

# INA122

## Single Supply, *MicroPower* INSTRUMENTATION AMPLIFIER

### FEATURES

- LOW QUIESCENT CURRENT: 60µA
- WIDE POWER SUPPLY RANGE  
Single Supply: 2.2V to 36V  
Dual Supply: -0.9/+1.3V to ±18V
- COMMON-MODE RANGE TO (V-) - 0.1V
- RAIL-TO-RAIL OUTPUT SWING
- LOW OFFSET VOLTAGE: 250µV max
- LOW OFFSET DRIFT: 3µV/°C max
- LOW NOISE: 60nV/√Hz
- LOW INPUT BIAS CURRENT: 25nA max
- 8-PIN DIP AND SO-8 SURFACE-MOUNT

### APPLICATIONS

- PORTABLE, BATTERY OPERATED SYSTEMS
- INDUSTRIAL SENSOR AMPLIFIER:  
Bridge, RTD, Thermocouple
- PHYSIOLOGICAL AMPLIFIER:  
ECG, EEG, EMG
- MULTI-CHANNEL DATA ACQUISITION

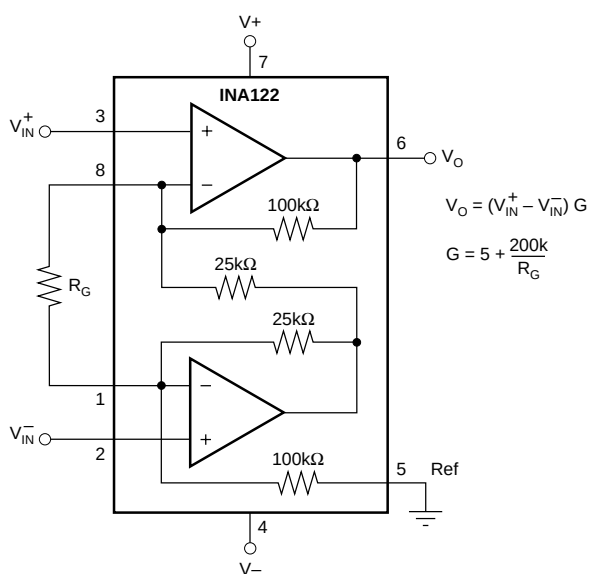
### DESCRIPTION

The INA122 is a precision instrumentation amplifier for accurate, low noise differential signal acquisition. Its two-op-amp design provides excellent performance with very low quiescent current, and is ideal for portable instrumentation and data acquisition systems.

The INA122 can be operated with single power supplies from 2.2V to 36V and quiescent current is a mere 60µA. It can also be operated from dual supplies. By utilizing an input level-shift network, input common-mode range extends to 0.1V below negative rail (single supply ground).

A single external resistor sets gain from 5V/V to 10000V/V. Laser trimming provides very low offset voltage (250µV max), offset voltage drift (3µV/°C max) and excellent common-mode rejection.

Package options include 8-pin plastic DIP and SO-8 surface-mount packages. Both are specified for the -40°C to +85°C extended industrial temperature range.



# SPECIFICATIONS

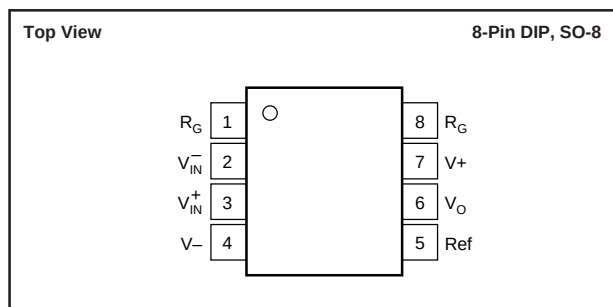
At  $T_A = +25^{\circ}\text{C}$ ,  $V_S = +5\text{V}$ ,  $R_L = 20\text{k}\Omega$  connected to  $V_S/2$ , unless otherwise noted.

