# INA122 Single Supply, Micropower Instrumentation Amplifier

## 1 Features

- Low quiescent current: 60µA
- Wide power supply range: 2.2V to 36V
- Rail-to-rail output swing
- Low offset voltage: 250µV maximum
- Low offset drift: 3µV/°C maximum
- Low noise: 60nV/√Hz
- Low input bias current: 25nA maximum
- Packages
  - 4.9mm × 6mm SOIC
  - 9.81mm × 9.43mm PDIP

## 2 Applications

- Portable electronics
- Field transmitters and sensors
- Pressure transmitters
- Infusion pumps
- Electrocardiograms (ECGs)

## 3 Description

The INA122 is a precision instrumentation amplifier for accurate, low-noise differential signal acquisition. The two-op-amp design provides excellent performance with very low quiescent current (60µA), and is designed for portable instrumentation and data acquisition systems. The INA122 can be operated with single or dual power supplies from 2.2V to 36V.

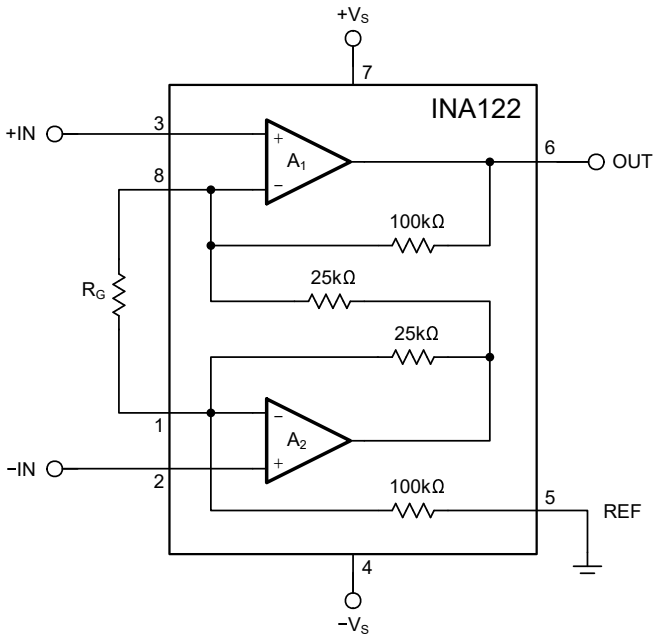
A single external resistor sets gain from 5V/V to 10000V/V. Laser trimming provides very low offset voltage (250µV maximum), offset voltage drift (3µV/°C maximum) and excellent common-mode rejection.

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

**Package Information**

| PART NUMBER | PACKAGE(1) | PACKAGE SIZE(2) |
|---|---|---|
| INA122 | P (PDIP, 8) | 9.81mm × 9.43mm |
| | D (SOIC, 8) | 4.9mm × 6mm |

(1) For all available packages, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.




$G = 5 + \frac{200k\Omega}{R_G}$ $V_{OUT} = (V_{+IN} - V_{-IN}) \times G$

**INA122 Basic Connections**

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

# Table of Contents

**1 Features**....1
**2 Applications**....1
**3 Description**....1
**4 Pin Configuration and Functions**....3
**5 Specifications**....4
5.1 Absolute Maximum Ratings....4
5.2 ESD Ratings....4
5.3 Recommended Operating Conditions....4
5.4 Thermal Information....5
5.5 Electrical Characteristics....6
5.6 Typical Characteristics....8
**6 Detailed Description**....11
6.1 Overview....11
6.2 Functional Block Diagram....11
6.3 Feature Description....12
6.4 Device Functional Modes....14
**7 Application and Implementation**....15
7.1 Application Information....15
7.2 Typical Application....17
7.3 Power Supply Recommendations....20
7.4 Layout....20
**8 Device and Documentation Support**....22
8.1 Device Support....22
8.2 Development Support....22
8.3 Receiving Notification of Documentation Updates....22
8.4 Support Resources....22
8.5 Trademarks....22
8.6 Electrostatic Discharge Caution....23
8.7 Glossary....23
**9 Revision History**....23
**10 Mechanical, Packaging, and Orderable Information**....24


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# 4 Pin Configuration and Functions

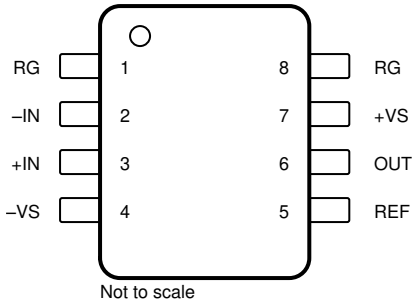



**Figure 4-1. P or D Package, 8-Pin PDIP or SOIC (Top View)**

**Table 4-1. Pin Functions**

| PIN | | TYPE | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| –IN | 2 | Input | Negative (inverting) input |
| +IN | 3 | Input | Positive (noninverting) input |
| OUT | 6 | Output | Output |
| REF | 5 | Input | Reference input. This pin must be driven by a low-impedance source. |
| RG | 1, 8 | — | Gain setting pin. Place a gain resistor between pin 1 and pin 8. |
| –VS | 4 | — | Negative (lowest) power supply |
| +VS | 7 | — | Positive (highest) power supply |

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# 5 Specifications

**Note**

TI has qualified multiple fabrication flows for this device. Differences in performance are labeled by chip site origin (CSO). For system robustness, designing for all flows is highly recommended. For more information, please see Section 8.1.1.

## 5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_S$ | Supply voltage | Dual supply, $V_S$ = (V+) – (V–) | | ±18 | V |
| | | Single supply, $V_S$ = (V+) – 0V | | 36 | |
| | Signal input voltage | | (V–)–0.3 | (V+)+0.3 | V |
| | Signal input current | | | 5 | mA |
| | Output short-circuit(2) | | Continuous | | |
| $T_A$ | Operating temperature | | –40 | 125 | °C |
| $T_{stg}$ | Storage temperature | | –55 | 125 | °C |
| | Lead temperature (soldering, 10s) | | | 300 | °C |

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) Short-circuit to $V_S$ / 2.

## 5.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | 1500 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | 1000 | |

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

## 5.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| Supply voltage | $V_S$ = (V+) – (V–) | 2.2 | | 36 | V |
| Specified temperature | | –40 | | 85 | °C |


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## 5.4 Thermal Information

| THERMAL METRIC[1] | | INA122 8 PINS D (SOIC) | UNIT |
|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 129.2 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 69.1 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 76.8 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 16.1 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 75.8 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | n/a | °C/W |

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application note.

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## 5.5 Electrical Characteristics

at $T_A$ = 25°C, $V_S$ = +5V, $R_L$ = 20kΩ connected to $V_S$/2, $V_{REF}$ = 0V, all chips site origins (CSO), unless otherwise noted

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **INPUT** | | | | | | | |
| $V_{OS}$ | Offset voltage (RTI) | | INA122P, U | | ±100 | ±250 | µV |
| | | | INA122PA, UA | | ±150 | ±500 | |
| | Offset voltage drift (RTI) | $T_A$ = –40°C to +85°C | INA122P, U | | ±1 | ±3 | µV/°C |
| | | | INA122PA, UA | | ±1 | ±5 | |
| PSRR | Power-supply rejection ratio (RTI) | $V_S$ = 2.2V to 36V | INA122P, U | | 10 | 30 | µV/V |
| | | | INA122PA, UA | | 10 | 100 | |
| $V_{CM}$ | Operating input range[1] | | | 0 | | 3.4 | V |
| CMRR | Common-mode rejection ratio (RTI) | $V_{CM}$ = 0V to 3.4V | INA122P, U | 83 | 96 | | dB |
| | | | INA122PA, UA | 76 | 96 | | |
| | Differential impedance | | | | 100 \|\| 3 | | GΩ \|\| pF |
| | Common-mode impedance | | | | 100 \|\| 3 | | |
| **BIAS CURRENT** | | | | | | | |
| $I_B$ | Input bias current | $V_{CM}$ = $V_S$ / 2 | INA122P, U | | –10 | –25 | nA |
| | | | INA122PA, UA | | –10 | –50 | |
| $I_{OS}$ | Input offset current | $V_{CM}$ = $V_S$ / 2 | INA122P, U | | ±1 | ±2 | nA |
| | | | INA122PA, UA | | ±1 | ±5 | |
| | Input offset current drift | $T_A$ = –40°C to +85°C | INA122P, U | | ±40 | | pA/°C |
| | | | INA122PA, UA | | ±40 | | |
| **NOISE VOLTAGE** | | | | | | | |
| $e_{NI}$ | Voltage noise (RTI) | f = 10Hz | | | 110 | | nV/√Hz |
| | | f = 100Hz | | | 100 | | |
| | | f = 1kHz | | | 60 | | |
| | | $f_B$ = 0.1Hz to 10Hz | | | 2.7 | | $µV_{PP}$ |
| $i_{NI}$ | Current noise (RTI) | f = 1kHz | | | 80 | | fA/√Hz |
| | | $f_B$ = 0.1Hz to 10Hz | | | 5 | | $pA_{PP}$ |


