

# INA141

## Precision, Low Power, $G = 10, 100$ INSTRUMENTATION AMPLIFIER

### FEATURES

- **LOW OFFSET VOLTAGE:**  $50\mu\text{V}$  max
- **LOW DRIFT:**  $0.5\mu\text{V}/^\circ\text{C}$  max
- **ACCURATE GAIN:**  $\pm 0.05\%$  at  $G = 10$
- **LOW INPUT BIAS CURRENT:**  $5\text{nA}$  max
- **HIGH CMR:** 117dB min
- **INPUTS PROTECTED TO  $\pm 40\text{V}$**
- **WIDE SUPPLY RANGE:**  $\pm 2.25$  to  $\pm 18\text{V}$
- **LOW QUIESCENT CURRENT:**  $750\mu\text{A}$
- **8-PIN PLASTIC DIP, SO-8**

### APPLICATIONS

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

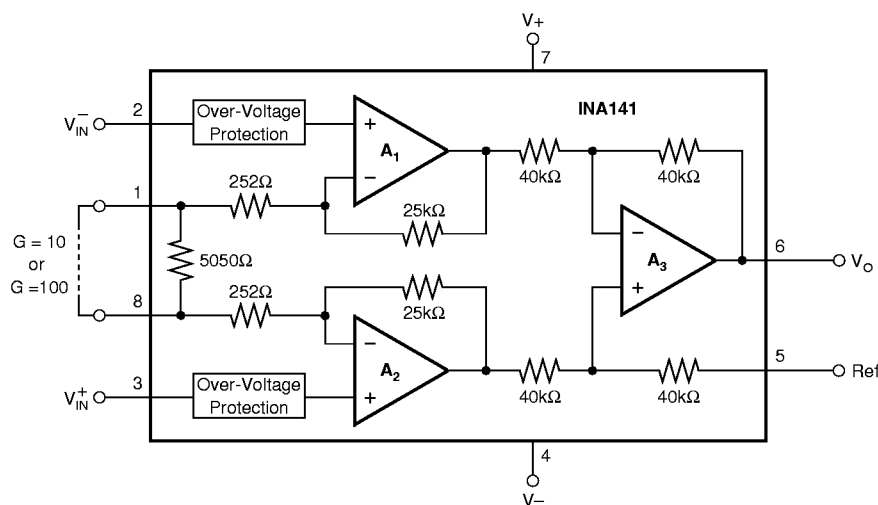
### DESCRIPTION

The INA141 is a low power, general purpose instrumentation amplifier offering excellent accuracy. Its versatile 3-op amp design and small size make it ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain ( $200\text{kHz}$  at  $G = 100$ ).

Simple pin connections set an accurate gain of 10 or  $100\text{V/V}$  without external resistors. Internal input protection can withstand up to  $\pm 40\text{V}$  without damage.

The INA141 is laser trimmed for very low offset voltage ( $50\mu\text{V}$ ), drift ( $0.5\mu\text{V}/^\circ\text{C}$ ) and high common-mode rejection (117dB at  $G = 100$ ). It operates with power supplies as low as  $\pm 2.25\text{V}$ , and quiescent current is only  $750\mu\text{A}$ —ideal for battery operated systems.

The INA141 is available in 8-pin plastic DIP, and SO-8 surface-mount packages, specified for the  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  temperature range.



