# INA128UA/2K5

## TI,Texas Instruments

Instrumentation Amplifiers Precision Low Power Instrumentation Amp

# INA12x Precision, Low-Power Instrumentation Amplifiers

*A newer version of this device is now available: INA828*

## 1 Features

- A newer version of this device is now available: INA828
- Low offset voltage: 50 μV maximum
- Low drift: 0.5 μV/°C maximum
- Low Input Bias Current: 5 nA maximum
- High CMR: 120 dB minimum
- Inputs protected to ±40 V
- Wide supply range: ±2.25 V to ±18 V
- Low quiescent current: 700 μA
- Packages: 8-pin plastic DIP, SO-8

## 2 Applications

- Bridge amplifier
- Thermocouple amplifier
- RTD sensor amplifier
- Medical instrumentation
- Data acquisition

## 3 Description

The INA128 and INA129 are low-power, general purpose instrumentation amplifiers offering excellent accuracy. The versatile 3-op amp design and small size make these amplifiers ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain (200 kHz at G = 100).

A single external resistor sets any gain from 1 to 10,000. The INA128 provides an industry-standard gain equation; the INA129 gain equation is compatible with the AD620.

The INA12x is available in 8-pin plastic DIP and SO-8 surface-mount packages, specified for the –40°C to +85°C temperature range. The INA128 is also available in a dual configuration, the INA2128.

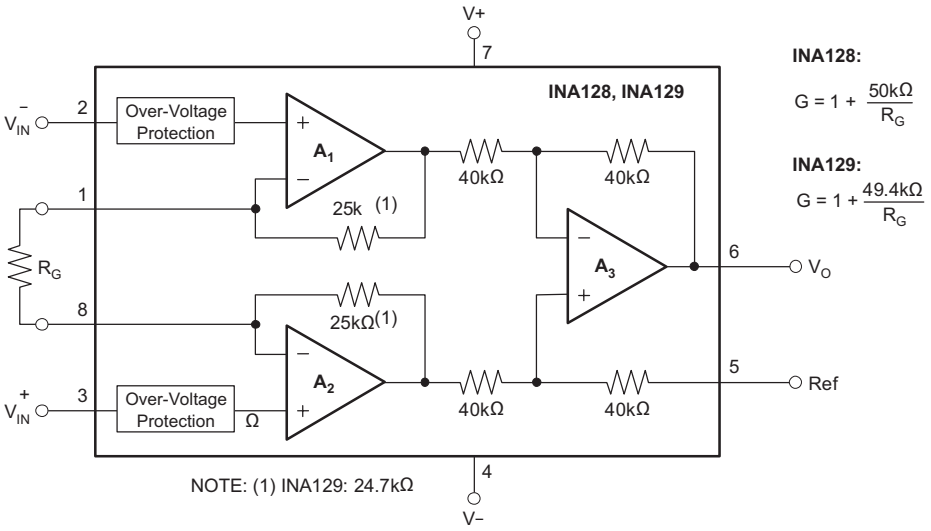
The upgraded INA828 offers a lower input bias current (0.6 nA maximum) and lower noise (7 nV/√Hz) at the same quiescent current. See the *Device Comparison Table* for a selection of precision instrumentation amplifiers from Texas Instruments.

**Device Information**[1]

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| INA128, INA129 | SOIC (8) | 3.91 mm × 4.90 mm |
| | PDIP (8) | 6.35 mm × 9.81 mm |

(1) For all available packages, see the package option addendum at the end of the data sheet.

**Simplified Schematic**



## Table of Contents



## 4 Revision History

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

**Changes from Revision D (January 2018) to Revision E** — **Page**

- Added information about the newer, upgraded INA828 ... 1
- Added *Device Comparison Table* ... 3

**Changes from Revision C (October 2015) to Revision D** — **Page**

- Added top navigator icon for TI Reference Design ... 1
- Changed "±0.5±0/G" to "±0.5±20/G" in MAX column of Offset voltage RTI vs temperature row of *Electrical Characteristics* ... 5

**Changes from Revision B (February 2005) to Revision C** — **Page**

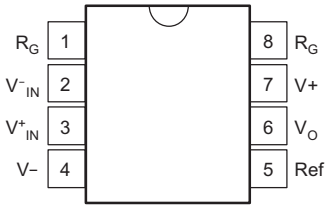
- Added *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. ... 1

# 5 Device Comparison Table

| DEVICE | DESCRIPTION | GAIN EQUATION | RG PINS AT PIN |
|---|---|---|---|
| INA828 | 50-µV Offset, 0.5 µV/°C $V_{OS}$ drift, 7-nV/√Hz Noise, Low-Power, Precision Instrumentation Amplifier | G = 1 + 50 kΩ / RG | 1, 8 |
| INA819 | 35-µV Offset, 0.4 µV/°C $V_{OS}$ drift, 8-nV/√Hz Noise, Low-Power, Precision Instrumentation Amplifier | G = 1 + 50 kΩ / RG | 2, 3 |
| INA821 | 35-µV Offset, 0.4 µV/°C $V_{OS}$ drift, 7-nV/√Hz Noise, High-Bandwidth, Precision Instrumentation Amplifier | G = 1 + 49.4 kΩ / RG | 2, 3 |
| INA828 | 50-µV Offset, 0.5 µV/°C $V_{OS}$ drift, 7-nV/√Hz Noise, Low-Power, Precision Instrumentation Amplifier | G = 1 + 50 kΩ / RG | 1, 8 |
| INA333 | 25-µV $V_{OS}$, 0.1 µV/°C $V_{OS}$ drift, 1.8-V to 5-V, RRO, 50-µA $I_Q$, chopper-stabilized INA | G = 1 + 100 kΩ / RG | 1, 8 |
| PGA280 | 20-mV to ±10-V programmable gain IA with 3-V or 5-V differential output; analog supply up to ±18 V | digital programmable | N/A |
| INA159 | G = 0.2 V differential amplifier for ±10-V to 3-V and 5-V conversion | G = 0.2 V/V | N/A |
| PGA112 | Precision programmable gain op amp with SPI | digital programmable | N/A |

# 6 Pin Configuration and Functions

**D and P Packages**
**8-Pin SOIC and PDIP**
**Top View**




**Pin Functions**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| REF | 5 | I | Reference input. This pin must be driven by low impedance or connected to ground. |
| $R_G$ | 1,8 | — | Gain setting pin. For gains greater than 1, place a gain resistor between pin 1 and pin 8. |
| V- | 4 | — | Negative supply |
| V+ | 7 | — | Positive supply |
| $V_{IN-}$ | 2 | I | Negative input |
| $V_{IN+}$ | 3 | I | Positive input |
| $V_O$ | 6 | I | Output |

# 7 Specifications

## 7.1 Absolute Maximum Ratings

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

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply voltage | | ±18 | V |
| Analog input voltage | | ±40 | V |
| Output short circuit (to ground) | | continuous | |
| Operating temperature | –40 | 125 | °C |
| Junction temperature | | 150 | °C |
| Lead temperature (soldering, 10 seconds) | | 300 | °C |
| Storage temperature, $T_{stg}$ | –55 | 125 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1) | ±2000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 (2) | ±50 | |

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

## 7.3 Recommended Operating Conditions

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

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| V power supply | ±2.25 | ±15 | ±18 | V |
| Input common-mode voltage range for $V_O$ = 0 | V – 2 V | | V + –2 V | |
| $T_A$ operating temperature INA128-HT | –55 | | 175 | °C |
| $T_A$ operating temperature INA129-HT | –55 | | 210 | °C |

## 7.4 Thermal Information

| THERMAL METRIC[1] | | INA12x | | UNIT |
|---|---|---|---|---|
| | | D (SOIC) | P (PDIP) | |
| | | 8 PINS | 8 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 110 | 46.1 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 57 | 34.1 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 54 | 23.4 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 11 | 11.3 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 53 | 23.2 | °C/W |

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

## 7.5 Electrical Characteristics

at $T_A$ = 25°C, $V_S$ = ±15 V, and $R_L$ = 10 kΩ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **INPUT** | | | | | | | |
| Offset voltage, RTI | Initial | $T_A$ = 25°C | INA128P, U<br>INA129P, U | | ±10±100/G | ±50±500/G | µV |
| | | | INA128PA, UA<br>INA129PA, UA | | ±25±100/G | ±125±1000/G | |
| | vs temperature | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | INA128P, U<br>INA129P, U | | ±0.2±2/G | ±0.5±20/G | µV/°C |
| | | | INA128PA, UA<br>INA129PA, UA | | ±0.2±5/G | ±1±20/G | |
| | vs power supply | $V_S$ = ±2.25 V to ±18 V | INA128P, U<br>INA129P, U | | ±0.2±20/G | ±1±100/G | µV/V |
| | | | INA128PA, UA<br>INA129PA, UA | | | ±2±200/G | |
| | Long-term stability | | | | ±0.1±3/g | | µV/mo |
| Impedance | Differential | | | | $10^{10}$ \|\| 2 | | Ω \|\| pF |
| | Common mode | | | | $10^{11}$ \|\| 9 | | |
| Common-mode voltage range[1] | | $V_O$ = 0 V | | (V+) - 2 | (V+) - 1.4 | | V |
| | | | | (V…) + 2 | (V–) + 1.7 | | |
| Safe input voltage | | | | | | ±40 | V |

(1) Input common-mode range varies with output voltage; see Typical Characteristics.