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## 5.5 Electrical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = +5V, $R_L$ = 20kΩ connected to $V_S$/2, $V_{REF}$ = 0V, all chips site origins (CSO), unless otherwise noted

| PARAMETER | | TEST CONDITIONS | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| **GAIN** | | | | | | | | |
| | Gain equation | | | | | 5 + (200kΩ / $R_G$) | | V/V |
| G | Gain | | | | 5 | | 10000 | V/V |
| GE | Gain error | G = 5, $V_O$ = ±10V | INA122P, U | | | ±0.05 | ±0.1 | % |
| | | | INA122PA, UA | | | ±0.05 | ±0.15 | |
| | | G = 100, $V_O$ = ±10V | INA122P, U | | | ±0.3 | ±0.5 | |
| | | | INA122PA, UA | | | ±0.3 | ±1 | |
| | Gain vs temperature(2) | G = 5 | | | | ±5 | ±10 | ppm/°C |
| | | G = 100 | | | | ±25 | ±100 | |
| | Gain nonlinearity | G = 100, $V_O$ = –14.85V to +14.9V | INA122P, U | | | ±0.005 | ±0.012 | % of FSR |
| | | | INA122PA, UA | | | ±0.005 | ±0.024 | |
| **OUTPUT** | | | | | | | | |
| | Positive output voltage swing | $V_S$ = ±15V | | | (V+) - 0.1 | (V+) - 0.05 | | V |
| | Negative output voltage swing | $V_S$ = ±15V | | | (V–) + 0.15 | (V-) + 0.1 | | V |
| | Load capacitance stability | | | | | 1000 | | pF |
| $I_{SC}$ | Short-circuit current | Continuous to $V_S$ / 2 | Sourcing | CSO: SHE | | +3 | | mA |
| | | | | CSO: TID | | +30 | | |
| | | | Sinking | | | -30 | | |
| **FREQUENCY RESPONSE** | | | | | | | | |
| BW | Bandwidth, –3dB | G = 5 | | | | 100 | | kHz |
| | | G = 100 | | | | 3.5 | | |
| | | G = 500 | | | | 0.9 | | |
| SR | Slew rate | G = 5, $V_O$ = ±10V | Rising | CSO: SHE | | 0.08 | | V/µs |
| | | | | CSO: TID | | 0.125 | | |
| | | G = 5, $V_O$ = ±10V, | Falling | | | 0.12 | | |
| | Overload recovery | 50 % overdrive | | | | 22 | | µs |
| $t_S$ | Settling time | 0.01% | G = 5 | | | 350 | | µs |
| | | | G = 100 | | | 450 | | |
| | | | G = 500 | | | 1800 | | |
| **POWER SUPPLY** | | | | | | | | |
| $I_Q$ | Quiescent current | $I_O$ = 0A | | | | 60 | 85 | µA |

(1) Input voltage range of the INA122 input stage. The input range depends on the common-mode voltage, differential voltage, gain, and reference voltage. See *Typical Characteristic* curves Figure 5-5 and Figure 5-6 for more information.
(2) The values specified for G > 5 do not include the effects of the external gain-setting resistor, $R_G$.

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## 5.6 Typical Characteristics

at $T_A$ = +25°C and $V_S$ = ±5V, all chips site origins (CSO), unless otherwise noted.

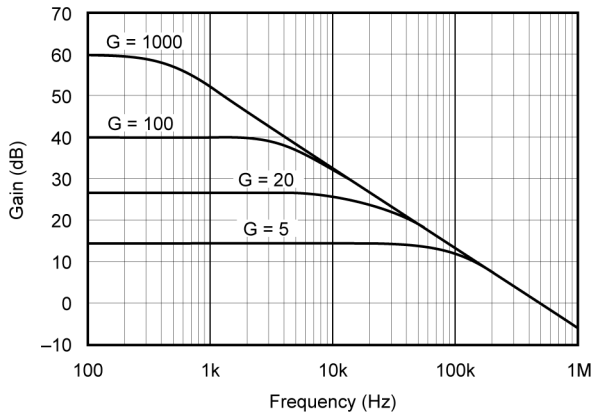



**Figure 5-1. Gain vs Frequency**

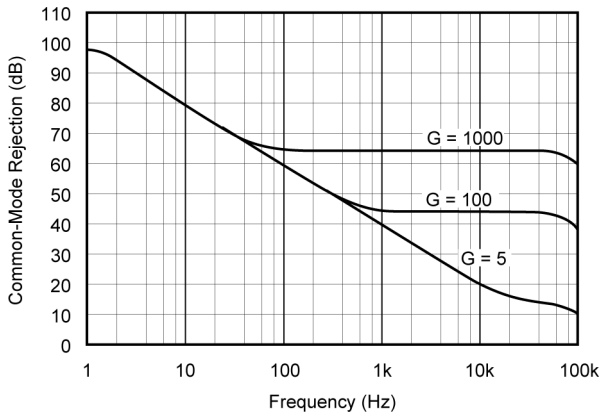



**Figure 5-2. Common-Mode Rejection vs Frequency**

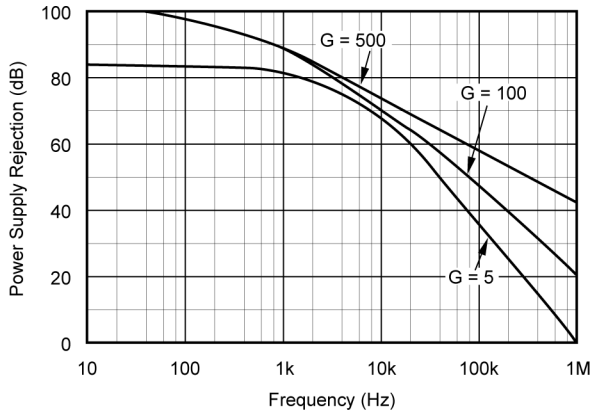



**Figure 5-3. Positive Power Supply Rejection vs Frequency**

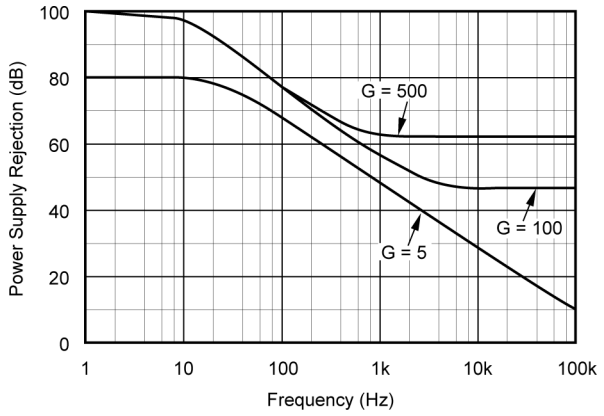



**Figure 5-4. Negative Power Supply Rejection vs Frequency**

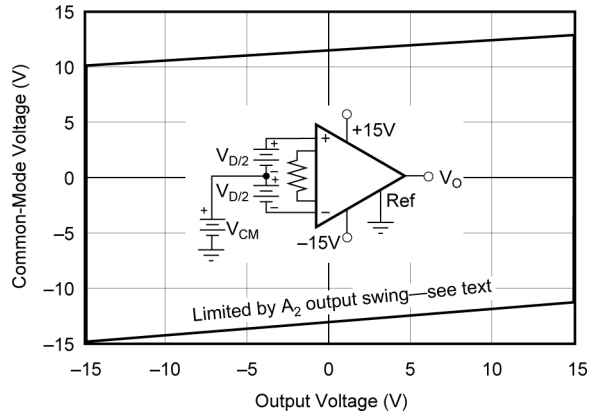



**Figure 5-5. Input Common-Mode Range vs Output Voltage, $V_S$ = ±15V, G = 5**

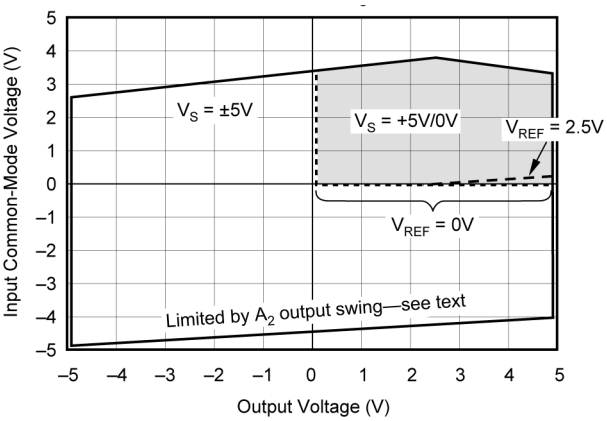



**Figure 5-6. Input Common-Mode Voltage vs Output Voltage, $V_S$ = ±5V, G = 5**


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## 5.6 Typical Characteristics (continued)

at $T_A$ = +25°C and $V_S$ = ±5V, all chips site origins (CSO), unless otherwise noted.