| PARAMETER                            | CONDITIONS                                        | INA122P, U                      |                       |              | INA122PA, UA |           |             | UNITS                          |
|--------------------------------------|---------------------------------------------------|---------------------------------|-----------------------|--------------|--------------|-----------|-------------|--------------------------------|
|                                      |                                                   | MIN                             | TYP                   | MAX          | MIN          | TYP       | MAX         |                                |
| <b>INPUT</b>                         |                                                   |                                 |                       |              |              |           |             |                                |
| Offset Voltage, RTI                  | $V_S = +2.2\text{V to } +36\text{V}$              |                                 | $\pm 100$             | $\pm 250$    |              | $\pm 150$ | $\pm 500$   | $\mu\text{V}$                  |
| vs Temperature                       |                                                   |                                 | $\pm 1$               | $\pm 3$      |              | *         | $\pm 5$     | $\mu\text{V}/^{\circ}\text{C}$ |
| vs Power Supply (PSRR)               |                                                   |                                 | 10                    | 30           |              | *         | 100         | $\mu\text{V}/\text{V}$         |
| Input Impedance                      |                                                   |                                 | $10^{10} \parallel 3$ |              |              | *         |             | $\Omega \parallel \text{pF}$   |
| Safe Input Voltage                   | $R_S = 0$                                         | $(V-) - 0.3$                    |                       | $(V+) + 0.3$ | *            |           | *           | V                              |
|                                      | $R_S = 10\text{k}\Omega$                          | $(V-) - 40$                     |                       | $(V+) + 40$  | *            |           | *           | V                              |
| Common-Mode Voltage Range            |                                                   | 0                               |                       | 3.4          | *            |           | *           | V                              |
| Common-Mode Rejection                | $V_{CM} = 0\text{V to } 3.4\text{V}$              | 83                              | 96                    |              | 76           | 90        |             | dB                             |
| <b>INPUT BIAS CURRENT</b>            |                                                   |                                 |                       |              |              |           |             |                                |
| vs Temperature                       |                                                   |                                 | $-10$                 | $-25$        |              | *         | $-50$       | nA                             |
| Offset Current                       |                                                   |                                 | $\pm 40$              |              |              | *         |             | $\text{pA}/^{\circ}\text{C}$   |
| vs Temperature                       |                                                   |                                 | $\pm 1$               | $\pm 2$      |              | *         | $\pm 5$     | nA                             |
|                                      |                                                   |                                 | $\pm 40$              |              |              | *         |             | $\text{pA}/^{\circ}\text{C}$   |
| <b>GAIN</b>                          |                                                   |                                 |                       |              |              |           |             |                                |
| Gain Equation                        |                                                   | $G = 5 \text{ to } 10\text{k}$  |                       |              |              | *         |             | V/V                            |
| Gain Error                           |                                                   | $G = 5 + 200\text{k}\Omega/R_G$ |                       |              |              | *         |             | V/V                            |
| Gain Error                           | $G = 5$                                           |                                 | $\pm 0.05$            | $\pm 0.1$    |              | *         | $\pm 0.15$  | %                              |
| vs Temperature                       | $G = 5$                                           |                                 | 5                     | 10           |              | *         | *           | $\text{ppm}/^{\circ}\text{C}$  |
| Gain Error                           | $G = 100$                                         |                                 | $\pm 0.3$             | $\pm 0.5$    |              | *         | $\pm 1$     | %                              |
| vs Temperature                       | $G = 100$                                         |                                 | $\pm 25$              | $\pm 100$    |              | *         | *           | $\text{ppm}/^{\circ}\text{C}$  |
| Nonlinearity                         | $G = 100, V_O = -14.85\text{V to } +14.9\text{V}$ |                                 | $\pm 0.005$           | $\pm 0.012$  |              | *         | $\pm 0.024$ | %                              |
| <b>NOISE (RTI)</b>                   |                                                   |                                 |                       |              |              |           |             |                                |
| Voltage Noise, $f = 1\text{kHz}$     |                                                   |                                 | 60                    |              |              | *         |             | $\text{nV}/\sqrt{\text{Hz}}$   |
| $f = 100\text{Hz}$                   |                                                   |                                 | 100                   |              |              | *         |             | $\text{nV}/\sqrt{\text{Hz}}$   |
| $f = 10\text{Hz}$                    |                                                   |                                 | 110                   |              |              | *         |             | $\text{nV}/\sqrt{\text{Hz}}$   |
| $f_B = 0.1\text{Hz to } 10\text{Hz}$ |                                                   |                                 | 2                     |              |              | *         |             | $\mu\text{Vp-p}$               |
| Current Noise, $f = 1\text{kHz}$     |                                                   |                                 | 80                    |              |              | *         |             | $\text{fA}/\sqrt{\text{Hz}}$   |
| $f_B = 0.1\text{Hz to } 10\text{Hz}$ |                                                   |                                 | 2                     |              |              | *         |             | $\text{pAp-p}$                 |
| <b>OUTPUT</b>                        |                                                   |                                 |                       |              |              |           |             |                                |
| Voltage, Positive                    | $V_S = \pm 15\text{V}$                            | $(V+) - 0.1$                    | $(V+) - 0.05$         |              | *            | *         |             | V                              |
| Negative                             | $V_S = \pm 15\text{V}$                            | $(V-) + 0.15$                   | $(V-) + 0.1$          |              | *            | *         |             | V                              |
| Short-Circuit Current                | Short-Circuit to Ground                           |                                 | $+3/-30$              |              |              | *         |             | mA                             |
| Capacitive Load Drive                |                                                   |                                 | 1                     |              |              | *         |             | nF                             |
| <b>FREQUENCY RESPONSE</b>            |                                                   |                                 |                       |              |              |           |             |                                |
| Bandwidth, $-3\text{dB}$             | $G = 5$                                           |                                 | 120                   |              |              | *         |             | kHz                            |
|                                      | $G = 100$                                         |                                 | 5                     |              |              | *         |             | kHz                            |
|                                      | $G = 500$                                         |                                 | 0.9                   |              |              | *         |             | kHz                            |
| Slew Rate                            |                                                   |                                 | $+0.08/-0.16$         |              |              | *         |             | $\text{V}/\mu\text{s}$         |
| Settling Time, 0.01%                 | $G = 5$                                           |                                 | 350                   |              |              | *         |             | $\mu\text{s}$                  |
|                                      | $G = 100$                                         |                                 | 450                   |              |              | *         |             | $\mu\text{s}$                  |
|                                      | $G = 500$                                         |                                 | 1.8                   |              |              | *         |             | ms                             |
| Overload Recovery                    | 50% Input Overload                                |                                 | 3                     |              |              | *         |             | $\mu\text{s}$                  |
| <b>POWER SUPPLY</b>                  |                                                   |                                 |                       |              |              |           |             |                                |
| Voltage Range, Single Supply         |                                                   | $+2.2$                          | $+5$                  | $+36$        | *            | *         | *           | V                              |
| Dual Supplies                        |                                                   | $-0.9/+1.3$                     |                       | $\pm 18$     | *            | *         | *           | V                              |
| Current                              | $I_O = 0$                                         |                                 | 60                    | 85           |              | *         | *           | $\mu\text{A}$                  |
| <b>TEMPERATURE RANGE</b>             |                                                   |                                 |                       |              |              |           |             |                                |
| Specification                        |                                                   | $-40$                           |                       | $+85$        | *            |           | *           | $^{\circ}\text{C}$             |
| Operation                            |                                                   | $-55$                           |                       | $+85$        | *            |           | *           | $^{\circ}\text{C}$             |
| Storage                              |                                                   | $-55$                           |                       | $+125$       | *            |           | *           | $^{\circ}\text{C}$             |
| Thermal Resistance, $\theta_{JA}$    |                                                   |                                 |                       |              |              |           |             |                                |
| 8-Pin DIP                            |                                                   |                                 | 150                   |              |              | *         |             | $^{\circ}\text{C}/\text{W}$    |
| SO-8 Surface-Mount                   |                                                   |                                 | 150                   |              |              | *         |             | $^{\circ}\text{C}/\text{W}$    |

