ANALOG DEVICES

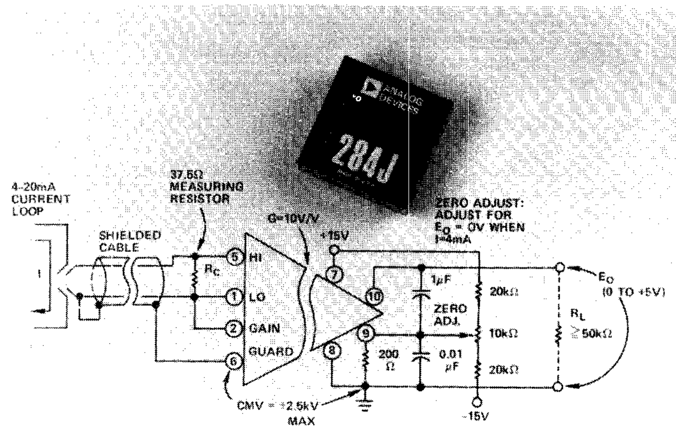
Economy, High Performance, Self Contained, Isolation Amplifier

FEATURES

- Low Cost
- Low Nonlinearity: ±0.05% @ 10V pk-pk Output
- High Gain Stability: ±0.0075%/°C, ±0.001%/1000 hours
- Isolated Power Supply: ±8.5V dc @ ±5mA
- High CMR: 110dB min with 5kΩ Imbalance
- High CMV: $\pm 5000V_{pk}$, 10ms Pulse; ±2500V dc continuous
- Small Size: 1.5" x 1.5" x 0.6"
- Adjustable Gain: 1 to 10V/V; Single Resistor Adjust
- Meets IEEE Std 472: Transient Protection (SWC)
- Meets UL Std 544 Leakage: 2.0μA max @ 115V ac, 60Hz

APPLICATIONS

- Biomedical and Patient Monitoring Instrumentation
- Ground Loop Elimination in Industrial Control
- Off-Ground Signal Measurements
- 4-20mA Isolated Current Loop Receiver



ISOLATED 4-20mA ANALOG INTERFACE

GENERAL DESCRIPTION

Model 284J is a low cost isolation amplifier featuring isolated power, ±8.5V dc @ ±5mA loads, ±2500V dc off-ground isolation (CMV) and 110dB minimum CMR at 60Hz, 5kΩ source imbalance, in a compact 1.5" x 1.5" x 0.6" epoxy encapsulated package. This improved design achieves low nonlinearity of ±0.05% @ 10V pk-pk output, gain stability of ±0.0075%/°C and input offset drift of ±15μV/°C at G=10V/V. Using modulation techniques with reliable transformer isolation, model 284J will interrupt ground loops, leakage paths and high voltage transients to $\pm 5kV_{pk}$ (10ms pulse) providing dc to 1kHz (-3dB) response over an adjustable gain range of 1V/V to 10V/V. Model 284J's fully floating guarded input stage and floating isolated power for external input circuitry, offers versatility for both medical and industrial OEM applications.

WHERE TO USE MODEL 284J

Medical Applications: In all biomedical and patient monitoring equipment such as multi-lead ECG recorders and portable diagnostic designs, model 284J offers protection from lethal ground fault currents as well as 5kV defibrillator pulse inputs. Low level bioelectric signal recording is achieved with model 284J's low input noise (8μV p-p) and high CMR (110dB, min).

Industrial Applications: In computer interface systems, process signal isolators and high CMV instrumentation, model 284J offers complete galvanic isolation and protection against damage from transients and fault voltages. High level transducer interface is afforded with model 284J's 10V pk-pk input signal capability at a gain of 1V/V operation. In portable field designs, model 284J's single supply, low power drain of 85mW @ +12V operation offers long battery operation.

DESIGN FEATURES AND USER BENEFITS

Isolated Power: Dual ±8.5V dc @ ±5mA, completely isolated from the input power terminals (±2500V dc isolation), provides the capability to excite floating signal conditioners, front end buffer amplifiers and remote transducers such as thermistors or bridges.

Adjustable Gain: Model 284J's adjustable gain combined with its 10V pk-pk output signal dynamic range offers compatibility with a wide class of input signals. A single external resistor enables gain adjustment from 1V/V to 10V/V providing the flexibility of applying model 284J in both high level transducer interfacing as well as low level sensor measurements.

Floating, Guarded Front-End: The input stage of model 284J can directly accept floating differential signals, such as ECG biomedical signals, or it may be configured as a high performance instrumentation front-end to accept signals having CMV with respect to input power common.

