

High-performance Instrumentation Amplifier

FEATURES

- **Internal Gain Setting**
Resistors for G=1, 10, 100, 1000
- **Excellent Gain Accuracy:**
 $\pm 0.1\%$ G=100 +25°C
 $\pm 0.16\%$ G=100 +85°C
 $\pm 0.3\%$ G=100 +125°C
- **Low Offset Voltage**
Drift $\pm 0.6\mu\text{V}/^\circ\text{C}$ @ G=100
- **Small 18-Pin DIP**
- **Full Mil Operation**
-55°C to +125°C
MN2200H, H/B Models

DESCRIPTION

MN2200 is a high-performance hybrid instrumentation amplifier in a small, 18-pin, ceramic dual-in-line package. Internal, laser-trimmed, thin-film resistors provide user-selectable gains of 1, 10, 100 and 1000. The internal gain setting resistors provide much better accuracy over temperature than conventional designs requiring an external gain setting resistor. A single external resistor may also be used for gain adjustment in applications calling for gains between the fixed ranges.

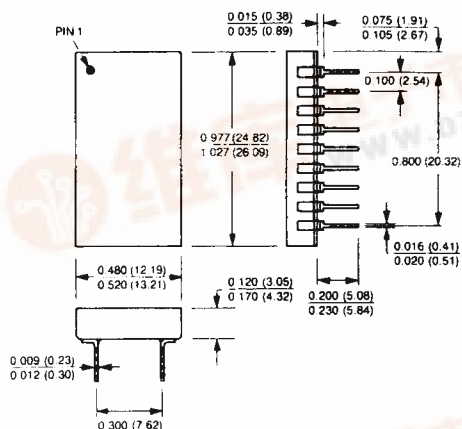
An additional unique feature of MN2200 is its user-optional, two-pole Butterworth filter. Two external capacitors can be used to set the breakpoint of this lowpass filter from full bandwidth to well below 1Hz.

MN2200 has a typical input offset voltage of $\pm 100\mu\text{V}$ at $+25^\circ\text{C}$, and this can be adjusted to zero with an external trimpot. Input offset voltage drift with temperature is an extremely low $\pm 1.5\mu\text{V}/^\circ\text{C}$ at $G=10$ and drops to $\pm 0.5\mu\text{V}/^\circ\text{C}$ at $G=1000$. In addition, MN2200 offers 7kHz of full power bandwidth, 1000M Ω input impedance, and has only $\pm 5\text{nA}$ of input bias current.

The standard device is fully specified for either -25°C to $+85^{\circ}\text{C}$ or -55°C to $+125^{\circ}\text{C}$ ("H" model) operation. For military/aerospace or harsh-environment commercial/industrial applications, MN2200H/B is available with Environmental Stress Screening.

Typical applications for MN2200 include: amplifying strain gauges, thermocouples and other low-output transducers; high-accuracy data acquisition systems and biomedical instrumentation.

18 PIN DIP



**Dimensions in Inches
(millimeters)**

MN2200 HIGH-PERFORMANCE INSTRUMENTATION AMPLIFIER

ABSOLUTE MAXIMUM RATINGS

Operating Temperature	-55°C to +125°C
Specified Temperature	-25°C to +85°C (Standard) -55°C to +125°C ("H" Model)
Storage Temperature	-65°C to +150°C
+Vcc Supply (Pin 12)	+18 Volts
-Vcc Supply (Pin 6)	-18 Volts
Differential Input (Pin 2 to Pin 16)	±30 Volts
Analog Inputs (Pins 2, 16)	±Vcc
Output Short Circuit	Protected

