# 3.3 V Dual-Loop, 50 Mbps to 3.3 Gbps Laser Diode Driver

Data Sheet

# ADN2872

## FEATURES

- SFP/SFF and SFF-8472 MSA compliant
- SFP reference design available
- Any rate from 50 Mbps to 3.3 Gbps operation
- Dual-loop control of average power and extinction ratio
- Typical rise/fall time: 60 ps
- Bias current range: 2 mA to 100 mA
- Modulation current range: 5 mA to 90 mA
- Laser FAIL alarm and automatic laser shutdown (ALS)
- Bias and modulation current monitoring
- 3.3 V operation
- 4 mm × 4 mm LFCSP
- Voltage setpoint control
- Resistor setpoint control

## APPLICATIONS

- Multirate OC3 to OC48-FEC SFP/SFF modules
- 1×/2×/4× Fibre Channel SFP/SFF modules
- LX-4 modules
- DWDM/CWDM SFP modules
- 1GE SFP/SFF transceiver modules

## GENERAL DESCRIPTION

Like the ADN2870, the ADN2872[1] laser diode driver is designed for advanced SFP and SFF modules, using SFF-8472 digital diagnostics. The device features dual-loop control of the average power and extinction ratio (ER), which automatically compensates for variations in laser characteristics over temperature and aging. The laser needs only be calibrated at 25°C, eliminating the need for expensive and time consuming temperature calibration. The ADN2872 supports single-rate operation from 50 Mbps to 3.3 Gbps, or multirate operation from 155 Mbps to 3.3 Gbps. With a new alarm scheme, this device avoids the shutdown issue caused by the system transient generated from various lasers.

The average power and ER can be set with a voltage provided by a microcontroller digital-to-analog converter (DAC) or by a trimmable resistor. The device provides both bias and modulation current monitoring, as well as fail alarms and automatic laser shutdown. The ADN2872, a SFF-/SFP-compliant laser diode driver, can work with the Analog Devices, Inc., ADuC7019, ADuC7020, and ADuC7023 MicroConverter® family and the ADN2890, ADN2891, and ADN2892 limiting amplifier family, to form a complete SFP/SFF transceiver solution. The ADN2872 is available in a space-saving 4 mm × 4 mm LFCSP specified over the −40°C to +85°C temperature range.

Figure 1 shows an application diagram with a microcontroller interface.

[1] Protected by U.S. Patent 6,414,974.

## APPLICATIONS DIAGRAM

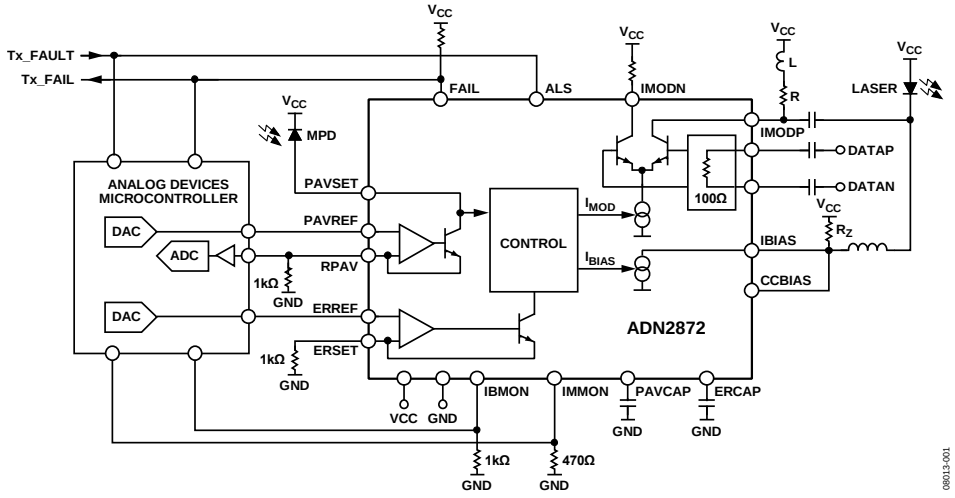


*Figure 1.*

**Rev. B** Document Feedback



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- ADN2872: 3.3 V Dual-Loop, 50 Mbps to 3.3 Gbps Laser Diode Driver Data Sheet

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**2/2016—Rev. 0 to Rev. A**

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Updated Outline Dimensions ... 17

**3/2009—Revision 0: Initial Version**

# SPECIFICATIONS

$V_{CC}$ = 3.0 V to 3.6 V. All specifications $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.[1] Typical values as specified at 25°C.

**Table 1.**

| Parameter | Min | Typ | Max | Unit | Conditions/Comments |
|---|---|---|---|---|---|
| LASER BIAS CURRENT (IBIAS) | | | | | |
| Output Current, $I_{BIAS}$ | 2 | | 100 | mA | |
| Compliance Voltage | 1.2 | | $V_{CC}$ | V | |
| IBIAS when ALS High | | | 0.2 | mA | |
| CCBIAS Compliance Voltage | 1.2 | | | V | |
| MODULATION CURRENT (IMODP, IMODN)[2] | | | | | |
| Output Current, $I_{MOD}$ | 5 | | 90 | mA | |
| Compliance Voltage | 1.5 | | $V_{CC}$ | V | |
| $I_{MOD}$ when ALS High | | | 0.05 | mA | |
| Rise Time[2, 3] | | 60 | 104 | ps | |
| Fall Time[2, 3] | | 60 | 96 | ps | |
| Random Jitter[2, 3] | | 0.8 | 1.1 | ps rms | |
| Deterministic Jitter[2, 3] | | | 35 | ps | 20 mA < $I_{MOD}$ < 90 mA |
| Pulse Width Distortion[2, 3] | | | 30 | ps | 20 mA < $I_{MOD}$ < 90 mA |
| AVERAGE POWER SET (PAVSET) | | | | | |
| Pin Capacitance | | | 80 | pF | |
| Voltage | 1.1 | 1.2 | 1.35 | V | |
| Photodiode Monitor Current (Average Current) | 50 | | 1200 | µA | Resistor setpoint mode |
| EXTINCTION RATIO SET INPUT (ERSET) | | | | | |
| Resistance Range | 1.2 | | 25 | kΩ | Resistor setpoint mode |
| Voltage | 1.1 | 1.2 | 1.35 | V | Resistor setpoint mode |
| AVERAGE POWER REFERENCE VOLTAGE INPUT (PAVREF) | | | | | |
| Voltage Range | 0.12 | | 1 | V | Voltage setpoint mode (RPAV fixed at 1 kΩ) |
| Photodiode Monitor Current (Average Current) | 120 | | 1000 | µA | Voltage setpoint mode (RPAV fixed at 1 kΩ) |
| EXTINCTION RATIO REFERENCE VOLTAGE INPUT (ERREF) | | | | | |
| Voltage Range | 0.1 | | 1 | V | Voltage setpoint mode ($R_{ERSET}$ fixed at 1 kΩ) |
| DATA INPUTS (DATAP, DATAN)[4] | | | | | |
| Input Voltage Swing (Differential) | 0.4 | | 2.4 | V p-p | AC-coupled |
| Input Impedance (Single-Ended) | | 50 | | Ω | |
| LOGIC INPUTS (ALS) | | | | | |
| $V_{IH}$ | 2 | | | V | |
| $V_{IL}$ | | | 0.8 | V | |
| ALARM OUTPUT (FAIL)[5] | | | | | |
| $V_{OFF}$ | | >1.8 | | V | Voltage required at FAIL for $I_{BIAS}$ and $I_{MOD}$ to turn off when FAIL asserted |
| $V_{ON}$ | | <1.3 | | V | Voltage required at FAIL for $I_{BIAS}$ and $I_{MOD}$ to stay on when FAIL asserted |
| IBMON, IMMON DIVISION RATIO | | | | | |
| $I_{BIAS}/I_{BMON}$[3] | 85 | 100 | 115 | A/A | 11 mA < $I_{BIAS}$ < 50 mA |
| $I_{BIAS}/I_{BMON}$[3] | 92 | 100 | 108 | A/A | 50 mA < $I_{BIAS}$ < 100 mA |
| $I_{BIAS}/I_{BMON}$ Stability[3, 6] | | | ±5 | % | 10 mA < $I_{BIAS}$ < 100 mA |
| $I_{MOD}/I_{MMON}$ | | 50 | | A/A | |
| $I_{BMON}$ Compliance Voltage | 0 | | 1.3 | V | |

| Parameter | Min | Typ | Max | Unit | Conditions/Comments |
|---|---|---|---|---|---|
| SUPPLY | | | | | |
| $I_{CC}$[7] | | 30 | | mA | When $I_{BIAS} = I_{MOD} = 0$ |
| $V_{CC}$ (with respect to GND)[8] | 3.0 | 3.3 | 3.6 | V | |