\* Specification same as INA122P, INA122U.

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## PIN CONFIGURATION



## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

|                                                      |                                             |
|------------------------------------------------------|---------------------------------------------|
| Supply Voltage, $V^+$ to $V^-$ .....                 | 36V                                         |
| Signal Input Terminals, Voltage <sup>(2)</sup> ..... | $(V^-) - 0.3V$ to $(V^+) + 0.3V$            |
| Current <sup>(2)</sup> .....                         | 5mA                                         |
| Output Short Circuit .....                           | Continuous                                  |
| Operating Temperature .....                          | $-40^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Storage Temperature .....                            | $-55^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Lead Temperature (soldering, 10s) .....              | $+300^\circ\text{C}$                        |

NOTES: (1) Stresses above these ratings may cause permanent damage.

(2) Input terminals are internally diode-clamped to the power supply rails. Input signals that can exceed the supply rails by more than 0.3V should be current-limited to 5mA or less.

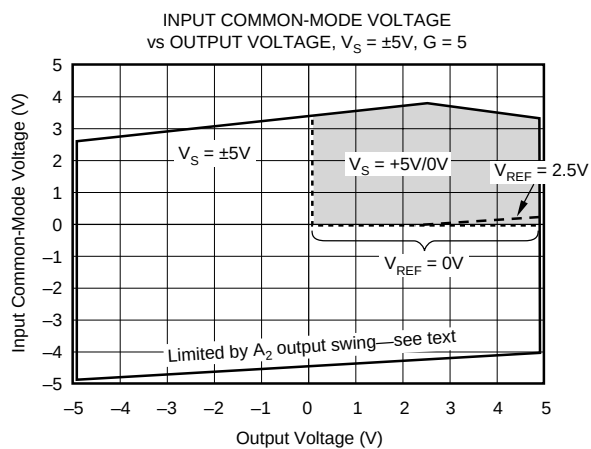
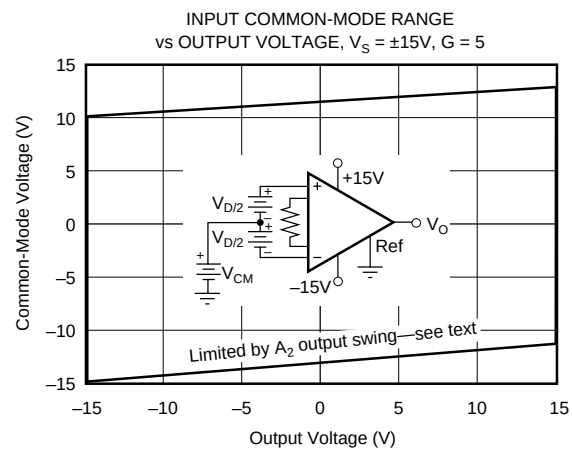
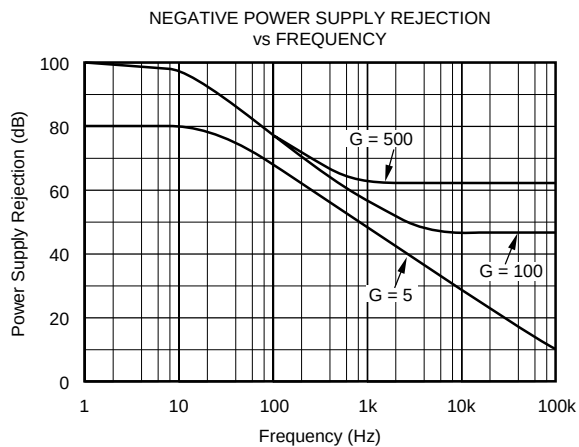
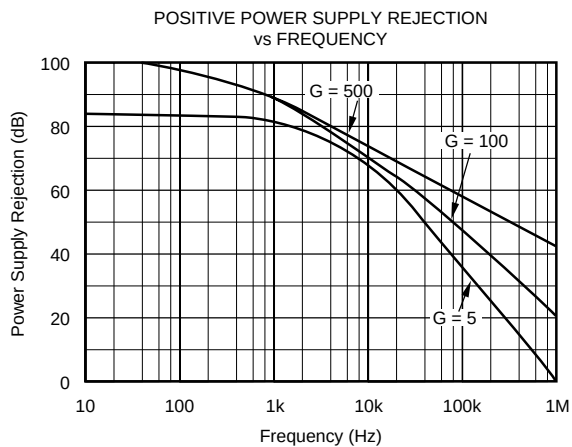
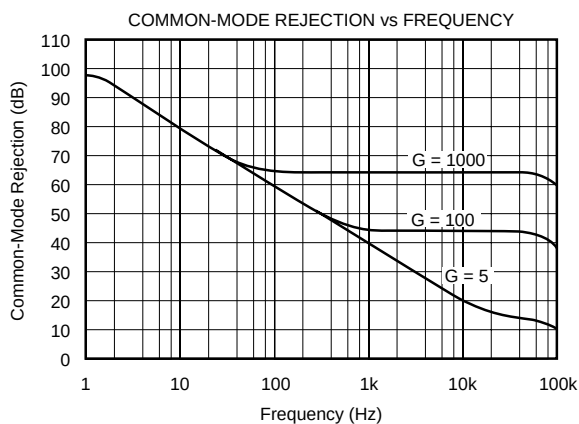
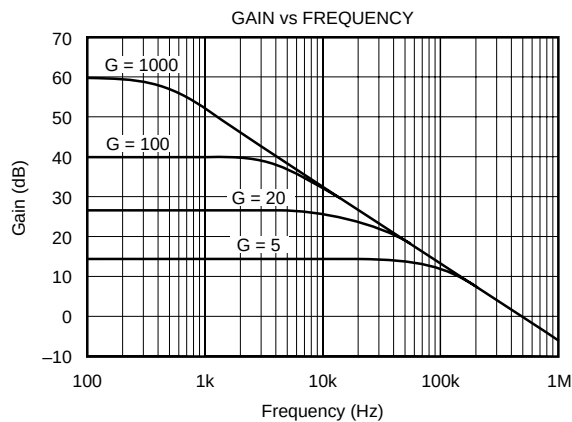
## PACKAGE INFORMATION

