

INA125

## INSTRUMENTATION AMPLIFIER With Precision Voltage Reference

### FEATURES

- LOW QUIESCENT CURRENT: 460µA
- PRECISION VOLTAGE REFERENCE:  
1.24V, 2.5V, 5V or 10V
- SLEEP MODE
- LOW OFFSET VOLTAGE: 250µV max
- LOW OFFSET DRIFT: 2µV/°C max
- LOW INPUT BIAS CURRENT: 20nA max
- HIGH CMR: 100dB min
- LOW NOISE: 38nV/√Hz at f = 1kHz
- INPUT PROTECTION TO ±40V
- WIDE SUPPLY RANGE  
Single Supply: 2.7V to 36V  
Dual Supply: ±1.35V to ±18V
- 16-PIN DIP AND SO-16 SOIC PACKAGES

### DESCRIPTION

The INA125 is a low power, high accuracy instrumentation amplifier with a precision voltage reference. It provides complete bridge excitation and precision differential-input amplification on a single integrated circuit.

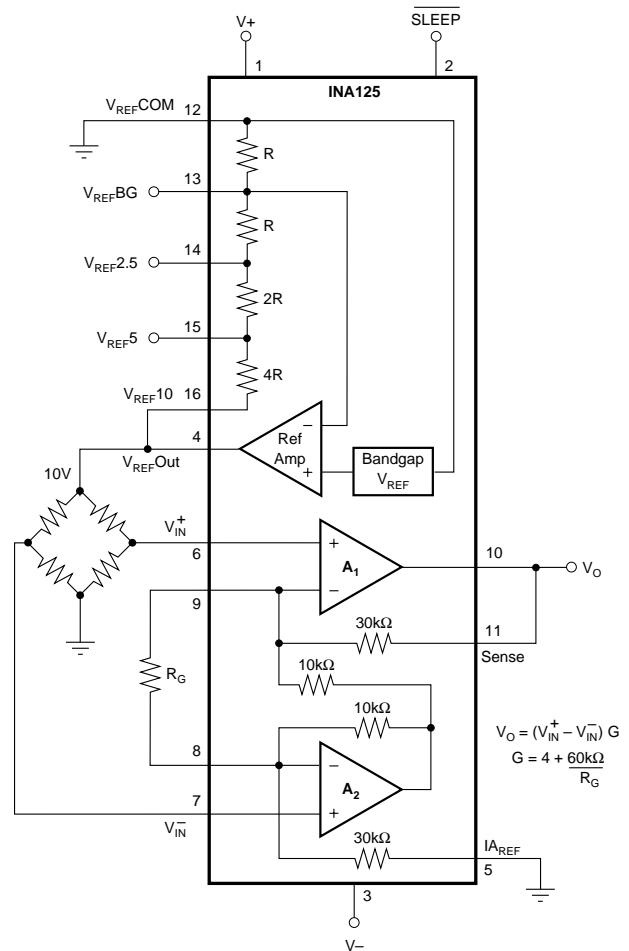
A single external resistor sets any gain from 4 to 10,000. The INA125 is laser-trimmed for low offset voltage (250µV), low offset drift (2µV/°C), and high common-mode rejection (100dB at G = 100). It operates on single (+2.7V to +36V) or dual (±1.35V to ±18V) supplies.

The voltage reference is externally adjustable with pin-selectable voltages of 2.5V, 5V, or 10V, allowing use with a variety of transducers. The reference voltage is accurate to ±0.5% (max) with ±35ppm/°C drift (max). Sleep mode allows shutdown and duty cycle operation to save power.

The INA125 is available in 16-pin plastic DIP and SO-16 surface-mount packages and is specified for the -40°C to +85°C industrial temperature range.

### APPLICATIONS

- PRESSURE AND TEMPERATURE BRIDGE AMPLIFIERS
- INDUSTRIAL PROCESS CONTROL
- FACTORY AUTOMATION
- MULTI-CHANNEL DATA ACQUISITION
- BATTERY OPERATED SYSTEMS
- GENERAL PURPOSE INSTRUMENTATION



$$V_O = (V_{IN}^+ - V_{IN}^-) G$$

$$G = 4 + \frac{60k\Omega}{R_G}$$

# SPECIFICATIONS: $V_S = \pm 15V$

At  $T_A = +25^\circ C$ ,  $V_S = \pm 15V$ ,  $I_A$  common =  $0V$ ,  $V_{REF}$  common =  $0V$ , and  $R_L = 10k\Omega$ , unless otherwise noted.

| PARAMETER                               | CONDITIONS                               | INA125P, U         |                       |                       | INA125PA, UA |     |                       | UNITS                 |          |
|---|--|--------------------|-----------------------|-----------------------|--------------|-----|-----------------------|-----------------------|----------|
|   |  | MIN                | TYP                   | MAX                   | MIN          | TYP | MAX                   |                       |          |
| <b>INPUT</b>                            |  |                    |                       |                       |              |     |                       |                       |          |
| Offset Voltage, RTI                     | $V_S = \pm 1.35V$ to $\pm 18V$ , $G = 4$ |                    | $\pm 50$              | $\pm 250$             |              | *   | $\pm 500$             | $\mu V$               |          |
| Initial vs Temperature                  |  |                    | $\pm 0.25$            | $\pm 2$               |              | *   | $\pm 5$               | $\mu V/^\circ C$      |          |
| vs Power Supply                         |  |                    | $\pm 3$               | $\pm 20$              |              | *   | $\pm 50$              | $\mu V/V$             |          |
| Long-Term Stability                     |  |                    |                       | $\pm 0.2$             |              | *   |                       | $\mu V/mo$            |          |
| Impedance, Differential                 |  |                    |                       | $10^{11} \parallel 2$ |              | *   |                       | $\Omega \parallel pF$ |          |
| Common-Mode                             |  |                    | $10^{11} \parallel 9$ |                       | *            |     | $\Omega \parallel pF$ |                       |          |
| Safe Input Voltage                      |  |                    |                       | $\pm 40$              |              |     | *                     | V                     |          |
| Input Voltage Range                     | $V_{CM} = -10.7V$ to $+10.2V$            |                    | See Text              |                       |              | *   |                       |                       |          |
| Common-Mode Rejection                   |  | $G = 4$            | 78                    | 84                    | 72           | *   |                       | dB                    |          |
|   |  | $G = 10$           | 86                    | 94                    | 80           | *   |                       | dB                    |          |
|   |  | $G = 100$          | 100                   | 114                   | 90           | *   |                       | dB                    |          |
|   |  | $G = 500$          | 100                   | 114                   | 90           | *   |                       | dB                    |          |
| <b>BIAS CURRENT</b>                     | $V_{CM} = 0V$                            |                    | 10                    | 25                    |              | *   | 50                    | nA                    |          |
| vs Temperature                          |  |                    | $\pm 60$              |                       |              | *   |                       | $pA/^\circ C$         |          |
| Offset Current                          |  |                    | $\pm 0.5$             | $\pm 2.5$             |              | *   | $\pm 5$               | nA                    |          |
| vs Temperature                          |  |                    | $\pm 0.5$             |                       |              | *   |                       | $pA/^\circ C$         |          |
| <b>NOISE, RTI</b>                       | $R_S = 0\Omega$                          |                    |                       |                       |              | *   |                       | $nV/\sqrt{Hz}$        |          |
| Voltage Noise, $f = 10Hz$               |  |                    | 40                    |                       |              | *   |                       | $nV/\sqrt{Hz}$        |          |
| $f = 100Hz$                             |  |                    | 38                    |                       |              | *   |                       | $nV/\sqrt{Hz}$        |          |
| $f = 1kHz$                              |  |                    | 38                    |                       |              | *   |                       | $nV/\sqrt{Hz}$        |          |
| $f = 0.1Hz$ to $10Hz$                   |  |                    | 0.8                   |                       |              | *   |                       | $\mu Vp-p$            |          |
| Current Noise, $f = 10Hz$               |  |                    | 170                   |                       |              | *   |                       | $fA/\sqrt{Hz}$        |          |
| $f = 1kHz$                              |  |                    | 56                    |                       |              | *   |                       | $fA/\sqrt{Hz}$        |          |
| $f = 0.1Hz$ to $10Hz$                   |  |                    | 5                     |                       |              | *   |                       | $pAp-p$               |          |
| <b>GAIN</b>                             |  |                    |                       |                       |              | *   | *                     | V/V                   |          |
| Gain Equation                           | $V_O = -14V$ to $+13.3V$                 | 4                  | $4 + 60k\Omega/R_G$   | 10,000                | *            | *   | *                     | V/V                   |          |
| Range of Gain                           |  | $G = 4$            |                       | $\pm 0.01$            | $\pm 0.075$  |     | *                     | $\pm 0.1$             | %        |
| Gain Error                              |  | $G = 10$           |                       | $\pm 0.03$            | $\pm 0.3$    |     | *                     | $\pm 0.5$             | %        |
|   |  | $G = 100$          |                       | $\pm 0.05$            | $\pm 0.5$    |     | *                     | $\pm 1$               | %        |
|   |  | $G = 500$          |                       | $\pm 0.1$             |              |     | *                     |                       | %        |
| Gain vs Temperature                     | $G = 4$                                  |                    | $\pm 1$               | $\pm 15$              |              | *   | *                     | $ppm/^\circ C$        |          |
|   | $G > 4^{(1)}$                            |                    | $\pm 25$              | $\pm 100$             |              | *   | *                     | $ppm/^\circ C$        |          |
| Nonlinearity                            | $V_O = -14V$ to $+13.3V$                 |                    | $\pm 0.0004$          | $\pm 0.002$           |              | *   | $\pm 0.004$           | % of FS               |          |
|   |  | $G = 10$           |                       | $\pm 0.0004$          | $\pm 0.002$  |     | *                     | $\pm 0.004$           | % of FS  |
|   |  | $G = 100$          |                       | $\pm 0.001$           | $\pm 0.01$   |     | *                     | *                     | % of FS  |
|   |  | $G = 500$          |                       | $\pm 0.002$           |              |     | *                     | *                     | % of FS  |
| <b>OUTPUT</b>                           |  |                    |                       |                       |              | *   | *                     | V                     |          |
| Voltage: Positive                       |  | $(V+) - 1.7$       | $(V+) - 0.9$          |                       | *            | *   |                       | V                     |          |
| Negative                                |  | $(V-) + 1$         | $(V-) + 0.4$          |                       | *            | *   |                       | V                     |          |
| Load Capacitance Stability              |  |                    | 1000                  |                       |              | *   |                       | pF                    |          |
| Short-Circuit Current                   |  |                    | $-9/+12$              |                       |              | *   |                       | mA                    |          |
| <b>VOLTAGE REFERENCE</b>                | $V_{REF} = +2.5V, +5V, +10V$             |                    |                       |                       |              | *   |                       | %                     |          |
| Accuracy                                | $I_L = 0$                                |                    | $\pm 0.15$            | $\pm 0.5$             |              | *   | $\pm 1$               | %                     |          |
| vs Temperature                          | $I_L = 0$                                |                    | $\pm 18$              | $\pm 35$              |              | *   | $\pm 100$             | $ppm/^\circ C$        |          |
| vs Power Supply, $V+$                   | $V+ = (V_{REF} + 1.25V)$ to $+36V$       |                    | $\pm 20$              | $\pm 50$              |              | *   | $\pm 100$             | $ppm/V$               |          |
| vs Load                                 |  | $I_L = 0$ to $5mA$ |                       | 3                     | 75           |     | *                     | *                     | $ppm/mA$ |
| Dropout Voltage, $(V+) - V_{REF}^{(2)}$ | Ref Load = $2k\Omega$                    | 1.25               | 1                     |                       | *            | *   |                       | V                     |          |
| Bandgap Voltage Reference               |  |                    | 1.24                  |                       |              | *   |                       | V                     |          |
| Accuracy                                | $I_L = 0$                                |                    | $\pm 0.5$             |                       |              | *   |                       | %                     |          |
| vs Temperature                          | $I_L = 0$                                |                    | $\pm 18$              |                       |              | *   |                       | $ppm/^\circ C$        |          |