# SPECIFICATIONS

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

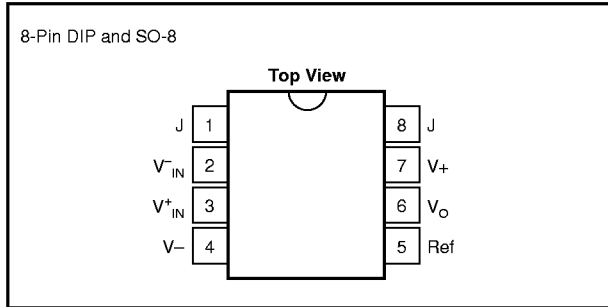
| PARAMETER                                | CONDITIONS   | INA141P, U               |                              |             | INA141PA, UA |     |             | UNITS                        |
|--|--|--------------------------|------------------------------|-------------|--------------|-----|-------------|------------------------------|
|  |  | MIN                      | TYP                          | MAX         | MIN          | TYP | MAX         |                              |
| <b>INPUT</b>                             |  |                          |                              |             |              |     |             |                              |
| Offset Voltage, RTI                      | $G = 100$  |                          | $\pm 20$                     | $\pm 50$    |              | *   | $\pm 125$   | $\mu\text{V}$                |
|  | $G = 10$   |                          | $\pm 50$                     | $\pm 100$   |              | *   | $\pm 250$   | $\mu\text{V}$                |
| vs Temperature                           | $G = 100$  |                          | $\pm 0.2$                    | $\pm 0.5$   |              | *   | $\pm 1.5$   | $\mu\text{V}/^\circ\text{C}$ |
|  | $G = 10^{(2)}$   |                          | $\pm 0.5$                    | $\pm 2$     |              | *   | $\pm 2.5$   | $\mu\text{V}/^\circ\text{C}$ |
| vs Power Supply                          | $V_S = \pm 2.25$ to $\pm 18\text{V}$ , $G = 100$           |                          | $\pm 0.4$                    | $\pm 1$     |              | *   | $\pm 3$     | $\mu\text{V}/\text{V}$       |
|  | $G = 10$   |                          | $\pm 2$                      | $\pm 10$    |              | *   | $\pm 20$    | $\mu\text{V}/\text{V}$       |
| Long-Term Stability                      | $G = 100$  |                          | 0.2                          |             |              | *   |             | $\mu\text{V}/\text{mo}$      |
|  | $G = 10$   |                          | 0.5                          |             |              | *   |             | $\mu\text{V}/\text{mo}$      |
| Impedance, Differential                  |  |                          | $10^{10} \parallel 2$        |             |              | *   |             | $\Omega \parallel \text{pF}$ |
| Common-Mode                              |  |                          | $10^{10} \parallel 9$        |             |              | *   |             | $\Omega \parallel \text{pF}$ |
| 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                    | $V_{CM} = \pm 13\text{V}$ , $\Delta R_S = 1\text{k}\Omega$ |                          |                              |             |              |     |             |                              |
|  | $G = 100$  | 117                      | 125                          |             | 110          | 120 |             | dB                           |
|  | $G = 10$   | 100                      | 106                          |             | 93           | 100 |             | dB                           |
| <b>BIAS CURRENT</b>                      |  |                          |                              |             |              |     |             |                              |
| vs Temperature                           |  |                          | $\pm 2$                      | $\pm 5$     |              | *   | $\pm 10$    | nA                           |
| Offset Current                           |  |                          | $\pm 30$                     |             |              | *   |             | $\text{pA}/^\circ\text{C}$   |
| vs Temperature                           |  |                          | $\pm 1$                      | $\pm 5$     |              | *   | $\pm 10$    | nA                           |
|  |  |                          | $\pm 30$                     |             |              | *   |             | $\text{pA}/^\circ\text{C}$   |
| <b>NOISE VOLTAGE, RTI</b>                |  |                          |                              |             |              |     |             |                              |
| $f = 10\text{Hz}$                        | $G = 100$ , $R_S = 0\Omega$                                |                          | 10                           |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f = 100\text{Hz}$                       |  |                          | 8                            |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f = 1\text{kHz}$                        |  |                          | 8                            |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f_B = 0.1\text{Hz}$ to $10\text{Hz}$    |  |                          | 0.2                          |             |              | *   |             | $\mu\text{Vp-p}$             |
| $f = 10\text{Hz}$                        | $G = 10$ , $R_S = 0\Omega$                                 |                          | 22                           |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f = 100\text{Hz}$                       |  |                          | 13                           |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f = 1\text{kHz}$                        |  |                          | 12                           |             |              | *   |             | $\text{nV}/\sqrt{\text{Hz}}$ |
| $f_B = 0.1\text{Hz}$ to $10\text{Hz}$    |  |                          | 0.6                          |             |              | *   |             | $\mu\text{Vp-p}$             |
| Noise Current                            |  |                          |                              |             |              |     |             |                              |
| $f = 10\text{Hz}$                        |  |                          | 0.9                          |             |              | *   |             | $\text{pA}/\sqrt{\text{Hz}}$ |
| $f = 1\text{kHz}$                        |  |                          | 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 Error                               | $V_O = \pm 13.6\text{V}$ , $G = 100$                       |                          | $\pm 0.03$                   | $\pm 0.075$ |              | *   | $\pm 0.15$  | %                            |
|  | $G = 10$   |                          | $\pm 0.01$                   | $\pm 0.05$  |              | *   | $\pm 0.15$  | %                            |
| Gain vs Temperature <sup>(2)</sup>       | $G = 10, 100$  |                          | $\pm 2$                      | $\pm 10$    |              | *   | *           | $\text{ppm}/^\circ\text{C}$  |
| Nonlinearity                             | $G = 100$  |                          | $\pm 0.0005$                 | $\pm 0.002$ |              | *   | $\pm 0.004$ | % of FSR                     |
|  | $G = 10$   |                          | $\pm 0.0003$                 | $\pm 0.001$ |              | *   | $\pm 0.002$ | % of FSR                     |
| <b>OUTPUT</b>                            |  |                          |                              |             |              |     |             |                              |
| Voltage: Positive                        | $R_L = 10\text{k}\Omega$                                   | $(V+) - 1.4$             | $(V+) - 0.9$                 |             | *            | *   |             | V                            |
| Negative                                 | $R_L = 10\text{k}\Omega$                                   | $(V-) + 1.4$             | $(V-) + 0.9$                 |             | *            | *   |             | V                            |
| Load Capacitance Stability               |  |                          | 1000                         |             |              | *   |             | pF                           |
| Short-Circuit Current                    |  |                          | +6/-15                       |             |              | *   |             | mA                           |
| <b>FREQUENCY RESPONSE</b>                |  |                          |                              |             |              |     |             |                              |
| Bandwidth, -3dB                          | $G = 100$  |                          | 200                          |             |              | *   |             | kHz                          |
|  | $G = 10$   |                          | 1                            |             |              | *   |             | MHz                          |
| Slew Rate                                | $V_O = \pm 10\text{V}$ , $G = 10$                          |                          | 4                            |             |              | *   |             | $\text{V}/\mu\text{s}$       |
| Settling Time, 0.01%                     | $V_O = \pm 5\text{V}$ , $G = 100$                          |                          | 9                            |             |              | *   |             | $\mu\text{s}$                |
|  | $G = 10$   |                          | 7                            |             |              | *   |             | $\mu\text{s}$                |
| Overload Recovery                        | 50% Overdrive  |                          | 4                            |             |              | *   |             | $\mu\text{s}$                |
| <b>POWER SUPPLY</b>                      |  |                          |                              |             |              |     |             |                              |
| Voltage Range                            |  | $\pm 2.25$               | $\pm 15$                     | $\pm 18$    | *            | *   | *           | V                            |
| Current, Total                           | $V_{IN} = 0\text{V}$                                       |                          | $\pm 750$                    | $\pm 800$   |              | *   | *           | $\mu\text{A}$                |
| <b>TEMPERATURE RANGE</b>                 |  |                          |                              |             |              |     |             |                              |
| Specification                            |  | -40                      |                              | 85          | *            |     | *           | $^\circ\text{C}$             |
| Operating                                |  | -40                      |                              | 125         | *            |     | *           | $^\circ\text{C}$             |
| $\theta_{JA}$ 8-Pin DIP                  |  |                          | 80                           |             |              | *   |             | $^\circ\text{C}/\text{W}$    |
| SO-8 SOIC                                |  |                          | 150                          |             |              | *   |             | $^\circ\text{C}/\text{W}$    |