High Reliability: Model 284J is a conservatively designed, compact module, capable of reliable operation in harsh environments. Model 284J has a calculated MTBF of over 400,000 hours and is designed to meet MIL-STD-202E environmental testing as well as the IEEE Standard for Transient Voltage Protection (472-1974: Surge Withstand Capability). As an additional assurance of reliability, every model 284J is factory tested for CMV and input ratings by application of 5kV pk, 10ms pulses, between input terminals as well as input/output terminals.

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

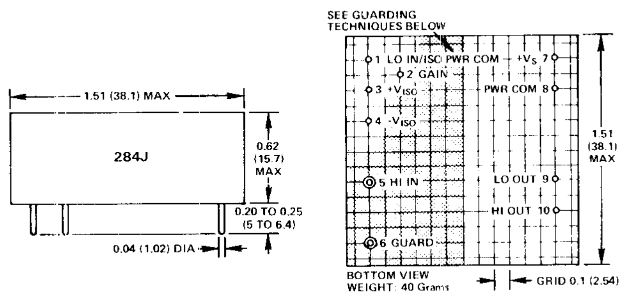
MODEL	284J
GAIN (NON-INVERTING)	
Range (50kΩ Load)	1 to 10V/V
Formula	Gain = $[1 + \frac{100k\Omega}{10.7k\Omega + R_i(k\Omega)}]$
Deviation from Formula	±3%
vs. Time	±0.001%/1000 Hours
*vs. Temperature (0 to +70°C)[1]	±0.0075%/°C
*Nonlinearity, G = 1V/V to 10V/V[2]	±0.05%
INPUT VOLTAGE RATINGS	
Linear Differential Range, G = 1V/V	±5V min
Max Safe Differential Input	
Continuous	240V_{rms}
Pulse, 10ms duration, 1 pulse/10 sec	±6500V_{pk} max
Max CMV, Inputs to Outputs	
AC, 60Hz, 1 minute duration	2500V_{rms}
Pulse, 10ms duration, 1 pulse/10 sec	±2500V_{pk} max
With 510kΩ in series with Guard	±5000V_{pk} max
Continuous, ac or dc	±2500V_{pk} max
CMR, Inputs to Outputs, 60Hz, $R_S \leq 5k\Omega$	
Balanced Source Impedance	114dB
5kΩ Source Impedance Imbalance	110dB min
CMR, Inputs to Guard, 60Hz	
1kΩ Source Impedance Imbalance	78dB
Max Leakage Current, Inputs to Power Common @ 115V ac, 60Hz	2.0μA rms max
INPUT IMPEDANCE	
Differential	10^8 Ω‖70pF
Overload	300kΩ
Common Mode	5x10^{10} Ω‖20pF
INPUT DIFFERENCE CURRENT	
Initial, @ +25°C	±7nA max
vs. Temperature (0 to +70°C)	±0.1nA/°C
INPUT NOISE	
Voltage, G = 10V/V	
0.05Hz to 100Hz	8μV p-p
10Hz to 1kHz	10μV rms
Current	
0.05Hz to 100Hz	5pA p-p
FREQUENCY RESPONSE	
Small Signal, -3dB, G = 1V/V to 10V/V	1kHz
Slew Rate	25mV/μs
Full Power, 10V p-p Output	
Gain = 1V/V	700Hz
Gain = 10V/V	200Hz
Recovery Time, to ±100μV after Application of ±6500V_{pk} Differential Input Pulse	200ms
OFFSET VOLTAGE REFERRED TO INPUT	
*Initial, @ +25°C, Adjustable to Zero	±(5 + 20/G)mV
*vs. Temperature (0 to +70°C)	±([illegible] + 150/G)μV/°C
vs. Supply Voltage	±1 nV/%
RATED OUTPUT	
Voltage, 50kΩ Load	±5V min
Output Impedance	1kΩ
Output Ripple, 1MHz Bandwidth	5mV pk-pk
ISOLATED POWER OUTPUTS	
Voltage, ±5mA Load	±8.5V dc
Accuracy	±5%
Current	±5 nA min
Regulation, No Load to Full Load	+0 –15%
Ripple, 100kHz Bandwidth	100mV p-p
POWER SUPPLY, SINGLE POLARITY[3]	
Voltage, Rated Performance	+15V dc
Voltage Operating	+(8 to 15.5)V dc
Current, Quiescent	+10mA
TEMPERATURE RANGE	
Rated Performance	0 to +70°C
Operating	-25°C to +85°C
Storage	-55°C to +85°C
CASE DIMENSIONS	1.5" x 1.5" x 0.62"

*Improved performance over earlier design.
[1] Gain temperature drift is specified as a percentage of output signal level.
[2] Gain nonlinearity is specified as a percentage of 10V pk-pk output span.
[3] Recommended power supply, ADI model 904, +15V @ 50mA output