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## SPECIFICATIONS: $V_S = \pm 15V$ (CONT)

At  $T_A = +25^\circ C$ ,  $V_S = \pm 15V$ ,  $I_A$  common = 0V,  $V_{REF}$  common = 0V, and  $R_L = 10k\Omega$ , unless otherwise noted.

| PARAMETER CONDITIONS   | CONDITIONS                                 | INA125P, U |          |          | INA125PA, UA |     |     | UNITS        |
|--|--|------------|----------|----------|--------------|-----|-----|--------------|
|  |  | MIN        | TYP      | MAX      | MIN          | TYP | MAX |              |
| <b>FREQUENCY RESPONSE</b><br>Bandwidth, -3dB                               | G = 4                                      |            | 150      |          |              | *   |     | kHz          |
|  | G = 10                                     |            | 45       |          |              | *   |     | kHz          |
|  | G = 100                                    |            | 4.5      |          |              | *   |     | kHz          |
|  | G = 500                                    |            | 0.9      |          |              | *   |     | kHz          |
| Slew Rate  | G = 4, 10V Step                            |            | 0.2      |          |              | *   |     | V/ $\mu s$   |
| Settling Time, 0.01%   | G = 4, 10V Step                            |            | 60       |          |              | *   |     | $\mu s$      |
|  | G = 10, 10V Step                           |            | 83       |          |              | *   |     | $\mu s$      |
|  | G = 100, 10V Step                          |            | 375      |          |              | *   |     | $\mu s$      |
| Overload Recovery  | G = 500, 10V Step                          |            | 1700     |          |              | *   |     | $\mu s$      |
|  | 50% Overdrive                              |            | 5        |          |              | *   |     | $\mu s$      |
| <b>POWER SUPPLY</b><br>Specified Operating Voltage                         |  |            | $\pm 15$ |          |              | *   |     | V            |
| Specified Voltage Range  |  | $\pm 1.35$ |          | $\pm 18$ | *            |     | *   | V            |
| Quiescent Current, Positive  | $I_O = I_{REF} = 0mA$                      |            | 460      | 525      |              | *   | *   | $\mu A$      |
|  | $I_O = I_{REF} = 0mA$                      |            | -280     | -325     |              | *   | *   | $\mu A$      |
| Reference Ground Current <sup>(3)</sup>                                    |  |            | 180      |          |              | *   | *   | $\mu A$      |
| Sleep Current ( $V_{SLEEP} \leq 100mV$ )                                   | $R_L = 10k\Omega$ , Ref Load = 2k $\Omega$ |            | $\pm 1$  | $\pm 25$ |              | *   | *   | $\mu A$      |
| <b>SLEEP MODE PIN<sup>(4)</sup></b><br>$V_{IH}$ (Logic high input voltage) |  | +2.7       |          | V+       | *            |     | *   | V            |
| $V_{IL}$ (Logic low input voltage)   |  | 0          |          | +0.1     | *            |     | *   | V            |
| $I_{IH}$ (Logic high input current)  |  |            | 15       |          |              | *   |     | $\mu A$      |
| $I_{IL}$ (Logic low input current)   |  |            | 0        |          |              | *   |     | $\mu A$      |
| Wake-up Time <sup>(5)</sup>  |  |            | 150      |          |              | *   |     | $\mu s$      |
| <b>TEMPERATURE RANGE</b><br>Specification Range                            |  | -40        |          | +85      | *            |     | *   | $^\circ C$   |
| Operation Range  |  | -55        |          | +125     | *            |     | *   | $^\circ C$   |
| Storage Range  |  | -55        |          | +125     | *            |     | *   | $^\circ C$   |
| Thermal Resistance, $\theta_{JA}$  |  |            |          |          |              |     |     |              |
| 16-Pin DIP   |  |            | 80       |          |              | *   |     | $^\circ C/W$ |
| SO-16 Surface-Mount  |  |            | 100      |          |              | *   |     | $^\circ C/W$ |

\* Specification same as INA125P, U.

NOTES: (1) Temperature coefficient of the "Internal Resistor" in the gain equation. Does not include TCR of gain-setting resistor,  $R_G$ . (2) Dropout voltage is the positive supply voltage minus the reference voltage that produces a 1% decrease in reference voltage. (3)  $V_{REFCOM}$  pin. (4) Voltage measured with respect to Reference Common. Logic low input selects Sleep mode. (5)  $I_A$  and Reference, see Typical Performance Curves.

