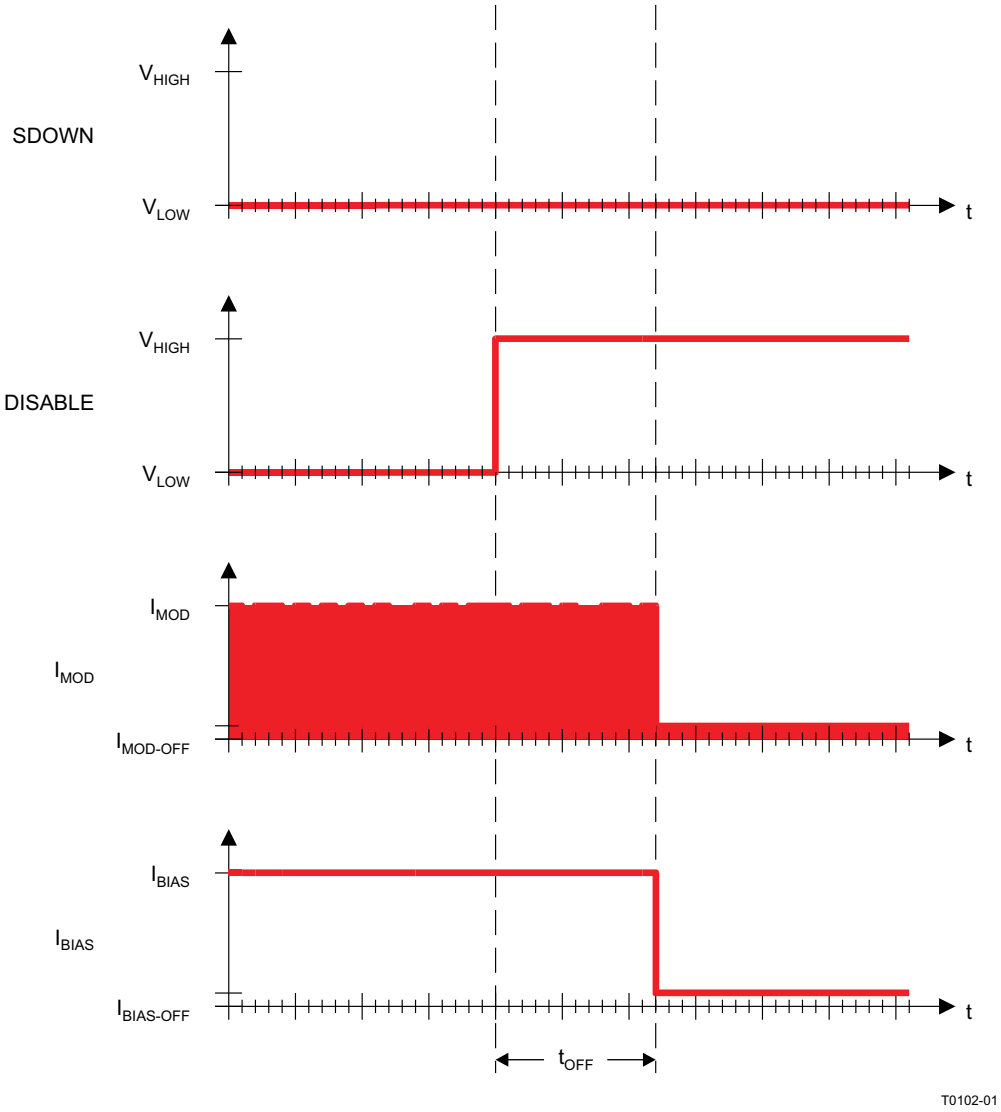
(1) Absolute accuracy refers to part-to-part variation.

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} = 50 mA		±25%		
		I_{MOD} = 80 mA		±20%		
	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		55	75	ps
t_f	Output fall time (20% to 80%)	V_{MOD+} ≥ 1 V, $V_{MOD–}$ ≥ 1 V, I_{MOD} = 30 mA		55	75	ps
t_{OFF}	Disable assert time (see Figure 4)	Time from rising edge of DISABLE to when 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 to when 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 length at DISABLE being ignored			0.8	µs
		Time DISABLE must be high to reset SDOWN			6	µs
	Output overshoot/undershoot		–13.5%		13.5 %	
	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}

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


SDOWN
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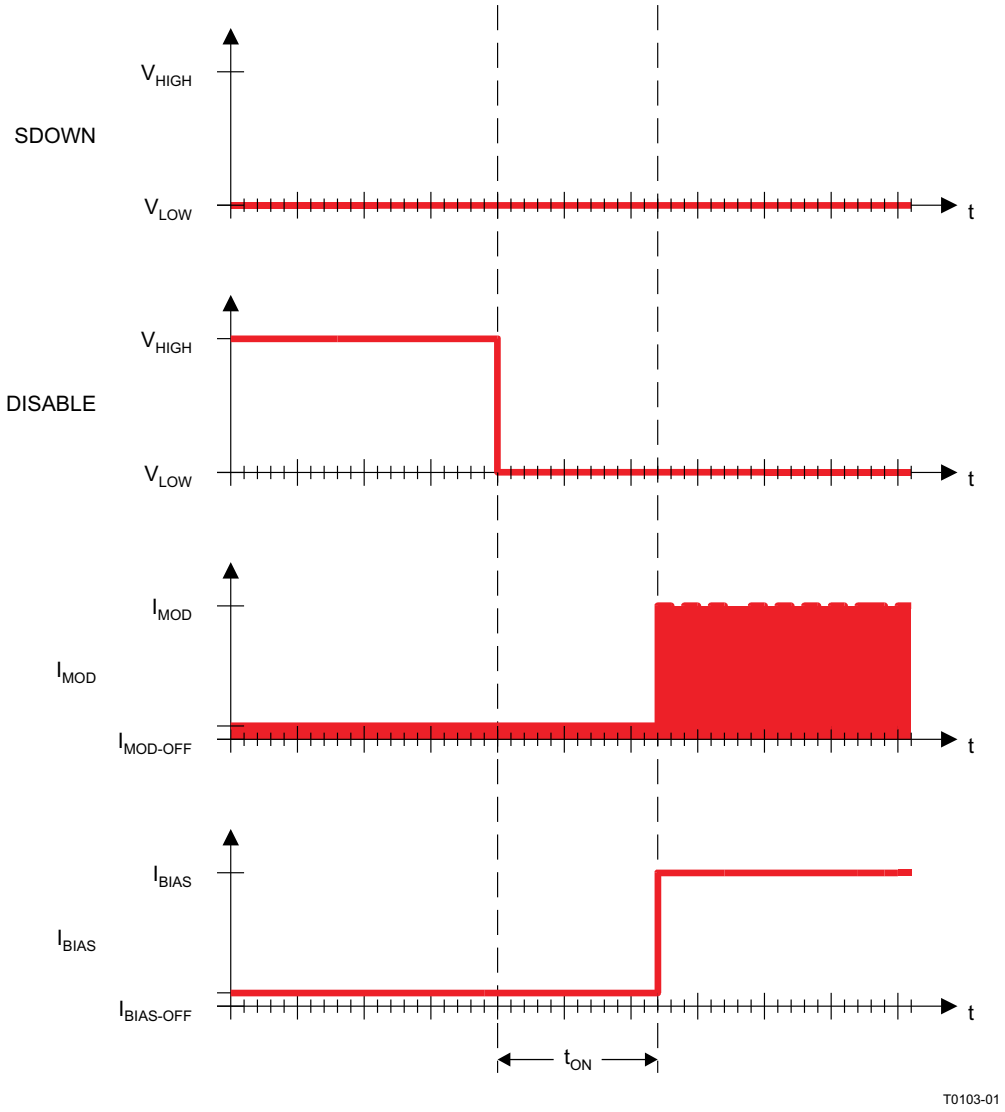