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

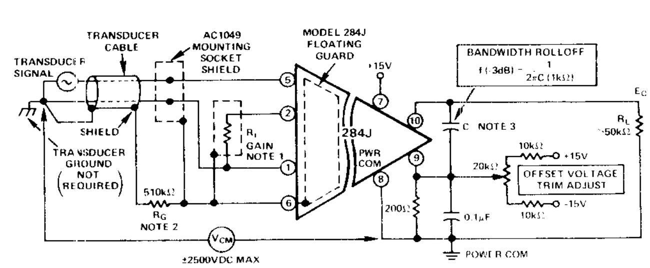


SHIELDED MOUNTING SOCKET AC1049

INTERCONNECTION AND GUARDING TECHNIQUES

Model 284J can be applied directly to achieve rated performance as shown in Figure 1 below. To preserve the high CMR performance of model 284J, care must be taken to keep the capacitance balanced about the input terminals. A shield should be provided on the printed circuit board under model 284J as illustrated in the outline drawing above (screened area). The GUARD (Pin 6) should be connected to this shield. This guard-shield is provided with the mounting socket, model AC1049. A recommended guarding technique using model AC1049 is illustrated in Figure 1. To reduce effective cable capacitance, cable shield should be connected to the common mode signal source by connecting the shield as close as possible to the signal low.

Offset Voltage Trim Adjust: The trim adjust circuit shown in Figure 1 can be used to zero the output offset voltage over the gain range from 1 to 10V/V. The output terminals, HI OUT and LO OUT, can be floated with respect to PWR COM up to ±50V_{pk} max, offering three-port isolation. A 0.1μF capacitor is required from LO OUT to PWR COM whenever the output terminals are floated with respect to PWR COM. LO OUT can be connected directly to PWR COM when output offset trimming is not required.



NOTE 1. GAIN RESISTOR, R_i, 1%, 50ppm/°C METAL FILM TYPE IS RECOMMENDED.
FOR GAIN = 1V/V, LEAVE TERMINAL 2 OPEN.
FOR GAIN = 10V/V, SHORT TERMINAL 2 TO TERMINAL 1

$$GAIN = 1 + \frac{100k\Omega}{10.7k\Omega + R_i(k\Omega)}$$

NOTE 2. GUARD RESISTOR, R_G, REQUIRED ONLY FOR CMV > ±2500V_{PK} (±5kV_{PK} MAX).
R_G MAY BE MOUNTED ON AC1049 MOUNTING SOCKET USING STANDOFF PROVIDED.
(USE ¼ WATT, 5%, CARBON COMPOSITION TYPE; ALLEN BRADLEY RECOMMENDED).

NOTE 3. OUTPUT FILTER CAPACITOR, C. SELECT TO ROLLOFF NOISE AND OUTPUT RIPPLE: (e.g. SELECT C = 1.5μF FOR dc TO 100Hz BANDWIDTH).

Figure 1. Basic Isolator Interconnection

THEORY OF OPERATION

The remarkable performance of model 284J is derived from the carrier isolation technique which is used to transfer both signal and power between the amplifier's guarded input stage and the rest of the circuitry. The block diagram for model 284J is shown in Figure 2 below.

The 320kΩ input protection resistor limits the differential input current during periods of input amplifier saturation and also limits the differential fault current to approximately 35μA in case the preamplifier fails.

The bipolar input preamplifier operates single-ended (non-inverting). Only a difference bias current flows with zero net bias current. A third wire return path for input bias current is not required. Gain can be set from 1V/V to 10V/V by changing the gain resistor, R_i. *To preserve high CMR, the gain resistor must be guarded.* Best performance is achieved by shorting terminal 2 to terminal 1 and operating model 284J at a gain of 10V/V.

For powering floating input circuitry such as buffer amplifiers, instrumentation amplifiers, calibration signals and transducers, dual isolated power is provided. High CMV isolation is achieved by the low-leakage transformer coupling between the input preamplifier, modulator section and the output circuitry. Only the 20pF leakage capacitance between the floating guarded input section and the rest of the circuitry keeps the CMR from being infinite.

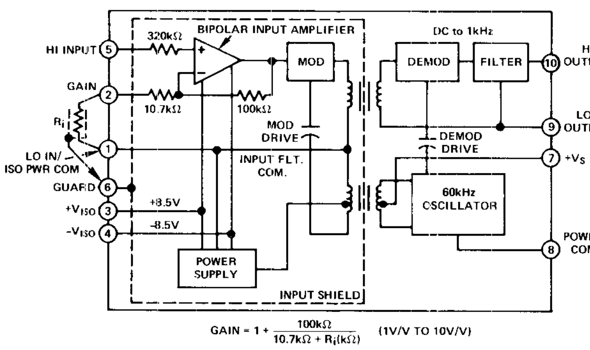


Figure 2. Block Diagram – Model 284J

INTERELECTRODE CAPACITANCE, TERMINAL RATINGS AND LEAKAGE CURRENTS LIMITS

Capacitance: Interelectrode terminal capacitance arising from stray coupling capacitance effects between the input terminals and the signal output terminals are each shunted by leakage resistance values exceeding 50kMΩ. Figure 3 illustrates the CMR ratings at 60Hz and 5kΩ source imbalance between signal input/output terminals, along with their respective capacitance.