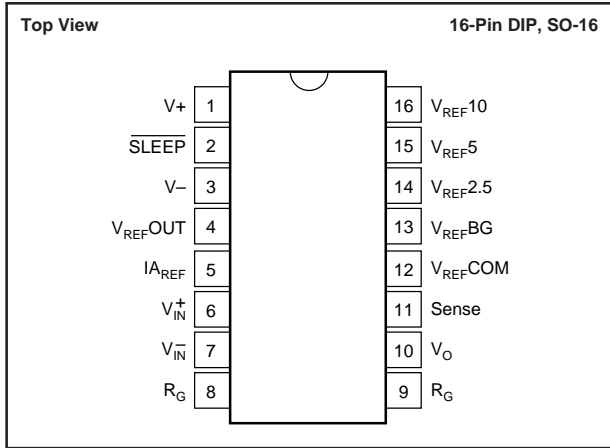
## SPECIFICATIONS: $V_S = +5V$

At  $T_A = +25^\circ C$ ,  $V_S = +5V$ ,  $I_A$  common at  $V_S/2$ ,  $V_{REF}$  common =  $V_S/2$ ,  $V_{CM} = V_S/2$ , and  $R_L = 10k\Omega$  to  $V_S/2$ , unless otherwise noted.

| PARAMETER  | CONDITIONS                                 | INA125P, U |            |           | INA125PA, UA |     |           | UNITS            |
|--|--|------------|------------|-----------|--------------|-----|-----------|------------------|
|  |  | MIN        | TYP        | MAX       | MIN          | TYP | MAX       |                  |
| <b>INPUT</b><br>Offset Voltage, RTI<br>Initial     | $V_S = +2.7V$ to $+36V$                    |            | $\pm 75$   | $\pm 500$ |              | *   | $\pm 750$ | $\mu V$          |
| vs Temperature                                     |  |            | $\pm 0.25$ |           |              | *   |           | $\mu V/^\circ C$ |
| vs Power Supply                                    |  |            | 3          | 20        |              | *   | 50        | $\mu V/V$        |
| Input Voltage Range                                | $V_{CM} = +1.1V$ to $+3.6V$                |            | See Text   |           |              | *   |           |                  |
| Common-Mode Rejection                              |  | G = 4      | 78         | 84        | 72           | *   |           | dB               |
|  |  | G = 10     | 86         | 94        | 80           | *   |           | dB               |
|  |  | G = 100    | 100        | 114       | 90           | *   |           | dB               |
|  |  | G = 500    | 100        | 114       | 90           | *   |           | dB               |
| <b>GAIN</b><br>Gain Error                          | $V_O = +0.3V$ to $+3.8V$<br>G = 4          |            | $\pm 0.01$ |           |              | *   |           | %                |
| <b>OUTPUT</b><br>Voltage, Positive                 |  | (V+)-1.2   | (V+)-0.8   |           | *            | *   |           | V                |
| Negative   |  | (V-)+0.3   | (V-)+0.15  |           | *            | *   |           | V                |
| <b>POWER SUPPLY</b><br>Specified Operating Voltage |  |            | +5         |           |              | *   |           | V                |
| Operating Voltage Range                            |  | +2.7       |            | +36       | *            |     | *         | V                |
| Quiescent Current                                  | $I_O = I_{REF} = 0mA$                      |            | 460        | 525       |              | *   | *         | $\mu A$          |
| Sleep Current ( $V_{SLEEP} \leq 100mV$ )           | $R_L = 10k\Omega$ , Ref Load = 2k $\Omega$ |            | $\pm 1$    | $\pm 25$  |              | *   | *         | $\mu A$          |

\* Specification same as INA125P, U.

## 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>

|                                   |                 |
|-----------------------------------|-----------------|
| Power Supply Voltage, V+ to V-    | 36V             |
| Input Signal Voltage              | ±40V            |
| Output Short Circuit              | Continuous      |
| Operating Temperature             | -55°C to +125°C |
| Storage Temperature               | -55°C to +125°C |
| Lead Temperature (soldering, 10s) | +300°C          |

NOTE: Stresses above these ratings may cause permanent damage.

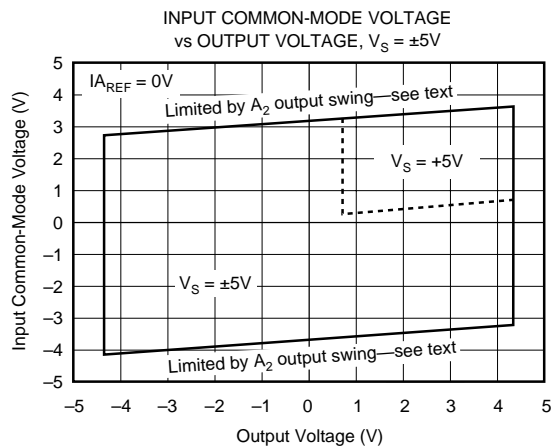
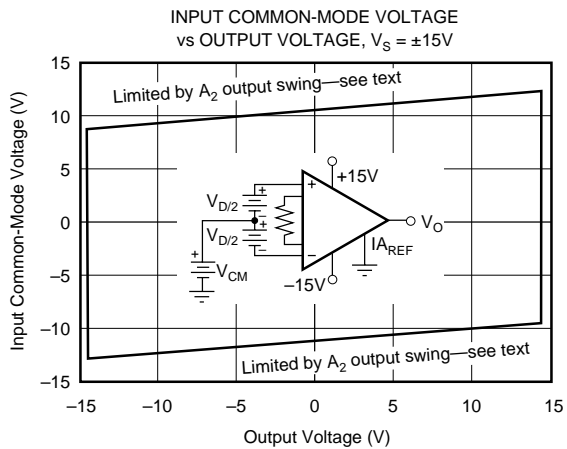
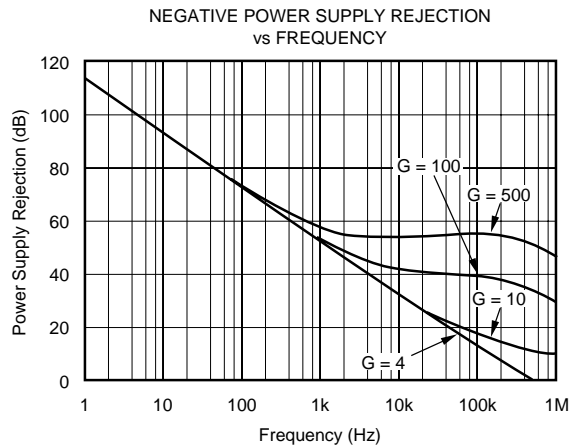
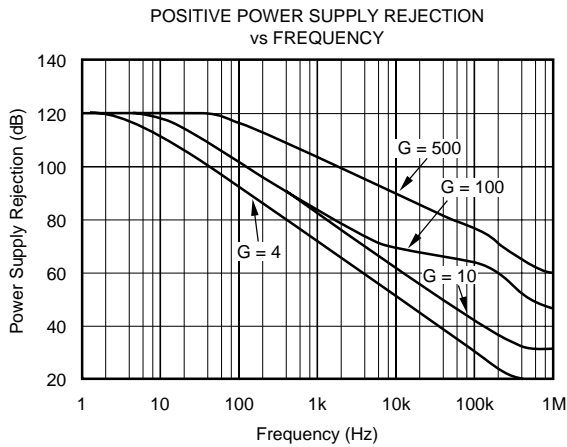
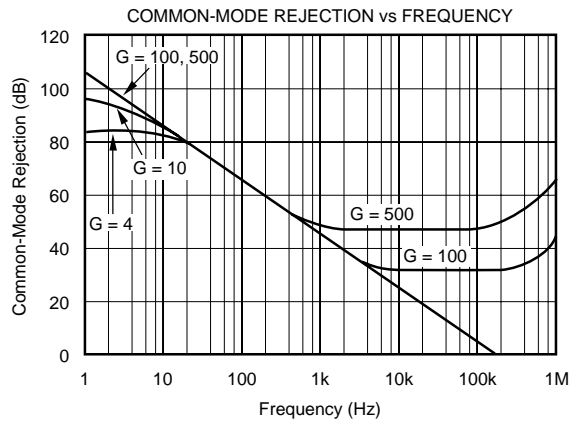
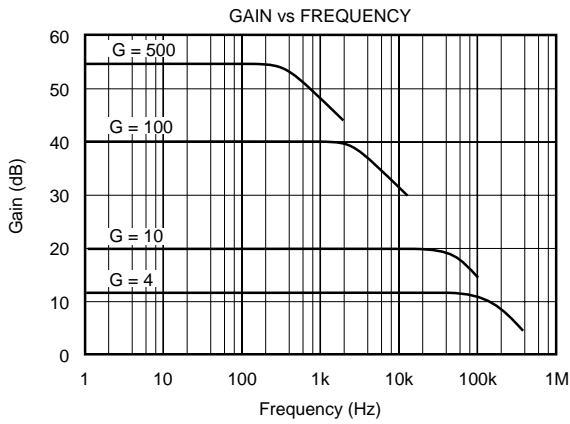
## PACKAGE INFORMATION

| PRODUCT  | PACKAGE             | PACKAGE DRAWING NUMBER <sup>(1)</sup> |
|----------|---------------------|---------------------------------------|
| INA125PA | 16-Pin Plastic DIP  | 180                                   |
| INA125P  | 16-Pin Plastic DIP  | 180                                   |
| INA125UA | SO-16 Surface-Mount | 265                                   |
| INA125U  | SO-16 Surface-Mount | 265                                   |

