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## **±200V Common-Mode Voltage DIFFERENCE AMPLIFIER**

### **FEATURES**

- **HIGH COMMON-MODE VOLTAGE:**  
 +75V at  $V_s = +5V$   
 ±200V at  $V_s = ±15V$
- **FIXED DIFFERENTIAL GAIN = 1V/V**
- **LOW QUIESCENT CURRENT: 260µA**
- **WIDE SUPPLY RANGE:**  
 Single Supply: 2.7V to 36V  
 Dual Supplies: ±1.35V to ±18V
- **LOW GAIN ERROR: 0.075% max**
- **LOW NONLINEARITY: 0.002% max**
- **HIGH CMR: 86dB**
- **SO-8 PACKAGE**

### **DESCRIPTION**

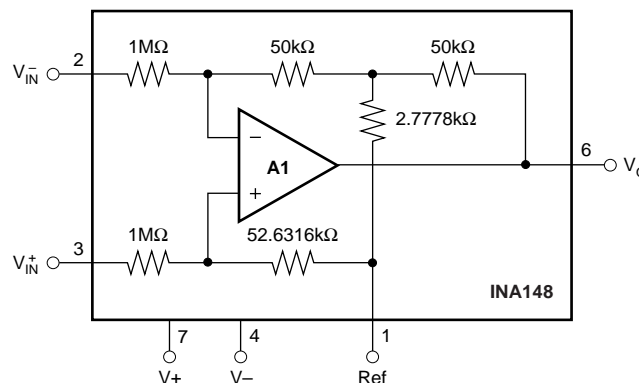
The INA148 is a precision, low-power, unity-gain difference amplifier with a high common-mode input voltage range. It consists of a monolithic precision bipolar op amp with a thin-film resistor network.

The on-chip resistors are laser trimmed for an accurate 1V/V differential gain and high common-mode rejection. Excellent temperature tracking of the resistor network maintains high gain accuracy and common-mode rejection over temperature. The INA148 will operate on single or dual supplies.

The INA148 is available in a small SO-8 surface-mount package and it is specified for the -40°C to +85°C extended industrial temperature range.

### **APPLICATIONS**

- **CURRENT SHUNT MEASUREMENTS**
- **DIFFERENTIAL SENSOR AMPLIFIERS**
- **LINE RECEIVERS**
- **BATTERY POWERED SYSTEMS**
- **AUTOMOTIVE INSTRUMENTATION**
- **STACKED CELL MONITORS**