\* Specification same as INA141P, U.

NOTE: (1) Input common-mode range varies with output voltage—see typical curves. (2) Guaranteed by wafer test.

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## 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.

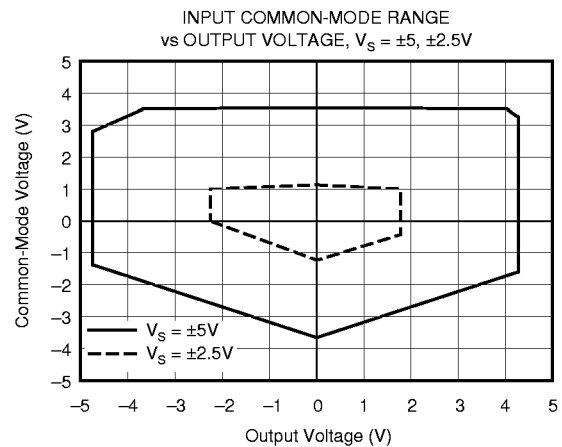
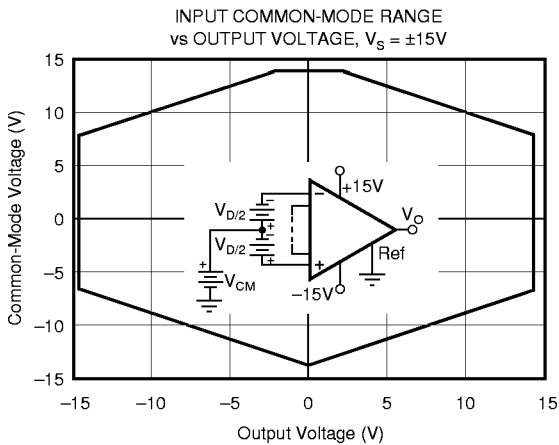
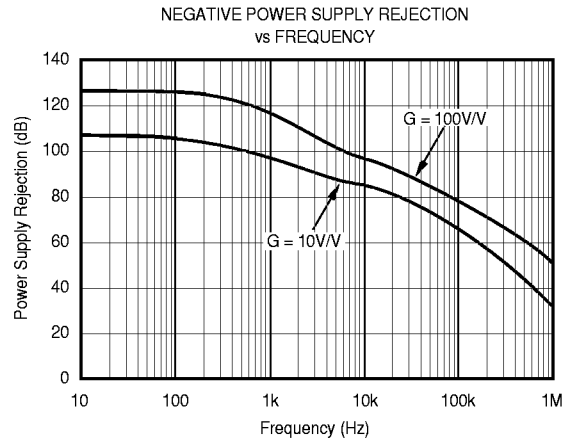
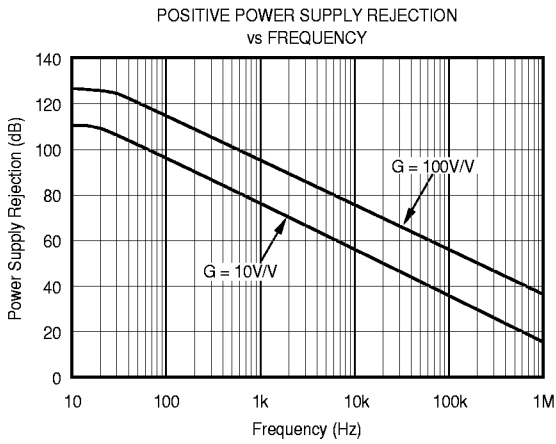
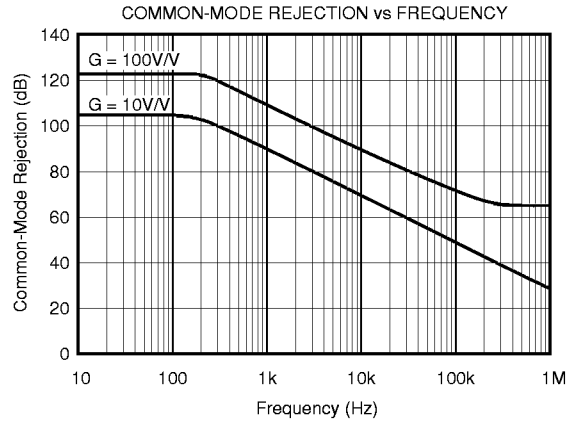
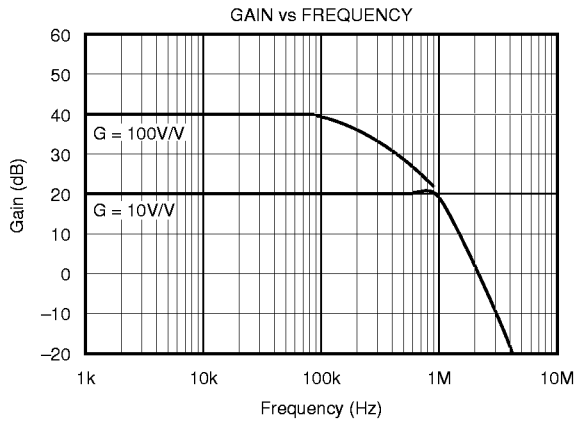
## ORDERING INFORMATION

