Self-Contained High Performance Wide Band Instrumentation Amplifiers

ANALOG DEVICES

AD612, AD614

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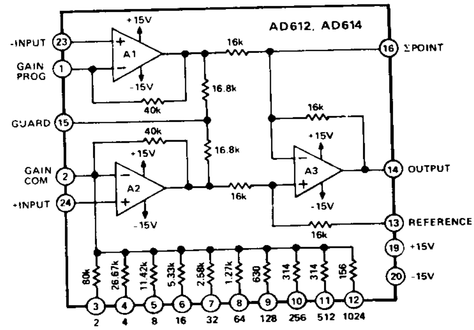
FEATURES
- Pin-Programmable Gain: 1 to 1,024 in Binary Steps
- Fast Settling: 20µs max to 0.05%, @ G = 128 (AD614A,B)
- High Gain Accuracy: ±0.02% max (AD612C)
- Gain Nonlinearity: ±0.001%
- Low Gain TC: ±10ppm/°C max
- Low Offset Drift: ±1µV/°C max, RTI, G = 1024 (AD612C)
- High CMR: 94dB min @ G = 1,024
- Hybrid Construction

APPLICATIONS
- Low Level High Speed Data Acquisition Systems
- Bridge Amplifiers for Resistance Transducers
- Precision Current Amplifiers
- Preamplifier for Recorder Instrumentation

AD612, AD614 FUNCTIONAL BLOCK DIAGRAM



PRODUCT DESCRIPTION
The AD612, AD614 are self-contained, high accuracy, high speed hybrid instrumentation amplifiers designed for data acquisition applications requiring speed and accuracy under worst-case operating conditions. Three versions (A, B, C) of the AD612 are available which provide superior dc characteristics with good dynamic performance, while the AD614 (A & B) versions provide superior dynamic performance with good dc characteristics.

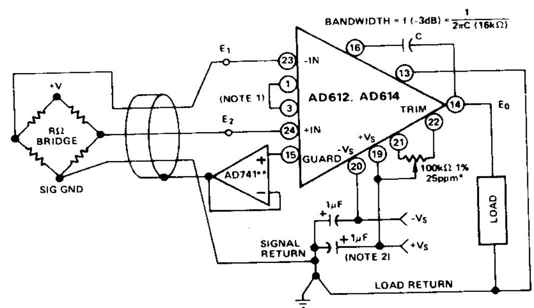
The AD612, AD614 contain precision thin-film resistor networks that allows the user to set the gain in binary steps from 1 to 1024V/V by strapping the appropriate gain pins. In addition the excellent tracking characteristics of the active laser-trimmed thin-film resistors provide maximum gain drift of ±10ppm/°C max.

The AD612, AD614 are designed to provide high speed and high accuracy signal conditioning. They feature input offset drift of 1µV/°C max, output offset drift of ±75µV/°C max, CMR of 74dB min at unity gain (94dB min at G = 1024) in the highest accuracy version (AD612C) or 160kHz small signal bandwidth and settling time to 0.01% of 30µs max in the high speed version (AD614A or B).

APPLICATIONS
The AD612, AD614 offer exceptional quality and value to the data acquisition designer, either as a signal conditioner per channel or as a high speed instrumentation amplifier in multichannel data acquisition systems, analytical instruments and transducer interfacing.

High CMR, input protection, low noise and excellent temperature stability make the AD612, AD614 an excellent choice for precise measurement and control in harsh industrial environments. The high speed of the AD612, AD614 provide higher throughput rates in multichannel data acquisition systems

INTERCONNECTION DIAGRAM AND SHIELDING TECHNIQUES
Figure 1 shows the interconnection diagram for the AD612, AD614 along with the recommended shielding and grounding techniques. Because the AD612, AD614 are direct coupled, a ground return path for amplifier bias currents must be provided either by direct connection (as shown) or by an implicit ground path having up to 1MΩ resistance between signal ground and amplifier common. For best performance, sensitive input and gain setting terminals should be shielded from noise sources especially at high gains. The AD612, AD614 provide a guard terminal to drive the input cable shield at the input common mode voltage. This feature greatly reduces noise pickup and improves CMRR by maintaining the shield at the common mode voltage.



$$E_0 = (2) \times \left[(E_1 - E_2) + \left(\frac{E_1 + E_2}{2}\right) \times \left(\frac{1}{CMR}\right)\right]$$

GAIN (NOTE 1) — INPUT SIGNAL — CMR ERROR

NOTES
*OPTIONAL INITIAL OFFSET TRIM POT.
**RECOMMENDED FOR LONG LEAD LENGTHS OR HIGH BANDWIDTHS.
1. GAIN SHOWN IS EQUAL TO 2. GAIN IS SELECTABLE, IN BINARY STEPS, BY PIN STRAPPING.
2. IN NOISY ENVIRONMENTS BYPASS CAPACITORS ARE RECOMMENDED.

