ANALOG DEVICES

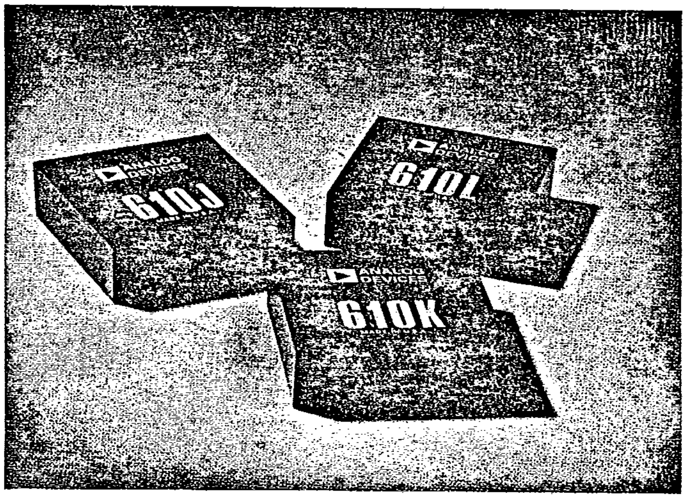
Economy, Low Noise, Low Drift Instrumentation Amplifier

Model 610

FEATURES
Low Cost: $39 (1-9)
Guaranteed Low Noise: 2μV (610L)
Low Drift: 0.5μV/°C (610L)
Nonlinearity: 0.02% max
CMRR: 86dB min – CMV: ±10V

VERSATILITY
Adjustable Gain (Single Resistor) 1 to 10,000
Output Offset & Remote Sense Terminals

APPLICATIONS
OEM Designs, Lab and Field Instruments
Bridge Amplifiers, Strain Gages, Thermistors, Probes
Data Acquisition & Switch Gain Designs
Precision Current Amplifiers (Floating or Grounded Loads)
Biologic Probes
High Speed Differential & Buffer Amplifiers



GENERAL DESCRIPTION

Analog Devices' model 610 combines high performance with low price to set an outstanding standard of value for this class of instrumentation amplifier. The 610 features guaranteed low noise performance: 2.5μV rms, max (610J) and 2μV rms, max (610K, L) for f = 10Hz to 10kHz. Other noteworthy guaranteed specifications include 0.02% max nonlinearity (610J, K, L), 0.5μV/°C max offset drift (610L), and 15ppm max gain error (610J, K, L). When coupled with 86dB (min) CMR (G = 100, CMV = ±10V) the model 610's performance characteristics enable it to maintain total amplifier errors below 0.2% over a +20°C temperature range. Other salient features of the 610 include virtually constant bandwidth (40kHz @ G = 1000) and very low power consumption (90mW). The model 610 is the component of choice when considering instrumentation amplifiers to meet the cost and performance objectives of OEM designs.

In addition to the above specifications, the model 610 offers the versatility of adjustable gain, remote output sensing and output offset. Amplifier gain can be controlled between 1 and 10,000 with a single external resistor. Output offset and remote sensing terminals may be employed to develop power booster and current amplifier circuit configurations for both grounded and floating leads. The reference terminal may also be used to provide level shifting of the output for comparative circuits and chart recorders.

The combination of these special features greatly increases the utility of model 610 and allows it to be employed in a broad scope of applications. By selecting the 610, the designer can realize a savings in components that might otherwise be required to perform the functions already built into this amplifier. Among the competition, the model 610 is alone at offering these capabilities at such a low price.

APPLICATIONS: INSTRUMENTATION AND DATA ACQUISITION

The combination of low cost and very good performance provided by model 610 offers exceptional quality and value to the OEM designer. This compact module may be applied as a high impedance differential preamplifier to accurately recover millivolt signals carried on noisy lines or high CMV levels. These environmental conditions are frequently encountered in biomedical, aerospace and industrial applications when processing transducer and control signals. Consideration should be given to model 610 for designs, such as bridge and null detector circuits, which require high CMR and high input impedance even under changes in gain. Model 610 is also an ideal component for use in lab and field instruments.