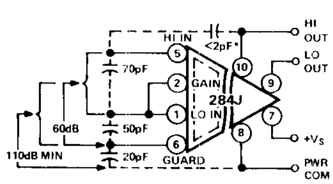


Figure 3. Model 284J Terminal Capacitance and CMR Ratings

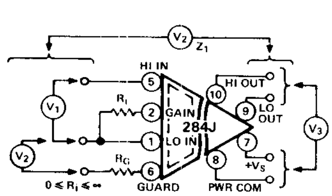


Figure 4. Model 284J Terminal Ratings

Terminal Ratings: CMV performance is given in both peak pulse and continuous ac or dc peak ratings. Pulse ratings are intended to support defibrillator and other transient voltages. Continuous peak ratings apply from dc up to the normal full power response frequencies. Figure 4 and Table 1 illustrate model 284J's ratings between terminals.

SYMBOL	RATING	REMARKS
V1 (pulse)	$\pm 6500V_{PK}$ (10ms)	Withstand Voltage, Defibrillator
V1 (cont.)	$\pm 240V_{RMS}$	Withstand Voltage, Steady State
V2 (pulse)	$\pm 2500V_{PK}$ (10ms) $R_G = 0$	Transient
V2 (pulse)	$\pm 5000V_{PK}$ (10ms) $R_G = 510k\Omega$	Isolation, Defibrillator
V2 (cont.)	$\pm 2500V_{PK}$	Isolation, Steady State
V3 (cont.)	$\pm 50V_{PK}$	Isolation, DC
Z1	50kMΩ‖20pF	Isolation Impedance

Table 1. Isolation Ratings Between Terminals

Leakage Current Limits: The low coupling capacitance between inputs and output yields a ground leakage current of less than 2.0μA rms at 115V ac, 60Hz (or 0.02μA/V ac). As shown in Figure 5, the transformer coupled modulator signal, through stray coupling, also creates an internally generated leakage current of about 5μA rms @ 60kHz. Line frequency leakage current levels are unaffected by the power on or off condition of model 284J.

For medical applications, model 284J is designed to improve on patient safety current limits proposed by F.D.A., U.L., A.A.M.I. and other regulatory agencies. (e.g. model 284J complies with leakage requirements for the Underwriters Laboratory STANDARD FOR SAFETY, MEDICAL AND DENTAL EQUIPMENT as established under UL544 for type A and B patient connected equipment – reference *Leakage Current*, paragraph 27.5).

In patient monitoring equipment, such as ECG recorders, model 284J will provide adequate isolation without exposing the patient to potentially lethal microshock hazards. Using passive components for input protection, this design limits input fault currents even under amplifier failure conditions.

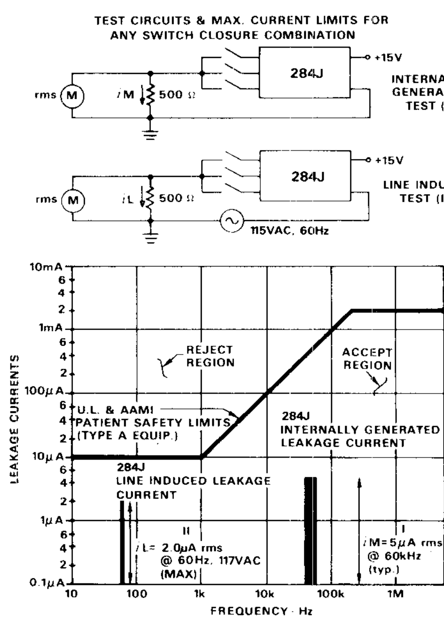


Figure 5. Model 284J Leakage Current Performance from Line Induced and Internally Generated (Modulator) Operating Conditions

PERFORMANCE CHARACTERISTICS

Common Mode Rejection: Input-to-Output CMR is dependent on source impedance imbalance, signal frequency and amplifier gain. CMR is rated at 115V ac, 60Hz and 5kΩ imbalance at a gain of 10V/V. Figure 6 illustrates CMR performance as a function of signal frequency. CMR approaches 146dB at dc with source imbalances as high as 5kΩ. As gain is decreased, CMR is reduced. At a gain of 1V/V, CMR is typically 6dB lower than at a gain of 10V/V.

