



[Maxim](#) > [Design Support](#) > [Technical Documents](#) > [Application Notes](#) > [Digital Potentiometers](#) > APP 4557
[Maxim](#) > [Design Support](#) > [Technical Documents](#) > [Application Notes](#) > [Optoelectronics](#) > APP 4557

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APPLICATION NOTE 4557

Digital Resistor Sets Operating Power for Laser Driver

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Abstract: Adding an op amp and a digital potentiometer to a standard laser-driver circuit produces a driver that varies the laser's power-set point in response to temperature, generating a photodiode current that is a linear function of the potentiometer value.

A similar version of this article appeared in the March 15, 2007 issue of *ED* magazine.

The [MAX3740](#) VCSEL laser driver and [DS1859](#) dual, temperature-controlled digital resistor are popular choices for SFP and SFF fiber-optic systems, due to their small size and high level of integration. The MAX3740 uses a monitoring photodiode and automatic power-control loop (APC) to compensate the laser power for temperature effects and aging. Photodiode responsivity can vary as much as 40%, so the system needs some additional compensation. That can be achieved with a digital resistor, which varies the power set-point in response to temperature.

A resistor between the MAX3740 reference pin (REF) and the power monitor photodiode (MD) sets the photodiode current. The power-control loop then drives the laser diode to the intensity that delivers that current. The problem with this approach is a too-low control voltage: the nominal voltage at MD is 1.6V and the nominal voltage at REF is 1.8V, leaving only 0.2V across the resistor for setting the photodiode current.

Digital resistors like those in the DS1859 can have minimum resistances as high as 1k Ω , which in turn gives a maximum current of only 200 μ A. The resulting current vs. resistance function is very nonlinear, with poor resolution at high currents. You can add a fixed resistor between REF and MD to raise the maximum current, but the adjustment range is still only 200 μ A. (Nor does the fixed resistor provide any improvement in nonlinearity and resolution.) A graph of photodiode current vs. DS1859 resistance (lower-left trace in **Figure 1**) shows the response of a circuit with series resistor value of 806 Ω , which biases up the response by 248 μ A.