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

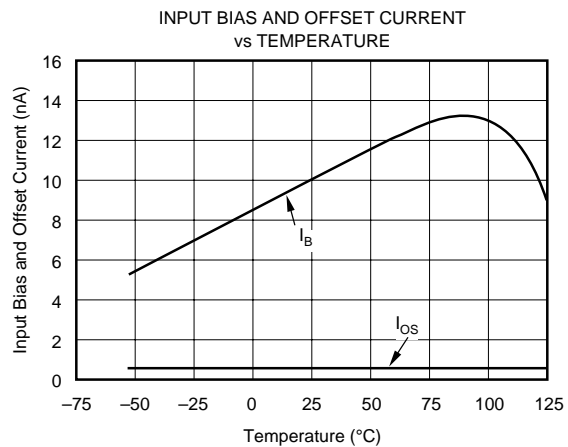
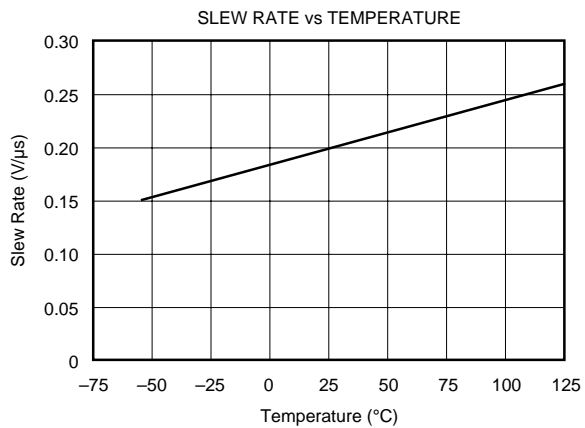
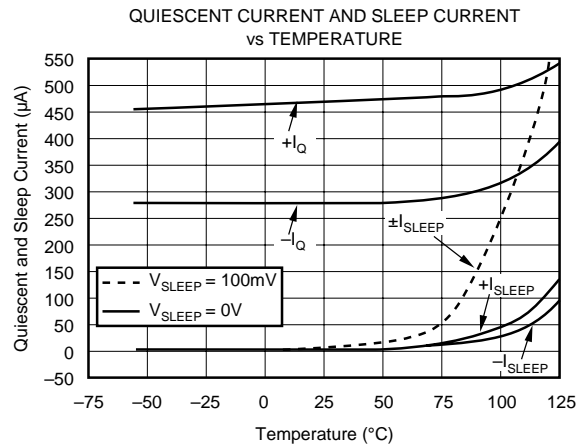
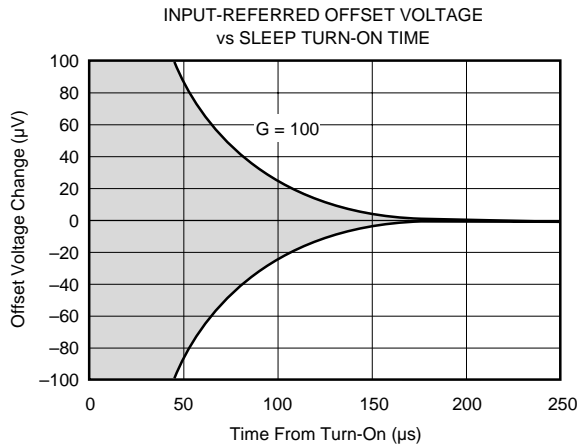
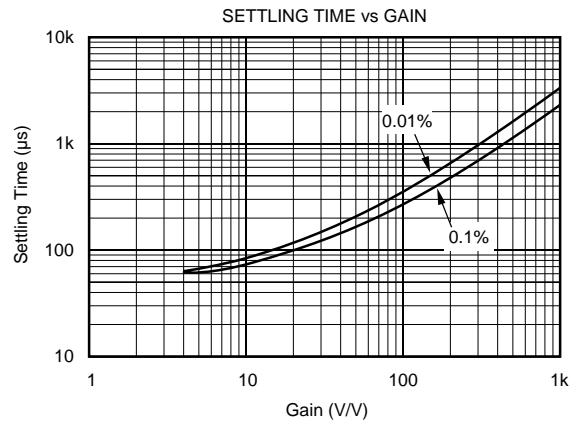
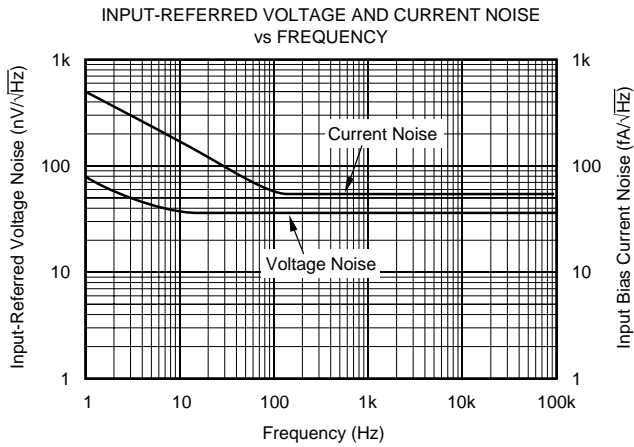
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 15\text{V}$ , unless otherwise noted.



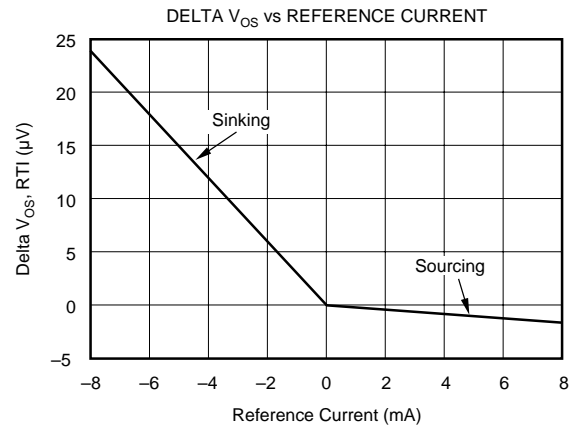
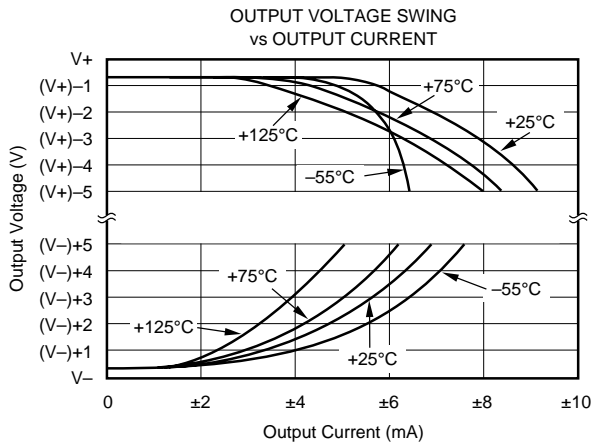
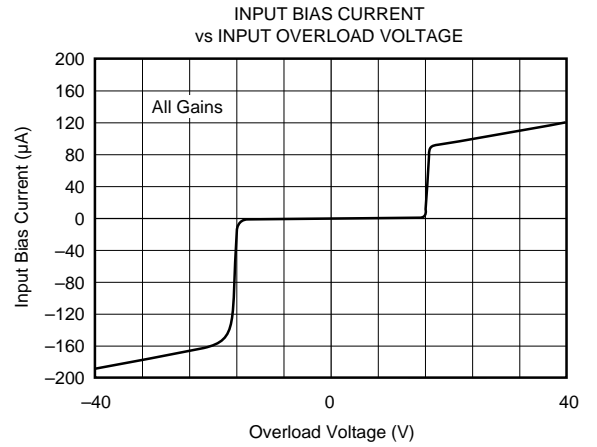
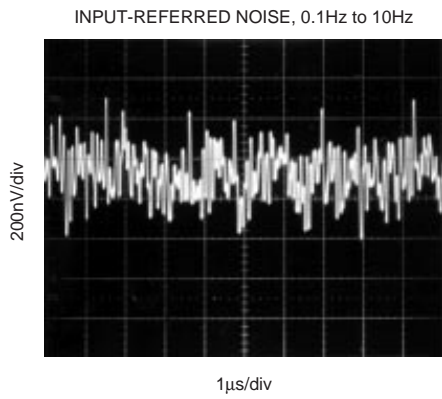
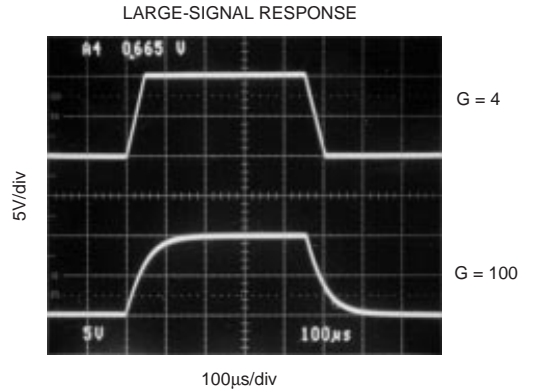
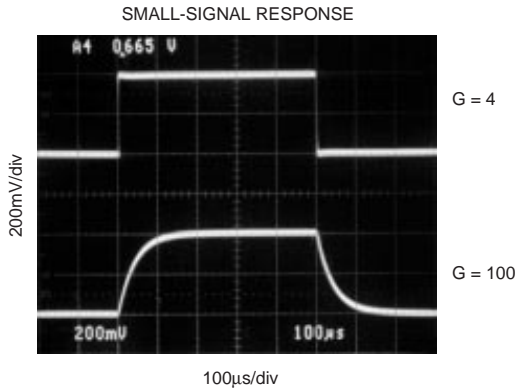
# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 15\text{V}$ , unless otherwise noted.