| PRODUCT  | PACKAGE            | PACKAGE DRAWING NUMBER <sup>(1)</sup> |
|----------|--------------------|---------------------------------------|
| INA122PA | 8-Pin DIP          | 006                                   |
| INA122P  | 8-Pin DIP          | 006                                   |
| INA122UA | SO-8 Surface Mount | 182                                   |
| INA122U  | SO-8 Surface Mount | 182                                   |

NOTE: (1) For detailed drawing and dimension table, see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

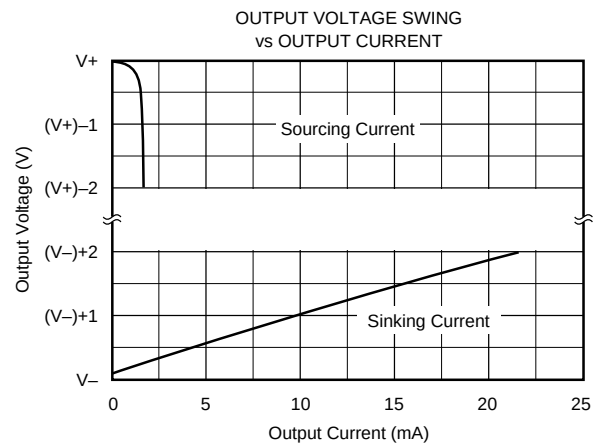
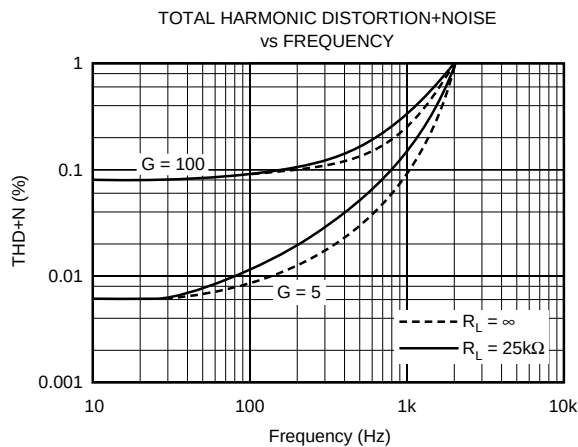
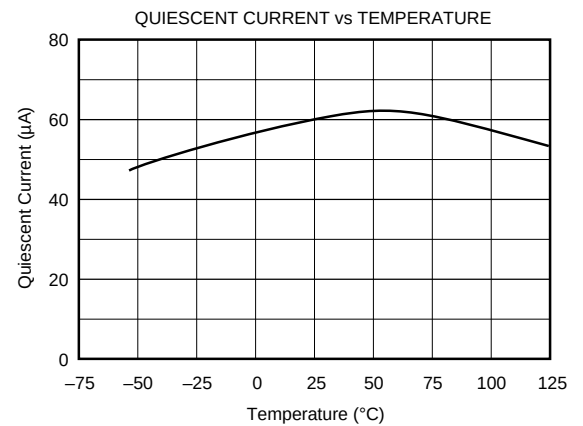
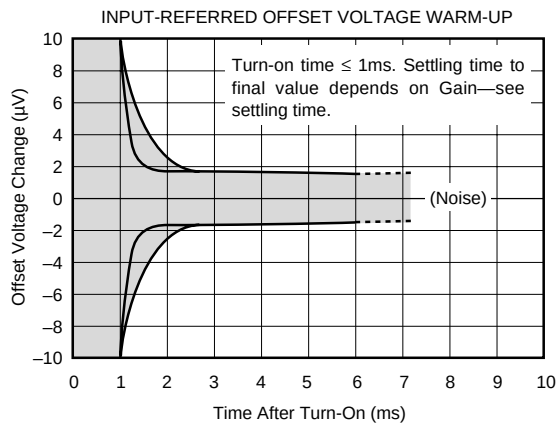
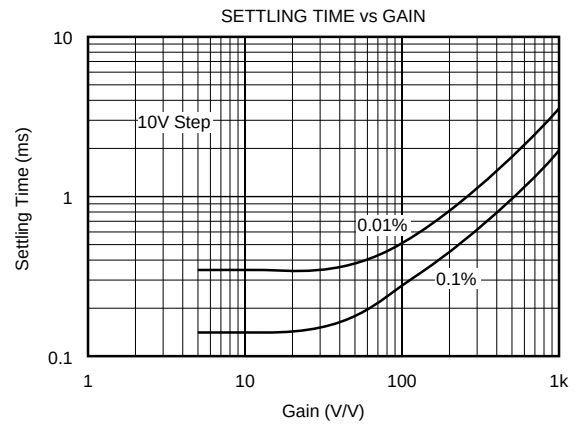
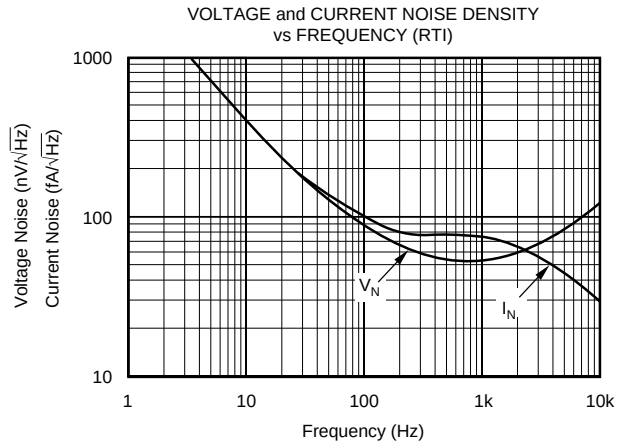
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 5\text{V}$ , unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)

