ANALOG DEVICES

AN-1207
APPLICATION NOTE

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Programmable High Voltage Source with Boosted Output Current Using the AD5292 Digital Potentiometer, OP184 Op Amp, and MOSFETs

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 provides a low cost, programmable, high voltage source with boosted output current using the AD5292 digital potentiometer in conjunction with the OP184 operational amplifier. The BSS138 PMOS transistor and Si2307CDS NMOS transistor provide current drive capability up to 2.5 A.

The circuit offers 1024 different voltage settings, controllable through an SPI-compatible digital interface. This circuit offers 10-bit resolution over an output voltage range of 0 V to 30 V and is capable of delivering up to 2.5 A output current.

The ±1% resistor tolerance of the AD5292, in conjunction with an external resistor shown in Figure 2, increases the accuracy of the circuit by providing 10-bit resolution over a reduced output voltage range. This, in effect, creates a vernier DAC, which offers higher resolution over the reduced range.

In addition, the AD5292 has an internal 20-times programmable memory that allows a customized V_{OUT} at power-up. The circuit provides an accurate, low noise, low drift output voltage and high current capabilities—and is well suited for power applications.

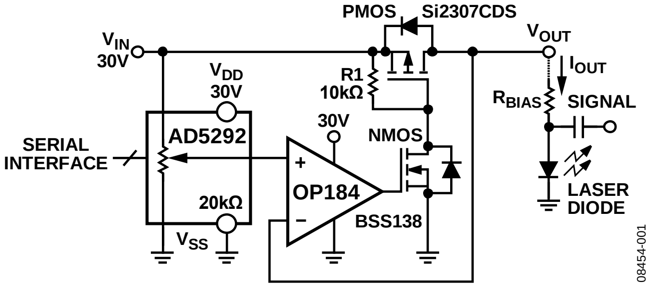

Figure 1. Programmable Voltage Source with Boosted Current Output (Simplified Schematic: Decoupling and All Connections Not Shown)

CIRCUIT DESCRIPTION

Table 1. Devices Connected/Referenced

Product	Description
AD5292	Digital potentiometer, 10 bits, 1% resistor tolerance
OP184	Precision instrumentation amplifier

This circuit employs the AD5292 digital potentiometer, in conjunction with the OP184, the BSS138 N-MOSFET from Diodes, Inc., and the Si2307CDS P-MOSFET from Vishay Siliconix, providing a low cost, 10-bit resolution, high voltage programmable source with boosted current output. The circuit guarantees monotonicity, ±1 LSB DNL, and integral nonlinearity of ±2 LSB typical.

The OP184 is a single op amp that offers a high slew rate, low noise, and rail-to-rail input and output. In the circuit, it is configured in the follower mode. It guarantees that the output voltage, V_{OUT}, is equal to the voltage set in the digital potentiometer by driving the BSS138 NMOS transistor. This MOSFET drives the Si2307CDS PMOS transistor that delivers the current, I_{OUT}, to the load.

Resistor R_1 ensures that the PMOS transistor is always on, thereby eliminating latch-up or start-up problems. However, this resistance limits the maximum settling time in the circuit. The value chosen is a trade-off between the power dissipated in the resistor and the maximum V_{OUT} settling time.

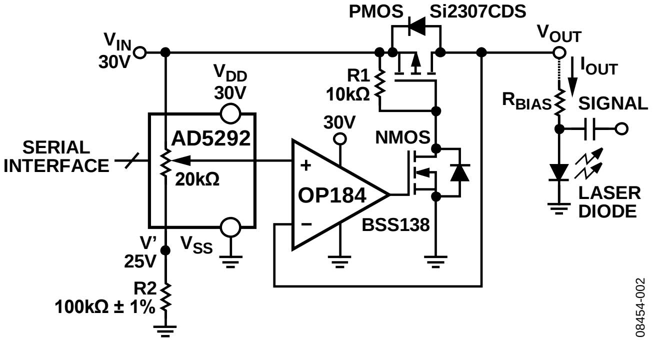

Figure 2. Programmable Voltage Source with Increased Accuracy Over Reduced Output Range (Simplified Schematic: Decoupling and All Connections Not Shown)

Equation 1 calculates the time constant of the network.

$$\tau = R_1 \times C_{IN} \quad (1)$$

where C_{IN} is the input capacitance in the PMOS gate (~380 pF for the Si2307CDS). The time constant of the network is 3.8 µs. The single-pole bandwidth of this network is approximately 42 kHz. Bandwidth can be increased by decreasing R_1, but power dissipation will increase.

Typical integral nonlinearity (INL) and differential nonlinearity (DNL) plots are shown in Figure 3 and Figure 4 using the configuration in Figure 1. In this configuration, the AD5292 is operating ratiometrically, which means that variation in the total resistor tolerance does not affect the performance.

To improve the circuit accuracy, the voltage reference across the AD5292 can be reduced by using an external resistor as shown in Figure 5. This gives the full 10 bits of resolution over a limited voltage range. Most digital potentiometers have a ±20% end-to-end resistor tolerance. This affects the circuit accuracy due to the mismatch between the digital potentiometer and the external resistors. The ±1% resistor tolerance of the AD5292 helps to overcome the mismatch resistance error.

