



# INA145

For most current data sheet and other product information, visit [www.burr-brown.com](http://www.burr-brown.com)

## Programmable Gain DIFFERENCE AMPLIFIER

### FEATURES

- DIFFERENTIAL GAIN = 1V/V TO 1000V/V:  
Set with External Resistors
- LOW QUIESCENT CURRENT: 570 $\mu$ A
- WIDE SUPPLY RANGE:  
Single Supply: 4.5V to 36V  
Dual Supplies:  $\pm 2.25$ V to  $\pm 18$ V
- HIGH COMMON-MODE VOLTAGE:  
+8V at  $V_S = +5$ V  
 $\pm 28$ V at  $V_S = \pm 15$ V
- LOW GAIN ERROR: 0.01%
- HIGH CMR: 86dB
- SO-8 PACKAGE

### DESCRIPTION

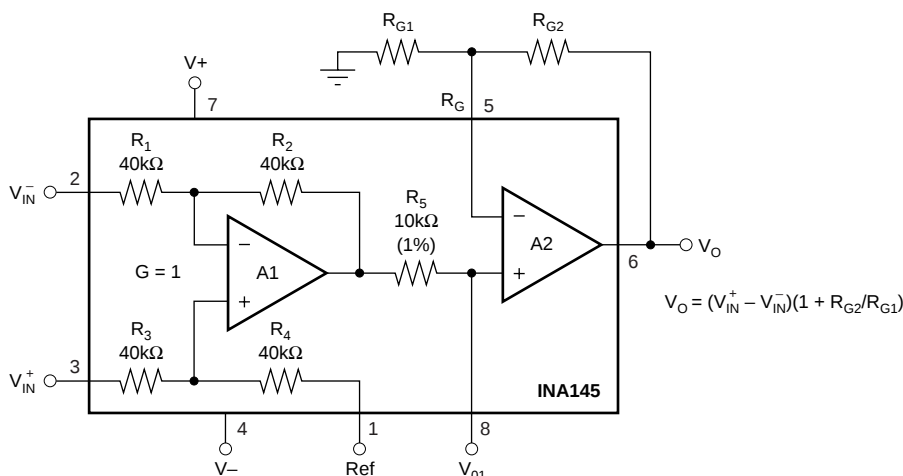
The INA145 is a precision, unity-gain difference amplifier consisting of a precision op amp and on-chip precision resistor network. Two external resistors set the gain from 1V/V to 1000V/V. The input common-mode voltage range extends beyond the positive and negative rails.

On-chip precision resistors are laser-trimmed to achieve accurate gain and high common-mode rejection. Excellent TCR tracking of these resistors assures continued high precision over temperature.

The INA145 is available in the SO-8 surface-mount package specified for the extended industrial temperature range,  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### APPLICATIONS

- CURRENT SHUNT MEASUREMENTS
- SENSOR AMPLIFIER
- DIFFERENTIAL LINE RECEIVER
- BATTERY POWERED SYSTEMS



# SPECIFICATIONS: $V_S = \pm 2.25V$ to $\pm 18V$

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$

At  $T_A = +25^{\circ}C$ ,  $G = 1$ ,  $R_L = 10k\Omega$  connected to ground and ref pin connected to ground unless otherwise noted.

| PARAMETER                                                                                                                                               | CONDITION                                                                                                                                                                                                                                                                                                                                                                                                                         | INA145UA                                                                                           |                                                                                                                                                         |                                                                                                           | UNITS                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
|                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                   | MIN                                                                                                | TYP                                                                                                                                                     | MAX                                                                                                       |                                                                         |
| <b>OFFSET VOLTAGE, <math>V_O</math></b><br>Input Offset Voltage<br><b>vs Temperature</b><br>vs Power Supply<br>vs Time<br>Offset Voltage, $V_{O1}$      | $RTI^{(1, 2)}$<br>$V_{CM} = V_O = 0V$<br><br>$V_S = \pm 1.35V$ to $\pm 18V$<br><br>$RTI^{(1, 2)}$                                                                                                                                                                                                                                                                                                                                 |                                                                                                    | $\pm 0.2$<br><b>See Typical Curve</b><br>$\pm 20$<br>$\pm 0.3$<br>$\pm 0.4$                                                                             | $\pm 1$<br><br>$\pm 60$                                                                                   | mV<br><br>$\mu V/V$<br>$\mu V/mo$<br>mV                                 |
| <b>INPUT VOLTAGE RANGE</b><br>Common-Mode Voltage Range<br>Common-Mode Rejection<br><b>Over Temperature</b>                                             | $(V_{IN+}) - (V_{IN-}) = 0V$ , $V_O = 0V$<br>$V_{CM} = 2(V-) \text{ to } 2(V+) - 2V$ , $R_S = 0\Omega$<br>$V_S = \pm 15V$                                                                                                                                                                                                                                                                                                         | $2(V-)$<br>76<br><b>70</b>                                                                         | <br>86<br><b>80</b>                                                                                                                                     | $2(V+) - 2$                                                                                               | V<br>dB<br>dB                                                           |
| <b>INPUT BIAS CURRENT<sup>(2)</sup></b><br>Bias Current<br>Offset Current                                                                               | $V_{CM} = V_S/2$                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                    | $\pm 50$<br>$\pm 5$                                                                                                                                     |                                                                                                           | nA<br>nA                                                                |
| <b>INPUT IMPEDANCE</b><br>Differential (non-inverting input)<br>Differential (inverting input)<br>Common-Mode                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                    | 80<br>27<br>40                                                                                                                                          |                                                                                                           | k $\Omega$<br>k $\Omega$<br>k $\Omega$                                  |
| <b>NOISE</b><br>Voltage Noise, $f = 0.1Hz$ to $10Hz$<br>Voltage Noise Density, $f = 1kHz$                                                               | $RTI^{(1, 3)}$                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                    | 2<br>90                                                                                                                                                 |                                                                                                           | $\mu Vp-p$<br>nV/ $\sqrt{Hz}$                                           |
| <b>GAIN</b><br>Gain Equation<br>Initial <sup>(1)</sup><br>Gain Error<br><b>vs Temperature</b><br><br><b>vs Temperature</b><br>Nonlinearity              | $R_L = 100k\Omega$ , $V_O = (V-)+0.15$ to $(V+)-1$ , $G = 1$<br><b><math>R_L = 100k\Omega</math>, <math>V_O = (V-)+0.25</math> to <math>(V+)-1</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $V_O = (V-)+0.3$ to $(V+)-1.25$ , $G = 1$<br><b><math>R_L = 10k\Omega</math>, <math>V_O = (V-)+0.5</math> to <math>(V+)-1.25</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $V_O = (V-)+0.3$ to $(V+)-1.25$ , $G = 1$ |                                                                                                    | $G = 1$ to $1000$<br>$G = 1 + R_{G2}/R_{G1}$<br>1<br>$\pm 0.01$<br><b><math>\pm 2</math></b><br>$\pm 0.01$<br><b><math>\pm 2</math></b><br>$\pm 0.0002$ | <br><br>$\pm 0.1$<br><b><math>\pm 10</math></b><br>$\pm 0.1$<br><b><math>\pm 10</math></b><br>$\pm 0.005$ | V/V<br>V/V<br>%<br>ppm/ $^{\circ}C$<br>%<br>ppm/ $^{\circ}C$<br>% of FS |
| <b>FREQUENCY RESPONSE</b><br>Small Signal Bandwidth<br><br>Slew Rate<br>Settling Time, 0.1%<br>0.01%<br>Overload Recovery                               | $G = 1$<br>$G = 10$<br><br>$G = 1$ , 10V Step<br>$G = 1$ , 10V Step<br>50% Input Overload                                                                                                                                                                                                                                                                                                                                         |                                                                                                    | 500<br>50<br>0.45<br>40<br>90<br>40                                                                                                                     |                                                                                                           | kHz<br>kHz<br>V/ $\mu s$<br>$\mu s$<br>$\mu s$<br>$\mu s$               |
| <b>OUTPUT, <math>V_O</math></b><br>Voltage Output<br><b>Over Temperature</b><br><br><b>Over Temperature</b><br>Short-Circuit Current<br>Capacitive Load | $R_L = 100k\Omega$ , $G = 1$<br><b><math>R_L = 100k\Omega</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $G = 1$<br><b><math>R_L = 10k\Omega</math>, <math>G = 1</math></b><br>Continuous to Common<br>Stable Operation                                                                                                                                                                                                    | $(V-) + 0.15$<br><b><math>(V-) + 0.25</math></b><br>$(V-) + 0.3$<br><b><math>(V-) + 0.5</math></b> | <br><br><br><br>$\pm 15$<br>1000                                                                                                                        | $(V+) - 1$<br><b><math>(V+) - 1</math></b><br>$(V+) - 1.25$<br><b><math>(V+) - 1.25</math></b>            | V<br>V<br>V<br>V<br>mA<br>pF                                            |
| <b>POWER SUPPLY</b><br>Specified Voltage Range, Dual Supplies<br>Operating Voltage Range<br>Quiescent Current<br><b>Over Temperature</b>                | $V_{IN} = 0$ , $I_O = 0$                                                                                                                                                                                                                                                                                                                                                                                                          | $\pm 2.25$<br>$\pm 1.35$                                                                           | <br><br>$\pm 570$                                                                                                                                       | $\pm 18$<br>$\pm 18$<br>$\pm 700$<br><b><math>\pm 800</math></b>                                          | V<br>V<br>$\mu A$<br>$\mu A$                                            |
| <b>TEMPERATURE RANGE</b><br>Specified Range<br>Operating Range<br>Storage Range<br>Thermal Resistance                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                   | $-40$<br>$-55$<br>$-55$                                                                            | <br><br>150                                                                                                                                             | $+85$<br>$+125$<br>$+125$                                                                                 | $^{\circ}C$<br>$^{\circ}C$<br>$^{\circ}C$<br>$^{\circ}C/W$              |