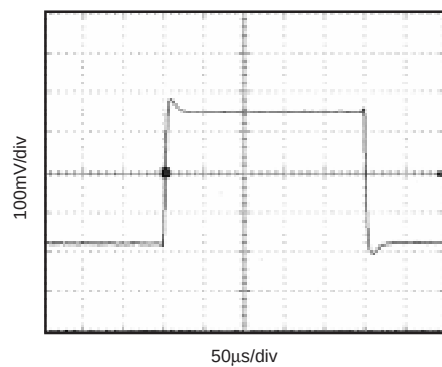
At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 5\text{V}$ , unless otherwise noted.



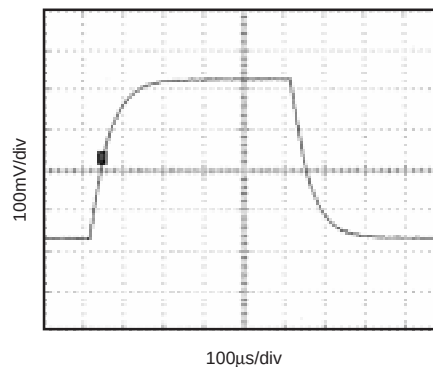
## TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 5\text{V}$ , unless otherwise noted.

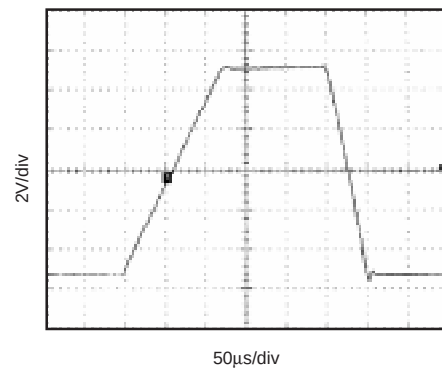
SMALL-SIGNAL STEP RESPONSE  
 $G = 5$



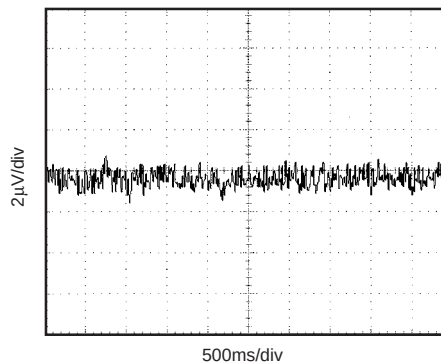
SMALL-SIGNAL STEP RESPONSE  
 $G = 100$



LARGE-SIGNAL STEP RESPONSE  
 $G = 5$



INPUT-REFERRED NOISE VOLTAGE  
0.1Hz to 10Hz



## APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA122. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins.

The output is referred to the output reference (Ref) terminal which is normally grounded. This must be a low-impedance connection to ensure good common-mode rejection. A resistance of 10Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR.

### SETTING THE GAIN

Gain of the INA122 is set by connecting a single external resistor,  $R_G$ , as shown:

$$G = 5 + \frac{200k\Omega}{R_G} \quad (1)$$

Commonly used gains and  $R_G$  resistor values are shown in Figure 1.

The 200kΩ term in equation 1 comes from the internal metal film resistors which are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA122.

The stability and temperature drift of the external gain setting resistor,  $R_G$ , also affects gain.  $R_G$ 's contribution to gain accuracy and drift can be directly inferred from the gain equation (1).

### OFFSET TRIMMING

The INA122 is laser trimmed for low offset voltage and offset voltage drift. Most applications require no external

offset adjustment. Figure 2 shows an optional circuit for trimming the output offset voltage. The voltage applied to the Ref terminal is added to the output signal. An op amp buffer is used to provide low impedance at the Ref terminal to preserve good common-mode rejection.