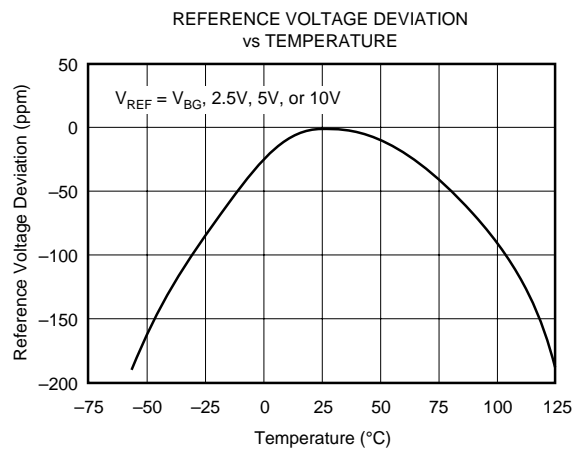
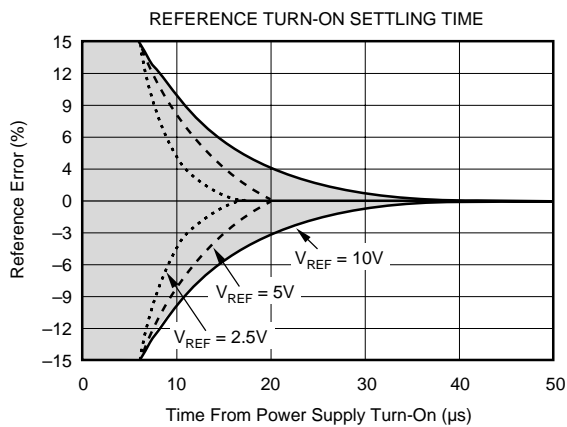
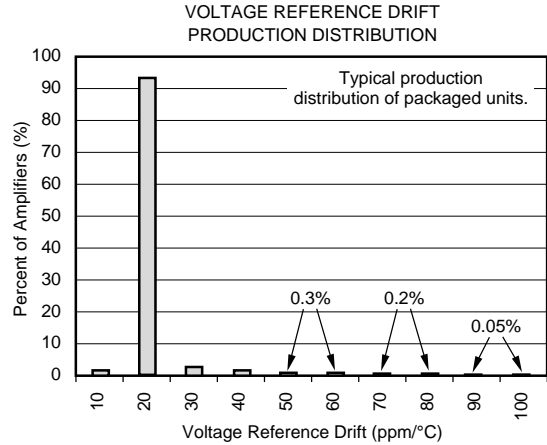
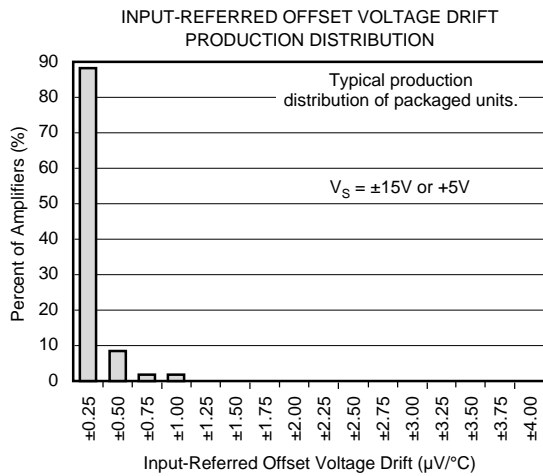
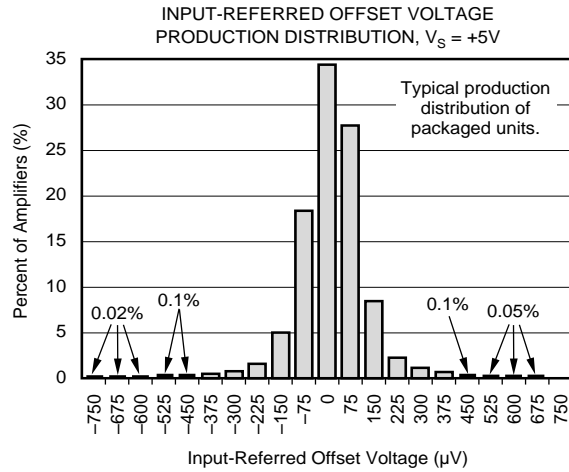
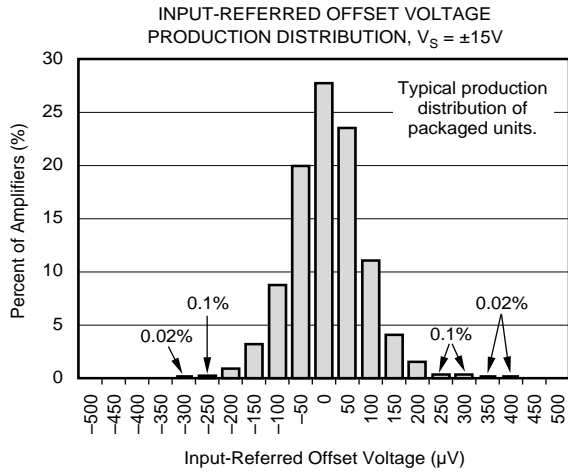
# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 15\text{V}$ , unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 15\text{V}$ , unless otherwise noted.

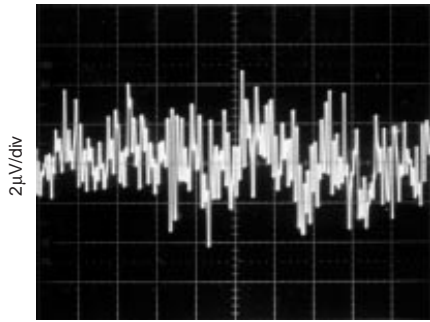




# TYPICAL PERFORMANCE CURVES (CONT)

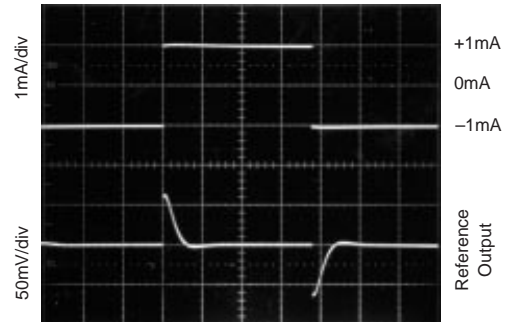
At  $T_A = +25^\circ\text{C}$  and  $V_S = \pm 15\text{V}$ , unless otherwise noted.