Figure 1. Typical Bridge Application

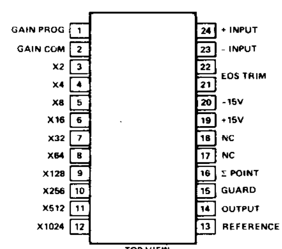
For detailed information, contact factory.

SPECIFICATIONS (typical @ +25°C and V_S = ±15V, unless otherwise noted)

MODEL	HIGH ACCURACY AD612A	AD612B	AD612C	HIGH SPEED AD614A	AD614B
GAIN					
Gain Range, in Binary Steps	1 to 1024V/V	*	*	1 to 1024V/V	**
Gain Temperature Coefficient	±10ppm/°C max	*	*	±10ppm/°C max	**
Gain Accuracy, R_L = 10kΩ	±0.1% max	±0.04% max	±0.02% max	±0.1% max	±0.04% max
Gain Nonlinearity	±0.001%	*	*	±0.001%	**
RATED OUTPUT					
Voltage	±10V min	*	*	±10V min	**
Current	±5mA min	*	*	±5mA min	**
Impedance	0.15Ω	*	*	0.15Ω	**
INPUT CHARACTERISTICS					
Absolute Max Voltage	$\pm V_S$	*	*	$\pm V_S$	**
Common Mode Voltage	±10V min	*	*	±10V min	**
Differential and Common Mode Impedance	10^9 Ω‖3pF	*	*	10^9 Ω‖3pF	**
OFFSET VOLTAGES					
Input Offset Voltage					
Initial @ +25°C (Adjustable to Zero)[1]	±200μV	*	*	±200μV	**
vs. Temperature (G = 1024)(-25°C to +85°C)	±5μV/°C max	±2μV/°C max	±1μV/°C max	±5μV/°C max	±2μV/°C max
vs. Supply (G = 1024)	±25μV/V	*	*	±25μV/V	**
Output Offset Voltage G = 1					
Initial @ +25°C (Adjustable to Zero)	±2mV	*	*	±2mV	**
vs. Temperature (-25°C to +85°C)	±200μV/°C max	±150μV/°C max	±75μV/°C max	±200μV/°C max	±150μV/°C max
INPUT BIAS CURRENT					
Initial @ +25°C	+100nA max	*	*	+100nA max	**
vs. Temperature (-25°C to +85°C)	±0.5nA/°C	*	*	±0.5nA/°C	**
INPUT DIFFERENCE CURRENT					
Initial @ +25°C	±2nA	*	*	±2nA	**
vs. Temperature (-25°C to +85°C)	±10pA/°C	*	*	±10pA/°C	**
INPUT VOLTAGE NOISE, G = 1024					
0.01Hz to 10Hz	1μV p-p	*	*	1μV p-p	**
10Hz to 10kHz	2μV rms	*	*	2μV rms	**
OUTPUT VOLTAGE NOISE, (G = 1)					
0.01Hz to 10Hz	20μV p-p	*	*	20μV p-p	**
10Hz to 10kHz	50μV rms	*	*	50μV rms	**
COMMON MODE REJECTION RATIO					
1kΩ Source Imbalance, dc to 60Hz					
G = 1	74dB min	*	*	74dB min	**
G = 1024	94dB min	*	*	94dB min	**
DYNAMIC RESPONSE					
Slew Rate	1V/μs	*	*	1V/μs	**
Small Signal Bandwidth (-3dB)					
G = 1	100kHz	*	*	100kHz	**
G = 128	60kHz	*	*	160kHz	**
G = 1024	10kHz	*	*	20kHz	**
Settling Time to 0.01% 20V p-p Output Step					
G = 1	200μs max	*	*	40μs max	**
G = 128	100μs max	*	*	30μs max	**
Settling Time to 0.05% 20V p-p Output Step					
G = 1 to 128	60μs max	*	*	20μs max	**
G = 1024	150μs max	*	*	70μs max	**
POWER SUPPLY[2]					
Voltage, Rated Performance	±15V	*	*	±15V	**
Voltage, Operating	±8V to ±18V	*	*	±8V to ±18V	**
Current, Quiescent	±8mA	*	*	±8mA	**
TEMPERATURE RANGE					
Rated Performance	-25°C to +85°C	*	*	-25°C to +85°C	**
Storage	-55°C to +125°C	*	*	-55°C to +125°C	**

*Specifications same as AD612A.
**Specifications same as AD614A.
[1] One minute warm-up.
[2] Recommend model 904, ±15V @ ±50mA.
Specifications subject to change without notice.