(continued on page 3)

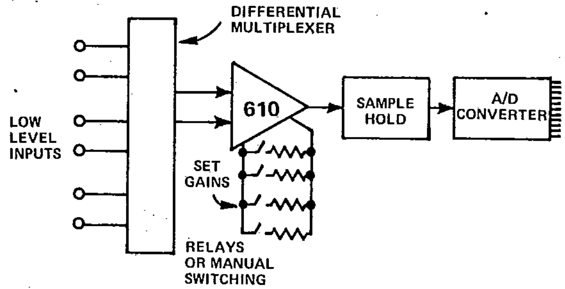


Figure 1. Multiple Input Data Acquisition System

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Mid-West Tel: 312/297-8710

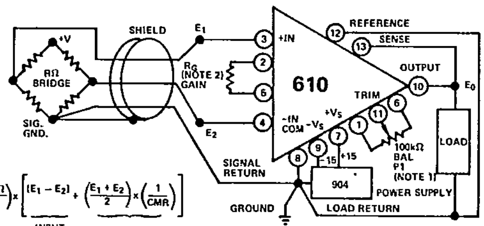
SPECIFICATIONS (typical @ +25°C and V_S = ±15VDC unless otherwise noted)

Model	610J / 610K / 610L
GAIN	
Gain Range	1 to 10,000V/V
Gain Equation	G = 1 + (400kΩ/Rg.)
vs. Temperature	±15ppm/°C Max
vs. Time	±0.001%/Mo.
Gain Accuracy, G = 100	±0.1% Max
Gain Nonlinearity, G = 100	±0.02% Max
OFFSET VOLTAGES	
Input Offset Voltage	
Initial (@ +25°C)	Adjust to Zero
vs. Temperature, G = 1000	±3 / ±1 / ±½µV/°C Max
vs. Supply, G = 1000	±3µV/V
Output Offset Voltage, G = 1	
vs. Temperature	±200 / ±150 / ±150µV/°C
FREQUENCY RESPONSE	
Small Signal Bandwidth	
±1% Gain Accuracy, G = 100	10kHz
-3dB Gain Accuracy, G = 1	0.5MHz
G = 1000	40kHz
Slew Rate	0.4V/µs
Full Power	6kHz
Settling Time, G = 100, ±10V Output Step ±0.1%	50µs
INPUT NOISE	
Voltage, G = 1000	
0.01Hz to 10Hz	2.5 / 2 / 2µV p-p Max
10Hz to 10kHz	2.5 / 2 / 2µV rms
Current, G = 1000	
0.01Hz to 10Hz	60pA p-p
10Hz to 10kHz	30pA rms
OUTPUT NOISE	
Voltage, G = 1	
0.01Hz to 10Hz	50µV p-p
10Hz to 10kHz	50µV rms
INPUT VOLTAGE RANGE	
Linear Differential Input	±10V Min
Max Differential Input	$\pm V_S$
Common Mode Voltage	±10V Min
CMR, CMV = ±10V, DC to 100Hz	
1k Source Imbalance, G = 1	60dB Min (70dB Typ)
G = 1000	90dB Min (106dB Typ)
INPUT IMPEDANCE	
Differential	10^9Ω‖3pF
Common Mode	10^9Ω‖3pF
INPUT BIAS CURRENT	
Initial, @ +25°C	+60nA Max
vs. Temperature	-0.2nA/°C
INPUT DIFFERENCE CURRENT	
Initial, @ +25°C	±5nA
vs. Temperature	±20pA/°C
RATED OUTPUT[1]	
Voltage, 2kΩ Load	±10V Min
Current	±5mA Min
Impedance DC to 100Hz, G = 100	0.1Ω
REFERENCE TERMINAL	
Impedance	200kΩ
Output Offset Range	±10V Min
POWER SUPPLY[2]	
Voltage, Rated Performance	±15VDC
Voltage, Operating	±(12 to 18)VDC
Current, Quiescent	±3mA
TEMPERATURE RANGE	
Rated Performance	0 to +70°C
Operating	-25°C to +85°C
Storage	-55°C to +125°C
CASE SIZE	2" x 2" x 0.4"
PRICE	
(1-9)	$39 / $49 / $59
(10-24)	$38 / $48 / $57

[1] Protected for shorts to ground or either supply voltage.
[2] Recommended power supply, ADI model 904, ±15V @ 50mA output: $41 (1-9).
Specifications subject to change without notice.

The figure below illustrates the basic hook-up diagram for voltage amplification in a simple bridge circuit along with several basic equations relating gain, CMV and input-output relationships. A recommended shielding and grounding technique for preserving the excellent amplifying characteristics of model 610 is shown. An error budget is presented on page 3.

Because model 610 is 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 (pin 8). The sensitive input and gain setting terminals should be shielded from noise sources for best performance, especially at high gains.



