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Circuit Note
CN-0114

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Devices Connected/Referenced	
AD5292	Digital Potentiometer, 10 Bits, 1% Resistor Tolerance
AD8221	Precision Instrumentation Amplifier

Low Cost, High Voltage, Programmable Gain Instrumentation Amplifier Using the AD5292 Digital Potentiometer and the AD8221 In-Amp

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 provides a low cost, high voltage, programmable gain instrumentation amplifier using the AD5292 digital potentiometer and the AD8221 instrumentation amplifier.

The circuit offers 1,024 different gain settings, controllable through an SPI 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 provides a high performance instrumentation amplifier that delivers the industry's highest CMRR over frequency in its class and dynamic programmable gain for both single supply operation at +30 V and dual supply operation at ±15 V. In addition, the AD5292 has an internal 20-times programmable memory that allows the user to customize the instrumentation amplifier gain at power-up.

The circuit provides accurate, low noise, high gain and is well suited for signal instrumentation conditioning, precision data acquisition, biomedical analysis, and aerospace instrumentation.

CIRCUIT DESCRIPTION

This circuit employs the AD5292 digital potentiometer in conjunction with the AD8221 instrumentation amplifier, providing an overall low cost, high voltage, programmable gain instrumentation amplifier.

The differential input signal, +IN and –IN, is amplified by the AD8221. The instrumentation amplifier offers accuracy, low noise, high CMRR, and high slew rate.

The maximum circuit gain is defined in Equation 1, where R_{AW_MIN} is the wiper resistance of the AD5292 in the rheostat mode and represents the minimum value of the gain-setting resistance (100 Ω).

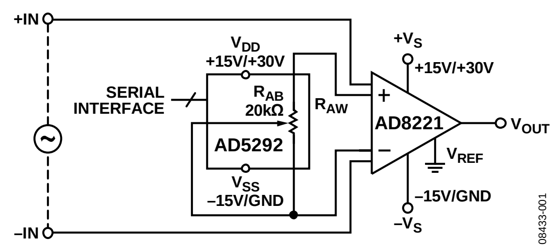

Figure 1. Programmable Gain Instrumentation Amplifier (Simplified Schematic: Decoupling and All Connections Not Shown)

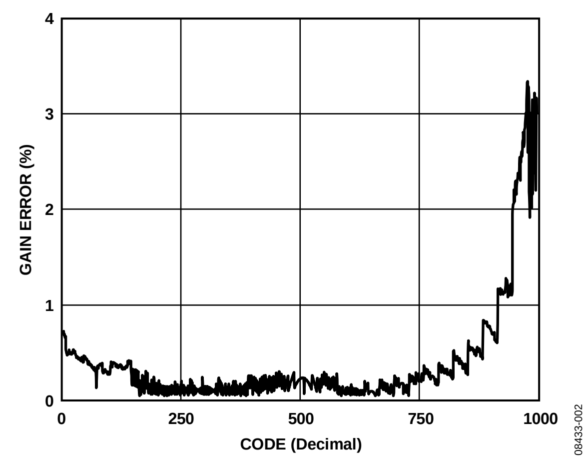

Figure 2. Gain Error vs. Code

$$G = 1 + \frac{49.4\,k\Omega}{R_{AB}} \leq 1 + \frac{49.4\,k\Omega}{R_{AW\_MIN}} \leq 500 \quad (1)$$

The circuit gain formula for any particular AD5292 resistance is

$$G = 1 + \frac{49.4\,k\Omega}{(1024 - D) \times R_{AB}/1024} \quad (2)$$

This equation is plotted in Figure 3 as a function of D, the decimal code.