[1] Temperature range is −40°C to +85°C.
[2] Measured into a 15 Ω load (22 Ω resistor in parallel with digital scope 50 Ω input) using a 11110000 pattern at 2.5 Gbps, shown in Figure 2.
[3] Guaranteed by design and characterization. Not production tested.
[4] When the voltage on DATAP is greater than the voltage on DATAN, the modulation current flows into the IMODP pin.
[5] Guaranteed by design. Not production tested.
[6] $I_{BIAS}/IB_{MON}$ ratio stability is defined in SFF-8472 Revision 9 over temperature and supply variation.
[7] See the Power Consumption section for $I_{CC}$ minimum for power calculation.
[8] All VCC pins must be shorted together.

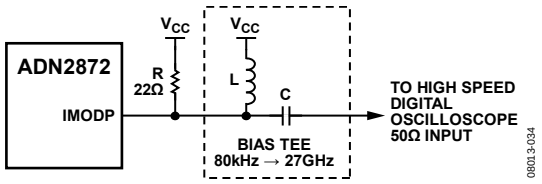


*Figure 2. High Speed Electrical Test Output Circuit*

## SFP TIMING SPECIFICATIONS

**Table 2.**

| Parameter | Symbol | Min | Typ | Max | Unit | Conditions/Comments |
|---|---|---|---|---|---|---|
| ALS Assert Time | t_off | | 1 | 5 | µs | Time for the rising edge of ALS (Tx_DISABLE) to when the bias current falls below 10% of nominal |
| ALS Negate Time[1] | t_on | | 0.83 | 0.95 | ms | Time for the falling edge of ALS to when the modulation current rises above 90% of nominal |
| Time to Initialize, Including Reset of FAIL[1] | t_init | | 25 | 275 | ms | From power-on or negation of FAIL using ALS |
| FAIL Assert Time | t_fault | | | 100 | µs | Time to fault to FAIL on |
| ALS to Reset Time | t_reset | | | 5 | µs | Time Tx_DISABLE must be held high to reset Tx_FAULT |

[1] Guaranteed by design and characterization. Not production tested.

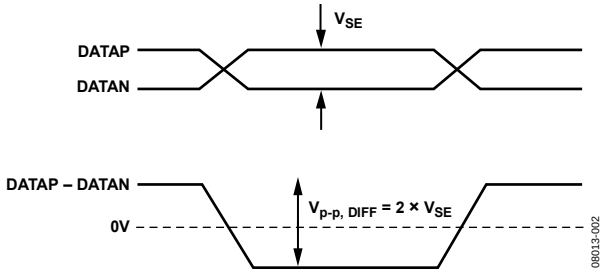


*Figure 3. Signal Level Definition*

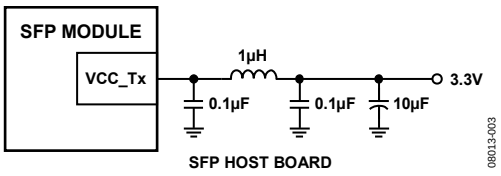


*Figure 4. Recommended SFP Supply*

# ABSOLUTE MAXIMUM RATINGS

$T_A$ = 25°C, unless otherwise noted.

**Table 3.**

| Parameter | Rating |
|---|---|
| VCC to GND | 4. 2 V |
| IMODN, IMODP | −0.3 V to +4.8 V |
| PAVCAP, ERCAP, PAVSET, PAVREF, ERREF, IBIAS, IBMON, IMMON, ALS, CCBIAS, RPAV, ERSET, FAIL | −0.3 V to +3.9 V |
| DATAP, DATAN (Single-Ended Differential) | 1.5 V |
| Junction Temperature ($T_J$ max) | 125°C |
| Operating Temperature Range, Industrial | −40°C to +85°C |
| Storage Temperature Range | −65°C to +150°C |
| Power Dissipation (W)[1] | $(T_J \text{ max} - T_A)/\theta_{JA}$ |
| $\theta_{JA}$ Thermal Impedance[2] | 48.6°C/W |
| $\theta_{JC}$ Thermal Impedance[2] | 5.0°C/W |
| $\theta_{JB}$ Thermal Impedance[2] | 28.4°C/W |

[1] Power consumption equations are provided in the Power Consumption section.
[2] $\theta_{JA}$, $\theta_{JB}$, and $\theta_{JC}$ are estimated when the exposed pad on the device is soldered on a 4-layer JEDEC board at zero airflow.

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

## ESD CAUTION

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

# PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

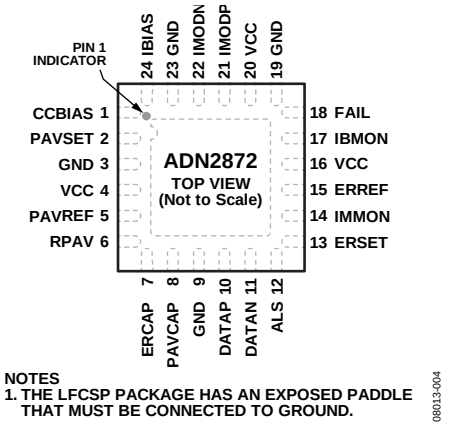


*Figure 5. Pin Configuration*

**Table 4. Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | CCBIAS | Control Output Current. |
| 2 | PAVSET | Average Optical Power Set Pin. |
| 3 | GND | Supply Ground. |
| 4 | VCC | Supply Voltage. |
| 5 | PAVREF | Reference Voltage Input for Average Optical Power Control. |
| 6 | RPAV | Average Power Resistor When Using PAVREF. |
| 7 | ERCAP | Extinction Ratio Loop Capacitor. |
| 8 | PAVCAP | Average Power Loop Capacitor. |
| 9 | GND | Supply Ground. |
| 10 | DATAP | Data, Positive Differential Input. |
| 11 | DATAN | Data, Negative Differential Input. |
| 12 | ALS | Automatic Laser Shutdown. |
| 13 | ERSET | Extinction Ratio Set Pin. |
| 14 | IMMON | Modulation Current Monitor Current Source. |
| 15 | ERREF | Reference Voltage Input for Extinction Ratio Control. |
| 16 | VCC | Supply Voltage. |
| 17 | IBMON | Bias Current Monitor Current Source. |
| 18 | FAIL | FAIL Alarm Output. |
| 19 | GND | Supply Ground. |
| 20 | VCC | Supply Voltage. |
| 21 | IMODP | Modulation Current Positive Output (Current Sink), Connect to Laser Diode. |
| 22 | IMODN | Modulation Current Negative Output (Current Sink). |
| 23 | GND | Supply Ground. |
| 24 | IBIAS | Laser Diode Bias (Current Sink to Ground). |
| | EPAD | Exposed Pad. The LFCSP package has an exposed pad that must connect to ground. |