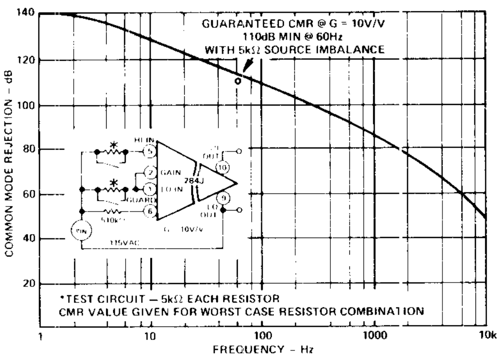


Figure 6. Common Mode Rejection vs. Frequency

Figure 7 illustrates the effect of source imbalance on CMR performance at 60Hz and Gain = 10V/V. CMR is typically 120dB at 60Hz and a balanced source. CMR is maintained greater than 80dB for source imbalances up to 100kΩ.

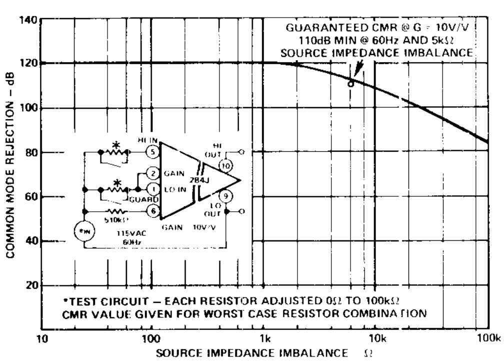


Figure 7. Common Mode Rejection vs. Source Impedance Imbalance

Input Voltage Noise: Voltage noise, referred to input, is dependent on gain and bandwidth as illustrated in Figure 8. RMS voltage noise is shown in a bandwidth from 0.05Hz to the frequency shown on the horizontal axis. The noise in a bandwidth from 0.05Hz to 100Hz is 8μV pk-pk at a gain of 10V/V. This value is derived by multiplying the rms value at f = 100Hz shown in Figure 8 (1.2μV rms) by 6.6.

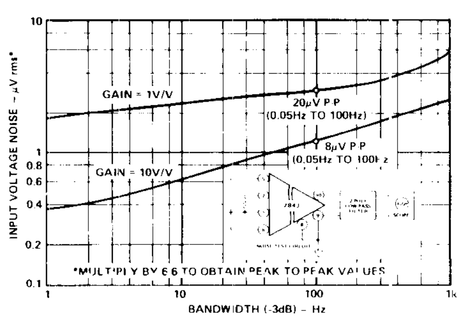


Figure 8. Input Voltage Noise vs. Bandwidth

For lowest noise performance, a low pass filter at the output should be used to selectively roll-off noise, output ripple and undesired signal frequencies beyond the bandwidth of interest (see note 3, Figure 1).

Input Offset Voltage Drift: Total input voltage drift is composed of two sources, input and output stage drifts and is gain dependent. The curve of Figure 9 illustrates the total input voltage drift over the gain range of 1 to 10V/V.

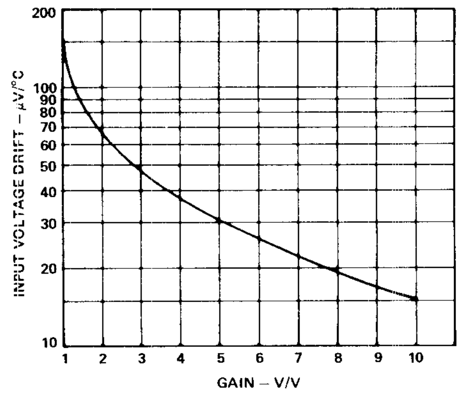


Figure 9. Input Offset Voltage Drift vs. Gain

Gain Nonlinearity: Linearity error is defined as the peak deviation of the output voltage from the best straight line and is specified as a % of peak-to-peak output voltage span; e.g. nonlinearity of model 284J operating at an output span of 10V pk-pk (±5V) is ±0.05% or ±5mV. In applying model 284J, highest accuracy is achieved by adjustment of gain and offset voltage to minimize the peak error over the operating output voltage span. A calibration technique illustrating how to minimize output error is shown below. In this example, model 284J is operating over an output span of +5V to −5V and a gain of 5V/V.

GAIN AND OFFSET TRIM PROCEDURE

1. Apply e_{IN} = 0 volts and adjust R_O for e_O = 0 volts.
2. Apply e_{IN} = +1.000V dc and adjust R_G for e_O = +5.000V dc.
3. Apply e_{IN} = −1.000V dc and measure the output error (see curve a).
4. Adjust R_G until the output error is one half that measured in step 3 (see curve b).
5. Apply e_{IN} = +1.000V dc and adjust R_O until the output error is one half that measured in step 4 (see curve c).