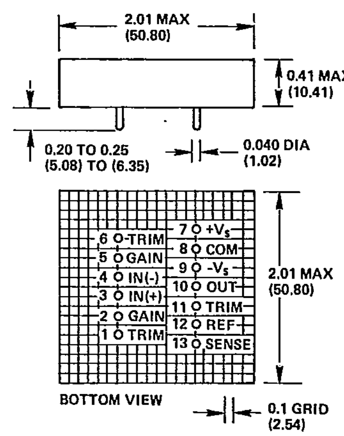
$$E_O = \left(1 + \frac{400k\Omega}{R_G}\right) \times \left[(E_1 - E_2) + \left(\frac{E_1 + E_2}{2}\right) \times \left(\frac{1}{CMR}\right)\right]$$

NOTES
1. TRIM POT, P1, 100K OHMS. RECOMMEND ADI PART NUMBER 79PR100K (100PPM/°C, 15 TURN CERMET) AT $3.25.
2. GAIN RESISTOR, R_G, 0.025%, 3PPM/°C WIRE WOUND, VISHAY TYPE IS RECOMMENDED.

Figure 2. Typical Bridge Application

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm)



NOTES:
1. Weight — 52 grams
2. Mating Socket AC 1040 @ $4.25 (1-9)

Applying the Instrumentation Amplifier

(continued from page 1)

For data acquisition systems and for amplifying transient phenomena, the model 610 may be used as a fixed gain amplifier at the signal site or combined with switch gain networks to develop a semi-programmable gain amplifier as shown in Figure 1.

BRIDGE APPLICATION: ERROR BUDGET ANALYSIS (See Figure 2)

Model 610 specifications employ min-max values as well as typicals to allow the designer wider latitude in formulating accurate error budgets for predictable operation. Total errors of 0.1% max (0.04% typical) are possible in most cases when the model 610 is used over a ±10°C temperature range. The error analysis computations in the table below illustrate the performance of the 610:

Error	% of F.S. (10V)	
Gain Nonlinearity	0.02%	Specified @ 10V f.s.
Gain Drift	0.015%	0.0015% x 10°C
Offset Drift		
Amplifier Offset	0.05%	0.5mV/°C(RTO) x ΔT x 1/10V
Current Offset	0.006%	200pA/°C x G x ΔT x 300 x 1/10V
Power Supply Change	0.0004%	0.2% x 0.2μV/% x G x 1/10V
Noise	0.01%	Specified (10Hz B.W.)
Total Output Error	0.100% max (0.04% typical)	

Assuming: 610L is used, G = 1000, ΔT = ±10°C, with 300Ω, 10V bridge.

Computations of errors are based on the following considerations:

Offset Drift and Bias Current Errors: This error term demonstrates the importance of low offset drift offered in model 610. Offset drift is usually the dominant error component and a low value for this parameter is critical in high accuracy designs, even over moderate temperature ranges.

Bias current flowing through the 300Ω source impedance, will develop offset voltages which are trimmed to zero during initial balance. The 200pA/°C current drift error produces less than 1μV/°C equivalent drift for up to 10kΩ bridges; drift error is 0.003% for the 300Ω bridge. Supply voltage rejection also introduces an equivalent offset which is nulled out with initial balance. Line voltage and temperature changes may be 0.2%, adding a negligible error of 0.0004%.

Gain Errors: By trimming R_G absolute gain errors can be made negligibly small. Gain nonlinearity is 0.02% max (0.01% typical) at 10V f.s. This value usually can be maintained at lesser than full scale swings by calibrating gain at the maximum anticipated output voltage, i.e. ±5V out @ G = 1000. Gain drift and time stability contribute 0.015% error, with long term effects becoming negligible.

CMR & Noise Errors: Since the CMV is virtually constant at 5V, the CMR error appears as an output offset which is nulled out with initial balance. However, for other applications, with widely varying CMV, high CMR is essential for low errors. The CMR for model 610 is conservatively specified and requires no trimming to achieve values of 120dB min (G = 1000). Use of the reference or sense terminal does not degrade CMR as with most other designs. The input noise at G = 1000 contributes about 0.01% in a 10Hz bandwidth which may be reduced by heavier filtering for lower frequency applications.

PERFORMANCE CHARACTERISTICS

Input Offset Voltage Drift: Model 610 offers a selection of three drift specifications; 3, 1 and ½μV/°C (max, RTI, G = 1000V/V). Total input drift is a gain dependent phenomenon and is composed of two sources (input and output stage drifts). Figure 3 shows worst case total drift over the gain range of 1 to 10,000.