## Electrical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = ±15 V, and $R_L$ = 10 kΩ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| Common-mode rejection | | $V_{CM}$ = ±13 V, $\Delta R_S$ = 1 kΩ | G = 1 | INA128P, U<br>INA129P, U | 80 | 86 | | dB |
| | | | | INA128PA, UA<br>INA129PA, UA | 73 | | | |
| | | | G = 10 | INA128P, U<br>INA129P, U | 100 | 106 | | |
| | | | | INA128PA, UA<br>INA129PA, UA | 93 | | | |
| | | | G = 100 | INA128P, U<br>INA129P, U | 120 | 125 | | |
| | | | | INA128PA, UA<br>INA129PA, UA | 110 | | | |
| | | | G = 1000 | INA128P, U<br>INA129P, U | 120 | 130 | | |
| | | | | INA128PA, UA<br>INA129PA, UA | 110 | | | |
| Bias current | | INA128P, U<br>INA129P, U | | | | ±2 | ±5 | nA |
| | | INA128PA, UA<br>INA129PA, UA | | | | | ±10 | |
| Bias current vs temperature | | | | | | ±30 | | pA/°C |
| Offset current | | INA128P, U<br>INA129P, U | | | | ±1 | ±5 | nA |
| | | INA128PA, UA<br>INA129PA, UA | | | | | ±10 | |
| Offset current vs temperature | | | | | | ±30 | | pA/°C |
| Noise voltage, RTI | f = 10 Hz | G = 1000, $R_S$ = 0Ω | | | | 10 | | nV/√Hz |
| | f = 100 Hz | | | | | 8 | | |
| | f = 1 kHz | | | | | 8 | | |
| | $f_B$ = 0.1 Hz to 10 Hz | | | | | 0.2 | | $\mu V_{PP}$ |
| Noise current | f = 10 Hz | | | | | 0.9 | | pA/√Hz |
| | f = 1 kHz | | | | | 0.3 | | |
| | $F_B$ = 0.1 Hz to 10 Hz | | | | | 30 | | $pA_{PP}$ |
| **GAIN**[2] | | | | | | | | |
| Gain equation | INA128 | | | | | 1 + (50 kΩ/$R_G$) | | V/V |
| | INA129 | | | | | 1 + (49.4 kΩ/$R_G$) | | |
| Range of gain | | | | | 1 | | 10000 | V/V |
| Gain error | | G = 1 | | INA128P, U<br>INA129P, U | | ±0.01% | ±0.024% | |
| | | | | INA128PA, UA<br>INA129PA, UA | | | ±0.01% | |
| | | G = 10 | | INA128P, U<br>INA129P, U | | ±0.02% | ±0.4% | |
| | | | | INA128PA, UA<br>INA129PA, UA | | | ±0.5% | |
| | | G = 100 | | INA128P, U<br>INA129P, U | | ±0.05% | ±0.5% | |
| | | | | INA128PA, UA<br>INA129PA, UA | | | ±0.7% | |
| | | G = 1000 | | INA128P, U<br>INA129P, U | | ±0.5% | ±1% | |
| | | | | INA128PA, UA<br>INA129PA, UA | | | ±2% | |

(2) Nonlinearity measurements in G = 1000 are dominated by noise. Typical non-linearity is ±0.001%.

## Electrical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = ±15 V, and $R_L$ = 10 kΩ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| Gain vs temperature(3) | | G = 1 | | | ±1 | ±10 | ppm/°C |
| | | 50-kΩ (or 49.4-kΩ) Resistance(3)(4) | | | ±25 | ±100 | |
| Nonlinearity | | $V_O$ = ±13.6 V, G = 1 | INA128P, U<br>INA129P, U | | ±0.0001 | ±0.001 | % of FSR |
| | | | INA128PA, UA<br>INA129PA, UA | | | ±0.002 | |
| | | G = 10 | INA128P, U<br>INA129P, U | | ±0.0003 | ±0.002 | |
| | | | INA128PA, UA<br>INA129PA, UA | | | ±0.004 | |
| | | G = 100 | INA128P, U<br>INA129P, U | | ±0.0005 | ±0.002 | |
| | | | INA128PA, UA<br>INA129PA, UA | | | ±0.004 | |
| | | G = 1000 | | | ±0.001 | /> | |
| **OUTPUT(2)** | | | | | | | |
| Voltage | Positive | $R_L$ = 10 kΩ | | (V+) – 1.4 | (V+) – 0.9 | | V |
| | Negative | $R_L$ = 10 kΩ | | (V–) + 1.4 | (V–) + 0.8 | | |
| Load capacitance stability | | | | | 1000 | | pF |
| Short-circuit current | | | | | 6/–15 | | mA |
| **FREQUENCY RESPONSE** | | | | | | | |
| Bandwidth, –3 dB | | G = 1 | | | 1.3 | | MHz |
| | | G = 10 | | | 700 | | kHz |
| | | G = 100 | | | 200 | | |
| | | G = 1000 | | | 20 | | |
| Slew rate | | $V_O$ = ±10 V, G = 10 | | | 4 | | V/µs |
| Settling time, 0.01% | | G = 1 | | | 7 | | µs |
| | | G = 10 | | | 7 | | |
| | | G = 100 | | | 9 | | |
| | | G = 1000 | | | 80 | | |
| Overload recovery | | 50% overdrive | | | 4 | | µs |
| **POWER SUPPLY** | | | | | | | |
| Voltage range | | | | ±2.25 | ±15 | ±18 | V |
| Current, total | | $V_{IN}$ = 0 V | | | ±700 | ±750 | µA |
| **TEMPERATURE RANGE** | | | | | | | |
| Specification | | | | –40 | | 85 | °C |
| Operating | | | | –40 | | 125 | °C |

(3) Specified by wafer test.
(4) Temperature coefficient of the 50 kΩ (or 49.4 kΩ) term in the gain equation.

## 7.6 Typical Characteristics

at $T_A$ = 25°C and $V_S$ = ±15 V (unless otherwise noted)

