CIRCUIT FUNCTION AND BENEFITS

This circuit provides a low cost, high voltage, variable gain inverting 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 input and output rail to rail 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, low THD, and is well suited for signal instrumentation conditioning.

CIRCUIT DESCRIPTION

This 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 input and output.

The maximum circuit gain is defined in Equation 1.

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

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

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

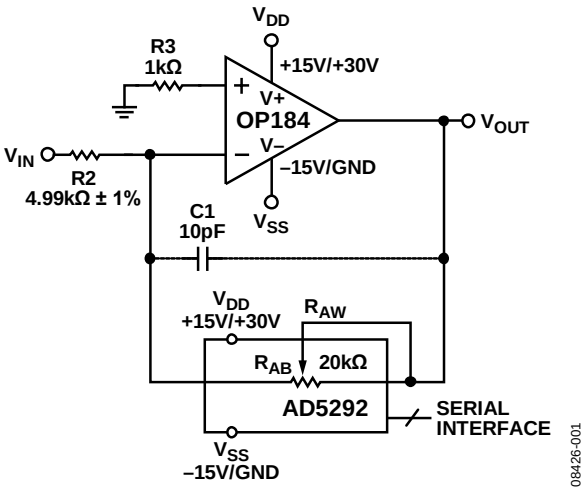

Figure 1. Variable Gain Inverting Amplifier (Simplified Schematic: Decoupling and All Connections Not Shown)

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

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

where D is the code loaded in the digital potentiometer.

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.

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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.

The circuit gain is defined in Equation 4.

$$G = \frac{1024 - D}{D} \quad (4)$$

where D is the code loaded in the digital potentiometer. A gain plot versus 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.

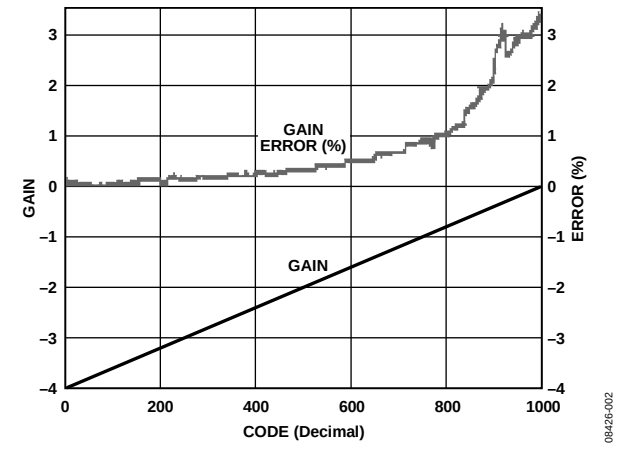

Figure 2. Gain and Gain Error vs. Decimal Code

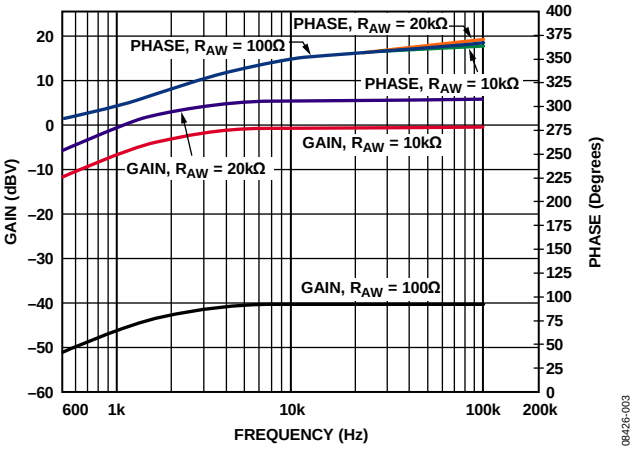

Figure 3. Gain and Phase vs Frequency for AC Input Signal

Excellent layout, grounding, and decoupling techniques must be utilized in order to achieve the desired performance from the circuits discussed in this note (see MT-031 Tutorial and MT-101 Tutorial). 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.

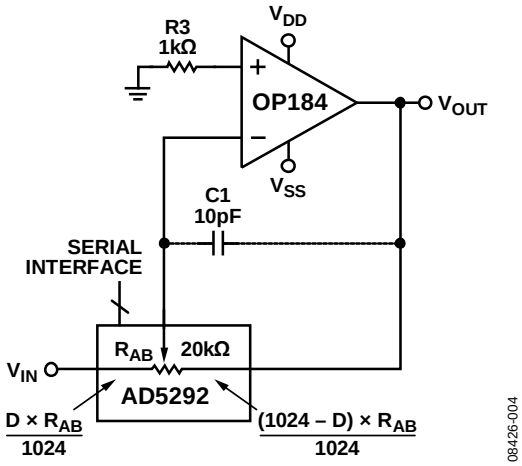

Figure 4. Logarithmic Gain Circuit

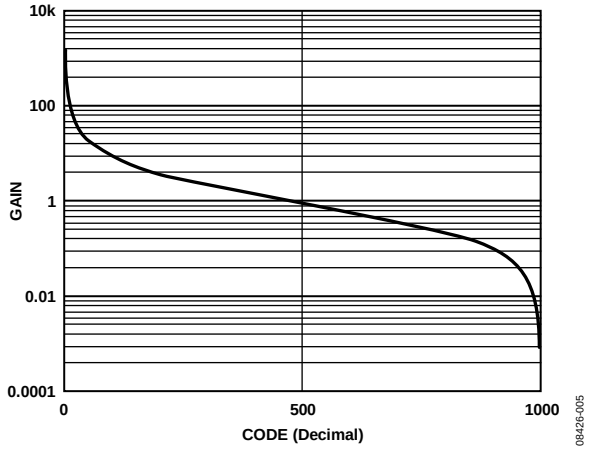

Figure 5. Logarithmic Gain Function

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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

4/10—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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