| PRODUCT  | PACKAGE            | PACKAGE DRAWING NUMBER <sup>(1)</sup> | TEMPERATURE RANGE |
|----------|--------------------|---------------------------------------|-------------------|
| INA141PA | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA141P  | 8-Pin Plastic DIP  | 006                                   | -40°C to +85°C    |
| INA141UA | SO-8 Surface-Mount | 182                                   | -40°C to +85°C    |
| INA141U  | 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.

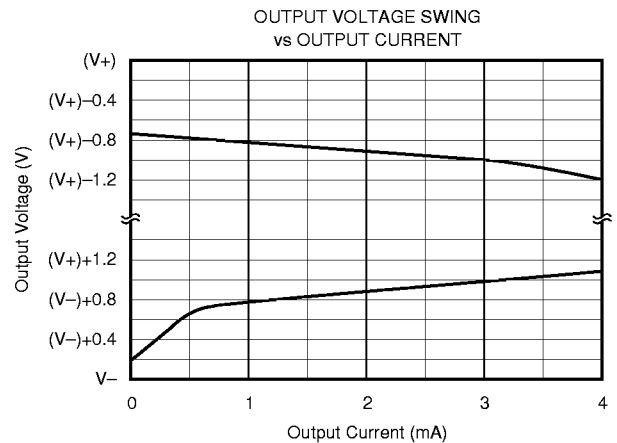
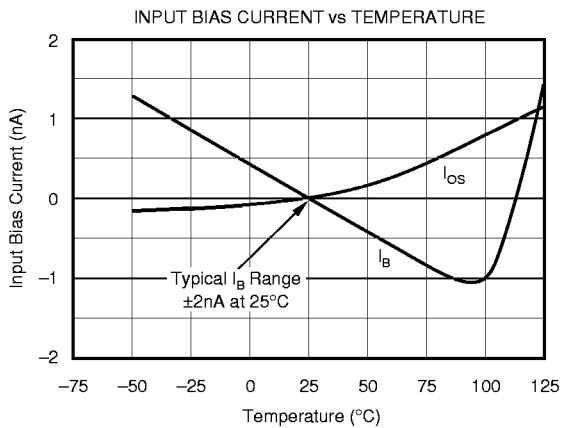
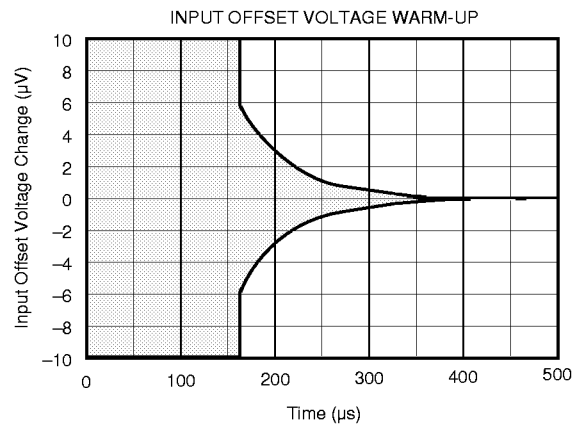
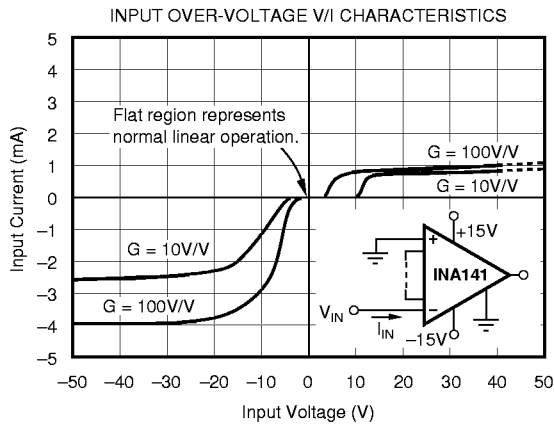
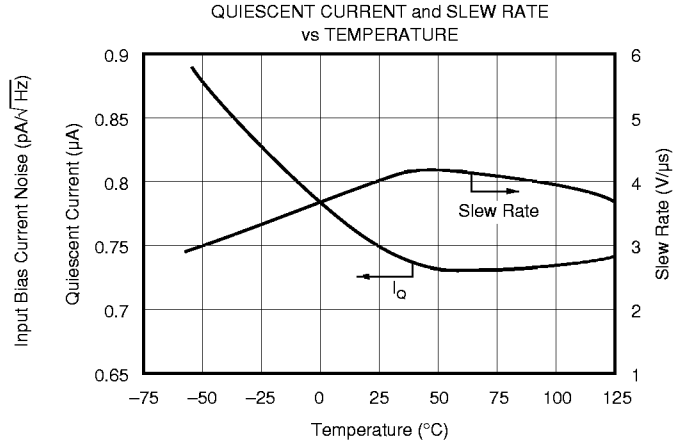
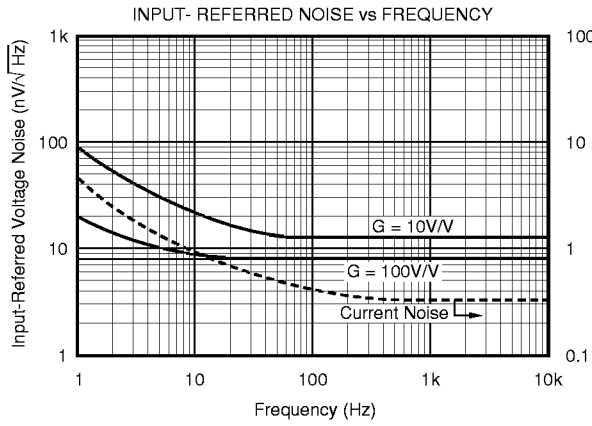
# TYPICAL PERFORMANCE CURVES