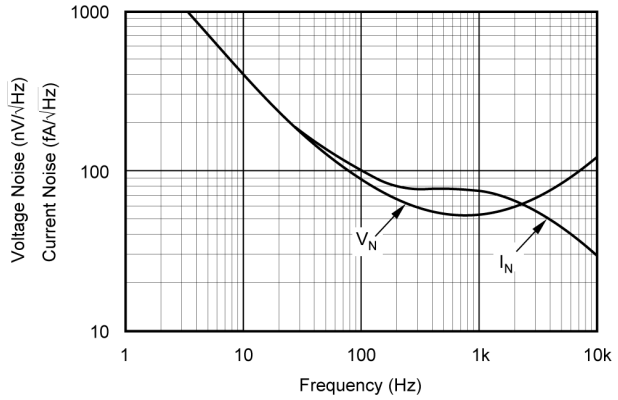



**Figure 5-7. Voltage and Current Noise Density vs Frequency (RTI)**

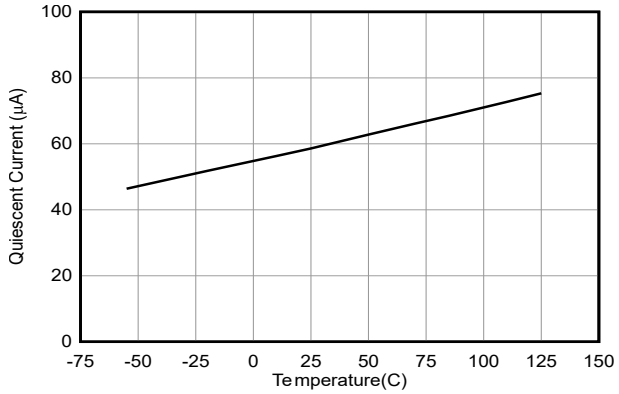



**Figure 5-8. Quiescent Current vs Temperature**

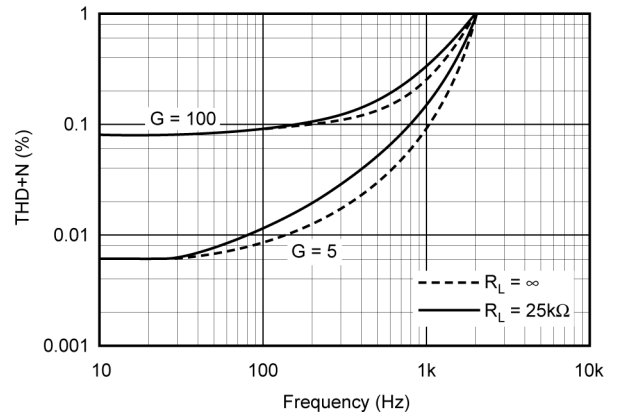
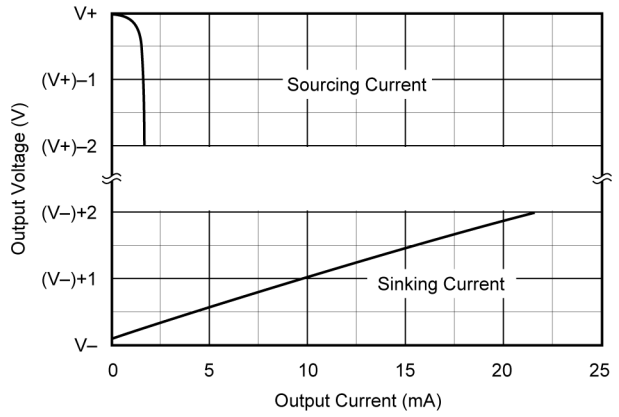
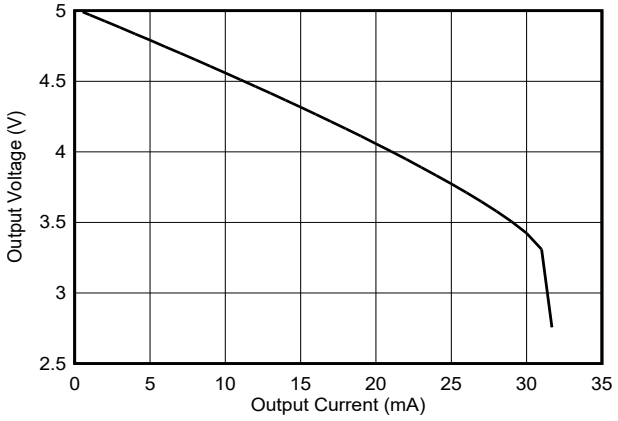



**Figure 5-9. Total Harmonic Distortion+Noise vs Frequency**



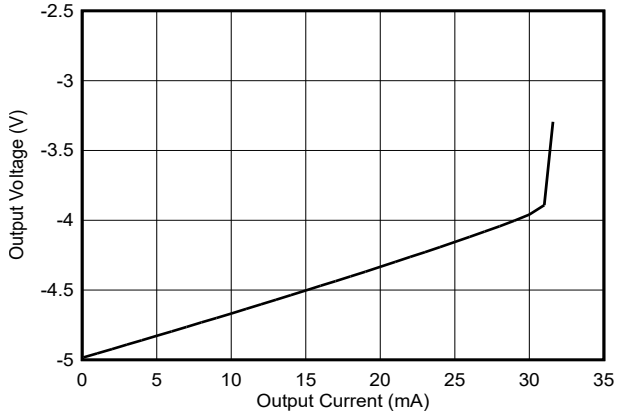

CSO: SHE

**Figure 5-10. Output Voltage Swing vs Output Current**




CSO: TID

**Figure 5-11. Output Voltage Swing vs Output Current (Sourcing)**




CSO: TID

**Figure 5-12. Output Voltage Swing vs Output Current (Sinking)**

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## 5.6 Typical Characteristics (continued)

at $T_A$ = +25°C and $V_S$ = ±5V, all chips site origins (CSO), unless otherwise noted.

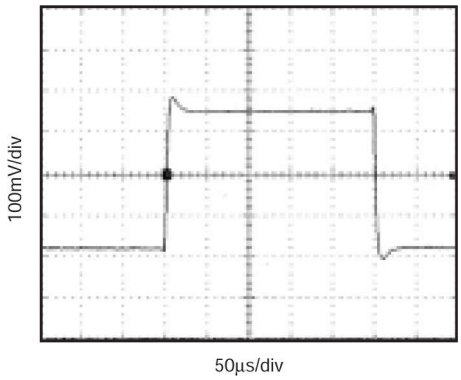



**Figure 5-13. Small-Signal Step Response G = 5**

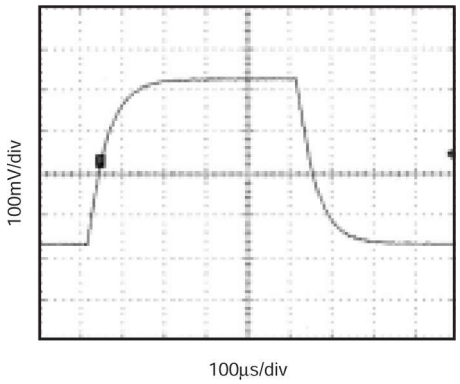
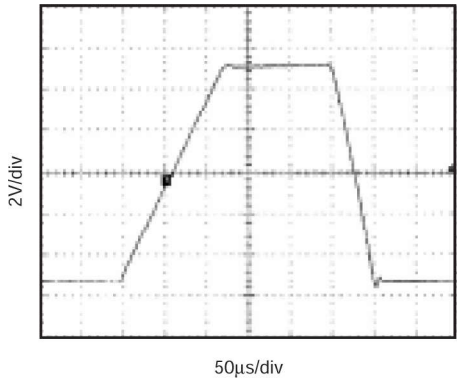
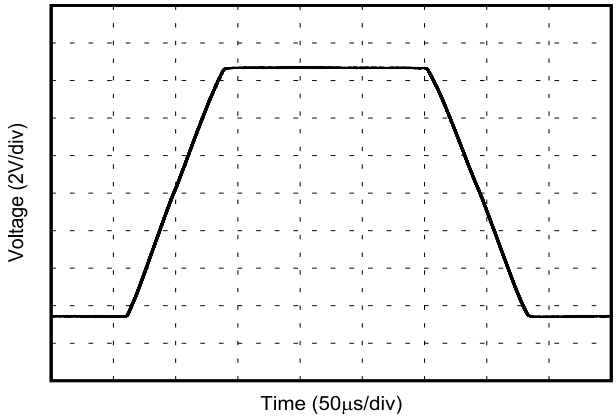



**Figure 5-14. Small-Signal Step Response G = 100**




CSO: SHE

**Figure 5-15. Large-Signal Step Response G = 5**




CSO: TID

**Figure 5-16. Large-Signal Step Response G = 5**

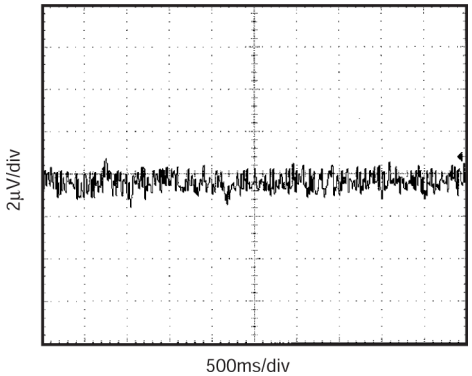



**Figure 5-17. Input-Referred Noise Voltage 0.1Hz to 10Hz**


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# 6 Detailed Description

## 6.1 Overview

The INA122 is a monolithic, precision instrumentation amplifier incorporating a two-op-amp design, providing savings in power consumption and designed for portable instrumentation and data acquisition systems. An external gain resistor ($R_G$) sets the gain from 5V/V to 10000V/V.

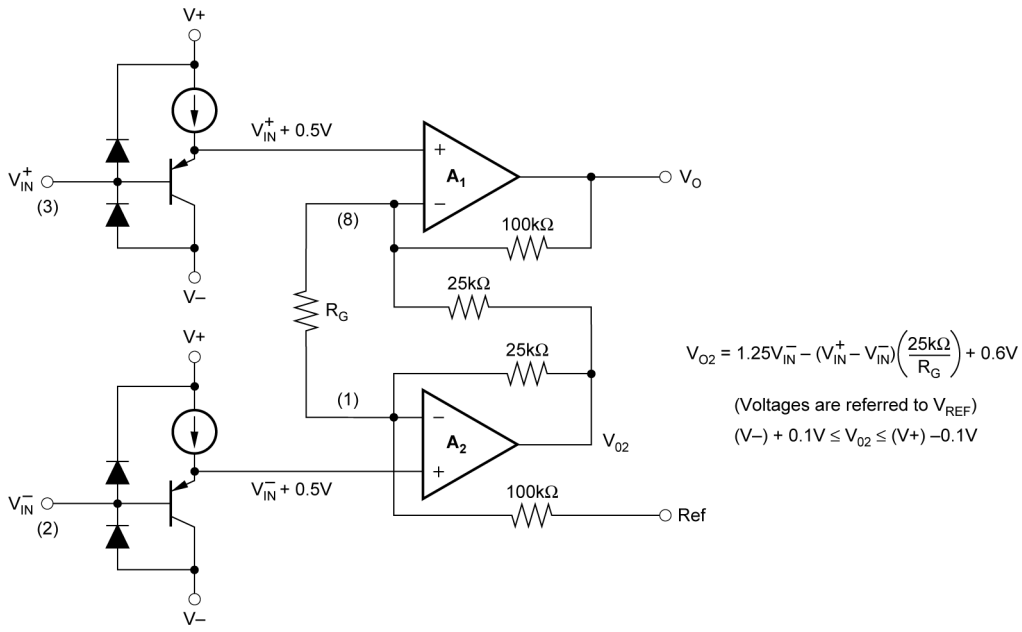
#unique_18/unique_18_Connect_42_GUID-2CA1494E-87A9-4F8D-B636-9A12A5003E17 shows a simplified circuit diagram of the INA122. The design of $A_1$ and $A_2$ are identical and both internal outputs can swing to within approximately 100mV of the power supply rails, depending on load conditions. When the output of $A_2$ is saturated, $A_1$ can still be in linear operation, responding to changes in the noninverting input voltage. This can give the appearance of linear operation but the output voltage is invalid.