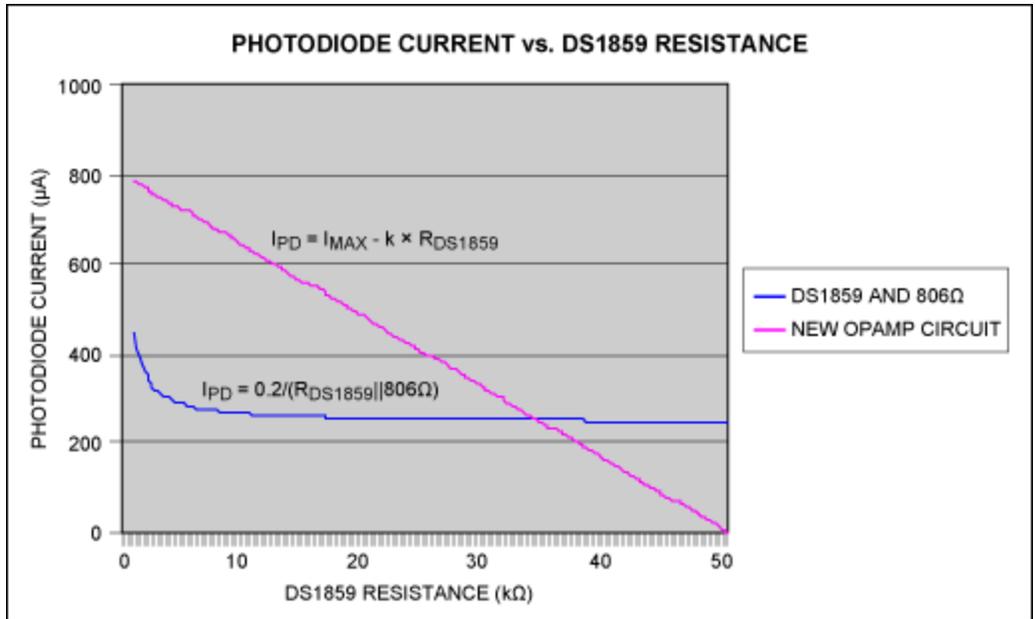


Figure 1. The MAX3740 laser driver with external photodiode produces a nonlinear control voltage for the laser (lower-left trace). Adding a digital resistor and op amp (Figure 2) produces the linear control voltage shown. The solution to these problems (Figure 2) is to allow the resistor between REF and MD (R1) to set the maximum photodiode current, and then subtract a current proportional to the DS1859 resistance. The subtracted current comes from the op-amp output, which steals current from the photodiode through R2. The op amp shown was chosen for its small size (SC70 package) and low cost. It is powered by the same +3.3V power supply as the digital resistor (DS1859) and laser driver (MAX3740).

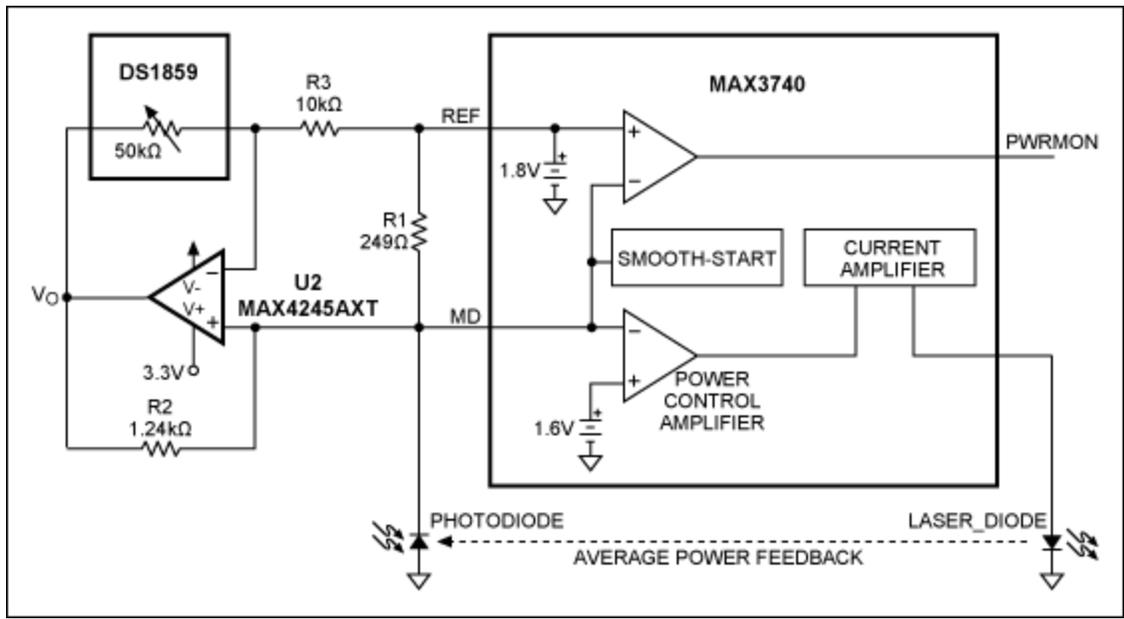


Figure 2. An external op amp and digital resistor (DS1859) enable the MAX3740 laser driver to generate the linear control voltage shown in Figure 1.