# TYPICAL PERFORMANCE CHARACTERISTICS

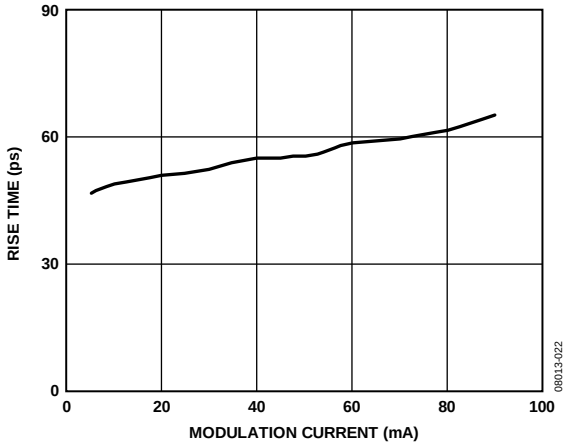


Figure 6. Rise Time vs. Modulation Current, $I_{BIAS}$ = 20 mA

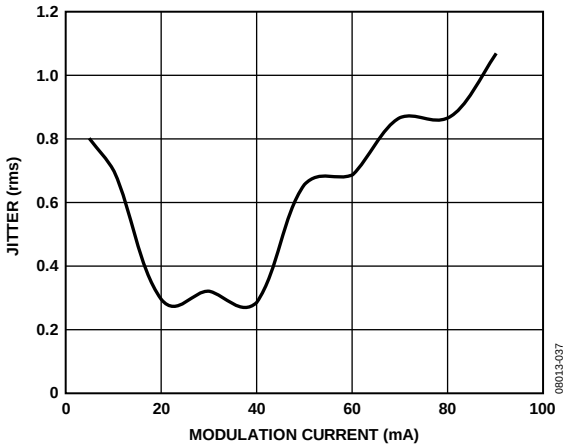


Figure 9. Random Jitter vs. Modulation Current, $I_{BIAS}$ = 20 mA

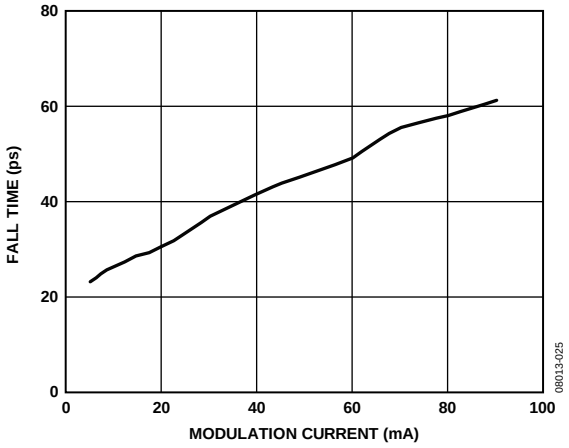


Figure 7. Fall Time vs. Modulation Current, $I_{BIAS}$ = 20 mA

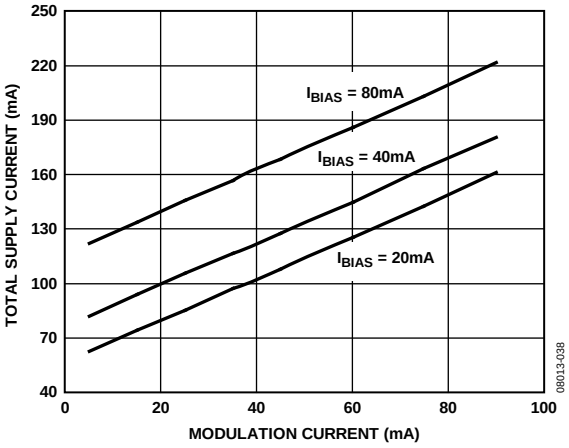


Figure 10. Total Supply Current vs. Modulation Current, Total Supply Current = $I_{CC} + I_{BIAS} + I_{MOD}$

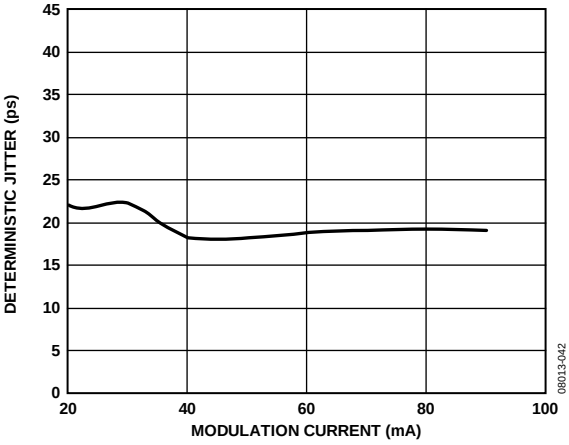


Figure 8. Deterministic Jitter vs. Modulation Current, $I_{BIAS}$ = 20 mA

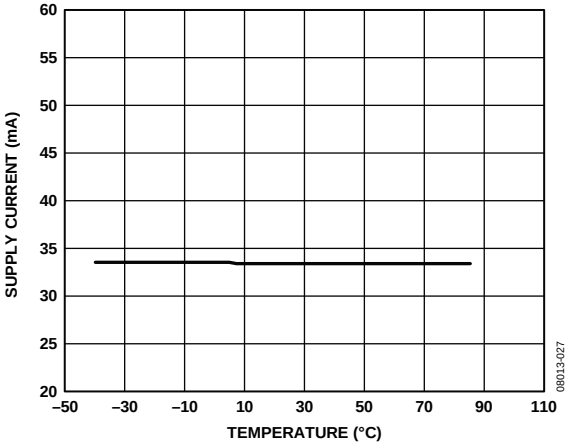


Figure 11. Supply Current ($I_{CC}$) vs. Temperature with ALS Asserted, $I_{BIAS}$ = 20 mA