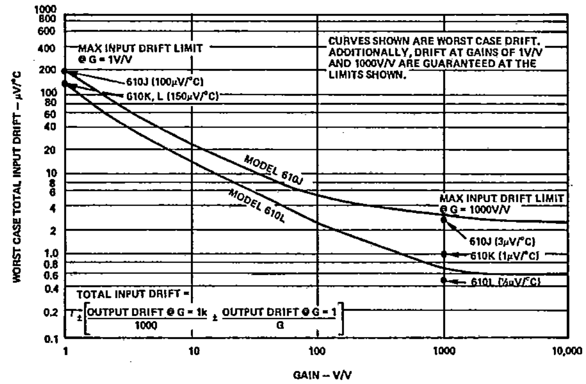


Figure 3. Total Input Offset Drift (Worst Case) vs. Gain

Gain Nonlinearity and Output Noise: Nonlinearity is specified as a percent of full scale (10V), e.g. 2mV RTO for 0.02%. By trimming gain at the maximum expected output voltage, nonlinearity may be maintained or improved for lower output levels. Also, as indicated in Figure 4, nonlinearity is minimum for gains above 100V/V. Thus the highest possible gain should be used when nonlinearity is a critical parameter.

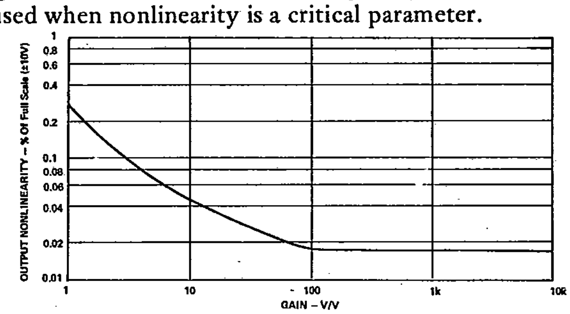


Figure 4. Nonlinearity Error vs. Gain

As one would expect, total output voltage noise increases with gain. Figure 5 shows noise density as a function of amplifier bandwidth.

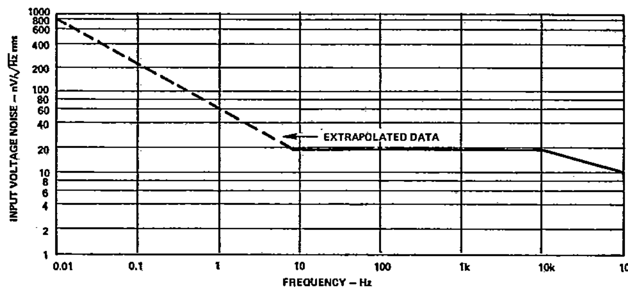


Figure 5. Voltage Noise per Root Hz of Bandwidth (G = 1000)

Common Mode Rejection: CMR is specified at ±10V CMV and 1kΩ source imbalance over the frequency range of DC to 100Hz. In this frequency band, CMR response is flat for all gains from

1 to 10,000 (see Figure 6). For model 610, CMR is typically 10dB above the specified minimum.

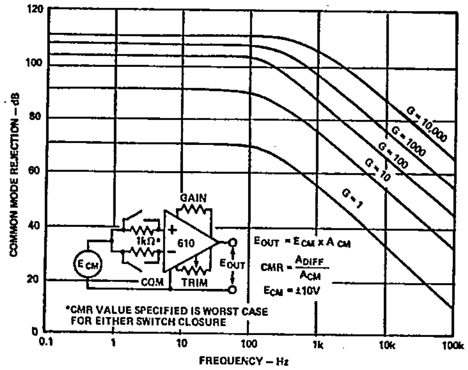


Figure 6. Common Mode Rejection vs. Frequency and Gain

Bandwidth and Settling Time: Bandwidth (-3dB) remains reasonably constant with gain. At G = 10V/V bandwidth is about 200kHz and it decreases to approximately 80kHz at G = 1000V/V. For gains less than 5V/V, the frequency response demonstrates peaking that starts at 10kHz. Figure 7 shows bandwidths vs. gain for model 610. Full power response and slew rate are 12kHz and 0.4V/μs (typ) respectively and are independent of gain.

Settling time response to a ±10V step output is relatively constant as a function of gain (except for gains below 5V/V). For 0.01% accuracy settling time is 80μs; for 0.1% accuracy settling time is 50μs.