The op amp generates a voltage (V_O) proportional to the value of MD (REF - MD) and the DS1859

value. In turn, the voltage generates a current through R2 proportional to the difference between the voltages at V_O and MD. The effects at MD cancel out, so the current through R2 depends only on (REF - MD), a stable 0.2V, and the DS1859 value. Current through the photodiode equals the current thru R1 (803µA) minus the current thru R2. Thus, photodiode current is a linear function of the potentiometer value, as illustrated in Figure 1. With appropriate resistor values, this circuit works with any value potentiometer and provides current over any range. Its only limitation is the current-drive capability of the op amp. Design calculations are:

Derivation of equations

Equation for op amp output voltage

$$V_{OUT} = V_{REF} \times \left(\frac{-R_{DS1859}}{R3} \right) + V_{MD} \times \left(1 + \frac{R_{DS1859}}{R3} \right)$$

Rearrange terms

$$V_{OUT} = V_{MD} + \frac{(V_{MD} - V_{REF}) \times R_{DS1859}}{R3}$$

Substitute 0.2V for reference voltage - modulation voltage

$$V_{OUT} = V_{MD} - \frac{0.2V \times R_{DS1859}}{R3}$$

Equation for current through R2 Substitute in equation for op amp output voltage

$$I_{R2} = \frac{V_{OUT} - V_{MD}}{R2} \qquad I_{R2} = \frac{\left(V_{MD} - \frac{0.2V \times R_{DS1859}}{R3} \right) - V_{MD}}{R2}$$

Modulation voltage terms cancel out

$$I_{R2} = \frac{-0.2V \times R_{DS1859}}{R3 \times R2}$$

Equation for current through R1 Substitute 0.2V for reference voltage - modulation voltage

$$I_{R1} = \frac{V_{REF} - V_{MD}}{R1} \qquad I_{R1} = \frac{0.2V}{R1}$$

Equation for current through photo diode

$$I_{PD} = I_{R1} + I_{R2}$$

Substitute equations for R1 current and R2 current

$$I_{PD} = \frac{0.2V}{R1} - \frac{0.2V \times R_{DS1859}}{R3 \times R2}$$

Where

R1 = 249Ω

R2 = 1240Ω

R3 = 10000Ω

I_{PD} = 787µA, DS1859 resistance = 1kΩ

$I_{PD} = -3.3\mu A$, DS1859 resistance = $50k\Omega$

Design procedure

Select desired photodiode min and max current

$$\begin{aligned} I_{PDmax} &\equiv 800 \times 10^{-6} A & I_{PDmin} &\equiv 0 A \\ I_{PDdelta} &= I_{PDmax} - I_{PDmin} & I_{PDdelta} &= 8 \times 10^{-4} A \end{aligned}$$

DS1859 min and max values

$$\begin{aligned} R_{DS1859max} &\equiv 50000\Omega & R_{DS1859min} &\equiv 1000\Omega \\ R_{DS1859delta} &= R_{DS1859max} - R_{DS1859min} & R_{DS1859delta} &= 4.9 \times 10^4\Omega \end{aligned}$$

Op amp output voltage range

$$\begin{aligned} V_{OUTmax} &\equiv 2.0V & V_{OUTmin} &\equiv 0V \\ V_{OUTdelta} &= V_{OUTmax} - V_{OUTmin} & V_{OUTdelta} &= 2V \end{aligned}$$

Modulation voltage min and max

$$\begin{aligned} V_{MDmin} &\equiv 1V & V_{MDmax} &\equiv 2V \\ V_{MDdelta} &= V_{MDmax} - V_{MDmin} & V_{MDdelta} &= 1V \\ R1 &= \frac{0.2V}{I_{PDmax}} & R1 &= 250\Omega \\ R3 &= \frac{0.2V \times R_{DS1859delta}}{V_{OUTdelta} - V_{MDdelta}} & R3 &= 9.8 \times 10^3\Omega \\ R2 &= 0.2V \times \frac{R_{DS1859delta}}{I_{PDdelta} \times R3} & R2 &= 1.25 \times 10^3\Omega \end{aligned}$$

Related Parts

DS1859	Dual, Temperature-Controlled Resistors with Internally Calibrated Monitors	Free Samples
MAX4245	Ultra-Small, Rail-to-Rail I/O with Disable, Single/Dual-Supply, Low-Power Op Amps	Free Samples

More Information

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