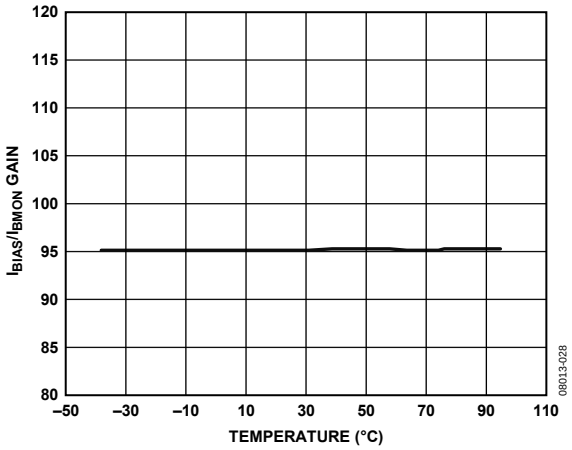


Figure 12. $I_{BIAS}/I_{BMON}$ Gain vs. Temperature, $I_{BIAS}$ = 20 mA

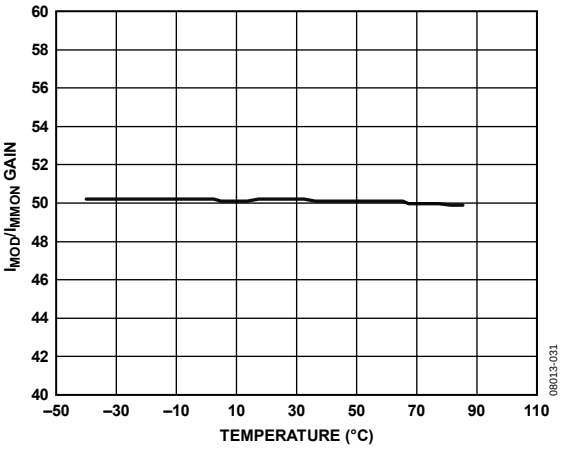


Figure 15. $I_{MOD}/I_{MMON}$ Gain vs. Temperature, $I_{MOD}$ = 30 mA

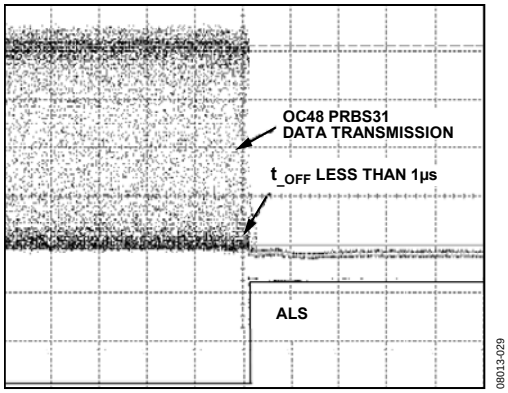


Figure 13. ALS Assert Time, 5 µs/DIV

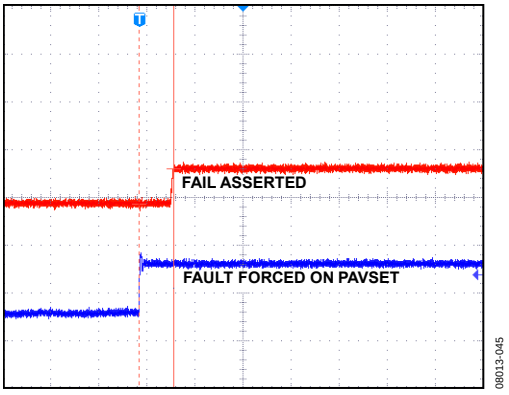


Figure 16. FAIL Assert Time, 1 µs/DIV

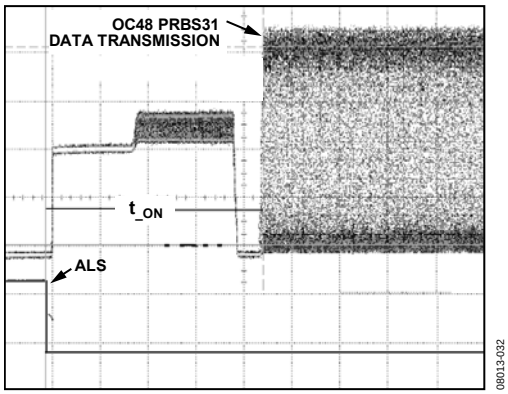


Figure 14. ALS Negate Time, 200 µs/DIV

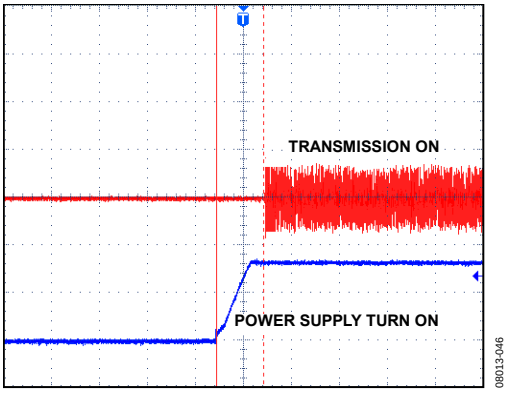


Figure 17. Time to Initialize, Including Reset, 40 ms/DIV

# OPTICAL WAVEFORMS

$V_{CC}$ = 3.3 V and $T_A$ = 25°C, unless otherwise noted. Note that there was no change to PAVCAP and ERCAP values when different data rates were tested. Figure 18, Figure 19, and Figure 20 show multirate performance using the low cost Fabry Perot (FP) TOSA NEC NX7315UA; Figure 21 and Figure 22 show dual-loop performance over temperature using the DFB TOSA Sumitomo SLT2486.

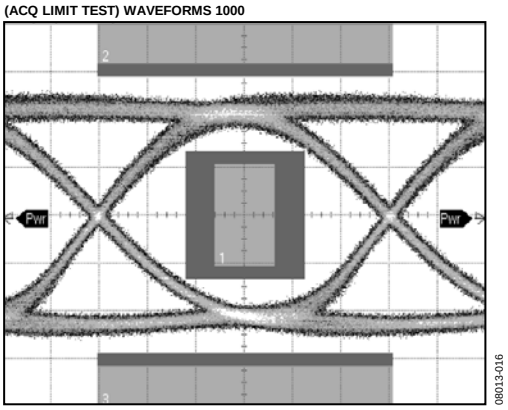


*Figure 18. Optical Eye 2.488 Gbps, 65 ps/DIV, PRBS $2^{31} - 1$, PAV = −4.5 dBm, ER = 9 dB, Mask Margin 25%*

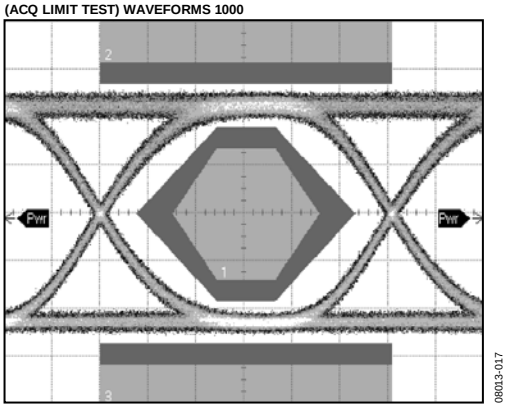


*Figure 19. Optical Eye 622 Mbps, 264 ps/DIV, PRBS $2^{31} - 1$, PAV = −4.5 dBm, ER = 9 dB, Mask Margin 50%*

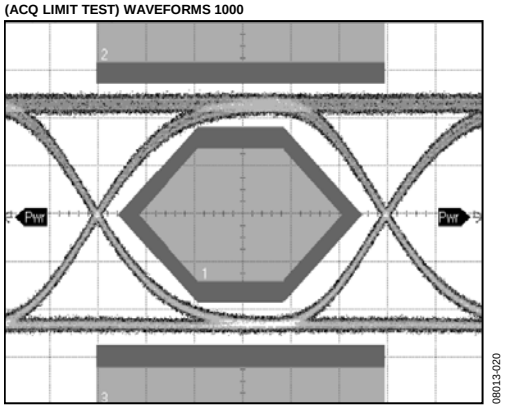


*Figure 20. Optical Eye 155 Mbps,1.078 ns/DIV, PRBS $2^{31} - 1$, PAV = −4.5 dBm, ER = 9 dB, Mask Margin 50%*

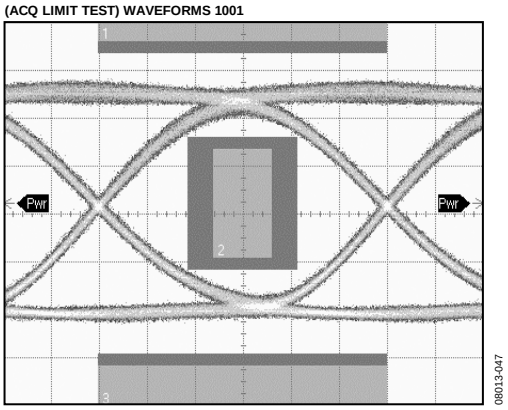


*Figure 21. Optical Eye 2.488 Gbps, 65 ps/DIV, PRBS $2^{31} - 1$, PAV = 0 dBm, ER = 9 dB, Mask Margin 22%, $T_A$ = 25°C*

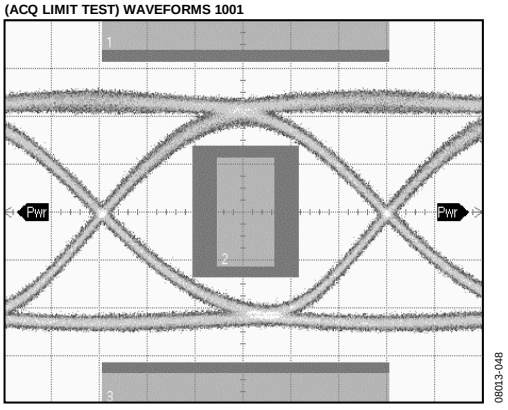


*Figure 22. Optical Eye 2.488 Gbps, 65 ps/DIV, PRBS $2^{31} - 1$, PAV = −0.2 dBm, ER = 8.96 dB, Mask Margin 21%, $T_A$ = 85°C*

# THEORY OF OPERATION

Laser diodes have a current-in to light-out transfer function, as shown in Figure 23. Two key characteristics of this transfer function are the threshold current, $I_{TH}$, and slope in the linear region beyond the threshold current, referred to as slope efficiency, LI.

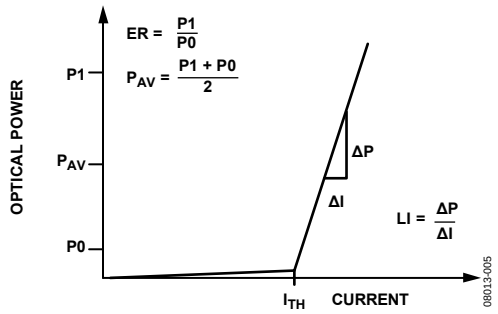


*Figure 23. Laser Transfer Function*

## DUAL-LOOP CONTROL

Typically, laser threshold current and slope efficiency are both functions of temperature. For FP and DFB type lasers, the threshold current increases and the slope efficiency decreases with increasing temperature. In addition, these parameters vary as the laser ages. To maintain a constant optical average power and a constant optical ER over temperature and laser lifetime, it is necessary to vary the applied electrical bias current and modulation current to compensate for the laser changing LI characteristics.