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 output of $A_2$ (see the equation in #unique_18/unique_18_Connect_42_GUID-2CA1494E-87A9-4F8D-B636-9A12A5003E17) provides a check for the most common overload conditions.

A single supply instrumentation amplifier has special design considerations. Using commonly available single supply op amps to implement the two op amp topology cannot yield equivalent performance. For example, consider the condition where both inputs of common single supply op amps are 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 $A_2$ output must swing below 0V, which is not feasible without a negative power supply.

To achieve common-mode range that extends to single supply ground, the INA122 uses precision level-shifting buffers on the inputs. This shifts both inputs by approximately 0.5V, and through the feedback network, shifts $A_2$ output by approximately 0.6V. With both inputs and $V_{REF}$ at single supply, $A_2$ output operates within linear range. A positive $V_{+IN}$ causes $A_2$ output to swing below 0.6V. As a result of the input level-shifting, the voltages at $R_G$ pins (pins 1 and 8) are not equal to the respective input pin voltages (pins 2 and 3). For most applications, this is not important because only the gain-setting resistor connects to $R_G$ pins.

## 6.2 Functional Block Diagram



## 6.3 Feature Description

### 6.3.1 Setting the Gain

Figure 6-1 shows the basic connections required for operation of the INA122. The output is referred to the output reference (Ref) pin that is normally grounded.

Use Equation 1 to calculate the gain of the INA122. Set the gain by connecting a single external resistor, $R_G$, to the INA122 as shown in Figure 6-1.

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

Table 6-1 shows the commonly used gains and $R_G$ resistor values.

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 $R_G$ also affects gain. The contribution to gain accuracy and drift from $R_G$ can be directly inferred from Equation 1.

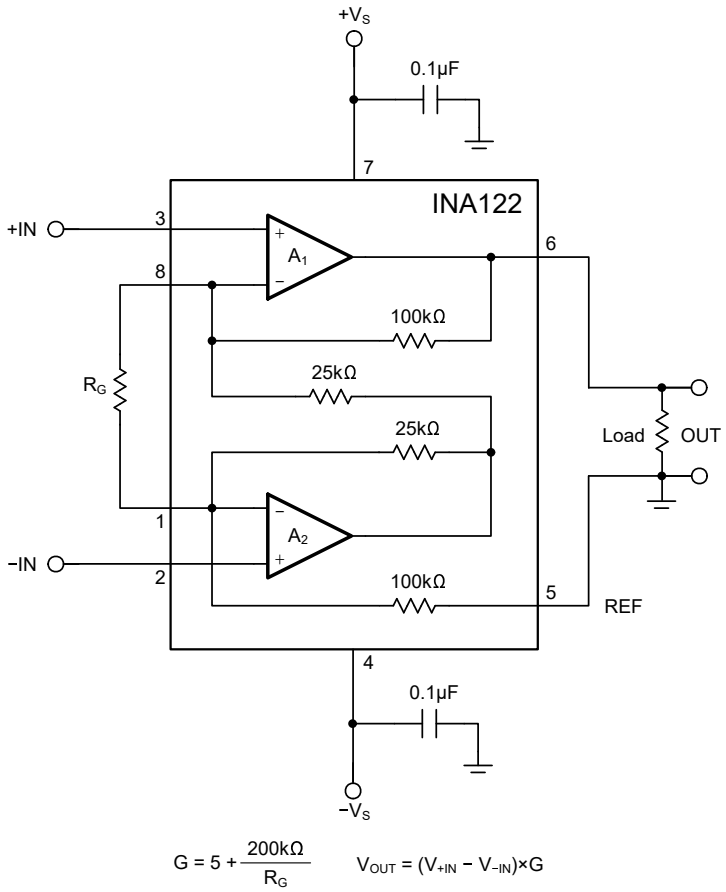



**Figure 6-1. INA122 Basic Connections**


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**Table 6-1. Commonly Used Gains and Resistor Values**

| DESIRED GAIN (V/V) | $R_G$ (Ω) | NEAREST 1% $R_G$ VALUE (Ω) |
|---|---|---|
| 5 | NC (1) | NC (1) |
| 10 | 40k | 40.2k |
| 20 | 13.33k | 13.3k |
| 50 | 4.444 | 4.42k |
| 100 | 2105 | 2.1k |
| 200 | 1026 | 1.02k |
| 500 | 404 | 402 |
| 1000 | 201 | 200 |
| 2000 | 100.3 | 100 |
| 5000 | 40 | 40.2 |
| 10000 | 20 | 20 |

(1) NC: No connection

### 6.3.2 Input Common-Mode Range

The input common-mode range of the INA122 can operate over a wide range of power supply and $V_{REF}$ configurations. The common-mode range for some common operating conditions is shown in the performance curves in the *Typical Characteristics* section, and also in Figure 6-2 and Figure 6-3.

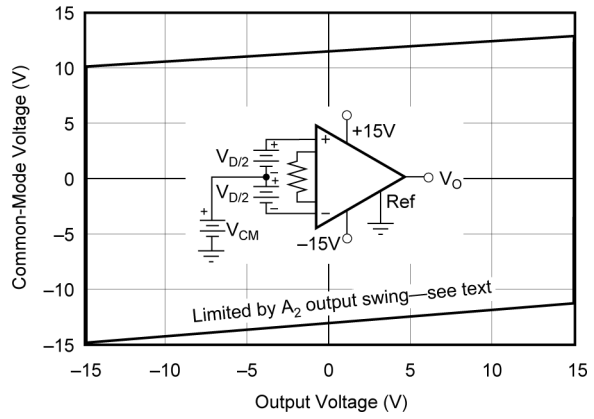



**Figure 6-2. Input Common-Mode Range vs Output Voltage, Vs = ±15V, G = 5**

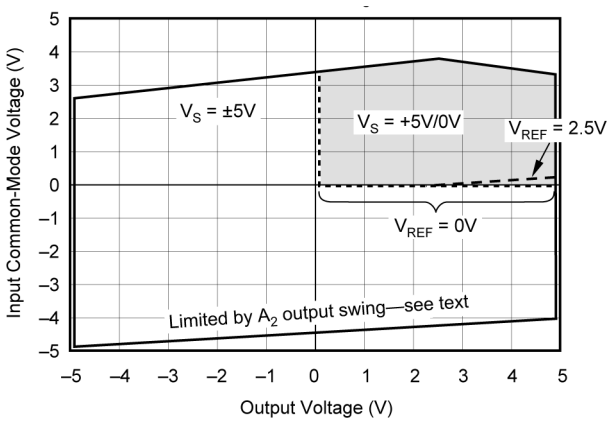



**Figure 6-3. Input Common-Mode Range vs Output Voltage, Vs = ±5, G = 5**

### 6.3.3 Input Protection

The inputs of the INA122 are protected with internal diodes connected to the power supply rails shown in #unique_18/unique_18_Connect_42_GUID-2CA1494E-87A9-4F8D-B636-9A12A5003E17. The diodes clamp the applied signal to prevent damaging the input circuitry. If the input signal source voltage exceeds the power supplies by more than 0.3V, limit the source current with a series input resistor to less than 5mA to protect the internal clamp diodes. Some signal sources are inherently current-limited and do not require limiting resistors.

### 6.3.4 Output Current Range

Output sourcing and sinking current values versus the output voltage ranges are shown in the *Typical Characteristics* section. The positive and negative current limits are not equal. Positive output current sourcing can drive moderate to high load impedance. Battery operation normally requires the careful management of power consumption to keep load impedance very high throughout the design.

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## 6.4 Device Functional Modes

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 ±18V). Most parameters vary only slightly throughout the full supply voltage range. See the typical performance curves in *Typical Characteristics* section.

Operation at very low supply voltage requires careful attention to maintain the linear operating condition with the input common-mode voltage range, as explained in the *Input Common-Mode Range* section.


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# 7 Application and Implementation

**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

## 7.1 Application Information

### *7.1.1 Offset Trimming*

The INA122 is laser trimmed for low offset voltage and offset voltage drift. The voltage applied to the Ref pin is added to the output signal. This connection must be low-impedance to provide expected common-mode rejection performance. A resistance of 10Ω in series with the Ref pin causes a typical device to degrade to approximately 80dB CMR. Most applications require no external offset adjustment using the Ref pin and is typically grounded.

Figure 7-1 shows an optional circuit for trimming the output offset voltage. An op amp buffer is used to provide low impedance at the Ref pin to preserve good common-mode rejection.

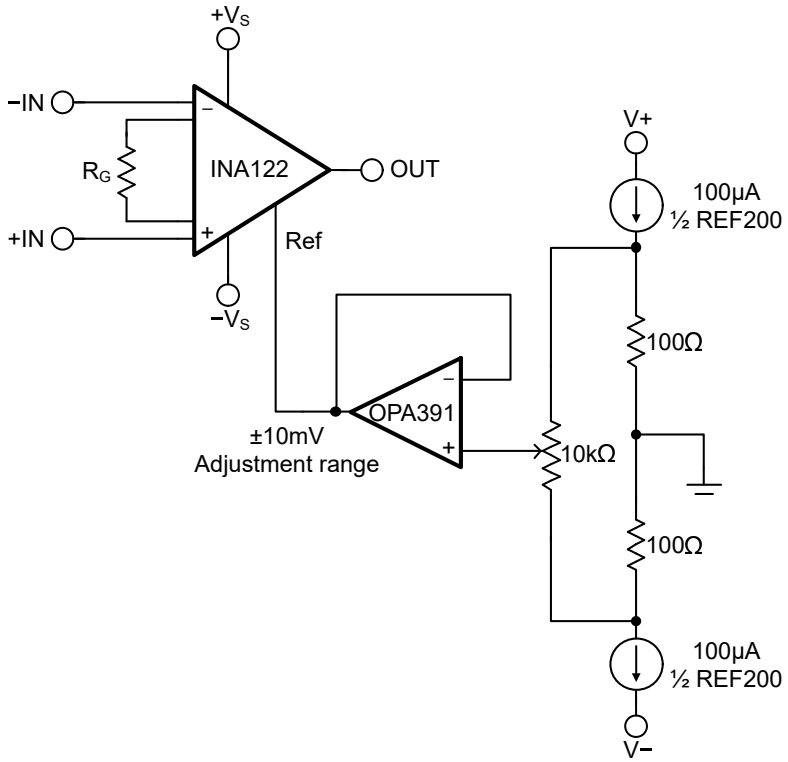



**Figure 7-1. Optional Trimming of Output Offset Voltage**

### 7.1.2 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 −10nA (current flows out of the input terminals). High input impedance means that the input bias current changes very little with varying input voltage.