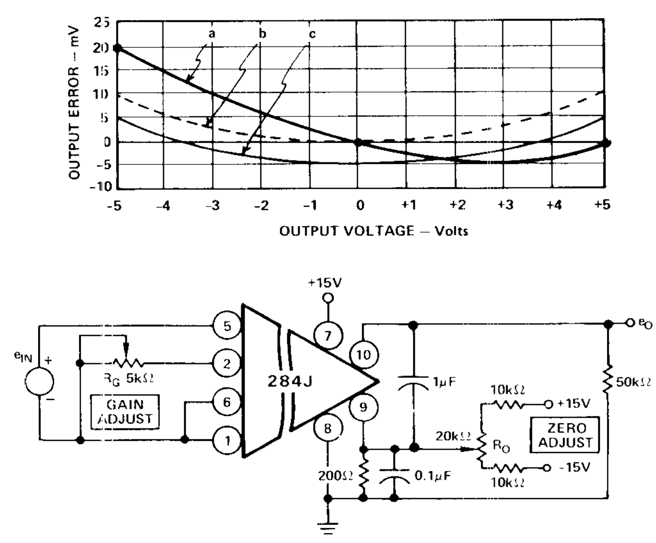


Figure 10. Gain and Offset Adjustment

GROUNDING PRACTICES

The more common sources of electrical noise arise from ground loops, electrostatic coupling and electromagnetic pickup. The guidelines listed below pertain to guarding low level, millivolt signals in hostile environments such as current shunt signals in "heavy industrial" plants.

Guidelines:

- Use twisted shielded cable to reduce inductive and capacitive pickup.
- Drive the transducer cable shield, S, with the common mode signal source, E_G, to reduce the effective cable capacitance as shown in Figure 11 below. This is accomplished by connecting the shield point S, as close as possible to the transducer signal low point B. This may not always be possible. In some cases the shield may be separated from signal low by a portion of the medium being measured (e.g. pressure transducer). This will cause a common mode signal, E_M, to be generated by the medium between the shield and the signal low. The 78dB CMR capability of model 284J between the input terminals (HI IN and LO IN) and GUARD, will work to suppress the common mode signal, E_M.
- To avoid ground loops and excessive hum, signal low, B, or the transducer cable shield, S, should never be grounded at more than one point.
- Dress unshielded leads short at the connection terminals and reduce the area formed by these leads to minimize inductive pickup.

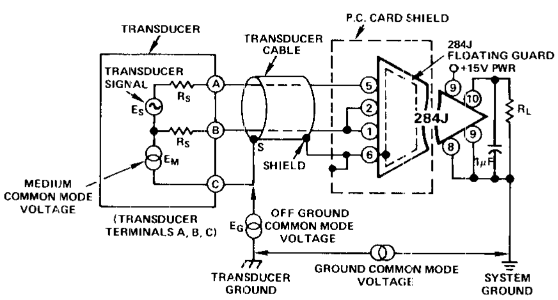


Figure 11. Transducer- Amplifier Interconnection

Isolated Power and Output Voltage Swing: Model 284J offers a floating power supply providing ±8.5V dc outputs with ±5mA output current rating. As shown in Figure 12, the minimum voltage output for $\pm V_{ISO}$, as well as the maximum load capability, is dependent on the input power supply, $+V_S$. Figure 12 also illustrates the typical output voltage range as both input supply, $+V_S$, and the isolated supply loads, $\pm I_L$, are varied. At ±5mA isolated load and V_S = +15V dc, model 284J can provide an output voltage swing of ±7.5V.

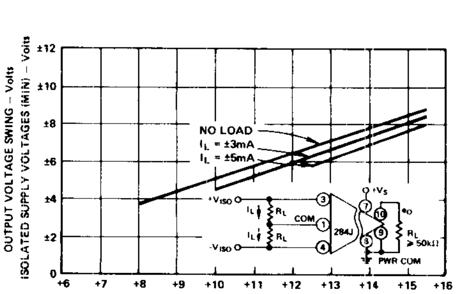


Figure 12. Isolated Power ($\pm V_{ISO}$) and Output Voltage Swing ($\pm E_O$) Versus Power Supply Input (V_S)

APPLICATIONS IN INDUSTRIAL MEASUREMENT AND CONTROL SYSTEMS

Remote Sensor Interface: In chemical, nuclear and metal processing industries, model 284J can be applied to measure and control off-ground millivolt signals in the presence of ±2500V dc CMV signals. In interface applications such as pH control systems of on-line process measurement systems such as pollution monitoring, model 284J offers complete galvanic isolation to eliminate troublesome ground loop problems. Isolated power outputs and adjustable gain add to the application flexibility of this model.