NOTES: (1) Referred to input pins ( $V_{IN+}$  and  $V_{IN-}$ ), Gain = 1V/V. Specified with 10k $\Omega$  in feedback of A2. (2) Input offset voltage specification includes effects of amplifier's input bias and offset currents. (3) Includes effects of input bias current noise and thermal noise contribution of resistor network.

The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

# SPECIFICATIONS: $V_S = +5V$ Single Supply

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$

At  $T_A = +25^{\circ}C$ ,  $G = 1$ ,  $R_L = 10k\Omega$  connected to ground and ref pin connected to 2.5V unless otherwise noted.

| PARAMETER                                                                                                                                                                                                 | CONDITION                                                                                                                                                                                                                                                                                                                                                                                 | INA145UA                                 |                                                                                                                                                        |                                                                                                   | UNITS                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                           | MIN                                      | TYP                                                                                                                                                    | MAX                                                                                               |                                                                                |
| <b>OFFSET VOLTAGE, <math>V_O</math></b><br>Input Offset Voltage $V_{OS}$<br><b>vs Temperature</b> $\Delta V_{OS}/\Delta T$<br>vs Power Supply Rejection Ratio PSRR<br>vs Time<br>Offset Voltage, $V_{O1}$ | $RTI^{(1, 2)}$<br>$V_{CM} = V_O = 2.5V$<br>$V_S = \pm 1.35V$ to $\pm 18V$<br>$RTI^{(1, 2)}$                                                                                                                                                                                                                                                                                               |                                          | $\pm 0.35$<br><b>See Typical Curve</b><br>$\pm 20$<br>$\pm 0.3$<br>$\pm 0.55$                                                                          | $\pm 1$<br><br>$\pm 60$                                                                           | mV<br><br>$\mu V/^{\circ}C$<br>$\mu V/mo$<br>mV                                |
| <b>INPUT VOLTAGE RANGE</b><br>Common-Mode Voltage Range <sup>(3)</sup> $V_{CM}$<br>Common-Mode Rejection Ratio CMRR<br><b>Over Temperature</b>                                                            | $V_{IN+} - V_{IN-} = 0V$ , $V_O = 2.5V$<br>$V_{CM} = -2.5V$ to $+5.5V$ , $R_S = 0\Omega$                                                                                                                                                                                                                                                                                                  | $-2.5$<br>76                             | 86<br><b>80</b>                                                                                                                                        | 5.5                                                                                               | V<br>dB<br>dB                                                                  |
| <b>INPUT BIAS CURRENT<sup>(2)</sup></b><br>Bias Current $I_B$<br>Offset Current $I_{OS}$                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                           |                                          | $\pm 50$<br>$\pm 5$                                                                                                                                    |                                                                                                   | nA<br>nA                                                                       |
| <b>INPUT IMPEDANCE</b><br>Differential (non-inverting input)<br>Differential (inverting input)<br>Common-Mode                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                           |                                          | 80<br>27<br>40                                                                                                                                         |                                                                                                   | k $\Omega$<br>k $\Omega$<br>k $\Omega$                                         |
| <b>NOISE</b><br>Voltage Noise, $f = 0.1Hz$ to $10Hz$<br>Voltage Noise Density, $f = 1kHz$ $e_n$                                                                                                           | $RTI^{(1, 4)}$                                                                                                                                                                                                                                                                                                                                                                            |                                          | 2<br>90                                                                                                                                                |                                                                                                   | $\mu Vp-p$<br>nV/ $\sqrt{Hz}$                                                  |
| <b>GAIN</b><br>Gain Equation<br>Initial <sup>(1)</sup><br>Gain Error<br><b>vs Temperature</b><br><b>vs Temperature</b><br>Nonlinearity                                                                    | $R_L = 100k\Omega$ , $V_O = 0.15V$ to $4V$ , $G = 1$<br><b><math>R_L = 100k\Omega</math>, <math>V_O = 0.25V</math> to <math>4V</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $V_O = 0.3V$ to $3.75V$ , $G = 1$<br><b><math>R_L = 10k\Omega</math>, <math>V_O = 0.5V</math> to <math>3.75V</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $V_O = +0.3$ to $+3.75$ , $G = 1$ |                                          | $G = 1$ to $1000$<br>$G = 1 + R_{G2}/R_{G1}$<br>1<br>$\pm 0.01$<br><b><math>\pm 2</math></b><br>$\pm 0.01$<br><b><math>\pm 2</math></b><br>$\pm 0.001$ | $\pm 0.1$<br><b><math>\pm 10</math></b><br>$\pm 0.1$<br><b><math>\pm 10</math></b><br>$\pm 0.005$ | V/V<br>V/V<br>V/V<br>%<br>ppm/ $^{\circ}C$<br>%<br>ppm/ $^{\circ}C$<br>% of FS |
| <b>FREQUENCY RESPONSE</b><br>Small Signal Bandwidth<br><br>Slew Rate<br>Settling Time, 0.1%<br>0.01%<br>Overload Recovery                                                                                 | $G = 0.1$<br>$G = 1$<br><br>$G = 1$ , 10V Step<br>$G = 1$ , 10V Step<br>50% Input Overload                                                                                                                                                                                                                                                                                                |                                          | 500<br>50<br>0.45<br>40<br>90<br>40                                                                                                                    |                                                                                                   | kHz<br>kHz<br>V/ $\mu s$<br>$\mu s$<br>$\mu s$<br>$\mu s$                      |
| <b>OUTPUT, <math>V_O</math></b><br>Voltage Output<br><b>Over Temperature</b><br><br><b>Over Temperature</b><br>Short-Circuit Current<br>Capacitive Load                                                   | $R_L = 100k\Omega$ , $G = 1$<br><b><math>R_L = 100k\Omega</math>, <math>G = 1</math></b><br>$R_L = 10k\Omega$ , $G = 1$<br><b><math>R_L = 10k\Omega</math>, <math>G = 1</math></b><br>Continuous to Common<br>Stable Operation                                                                                                                                                            | 0.15<br><b>0.25</b><br>0.3<br><b>0.5</b> |                                                                                                                                                        | 4<br><b>4</b><br>3.75<br><b>3.75</b>                                                              | V<br>V<br>V<br>V<br>mA<br>pF                                                   |
| <b>POWER SUPPLY</b><br>Specified Voltage Range, Single Supply<br>Operating Voltage Range<br>Quiescent Current<br><b>Over Temperature</b>                                                                  | $V_{IN} = 0$ , $I_O = 0$                                                                                                                                                                                                                                                                                                                                                                  | +4.5<br>+2.7                             | 550                                                                                                                                                    | +36<br>+36<br>700<br><b>800</b>                                                                   | V<br>V<br>$\mu A$<br>$\mu A$                                                   |
| <b>TEMPERATURE RANGE</b><br>Specified Range<br>Operating Range<br>Storage Range<br>Thermal Resistance $\theta_{JA}$                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                           | $-40$<br>$-55$<br>$-55$                  | 150                                                                                                                                                    | +85<br>+125<br>+125                                                                               | $^{\circ}C$<br>$^{\circ}C$<br>$^{\circ}C$<br>$^{\circ}C/W$                     |

NOTES: (1) Referred to input pins ( $V_{IN+}$  and  $V_{IN-}$ ), Gain =  $1V/V$ . Specified with  $10k\Omega$  in feedback of A2. (2) Input offset voltage specification includes effects of amplifier's input bias and offset currents. (3) Common-mode voltage range with single supply is  $2(V+) - 2V - V_{REF}$  to  $-V_{REF}$ . (4) Includes effects of input current noise and thermal noise contribution of resistor network.