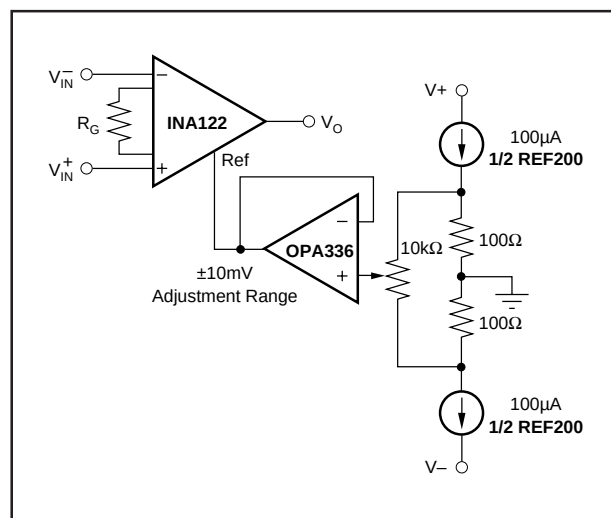


FIGURE 2. Optional Trimming of Output Offset Voltage.

### INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA122 is extremely high—approximately  $10^{10}\Omega$ . However, a path must be provided for the input bias current of both inputs. This input bias current is approximately  $-10\text{nA}$  (current flows out of the input terminals). High input impedance means that this input bias current changes very little with varying input voltage.

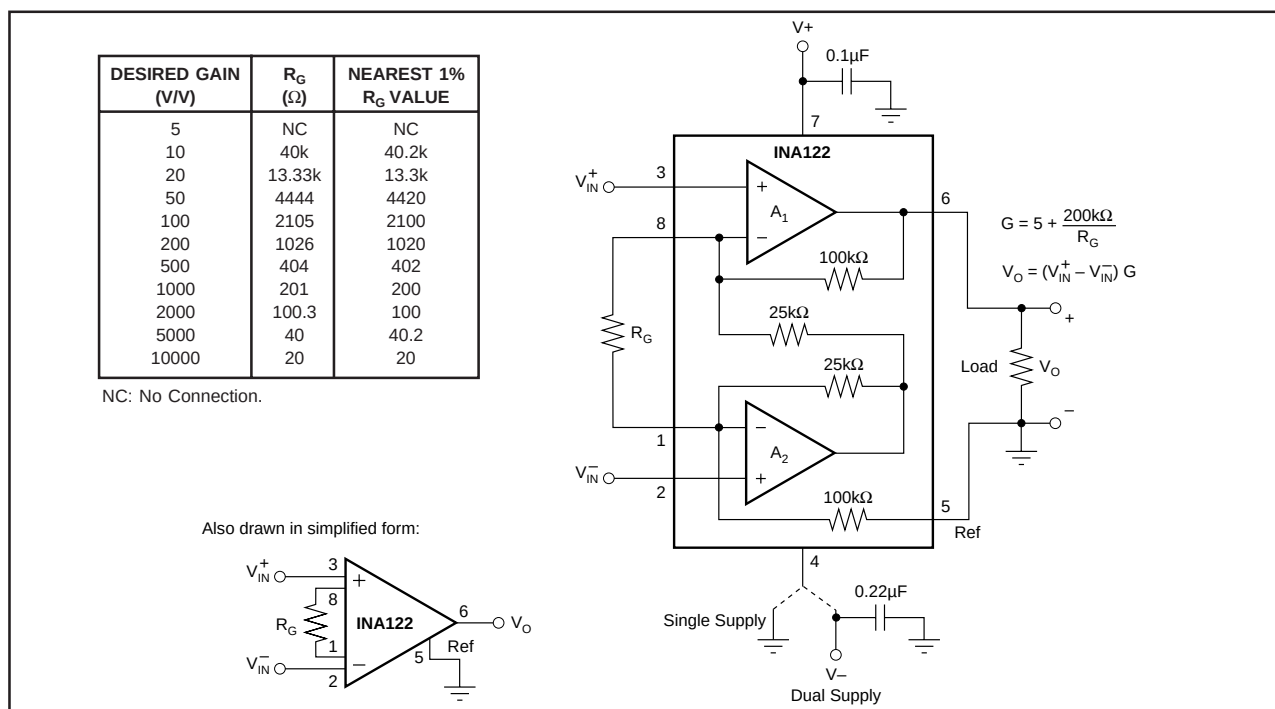


FIGURE 1. Basic Connections.

Input circuitry must provide a path for this input bias current for proper operation. Figure 3 shows various provisions for an input bias current path. Without a bias current path, the inputs will float to a potential which exceeds the common-mode range of the INA122 and the input amplifiers will saturate.

If the differential source resistance is low, the bias current return path can be connected to one input (see the thermocouple example in Figure 3). With higher source impedance, using two equal resistors provides a balanced input with possible advantages of lower input offset voltage due to bias current and better high-frequency common-mode rejection.