Input circuitry must provide a path for this input bias current for proper operation. Figure 7-2 shows various provisions for an input bias current path. Without a bias current path, the inputs can float to a potential which exceeds the common-mode range of the INA122 and the input amplifiers 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 7-2). 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.

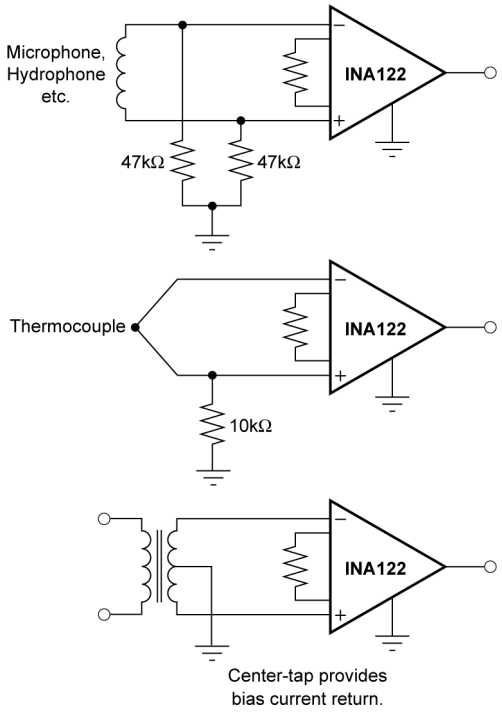



**Figure 7-2. Providing an Input Common-Mode Current Path**


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## 7.2 Typical Application

### 7.2.1 Resistive-Bridge Pressure Sensor

The INA122 is an instrumentation amplifier that measures small differential voltages while simultaneously rejecting larger common-mode voltages. The device offers a low power consumption of 60µA (typical) and is designed for portable applications where sensors measure physical parameters, such as changes in fluid, pressure, temperature, or humidity.

The pressure sensor is made of a piezo-resistive element that can be derived as a classical 4-resistor Wheatstone bridge. Changes in the strain gauge resistance on one leg of the Wheatstone bridge (R + ΔR) induces a differential voltage $V_{DIFF}$.

Figure 7-3 shows an example circuit for a pressure sensor application. The signal chain connected to the bridge downstream processes the pressure change and can trigger an alarm.

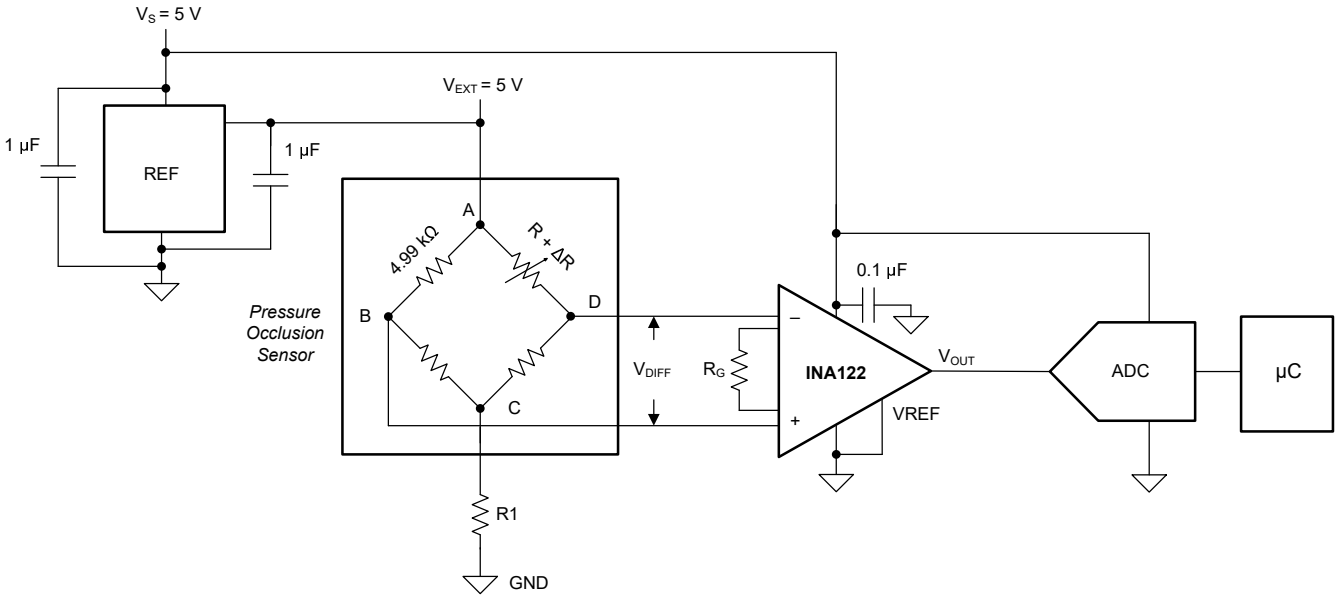



**Figure 7-3. Resistive-Bridge Pressure Sensor**

Low-tolerance bridge resistors must be used to minimize the offset and gain errors.

Given that there is only a positive differential voltage applied, this circuit is laid out in single supply mode. The excitation voltage, $V_{EXT}$, to the bridge must be precise and stable; otherwise, measurement errors can be introduced.

#### 7.2.1.1 Design Requirements

For this application, the design requirements are as provided in Table 7-1.

**Table 7-1. Design Requirements**

| DESCRIPTION | VALUE |
|---|---|
| Single supply voltage | $V_S$ = 5V |
| Excitation voltage | $V_{EXT}$ = 5.0V |
| Pressure range | P = 1psi to 12psi, increments of P = 0.5psi |
| Pressure sensitivity | S = 2 ±0.5 (25%) mV/V/psi |
| Pressure impedance | R = 4.99kΩ ±50Ω (0.1%) |
| Total pressure sampling rate | Sr = 20Hz |
| Full-scale range of ADC | $V_{ADC(fs)}$ = $V_{OUT}$ = 3.0V |

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#### 7.2.1.2 Detailed Design Procedure

This section provides basic calculations to design the instrumentation amplifier circuit with respect to the given design requirements.

One of the key considerations in resistive-bridge sensors is the common-mode voltage, $V_{CM}$. If the bridge is balanced (no pressure, thus no voltage change), $V_{CM(zero)}$ is half of the bridge excitation ($V_{EXT}$). In this example $V_{CM\ (zero)}$ is 2.5V. For the maximum pressure of 12psi, the bridge common-mode voltage, $V_{CM(MIN)}$, is calculated by:

$$V_{CM(MIN)} = \frac{V_{DIFF}}{2} + V_{CM(zero)} \quad (2)$$

where

$$V_{DIFF} = S_{MAX} \times V_{EXT} \times P_{MAX} = 2.5\,\frac{mV}{V \times psi} \times 5V \times 12psi = 150mV \quad (3)$$

Thus, the minimum common-mode voltage applied results in Equation 4:

$$V_{CM(MIN)} = \frac{-150\ mV}{2} + 2.5V = 2.425V \quad (4)$$

The maximum common-mode voltage, will be determined when $V_{CM\ (zero)}$, which is 2.5V.

The next step is to calculate the gain required for the given maximum sensor output voltage span, $V_{DIFF}$, in respect to the required $V_{OUT}$, which is the full-scale range of the ADC.

Equation 5 calculates the gain value using the maximum input voltage and the required output voltage:

$$G = \frac{V_{OUT}}{V_{DIFF(MAX)}} = \frac{3.0\ V}{150\ mV} = 20V/V \quad (5)$$

The INA122 has a gain range from 5V/V to 10000V/V. To set the gain to 20V/V, set $R_G$ to 13.3kΩ to provide the maximum output signal swing for the ADC.

Next, make sure that the INA122 can operate within this range by checking the *Input Common-Mode Voltage vs Output Voltage* curves listed in the *Typical Characteristics* section. The relevant figure is also in this section for convenience. Based on Figure 7-4, an output signal swing of 3V is supported for the input signal swing between 2.425V and 2.575V, thus allowing linear operation.

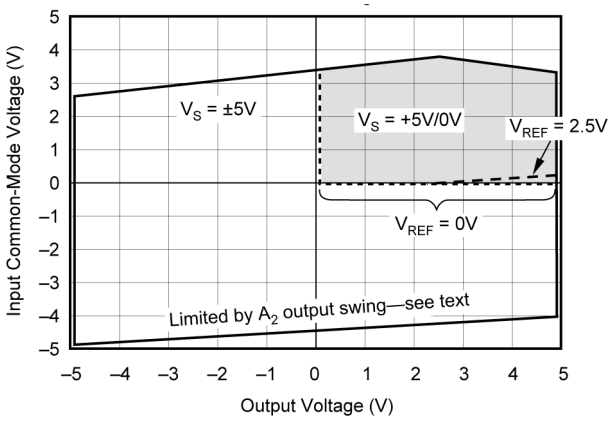



**Figure 7-4. Input Common-Mode Voltage vs Output Voltage**

An additional series resistor in the Wheatstone bridge string (R1) can or can not be required. This decision is made based on the intended output voltage swing for a particular combination of supply voltage, reference voltage, and the selected gain for an input common-mode voltage range. R1 helps adjust the input common-


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mode voltage range, and thus can help accommodate the intended output voltage swing. In this particular example, R1 is not required and can be shorted to ground.