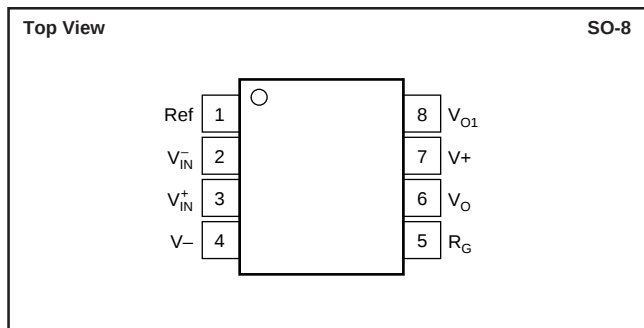
# AMPLIFIER A1, A2 PERFORMANCE

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

At  $T_A = +25^{\circ}\text{C}$ ,  $G = 1$ ,  $R_L = 10\text{k}\Omega$  connected to ground and ref pin connected to ground unless otherwise noted.

| PARAMETER                                                                                                              | CONDITION                                                                                   | INA145UA |                                   |     | UNITS                                      |
|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------|-----------------------------------|-----|--------------------------------------------|
|                                                                                                                        |                                                                                             | MIN      | TYP                               | MAX |                                            |
| <b>OFFSET VOLTAGE, <math>V_O</math></b><br>Input Offset Voltage vs Temperature<br>$V_{OS}$<br>$\Delta V_{OS}/\Delta T$ | $RTI^{(1, 2)}$<br>$V_S = \pm 15\text{V}$ , $V_{CM} = V_O = 0\text{V}$                       |          | $\pm 0.5$<br>$\pm 1$              |     | mV<br>$\mu\text{V}/^{\circ}\text{C}$       |
| <b>INPUT VOLTAGE RANGE</b><br>Common-Mode Voltage Range<br>Common-Mode Rejection Ratio<br>$V_{CM}$<br>CMRR             | $V_{IN+} - V_{IN-} = 0\text{V}$ , $V_O = 0\text{V}$<br>$V_{CM} = (V-) \text{ to } (V+) - 1$ |          | $(V-) \text{ to } (V+) - 1$<br>90 |     | V<br>dB                                    |
| <b>OPEN-LOOP GAIN</b><br>Open Loop Gain<br>$A_{OL}$                                                                    |                                                                                             |          | 110                               |     | dB                                         |
| <b>INPUT BIAS CURRENT<sup>(2)</sup></b><br>Bias Current<br>Offset Current<br>$I_B$<br>$I_{OS}$                         |                                                                                             |          | $\pm 50$<br>$\pm 5$               |     | nA<br>nA                                   |
| <b>RESISTOR AT A1 OUTPUT, <math>V_{O1}</math></b><br>Initial Error<br>Temperature Drift Coefficient                    |                                                                                             |          | 10<br>$\pm 0.2$<br>$\pm 50$       |     | k $\Omega$<br>%<br>ppm/ $^{\circ}\text{C}$ |

## PIN CONFIGURATION



## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

|                                         |                                                 |
|-----------------------------------------|-------------------------------------------------|
| Supply Voltage, $V+$ to $V-$ .....      | 36V                                             |
| Signal Input Terminals, Voltage .....   | $\pm 80\text{V}$                                |
| Current .....                           | $\pm 1\text{mA}$                                |
| Output Short Circuit (to ground) .....  | Continuous                                      |
| Operating Temperature .....             | $-55^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ |
| Storage Temperature .....               | $-55^{\circ}\text{C}$ to $+150^{\circ}\text{C}$ |
| Junction Temperature .....              | $+150^{\circ}\text{C}$                          |
| Lead Temperature (soldering, 10s) ..... | $+240^{\circ}\text{C}$                          |

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.

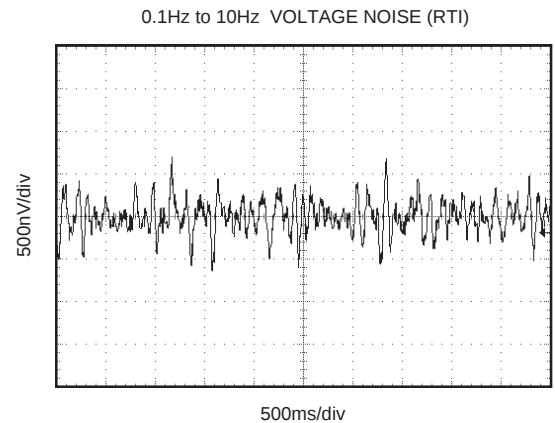
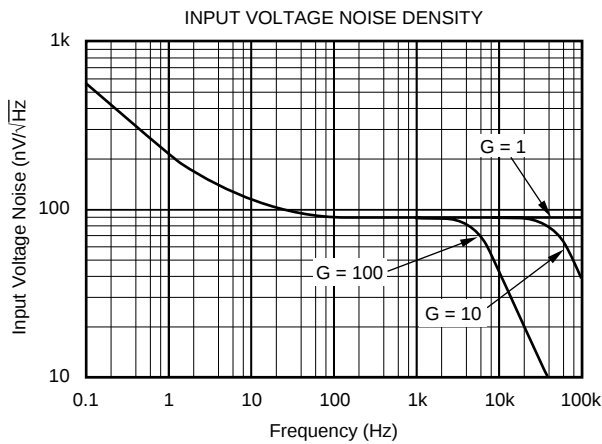
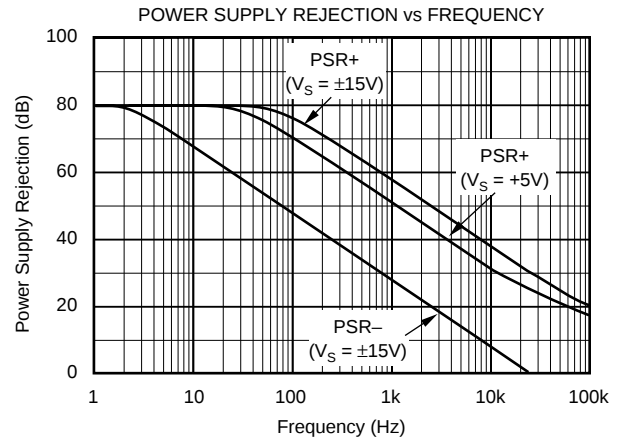
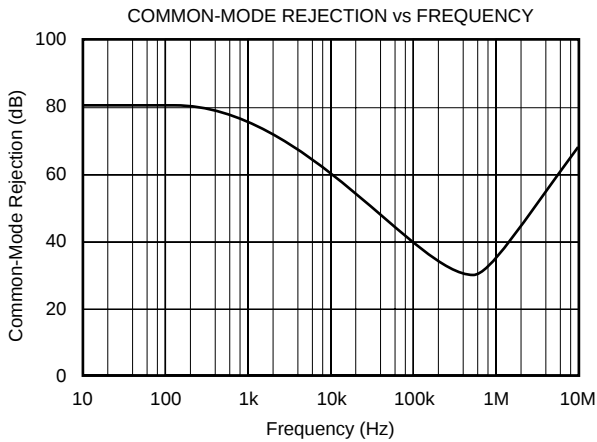
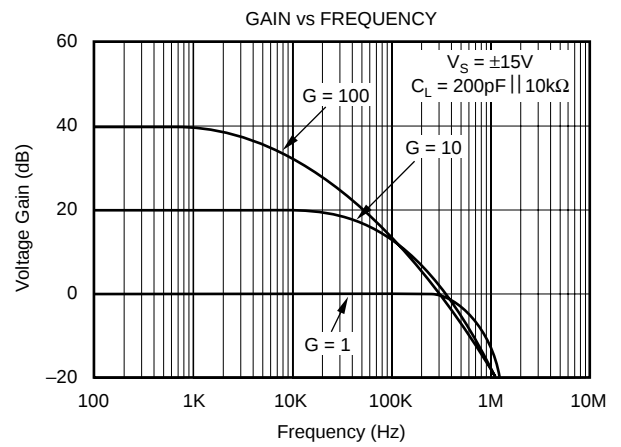
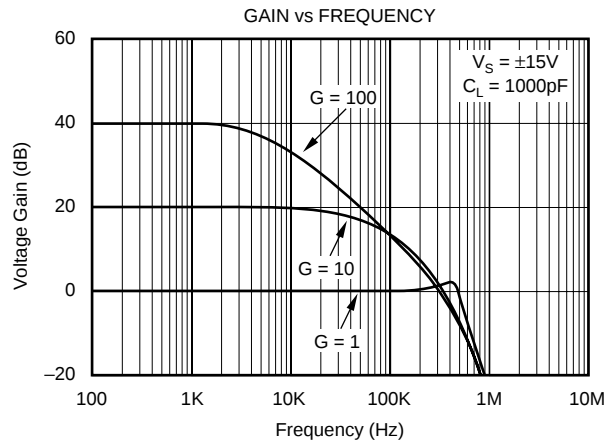
## PACKAGE/ORDERING INFORMATION