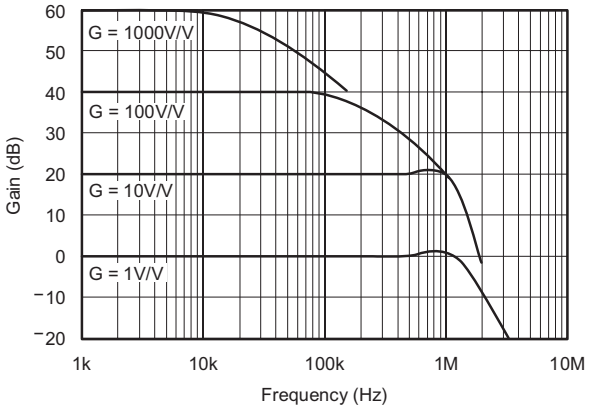



**Figure 1. Gain vs Frequency**

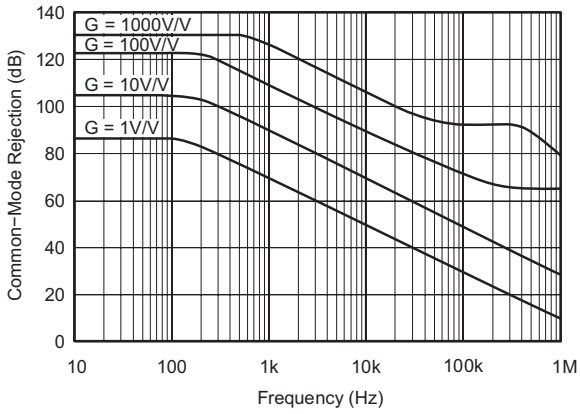



**Figure 2. Common-Mode Rejection vs Frequency**

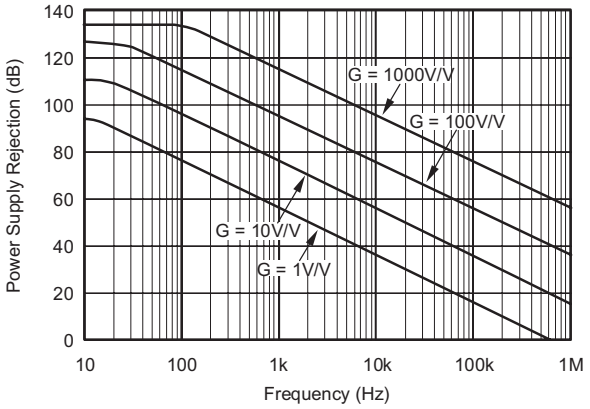



**Figure 3. Positive Power Supply Rejection vs Frequency**

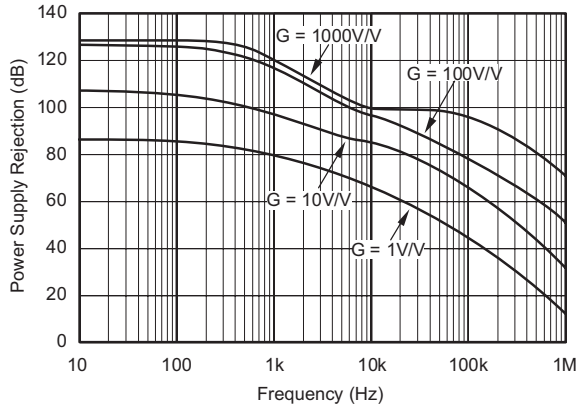



**Figure 4. Negative Power Supply Rejection vs Frequency**

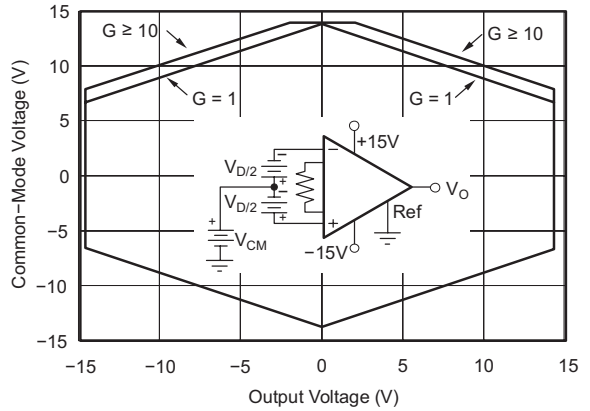



**Figure 5. Input Common-Mode Range vs Output Voltage, $V_S$ = ±15 V**

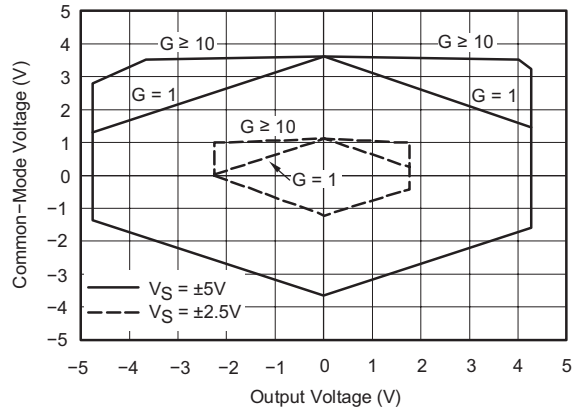



**Figure 6. Input Common-Mode Range vs Output Voltage, $V_S$ = ±5 V, ±2.5 V**

## Typical Characteristics (continued)

at $T_A$ = 25°C and $V_S$ = ±15 V (unless otherwise noted)

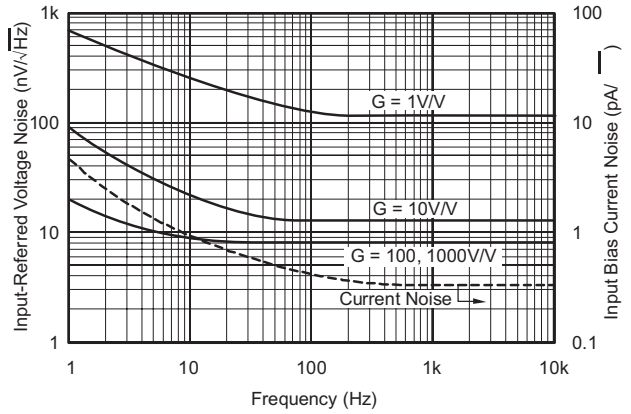



**Figure 7. Input-Referred Noise vs Frequency**

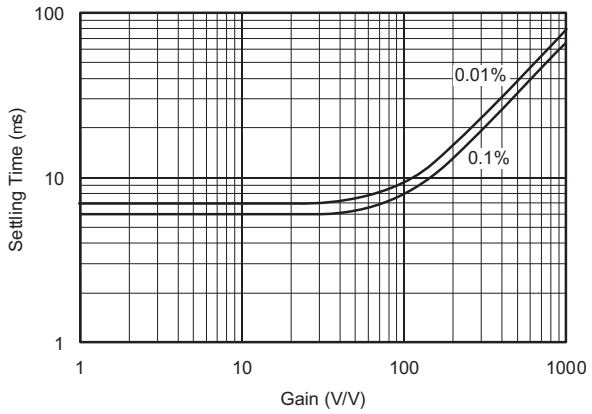



**Figure 8. Settling Time vs Gain**

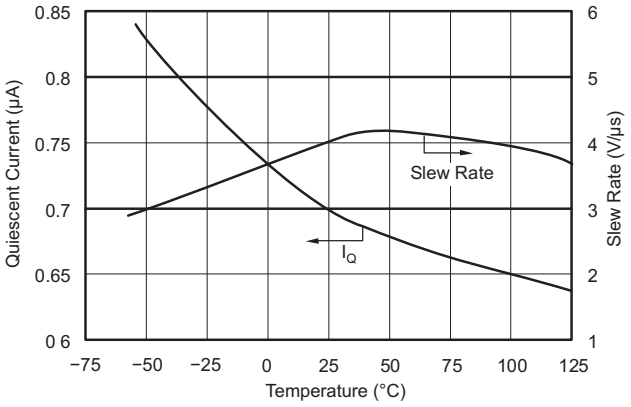



**Figure 9. Quiescent Current and Slew Rate vs Temperature**

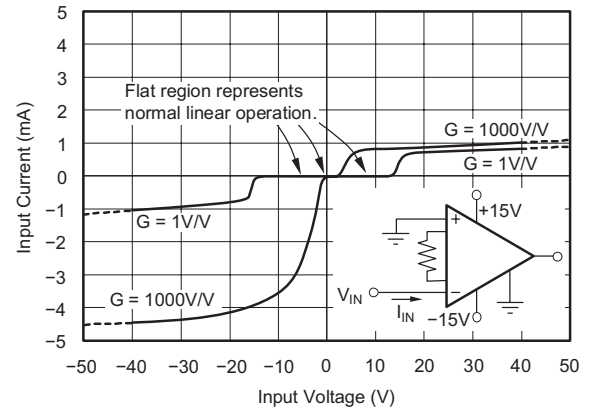



**Figure 10. Input Overvoltage V/I Characteristics**

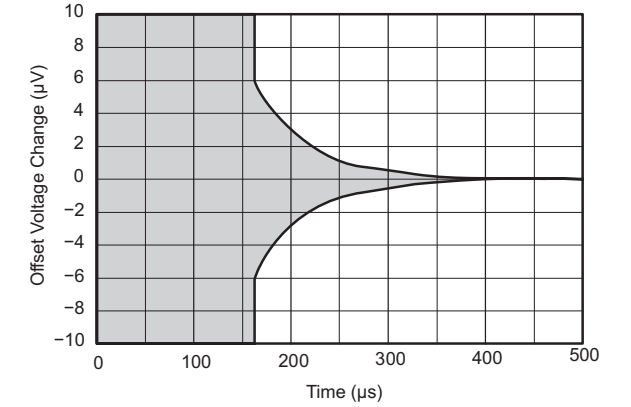



**Figure 11. Input Offset Voltage Warm-Up**

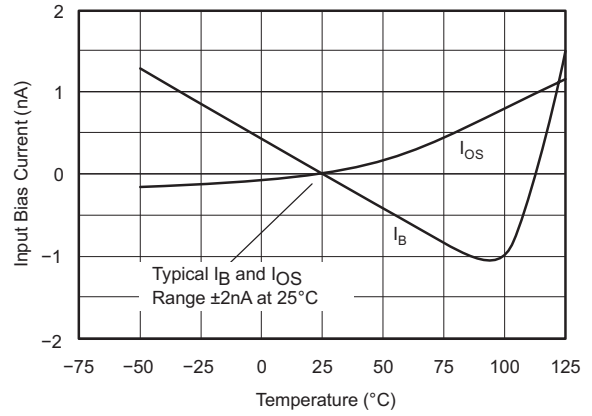



**Figure 12. Input Bias Current vs Temperature**

## Typical Characteristics (continued)

at $T_A$ = 25°C and $V_S$ = ±15 V (unless otherwise noted)