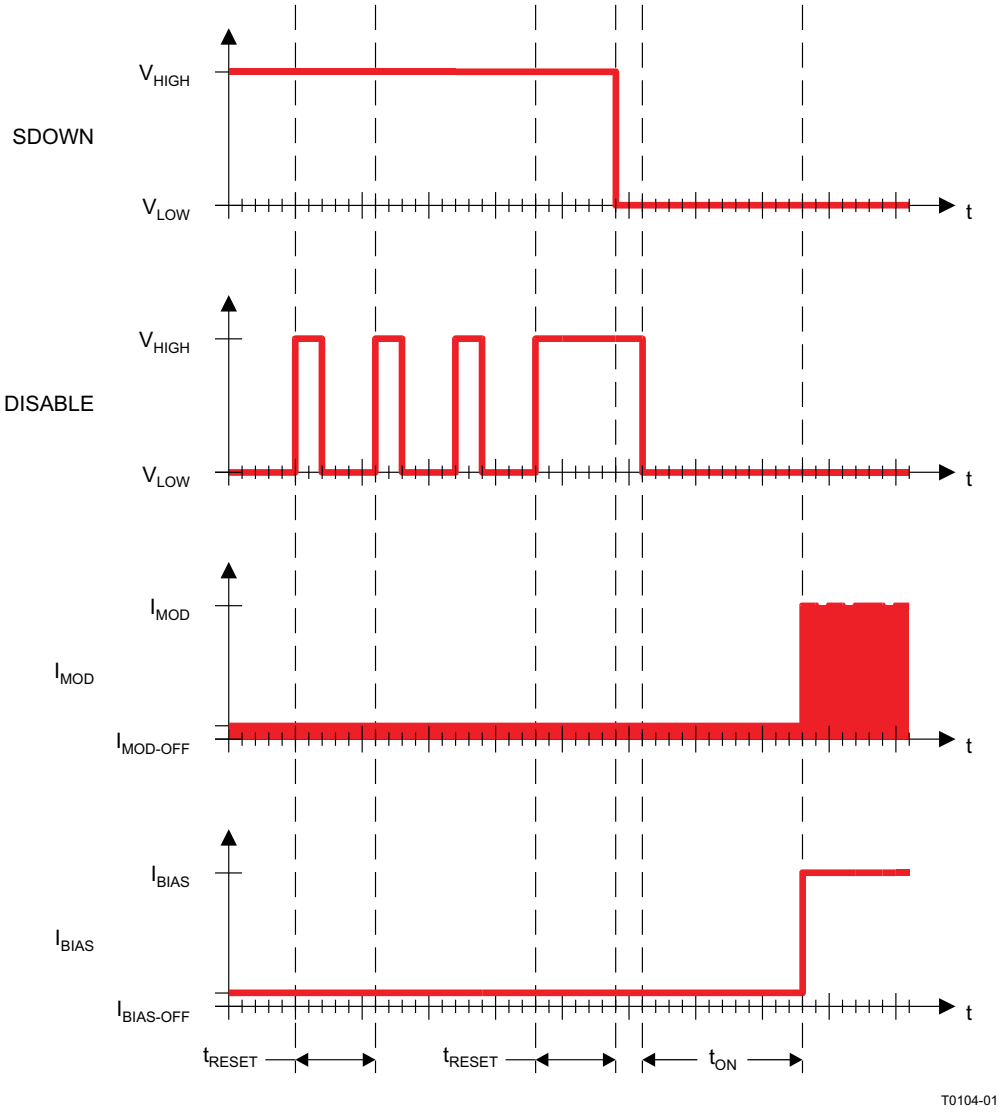
SDOWN
V_HIGH
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I_BIAS
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I_BIAS-OFF
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t_RESET
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t_ON
T0104-01

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, I_{MOD} = 30 mA

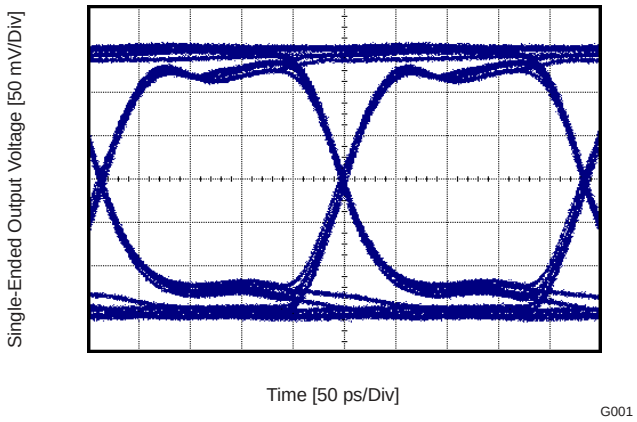


Figure 7.