Rev. A

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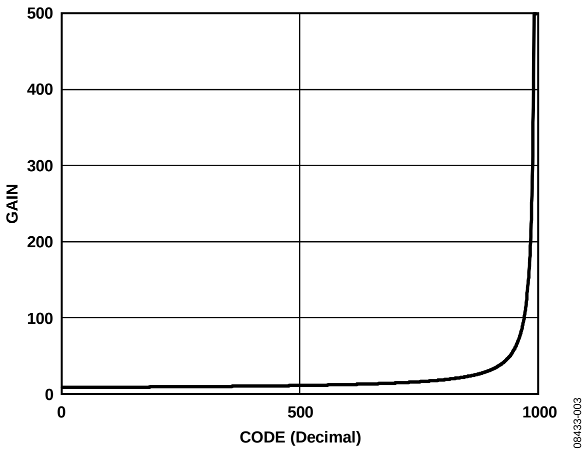

Figure 3. Gain vs. Decimal Code

The maximum current allowed through the AD5292 is ±3 mA, which limits the allowable circuit gain as a function of differential input voltage.

Equation 3 shows the maximum gain limit as a function of the differential input voltage, V_{IN}. This equation is derived by substituting $R_{AB} = V_{IN}/3$ mA into Equation 1. The equation is plotted in Figure 5.

$$G \leq 1 + \frac{148}{V_{IN}} \tag{3}$$

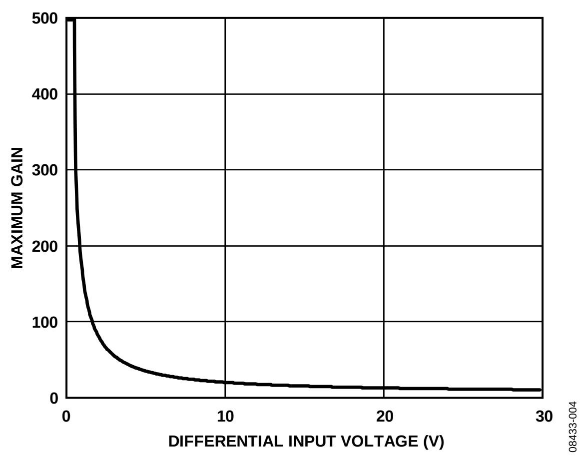

Figure 4. Allowable Gain vs. Differential Input Voltage

Equation 1 limits the maximum circuit gain to 500. Equation 2 can be solved for D, yielding Equation 4, which calculates the minimum allowable resistance (in terms of the digital code) in the AD5292 without exceeding the current limit.

$$D \geq 1024 - \left(\frac{49.4k\Omega \times 1024}{R_{AB} \times (G-1)} \right) \tag{4}$$

where D is the code loaded in the digital potentiometer, and G is the maximum gain calculated from Equation 3.

When the input to the circuit is an ac signal, the parasitic capacitances in the digital potentiometer can cause a reduction in the maximum AD8221 bandwidth. A gain and phase plot is shown in Figure 5.

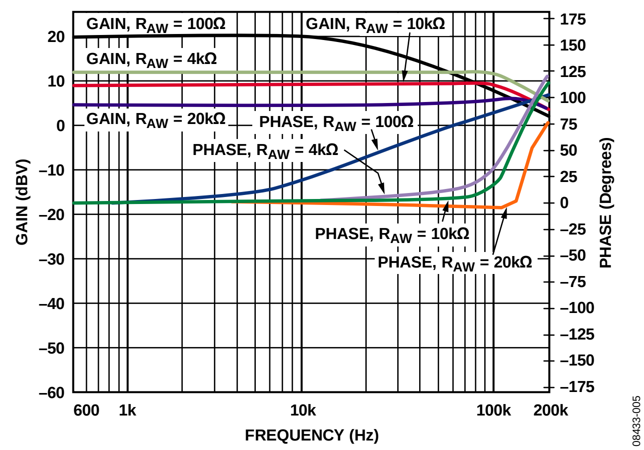

Figure 5. Gain and Phase vs. Frequency (Vertical Scale Compressed to Show All Gain Curves)

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 used 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 (eight 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.

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 (In-Amp) 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 and Evaluation Boards

AD5292 Data Sheet.

AD5292 Evaluation Board.

AD8221 Data Sheet.

AD8221 Evaluation Board.

AD5291 Data Sheet.

AD5293 Data Sheet.

REVISION HISTORY

3/10—Rev. 0 to Rev. A
Changes to Circuit Function and Benefits Section....................... 1

8/09—Revision 0: Initial Version