#### 7.2.1.3 Application Curve

Figure 7-5 shows the typical characteristic curve for the circuit in Figure 7-3 for the pressure range specified in Table 7-1.

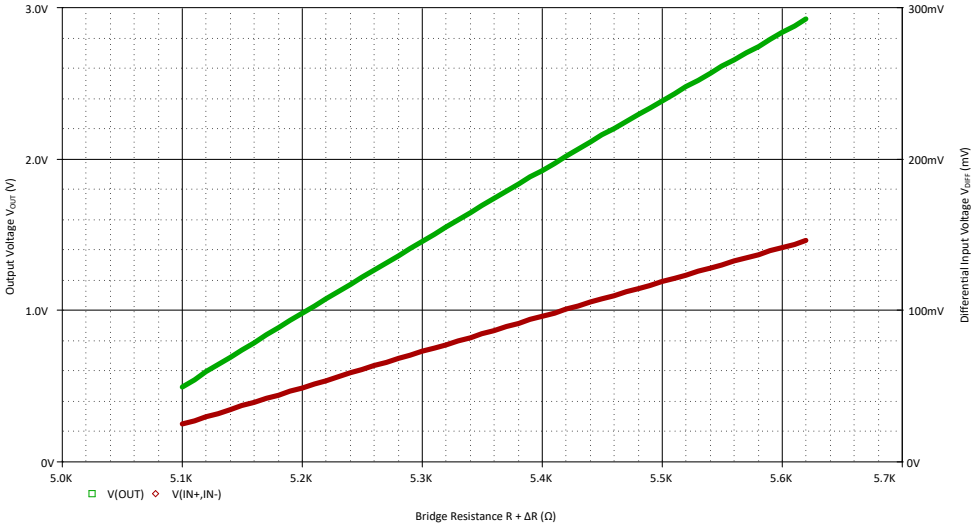



**Figure 7-5. Input Differential Voltage, Output Voltage vs Bridge Resistance**

## 7.3 Power Supply Recommendations

The nominal performance of the INA122 is specified with a single supply voltage ($+V_S$) of 5V and reference voltage (REF) connected to ground. The device operates using power supplies from 2.2V to 36V in single or dual supply.

**CAUTION**

Supply voltages higher than 36V (±18V) can permanently damage the device. Parameters that vary over supply voltage or temperature are shown in *Typical Characteristics* of this data sheet.

## 7.4 Layout

### *7.4.1 Layout Guidelines*

For best operational performance of the device, use good PCB layout practices, including:

- Make sure that both input paths are well-matched for source impedance and capacitance to avoid converting common-mode signals into differential signals. Even a slight mismatch in parasitic capacitance at the gain setting pins can degrade CMRR over frequency. For example, in applications that implement gain switching using switches or PhotoMOS® relays to change the value of $R_G$, select the component so that the switch capacitance is as small as possible. Take care to minimize the capacitance mismatch between the $R_G$ pins as much as possible.
- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and through the device. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1µF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. As shown in Figure 7-6, keeping $R_G$ close to the device minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit can experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.


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### 7.4.2 Layout Example

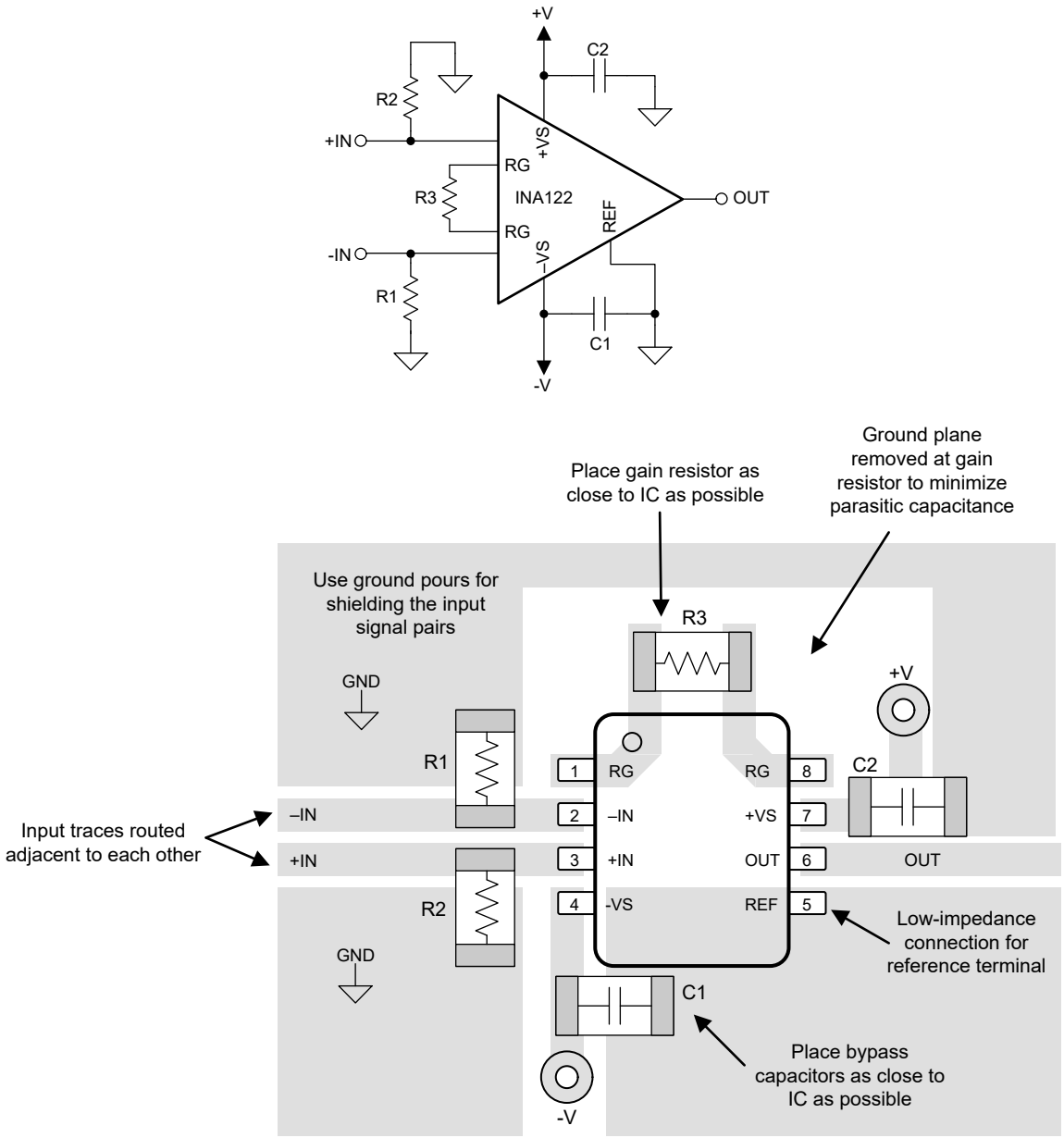



**Figure 7-6. Example Schematic and PCB Layout**

# 8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

## 8.1 Device Support

### 8.1.1 Device Nomenclature

| PART NUMBER | DEFINITION |
|---|---|
| INA122U, INA122U/2K5, INA122UA, INA122UA/2K5 | The die is manufactured in CSO: SHE or CSO: TID. |
| INA122P, INA122PA, INA122-W | The die is only manufactured in CSO: SHE. |

## 8.2 Development Support

For development support on this product, see the following:

### 8.2.1 PSpice® for TI

PSpice® for TI is a design and simulation environment that helps evaluate performance of analog circuits. Create subsystem designs and prototype solutions before committing to layout and fabrication, reducing development cost and time to market.

### 8.2.2 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI is a free, fully-functional version of the TINA software, preloaded with a library of macro models in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a free download from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

**Note**

These files require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.

## 8.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 8.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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## 8.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments 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.

## 8.7 Glossary

TI Glossary — This glossary lists and explains terms, acronyms, and definitions.

# 9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from Revision A (December 2024) to Revision B (December 2025)** — **Page**

- Added description of device flow information in *Specifications* ... 4
- Added *all chips site origins (CSO)* condition to the typical test conditions in the *Electrical Characteristics* ... 6
- Changed current noise from 2pApp to 5pApp in the *Electrical Characteristics* ... 6
- Added different fabrication process specs for Short-Circuit Current in the *Electrical Characteristics* ... 6
- Added different fabrication process specs for Slew Rate (Rising) in the *Electrical Characteristics* ... 6
- Added *all chips site origins (CSO)* condition to the typical test conditions in the *Typical Characteristics* ... 8
- Added CSO: SHE flow information to *Output Voltage Swing vs Output Current* and *Large-Signal Step Response G = 5* curves in the *Typical Characteristics* ... 8
- Added *Output Voltage Swing vs Output Current (Sourcing)*, *Output Voltage Swing vs Output Current (Sinking)*, and *Large-Signal Step Response G = 5* curves for CSO: TID flow in the *Typical Characteristics* ... 8
- Updated common-mode range calculations in the *Detailed Design Procedure* ... 18
- Added part number flow information table to the *Device Nomenclature* ... 22

**Changes from Revision * (October 1997) to Revision A (December 2024)** — **Page**

- Added *Pin Functions* table, *Recommended Operating Conditions* table, *Thermal Information* table, *Detailed Description* section, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, and the *Device and Documentation Support* section ... 1
- Changed names on pins 2, 3, 4, 6, and 7 from: $V_{IN–}$, $V_{IN+}$, V–, $V_O$ and V+ to: –IN, +IN, –VS, OUT and +VS ... 3
- Added dual supply specification to *Absolute Maximum Ratings* ... 4
- Added note clarifying output short-circuit "to ground" in *Absolute Maximum Ratings* refers to short-circuit to $V_S$ / 2 ... 4
- Added test condition of $T_A$ =–40°C to +85°C to input bias current drift and input offset current drift parameter in *Electrical Characteristics* ... 6
- Changed parameter from *Offset Voltage RTI* vs *Power Supply to Power Supply Rejection Ratio* in *Electrical Characteristics* ... 6
- Changed parameter from *Input Impedance* to *Differential impedance* and *Common-mode impedance* in *Electrical Characteristics* ... 6
- Added test condition to input bias current parameter in *Electrical Characteristics* ... 6
- Changed voltage noise from 2μ$V_{pp}$ to 2.7μ$V_{pp}$ in *Electrical Characteristics* ... 6
- Changed Bandwidth, –3dB at G = 5 from 120kHz to 100kHz in *Electrical Characteristics* ... 6
- Changed Bandwidth, –3dB G = 100 from 5kHz to 3kHz in *Electrical Characteristics* ... 6
- Added test conditions to Slew rate parameter in *Electrical Characteristics* ... 6
- Changed falling Slew rate from 0.16V/μs to 0.12V/μs in *Electrical Characteristics* ... 6
- Changed Overload recovery from 3μs to 22μs in *Electrical Characteristics* ... 6
- Updated *Quiescent Current vs Temperature* curve in *Typical Characteristics* ... 8
- Changed *Offset Trimming* section ... 15

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## 10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.