ELECTRICAL EYE-DIAGRAM AT 2.125 Gbps WITH K28.5 PATTERN, I_{MOD} = 30 mA

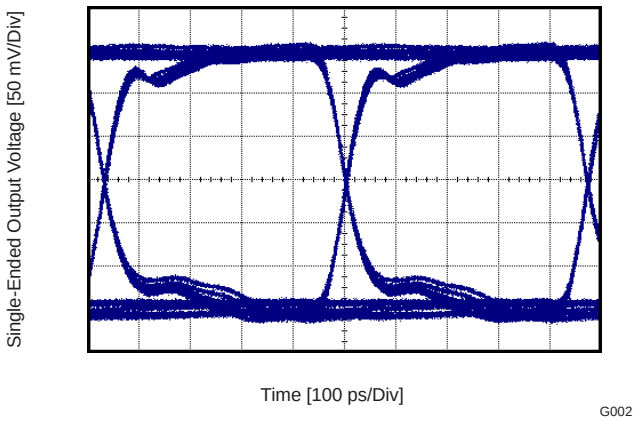


Figure 8.

ELECTRICAL EYE-DIAGRAM AT 1.0625 Gbps WITH K28.5 PATTERN, I_{MOD} = 30 mA

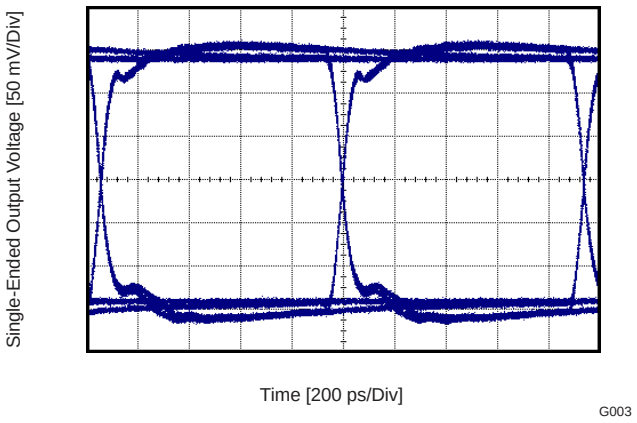


Figure 9.

DETERMINISTIC JITTER vs MODULATION CURRENT

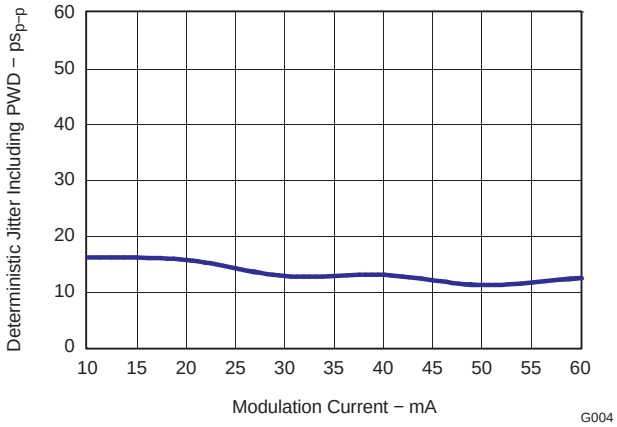


Figure 10.

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)

RANDOM JITTER vs MODULATION CURRENT

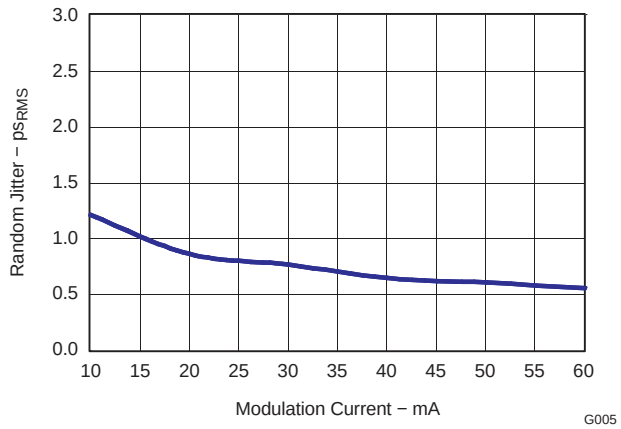


Figure 11.

RANDOM JITTER vs TEMPERATURE

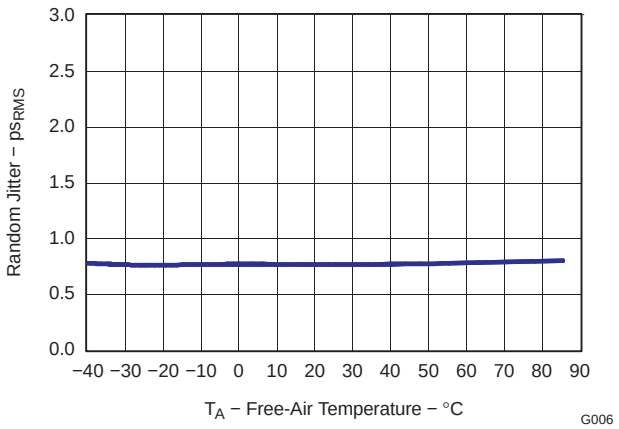


Figure 12.

RISE TIME AND FALL TIME vs MODULATION CURRENT

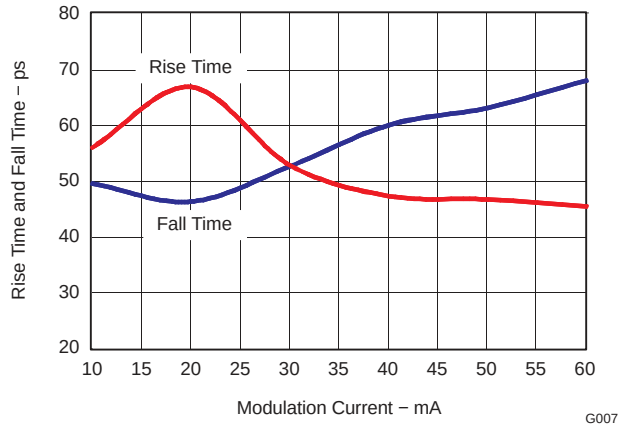


Figure 13.