Figure 13 illustrates how model 284J can be combined with a low drift, 1µV/°C max, front-end amplifier, model AD510K, to interface low level transducer signals. Model 284J's isolated ±8.5V dc power and front-end guard eliminate ground loops and preserve high CMR (114dB @ 60Hz).

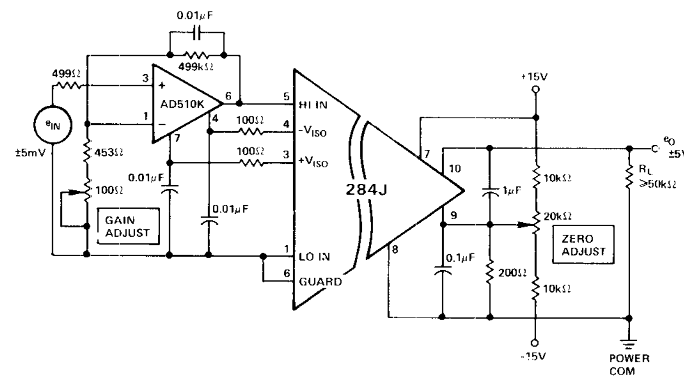


Figure 13. Input Signal Conditioning Using Isolated Power for Transducer Buffer Amplifier

Instrumentation Amplifier: Model 284J provides a floating guarded input stage capable of directly accepting isolated differential signals. The non-inverting, single-ended input stage offers simple two wire interconnection with floating input signals.

In applications where the isolated power is applied to transducers such as bridges which generate differential input signals with common mode voltages measured with respect to the isolated power common, model 284J can be connected as shown in Figure 14. To achieve high CMR with respect to the ISO PWR COM, the following trim procedure is recommended.

CMR Trim Procedure

1) Connect a 1V pk-pk oscillator between the +IN/-IN and IN COM terminals as shown in Figure 14.
2) Set the input frequency at 0.5Hz and adjust R1 for minimum e_O.
3) Set the input frequency at 60Hz and adjust R2 for minimum e_O.
4) Repeat steps 2 and 3 for best CMR performance.

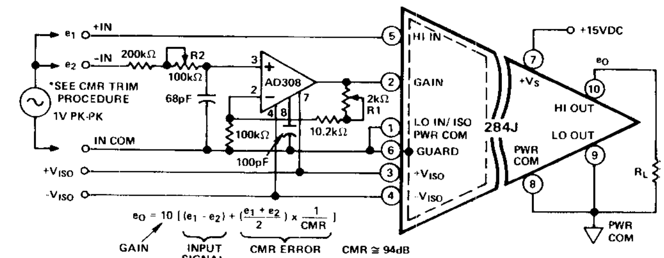


Figure 14. Application of 284J as Instrumentation Amplifier

APPLICATIONS IN BIOMEDICAL DESIGNS

Cardiac Monitoring: Heart signals can be masked by muscle noise, electrochemical noise, residual electrode voltages and 60Hz power line pickup. To achieve high performance in cardiac monitoring, model 284J's design provides high CMR in the dc to 100Hz bandwidth and substantial source impedance – to 5kΩ. An especially demanding ECG requirement is that of fetal heart monitoring as illustrated in Figure 15. The low input noise of model 284J and the dual CMR ratings are exploited in this application to extract the fetal ECG signals. The separation between the mother's and the fetal heartbeat is enhanced by the 78dB of CMR between the input electrodes and guard, while the 110dB of CMR from input to output ground screens out 60Hz pickup and other external interference.