Single-loop compensation schemes use the average monitor photodiode (MPD) current to measure and maintain the average optical output power over temperature and laser aging. The ADN2872 is a dual-loop device, implementing both this primary average power control loop and a secondary control loop, which maintains a constant optical ER. The dual-loop control of the average power and ER implemented in the ADN2872 can be used successfully with both lasers that maintain good linearity of LI transfer characteristics over temperature, and with those that exhibit increasing nonlinearity of the LI characteristics over temperature.

### *Dual Loop*

The ADN2872 uses a proprietary patented method to control both average power and ER. The ADN2872 is constantly sending a test signal on the modulation current signal and reading the resulting change in the MPD current as a means of detecting the slope of the laser in real time. This information is used in a servo to control the ER of the laser, which is done in a time-multiplexed manner at a low frequency, typically 80 Hz. Figure 24 shows the dual-loop control implementation on the ADN2872.

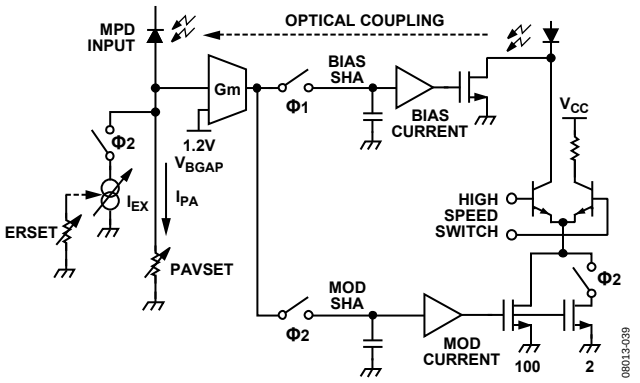


*Figure 24. Dual-Loop Control of Average Power and ER*

A dual loop is made up of an average power control loop (APCL) and the ER control loop (ERCL), which are separated into two time states. During Time Φ1, the APCL is operating, and during Time Φ2, the ER loop is operating.

### *Average Power Control Loop*

The APCL compensates for changes in the laser diode (LD), $I_{TH}$ and LI, by varying $I_{BIAS}$. APC control is performed by measuring the MPD current, $I_{MPD}$. This current is bandwidth limited by the MPD. This is not a problem because the APCL must be low frequency and the APCL must respond to the average current from the MPD. The APCL compares $I_{MPD} \times R_{PAVSET}$ to the band gap (BGAP) voltage, $V_{BGAP}$. If $I_{MPD}$ falls, the bias current is increased until $I_{MPD} \times R_{PAVSET}$ equals $V_{BGAP}$. Conversely, if the $I_{MPD}$ increases, $I_{BIAS}$ is decreased.

### *Modulation Control Loop*

The ERCL measures the slope efficiency, LI, of the laser diode by monitoring the $I_{MPD}$ changes. During the ERCL, $I_{MPD}$ is temporarily increased by $\Delta I_{MOD}$. The ratio between $I_{MPD}$ and $\Delta I_{MOD}$ is a fixed ratio of 50:1, but during startup, this ratio is increased to decrease settling time.

During ERCL, switching in $\Delta I_{MOD}$ causes a temporary increase in average optical power, $\Delta P_{AV}$. However, the APCL is disabled during ERCL, and the increase is kept small enough so as not to disturb the optical eye. When $\Delta I_{MOD}$ is switched into the laser circuit, an equal current, $I_{EX}$, is switched into the PAVSET resistor. The user sets the value of $I_{EX}$; this is the ERSET setpoint. If $\Delta I_{MPD}$ is too small, the control loop knows that LI has decreased, and increases $I_{MPD}$ and, therefore, $\Delta I_{MOD}$ accordingly until $\Delta I_{MPD}$ is equal to $I_{EX}$. The previous control cycle status of the $I_{BIAS}$ and $I_{MOD}$ settings are stored on the hold capacitors, PAVCAP and ERCAP.

The ERCL is constantly measuring the actual LI curve; it compensates for the effects of temperature and for changes in the LI curve due to laser aging. Therefore, the laser can be calibrated once at 25°C so that it can then automatically control the laser over temperature. This eliminates the expensive and time consuming temperature calibration of a laser.

### *Operation with Lasers with Temperature-Dependent Nonlinearity of Laser LI Curve*

The ADN2872 ERCL extracts information from the monitor photodiode signal relating to the slope of the LI characteristics at the Optical 1 level (P1). For lasers with good linearity over temperature, the slope measured by the ADN2872 at the Optical 1 level is representative of the slope anywhere on the LI curve. This slope information sets the required modulation current to achieve the required optical ER.

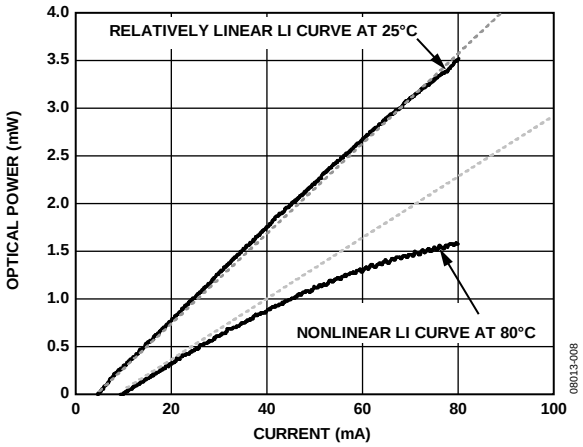


*Figure 25. Measurement of a Laser LI Curve Showing Laser Nonlinearity at High Temperatures*

Some types of lasers have LI curves that become progressively more nonlinear with increasing temperature (see Figure 25). At temperatures where the LI curve shows significant nonlinearity, the LI curve slope measured by the ADN2872 at the Optical 1 level is no longer representative of the overall LI curve. It is evident that applying a modulation current based on this slope information cannot maintain a constant ER over temperature.

However, the ADN2872 can be configured to maintain near constant optical bias and an ER with a laser exhibiting a monotonic temperature-dependent nonlinearity. To implement this correction, it is necessary to characterize a small sample of lasers for their typical nonlinearity by measuring them at two temperature points, typically 25°C and 85°C. The measured nonlinearity determines the amount of feedback to apply.

Typically, the user must characterize five to 10 lasers of a particular model to obtain a good number. The product can then be calibrated at 25°C only, avoiding the expense of temperature calibration. Typically, the microcontroller measures the laser and apply the feedback. This scheme is particularly suitable for circuits that already use a microcontroller for control and digital diagnostic monitoring.

The ER correction scheme, while using the average nonlinearity for the laser population, supplies a corrective measurement based on the actual performance of each laser as measured during operation. The ER correction scheme corrects for errors due to laser nonlinearity while the dual loop continues to adjust for changes in the Laser LI.

For more details on maintaining average optical power and ER over temperature when working with lasers displaying a temperature-dependent nonlinearity of LI curve, contact sales at Analog Devices.

## CONTROL

The ADN2872 has two methods for setting the average power ($P_{AV}$) and ER. The average power and ER can be voltage set using the voltage DAC outputs of a microcontroller to provide controlled reference voltages to PAVREF and ERREF. Alternatively, the average power and ER can be resistor set using potentiometers at the PAVSET and ERSET pins, respectively.

## VOLTAGE SETPOINT CALIBRATION

The ADN2872 allows an interface to a microcontroller for both control and monitoring (see Figure 26). The average power at the PAVSET pin and ER at the ERSET pin can be set using the DAC of the microcontroller to provide controlled reference voltages to PAVREF and ERREF. Note that during power-up, there is an internal sequence that allows 25 ms before enabling the alarms; therefore, the user must ensure that the voltage for PAVREF and ERREF are active within 20 ms.

$$PAVREF = P_{AV} \times R_{SP} \times RPAV \quad \text{(V)}$$

$$ERREF = R_{ERSET} \times \frac{I_{MPD\_CW}}{P_{CW}} \times \frac{ER-1}{ER+1} \times P_{AV} \quad \text{(V)}$$

where:
$P_{AV}$ (mW) is the average power required.
$ER$ is the desired extinction ratio (ER = P1/P0).
$R_{SP}$ (A/W) is the monitor photodiode responsivity.
$I_{MPD\_CW}$ (mA) is the MPD current at that specified PCW.
$P_{CW}$ (mW) is the dc optical power specified on the laser data sheet.