ORDERING INFORMATION

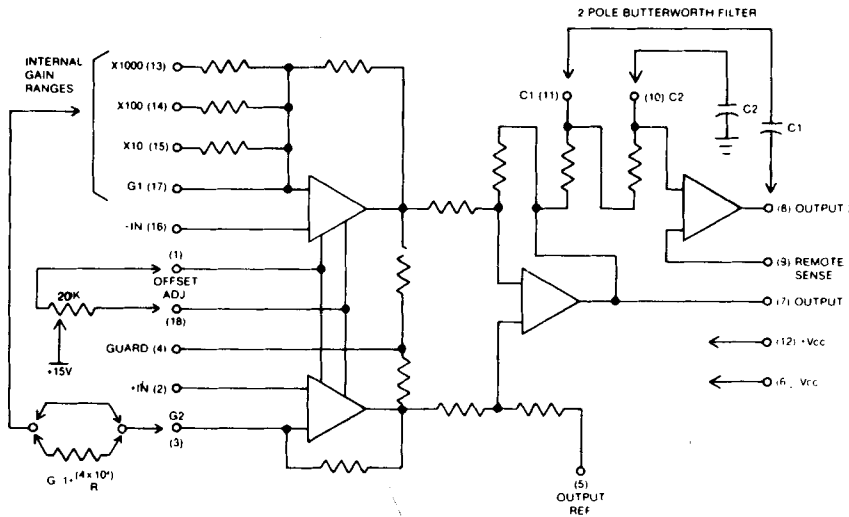
PART NUMBER	MN2200H/B
Standard part is specified for -25°C to +85°C operation.	
Add "H" for specified -55°C to +125°C operation.	
Add "B" to "H" models for Environmental Stress Screening.	

SPECIFICATIONS (T_A = +25°C, ±Vcc = ±15V unless otherwise indicated)

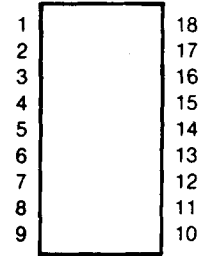
FIXED GAIN LEVELS (Note 4)	G=1		G=10		G=100		G=1000		UNITS
	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
Gain Accuracy*: +25° C	±0.005	±0.01	±0.03	±0.1	±0.03	±0.1	±0.05	±0.1	%
-25° C to +85° C	±0.01	±0.02	±0.06	±0.16	±0.06	±0.16	±0.14	±0.45	%
-55° C to +125° C ("H" Model)	±0.02	±0.04	±0.1	±0.25	±0.15	±0.3	±0.25	±0.6	%
Gain Nonlinearity: +25° C	±0.001	±0.002	±0.002	±0.005	±0.002	±0.005	±0.02	±0.05	%
-25° C to +85° C	±0.002	±0.005	±0.005	±0.01	±0.005	±0.01	±0.05	±0.1	%
-55° C to +125° C ("H" Model)	±0.004	±0.01	±0.01	±0.02	±0.01	±0.02	±0.1	±0.2	%
INPUT CHARACTERISTICS	MIN		TYP		MAX		UNITS		
Input Impedance									
Differential	1000						MΩ		
Common mode	1000						MΩ		
Input Voltage Range									
Differential	±10						V		
Common mode	±10		±13				V		
Common Mode Rejection Ratio									
G=100 DC—10 Hz			110				dB		
Offset Voltage (referred to input)*									
Initial @ G=100 (Note 1)			±100		±200		μV		
Drift vs. Temperature (Note 2)*									
G=1			10		20		μV/°C		
G=1000			0.5		2		μV/°C		
1<G<1000			±(10/G)+0.5				μV/°C		
vs. Supplies									
G=1			10				μV/% Supply		
G=1000			0.5				μV/% Supply		
Voltage Noise (referred to input)									
G=1 (0.1 to 10 Hz)			2.0				μVp-p		
G=1000 (0.1 to 10 Hz)			0.6				μVp-p		
Input Bias Current									
Initial 25° C			±5		±7		nA		
Drift			12				pA/°C		
Input Offset Current									
Initial 25° C			±5		±7		nA		
Drift			12				pA/°C		
OUTPUT CHARACTERISTICS									
Output Voltage Swing	±12		±13				V		
Output Drive Current	±5		±10				mA		
Output Impedance			0.2				Ω		
Output Load Capacitance			250				pf		
DYNAMIC CHARACTERISTICS									
Slew Rate			0.25				V/μSec.		
Small Signal Bandwidth									
G=1			750				KHz		
G=100			7				KHz		
G=1000			700				Hz		
Settling time to 0.01%, 10V step									
G=1, 10			50				μSec.		
G=100			200				μSec.		
G=1000			1500				μSec.		
POWER REQUIREMENTS									
Power Supply Range	±5		±15		±18		V		
Current Drain +Vcc*			+8		+15		mA		
Current Drain -Vcc*			-8		-15		mA		
Power Consumption			240		450		mW		

- NOTES:** 1. Externally adjustable to zero.
 2. Verified by testing at -25, +25, and +85°C.
 3. *Parameters 100% tested. Other parameters guaranteed by design.
 4. Gain can be set to any level between 1 and 1000 with a single external resistor.