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

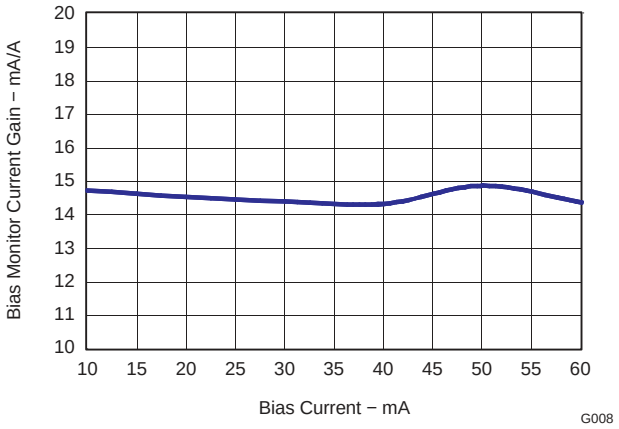


Figure 14.

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

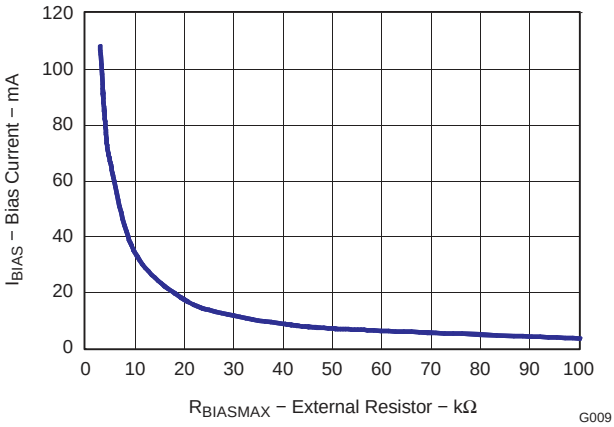


Figure 15.

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

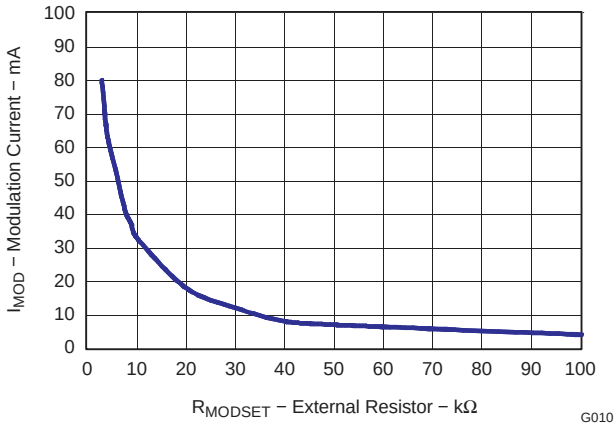


Figure 16.

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

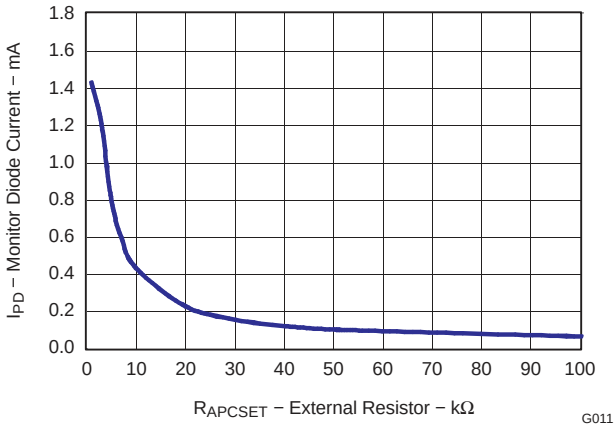


Figure 17.

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

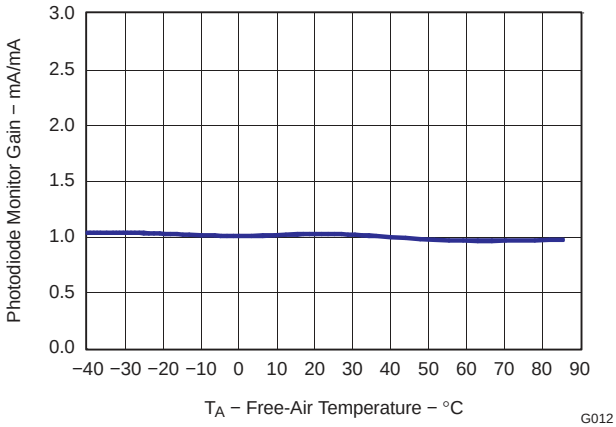


Figure 18.

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

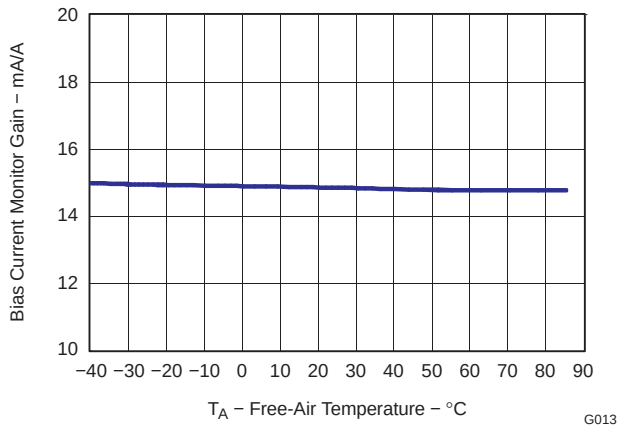


Figure 19.

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

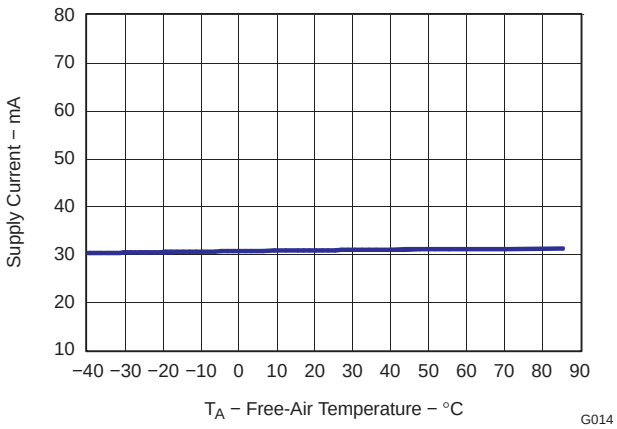


Figure 20.