0.1Hz to 10Hz REFERENCE NOISE  
 $V_{REF} = 2.5\text{V}$ ,  $C_L = 100\text{pF}$



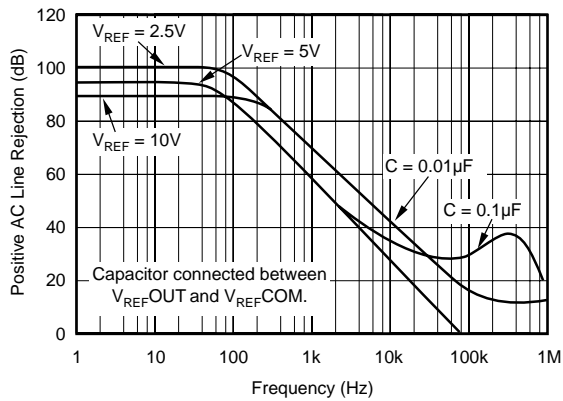
1µs/div

REFERENCE TRANSIENT RESPONSE  
 $V_{REF} = 2.5\text{V}$ ,  $C_L = 100\text{pF}$

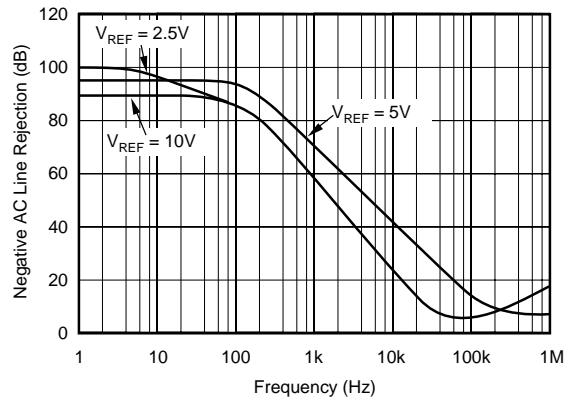


10µs/div

POSITIVE REFERENCE AC LINE REJECTION  
 vs FREQUENCY



NEGATIVE REFERENCE AC LINE REJECTION  
 vs FREQUENCY



# APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA125. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins as shown.

The output is referred to the instrumentation amplifier reference ( $I_{A\_REF}$ ) terminal which is normally grounded. This must be a low impedance connection to assure good common-mode rejection. A resistance of  $12\Omega$  in series with the  $I_{A\_REF}$  pin will cause a typical device to degrade to approximately 80dB CMR ( $G = 4$ ).

Connecting  $V_{REF\_OUT}$  (pin 4) to one of the four available reference voltage pins ( $V_{REF\_BG}$ ,  $V_{REF\_2.5}$ ,  $V_{REF\_5}$ , or  $V_{REF\_10}$ ) provides an accurate voltage source for bridge applications.

For example, in Figure 1  $V_{REF\_OUT}$  is connected to  $V_{REF\_10}$  thus supplying 10V to the bridge. It is recommended that  $V_{REF\_OUT}$  be connected to one of the reference voltage pins even when the reference is not being utilized to avoid saturating the reference amplifier. Driving the  $SLEEP$  pin LOW puts the INA125 in a shutdown mode.

## SETTING THE GAIN

Gain of the INA125 is set by connecting a single external resistor,  $R_G$ , between pins 8 and 9:

$$G = 4 + \frac{60k\Omega}{R_G} \quad (1)$$

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

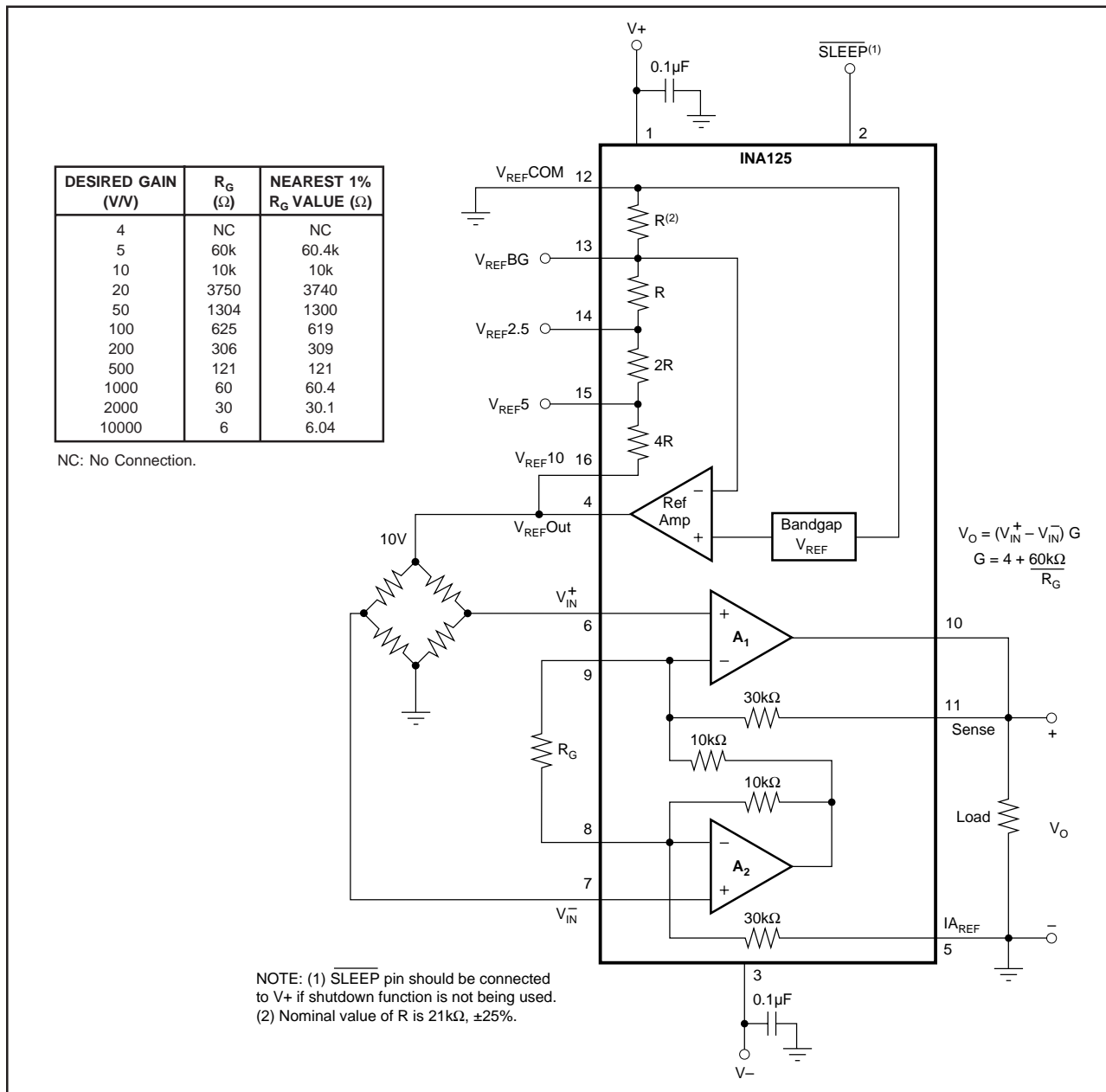


FIGURE 1. Basic Connections.

The 60kΩ 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 INA125.

The stability and temperature drift of the external gain setting resistor, R<sub>G</sub>, also affects gain. R<sub>G</sub>'s contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance, which will contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater.

### OFFSET TRIMMING

The INA125 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 I<sub>AREF</sub> terminal is added to the output signal. The op amp buffer is used to provide low impedance at the I<sub>AREF</sub> terminal to preserve good common-mode rejection.

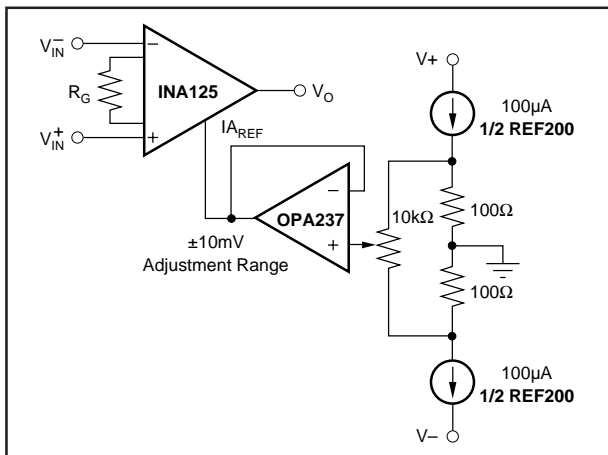


FIGURE 2. Optional Trimming of Output Offset Voltage.

