

High-Density DACs Offer Superior Noise And Accuracy Performance in Laser-Drive Applications

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This technical note explores the benefits of using high-density, high-precision Digital to Analog Converters (DACs) and Operational Amplifiers (OPAMPs) in laser drive applications. It will demonstrate that with these devices and some discrete components, a high-precision solution can be created and easily modified to accommodate different current-output requirements and power-supply specifications. The DAC80508 and OPA2376 from Texas Instruments will be used to illustrate the functionality of this application.

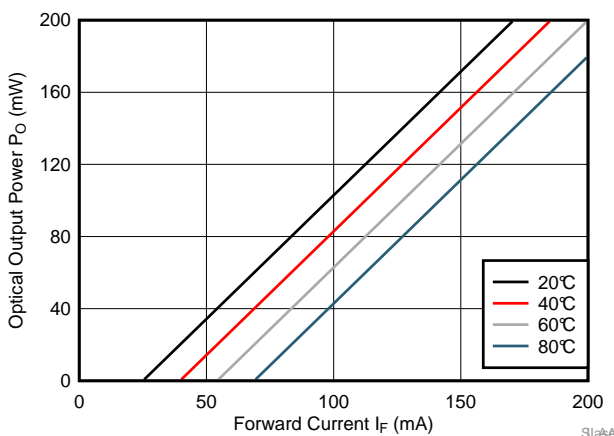
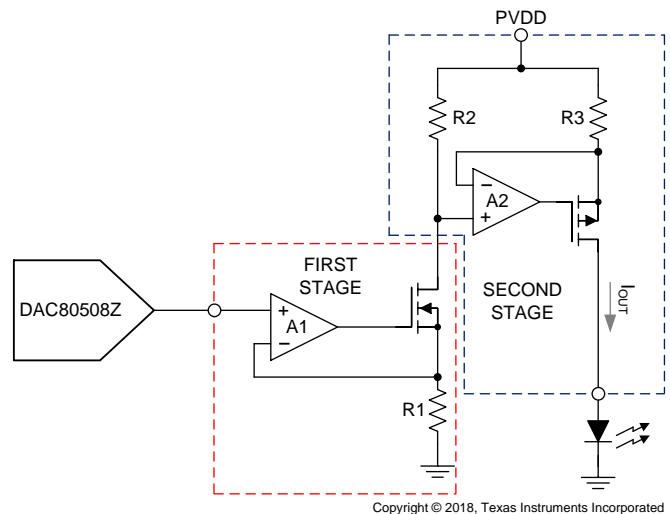


Figure 1. Laser Diode Output Power

Laser diodes generally require a precisely controlled current to regulate their output power. It is advantageous for this current to be adjustable as output power can change over temperature, as seen in Figure 1. For this reason, a DAC can be used to dynamically update the forward current. In addition, a low-noise source is desired to reduce the intensity noise (instability in the output power) of a laser output. Current-output DACs that can drive hundreds of milliamps are uncommon, so a voltage-output DAC with a voltage-to-current (V/I) converter can be used to create a high-side current source to drive the laser diode.



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Figure 2. High-Side Current Output Circuit

The output V/I converter is comprised of two stages: an OPAMP is used to create a precise current determined by the voltage output of the DAC and resistance of R1; and a precision current-mirror with a gain set by R2 and R3. As the voltage across R2 and R3 is ideally the same, R3 is a much smaller value to achieve the desired current gain. Equation 1 shows the gain of the system. Minimizing the supply of the high-side of current mirror (PVDD) reduces unnecessary power dissipation across the P-channel MOSFET.

$$I_{OUT} = (V_{DAC} \times R2) / (R1 \times R3) \quad (1)$$

For example, the current output range requirement for this circuit will be 0mA to 200mA. By selecting the 1.25V range of the DAC80508 and choosing resistor values as shown below, the range requirement can be satisfied.

$$R1 = 5k\Omega, R2 = 2k\Omega, R3 = 2.5\Omega \quad (2)$$

$$I_{OUT-MAX} = (1.25V \times 2k\Omega) / (5k\Omega \times 2.5\Omega) \quad (3)$$

$$I_{OUT-MAX} = 200mA \quad (4)$$

As laser-diode applications generally require a high channel count, it is important to select small devices for maximum channel density. The DAC80508ZYZT provides eight 16-bit voltage DAC channels in a 2.4mm x 2.4mm DSBGA package while the OPA2376AIYZD provides two amplifiers in a single 1.3mm x 2.3mm package. These small devices can be

used with devices from the Texas Instruments FemtoFET family of devices to make an incredibly dense, high channel count solution. Figure 3 shows the relative size of the Texas Instruments ICs used in the circuit.