| PRODUCT       | PACKAGE   | PACKAGE DRAWING NUMBER | SPECIFIED TEMPERATURE RANGE                         | PACKAGE MARKING | ORDERING NUMBER <sup>(1)</sup> | TRANSPORT MEDIA        |
|---------------|-----------|------------------------|-----------------------------------------------------|-----------------|--------------------------------|------------------------|
| INA145UA<br>" | SO-8<br>" | 182<br>"               | $-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$<br>" | INA145UA<br>"   | INA145UA<br>INA145UA/2K5       | Rails<br>Tape and Reel |

NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of "INA145UA/2K5" will get a single 2500-piece Tape and Reel.

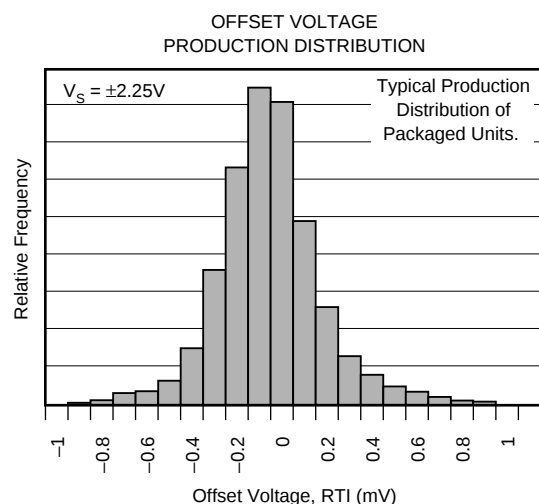
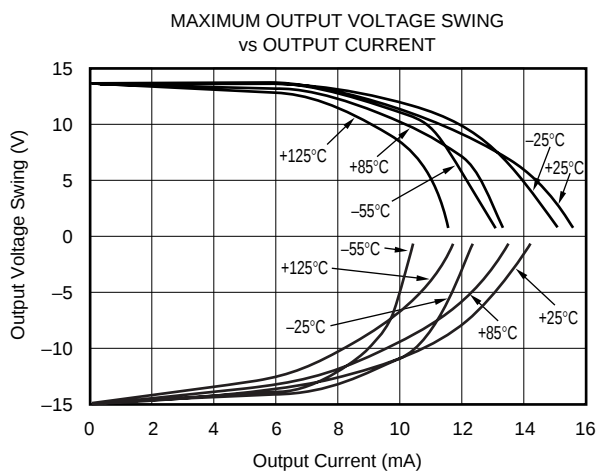
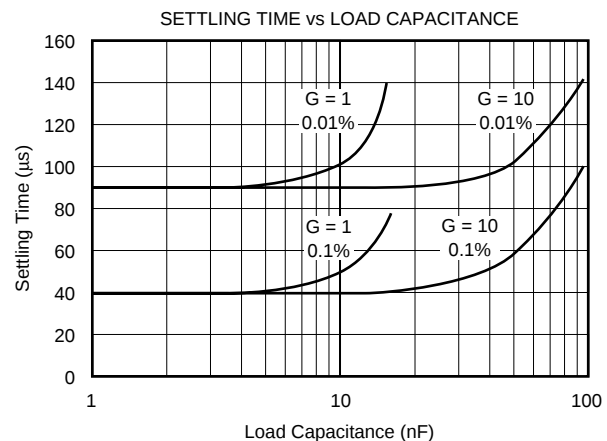
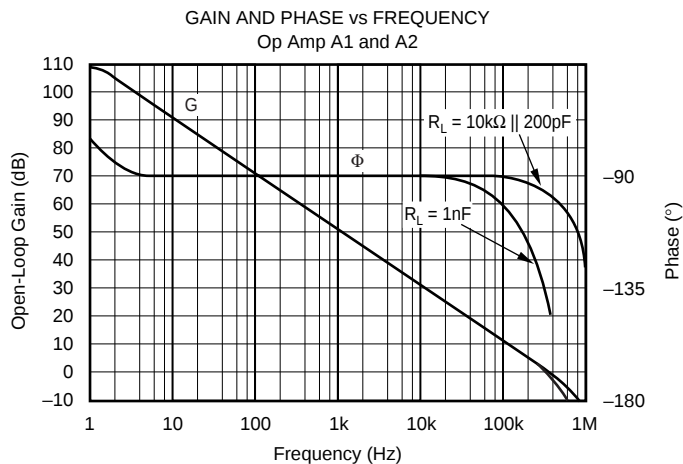
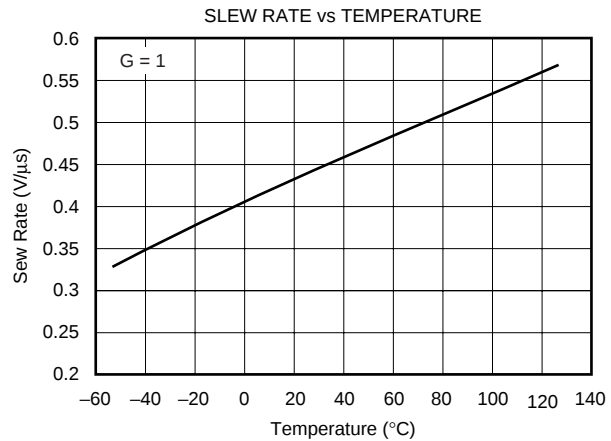
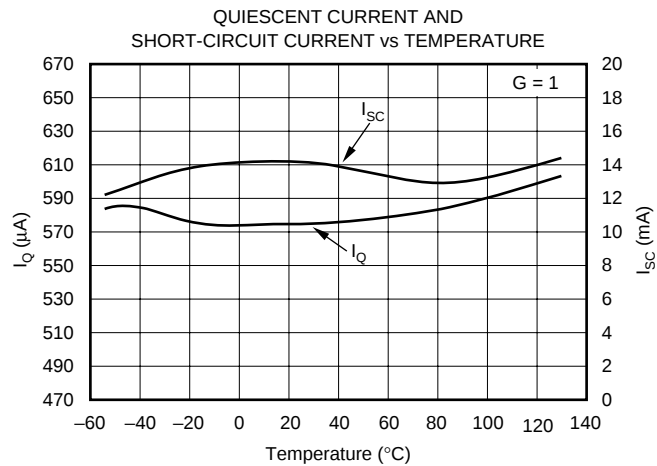
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $G = 1$ ,  $R_L = 10\text{k}\Omega$  connected to ground and Ref pin connected to ground, unless otherwise noted.