DISABLE ASSERT TIME t_{OFF}

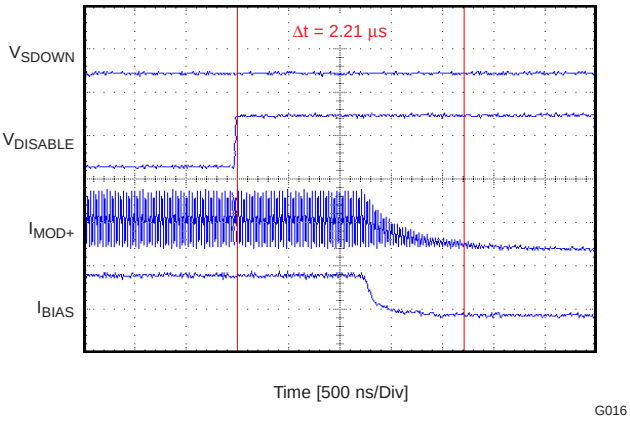


Figure 21.

DISABLE NEGATE TIME t_{ON}

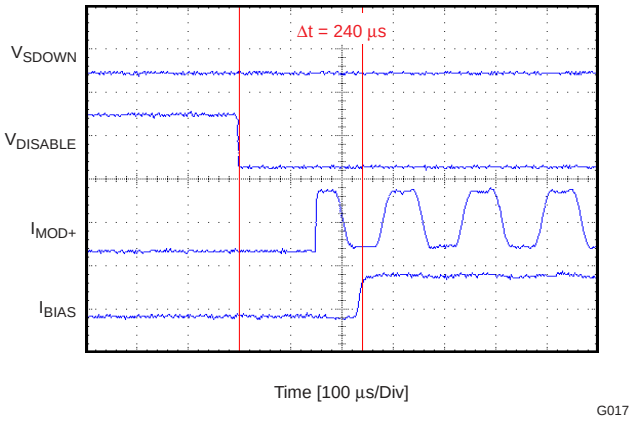


Figure 22.

SHUTDOWN RESET TIME t_{RESET}

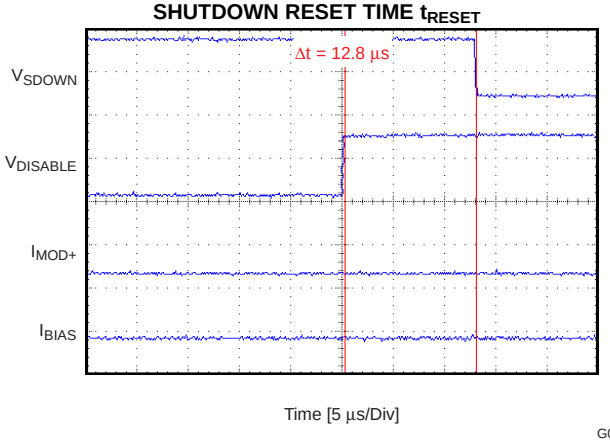


Figure 23.

APPLICATION INFORMATION

Figure 24 shows the ONET4201LD connected with a dc-coupled interface to the laser diode, alternatively the ONET4201LD laser driver can be ac-coupled.

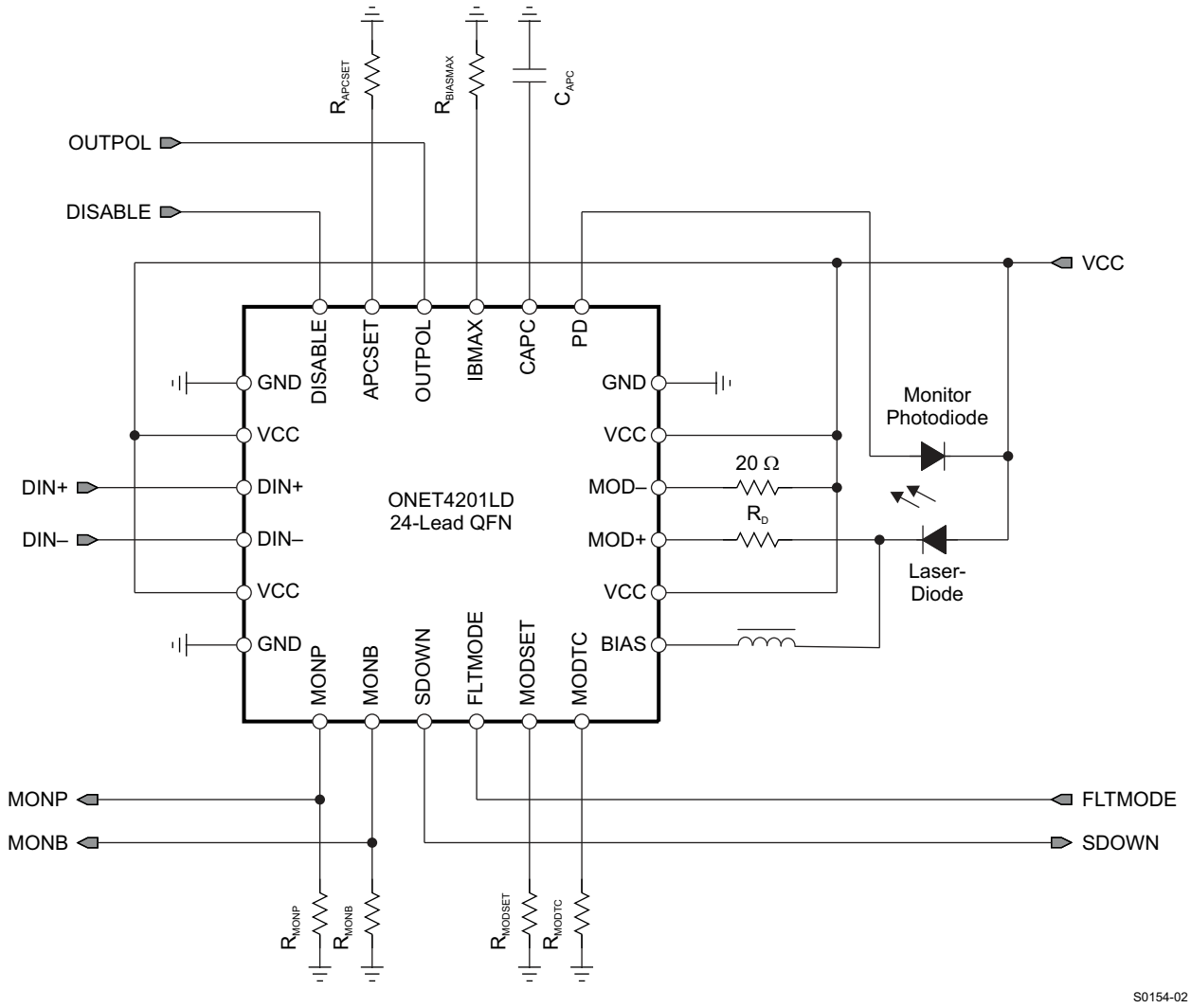


Figure 24. Basic Application Circuit With DC-Coupled Interface Between the ONET4201LD and the Laser Diode

APC loop instability may 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.