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



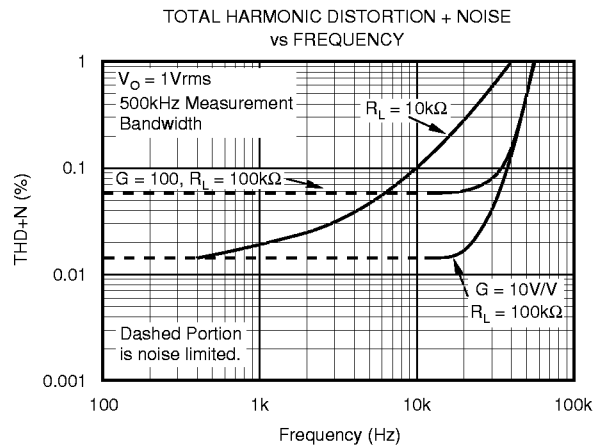
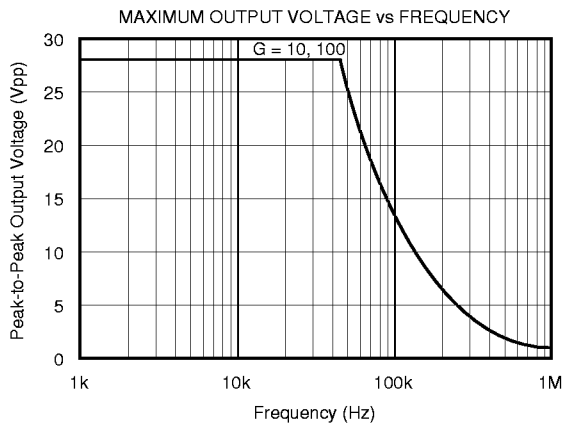
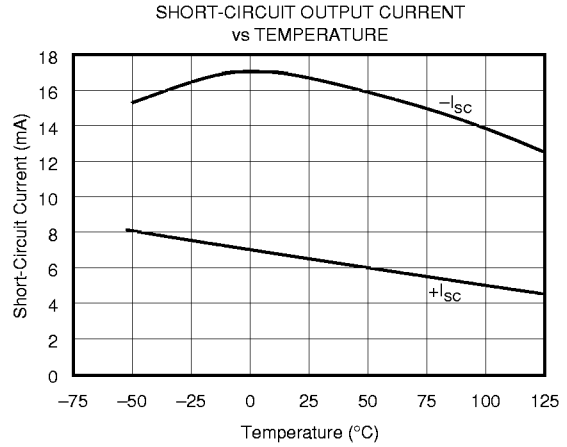
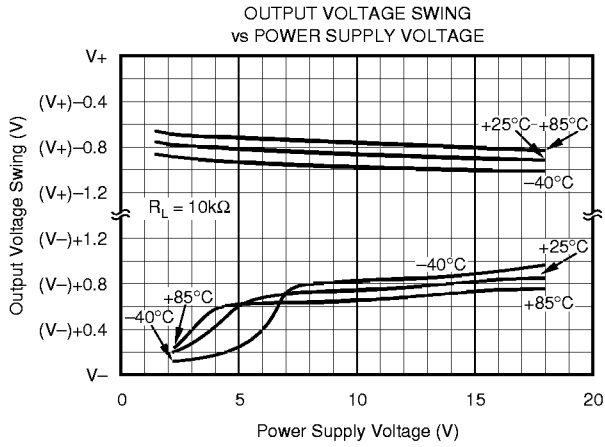
# TYPICAL PERFORMANCE CURVES (CONT)