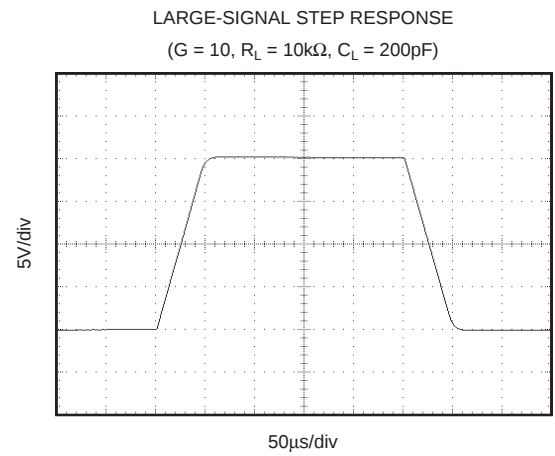
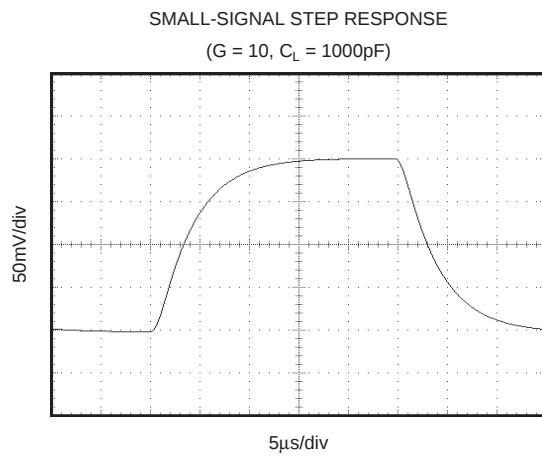
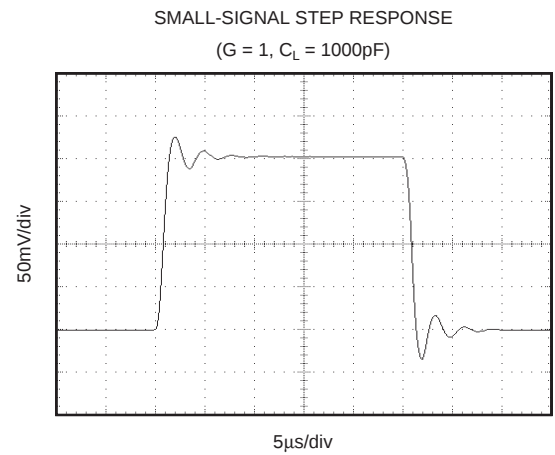
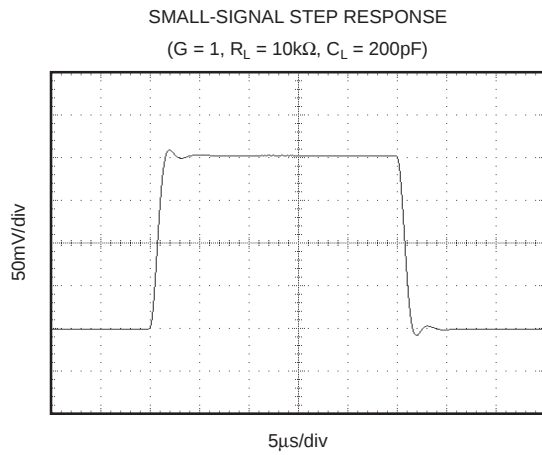
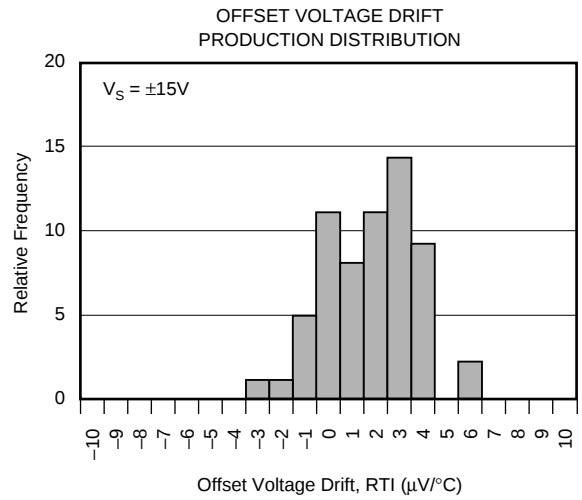
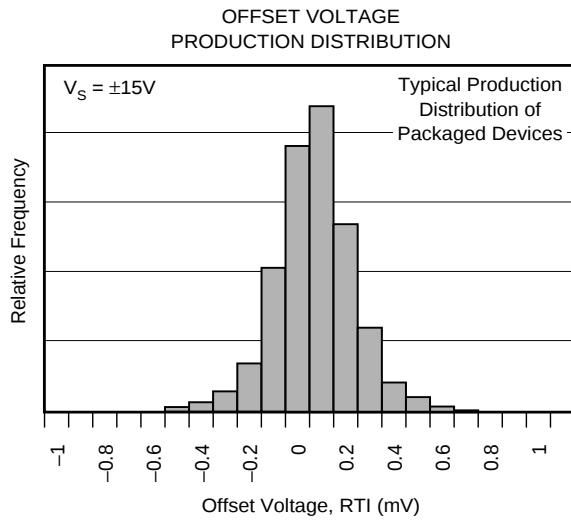
# TYPICAL PERFORMANCE CURVES (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $G = 1$ ,  $R_L = 10\text{k}\Omega$  connected to ground and Ref pin connected to ground, unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $G = 1$ ,  $R_L = 10\text{k}\Omega$  connected to ground and Ref pin connected to ground, unless otherwise noted.



## APPLICATION INFORMATION

The INA145 is a programmable gain difference amplifier consisting of a gain of 1 difference amplifier and a programmable-gain output buffer stage. Basic circuit connections are shown in Figure 1. Power supply bypass capacitors should be connected close to pins 4 and 7, as shown. The amplifier is programmable in the range of  $G = 1$  to  $G = 1000$  with two external resistors.

The output of A1 is connected to the noninverting input of A2 through a  $10\text{k}\Omega$  resistor which is trimmed to  $\pm 1\%$  absolute accuracy. The A2 input is available for applications such as a filter or a precision current source. See application figures for examples.

### OPERATING VOLTAGE

The INA145 is fully specified for supply voltages from  $\pm 2.25\text{V}$  to  $\pm 18\text{V}$ , with key parameters guaranteed over the temperature range  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ . The INA145 can be operated with single or dual supplies, with excellent performance. Parameters that vary significantly with operating voltage, load conditions, or temperature are shown in the typical performance curves.

### SETTING THE GAIN

The gain of the INA145 is set by using two external resistors,  $R_{G1}$  and  $R_{G2}$ , according to the equation:

$$G = 1 + R_{G2}/R_{G1}$$

For a total gain of 1, A2 is connected as a buffer amplifier with no  $R_{G1}$ . A feedback resistor,  $R_{G2} = 10\text{k}\Omega$ , should be used in the buffer connection. This provides bias current cancellation (in combination with internal  $R_5$ ) to assure specified offset voltage performance. Commonly used values are shown in the table of Figure 1. Resistor values for other gains should be chosen to provide a  $10\text{k}\Omega$  parallel resistance.

### COMMON-MODE RANGE

The input resistors of the INA145 provides an input common-mode range that extends well beyond the power supply rails. Exact range depends on the power supply voltage and the voltage applied to the Ref terminal (pin 1). To assure proper operation, the voltage at the non-inverting input of A1 (an internal node) must be within its linear operating range. Its voltage is determined by the simple 1:1 voltage divider between pin 3 and pin 1. This voltage must be between  $V_-$  and  $(V_+) - 1\text{V}$ .