PIN CONFIGURATION



TYPICAL ERROR BUDGET ANALYSIS

The error calculations for a typical transducer application shown in Figure 1 (350Ω bridge, 1mV/V FS, 10V excitation) are listed in Table 1.

Assumptions: AD612C is used, G = 1024V/V, temperature range is +25°C ±10°C, source imbalance is 100Ω, common mode noise is 0.05V rms (60Hz) on the ground return.

Error	% of FS (10V)	Calculations
Gain Nonlinearity	±0.001%	
Gain Accuracy	±0.02%	
Gain Drift	±0.01%	
Voltage Offset Drift	±0.11%	±11mV/°C (RTO) x ΔT x 1/10V
Offset Current Drift	±0.0004%	±10pA/°C x G x ΔT x 350Ω x 1/10V
Noise	±0.01%	
Total Output Error	±0.15% Worst Case	

Table 1. Error Budget Analysis

OPERATING INSTRUCTIONS

Install AD612, AD614 as shown in the diagram of Figure 1. Gain setting, offset trim and use of reference and guard terminals are described below.

Gain Setting: The AD612, AD614 operates at G = 1 without pin strapping. For binary gains 2 thru 256, strap appropriate gain pin (3 thru 10) to the gain programming pin (1). For gain 512, strap both pins 10 and 11 to pin 1; for gain 1024, strap pins 10, 11 and 12 to pin 1. The exceptional gain accuracy and gain drift of the AD612, AD614 are provided by the internal laser-trimmed thin-film resistor network.

If a nonbinary gain is required, an external resistor (R_G) can be connected between pins 1 and 2 to set the gain according to the formula $G = 1 + (80k/R_G)$. For R_G a precision resistor with a 10ppm/°C temperature coefficient is recommended.

Figure 2 shows a way to reduce the effects of R_G on gain accuracy and drift by using part of the internal resistor network in parallel with an external resistor to set the gain. Since the current flowing through the external resistor in Figure 2 is a small part of the total current, the effect of the external resistor is reduced by the ratio.

$$\left(\frac{R_{internal}}{R_{internal} + R_{external}}\right)$$

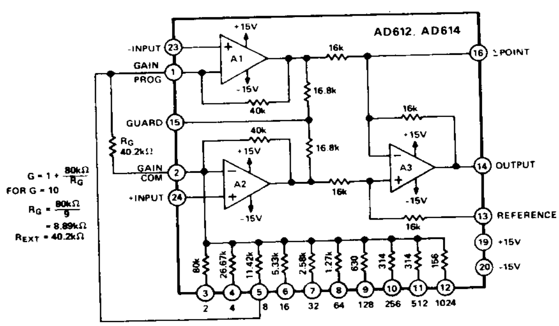


Figure 2. Nonbinary Gain Setting

Reference Output: Normally tied to load low, the reference terminal (pin 13) may be connected to a stable reference voltage, E_{REF}, to permit adjustment of the output level between ±10V, independent of initial offset adjustments. Source impedance of E_{REF} will be critical to CMR rating since the impedance at pin 13 is 16kΩ and forms a balanced bridge network around the output amplifier stage. (For example, a 60Ω imbalance results in a CMR of 49dB; 16kΩ/60Ω = 49dB). The use of a buffer amplifier, as shown below, will eliminate these difficulties. Reference source stability becomes critical when operating at low gains since any shifts may be referred to the input as RTI offset errors; i.e., $\Delta E_{REF}/G$ = Offset Error (RTI).

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Common Mode Rejection: CMR is dependent on source impedance imbalance, signal frequency and amplifier gain. CMR is specified at gains 1 and 1024 with ±10V CMV and 1kΩ source imbalance over the frequency range of dc to 60Hz. Figure 5 shows the typical CMR performance vs. gain and frequency. For AD612, AD614 CMR is typically 26dB above the specified minimum.

Figures 6 and 7 illustrate the effect of source imbalance on CMR performance at dc (Figure 6) and at 60Hz (Figure 7) for several gains. CMR is typically 120dB at 60Hz and a 1kΩ source imbalance. At Gain = 1, CMR is maintained greater than 80dB for source imbalances up to 100kΩ.

Output Noise: As one would expect, total output voltage noise increases with gain and frequency. Figure 9 shows the typical wideband (10Hz to 10kHz) output noise performance vs. gain for 0Ω and 100kΩ source resistances.

Figure 10 shows output noise for several source resistances.

Bandwidth and Settling Time: Bandwidth (-3dB) is relatively constant with gain (see Figure 11) and is typically 100kHz at gain 1. At 4V/V and below, gain starts peaking at about 20kHz. Full power response and slew rate are 16kHz and 1V/μs (typ) respectively, independent of gain.