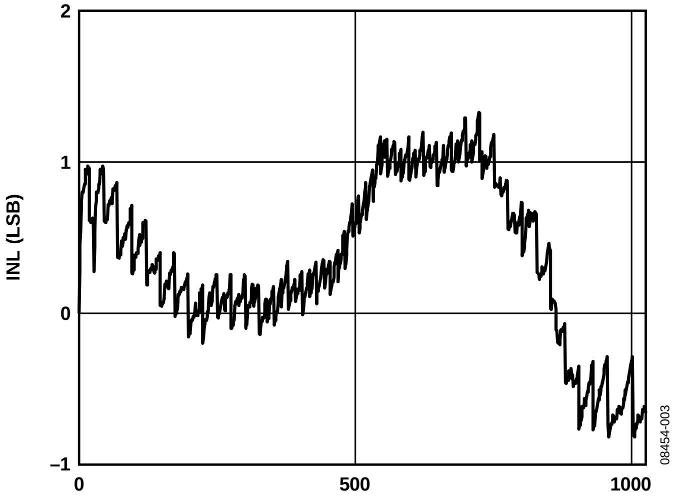

Figure 3. INL vs. Decimal Code

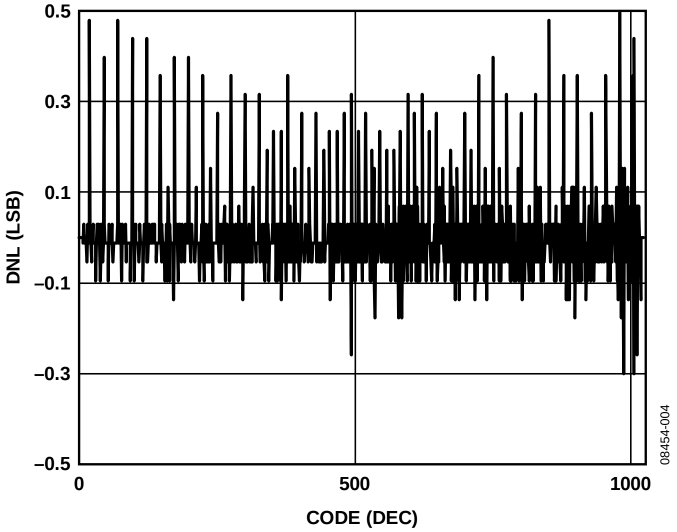

Figure 4. DNL vs. Decimal Code

Figure 6 shows the output voltage vs. digital code for the circuits of Figure 1 (normal mode, 1 LSB = 29 mV) and Figure 2 (reduced output mode, 1 LSB = 4.9 mV).

The AD5292 has 20 times programmable memory, which enables the user to preset the output voltage to a specific value at power-up.

Excellent layout, grounding, and decoupling techniques must be utilized in order to achieve the desired performance from the circuits discussed in this note (see Tutorial MT-031 and Tutorial MT-101). As a minimum, a 4-layer PCB should be used with one ground plane layer, one power plane layer, and two signal layers.

COMMON VARIATIONS

The AD5291 (8 bits with 20-times programmable power-up memory) and the AD5293 (10 bits, no power-up memory) are both ±1% tolerance digital potentiometers that are suitable for this application.

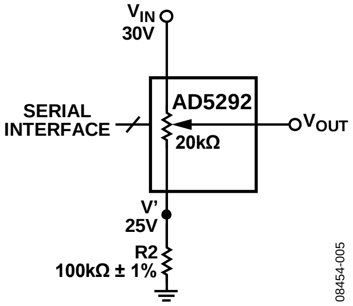

Figure 5. Increased Accuracy Over a Reduced Output Range (Simplified Schematic: Decoupling and All Connections Not Shown)

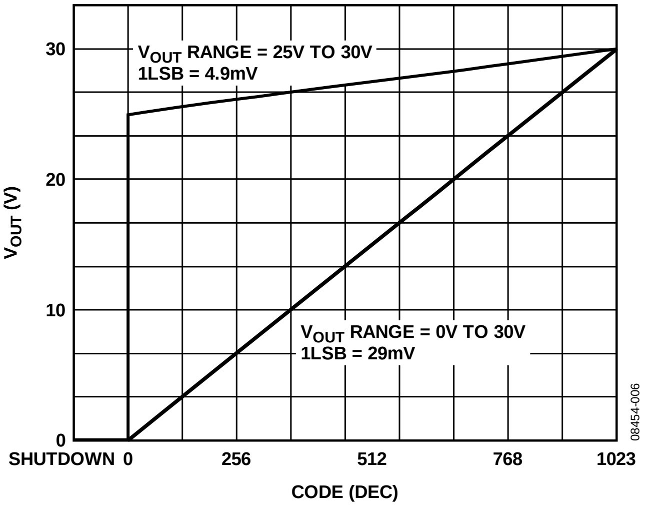

Figure 6. Output Voltage vs. Decimal Code for Circuits of Figure 1 and Figure 2

LEARN MORE

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"*, Analog Devices.

MT-032 Tutorial, *Ideal Voltage Feedback (VFB) Op Amp*, Analog Devices.

MT-061 Tutorial, *Instrumentation Amplifier Basics*, Analog Devices.

MT-087 Tutorial, *Voltage References*, Analog Devices.

MT-091 Tutorial, *Digital Potentiometers*, Analog Devices.

MT-095 Tutorial, *EMI, RFI, and Shielding Concepts*, Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*, Analog Devices.

Data Sheets

AD5292 Data Sheet

AD5291 Data Sheet

AD5293 Data Sheet

OP184 Data Sheet

REVISION HISTORY

4/13—Rev. A to Rev. B

Changed Document Title from CN-0015 to AN-1207 .... Universal

3/10—Rev. 0 to Rev. A

Changes to Circuit Function and Benefits Section.......... 1

9/09—Revision 0: Initial Version

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