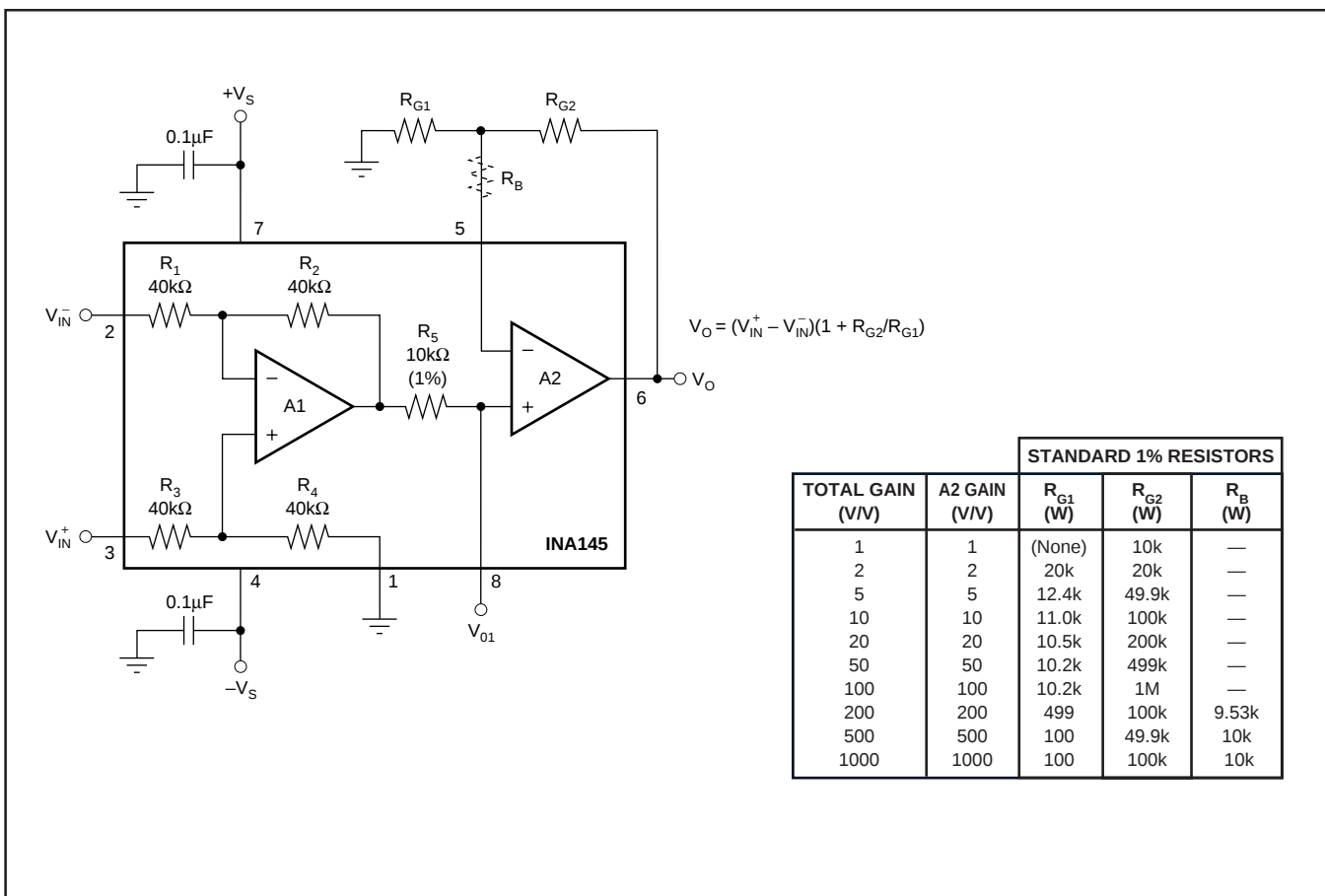


FIGURE 1. Basic Circuit Connections.

## OFFSET TRIM

The INA145 is laser-trimmed for low offset voltage and drift. Most applications require no external offset adjustment. Figure 2 shows an optional circuit for trimming the offset voltage. A voltage applied to the Ref terminal will be summed with the output signal. This can be used to null offset voltage. To maintain good common-mode rejection, the source impedance of a signal applied to the Ref terminal should be less than  $10\Omega$  and a resistor added to the positive input terminal should be 10 times that, or  $100\Omega$ . Alternatively, the trim voltage can be buffered with an op amp such as the OPA277.

## INPUT IMPEDANCE

The input impedance of the INA145 is determined by the input resistor network and is approximately  $40k\Omega$ . The source impedance at the two input terminals must be nearly equal to maintain good common-mode rejection. A  $5\Omega$  mismatch in impedance between the two inputs will cause the typical common-mode rejection to be degraded to approximately 72dB. Figure 7 shows a common application measuring power supply current through a shunt resistor. The source impedance of the shunt resistor,  $R_S$ , is balanced by an equal compensation resistor,  $R_C$ .

Source impedances greater than  $300\Omega$  are not recommended, even if they are perfectly matched. Internal resistors are laser trimmed for accurate ratios, not to absolute values. Adding equal resistors greater than  $300\Omega$  can cause a mismatch in the total resistor ratios, degrading CMR.

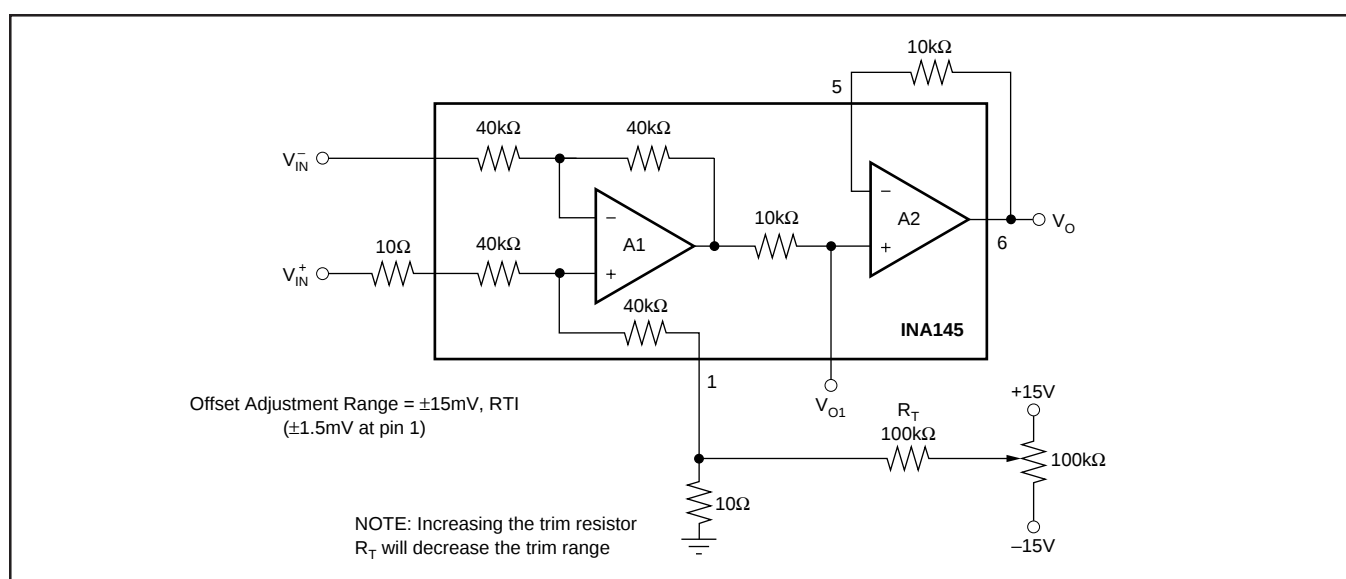


FIGURE 2. Optional Offset Trim Circuit.

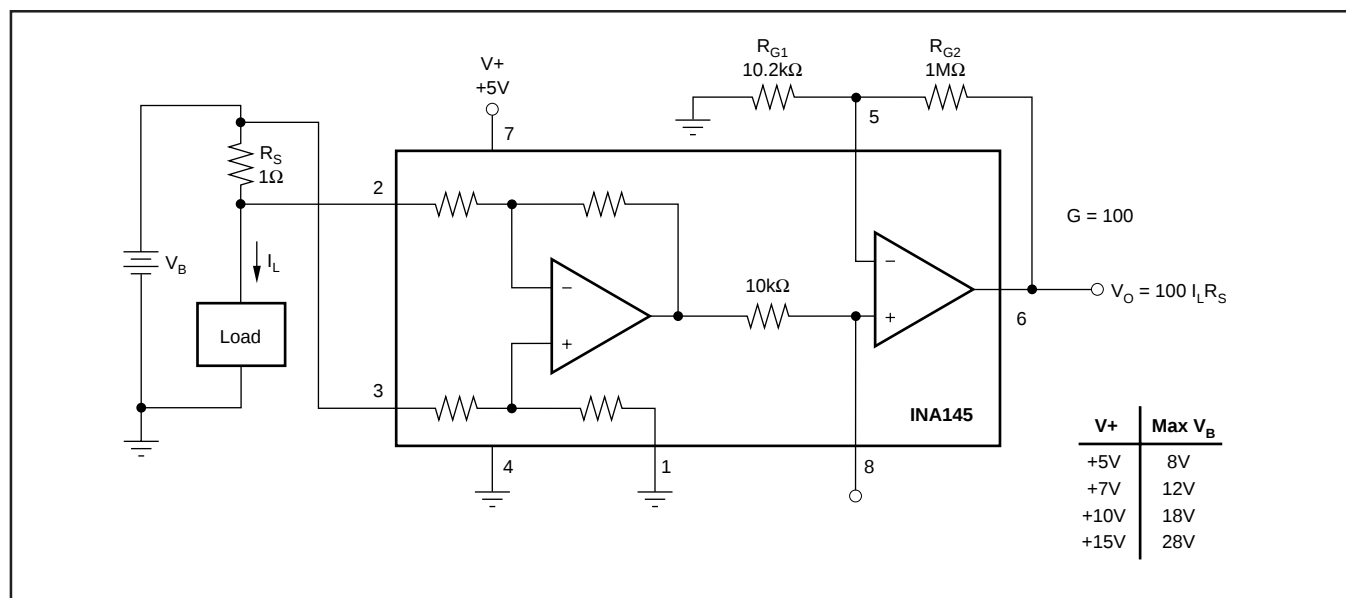


FIGURE 3. Measuring Current with Shunt Resistor.

