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Devices Connected/Referenced	
ADG1611	±5 V Quad SPST Switch with 1 Ω On Resistance
AD620	Precision Instrumentation Amplifier
AD8221	Precision Instrumentation Amplifier

Low Cost Programmable Gain Instrumentation Amplifier Circuit Using the ADG1611 Quad SPST Switch and AD620 Instrumentation Amplifier

CIRCUIT FUNCTION AND BENEFITS

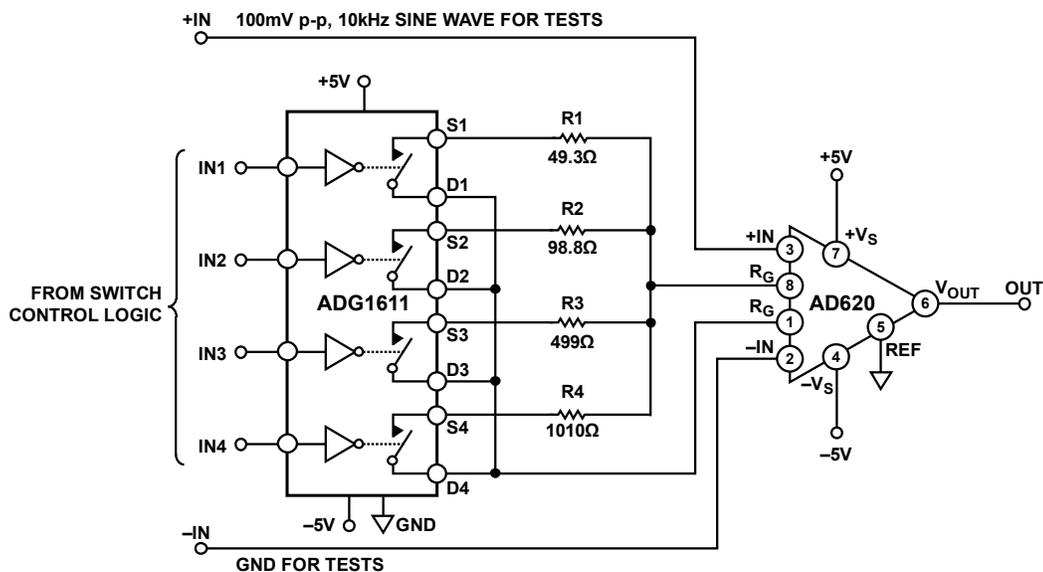
Data acquisition systems with wide dynamic range often need some method for adjusting the input signal level to the analog-to-digital converter (ADC). In order to get the most from an ADC, the maximum input signal should match its full-scale voltage. This is achieved by implementing a programmable gain amplifier circuit.

This circuit provides a programmable gain function using a quad SPST switch (ADG1611) and a resistor-programmable instrumentation amplifier (AD620).

The gain values are set by controlling the external gain setting resistor value, R_G , with the four SPST switches, which are connected to four precision resistors.

Low switch on resistance is critical in this application, and the ADG1611 has the industry's lowest R_{ON} (1 Ω typical) and is available in the smallest package, a 16-lead, 4 mm × 4 mm LFCSP.

The combination of the industry-standard low cost AD620 and the ADG1611 quad switch yields unmatched performance in this circuit and provides all the benefits of a precision instrumentation amplifier, along with the programmable gain feature.



NOTES
 1. R1, R2, R3 AND R4 ARE 0.1%.

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

Rev. 0

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CIRCUIT DESCRIPTION

Figure 1 shows the programmable gain instrumentation amplifier circuit, which is made up of an ultralow R_{ON} , ± 5 V quad SPDT, the industry standard AD620 instrumentation amplifier, and four 0.1% standard resistors.

The ultralow on resistance of the ADG1611 makes it an ideal solution for gain switching applications, where low on resistance and distortion are critical. The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor, R_G , across pins 1 and 8 to set gain between 1 and 10,000.

Combining the ADG1611 and AD620 allows the designer to control the gain of the AD620 by switching in different gain setting resistors for R_G . This circuit provides a low power, low cost programmable gain instrumentation amplifier solution.

The gain is changed by closing combinations of switches S1, S2, S3, and S4 to change R_G . There are 16 possible gain settings controlled through the ADG1611 parallel interface. The AD620's gain is resistor-programmed by the resistance between pins 1 and 8. The AD620 is designed to offer accurate gains using 0.1% to 1% tolerance resistors.