SELECT A LASER

In the design example according to Figure 24, the ONET4201LD is dc coupled to a typical communication-grade laser diode capable of operating at 4.25 Gbps with the 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 IPD 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 seen 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 (6.3) 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 of the modulation current TC 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:

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

If 4000 ppm/°C is the desired temperature coefficient and the modulation current from the example above, 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} 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:

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

To compensate for the decreased slope efficiency of the laser in Table 2, T_C 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.

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

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 photodiode 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 ONET4201LD 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.

REVISION HISTORY

Changes from Original (November 2005) to Revision A	Page
• Changed 200us to 80us for typ value of t_{ON}	10
• Changed 200us to 80us for typ value of t_{INIT}	10
• Changed 10us to 0.8us for max value of t_{RESET} max spike	10
• Changed 20us min to 6us max value of t_{RESET} time DISABLE	10

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ONET4201LDRGER	ACTIVE	VQFN	RGE	24	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ONET 4201L	Samples
ONET4201LDRGET	ACTIVE	VQFN	RGE	24	250	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ONET 4201L	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

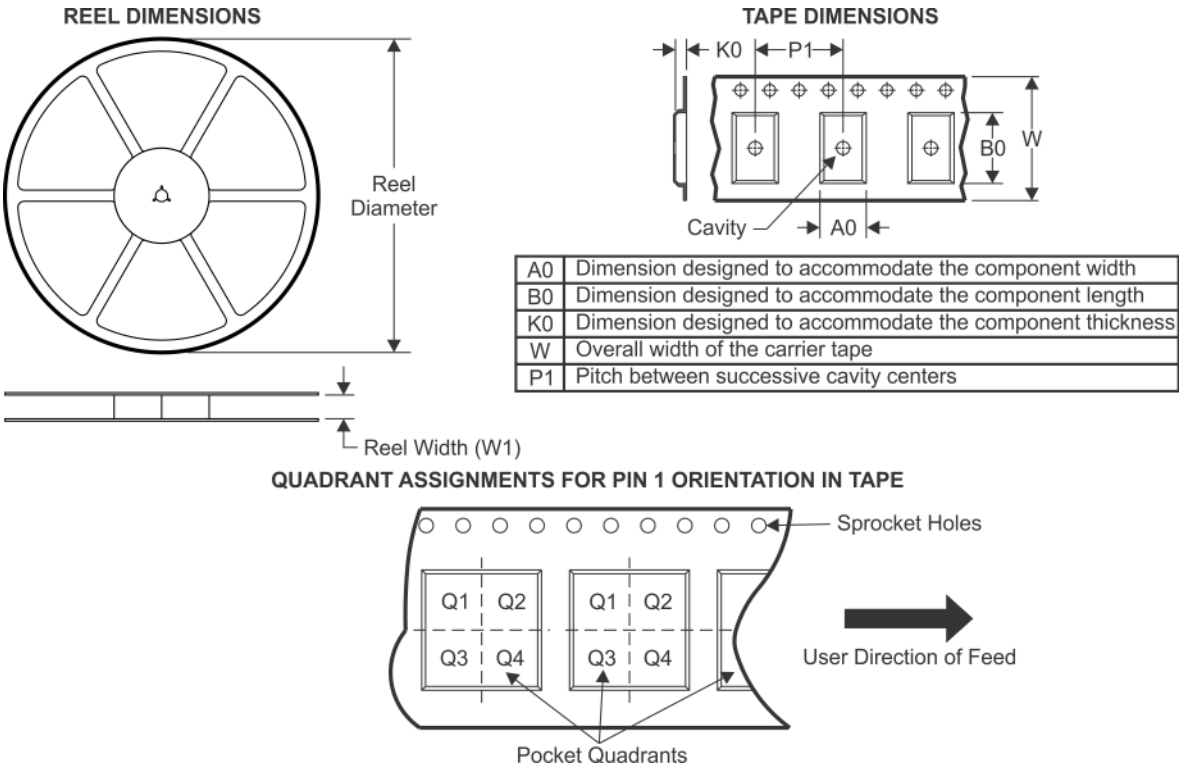
(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

TAPE AND REEL INFORMATION

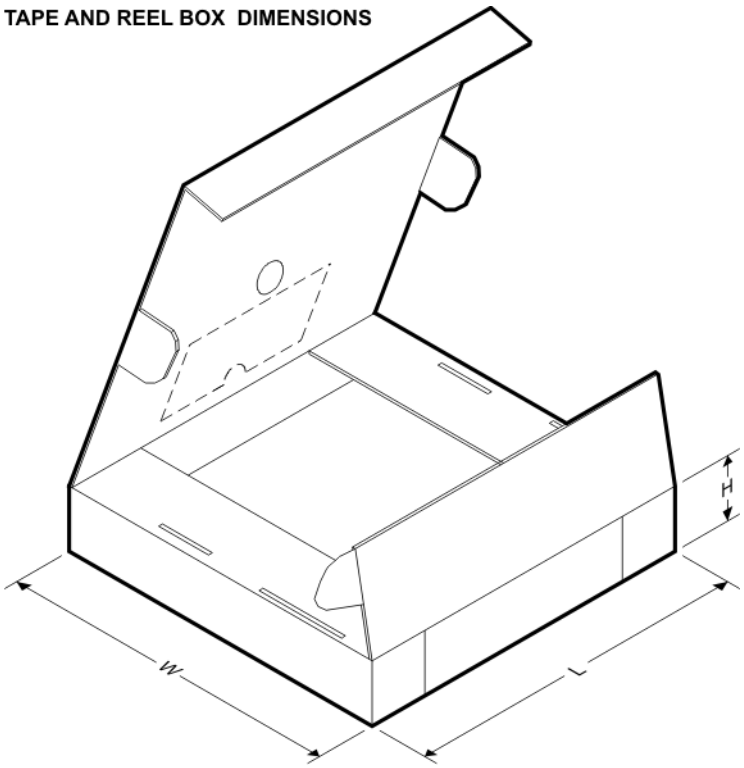


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ONET4201LDRGER	VQFN	RGE	24	3000	330.0	12.4	4.3	4.3	1.5	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