BLOCK DIAGRAM



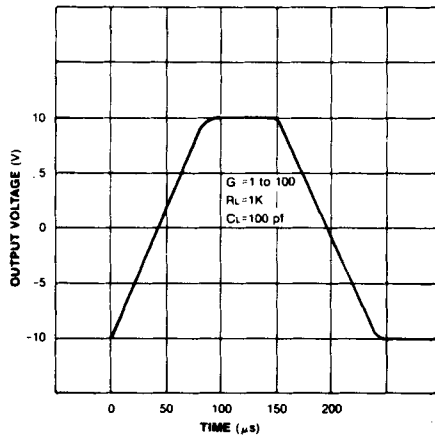
PINNING



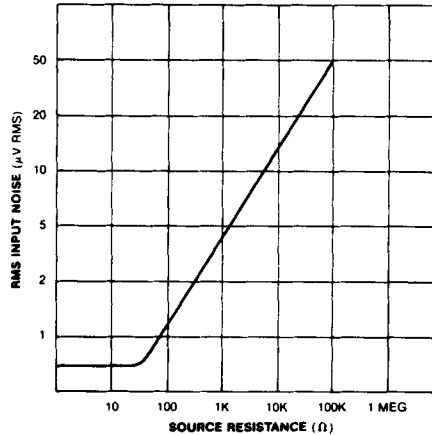
- | | |
|----------------|----------------|
| 1 OFFSET ADJ. | 10 C2 (FILTER) |
| 2 + INPUT | 11 C1 (FILTER) |
| 3 GAIN 2 | 12 +Vcc |
| 4 GUARD | 13 X1000 |
| 5 OUTPUT REF. | 14 X100 |
| 6 -Vcc | 15 X10 |
| 7 OUTPUT 1 | 16 - INPUT |
| 8 OUTPUT 2 | 17 GAIN 1 |
| 9 REMOTE SENSE | 18 OFFSET ADJ. |

TYPICAL CHARACTERISTICS
($T_A=25^\circ\text{C}$, Supplies $\pm 15\text{V}$)

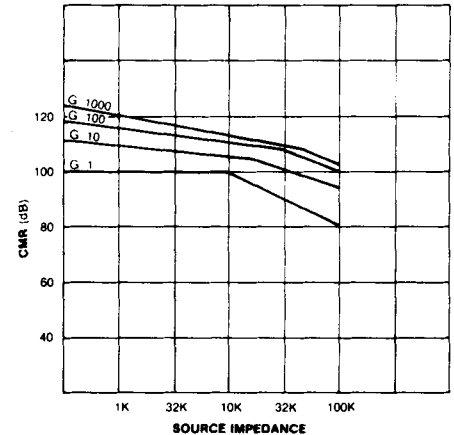
STEP RESPONSE



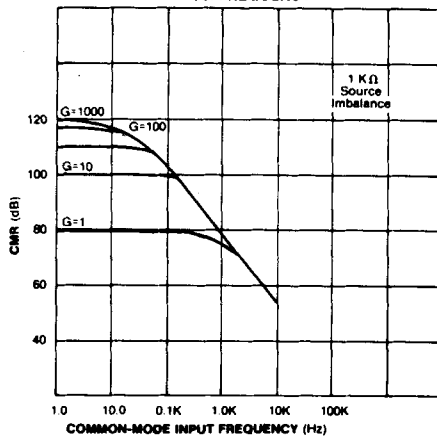
RMS INPUT NOISE VOLTAGE VS. SOURCE RESISTANCE



