ANALOG DEVICES

Circuit Note CN-0112

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Devices Connected/Referenced	
AD5292	10-Bit, 1% Resistor Tolerance Digital Potentiometer
OP184	Rail-to-Rail Input and Output, Low Noise, High Slew Rate Operational Amplifier

Variable Gain Noninverting Amplifier Using the AD5292 Digital Potentiometer and the OP184 Op Amp

CIRCUIT FUNCTION AND BENEFITS

This circuit provides a low cost, high voltage, variable gain noninverting amplifier using the AD5292 digital potentiometer in conjunction with the OP184 operational amplifier.

The circuit offers 1024 different gains, controllable through an SPI-compatible serial digital interface. The ±1% resistor tolerance performance of the AD5292 provides low gain error over the full resistor range, as shown in Figure 2.

The circuit supports rail-to-rail inputs and outputs for both single-supply operation at +30 V and dual-supply operation at ±15 V, and is capable of delivering up to ±6.5 mA output current.

In addition, the AD5292 has an internal 20-times programmable memory that allows a customized gain setting at power-up.

The circuit provides accuracy, low noise, and low THD and is well suited for signal instrumentation conditioning.

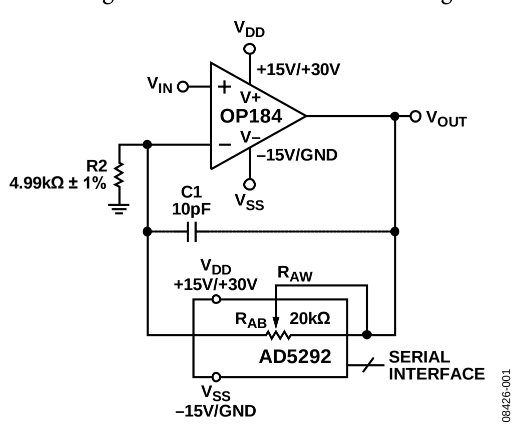

Figure 1. Variable Gain NonInverting Amplifier Simplified Schematic (Decoupling and All Connections Not Shown)

CIRCUIT DESCRIPTION

The circuit employs the AD5292 digital potentiometer in conjunction with the OP184 operational amplifier, providing a low cost, variable gain noninverting amplifier.

The input signal, V_{IN}, is amplified by the OP184. The op amp offers low noise, high slew rate, and rail-to-rail inputs and outputs.

The maximum circuit gain is defined in Equation 1.

$$G = 1 + \frac{R_{AB}}{R_2} \rightarrow R_2 = \frac{R_{AB}}{G-1} \quad (1)$$

The maximum current through the AD5292 is ±3 mA, which limits the maximum input voltage, V_{IN}, based on the circuit gain as described in Equation 2.

$$|V_{IN}| \leq 0.003 \times R_2 \quad (2)$$

When the input signal connected to V_{IN} is higher than the theoretical maximum value from Equation 2, R_2 should be increased, and the new gain can be recalculated using Equation 1.

The ±1% internal resistor tolerance of the AD5292 ensures a low gain error, as shown in Figure 2.

The circuit gain equation is

$$G = 1 + \frac{(1024 - D) \times {R_{AB}}/{1024}}{R_2} \quad (3)$$

where D is the code loaded in the digital potentiometer.

Rev. B

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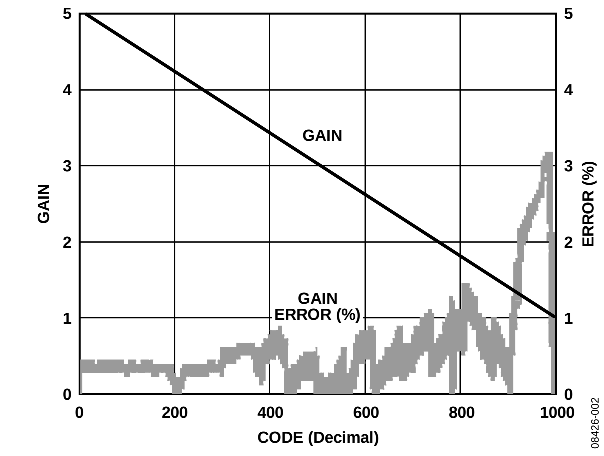