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



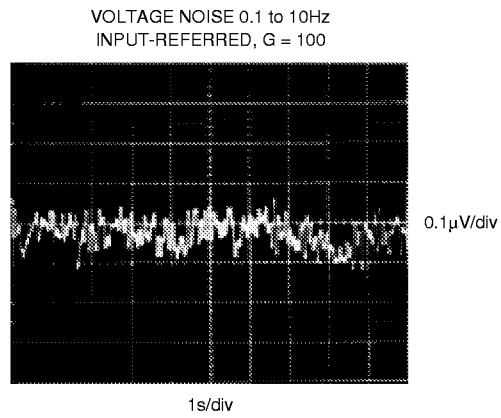
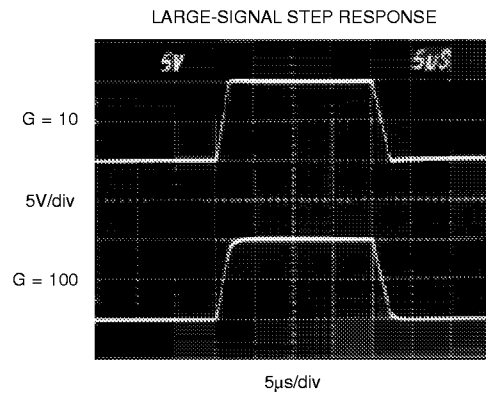
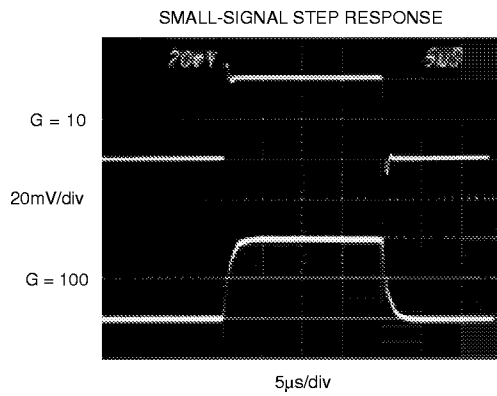
# TYPICAL PERFORMANCE CURVES (CONT)

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.



# APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA141. 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 selected with a jumper connection as shown in Figure 1.  $G = 10V/V$  with no jumper installed. With a jumper installed,  $G = 100V/V$ . To preserve good gain accuracy, this jumper must have low series resistance. A resistance of 0.5Ω in series with the jumper will decrease the gain by 0.1%.

Internal resistor ratios are laser trimmed to assure excellent gain accuracy. Actual resistor values can vary by approximately ±25% from the nominal values shown.

Gains between 10 and 100 can be achieved by connecting an external resistor to the jumper pins. This is not recommended, however, because the ±25% variation of internal resistor values makes the required external resistor value uncertain. A companion model, INA128, features accurately trimmed internal resistors so that gains from 1 to 10,000 can be set with an external resistor.

## DYNAMIC PERFORMANCE

The typical performance curve “Gain vs Frequency” shows that, despite its low quiescent current, the INA141 achieves wide bandwidth, even at  $G = 100$ . This is due to the current-feedback topology of the INA141. Settling time also remains excellent at  $G = 100$ .

## NOISE PERFORMANCE

The INA141 provides very low noise in most applications. Low frequency noise is approximately 0.2μVp-p measured from 0.1 to 10Hz ( $G = 100$ ). This provides dramatically improved noise when compared to state-of-the-art chopper-stabilized amplifiers.