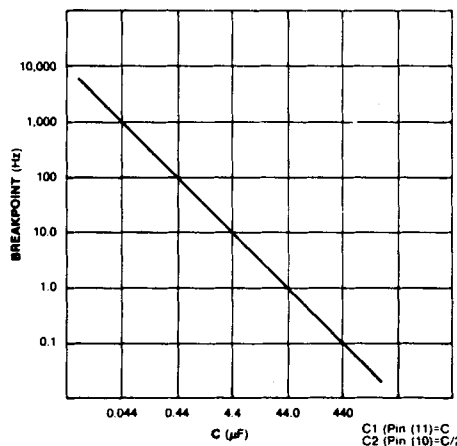
CMR VS. SOURCE IMPEDANCE IMBALANCE



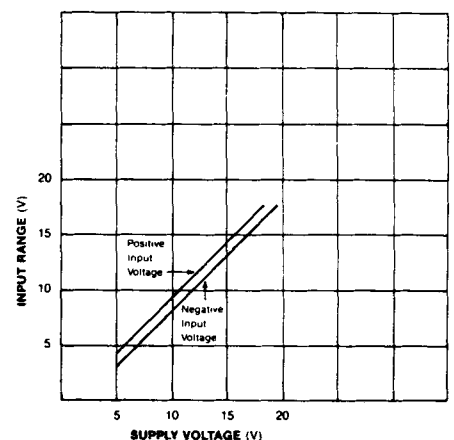
COMMON MODE REJECTION VS. FREQUENCY



FILTER BREAKPOINT



INPUT RANGE FOR LINEAR RESPONSE





INSTRUMENTATION AMPLIFIERS

ADVANTAGES:

Instrumentation Amplifiers are committed, closed loop, gain blocks that offer significant performance advantages over simple operational amplifiers.

The principle advantages provided by Instrumentation Amplifiers are:

- Very high input impedance that is independent of gain.
- Very high common mode rejection ratios.
- High accuracies.
- Low Drifts.
- Addition of guard and reference terminals to compensate for noise and external wiring resistance.
- Immunity to temperature variations.

APPLICATIONS:

Instrumentation Amplifiers are used to accurately amplify high impedance low level signals, in the presence of noise and common mode voltages.

Typical applications include:

Amplifying thermocouples, strain gauges and other low level transducers, high accuracy data acquisition systems and bio-medical monitoring.

APPLICATIONS INFORMATION:

GAIN SETTING:

The MN2200 includes internal laser trimmed thin film resistors for gains of 1, 10, 100, and 1000. These internal resistors track very closely with the other resistors in the amplifier providing superior performance over temperature, and should be used whenever possible.

Connections for internal gain selection are as follows:

Gain	Connect Pin to Pin
1	No connection
10	15 to 3
100	14 to 3
1000	13 to 3

In addition, the gain can be set to any value >1 with the addition of a single resistor connected between pins 3 and 17. Specifications will be gradually degraded for gains in excess of 1000.

This gain setting resistor should be low TC (<10 ppm/ $^{\circ}$ C) metal film for best performance.

The value of the external gain setting resistor is defined by,

$$\text{Gain} = 1 + \frac{(4 \times 10^4)}{R}$$

The gain error of the above equation is typically 0.1% and a maximum of 0.5% for gains >1.0 . Gain drift with temperature will be less than 0.006%/ $^{\circ}$ C if resistors with TC's of 10 ppm/ $^{\circ}$ C or less are used.

OFFSET ADJUSTMENT:

The MN2200 meets all specifications without adjustment. However, the initial offset voltage (200 μ V max. referred to input) may be adjusted to zero with the addition of a trimpot between pins 1 and 18 as shown in the block diagram. A 10 turn <100 ppm/ $^{\circ}$ C TC trimpot should be used for best performance.

GUARD TERMINAL:

The MN2200 incorporates a guard (Pin 4) to drive the input cable shield when long input runs are necessary. The use of the guard and shielded input cable greatly reduces the effects of common mode voltages and induced noise and is recommended for noisy environments and input lead runs of more than a few inches.

REMOTE SENSE:

Another feature of the MN2200 is the Remote Sense Terminal. The Remote Sense is used to eliminate the effects of external lead resistance and insure that an accurate output voltage is present at locations remote from the actual instrumentation amplifier.

OUTPUT REFERENCE:

The MN2200's Output Reference Terminal can be used in conjunction with the Sense Terminal to provide accurate output voltages at locations remote from the instrumentation amplifier.

The Output Reference can also be used to offset the instrumentation Amplifier's output by a fixed amount. Any voltage applied between analog ground and the Output Reference will appear as a fixed offset in the output. When used as an offsetting input, the Output Reference is a 20 k Ohm Resistive load. If not used to offset the output, the Output Reference Terminal should be connected to analog ground.

OPTIONAL 2 POLE BUTTERWORTH FILTER:

A unique feature of the MN2200 is the internal two pole Butterworth filter. Two external capacitors applied to pins 10 and 11 set the breakpoint of this filter from full bandwidth to well below 1 Hz.