Figure 2. Gain and Gain Error vs. Decimal Code

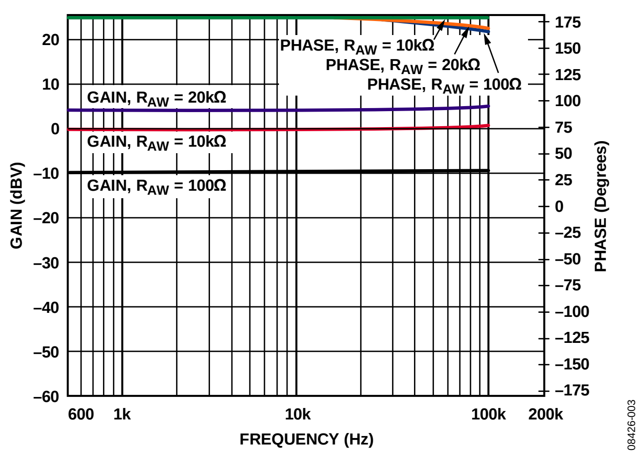

Figure 3. Gain and Phase vs. Frequency for AC Input Signal

When the circuit input is an ac signal, the parasitic capacitances of the digital potentiometer can cause undesirable oscillation in the output. This can be avoided, however, by connecting a small capacitor, C_1, between the inverter input and its output. A value of 10 pF was used for the gain and phase plots shown in Figure 3.

A simple modification of the circuit provides a logarithmic gain function, as shown in Figure 4. In this case, the digital potentiometer is configured in the ratiometric mode.

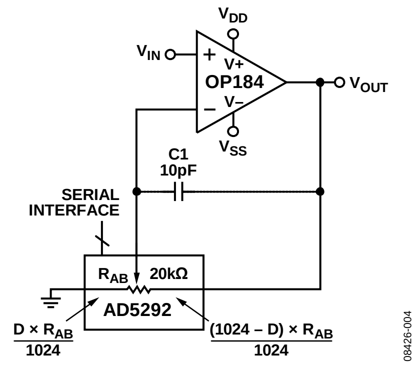

Figure 4. Logarithmic Gain Circuit

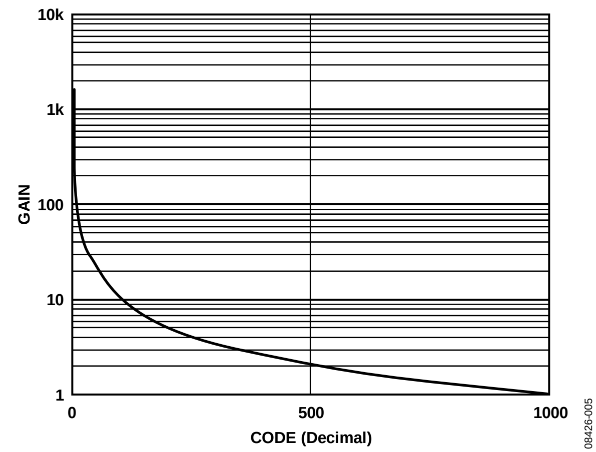

Figure 5. Logarithmic Gain Function

The circuit gain is defined in Equation 4

$$G = 1 + \frac{(1024 - D)}{D} = \frac{1024}{D} \tag{4}$$

where D is the code loaded in the digital potentiometer. A gain plot vs. code is shown in Figure 5.

The AD5292 has a 20-times programmable memory, which allows presetting the output voltage in 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, *Grounding Data Converters and Solving the Mystery of AGND and DGND* and Tutorial MT-101, *Decoupling Techniques*). 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 with no power-up memory) are both ±1% tolerance digital potentiometers that are suitable for this application.

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

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

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

Data Sheets and Evaluation Boards

AD5291 Data Sheet.

AD5292 Data Sheet.

AD5292 Evaluation Board.

AD5293 Data Sheet.

OP184 Data Sheet.

REVISION HISTORY

3/10—Rev. A to Rev. B

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

12/09—Rev. 0 to Rev. A

Corrected trademark 1

8/09—Revision 0: Initial Version

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