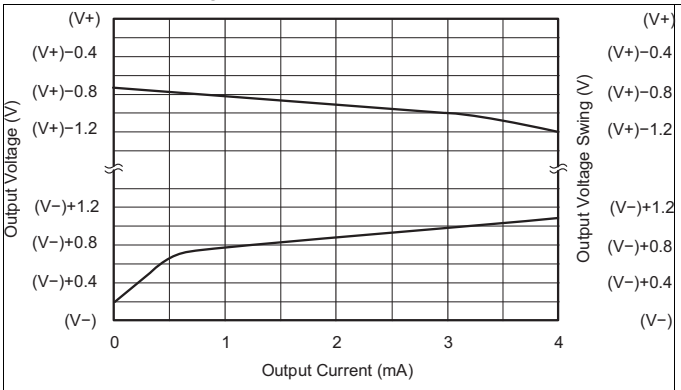



**Figure 13. Output Voltage Swing vs Output Current**

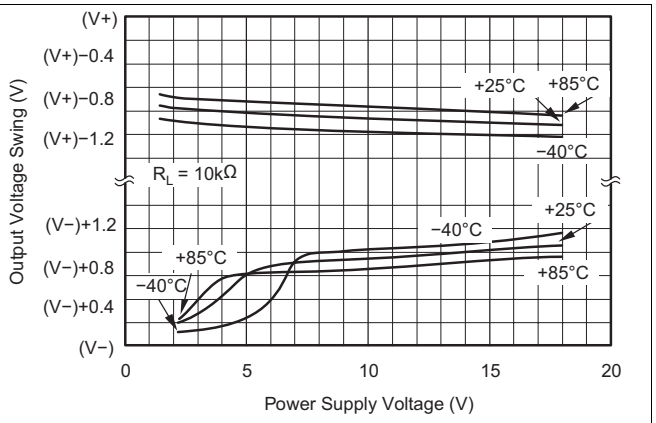



**Figure 14. Output Voltage Swing vs Power Supply Voltage**

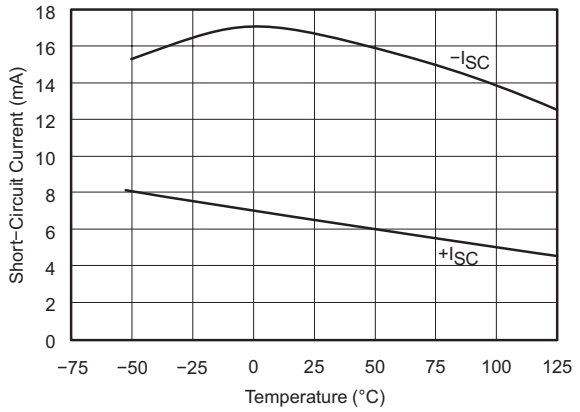



**Figure 15. Short Circuit Output Current vs Temperature**

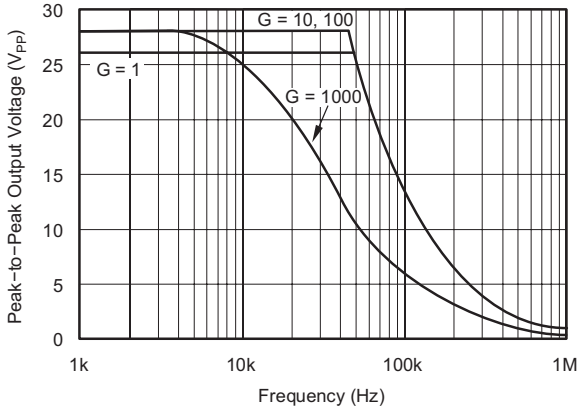



**Figure 16. Maximum Output Voltage vs Frequency**

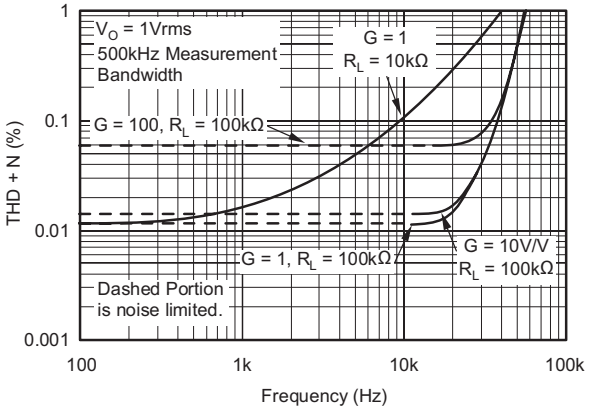



**Figure 17. Total Harmonic Distortion + Noise vs Frequency**

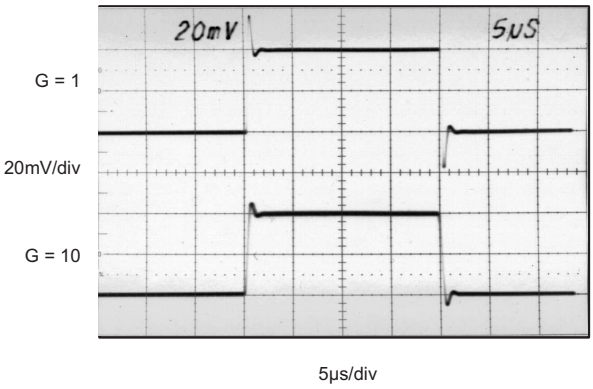



**Figure 18. Small Signal (G = 1, 10)**

## Typical Characteristics (continued)

at $T_A$ = 25°C and $V_S$ = ±15 V (unless otherwise noted)

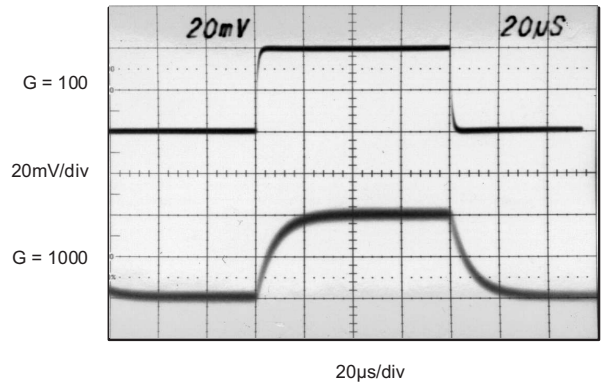



**Figure 19. Small Signal (G = 100, 1000)**

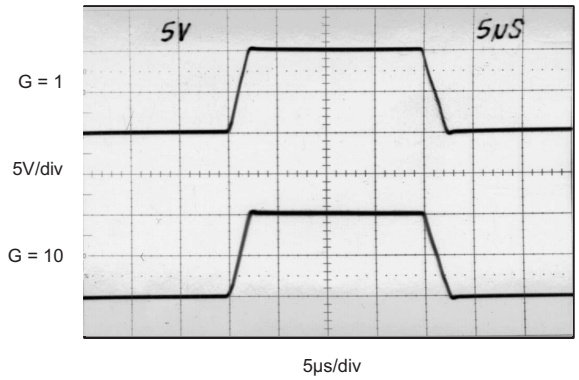



**Figure 20. Large Signal (G = 1, 10)**

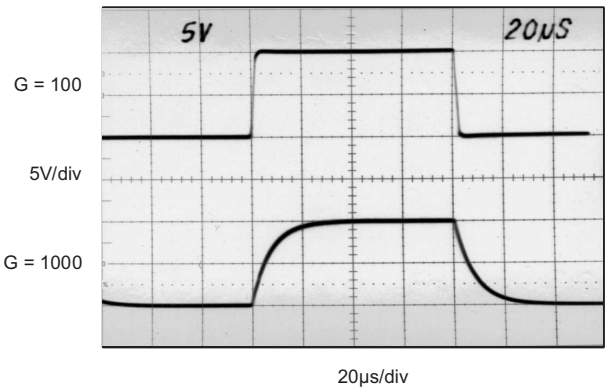



**Figure 21. Large Signal (G = 100, 1000)**

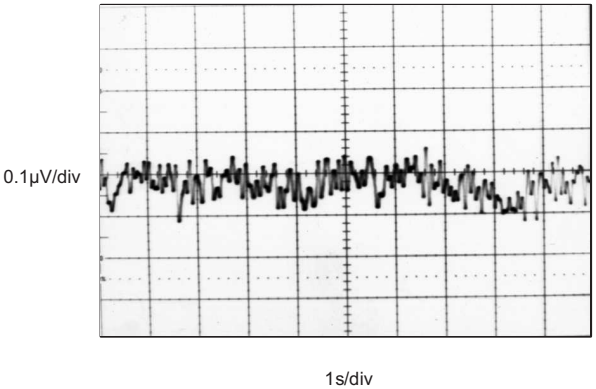


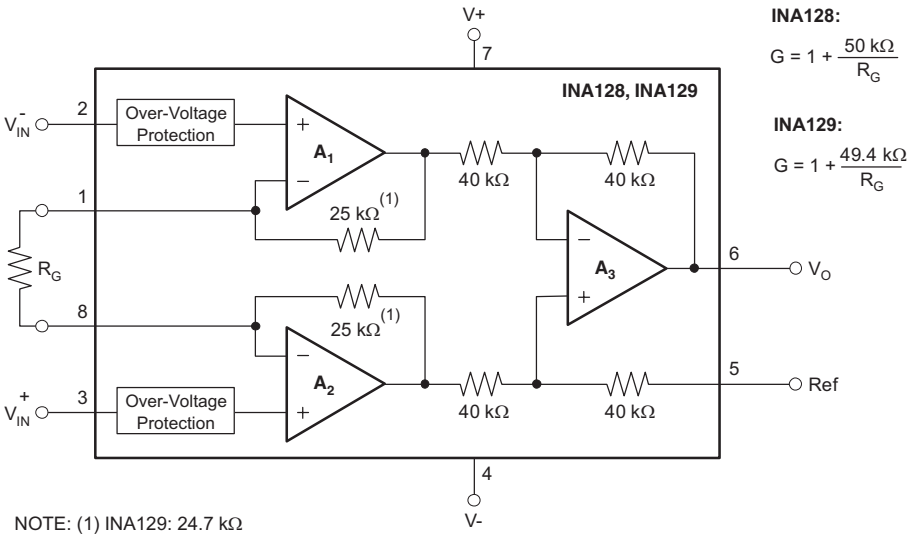

**Figure 22. Voltage Noise 0.1 to 10-Hz Input-Referred, G ≥ 100**

# 8 Detailed Description

## 8.1 Overview

The INA12x instrumentation amplifier is a type of differential amplifier that has been outfitted with input protection circuit and input buffer amplifiers, which eliminate the need for input impedance matching and make the amplifier particularly suitable for use in measurement and test equipment. Additional characteristics of the INA128 include a very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances. The INA12x is used where great accuracy and stability of the circuit both short and long term are required.

## 8.2 Functional Block Diagram



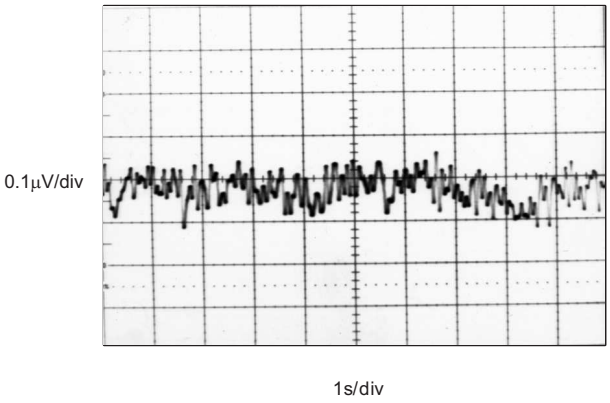

## 8.3 Feature Description

The INA12x devices are low power, general-purpose instrumentation amplifiers offering excellent accuracy. The versatile three-operational-amplifier design and small size make the amplifiers ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth, even at high gain. A single external resistor sets any gain from 1 to 10,000. The INA128 is laser trimmed for very low offset voltage (25 μV typical) and high common-mode rejection (93 dB at G ≥ 100). These devices operate with power supplies as low as ±2.25 V, and quiescent current of 2 mA, typically. The internal input protection can withstand up to ±40 V without damage.

## 8.4 Device Functional Modes

### 8.4.1 Noise Performance

The INA12x provides very low noise in most applications. Low-frequency noise is approximately 0.2 $\mu V_{PP}$ measured from 0.1 to 10 Hz (G ≥ 100). This provides dramatically improved noise when compared to state-of-the-art chopper-stabilized amplifiers.




G ≥ 100

**Figure 23. 0.1-Hz to 10-Hz Input-Referred Voltage Noise**

### 8.4.2 Input Common-Mode Range

The linear input voltage range of the input circuitry of the INA12x is from approximately 1.4 V below the positive supply voltage to 1.7 V above the negative supply. As a differential input voltage causes the output voltage increase, however, the linear input range is limited by the output voltage swing of amplifiers $A_1$ and $A_2$. Thus the linear common-mode input range is related to the output voltage of the complete amplifier. This behavior also depends on supply voltage (see performance curve Figure 6).

Input-overload can produce an output voltage that appears normal. For example, if an input overload condition drives both input amplifiers to their positive output swing limit, the difference voltage measured by the output amplifier will be near zero. The output of $A_3$ will be near 0 V even though both inputs are overloaded.

# 9 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. Customers should validate and test their design implementation to confirm system functionality.

## 9.1 Application Information

The INA12x measures small differential voltage with high common-mode voltage developed between the noninverting and inverting input. The high-input voltage protection circuit in conjunction with high input impedance make the INA12x suitable for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations.

## 9.2 Typical Application

Figure 24 shows the basic connections required for operation of the INA12x. 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 output reference (Ref) terminal which is normally grounded. This must be a low-impedance connection to assure good common-mode rejection. A resistance of 8 Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR (G = 1).

**INA128:** $G = 1 + \frac{50k}{R_G}$ **INA129:** $G = 1 + \frac{49.4k}{R_G}$

| DESIRED GAIN (V/V) | INA128 $R_G$ (Ω) | INA128 NEAREST 1% $R_G$ (Ω) | INA129 $R_G$ (Ω) | INA129 NEAREST 1% $R_G$ (Ω |
|---|---|---|---|---|
| 1 | NC | NC | NC | NC |
| 2 | 50.00k | 49.9k | 49.4k | 49.9k |
| 5 | 12.50k | 12.4k | 12.35k | 12.4k |
| 10 | 5.556k | 5.62k | 5489 | 5.49k |
| 20 | 2.632k | 2.61k | 2600 | 2.61k |
| 50 | 1.02k | 1.02k | 1008 | 1k |
| 100 | 505.1 | 511 | 499 | 499 |
| 200 | 251.3 | 249 | 248 | 249 |
| 500 | 100.2 | 100 | 99 | 100 |
| 1000 | 50.05 | 49.9 | 49.5 | 49.9 |
| 2000 | 25.01 | 24.9 | 24.7 | 24.9 |
| 5000 | 10.00 | 10 | 9.88 | 9.76 |
| 10000 | 5.001 | 4.99 | 4.94 | 4.87 |

NC: No Connection

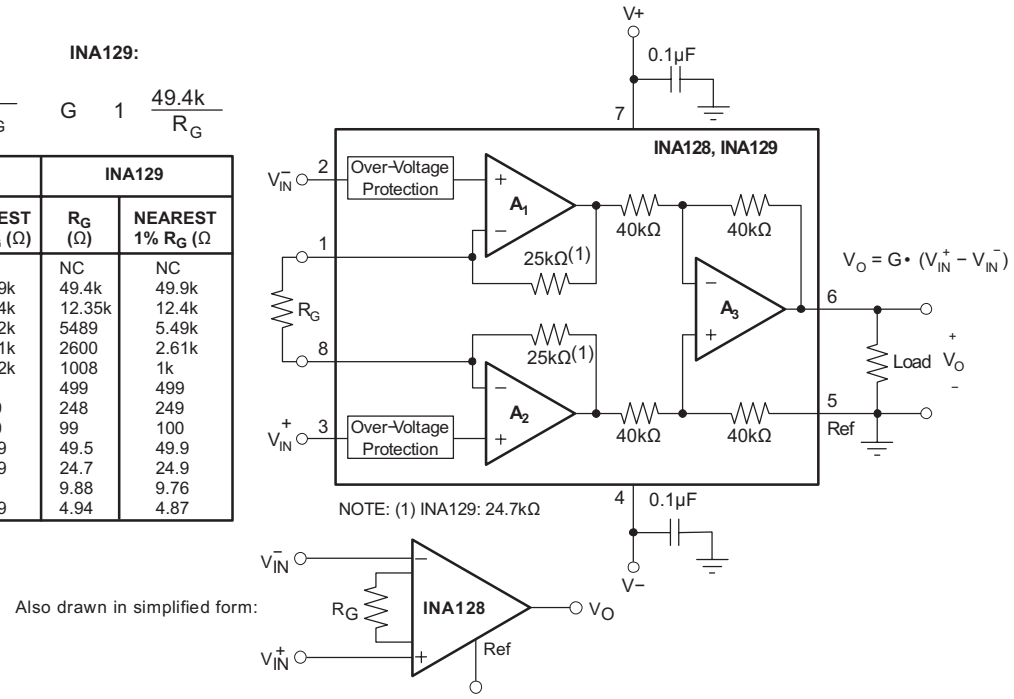



**Figure 24. Basic Connections**

## Typical Application (continued)

### 9.2.1 Design Requirements

The device can be configured to monitor the input differential voltage when the gain of the input signal is set by the external resistor $R_G$. The output signal references to the Ref pin. The most common application is where the output is referenced to ground when no input signal is present by connecting the Ref pin to ground, as Figure 24 shows. When the input signal increases, the output voltage at the OUT pin increases, too.

### 9.2.2 Detailed Design Procedure

#### *9.2.2.1 Setting the Gain*

Gain is set by connecting a single external resistor, $R_G$, connected between pins 1 and 8:

$$\text{INA128: } g = 1 + 50\ \text{k}\Omega/R_G \quad (1)$$

Commonly used gains and resistor values are shown in Figure 24.

The 50-kΩ term in Equation 1 comes from the sum of the two internal feedback resistors of $A_1$ and $A_2$. These on-chip metal film resistors are laser-trimmed to accurate absolute values. The accuracy and temperature coefficient of these internal resistors are included in the gain accuracy and drift specifications of the INA128.

The stability and temperature drift of the external gain setting resistor, $R_G$, also affects gain. The contribution of $R_G$ to gain accuracy and drift can be directly inferred from Equation 1. Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance, which contributes additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater.

#### *9.2.2.2 Dynamic Performance*

The typical performance curve *Figure 1* shows that, despite its low quiescent current, the INA12x achieves wide bandwidth even at high gain. This is due to the current-feedback topology of the input stage circuitry. Settling time also remains excellent at high gain.

#### *9.2.2.3 Offset Trimming*

The INA12x is laser-trimmed for low-offset voltage and offset voltage drift. Most applications require no external offset adjustment. Figure 25 shows an optional circuit for trimming the output offset voltage. The voltage applied to the Ref terminal is summed with the output. The op amp buffer provides low impedance at the Ref terminal to preserve good common-mode rejection.

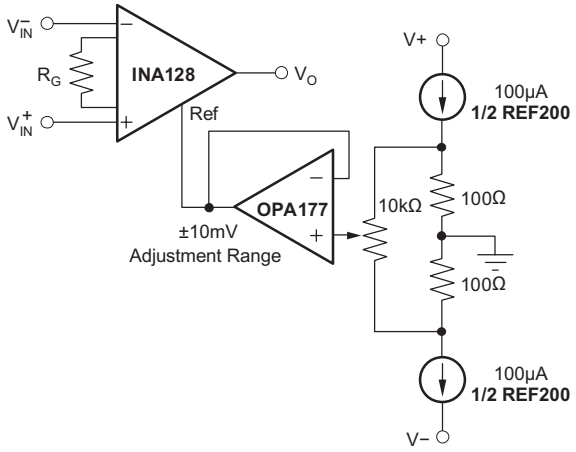



**Figure 25. Optional Trimming of Output Offset Voltage**

#### *9.2.2.4 Input Bias Current Return Path*

The input impedance of the INA12x is extremely high: approximately $10^{10}$ Ω. However, a path must be provided for the input bias current of both inputs. This input bias current is approximately ±2 nA. High input impedance means that this input bias current changes very little with varying input voltage.

## Typical Application (continued)

Input circuitry must provide a path for this input bias current for proper operation. Figure 26 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 26). 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.

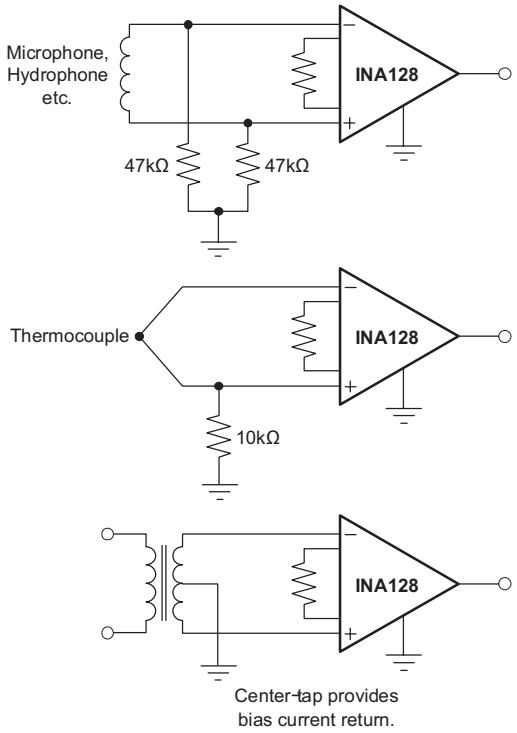
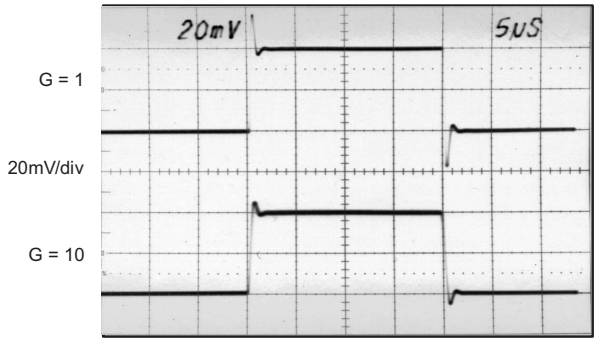



**Figure 26. Providing an Input Common-Mode Current Path**

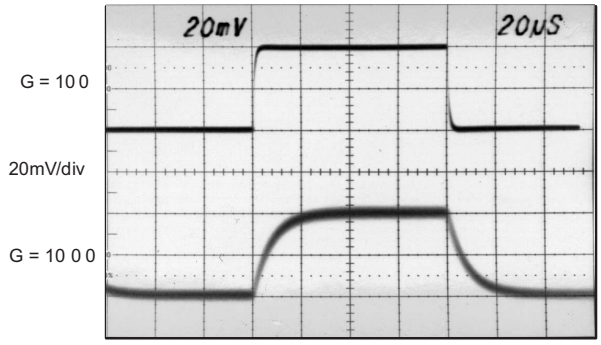
## Typical Application (continued)

### 9.2.3 Application Curves



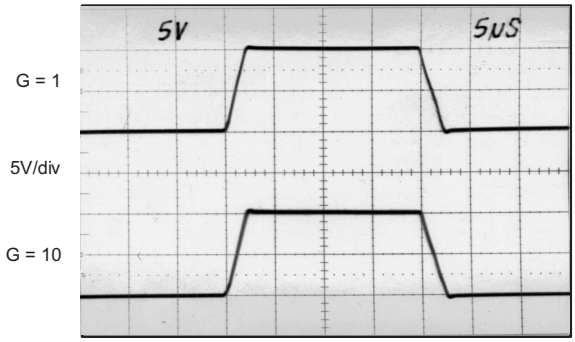

5µs/div
G = 1, 10

**Figure 27. Small Signal**



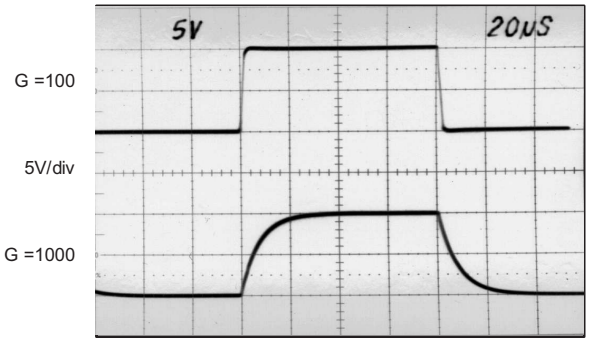

20µs/div
G = 100, 1000

**Figure 28. Small Signal**




5µs/div
G = 1, 10

**Figure 29. Large Signal**




20µs/div
G = 100, 1000

**Figure 30. Large Signal**

# 10 Power Supply Recommendations

The minimum power supply voltage for INA12x is ±2.25 V and the maximum power supply voltage is ±18 V. This minimum and maximum range covers a wide range of power supplies; but for optimum performance, ±15 V is recommended. TI recommends adding a bypass capacitor at the input to compensate for the layout and power supply source impedance.

## 10.1 Low Voltage Operation

The INA12x can be operated on power supplies as low as ±2.25 V. Performance remains excellent with power supplies ranging from ±2.25 V to ±18 V. Most parameters vary only slightly throughout this supply voltage range—see *Typical Characteristics*.

Operation at very low supply voltage requires careful attention to assure that the input voltages remain within their linear range. Voltage swing requirements of internal nodes limit the input common-mode range with low power supply voltage. Figure 6 shows the range of linear operation for ±15-V, ±5-V, and ±2.5-V supplies.

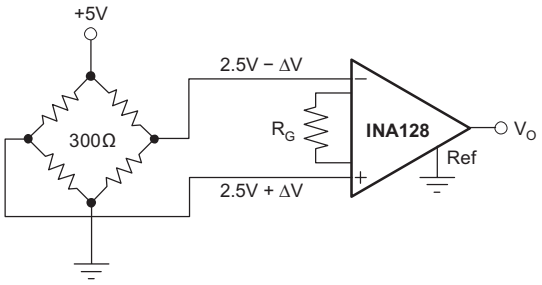



**Figure 31. Bridge Amplifier**

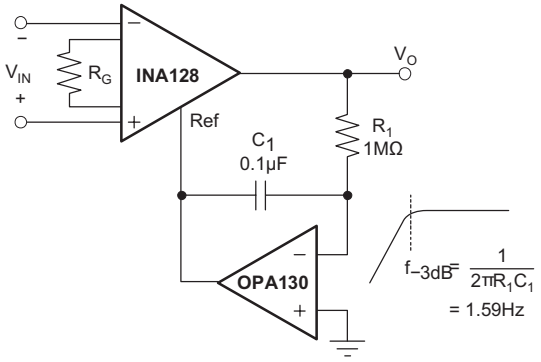
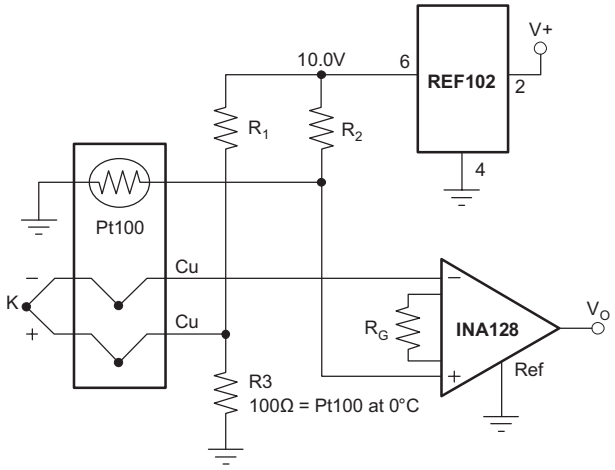


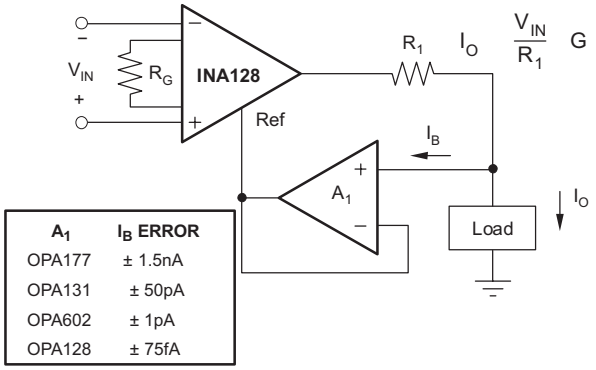

**Figure 32. AC-Coupled Instrumentation Amplifier**

## Low Voltage Operation (continued)




| ISA TYPE | MATERIAL | SEEBECK COEFFICIENT (μV/°C) | $R_1$, $R_2$ |
|---|---|---|---|
| E | + Chromel<br>− Constantan | 58.5 | 66.5kΩ |
| J | + Iron<br>− Constantan | 50.2 | 76.8kΩ |
| K | + Chromel<br>− Alumel | 39.4 | 97.6kΩ |
| T | + Copper<br>− Constantan | 38.0 | 102kΩ |

**Figure 33. Thermocouple Amplifier With RTD Cold-Junction Compensation**




| $A_1$ | $I_B$ ERROR |
|---|---|
| OPA177 | ± 1.5nA |
| OPA131 | ± 50pA |
| OPA602 | ± 1pA |
| OPA128 | ± 75fA |

**Figure 34. Differential Voltage to Current Converter**

### Low Voltage Operation (continued)

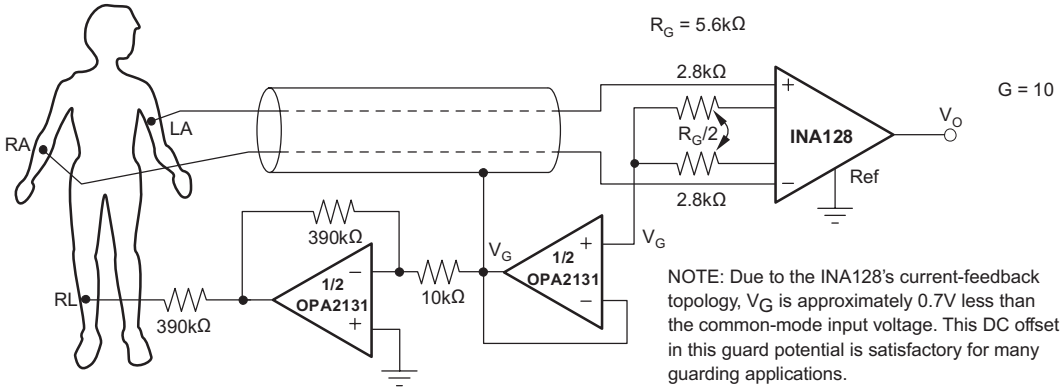



**Figure 35. ECG Amplifier With Right-Leg Drive**

## 11 Layout

### 11.1 Layout Guidelines

Place the power-supply bypass capacitor as closely as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1 μF to 1 μF. If necessary, additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies. These decoupling capacitors must be placed between the power supply and INA12x devices.

The gain resistor must be placed close to pin 1 and pin 8. This placement limits the layout loop and minimizes any noise coupling into the part.

### 11.2 Layout Example

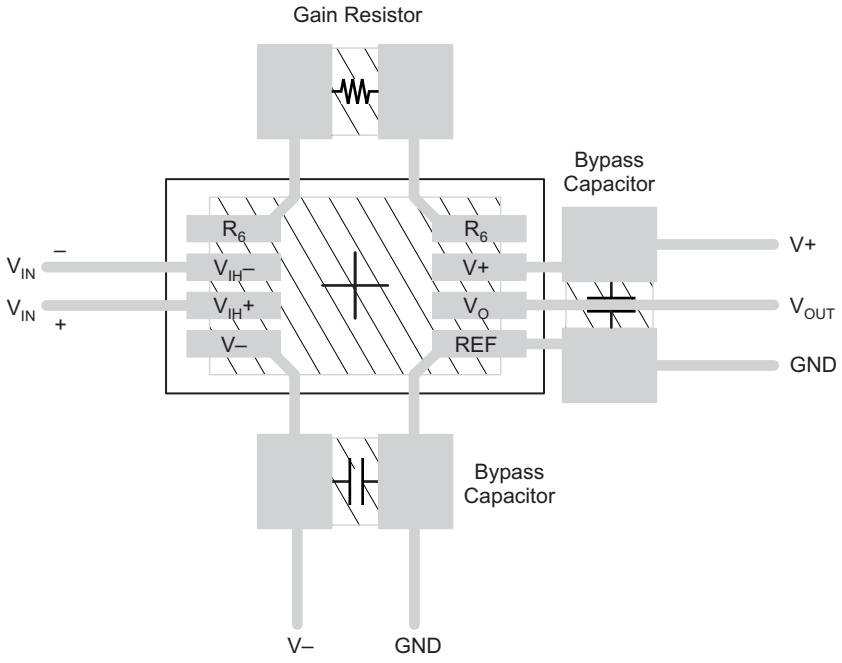



**Figure 36. Recommended Layout**

# 12 Device and Documentation Support

## 12.1 Related Links

Table 1 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 1. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| INA128 | Click here | Click here | Click here | Click here | Click here |
| INA129 | Click here | Click here | Click here | Click here | Click here |

## 12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

## 12.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

**TI E2E™ Online Community** ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

## 12.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

## 12.5 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## 12.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

# 13 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.

www.ti.com

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | O |
|---|---|---|---|---|---|---|---|---|---|
| INA128P | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |
| INA128PA | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |
| INA128PG4 | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |
| INA128U | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128U/2K5 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128U/2K5G4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UA | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UA/2K5 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UA/2K5E4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UA/2K5G4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UAE4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UAG4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA128UG4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129P | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |
| INA129PA | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |

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| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | O |
|---|---|---|---|---|---|---|---|---|---|
| INA129PG4 | ACTIVE | PDIP | P | 8 | 50 | RoHS & Green | NIPDAU | N / A for Pkg Type | |
| INA129U | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129U/2K5 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129UA | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129UA/2K5 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129UA/2K5G4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |
| INA129UAE4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | |

**(1)** The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

**(2)** **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including t
do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in sp
reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000pp
flame retardants must also meet the <=1000ppm threshold requirement.

**(3)** MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

**(4)** There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a li
of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/B
lines if the finish value exceeds the maximum column width.



**OTHER QUALIFIED VERSIONS OF INA128, INA129 :**

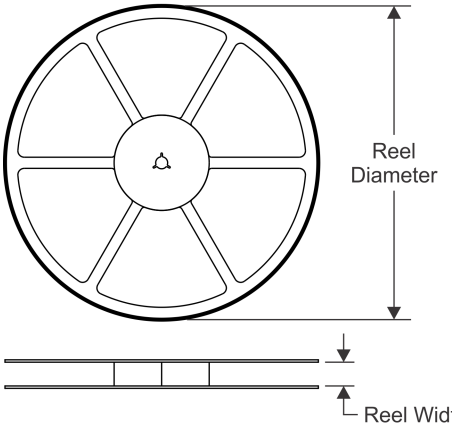
- Enhanced Product: INA129-EP

NOTE: Qualified Version Definitions:

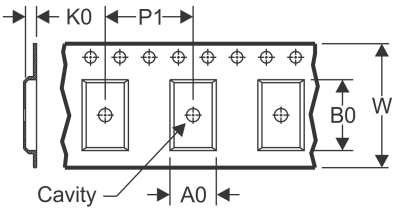
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

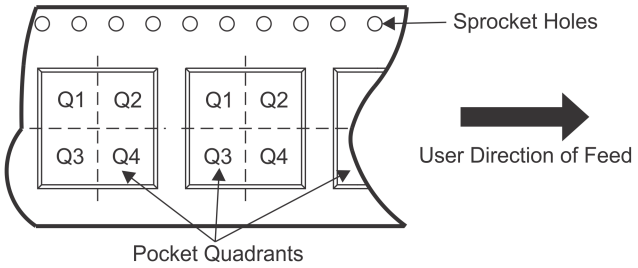



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

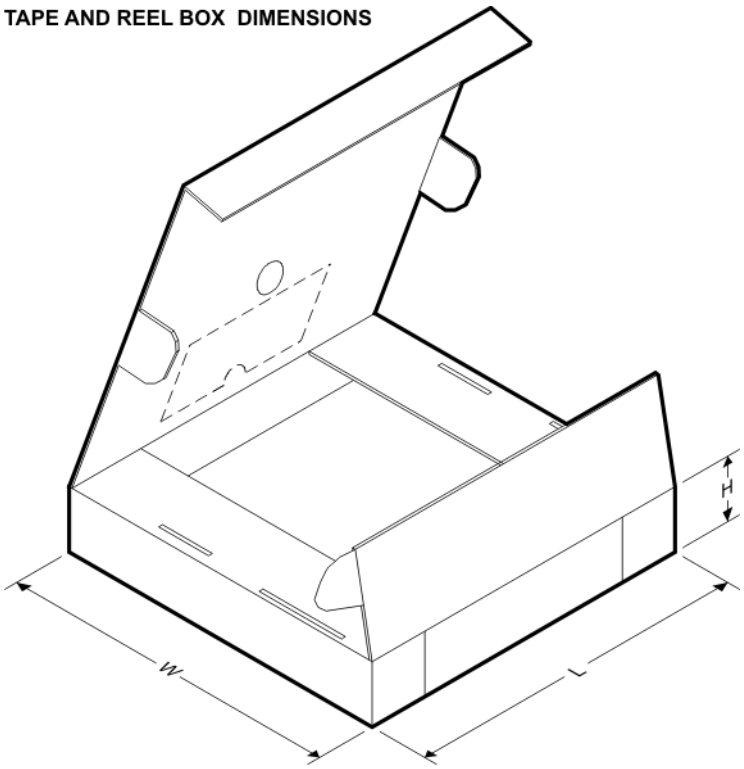
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA128U/2K5 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| INA128UA/2K5 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| INA129U/2K5 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| INA129UA/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

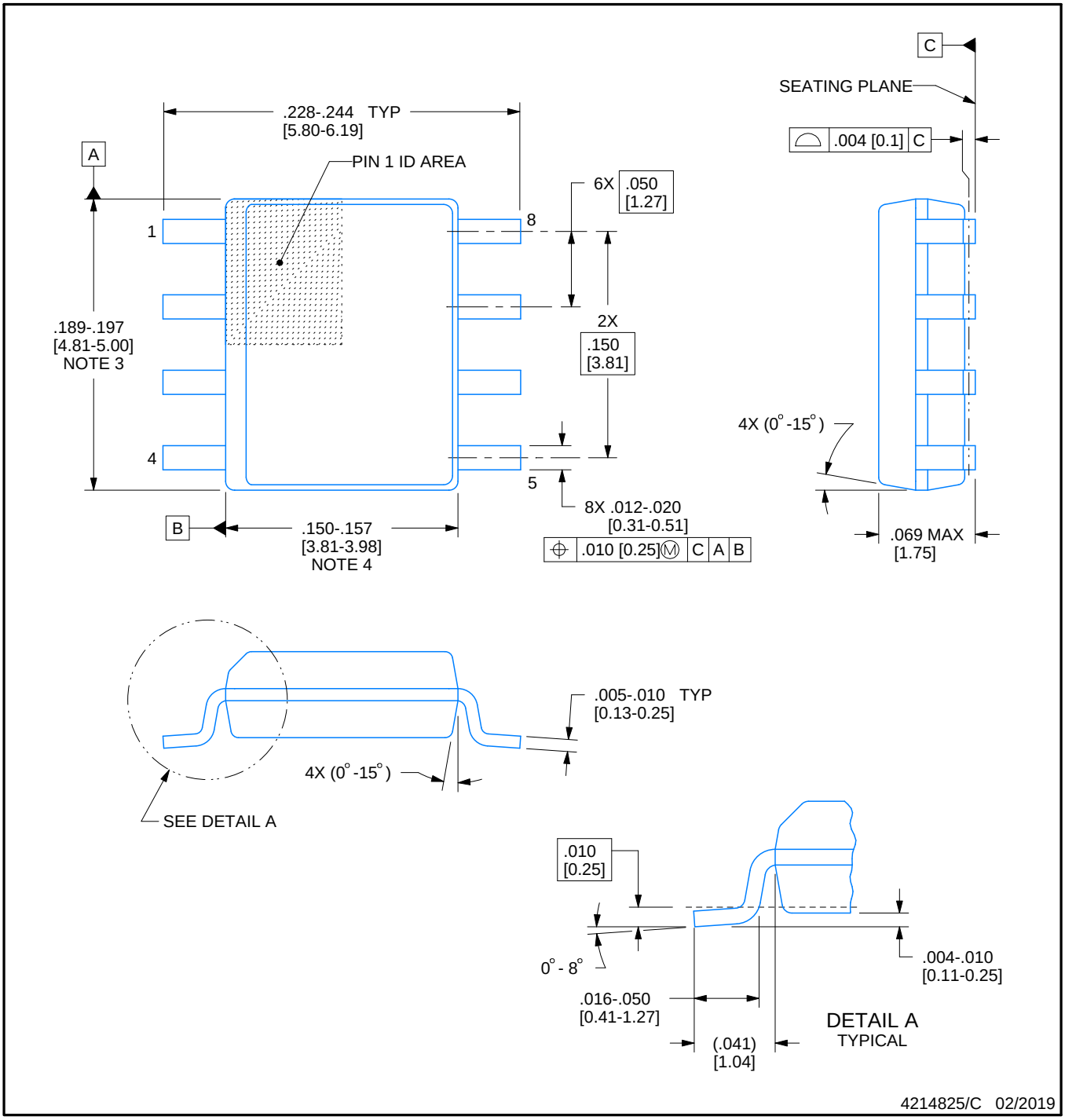
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA128U/2K5 | SOIC | D | 8 | 2500 | 853.0 | 449.0 | 35.0 |
| INA128UA/2K5 | SOIC | D | 8 | 2500 | 853.0 | 449.0 | 35.0 |
| INA129U/2K5 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| INA129UA/2K5 | SOIC | D | 8 | 2500 | 853.0 | 449.0 | 35.0 |