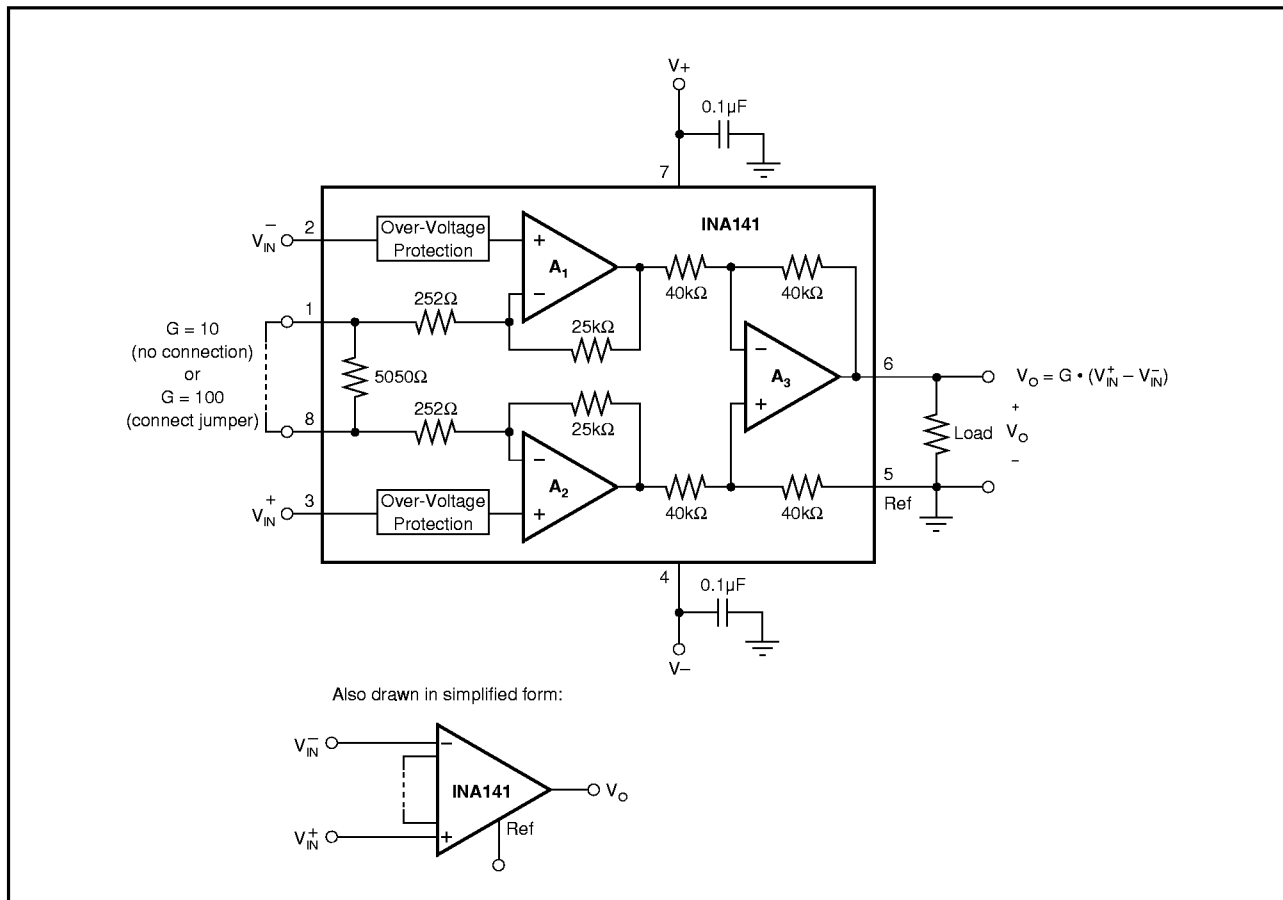


FIGURE 1. Basic Connections.



## OFFSET TRIMMING

The INA141 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.

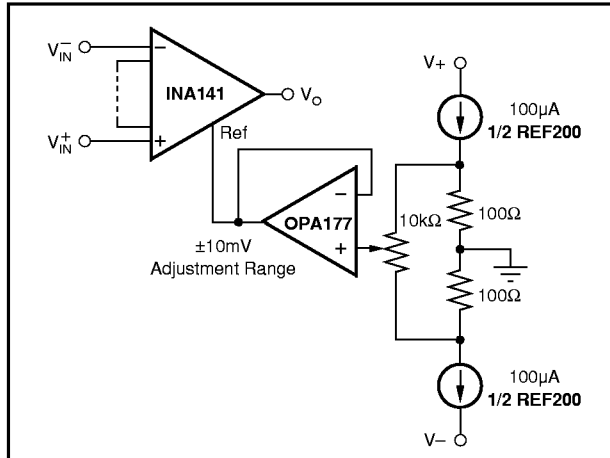


FIGURE 2. Optional Trimming of Output Offset Voltage.

## INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA141 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 of the INA141 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 INA141 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 to increase, however, the linear input range will be limited by the output voltage swing of amplifiers  $A_1$  and  $A_2$ . So 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 curves “Input Common-Mode Range vs Output Voltage”.

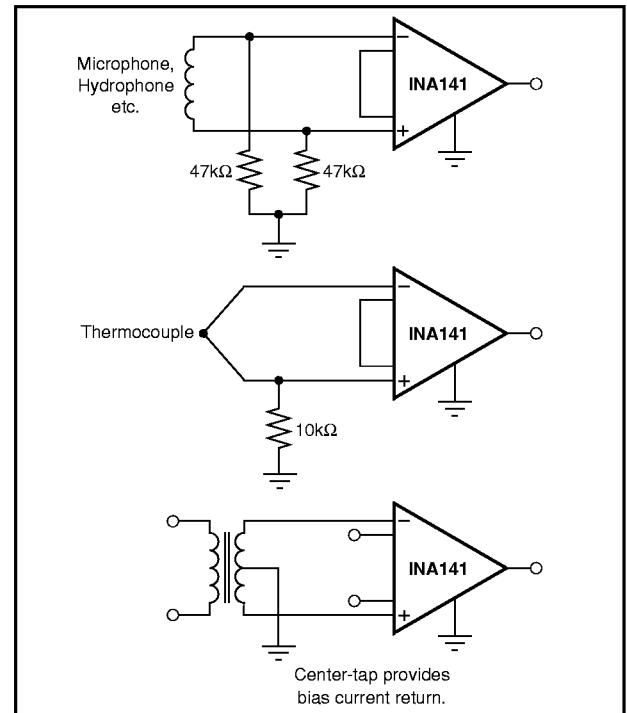


FIGURE 3. Providing an Input Common-Mode Current Path.

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 the INA141 will be near 0V even though both inputs are overloaded.

## LOW VOLTAGE OPERATION

The INA141 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 through 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  $\pm 15\text{V}$ ,  $\pm 5$ , and  $\pm 2.5\text{V}$  supplies.

## INPUT PROTECTION

The inputs of the INA141 are individually protected for voltages 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 1.5 to 5mA. The typical performance curve “Input Bias Current vs Common-Mode Input Voltage” shows this input current limit behavior. The inputs are protected even if the power supplies are disconnected or turned off.