In voltage setpoint, RPAV and $R_{ERSET}$ must be 1 kΩ resistors with a 1% tolerance and a temperature coefficient of 50 ppm/°C.

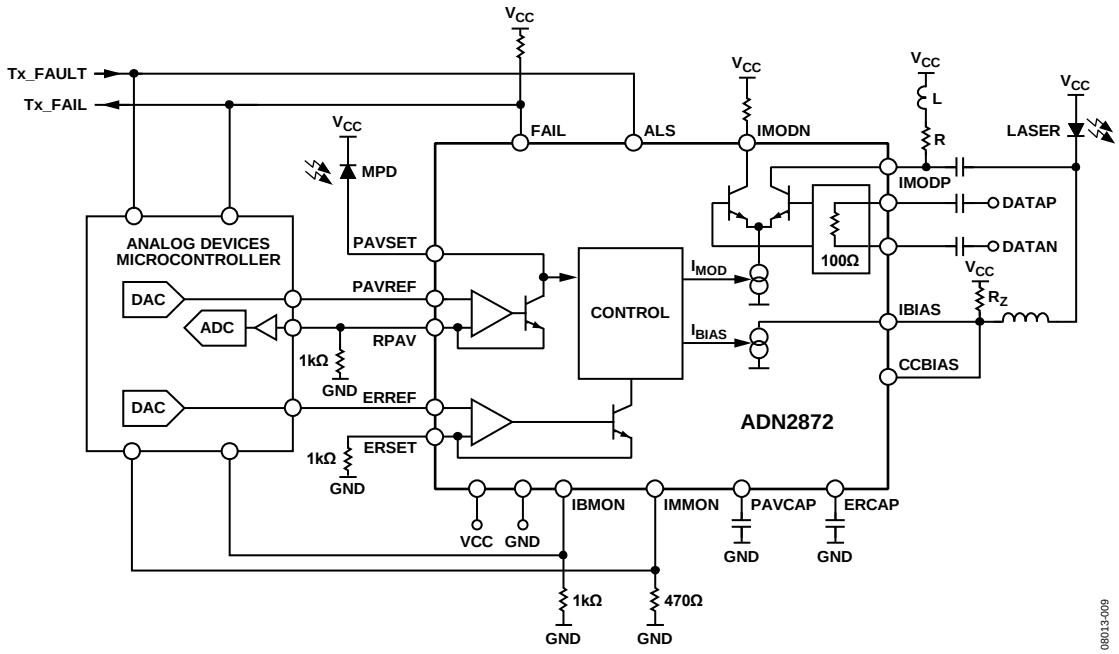


*Figure 26. ADN2872 Using MicroConverter Calibration and Monitoring*

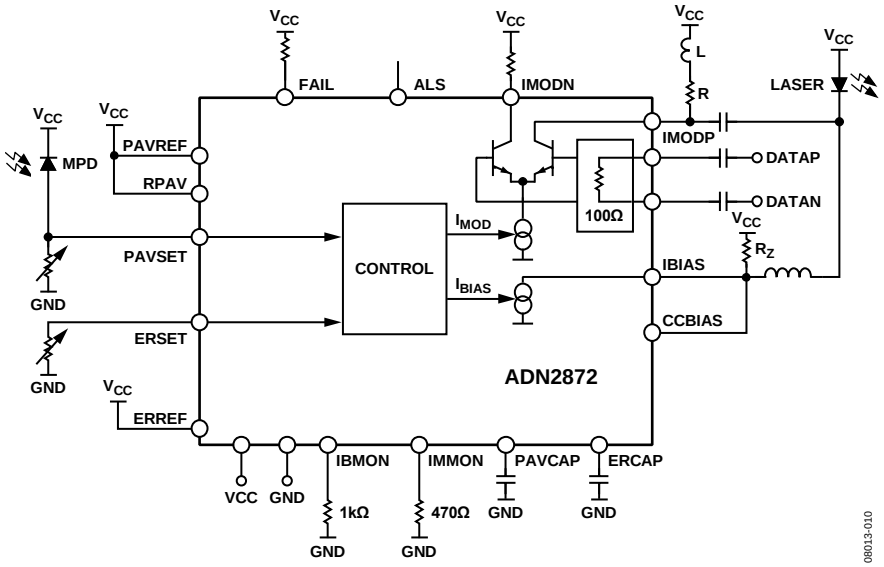


*Figure 27. ADN2872 Using Resistor Setpoint Calibration of Average Power and Energy Ratio*

## RESISTOR SETPOINT CALIBRATION

In resistor setpoint calibration, the PAVREF, ERREF, and RPAV pins must all be tied to VCC. Average power and ER can be set using the PAVSET and ERSET pins, respectively. A resistor is placed between the pin and GND to set the current flowing in each pin, as shown in Figure 27. The ADN2872 ensures that both PAVSET and ERSET are kept 1.2 V above GND. The PAVSET and ERSET resistors are given by

$$R_{PAVSET} = \frac{1.23\ \text{V}}{P_{AV} \times R_{SP}} \quad (\Omega)$$

$$R_{ERSET} = \frac{1.23\ \text{V}}{\frac{I_{MPD\_CW}}{P_{CW}} \times \frac{ER-1}{ER+1} \times P_{AV}} \quad (\Omega)$$

where:
$P_{AV}$ (mW) is the average power required.
$R_{SP}$ (A/W) is the monitor photodiode responsivity.
$P_{CW}$ (mW) is the dc optical power specified on the laser data sheet.
$I_{MPD\_CW}$ (mA) is the MPD current at that specified PCW.
*ER* is the desired extinction ratio (ER = P1/P0).

## $I_{MPD}$ MONITORING

$I_{MPD}$ monitoring can be implemented for voltage setpoint and resistor setpoint as follows.

### *Voltage Setpoint*

In voltage setpoint calibration, the following methods can be used for $I_{MPD}$ monitoring.

#### Method 1: Measuring Voltage at RPAV

The $I_{MPD}$ current is equal to the voltage at RPAV divided by the value of RPAV (see Figure 28) as long as the laser is on and is being controlled by the control loop. This method does not provide a valid $I_{MPD}$ reading when the laser is in shutdown or fail mode. A microconverter-buffered ADC input can be connected to RPAV to make this measurement. No decoupling or filter capacitors must be placed on the RPAV node because this can disturb the control loop.

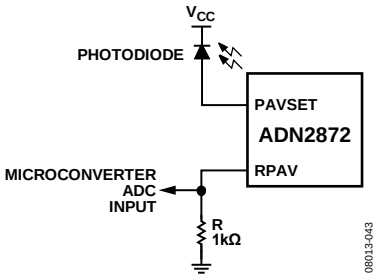


*Figure 28. Single Measurement of $I_{MPD}$ at RPAV in Voltage Setpoint Mode*

#### Method 2: Measuring $I_{MPD}$ Across a Sense Resistor

The second method has the advantage of providing a valid $I_{MPD}$ reading at all times but has the disadvantage of requiring a differential measurement across a sense resistor directly in series with the $I_{MPD}$. As shown in Figure 29, a small resistor, Rx, is placed in series with the $I_{MPD}$. If the laser used in the design has a pinout where the monitor photodiode cathode and the lasers anode are not connected, a sense resistor can be placed in series with the photodiode cathode and $V_{CC}$, as shown in Figure 30. When choosing the value of the resistor, the user must take into account the expected $I_{MPD}$ value in normal operation. The resistor must be large enough to make a significant signal for the buffered ADC to read, but small enough not to cause a significant voltage reduction across the $I_{MPD}$. The voltage across the sense resistor must not exceed 250 mV when the laser is in normal operation. It is recommended that a 10 pF capacitor be placed in parallel with the sense resistor.