The breakpoint of the filters is defined by:

$$f(\text{Hz}) = \left(\frac{44}{C(\mu\text{f})} \right) \quad \begin{array}{l} C_1 (\text{Pin } 11) = C \\ C_2 (\text{Pin } 10) = C/2 \end{array}$$

OUTPUTS:

The MN2200 has two analog outputs: pins 7 and 8. Normally the Pin 8 output, which includes the optional filter stage, is used. A slight improvement in offset drifts may be achieved at gains <10 by using the pin 7 output.

The pin 8 output must be used if remote sensing is employed.

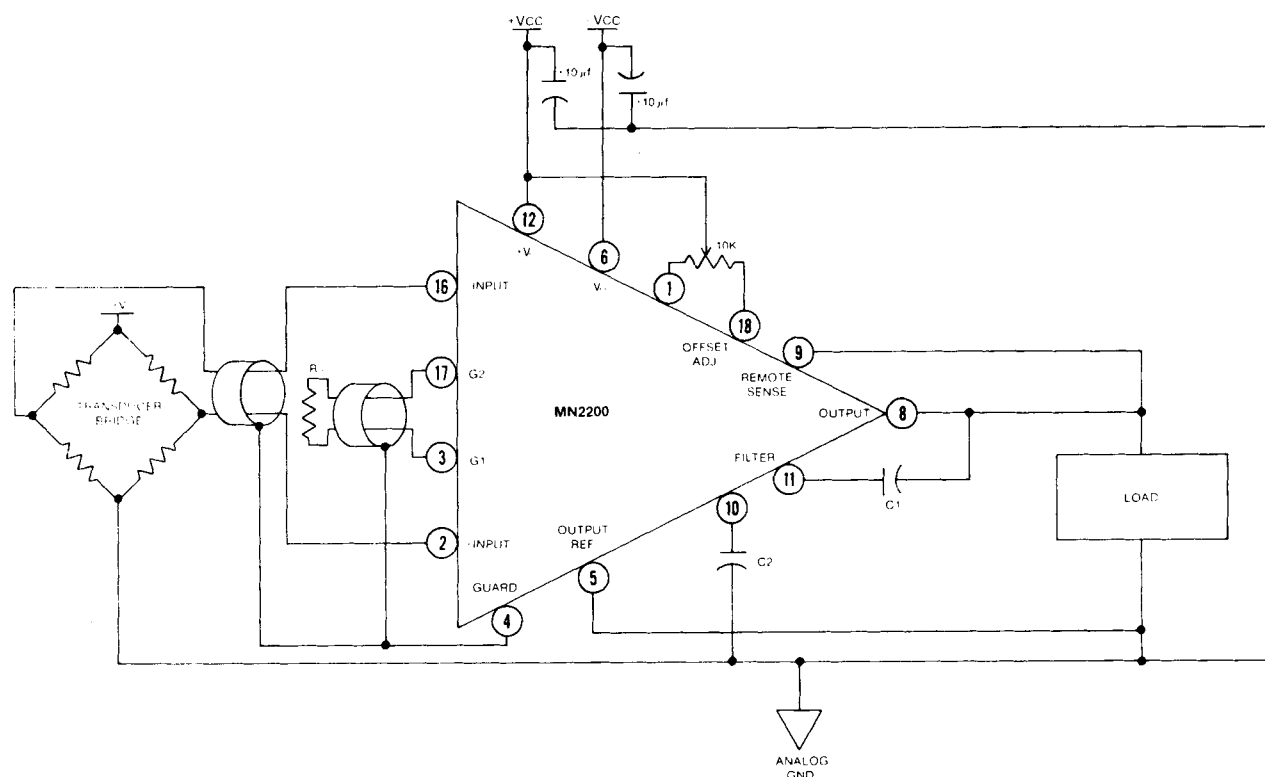
GENERAL CONSIDERATIONS:

While Instrumentation Amplifiers have inherently high common mode and power supply rejections, good bypassing, shielding, and grounding techniques should be employed.

Input leads should be shielded and the power supplies bypassed with 10 μ F capacitors close to the amplifier.

In addition, when an external gain setting resistor is used it is preferable to locate it close to the amplifier. If it is necessary to locate this resistor more than a few inches from the amplifier shielded leads should be used. Remotely locating the gain setting resistor may degrade CMRR at high frequencies.

TYPICAL APPLICATION



INSTRUMENTATION AMPLIFIER SPECIFICATION DEFINITIONS

Gain—The ratio of the change in output voltage to the change in input voltage.

Gain Nonlinearity—Maximum deviation from the ideal gain transfer function over the full output range.

Gain Accuracy—The percentage that actual gain differs from ideal gain.