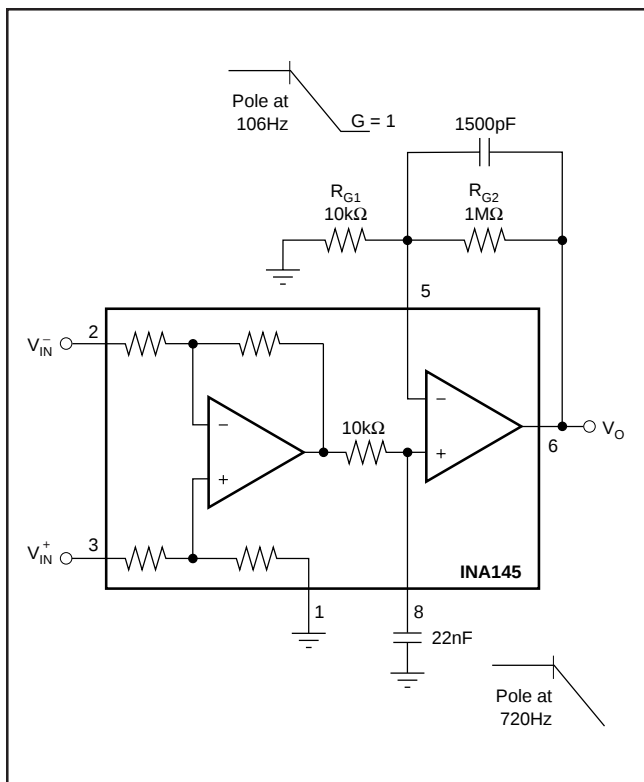


FIGURE 4. Noise Filtering.

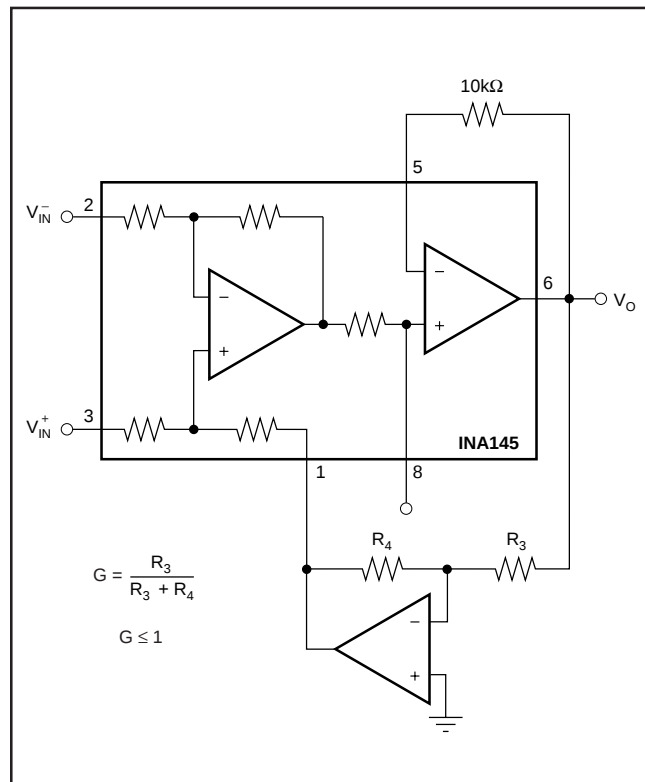


FIGURE 5. Creating Gains Less Than Unity.

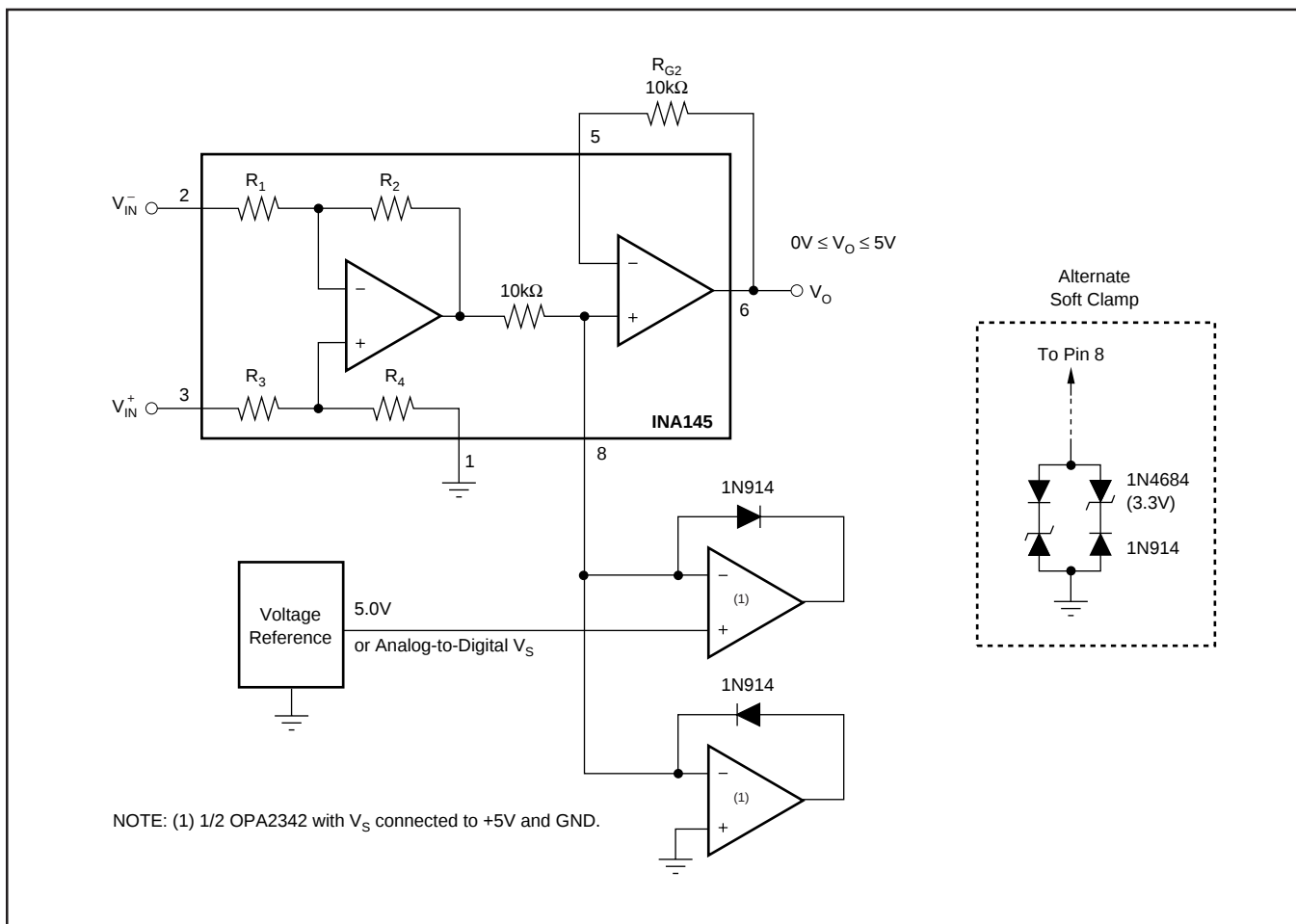


FIGURE 6. Clamp Circuits.