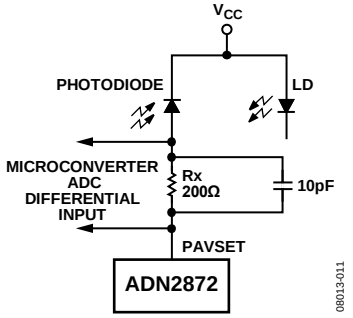


*Figure 29. Differential Measurement of $I_{MPD}$ Across a Sense Resistor*

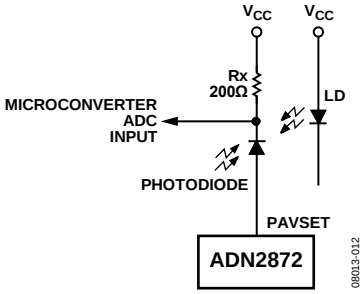


*Figure 30. Single Measurement of $I_{MPD}$ Across a Sense Resistor*

### *Resistor Setpoint*

In resistor setpoint calibration, the current through the resistor from PAVSET to ground is the $I_{MPD}$ current. The recommended method for measuring the $I_{MPD}$ current is to place a small resistor in series with the PAVSET resistor (or potentiometer) and measure the voltage across this resistor, as shown in Figure 31. The $I_{MPD}$ current is then equal to this voltage divided by the value of the resistor used. In resistor setpoint, PAVSET is held to 1.2 V nominal; it is recommended that the sense resistor must be selected so that the voltage across the sense resistor does not exceed 250 mV.

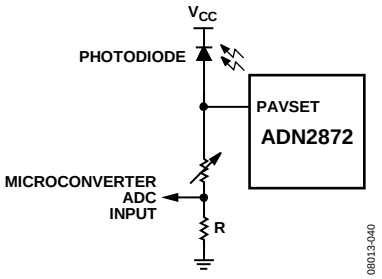


*Figure 31. Single Measurement of $I_{MPD}$ Across a Sense Resistor in Resistor Setpoint $I_{MPD}$ Monitoring*

## LOOP BANDWIDTH SELECTION

To ensure that the ADN2872 control loops have sufficient bandwidth, the average power loop capacitor (PAVCAP) and the ER loop capacitor (ERCAP) are calculated using the laser slope efficiency and the average power required.

For resistor setpoint control,

$$PAVCAP = 3.2 \times 10^{-6} \times \frac{LI}{P_{AV}} \quad \text{(Farad)}$$

$$ERCAP = \frac{PAVCAP}{2} \quad \text{(Farad)}$$

For voltage setpoint control,

$$PAVCAP = 1.28 \times 10^{-6} \times \frac{LI}{P_{AV}} \quad \text{(Farad)}$$

$$ERCAP = \frac{PAVCAP}{2} \quad \text{(Farad)}$$

where:
$P_{AV}$ (mW) is the average power required.
*LI* (mW/mA) is the typical slope efficiency at 25°C of a batch of lasers that are used in a design.

The preceding capacitor estimation formulas obtain a centered value for the particular type of laser that is used in a design and average power setting. Laser LI can vary by a factor of 7 between different physical lasers of the same type and across temperature without the need to recalculate the PAVCAP and ERCAP values. In the ac coupling configuration, LI can be calculated as

$$LI = \frac{P1 - P0}{I_{MOD}} \quad \text{(mW/mA)}$$

where *P1* is the optical power (mW) at the one level and *P0* is the optical power (mW) at the zero level.

These capacitors are placed between the PAVCAP and ERCAP pins and ground. It is important that these capacitors are low leakage multilayer ceramics with an insulation resistance greater than 100 GΩ or a time constant of 1000 sec, whichever is less. The capacitor tolerance can be ±30% from the calculated value to the available off the shelf value, including the tolerance of the capacitor.

## POWER CONSUMPTION

The ADN2872 die temperature must be kept below 125°C. The LFCSP package has an exposed paddle that must be connected such that it is at the same potential as the ADN2872 ground pins. Power consumption can be calculated as:

$$I_{CC} = I_{CC}\ min + 0.3\ I_{MOD}$$

$$P = V_{CC} \times I_{CC} + (I_{BIAS} \times V_{BIAS\_PIN}) + I_{MOD}\ (V_{MODP\_PIN} + V_{MODN\_PIN})/2$$

$$T_{DIE} = T_{AMBIENT} + \theta_{JA} \times P$$

where:
$I_{CC}\ min$ is 30 mA, the typical value of $I_{CC}$ provided in Table 1 with $I_{BIAS} = I_{MOD} = 0$.
$T_{DIE}$ is the die temperature.
$T_{AMBIENT}$ is the ambient temperature.
$V_{BIAS\_PIN}$ is the voltage at the IBIAS pin.
$V_{MODP\_PIN}$ is the voltage at the IMODP pin.
$V_{MODN\_PIN}$ is the voltage at the IMODN pin.

Thus, the maximum combination of $I_{BIAS} + I_{MOD}$ must be calculated.

## AUTOMATIC LASER SHUTDOWN (Tx_DISABLE)

ALS (Tx_DISABLE) is an input that shuts down the transmitter optical output. The ALS pin is pulled up internally with a 6 kΩ resistor and conforms to SFP MSA specifications. When ALS is logic high or open, both the bias and modulation currents are turned off.

## BIAS AND MODULATION MONITOR CURRENTS

IBMON and IMMON are current-controlled current sources that mirror a ratio of the bias and modulation current. The monitor bias current, IBMON, and the monitor modulation current, IMMON, must both be connected to ground through a resistor to provide a voltage proportional to the bias current and modulation current, respectively. When using a microcontroller, the voltage developed across these resistors can be connected to two of the ADC channels, making available a digital representation of the bias and modulation current.

## IBIAS PIN

ADN2872 has one on-chip, 800 Ω pull-up resistor. The current sink from this resistor is $V_{IBIAS}$ dependent.

$$I_{UP} = \frac{V_{CC} - V_{IBIAS}}{0.8} \quad \text{(mA)}$$

where $V_{IBIAS}$ is the voltage measured at the IBIAS pin after setup of one laser bias current, $I_{BIAS}$. Usually, when set up, a maximum laser bias current of 100 mA results in a $V_{IBIAS}$ of about 1.2 V. In a worst-case scenario, $V_{CC}$ = 3.6 V, $V_{IBIAS}$ = 1.2 V, and $I_{UP} \leq 3$ mA.

This on-chip resistor helps to damp out the low frequency oscillation observed from some inexpensive lasers. If the on-chip resistance does not provide enough damping, one external $R_Z$ may be necessary (see Figure 32 and Figure 33).

## DATA INPUTS

Data inputs must be ac-coupled (10 nF capacitors are recommended) and are terminated via a 100 Ω internal resistor between the DATAP and DATAN pins. A high impedance circuit sets the common-mode voltage and is designed to allow maximum input voltage headroom over temperature. It is necessary to use ac coupling to eliminate the need for matching between common-mode voltages.

## LASER DIODE INTERFACING

The schematic in Figure 32 describes the recommended circuit for interfacing the ADN2872 to most TO-Can or coax lasers. These lasers typically have impedances of 5 Ω to 7 Ω and have axial leads. The circuit shown works over the full range of data rates from 155 Mbps to 3.3 Gbps including multirate operation (with no change to PAVCAP and ERCAP values); see Figure 18, Figure 19, and Figure 20 in the Typical Performance Characteristics section for multirate performance examples. Coax lasers have special characteristics that make them difficult to interface to. They tend to have higher inductance, and their impedance is not well controlled. The circuit in Figure 32 operates by deliberately misterminating the transmission line on the laser side, while providing a very high quality matching network on the driver side. The impedance of the driver side matching network is very flat vs. frequency and enables multirate operation. A series damping resistor must not be used.

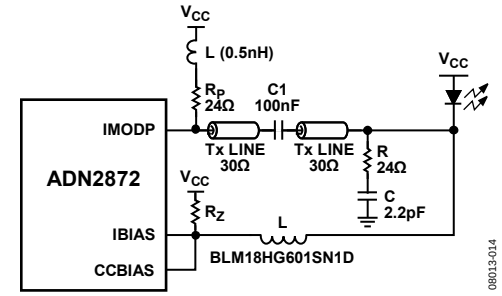


*Figure 32. Recommended Interface for ADN2872 AC Coupling*

The 30 Ω transmission line used is a compromise between drive current required and total power consumed. Other transmission line values can be used, with some modification of the component values. The R and C snubber values in Figure 32, 24 Ω and 2.2 pF, respectively, represent a starting point and must be tuned for the particular model of laser being used. $R_P$, the pull-up resistor, is in series with a very small (0.5 nH) inductor. In some cases, an inductor is not required or can be accommodated with deliberate parasitic inductance, such as a thin trace or a via placed on the PC board.