### INPUT BIAS CURRENT RETURN

The input impedance of the INA125 is extremely high—approximately 10<sup>11</sup>Ω. However, a path must be provided for the input bias current of both inputs. This input bias current flows out of the device and is approximately 10nA. High input impedance means that this 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 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, 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.

### INPUT COMMON-MODE RANGE

The input common-mode range of the INA125 is shown in the typical performance curves. The common-mode range is limited on the negative side by the output voltage swing of A<sub>2</sub>, an internal circuit node that cannot be measured on an external pin. The output voltage of A<sub>2</sub> can be expressed as:

$$V_{O2} = 1.3V_{IN}^- - (V_{IN}^+ - V_{IN}^-) (10k\Omega/R_G)$$

(voltages referred to I<sub>AREF</sub> terminal, pin 5)

The internal op amp A<sub>2</sub> is identical to A<sub>1</sub>. Its output swing is limited to approximately 0.8V from the positive supply and 0.25V from the negative supply. When the input common-mode range is exceeded (A<sub>2</sub>'s output is saturated), A<sub>1</sub> can still be in linear operation, responding to changes in the non-inverting input voltage. The output voltage, however, will be invalid.

### PRECISION VOLTAGE REFERENCE

The on-board precision voltage reference provides an accurate voltage source for bridge and other transducer applications or ratiometric conversion with analog-to-digital converters. A reference output of 2.5V, 5V or 10V is available by connecting V<sub>REF</sub>OUT (pin 4) to one of the V<sub>REF</sub> pins (V<sub>REF</sub>2.5, V<sub>REF</sub>5, or V<sub>REF</sub>10). Reference voltages are laser-trimmed for low initial error and low temperature drift. Connecting V<sub>REF</sub>OUT to V<sub>REF</sub>BG (pin 13) produces the bandgap reference voltage (1.24V ±0.5%) at the reference output.

Positive supply voltage must be 1.25V above the desired reference voltage. For example, with V<sub>+</sub> = 2.7V, only the 1.24V reference (V<sub>REF</sub>BG) can be used. If using dual supplies V<sub>REF</sub>COM can be connected to V<sub>-</sub>, increasing the

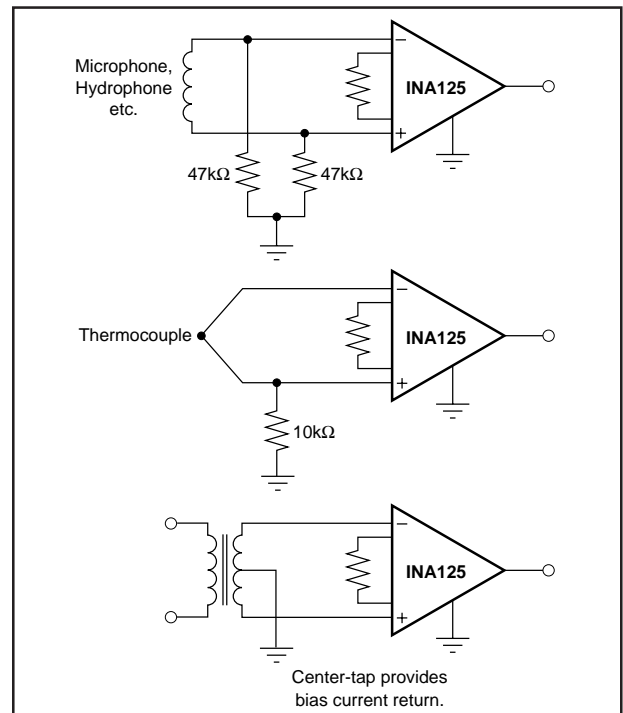


FIGURE 3. Providing an Input Common-Mode Current Path.

amount of supply voltage headroom available to the reference. Approximately  $180\mu\text{A}$  flows out of the  $V_{\text{REF-COM}}$  terminal, therefore, it is recommended that it be connected through a low impedance path to sensor common to avoid possible ground loop problems.

Reference noise is proportional to the reference voltage selected. With  $V_{\text{REF}} = 2.5\text{V}$ , 0.1Hz to 10Hz peak-to-peak noise is approximately  $9\mu\text{Vp-p}$ . Noise increases to  $36\mu\text{Vp-p}$  for the 10V reference. Output drive capability of the voltage reference is improved by connecting a transistor as shown in Figure 4. The external transistor also serves to remove power from the INA125.

Internal resistors that set the voltage reference output are ratio-trimmed for accurate output voltages ( $\pm 0.5\%$  max). The absolute resistance values, however, may vary  $\pm 25\%$ . Adjustment of the reference output voltage with an external resistor is not recommended because the required resistor value is uncertain.

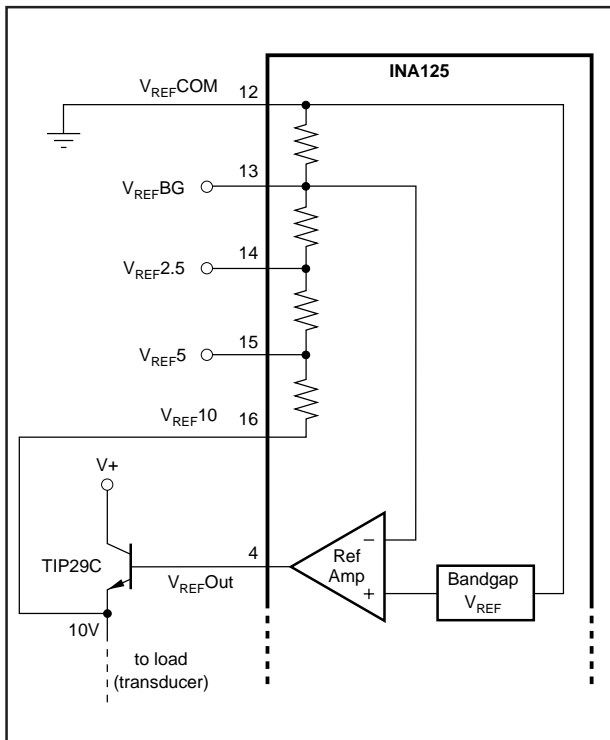


FIGURE 4. Reference Current Boost.

## SHUTDOWN

The INA125 has a shutdown option. When the  $\overline{\text{SLEEP}}$  pin is LOW (100mV or less), the supply current drops to approximately  $1\mu\text{A}$  and output impedance becomes approximately  $80\text{k}\Omega$ . Best performance is achieved with CMOS logic. To maintain low sleep current at high temperatures,  $V_{\text{SLEEP}}$  should be as close to 0V as possible. This should not be a problem if using CMOS logic unless the CMOS gate is driving other currents. Refer to the typical performance curve, “Sleep Current vs Temperature.”

A transition region exists when  $V_{\text{SLEEP}}$  is between 400mV and 2.7V (with respect to  $V_{\text{REF-COM}}$ ) where the output is unpredictable. Operation in this region is not recommended. The INA125 achieves high accuracy quickly following wake-up ( $V_{\text{SLEEP}} \geq 2.7\text{V}$ ). See the typical performance curve “Input-Referred Offset Voltage vs Sleep Turn-on Time.” If shutdown is not being used, connect the  $\overline{\text{SLEEP}}$  pin to  $V+$ .

## LOW VOLTAGE OPERATION

The INA125 can be operated on power supplies as low as  $\pm 1.35\text{V}$ . Performance remains excellent with power supplies ranging from  $\pm 1.35\text{V}$  to  $\pm 18\text{V}$ . 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. See “Input Common-Mode Voltage Range.” As previously mentioned, when using the on-board reference with low supply voltages, it may be necessary to connect  $V_{\text{REF-COM}}$  to  $V-$  to ensure  $V_S - V_{\text{REF}} \geq 1.25\text{V}$ .

## SINGLE SUPPLY OPERATION

The INA125 can be used on single power supplies of +2.7V to +36V. Figure 5 shows a basic single supply circuit. The  $I_{\text{A-REF}}$ ,  $V_{\text{REF-COM}}$ , and  $V-$  terminals are connected to ground. Zero differential input voltage will demand an output voltage of 0V (ground). When the load is referred to ground as shown, actual output voltage swing is limited to approximately 150mV above ground. The typical performance curve “Output Voltage Swing vs Output Current” shows how the output swing varies with output current.