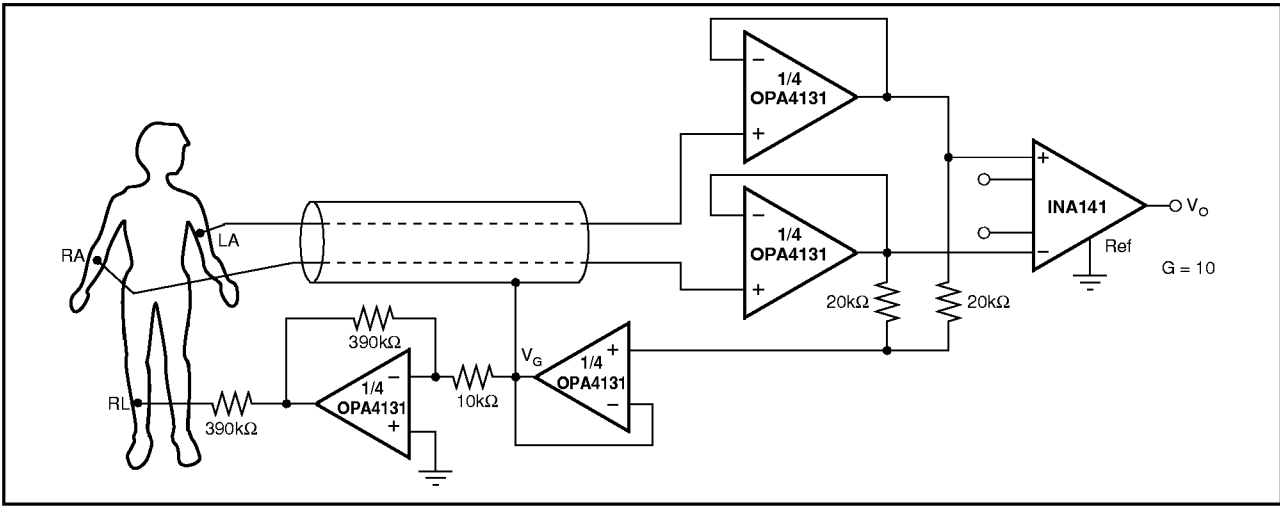


FIGURE 4. ECG Amplifier With Right-Leg Drive.

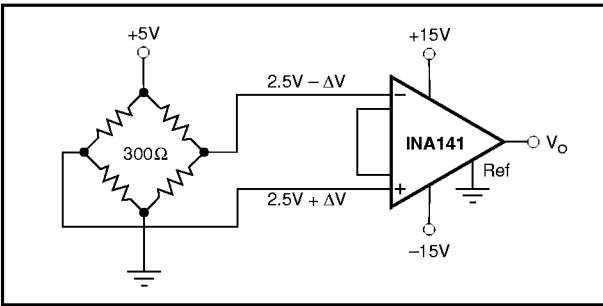


FIGURE 5. Bridge Amplifier.

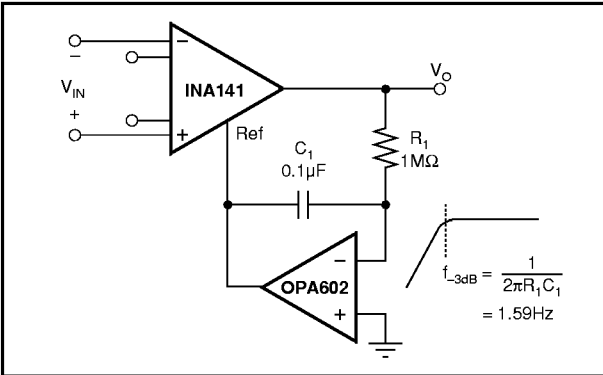


FIGURE 6. AC-Coupled Instrumentation Amplifier.

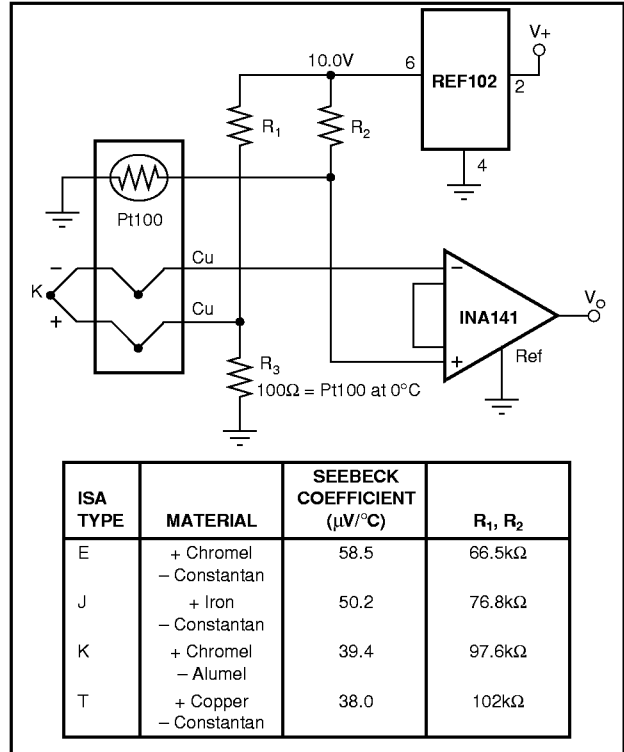


FIGURE 7. Thermocouple Amplifier With RTD Cold-Junction Compensation.

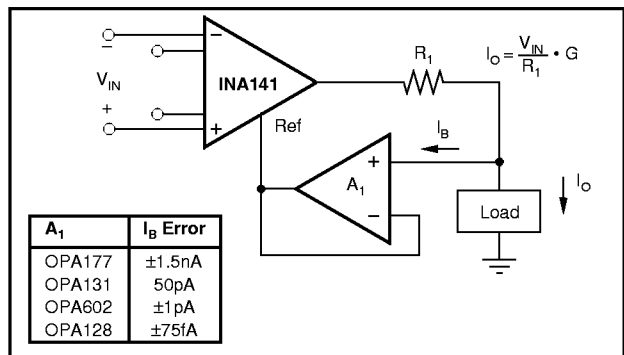


FIGURE 8. Differential Voltage to Current Converter.