Take care to mount the laser as close as possible to the PC board, minimizing the exposed lead length between the laser can and the edge of the board. The axial lead of a coax laser is very inductive (approximately 1 nH per millimeter). Long exposed leads result in slower edge rates and reduced eye margin.

Recommended component layouts and gerber files are available by contacting sales at Analog Devices. Note that the circuit in Figure 32 can supply up to 56 mA of modulation current to the laser, sufficient for most lasers available today. Higher currents can be accommodated by changing transmission lines and backmatch values. This interface circuit is not recommended for butterfly-style lasers or other lasers with 25 Ω characteristic impedance. Instead, a 25 Ω transmission line and inductive (instead of resistive) pull-up is recommended. Contact sales for recommendations on transmission lines and backmatch values.

The ADN2872 also supports differential drive schemes. These can be particularly useful when driving VCSELs or other lasers with slow fall times. Differential drive can be implemented by adding a few extra components. A possible implementation is shown in Figure 33.

In Figure 32 and Figure 33, Resistor $R_Z$ is required to achieve optimum eye quality. The recommended value is approximately 200 Ω ~ 500 Ω.

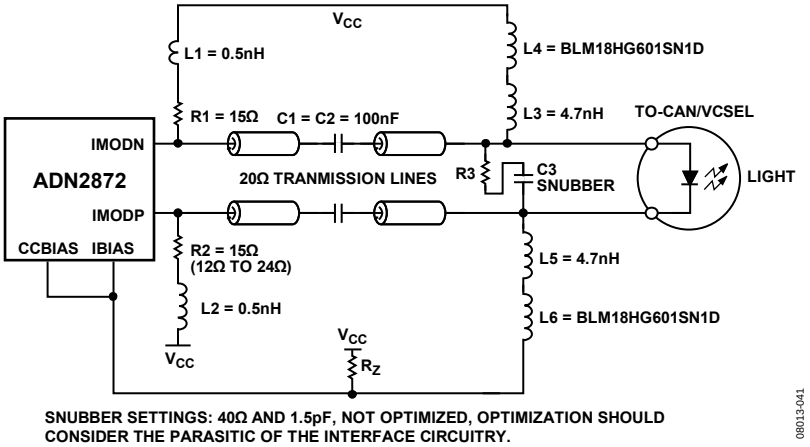


*Figure 33. Recommended Differential Drive Circuit*

## ALARMS

The ADN2872 has a latched active high monitoring alarm (FAIL). The FAIL alarm output is an open drain in conformance with SFP MSA specification requirements.

The ADN2872 has a three-fold alarm system that covers:

- Use of a bias current higher than expected, likely as a result of laser aging.
- Out-of-bounds average voltage at the monitor photodiode (MPD) input, indicating an excessive amount of laser power or a broken loop.
- Undervoltage in the IBIAS pin (laser diode cathode) that increases the laser power.

The bias current alarm trip point is set by selecting the value of resistor on the IBMON pin to GND. The alarm is triggered when the voltage on the IBMON pin goes above 1.2 V.

FAIL is activated when the single-point faults in Table 5 occur.

**Table 5. ADN2872 Single-Point Alarms**

| Alarm Type | Mnemonic | Overvoltage or Short to $V_{CC}$ Condition | Undervoltage or Short to GND Condition |
|---|---|---|---|
| Bias Current | IBMON | Alarm if > 1.2 V | Ignore |
| MPD Current | PAVSET | Alarm if > 2.0 V | Alarm if < 0.4 V |
| Crucial Nodes | ERREF (the ERRREF is designed tied to $V_{CC}$ in resistor setting mode) | Alarm if shorted to $V_{CC}$ (the alarm is valid for voltage setting mode only) | Alarm if shorted to GND |
| | IBIAS | Ignore | Alarm if < 0.6 V |

**Table 6. ADN2872 Response to Various Single-Point Faults in AC-Coupled Configuration, as Shown in Figure 32**

| Mnemonic | Short to $V_{CC}$ | Short to GND | Open |
|---|---|---|---|
| CCBIAS | Fault state occurs | Fault state occurs | Does not increase laser average power |
| PAVSET | Fault state occurs | Fault state occurs | Fault state occurs |
| PAVREF | Voltage mode: fault state occurs<br>Resistor mode: tied to $V_{CC}$ | Fault state occurs | Fault state occurs |
| RPAV | Voltage mode: fault state occurs<br>Resistor mode: tied to $V_{CC}$ | Fault state occurs | Voltage mode: fault state occurs<br>Resistor mode: does not increase average power |
| ERCAP | Does not increase laser average power | Does not increase laser average power | Does not increase laser average power |
| PAVCAP | Fault state occurs | Fault state occurs | Fault state occurs |
| DATAP | Does not increase laser average power | Does not increase laser average power | Does not increase laser average power |
| DATAN | Does not increase laser average power | Does not increase laser average power | Does not increase laser average power |
| ALS | Output currents shut off | Normal currents | Output currents shut off |
| ERSET | Does not increase laser average power | Does not increase laser average power | Does not increase laser average power |
| IMMON | Does not affect laser power | Does not increase laser average power | Does not increase laser average power |
| ERREF | Voltage mode: fault state occurs<br>Resistor mode: tied to $V_{CC}$ | Voltage mode: does not increase average power<br>Resistor mode: fault state occurs | Does not increase laser average power |
| IBMON | Fault state occurs | Does not increase laser average power | Does not increase laser average power |
| FAIL | Fault state occurs | Does not increase laser average power | Does not increase laser average power |
| IMODP | Does not increase laser average power | Does not increase laser average power | Does not increase laser average power |
| IMODN | Does not increase laser average power | Does not increase laser average power | Does not increase laser power |
| IBIAS | Fault state occurs | Fault state occurs | Fault state occurs |

# OUTLINE DIMENSIONS

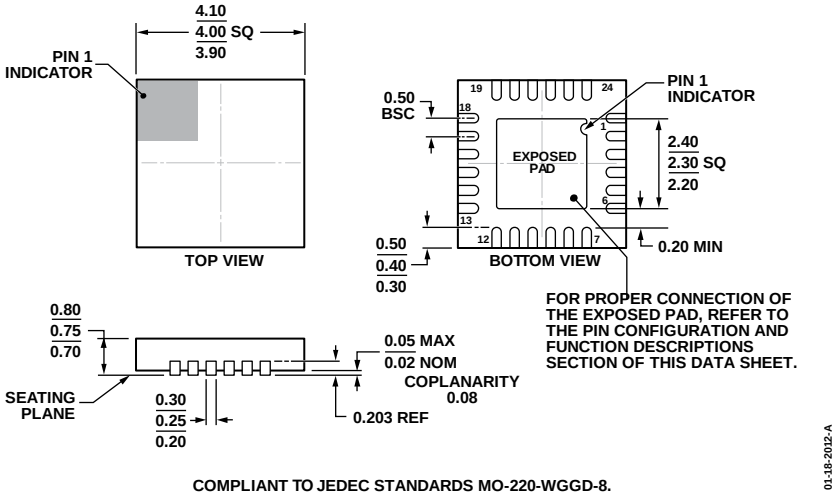


*Figure 34. 24-Lead Lead Frame Chip Scale Package [LFCSP]*
*4 mm × 4 mm Body and 0.75 mm Package Height*
*(CP-24-14)*
*Dimensions shown in millimeters*

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Option | Ordering Quantity |
|---|---|---|---|---|
| ADN2872ACPZ | −40°C to +85°C | 24-Lead Lead Frame Chip Scale Package [LFCSP] | CP-24-14 | 490 |
| ADN2872ACPZ-R7 | −40°C to +85°C | 24-Lead Lead Frame Chip Scale Package [LFCSP] | CP-24-14 | 1500 |

[1] Z = RoHS Compliant Part.

# NOTES

## NOTES

# NOTES


D08013-0-9/16(B)