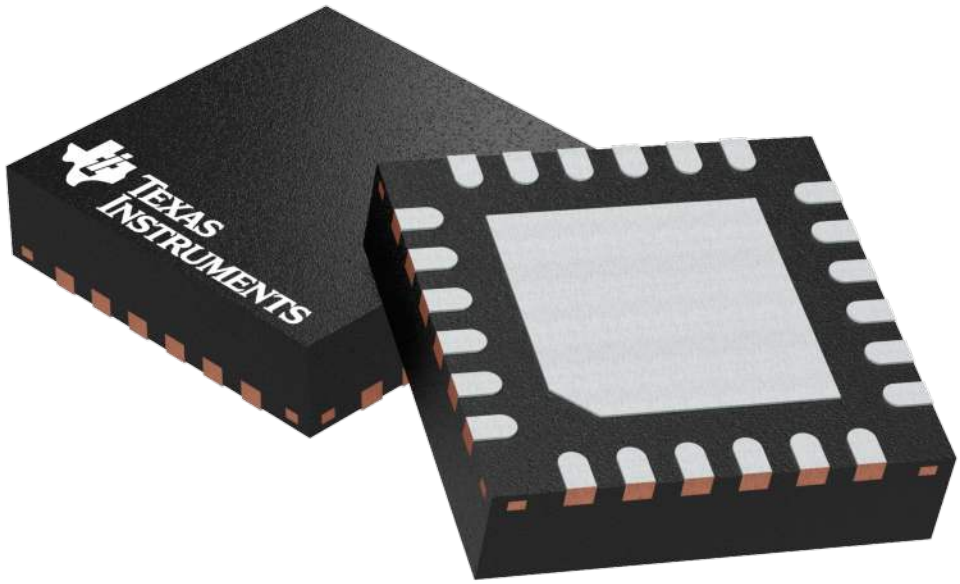
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ONET4201LDRGER	VQFN	RGE	24	3000	350.0	350.0	43.0

GENERIC PACKAGE VIEW

RGE 24 VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



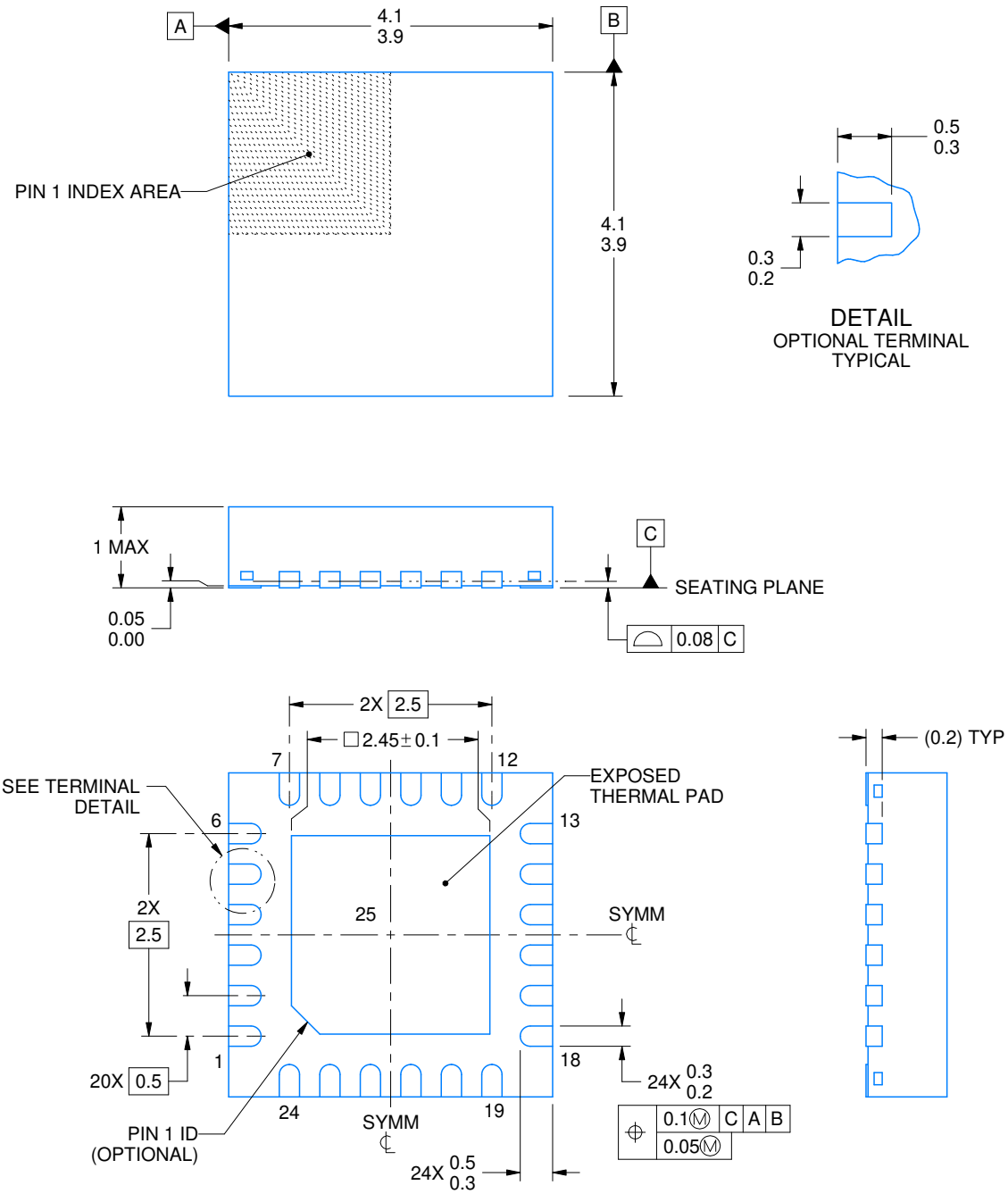
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