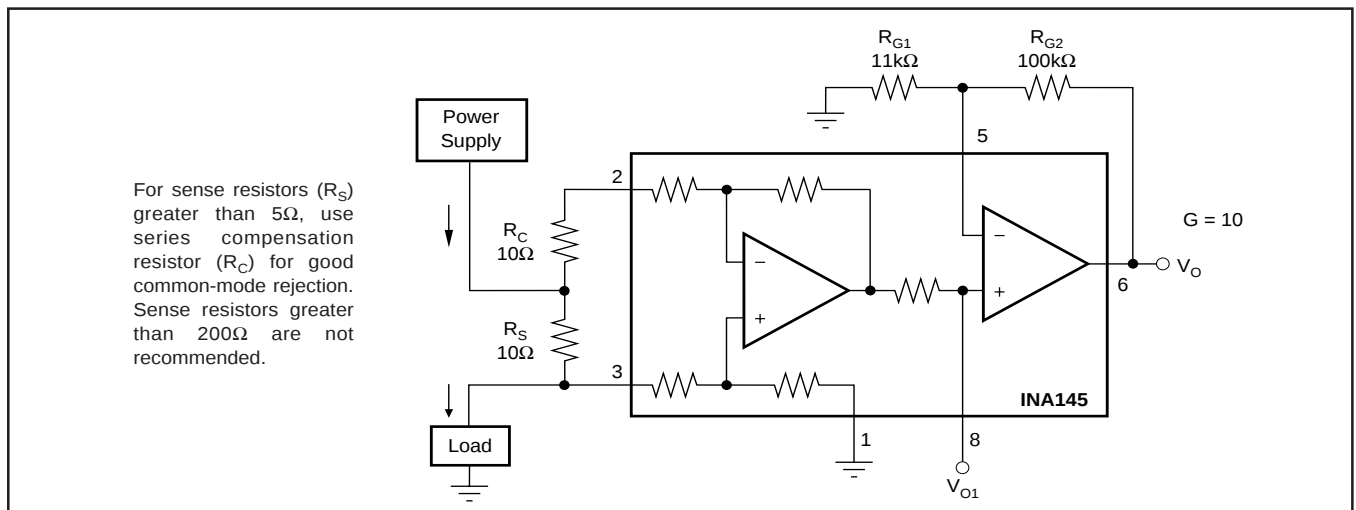


FIGURE 7. Current Monitor,  $G = 1$ .

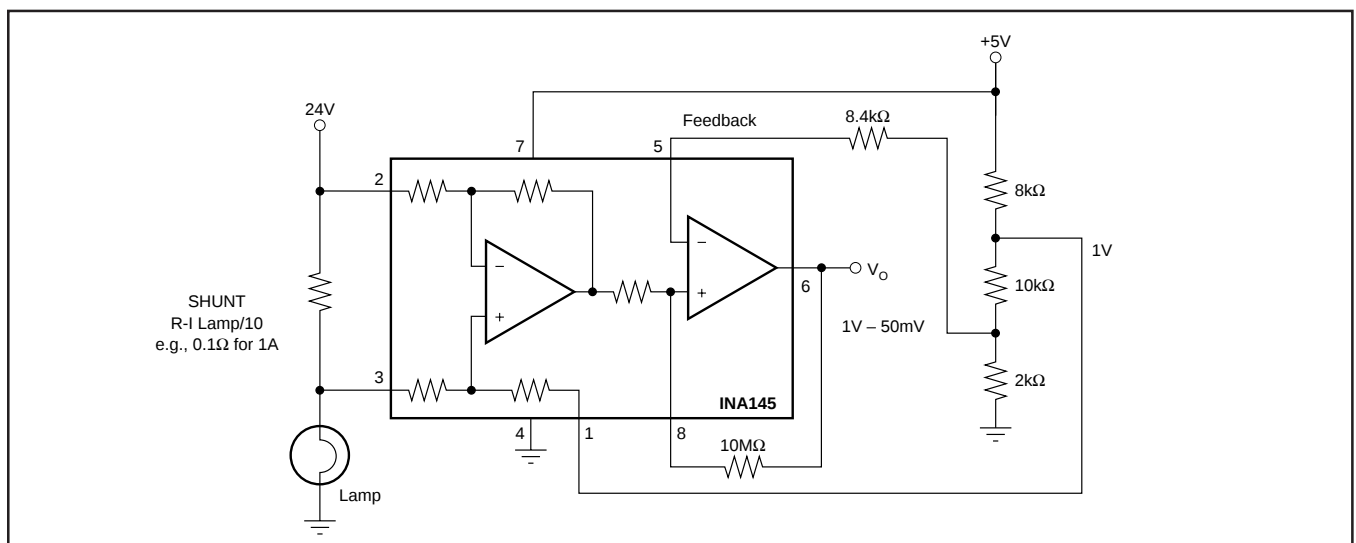


FIGURE 8. Comparator Output with Optional Hysteresis Application to Sense Lamp Burn-Out.

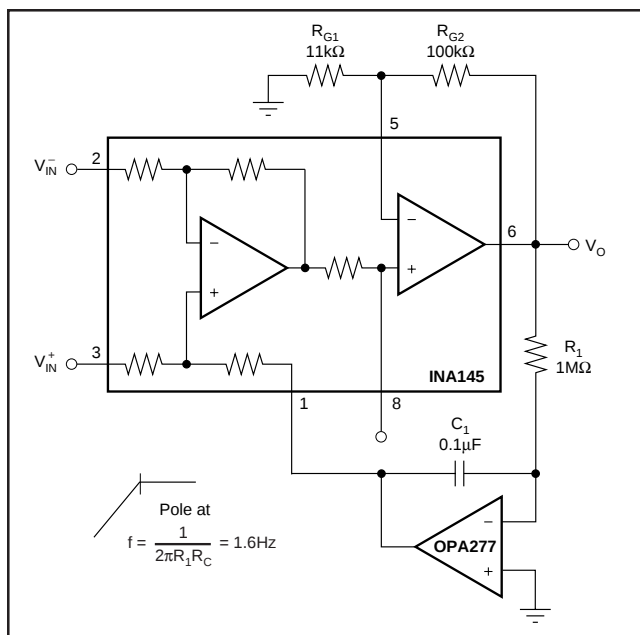


FIGURE 9. AC Coupling (DC Restoration).

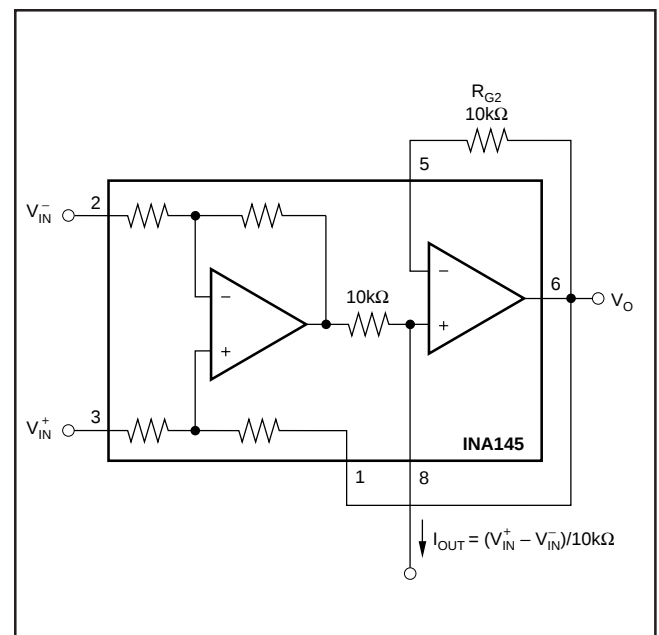


FIGURE 10. Precision Current Source.

## PACKAGING INFORMATION

| Orderable part number | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| INA145UA              | Obsolete      | Production           | SOIC (D)   8   | -                     | -           | Call TI                              | Call TI                           | -40 to 85    | INA<br>145UA        |
| INA145UA/2K5          | Active        | Production           | SOIC (D)   8   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -            | INA<br>145UA        |
| INA145UA/2K5.A        | Active        | Production           | SOIC (D)   8   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | INA<br>145UA        |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

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

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

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

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

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

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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

## TAPE AND REEL INFORMATION



\*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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| INA145UA/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) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| INA145UA/2K5 | SOIC         | D               | 8    | 2500 | 353.0       | 353.0      | 32.0        |

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated