

# INA128 INA129

## Precision, Low Power INSTRUMENTATION AMPLIFIERS

### FEATURES

- **LOW OFFSET VOLTAGE:** 50µV max
- **LOW DRIFT:** 0.5µV/°C max
- **LOW INPUT BIAS CURRENT:** 5nA max
- **HIGH CMR:** 120dB min
- **INPUTS PROTECTED TO ±40V**
- **WIDE SUPPLY RANGE:** ±2.25 to ±18V
- **LOW QUIESCENT CURRENT:** 700µA
- **8-PIN PLASTIC DIP, SO-8**

### APPLICATIONS

- **BRIDGE AMPLIFIER**
- **THERMOCOUPLE AMPLIFIER**
- **RTD SENSOR AMPLIFIER**
- **MEDICAL INSTRUMENTATION**
- **DATA ACQUISITION**

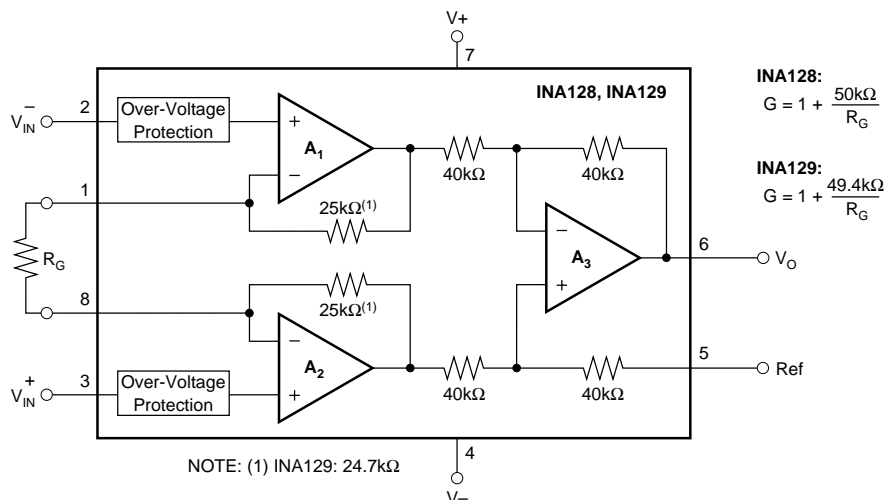
### DESCRIPTION

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

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

The INA128/INA129 is laser trimmed for very low offset voltage (50µV), drift (0.5µV/°C) and high common-mode rejection (120dB at G ≥ 100). It operates with power supplies as low as ±2.25V, and quiescent current is only 700µA—ideal for battery operated systems. Internal input protection can withstand up to ±40V without damage.

The INA128/INA129 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 dual configuration, the INA2128.



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# SPECIFICATIONS

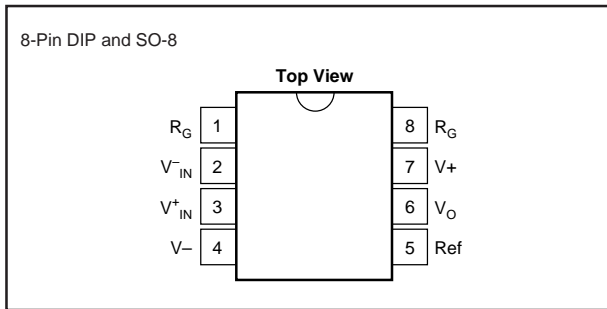
At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

| PARAMETER  | CONDITIONS  | INA128P, U<br>INA129P, U |  |                    | INA128PA, UA<br>INA129PA, UA |                    |                      | UNITS                        |
|--|---|--------------------------|--|--------------------|------------------------------|--------------------|----------------------|------------------------------|
|  |   | MIN                      | TYP  | MAX                | MIN                          | TYP                | MAX                  |                              |
| <b>INPUT</b>   |   |                          |  |                    |                              |                    |                      |                              |
| Offset Voltage, RTI<br>Initial                                 | $T_A = +25^\circ\text{C}$   |                          | $\pm 10 \pm 100/G$   | $\pm 50 \pm 500/G$ |                              | $\pm 25 \pm 100/G$ | $\pm 125 \pm 1000/G$ | $\mu\text{V}$                |
| vs Temperature   | $T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$                 |                          | $\pm 0.2 \pm 2/G$  | $\pm 0.5 \pm 20/G$ |                              | $\pm 0.2 \pm 5/G$  | $\pm 1 \pm 20/G$     | $\mu\text{V}/^\circ\text{C}$ |
| vs Power Supply  | $V_S = \pm 2.25\text{V to } \pm 18\text{V}$                       |                          | $\pm 0.2 \pm 20/G$   | $\pm 1 \pm 100/G$  |                              | *                  | $\pm 2 \pm 200/G$    | $\mu\text{V/V}$              |
| Long-Term Stability  |   |                          | $\pm 0.1 \pm 3/G$  |                    |                              | *                  |                      | $\mu\text{V}/\text{mo}$      |
| Impedance, Differential  |   |                          | $10^{10} \parallel 2$  |                    |                              | *                  |                      | $\Omega \parallel \text{pF}$ |
| Common-Mode  |   |                          | $10^{11} \parallel 9$  |                    |                              | *                  |                      | $\Omega \parallel \text{pF}$ |
| Common-Mode Voltage Range <sup>(1)</sup>                       | $V_O = 0\text{V}$   | $(V+) - 2$<br>$(V-) + 2$ | $(V+) - 1.4$<br>$(V-) + 1.7$                                   |                    | *                            | *                  |                      | V                            |
| Safe Input Voltage   |   |                          |  | $\pm 40$           | *                            | *                  |                      | V                            |
| Common-Mode Rejection  | $V_{\text{CM}} = \pm 13\text{V}$ , $\Delta R_S = 1\text{k}\Omega$ |                          |  |                    |                              |                    | *                    | V                            |
|  | G=1   | 80                       | 86   |                    | 73                           | *                  |                      | dB                           |
|  | G=10  | 100                      | 106  |                    | 93                           | *                  |                      | dB                           |
|  | G=100   | 120                      | 125  |                    | 110                          | *                  |                      | dB                           |
|  | G=1000  | 120                      | 130  |                    | 110                          | *                  |                      | dB                           |
| <b>BIAS CURRENT</b>  |   |                          | $\pm 2$  | $\pm 5$            |                              | *                  | $\pm 10$             | nA                           |
| vs Temperature   |   |                          | $\pm 30$   |                    |                              | *                  |                      | $\text{pA}/^\circ\text{C}$   |
| Offset Current   |   |                          | $\pm 1$  | $\pm 5$            |                              | *                  | $\pm 10$             | nA                           |
| vs Temperature   |   |                          | $\pm 30$   |                    |                              | *                  |                      | $\text{pA}/^\circ\text{C}$   |
| <b>NOISE VOLTAGE, RTI</b>                                      | $G = 1000$ , $R_S = 0\Omega$                                      |                          |  |                    |                              |                    |                      |                              |
| f = 10Hz   |   |                          | 10   |                    |                              | *                  |                      | $\text{nV}/\sqrt{\text{Hz}}$ |
| f = 100Hz  |   |                          | 8  |                    |                              | *                  |                      | $\text{nV}/\sqrt{\text{Hz}}$ |
| f = 1kHz   |   |                          | 8  |                    |                              | *                  |                      | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f_B = 0.1\text{Hz to } 10\text{Hz}$                           |   |                          | 0.2  |                    |                              | *                  |                      | $\mu\text{Vp-p}$             |
| Noise Current  |   |                          |  |                    |                              |                    |                      |                              |
| f=10Hz   |   |                          | 0.9  |                    |                              | *                  |                      | $\text{pA}/\sqrt{\text{Hz}}$ |
| f=1kHz   |   |                          | 0.3  |                    |                              | *                  |                      | $\text{pA}/\sqrt{\text{Hz}}$ |
| $f_B = 0.1\text{Hz to } 10\text{Hz}$                           |   |                          | 30   |                    |                              | *                  |                      | $\text{pAp-p}$               |
| <b>GAIN</b>  |   |                          |  |                    |                              |                    |                      |                              |
| Gain Equation, INA128<br>INA129                                |   |                          | $1 + (50\text{k}\Omega/R_G)$<br>$1 + (49.4\text{k}\Omega/R_G)$ |                    |                              | *                  |                      | V/V                          |
| Range of Gain  |   | 1                        |  | 10000              | *                            | *                  | *                    | V/V                          |
| Gain Error   | G=1   |                          | $\pm 0.01$   | $\pm 0.024$        |                              | *                  | $\pm 0.1$            | %                            |
|  | G=10  |                          | $\pm 0.02$   | $\pm 0.4$          |                              | *                  | $\pm 0.5$            | %                            |
|  | G=100   |                          | $\pm 0.05$   | $\pm 0.5$          |                              | *                  | $\pm 0.7$            | %                            |
|  | G=1000  |                          | $\pm 0.5$  | $\pm 1$            |                              | *                  | $\pm 2$              | %                            |
| Gain vs Temperature <sup>(2)</sup>                             | G=1   |                          | $\pm 1$  | $\pm 10$           |                              | *                  | *                    | $\text{ppm}/^\circ\text{C}$  |
| 50k $\Omega$ (or 49.4k $\Omega$ ) Resistance <sup>(2, 3)</sup> |   |                          | $\pm 25$   | $\pm 100$          |                              | *                  | *                    | $\text{ppm}/^\circ\text{C}$  |
| Nonlinearity   | $V_O = \pm 13.6\text{V}$ , G=1                                    |                          | $\pm 0.0001$   | $\pm 0.001$        |                              | *                  | $\pm 0.002$          | % of FSR                     |
|  | G=10  |                          | $\pm 0.0003$   | $\pm 0.002$        |                              | *                  | $\pm 0.004$          | % of FSR                     |
|  | G=100   |                          | $\pm 0.0005$   | $\pm 0.002$        |                              | *                  | $\pm 0.004$          | % of FSR                     |
|  | G=1000  |                          | $\pm 0.001$  | (Note 4)           |                              | *                  | *                    | % of FSR                     |
| <b>OUTPUT</b>  |   |                          |  |                    |                              |                    |                      |                              |
| Voltage: Positive  | $R_L = 10\text{k}\Omega$  | $(V+) - 1.4$             | $(V+) - 0.9$   |                    | *                            | *                  |                      | V                            |
| Negative   | $R_L = 10\text{k}\Omega$  | $(V-) + 1.4$             | $(V-) + 0.8$   |                    | *                            | *                  |                      | V                            |
| Load Capacitance Stability                                     |   |                          | 1000   |                    |                              | *                  |                      | pF                           |
| Short-Circuit Current  |   |                          | +6/-15   |                    |                              | *                  |                      | mA                           |
| <b>FREQUENCY RESPONSE</b>                                      |   |                          |  |                    |                              |                    |                      |                              |
| Bandwidth, -3dB  | G=1   |                          | 1.3  |                    |                              | *                  |                      | MHz                          |
|  | G=10  |                          | 700  |                    |                              | *                  |                      | kHz                          |
|  | G=100   |                          | 200  |                    |                              | *                  |                      | kHz                          |
|  | G=1000  |                          | 20   |                    |                              | *                  |                      | kHz                          |
| Slew Rate  | $V_O = \pm 10\text{V}$ , G=10                                     |                          | 4  |                    |                              | *                  |                      | V/ $\mu\text{s}$             |
| Settling Time, 0.01%   | G=1   |                          | 7  |                    |                              | *                  |                      | $\mu\text{s}$                |
|  | G=10  |                          | 7  |                    |                              | *                  |                      | $\mu\text{s}$                |
|  | G=100   |                          | 9  |                    |                              | *                  |                      | $\mu\text{s}$                |
|  | G=1000  |                          | 80   |                    |                              | *                  |                      | $\mu\text{s}$                |
| Overload Recovery  | 50% Overdrive   |                          | 4  |                    |                              | *                  |                      | $\mu\text{s}$                |
| <b>POWER SUPPLY</b>  |   |                          |  |                    |                              |                    |                      |                              |
| Voltage Range  |   | $\pm 2.25$               | $\pm 15$   | $\pm 18$           | *                            | *                  | *                    | V                            |
| Current, Total   | $V_{\text{IN}} = 0\text{V}$                                       |                          | $\pm 700$  | $\pm 750$          |                              | *                  | *                    | $\mu\text{A}$                |
| <b>TEMPERATURE RANGE</b>                                       |   |                          |  |                    |                              |                    |                      |                              |
| Specification  |   | -40                      |  | 85                 | *                            |                    | *                    | $^\circ\text{C}$             |
| Operating  |   | -40                      |  | 125                | *                            |                    | *                    | $^\circ\text{C}$             |
| $\theta_{\text{JA}}$ 8-Pin Dip                                 |   |                          | 80   |                    |                              | *                  |                      | $^\circ\text{C}/\text{W}$    |
| SO-8 SOIC  |   |                          | 150  |                    |                              | *                  |                      | $^\circ\text{C}/\text{W}$    |

\* Specification same as INA128P, U or INA129P, U.

NOTE: (1) Input common-mode range varies with output voltage—see typical curves. (2) Guaranteed by wafer test. (3) Temperature coefficient of the 50k $\Omega$  (or 49.4k $\Omega$ ) term in the gain equation. (4) Nonlinearity measurements in G = 1000 are dominated by noise. Typical nonlinearity is  $\pm 0.001\%$ .

## PIN CONFIGURATION



## ABSOLUTE MAXIMUM RATINGS

|   |                 |
|---|-----------------|
| Supply Voltage .....                    | ±18V            |
| Analog Input Voltage Range .....        | ±40V            |
| Output Short-Circuit (to ground) .....  | Continuous      |
| Operating Temperature .....             | -40°C to +125°C |
| Storage Temperature .....               | -40°C to +125°C |
| Junction Temperature .....              | +150°C          |
| Lead Temperature (soldering, 10s) ..... | +300°C          |



## 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.

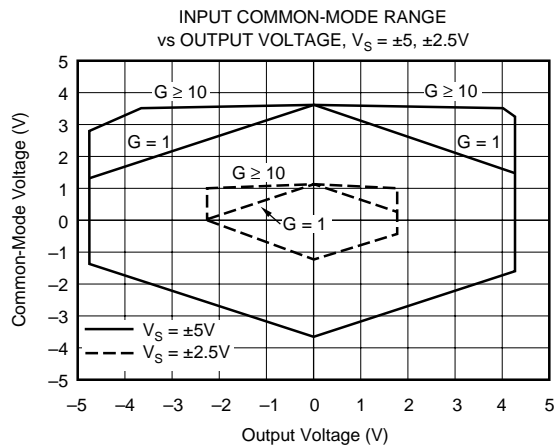
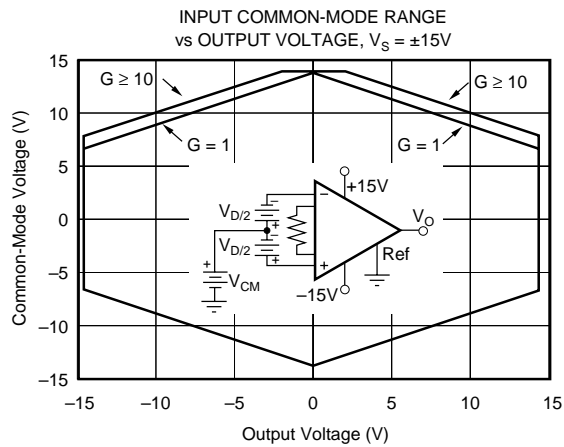
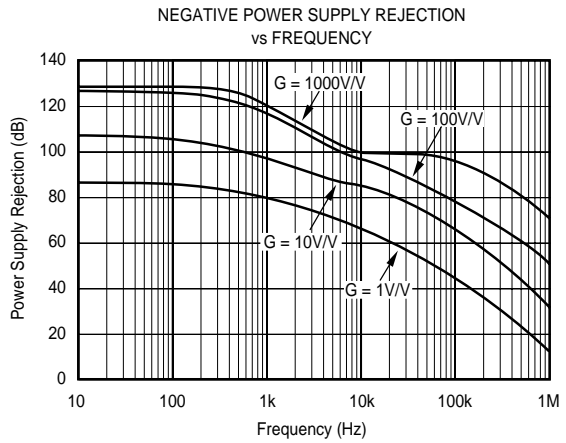
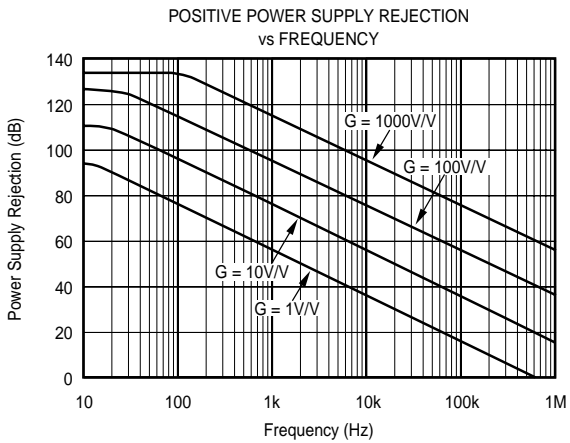
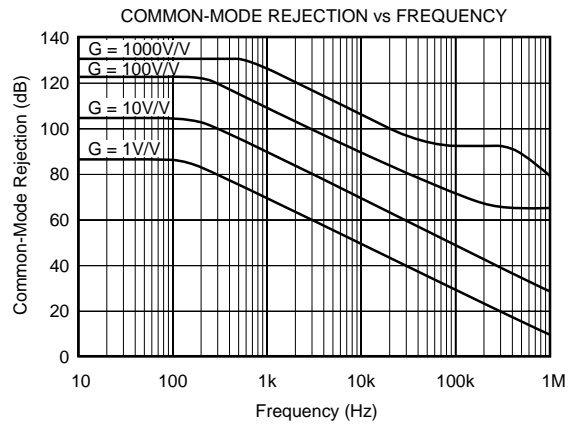
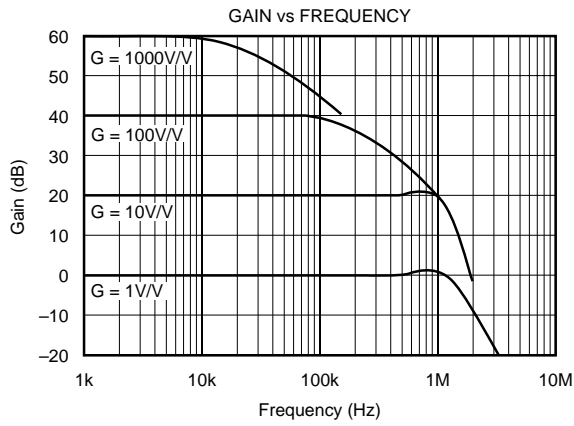
## ORDERING INFORMATION

| PRODUCT  | PACKAGE            | PACKAGE DRAWING NUMBER <sup>(1)</sup> | TEMPERATURE RANGE |
|----------|--------------------|---------------------------------------|-------------------|
| INA128PA | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA128P  | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA128UA | SO-8 Surface-Mount | 182                                   | -40°C to +85°C    |
| INA128U  | SO-8 Surface-Mount | 182                                   | -40°C to +85°C    |
| INA129PA | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA129P  | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA129UA | SO-8 Surface-Mount | 182                                   | -40°C to +85°C    |
| INA129U  | SO-8 Surface-Mount | 182                                   | -40°C to +85°C    |

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

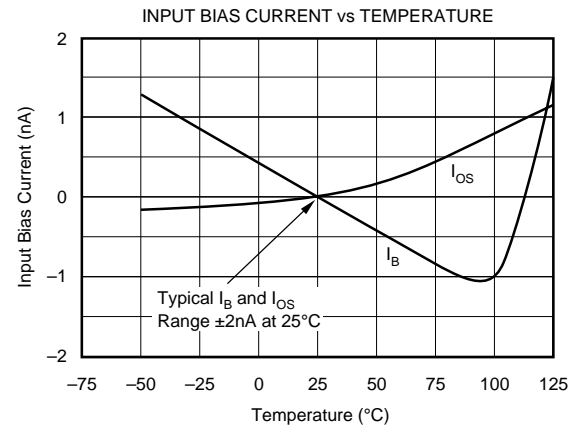
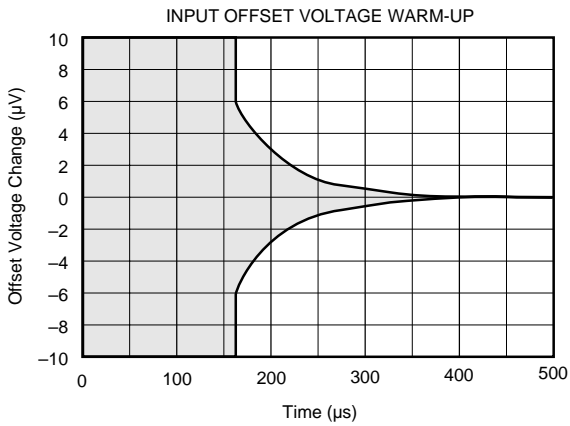
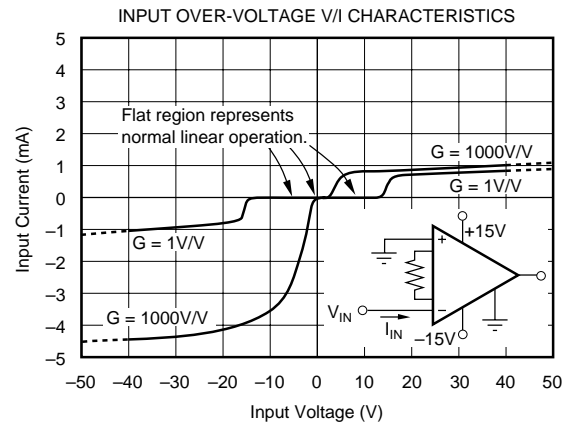
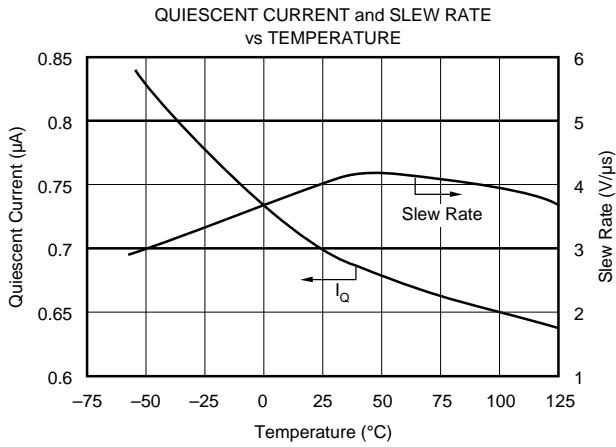
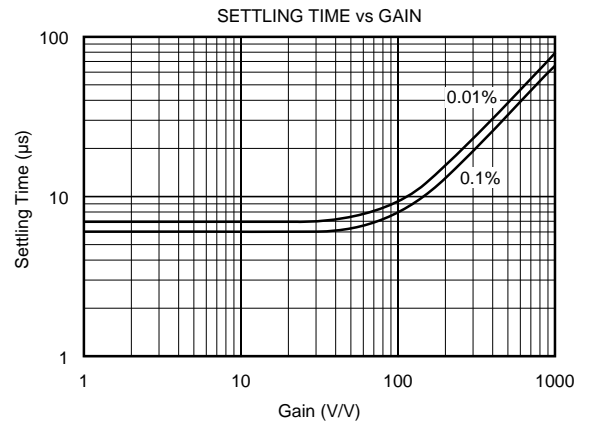
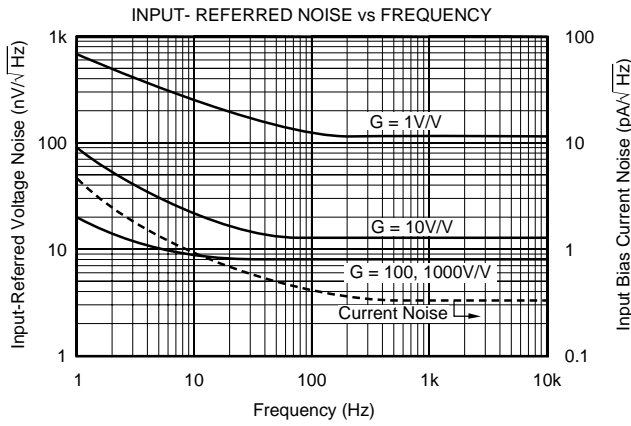
# TYPICAL PERFORMANCE CURVES

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



# TYPICAL PERFORMANCE CURVES (CONT)

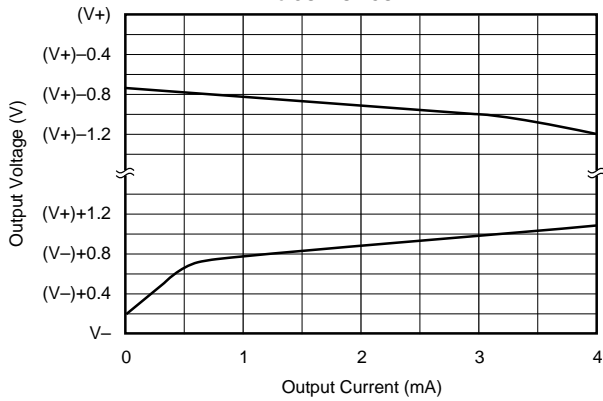
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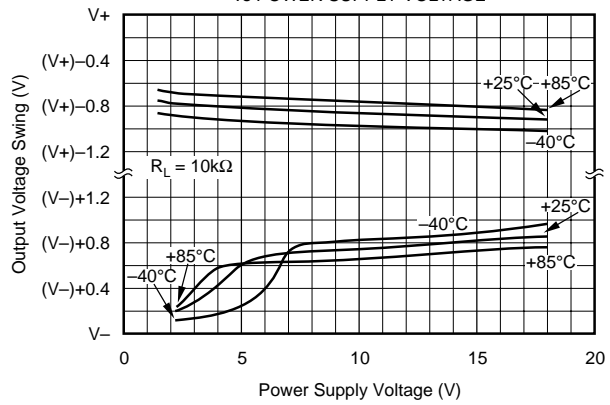
# TYPICAL PERFORMANCE CURVES (CONT)

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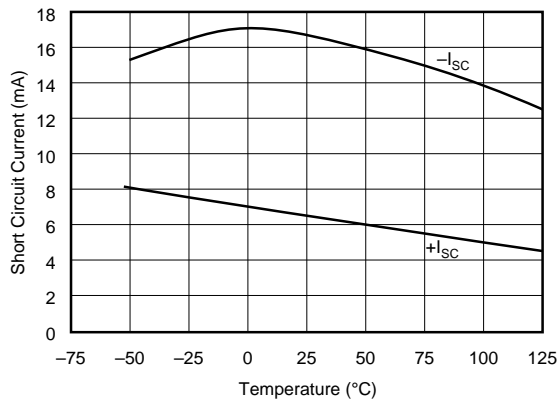
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



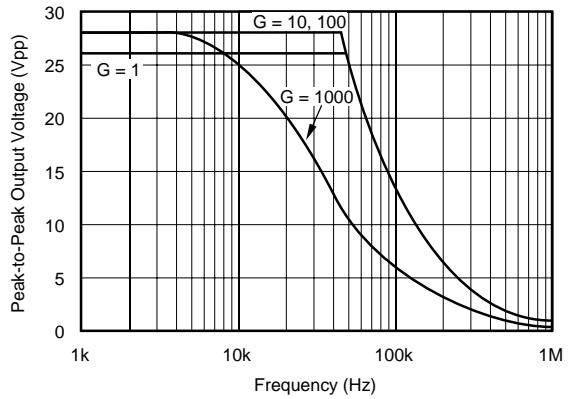
OUTPUT VOLTAGE SWING vs POWER SUPPLY VOLTAGE



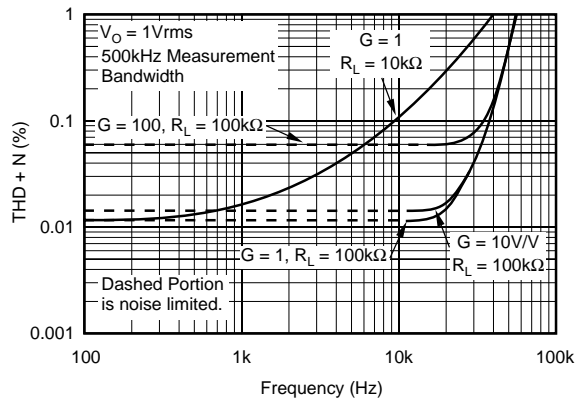
SHORT-CIRCUIT OUTPUT CURRENT vs TEMPERATURE



MAXIMUM OUTPUT VOLTAGE vs FREQUENCY

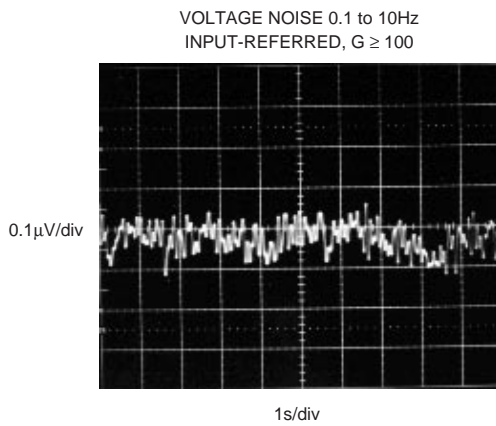
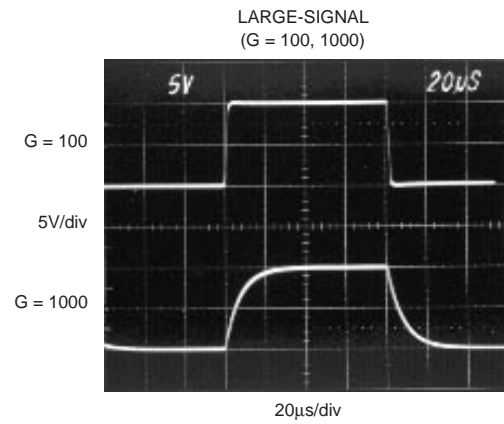
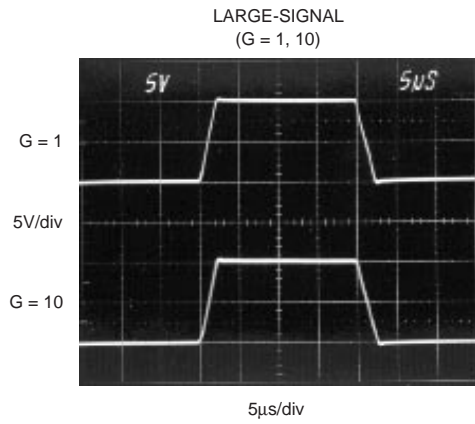
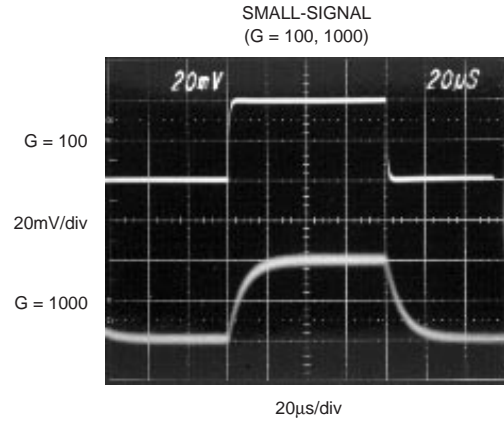
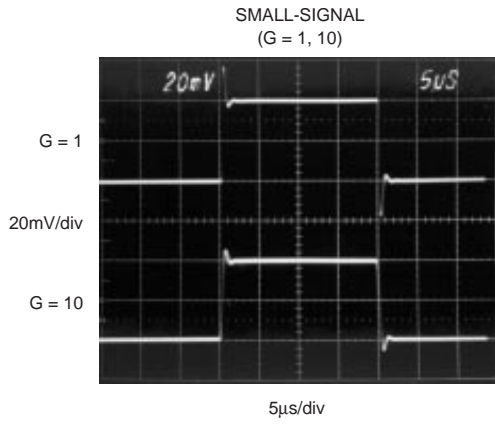


TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



# TYPICAL PERFORMANCE CURVES (CONT)

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



# APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA128/INA129. 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 8Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR ( $G = 1$ ).

## SETTING THE GAIN

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

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

$$\text{INA129: } G = 1 + \frac{49.4\text{k}\Omega}{R_G} \quad (2)$$

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

The 50kΩ term in Equation 1 (49.4kΩ in Equation 2) 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/INA129.

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

## DYNAMIC PERFORMANCE

The typical performance curve "Gain vs Frequency" shows that, despite its low quiescent current, the INA128/INA129 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.

## NOISE PERFORMANCE

The INA128/INA129 provides very low noise in most applications. Low frequency noise is approximately 0.2μVp-p measured from 0.1 to 10Hz ( $G \geq 100$ ). This provides dramatically improved noise when compared to state-of-the-art chopper-stabilized amplifiers.

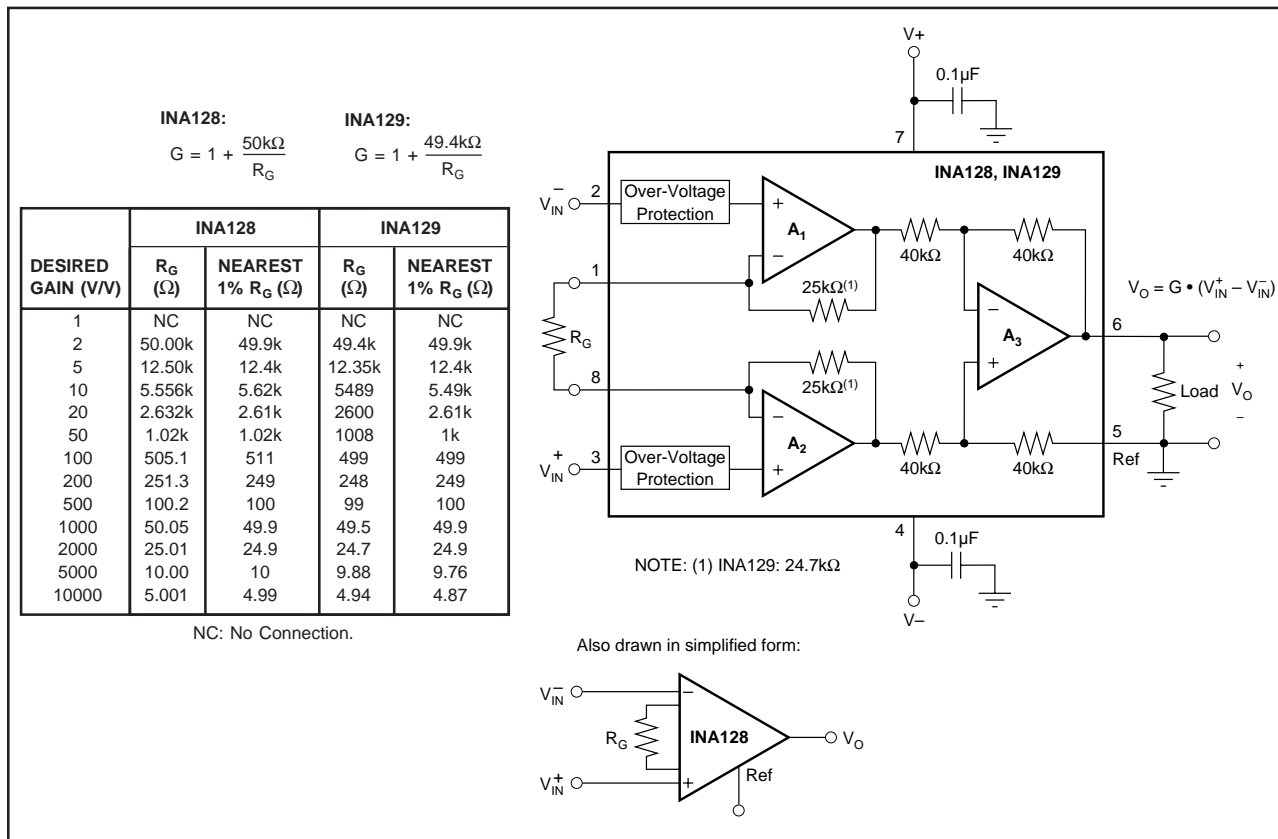


FIGURE 1. Basic Connections.



## OFFSET TRIMMING

The INA128/INA129 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 Ref terminal is summed with the output. The op amp buffer provides low impedance at the Ref terminal to preserve good common-mode rejection.

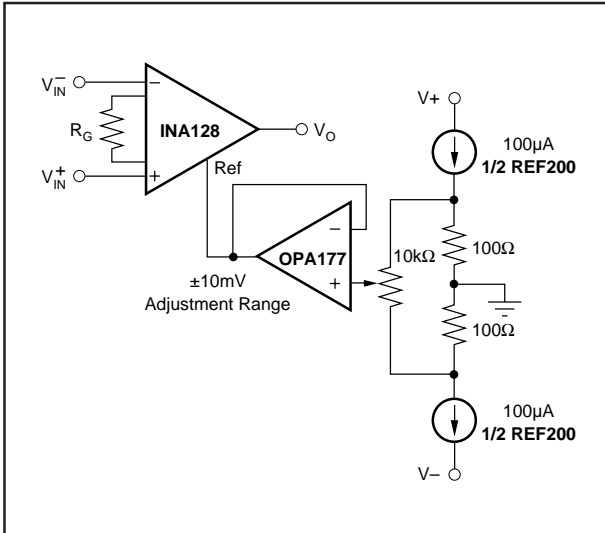


FIGURE 2. Optional Trimming of Output Offset Voltage.

## INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA128/INA129 is extremely high—approximately  $10^{10}\Omega$ . However, a path must be provided for the input bias current of both inputs. This input bias current is approximately  $\pm 2\text{nA}$ . 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 linear input voltage range of the input circuitry of the INA128/INA129 is from approximately 1.4V below the positive supply voltage to 1.7V above the negative supply. As a differential input voltage causes the output voltage increase, however, the linear input range will be limited by the output voltage swing of amplifiers  $A_1$  and  $A_2$ . So the

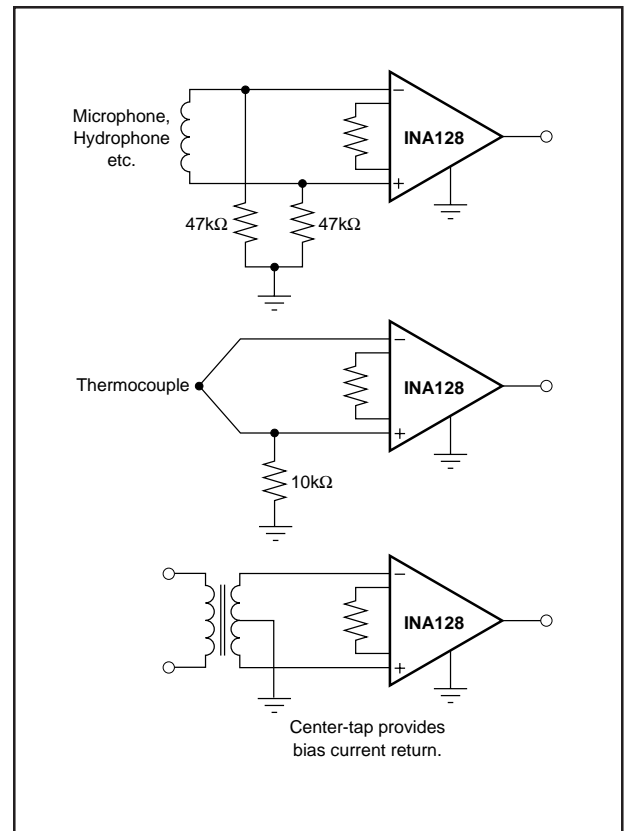


FIGURE 3. Providing an Input Common-Mode Current Path.

linear common-mode input range is related to the output voltage of the complete amplifier. This behavior also depends on supply voltage—see performance curves “Input Common-Mode Range vs Output Voltage”.

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 0V even though both inputs are overloaded.

## LOW VOLTAGE OPERATION

The INA128/INA129 can be operated on power supplies as low as  $\pm 2.25\text{V}$ . Performance remains excellent with power supplies ranging from  $\pm 2.25\text{V}$  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 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. Typical performance curves, “Input Common-Mode Range vs Output Voltage” show the range of linear operation for  $\pm 15\text{V}$ ,  $\pm 5\text{V}$ , and  $\pm 2.5\text{V}$  supplies.

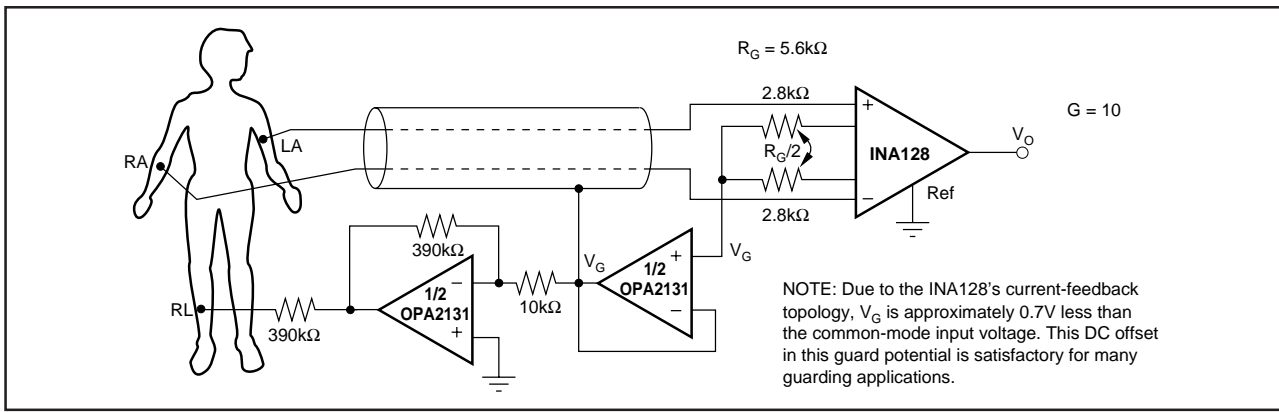


FIGURE 4. ECG Amplifier With Right-Leg Drive.

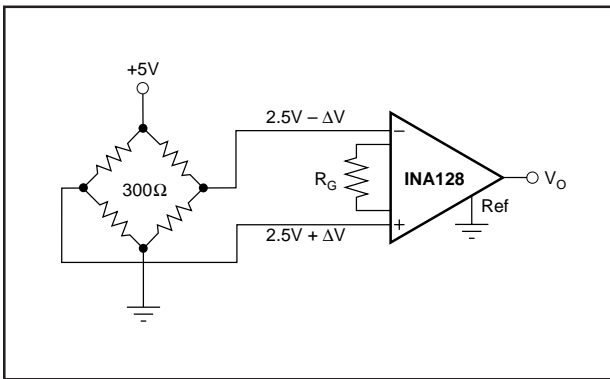


FIGURE 5. Bridge Amplifier.

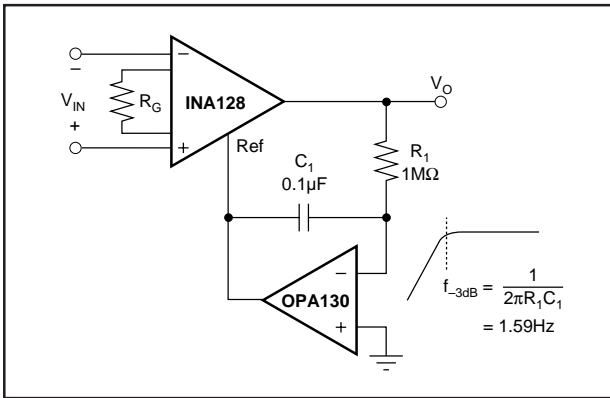


FIGURE 6. AC-Coupled Instrumentation Amplifier.

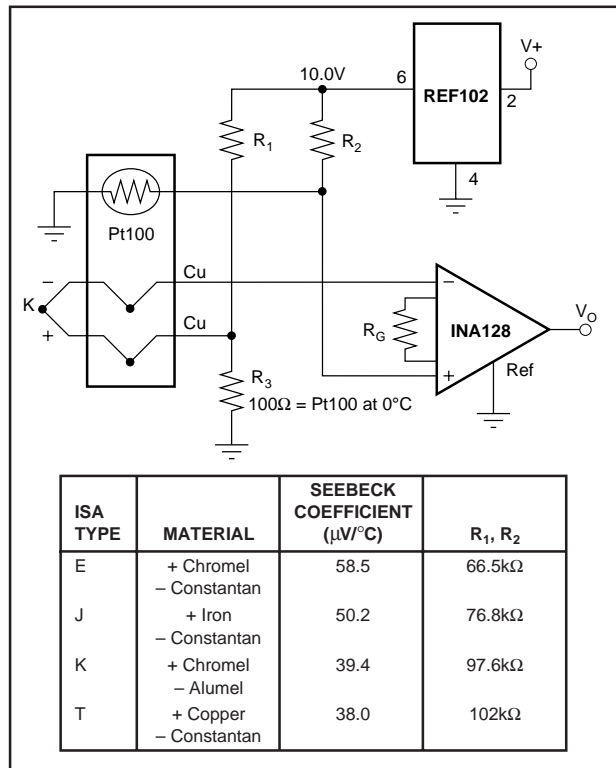


FIGURE 7. Thermocouple Amplifier With RTD Cold-Junction Compensation.

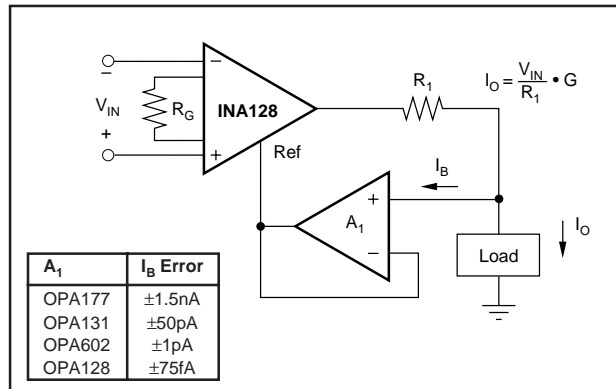


FIGURE 8. Differential Voltage to Current Converter.

**PACKAGING INFORMATION**

| ORDERABLE DEVICE | STATUS(1) | PACKAGE TYPE | PACKAGE DRAWING | PINS | PACKAGE QTY |
|------------------|-----------|--------------|-----------------|------|-------------|
| INA128P          | ACTIVE    | PDIP         | P               | 8    | 50          |
| INA128PA         | ACTIVE    | PDIP         | P               | 8    | 50          |
| INA128U          | ACTIVE    | SOIC         | D               | 8    | 100         |
| INA128U/2K5      | ACTIVE    | SOIC         | D               | 8    | 2500        |
| INA128UA         | ACTIVE    | SOIC         | D               | 8    | 100         |
| INA128UA/2K5     | ACTIVE    | SOIC         | D               | 8    | 2500        |
| INA129P          | ACTIVE    | PDIP         | P               | 8    | 50          |
| INA129PA         | ACTIVE    | PDIP         | P               | 8    | 50          |
| INA129U          | ACTIVE    | SOIC         | D               | 8    | 100         |
| INA129U/2K5      | ACTIVE    | SOIC         | D               | 8    | 2500        |
| INA129UA         | ACTIVE    | SOIC         | D               | 8    | 100         |
| INA129UA/2K5     | ACTIVE    | SOIC         | D               | 8    | 2500        |

(1) The marketing status values are defined as follows:

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**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.

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|------------------|--|---------------------|--|
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| DSP              | <a href="http://dsp.ti.com">dsp.ti.com</a>                         | Broadband           | <a href="http://www.ti.com/broadband">www.ti.com/broadband</a>           |
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| Power Mgmt       | <a href="http://power.ti.com">power.ti.com</a>                     | Optical Networking  | <a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a> |
| Microcontrollers | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a> | Security            | <a href="http://www.ti.com/security">www.ti.com/security</a>             |
|                  |  | Telephony           | <a href="http://www.ti.com/telephony">www.ti.com/telephony</a>           |
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