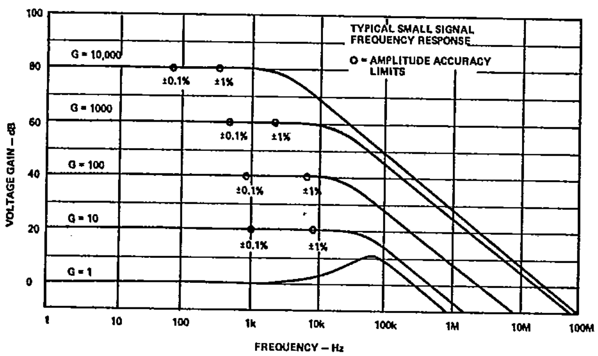


Figure 7. Small Signal Frequency Response

OPERATING INSTRUCTIONS

Install model 610 as shown in the diagram of Figure 2. Gain, offset trim and use of reference and sense terminals are described below.

Gain Adjustment: Gain accuracy and drift are a direct function of R_G tolerance. Use recommended types for best performance. A fine trim may be used in series or in parallel with R_G to improve accuracy. To avoid gain peaking vs. frequency, stray capacitance at these terminals should be less than 0.5pF x Gain. Gain should be set at that output level requiring greatest accuracy.

Balance Procedure: During initial balance, short the sense terminal to load high and the reference terminal to load low respectively. With gain set at the desired value, adjust the output offset for a null, using P1, with input leads shorted to signal ground through their source impedances. This adjusts for amplifier offset, bias current and power supply effects simultaneously. If several gains are to be used, adjust P1 for null, per above, at max gain initially and then switch to min gain. Apply a correction voltage to the reference terminal to reduce output offset and then switch back to max gain. Readjust P1 for a new null. Repeat process until desired null is achieved.

Current Feedback Circuits: The sense and reference terminals are also useful for driving currents to either floating or grounded loads as shown below (Figure 8). For floating loads, the reference terminal is grounded; for grounded loads, the sense terminal is connected to the output. The current sense resistor, R_S, is usually below 5 ohms, typically 1 ohm. Special care must be taken in the current control configuration to avoid voltage saturation when driving reactive loads; $E_o = IR + L\,(dI/dt)$.

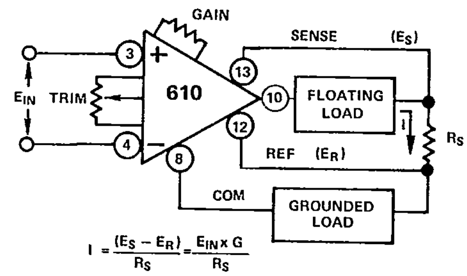


Figure 8. Current Feedback for Floating or Grounded Loads

USE OF REFERENCE TERMINAL

Normally tied to load low, the reference terminal (pin 12) 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 12 is 200kΩ and forms a balanced bridge network around the output amplifier stage. (Typically a 60Ω imbalance can result in a CMR of 69dB; 200kΩ/60Ω = 69dB). 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).

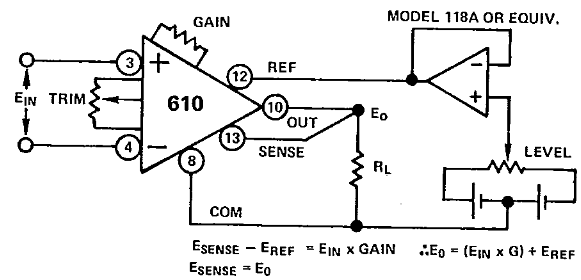


Figure 9. Output Level Control

USE OF REMOTE SENSE AND REFERENCE TERMINALS

The output sense point (pin 13), may be used to include a power booster for increased voltage or current output. When connected as shown below, the booster is contained within a feedback loop of model 610, thereby overcoming booster drift and similar error terms.

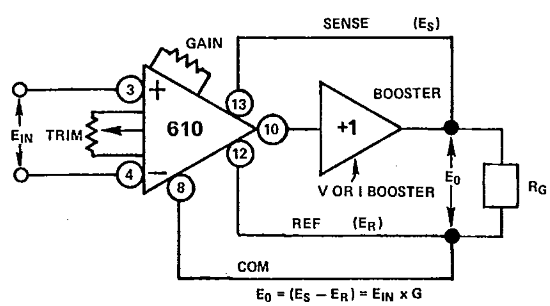


Figure 10. External Booster Connection

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