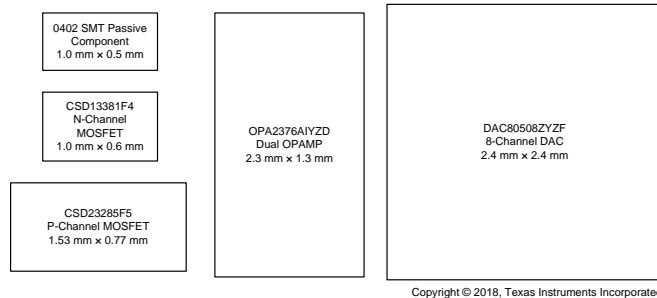


Figure 3. Device Size Comparison

There are several potential sources of error in the high-side current source design. First, there are the gain, offset, and linearity errors of the voltage-output DAC. It is important to select a precision DAC to minimize these errors, such as the DAC80508. Secondly, there is the gain error created by inaccuracy of the reference current created by R1 and mismatch of the of the resistors R2 and R3 in the that set the gain of the final stage, so high precision resistor should be used or a calibration method should be implemented. Thirdly, there is the input offset error of the two OPAMPs that will create an offset in the output current. Using the resistor values selected for the 200mA range, the total unadjusted error (TUE) of the system can be seen in Figure 4. It is clear that a major component of the error is a gain error. As discussed, this error is primarily created by the discrete resistors in the circuit. This gain error (and offset error) can easily be accounted for and removed with a simple two-point calibration.

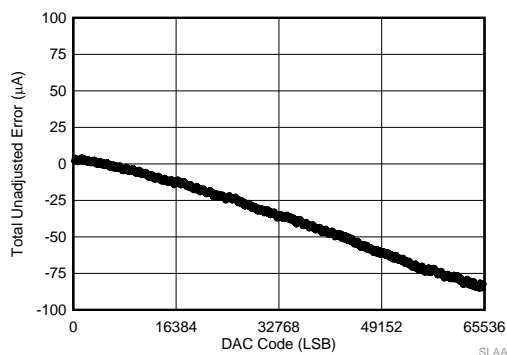


Figure 4. Total Unadjusted Error of Current Output

Output noise of the circuit will directly impact the output power of the laser-diode. There are a few sources of noise in the circuit, such as the reference for the DAC, thermal noise from the DAC's internal resistors and the circuits resistors, and the noised introduced by the OPAMPs. Noise generated in the DAC itself (from the internal reference and resistor ladder) will be gained through the same V/I stage on the output, and it generally the primary source of noise. Broadband noise of the 200mA output range circuit is shown in Figure 5. Typically the noise of current-sources in laser drive application is shown as a RMS noise value with a limited bandwidth, which is shown in Table 1.

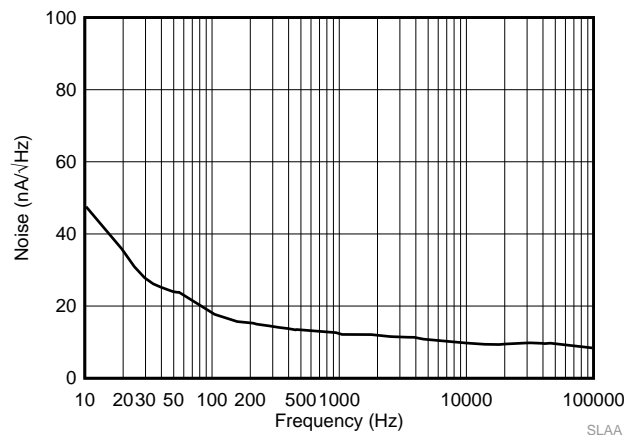


Figure 5. Current Noise at 100mA Output

Table 1. Bandwidth Limited RMS Noise

DAC Output Code (LSB)	Approx. Current Output	Noise (μA_{RMS}) ⁽¹⁾
0x4000	50 mA	3.1
0x8000	100 mA	3.4
0xFFFF	200 mA	4.3

In conclusion, an accurate, low-noise, discrete high-side current source solution is possible with the DAC80508 and OPA2376. The very small size of the IC device packages and the MOSFETs, allow a high-density implementation. This solution is comparable with most integrated solutions, while offering superior noise and accuracy performance.

Table 2. Device Recommendations

Device	Optimized Parameters
DAC80508ZYZF	Small Size, High Precision 16-bit Performance, Internal Reference
OPA2376AIYZD	Small Size, Low Offset Voltage, Low Noise
CSD13381F4	12 V N-Channel FemtoFET™ MOSFET
CSD23285F5	-12-V, P-Channel FemtoFET™ MOSFET

⁽¹⁾ Bandwidth limited to 100 kHz.

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