Differential Input Impedance—Impedance seen looking into the plus and minus input terminals with respect to each other.

Common Mode Input Impedance—Impedance seen looking into either the plus or minus input with respect to analog ground.

Initial Offset Voltage (referred to input)—Collection of internal voltage offsets summed and treated as a single offset appearing in series with the input. This offset, multiplied by the programmed gain, will appear at the amplifier output. This can normally be zeroed out with an external trimpot.

Offset Voltage Drift (referred to the input)—Drift in initial offset voltage due to temperature variation.

Offset Voltage vs. Supplies—Change in initial offset voltage due to variations in power supply voltages.

Voltage Noise (referred to input)—Sum of the internal noise sources treated as a single source appearing in series with the input signal. This noise, multiplied by the programmed gain, will appear at the amplifier output. Voltage noise is dependent on bandwidth and may be reduced by using the minimum bandwidth necessary for a given application.

Small Signal Bandwidth—Frequency at which the amplifiers gain drops 3 dB from its D.C. gain.

Settling Time—Time required for the output to reach specified accuracy for a given change in the input.

Common Mode Rejection Ratio—The ability of the amplifier to reject signals common to both the plus and minus inputs and extract the desired signal appearing between the plus and minus inputs. Usually given as the ratio of differential gain to common mode gain.

Filter Breakpoint—Frequency where the output is attenuated 3 dB by the internal filter.

Output Voltage Swing—Maximum allowable output excursion for faithful reproduction of the input signal. This is limited to several volts less than the associated power supply.

Output Drive Current—Current that the amplifier will source or sink to the load while remaining within specification.

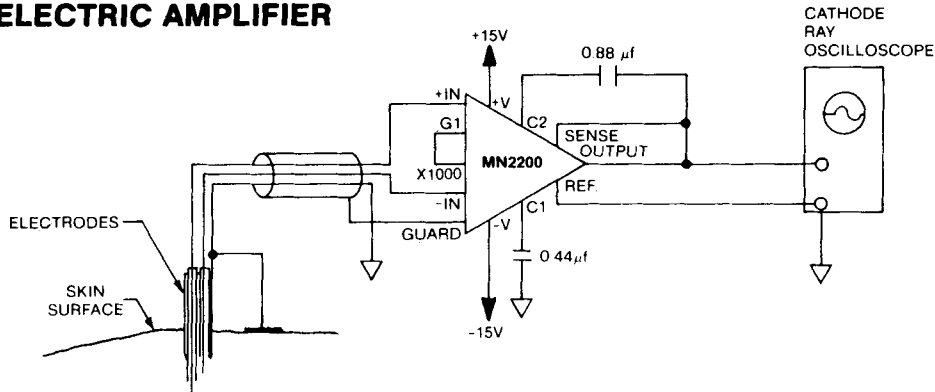
Output Impedance—Source impedance of the amplifier output.

Output Load Capacitance—Maximum capacitive load that the amplifier can drive while remaining stable and within specification.

Slew Rate—Rate of change of the output in response to a step change at the input.

APPLICATIONS INFORMATION:

BIOELECTRIC AMPLIFIER



The circuit shown may be used to measure any of a number of bioelectric phenomena.

The MN2200 high performance instrumentation amplifier is used to amplify and buffer low level signals from the bioelectric probe. The amplified signals are then displayed on a cathode ray oscilloscope or recorded by a strip chart recorder.

In general both AC and DC characteristics of a waveform with peak amplitude on the order of 10MV are measured. Since the electrodes used exhibit an output impedance of 20-100K it is necessary to use the MN2200's guard terminal to drive the input cable shield. This minimizes common mode error caused by the wire to shield capacitance of the input cable interacting with the unbalanced electrode impedances.

Next, there must be a path for instrumentation amplifier input bias current return.

In this circuit, the bias current return is provided by the ground plate on the skin surface. The internal fixed gain of 1000 is used because an accurate, absolute measurement of the magnitude of the input voltage is desired.

Also, wiring of the output circuit should be done so as to minimize errors caused by current flowing in ground lines or current drawn by the load. This is done by 1) connecting the instrumentation amplifier reference terminal to the ground reference of the load and 2) connecting the output sense terminal directly to the output side of the load.

A cutoff frequency (50HZ) is used in the active filter section of the MN2200 to reduce noise while maintaining sufficient bandwidth to display the AC component of the measured signal.