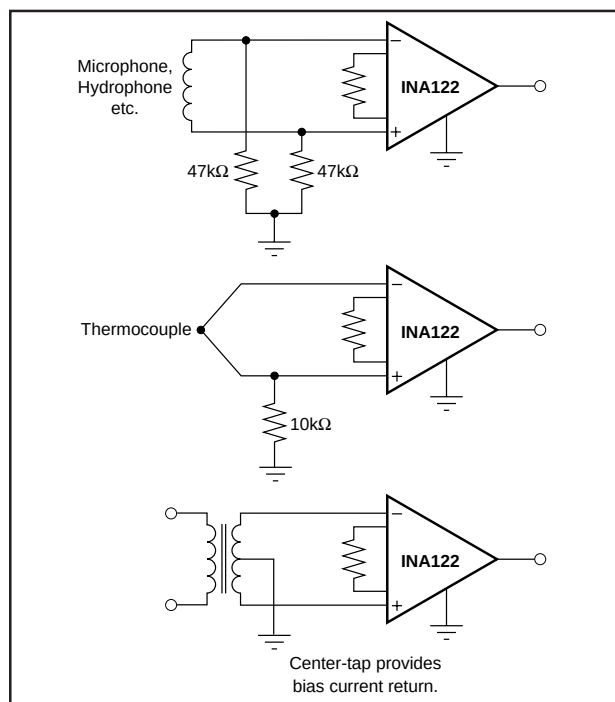


FIGURE 3. Providing an Input Common-Mode Current Path.

## INPUT PROTECTION

The inputs of the INA122 are protected with internal diodes connected to the power supply rails (Figure 4). These diodes will clamp the applied signal to prevent it from damaging the input circuitry. If the input signal voltage can exceed the power supplies by more than 0.3V, the input signal current should be limited to less than 5mA to protect the internal clamp diodes. This can generally be done with a series input resistor. Some signal sources are inherently current-limited and do not require limiting resistors.

## INPUT COMMON-MODE RANGE

The common-mode range for some common operating conditions is shown in the typical performance curves. The INA122 can operate over a wide range of power supply and  $V_{REF}$  configurations, making it impractical to provide a comprehensive guide to common-mode range limits for all possible conditions. The most commonly overlooked overload condition occurs by attempting to exceed the output swing of  $A_2$ , an internal circuit node that cannot be measured. Calculating the expected voltages at  $A_2$ 's output (see equation in Figure 4) provides a check for the most common overload conditions.

The design of  $A_1$  and  $A_2$  are identical and their outputs can swing to within approximately 100mV of the power supply rails, depending on load conditions. When  $A_2$ 's output is saturated,  $A_1$  can still be in linear operation, responding to changes in the non-inverting input voltage. This may give the appearance of linear operation but the output voltage is invalid.

A single supply instrumentation amplifier has special design considerations. Using commonly available single-supply op amps to implement the two-op amp topology will not yield equivalent performance. For example, consider the condition where both inputs of common single-supply op amps are

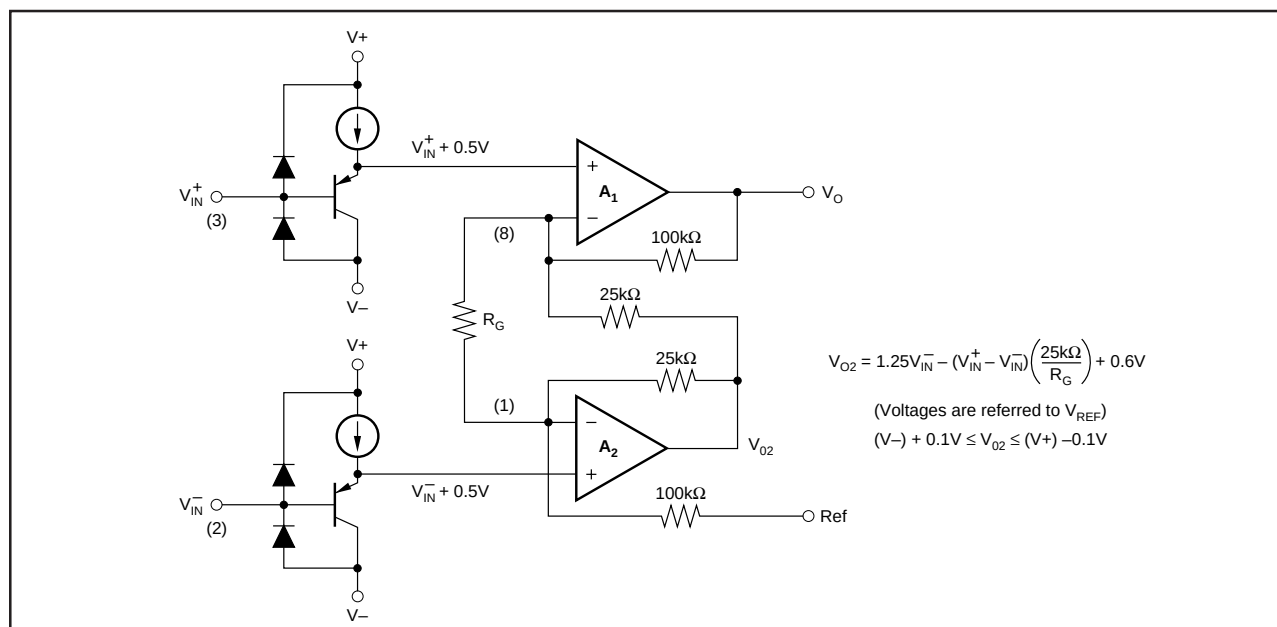


FIGURE 4. INA122 Simplified Circuit Diagram.



equal to 0V. The outputs of both  $A_1$  and  $A_2$  must be 0V. But any small positive voltage applied to  $V_{IN}^+$  requires that  $A_2$ 's output must swing below 0V, which is clearly impossible without a negative power supply.

To achieve common-mode range that extends to single-supply ground, the INA122 uses precision level-shifting buffers on its inputs. This shifts both inputs by approximately +0.5V, and through the feedback network, shifts  $A_2$ 's output by approximately +0.6V. With both inputs and  $V_{REF}$  at single-supply,  $A_2$ 's output is well within its linear range. A positive  $V_{IN}^+$  causes  $A_2$ 's output to swing below 0.6V.