The gain is easily calculated by

$$G = \frac{49.4 \text{ k}\Omega}{R_G} + 1$$

For any arbitrary gain, R_G is

$$R_G = \frac{49.4 \text{ k}\Omega}{G - 1}$$

The circuit in Figure 1 was setup where gains of 1, 50, 100, 500, and 1000 were required. Table 1 shows the ADG1611 control pins, IN1 through IN4, which control the resistance that appears between pins 1 and 8 of the ADG620. Standard 0.1% resistors were used to achieve the gain settings below. The table also shows the resulting gain by adding the on resistance of the ADG1611 in the signal chain and how the gain is affected by temperature. The ultralow on resistance of the ADG1611 switches makes it ideal because the R_{ON} is much less than R_G , and the variation of R_{ON} over temperature is quite small. Figure 2 shows the gain error due to ADG1611 R_{ON} over temperature.

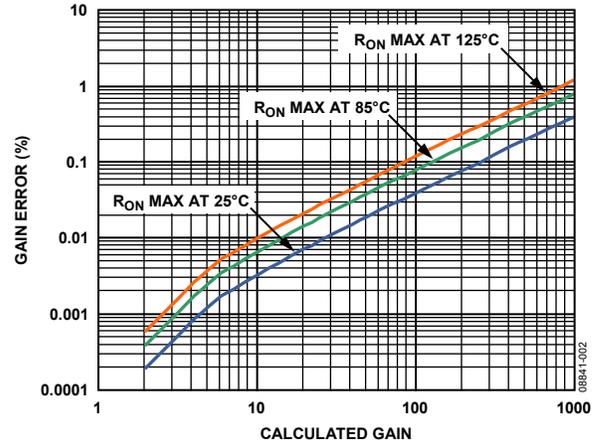


Figure 2. Gain Error Due to Switch R_{ON} Variation Over Temperature

The circuit tested in the lab included an automatic switching mode, which allows the automatic switching of the gain circuit from 1 to 50 to 100 to 500 to 1000 and back to 1 again.

The waveforms in Figure 3 capture the circuit switching through gains from 50 to 1000.

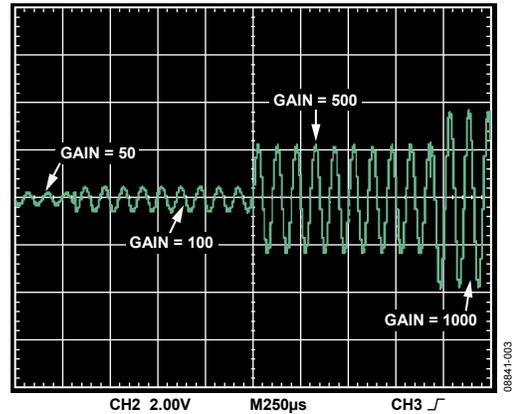


Figure 3. AD620 Output Showing Gain Switching from 50 to 1000

Table 1. ADG1611 Calculated Gain Settings and % Error at 85°C

IN1	IN2	IN3	IN4	Resistor Value (Ω)	Gain Setting (No Switch)	Total Resistance Including Switch (Ω)	Gain Setting with ADG1611	% Error Drift Due to Switch R_{ON} @ 85°C
0	0	0	0	∞	1	∞	1	0
0	0	0	1	1010	49.91	1011	49.85	0.039
0	0	1	0	499	100	500	99.8	0.079
0	1	0	0	98.8	501	99.8	496	0.394
1	0	0	0	49.3	1003	50.3	983	0.773
1	1	1	1	29.9	1653	30.3	1631	1.331

The combination of the ADG1611 and AD620 provides a low cost, high accuracy solution for a programmable gain instrumentation amplifier with 16 levels of programmable gain.

Excellent layout, grounding, and decoupling techniques must be used to achieve the desired performance from the circuits discussed (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

Although the circuit tested uses the industry-standard AD620, other instrumentation amplifiers are also suitable.

The [AD8221](#) is available in a low cost 8-lead SOIC and 8-lead MSOP, both of which offer the industry's best performance. The MSOP requires half the board space of the SOIC, making it ideal for multichannel or space-constrained applications.

The [AD8220](#) is a single-supply, JFET input instrumentation amplifier also available in an MSOP package. Both the AD8220 and the AD8221 utilize the same gain-setting resistor values as the AD620.

LEARN MORE

[A Designer's Guide to Instrumentation Amplifiers \(3rd Edition\)](#), Analog Devices.

[MT-061 Tutorial, Instrumentation Amplifier Basics](#), Analog Devices.

[MT-063 Tutorial, Basic Three Op Amp In-Amp Configuration](#), Analog Devices.

[MT-088 Tutorial, Analog Switches and Multiplexers Basics](#), Analog Devices.

Data Sheets and Evaluation Boards

[AD620 Data Sheet](#)

[AD620 Evaluation Board](#)

[AD8220 Data Sheet](#)

[AD8220 Evaluation Board](#)

[AD8221 Data Sheet](#)

[AD8221 Evaluation Board](#)

[ADG1611 Data Sheet](#)

REVISION HISTORY

4/10—Revision 0: Initial Version

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CN08841-0-4/10(0)



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