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## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| INA122P | Active | Production | PDIP (P) \| 8 | 50 \| TUBE | Yes | Call TI | N/A for Pkg Type | -40 to 85 | INA122P |
| INA122P.A | Active | Production | PDIP (P) \| 8 | 50 \| TUBE | Yes | Call TI | N/A for Pkg Type | -40 to 85 | INA122P |
| INA122PA | Active | Production | PDIP (P) \| 8 | 50 \| TUBE | Yes | Call TI | N/A for Pkg Type | - | INA122P A |
| INA122PA.A | Active | Production | PDIP (P) \| 8 | 50 \| TUBE | Yes | Call TI | N/A for Pkg Type | -40 to 85 | INA122P A |
| INA122PAG4 | Active | Production | PDIP (P) \| 8 | 50 \| TUBE | Yes | Call TI | N/A for Pkg Type | See INA122PA | INA122P A |
| INA122U | Obsolete | Production | SOIC (D) \| 8 | - | - | Call TI | Call TI | - | INA 122U |
| INA122U/2K5 | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | - | INA 122U |
| INA122U/2K5.A | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | -40 to 85 | INA 122U |
| INA122U/2K5.B | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | -40 to 85 | INA 122U |
| INA122UA | Obsolete | Production | SOIC (D) \| 8 | - | - | Call TI | Call TI | - | INA 122U A |
| INA122UA/2K5 | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | - | INA 122U A |
| INA122UA/2K5.A | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | -40 to 85 | INA 122U A |
| INA122UA/2K5.B | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | - | Call TI | Level-3-260C-168 HR | -40 to 85 | INA 122U A |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

**(3) RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

**(4) Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

**(5) MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

**(6) Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

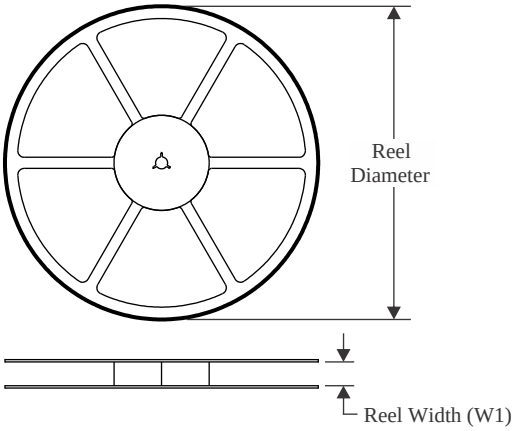
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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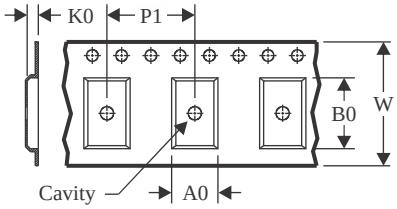
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

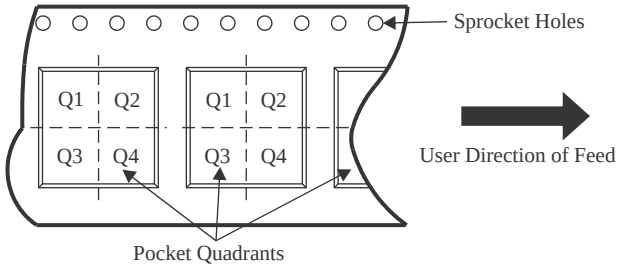



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

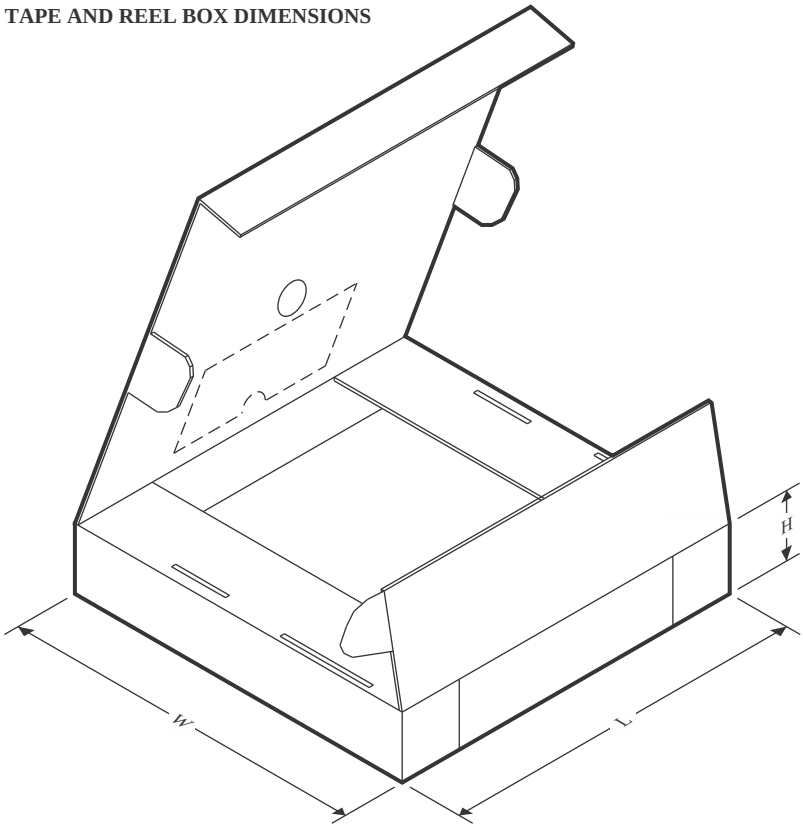
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA122U/2K5 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| INA122UA/2K5 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

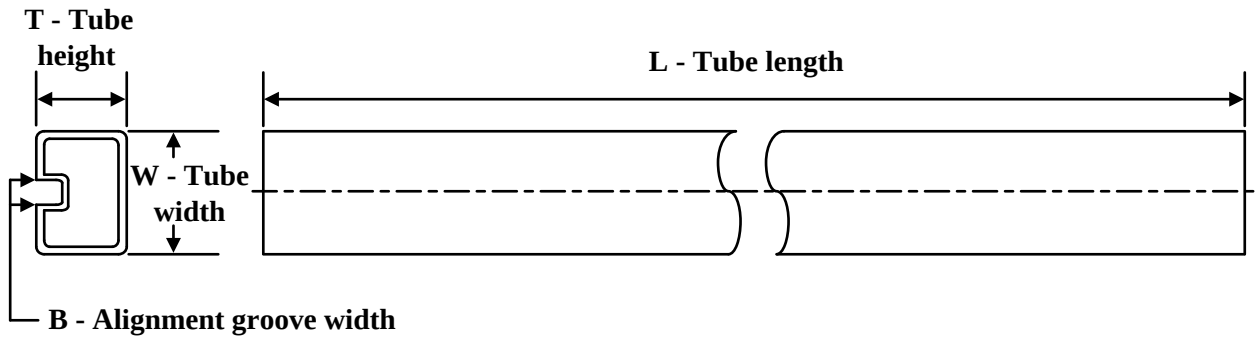
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

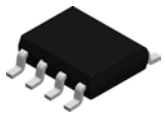
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA122U/2K5 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |
| INA122UA/2K5 | SOIC | D | 8 | 2500 | 353.0 | 353.0 | 32.0 |

## TUBE




*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (µm) | B (mm) |
|---|---|---|---|---|---|---|---|---|
| INA122P | P | PDIP | 8 | 50 | 506 | 13.97 | 11230 | 4.32 |
| INA122P.A | P | PDIP | 8 | 50 | 506 | 13.97 | 11230 | 4.32 |
| INA122PA | P | PDIP | 8 | 50 | 506 | 13.97 | 11230 | 4.32 |
| INA122PA.A | P | PDIP | 8 | 50 | 506 | 13.97 | 11230 | 4.32 |
| INA122PAG4 | P | PDIP | 8 | 50 | 506 | 13.97 | 11230 | 4.32 |