With single supply operation, careful attention should be paid to input common-mode range, output voltage swing of both op amps, and the voltage applied to the  $I_{\text{A-REF}}$  terminal.  $V_{\text{IN+}}$  and  $V_{\text{IN-}}$  must both be 1V above ground for linear operation. You cannot, for instance, connect the inverting input to ground and measure a voltage connected to the non-inverting input.

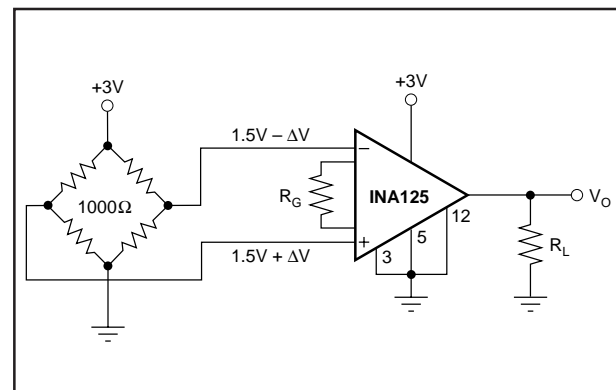


FIGURE 5. Single Supply Bridge Amplifier.

## INPUT PROTECTION

The inputs of the INA125 are individually protected for voltage up to  $\pm 40\text{V}$ . For example, a condition of  $-40\text{V}$  on one input and  $+40\text{V}$  on the other input will not cause damage. Internal circuitry on each input provides low series impedance under normal signal conditions. To provide equivalent protection, series input resistors would contribute

excessive noise. If the input is overloaded, the protection circuitry limits the input current to a safe value of approximately  $120\mu\text{A}$  to  $190\mu\text{A}$ . The typical performance curve “Input Bias Current vs Input Overload Voltage” shows this input current limit behavior. The inputs are protected even if the power supplies are disconnected or turned off.

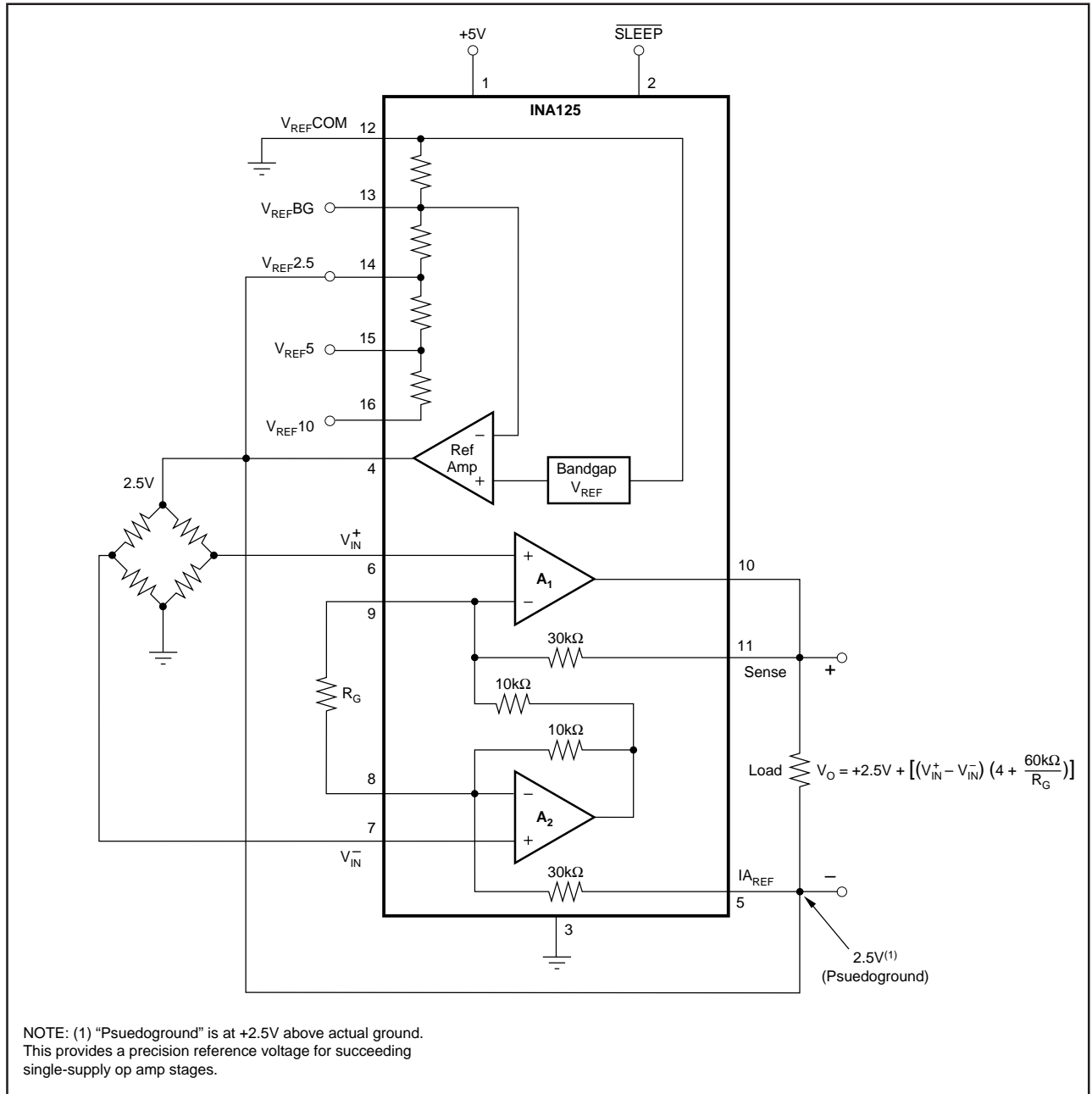


FIGURE 6. Pseudoground Bridge Measurement, 5V Single Supply.

**PACKAGING INFORMATION**

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">INA125P</a>      | Active        | Production           | PDIP (N)   16  | 25   TUBE             | Yes         | Call TI                              | N/A for Pkg Type                  | -40 to 85    | INA125P             |
| <a href="#">INA125PA</a>     | Active        | Production           | PDIP (N)   16  | 25   TUBE             | Yes         | Call TI                              | N/A for Pkg Type                  | -            | INA125P<br>A        |
| <a href="#">INA125U</a>      | Active        | Production           | SOIC (D)   16  | 40   TUBE             | Yes         | Call TI                              | Level-3-260C-168 HR               | -            | INA125U<br>A        |
| <a href="#">INA125U/2K5</a>  | Active        | Production           | SOIC (D)   16  | 2500   LARGE T&R      | Yes         | Call TI                              | Level-3-260C-168 HR               | -            | INA125U<br>A        |
| <a href="#">INA125UA</a>     | Active        | Production           | SOIC (D)   16  | 40   TUBE             | Yes         | Call TI                              | Level-3-260C-168 HR               | -            | INA125U<br>A        |
| <a href="#">INA125UA/2K5</a> | Active        | Production           | SOIC (D)   16  | 2500   LARGE T&R      | Yes         | Call TI                              | Level-3-260C-168 HR               | -            | INA125U<br>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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**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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| INA125U/2K5  | SOIC         | D               | 16   | 2500 | 330.0              | 16.4               | 6.5     | 10.3    | 2.1     | 8.0     | 16.0   | Q1            |
| INA125UA/2K5 | SOIC         | D               | 16   | 2500 | 330.0              | 16.4               | 6.5     | 10.3    | 2.1     | 8.0     | 16.0   | Q1            |



**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| INA125U/2K5  | SOIC         | D               | 16   | 2500 | 356.0       | 356.0      | 35.0        |
| INA125UA/2K5 | SOIC         | D               | 16   | 2500 | 356.0       | 356.0      | 35.0        |

**TUBE**


\*All dimensions are nominal

| Device     | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| INA125P    | N            | PDIP         | 16   | 25  | 506    | 13.97  | 11230  | 4.32   |
| INA125PA   | N            | PDIP         | 16   | 25  | 506    | 13.97  | 11230  | 4.32   |
| INA125PAG4 | N            | PDIP         | 16   | 25  | 506    | 13.97  | 11230  | 4.32   |
| INA125U    | D            | SOIC         | 16   | 40  | 506.6  | 8      | 3940   | 4.32   |
| INA125UA   | D            | SOIC         | 16   | 40  | 506.6  | 8      | 3940   | 4.32   |

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