# PACKAGE OUTLINE

## D0008A

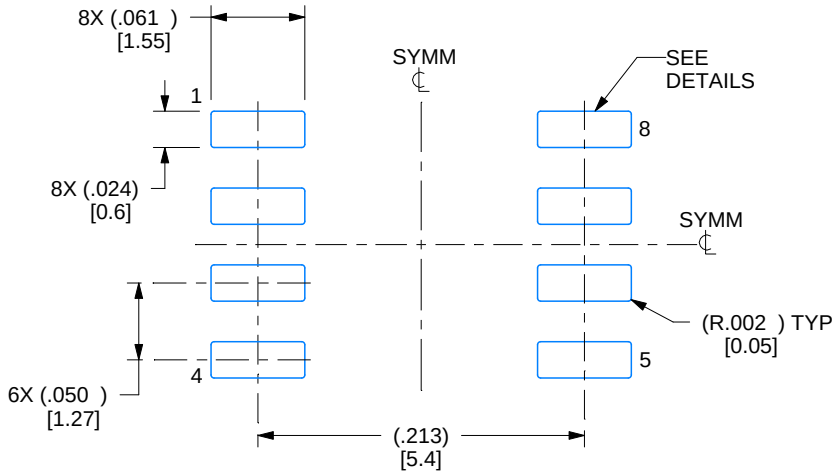
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

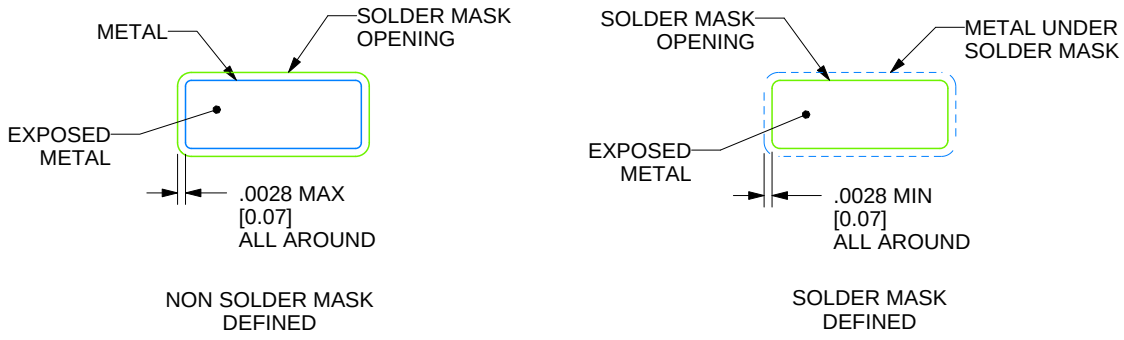



NOTES:

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)

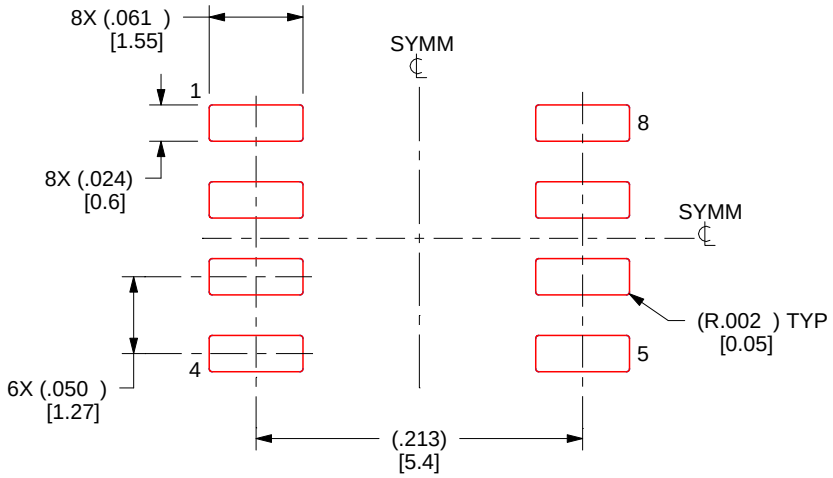
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

## D0008A

## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



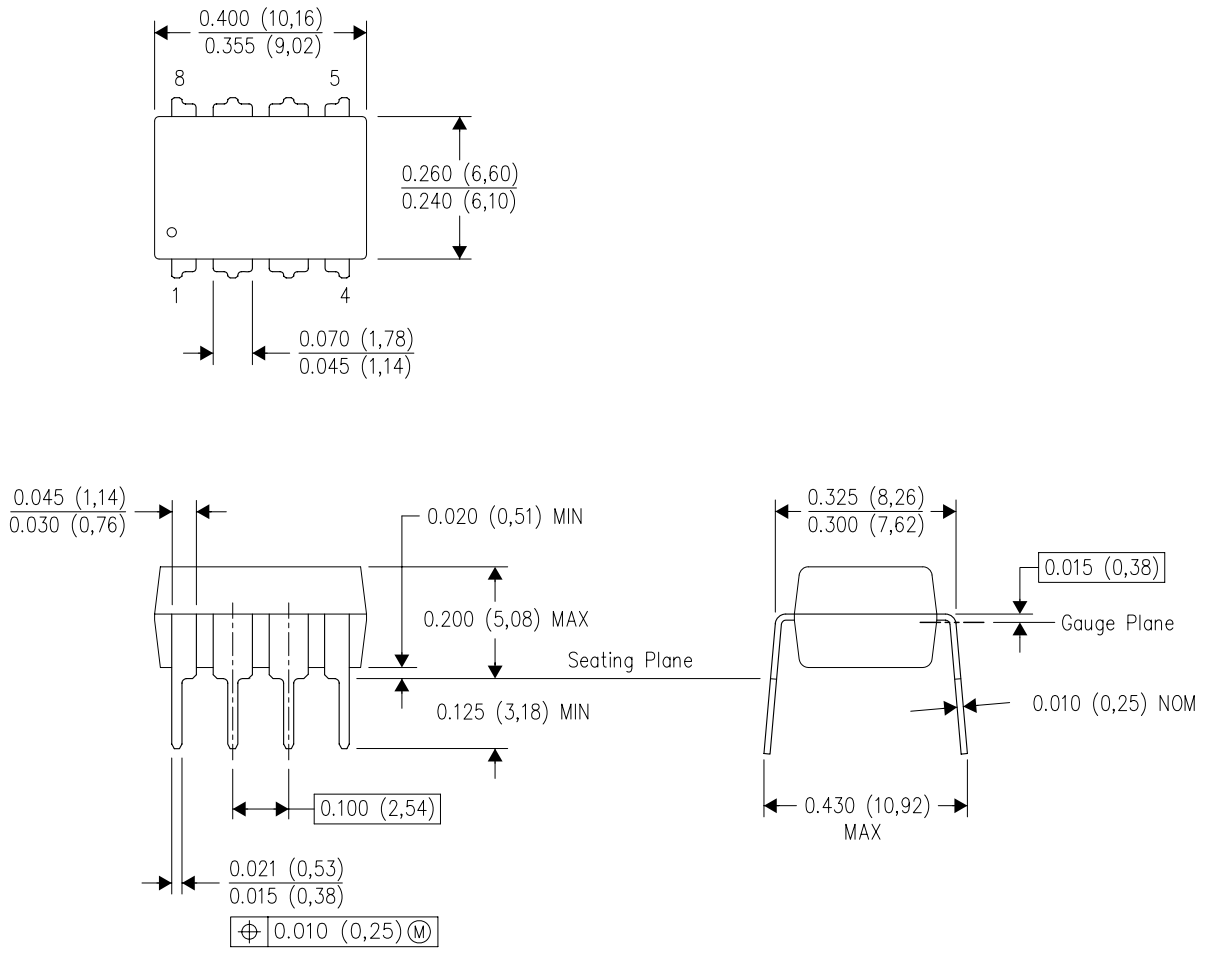

SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

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




4040082/E 04/2010

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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