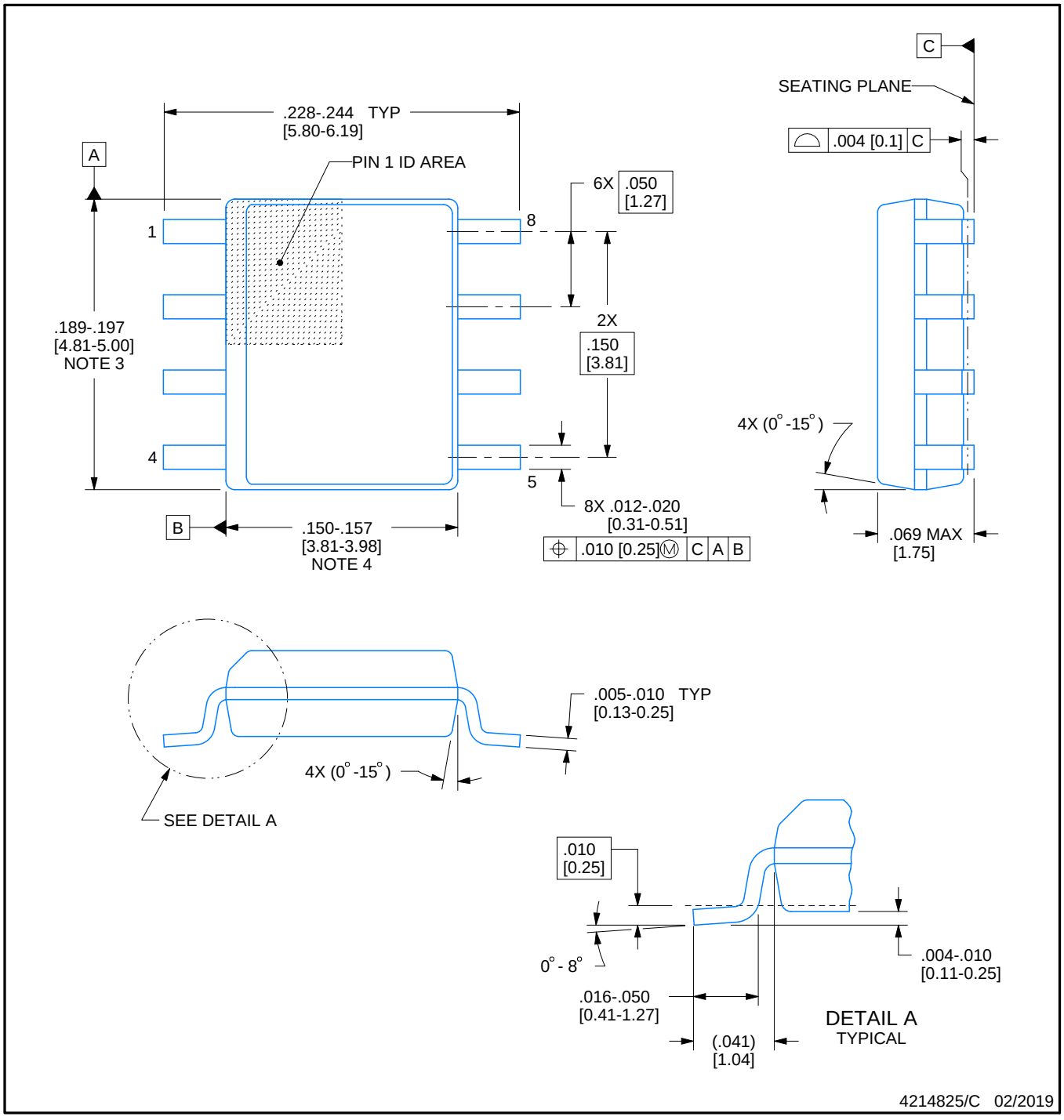


# PACKAGE OUTLINE

## D0008A

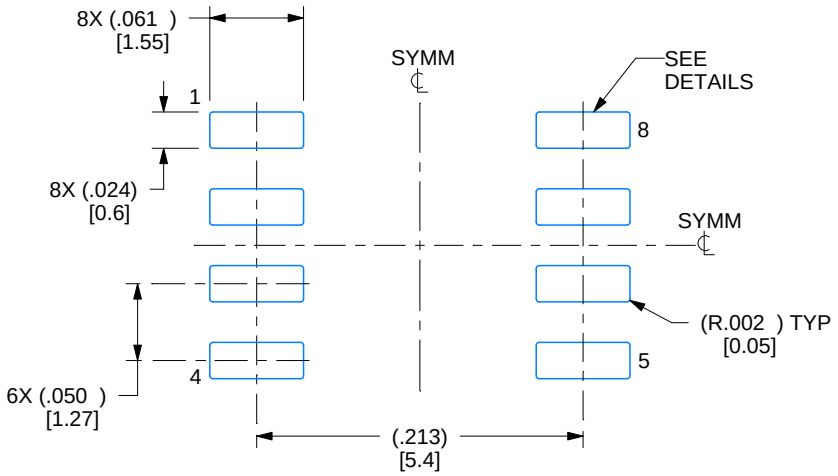
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

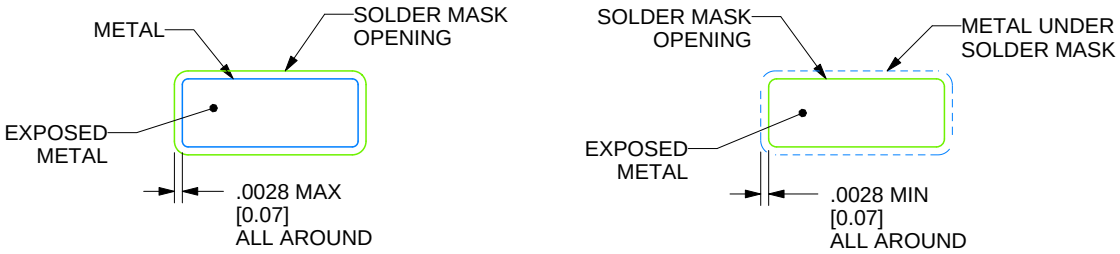



NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X




SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

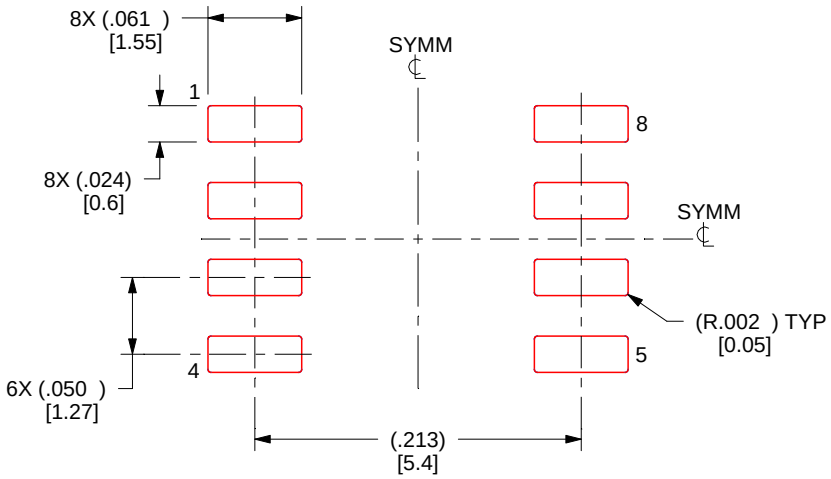
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

## D0008A

## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



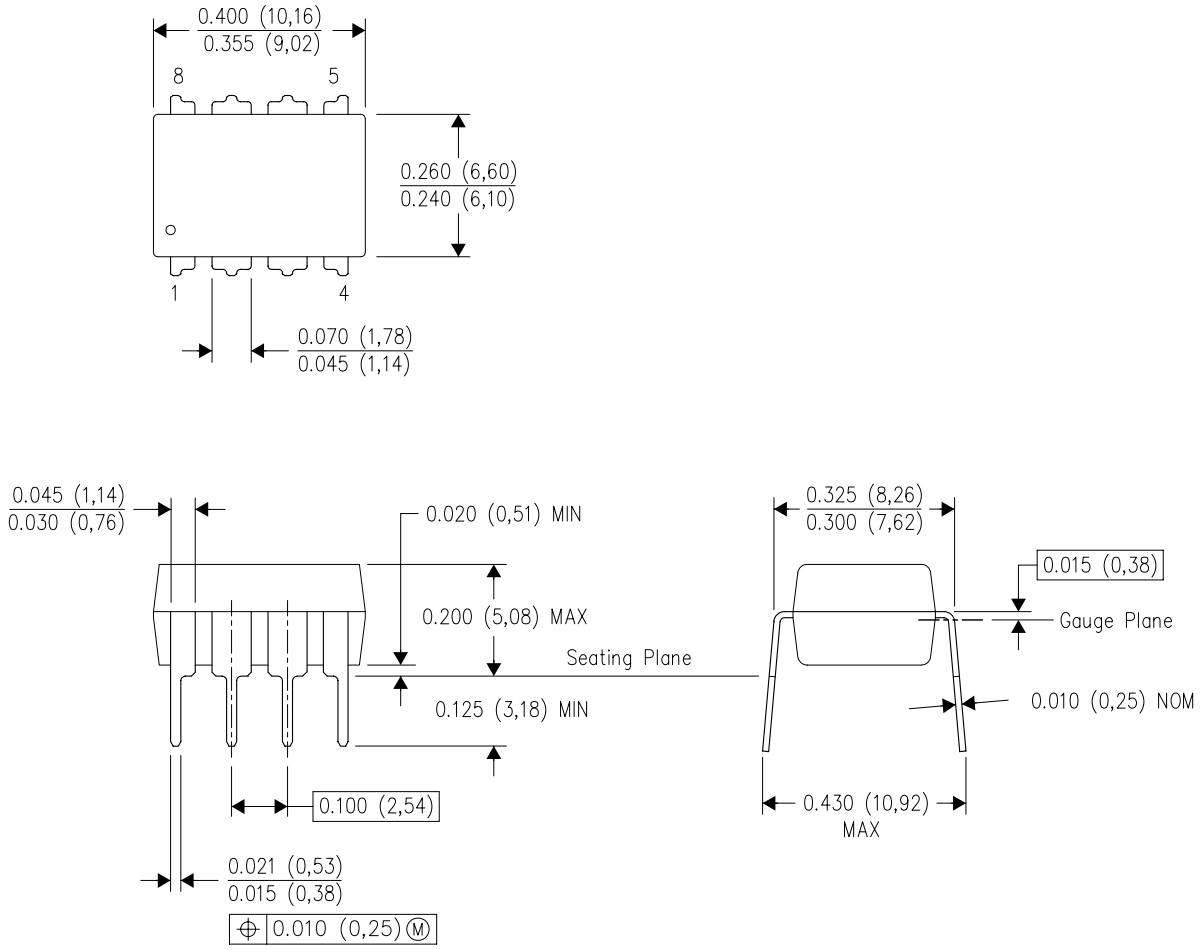

SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE




NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

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