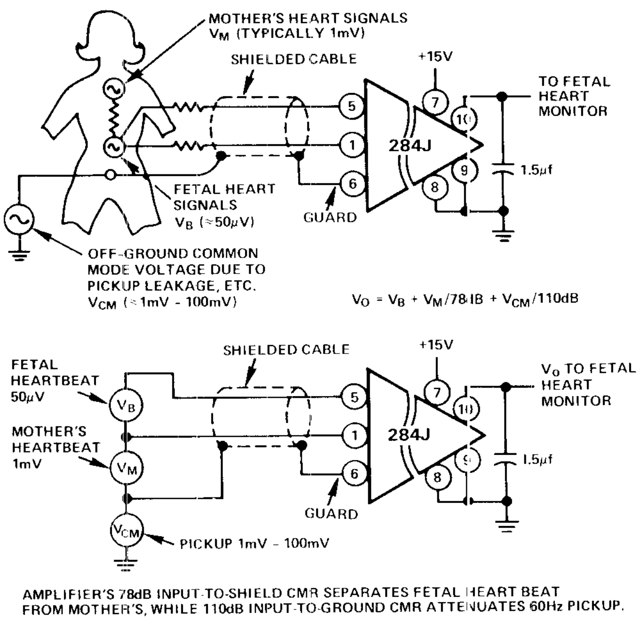


Figure 15. Fetal Heartbeat Monitoring

Single Lead ECG Recorder with Leads Off Indicator: In single lead applications model 284J offers simple two-wire hook-up to the ECG signal as illustrated in Figure 16. The floating signal can be connected directly to the HI IN and LO IN terminals using the GUARD tied to the patients' right leg for best CMR performance. Using the isolated power from model 284J an inexpensive calibration signal is easily provided. In ECG applications, model 284J provides a simple means to determine whenever a "Leads-Off" condition exists at the input. A "Leads-Off" condition ($R_S = \infty$) will cause the HI OUT terminal to be at a negative output saturation level; i.e. e_O = -8.5V to -9.5V @ V_S = +15V.

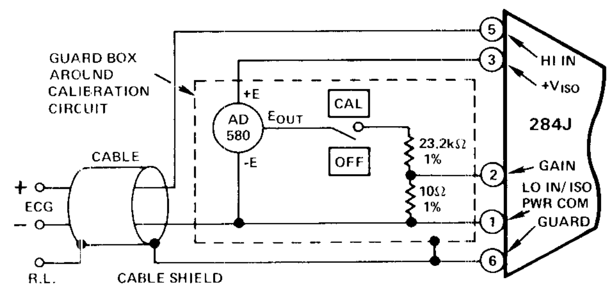


Figure 16. Single Lead ECG Recorder with 1mV Calibration Circuit and Leads Off Indicator

Multi-Lead ECG Recorder with Right Leg Drive: The small size, economy and isolated power makes model 284J an ideal isolation amplifier for application in clinical ECG recorders. Figure 17 illustrates how this new isolator can be applied in a high performance, portable multi-lead ECG recorder. In this application, model 284J's input is configured as an instrumentation amplifier with high CMR to the floating input common. The right leg drive offers improved CMR between input and isolated common by driving to zero any CMV existing between these points. The isolated power, $\pm V_{ISO}$, is used to drive the lead buffer amplifiers and the front-end, 1mV calibration signal.

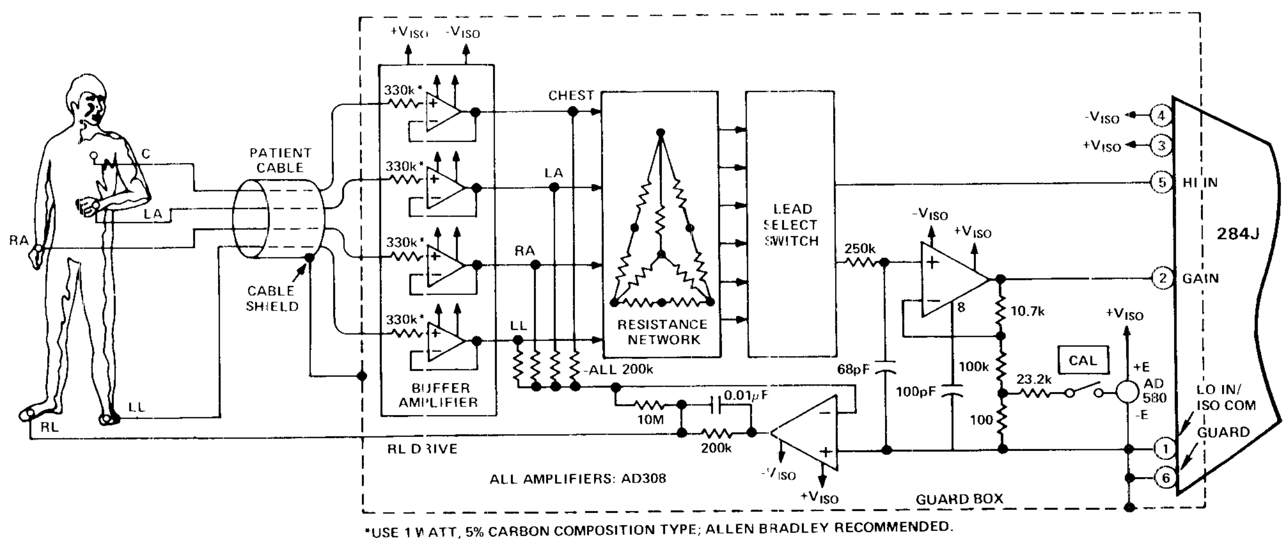


Figure 17. Multi-Lead ECG Recorder Application Using Model 284J with Right Leg Drive Output