PACKAGE OUTLINE

RGE0024B

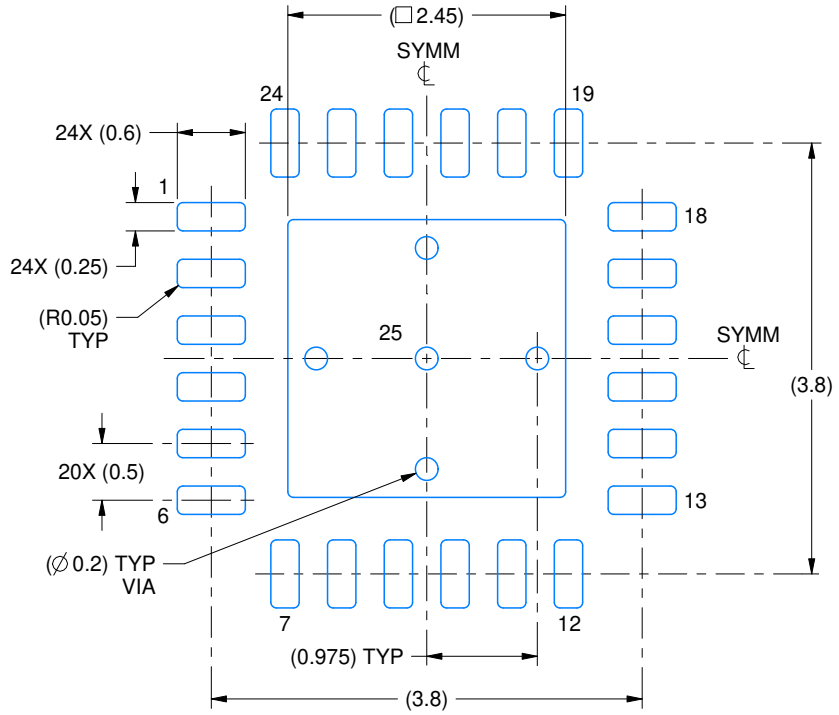
VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

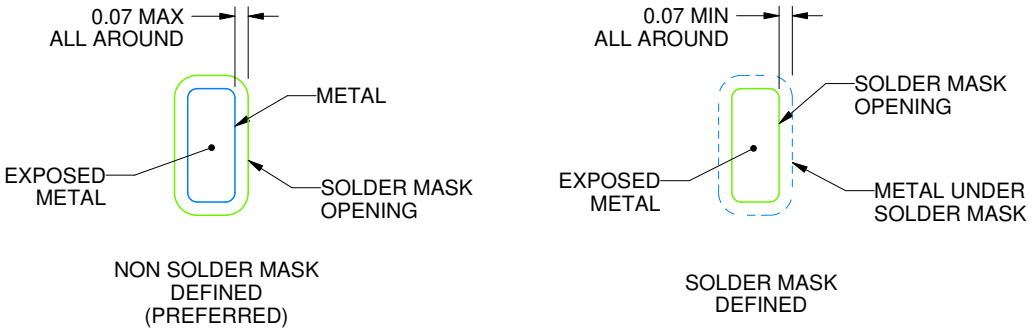


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

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NOTES: (continued)

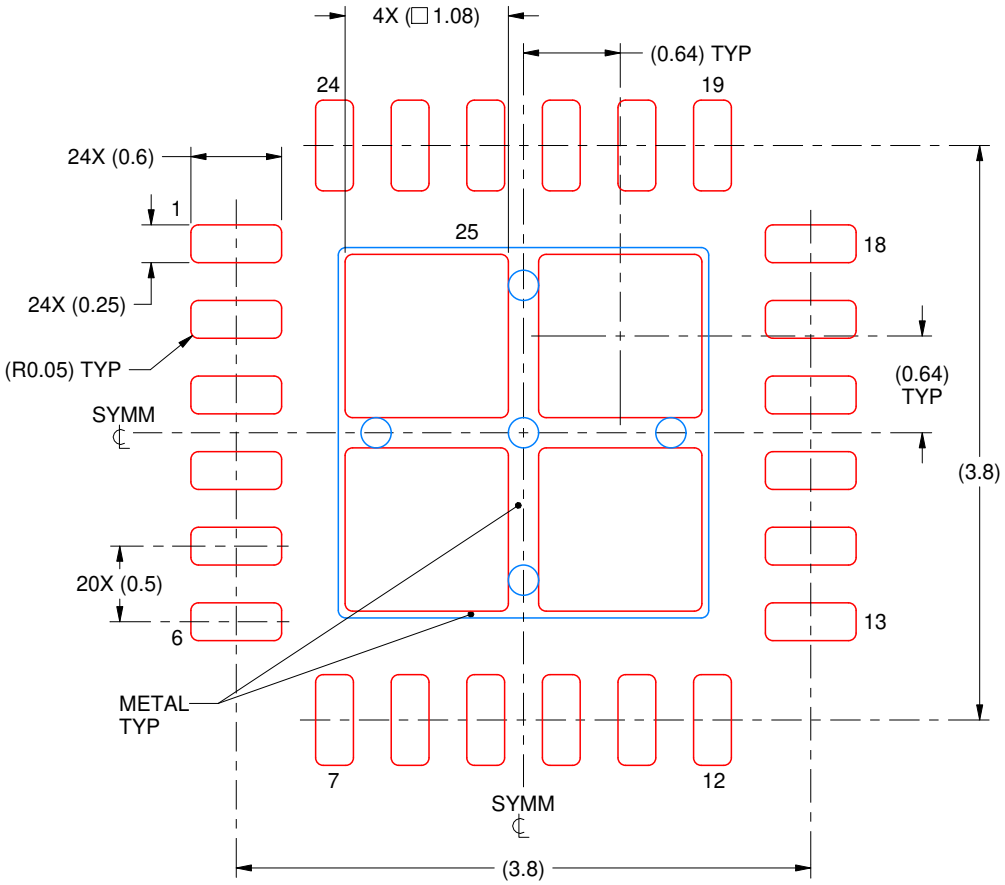
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RGE0024B

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 25
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

4219013/A 05/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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