Settling time response to ±10V step output is relatively constant and gain insensitive, except for gains below 4V/V. AD612, AD614 have two speed selections with the AD612A, B, C being the slower versions and the AD614A, B, the faster versions. Settling times are specified to 0.01% for gains 1 and 128, and 0.05% for gains 1, 128 and 1024. Figure 12 shows typical settling times vs. gain for both versions to 0.01% and 0.05% accuracies. Settling time to 0.01% for gains greater than 128 are not shown because of the effects of voltage noise at the higher gains.

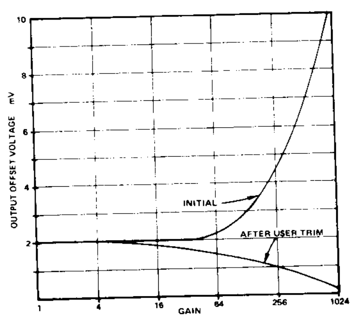

Figure 3. Total Offset Voltage (Typical) vs. Gain (RTO)

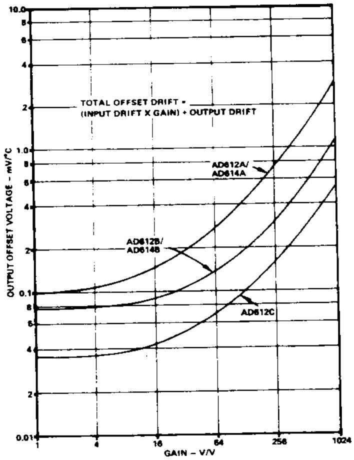

Figure 4. Total Offset Voltage Drift (Typical) vs. Gain (RTO)

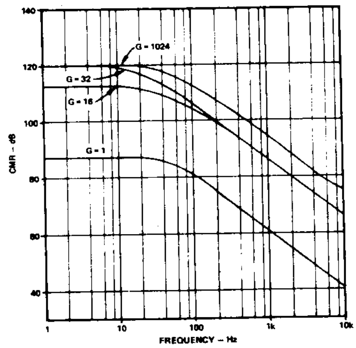

Figure 5. Common-Mode Rejection vs. Frequency and Gain

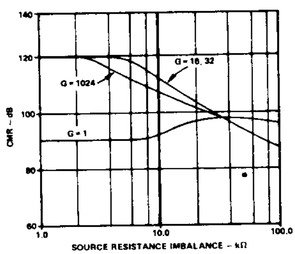

Figure 6. DC Common-Mode Rejection vs. Source Resistance Imbalance

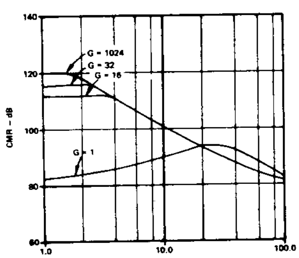

Figure 7. 60Hz Common-Mode Rejection vs. Source Resistance Imbalance

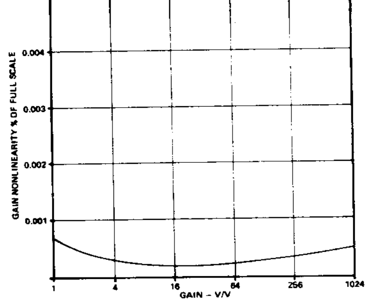

Figure 8. Gain Nonlinearity vs. Gain

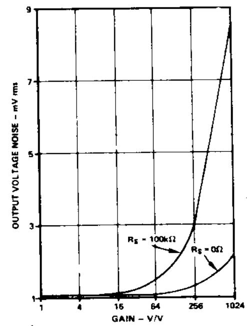

Figure 9. Wideband Output Voltage Noise vs. Gain

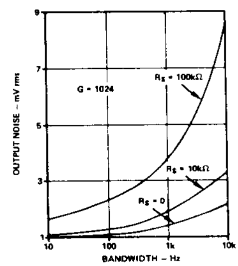

Figure 10. Output Voltage Noise vs. Bandwidth

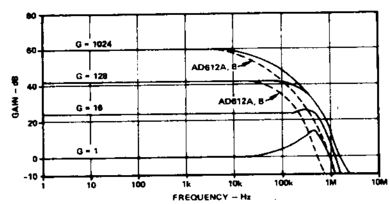

Figure 11. Small Signal Frequency Response

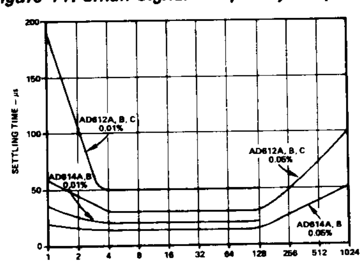

Figure 12. Settling Time vs. Gain