As a result of this input level-shifting, the voltages at pin 1 and pin 8 are not equal to their respective input terminal voltages (pins 2 and 3). For most applications, this is not important since only the gain-setting resistor connects to these pins.

### LOW VOLTAGE OPERATION

The INA122 can be operated on a single power supply as low as +2.2V (or a total of +2.2V on dual supplies). Performance remains excellent throughout the power supply range up to +36V (or  $\pm 18V$ ). Most parameters vary only slightly throughout this supply voltage range—see typical performance curves.

Operation at very low supply voltage requires careful attention to ensure that the common-mode voltage remains within its linear range.

### LOW QUIESCENT CURRENT OPERATION

The INA122 maintains its low quiescent current (60 $\mu$ A) while the output is within linear operation (up to 200mV from the supply rails). When the input creates a condition that overdrives the output into saturation, quiescent current increases. With  $V_O$  overdriven into the positive rail, the quiescent current increases to approximately 400 $\mu$ A. Likewise, with  $V_O$  overdriven into the negative rail (single supply ground) the quiescent current increases to approximately 200 $\mu$ A.

### OUTPUT CURRENT RANGE

Output sourcing and sinking current values versus the output voltage ranges are shown in the typical performance curves. The positive and negative current limits are not equal. Positive output current sourcing will drive moderate to high load impedances. Battery operation normally requires the careful management of power consumption to keep load impedances very high throughout the design.

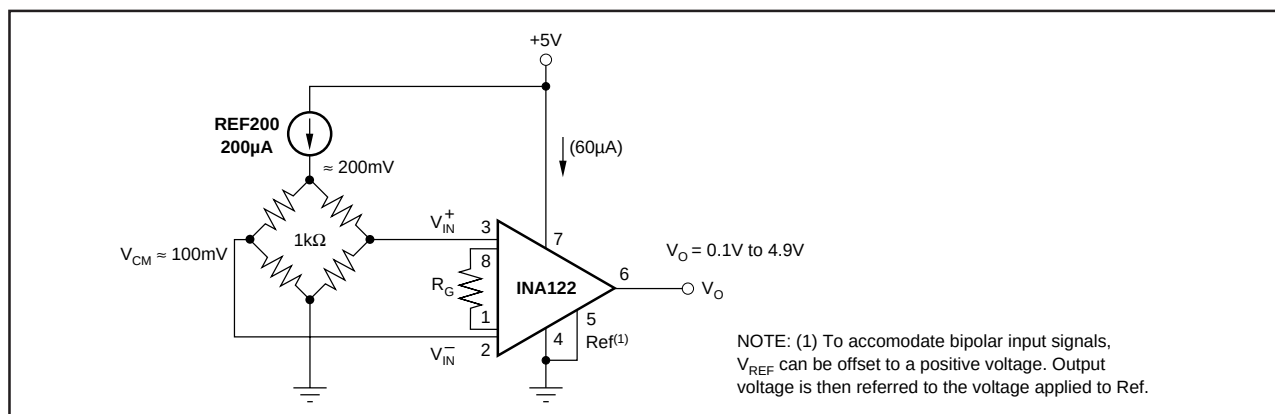


FIGURE 5. Micropower Single Supply Bridge Amplifier.

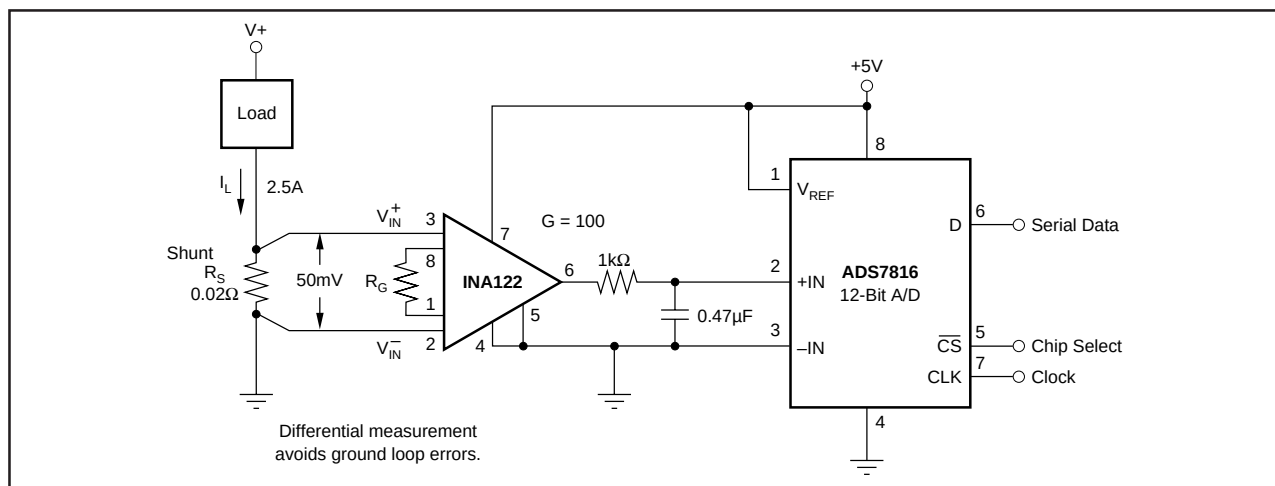


FIGURE 6. Single-Supply Current Shunt Measurement.