# SPECIFICATIONS: $V_S = \pm 5V$ to $\pm 15V$ Dual Supplies

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

PARAMETER	CONDITIONS	INA148UA			UNITS
		MIN	TYP	MAX	
<b>OFFSET VOLTAGE (<math>V_O</math>)</b>	<b>RTI<sup>(1)(2)</sup></b>				
Input Offset Voltage	$V_{OS}$ $V_S = \pm 15V, V_{CM} = 0V$ $V_S = \pm 5V, V_{CM} = 0V$		$\pm 1$	$\pm 5$	mV
Drift	$\Delta V_{OS}/\Delta T$ At $T_A = -40^\circ C$ to $+85^\circ C$		$\pm 1$	$\pm 5$	mV
vs Power Supply	PSRR $V_S = \pm 1.35V$ to $\pm 18V, V_{CM} = 0V$		$\pm 10$	$\pm 50$	$\mu V/^\circ C$ $\mu V/V$
<b>INPUT VOLTAGE RANGE</b>					
Common-Mode Voltage Range	$V_{CM}$ $V_S = \pm 15V, (V_{IN}^+) - (V_{IN}^-) = 0V$ $V_S = \pm 5V, (V_{IN}^+) - (V_{IN}^-) = 0V$	-200 -100		+200 +80	V V
Common-Mode Rejection	CMRR $V_S = \pm 15V, V_{CM} = -200V$ to $+200V, R_S = 0\Omega$ $V_S = \pm 5V, V_{CM} = -100V$ to $+80V, R_S = 0\Omega$	70 70	86 86		dB dB
<b>INPUT IMPEDANCE</b>					
Differential			2		$M\Omega$
Common Mode			1		$M\Omega$
<b>NOISE</b>	<b>RTI<sup>(1)(3)</sup></b>				
Voltage Noise, $f = 0.1Hz$ to $10Hz$	$e_n$		17		$\mu Vp-p$
Voltage Noise Density, $f = 1kHz$			880		$nV/\sqrt{Hz}$
<b>GAIN</b>					
Initial <sup>(1)</sup>			1		V/V
Gain Error	$V_O = (V-) + 0.5$ to $(V+) - 1.5$		$\pm 0.01$	$\pm 0.075$	%
vs Temperature			$\pm 3$	$\pm 10$	ppm/ $^\circ C$
Nonlinearity	$V_S = \pm 15V, V_O = (V-) + 0.5$ to $(V+) - 1.5$ $V_S = \pm 5V, V_O = (V-) + 0.5$ to $(V+) - 1.5$		$\pm 0.001$	$\pm 0.002$	% of FSR % of FSR
<b>FREQUENCY RESPONSE</b>					
Small Signal Bandwidth			100		kHz
Slew Rate			1		V/ $\mu s$
Settling Time: 0.1%	$V_S = \pm 15V, 10V$ Step		21		$\mu s$
0.01%	$V_S = \pm 15V, 10V$ Step		25		$\mu s$
0.1%	$V_S = \pm 5V, 6V$ Step		21		$\mu s$
0.01%	$V_S = \pm 5V, 6V$ Step		25		$\mu s$
Overload Recovery	50% Input Overload		24		$\mu s$
<b>OUTPUT (<math>V_O</math>)</b>					
Voltage Output	$R_L = 100k\Omega$ $R_L = 10k\Omega$	$(V-) + 0.25$ $(V-) + 0.5$		$(V+) - 1$ $(V+) - 1.5$	V V
Output Current	$I_O$		$\pm 13$		mA
Short-Circuit Current	Continuous to Common		10		nF
Capacitive Load	Stable Operation				
<b>POWER SUPPLY</b>					
Operating Range, Dual Supplies		$\pm 1.35$		$\pm 18$	V
Quiescent Current	$V_{IN} = 0, I_O = 0$		$\pm 260$	$\pm 300$	$\mu A$
<b>TEMPERATURE RANGE</b>					
Specified		-40		85	$^\circ C$
Operating		-55		125	$^\circ C$
Storage		-55		125	$^\circ C$
Thermal Resistance	$\theta_{JA}$ SO-8 Surface Mount		150		$^\circ C/W$

NOTES: (1) Overall difference amplifier configuration. Referred to input pins ( $V_{IN}^+$  and  $V_{IN}^-$ ), gain = 1V/V (2) Input offset voltage specification includes effects of amplifier's input bias and offset currents. (3) Includes effects of input current noise and thermal noise contribution of resistor network.

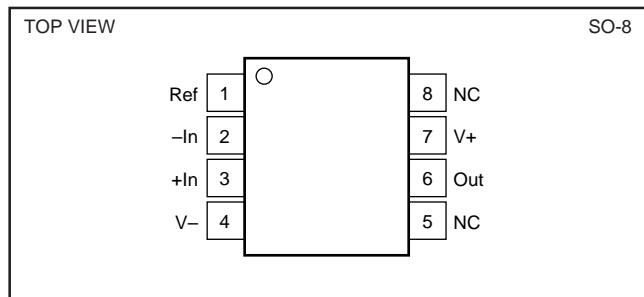
# SPECIFICATIONS: $V_S = +5V$ Single Supply

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10k\Omega$  connected to  $V_S/2$  and Ref pin connected to  $V_S/2$ , unless otherwise noted.

PARAMETER	CONDITIONS	INA148UA			UNITS
		MIN	TYP	MAX	
<b>OFFSET VOLTAGE (<math>V_O</math>)</b>	<b>RTI<sup>(1)(2)</sup></b>				
Input Offset Voltage	$V_{OS}$ $V_{CM} = V_S/2$		$\pm 1$	$\pm 5$	mV
Drift	$\Delta V_{OS}/\Delta T$ At $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		$\pm 10$		$\mu\text{V}/^\circ\text{C}$
vs Power Supply	PSRR $V_S = +2.7V$ to $+36V$ , $V_{CM} = V_S/2$		$\pm 50$	$\pm 400$	$\mu\text{V}/V$
<b>INPUT VOLTAGE RANGE</b>					
Common-Mode Voltage Range	$V_{CM}$ $(V_{IN+}) - (V_{IN-}) = 0V$ , $V_{REF} = 0.25V$	-4		+75	V
Common-Mode Rejection	CMRR $(V_{IN+}) - (V_{IN-}) = 0V$ , $V_{REF} = V_S/2$ $V_{CM} = -47.5V$ to $+32.5V$ , $R_S = 0\Omega$	-47.5 70	86	+32.5	V dB
<b>INPUT IMPEDANCE</b>					
Differential			2		$M\Omega$
Common Mode			1		$M\Omega$
<b>NOISE</b>	<b>RTI<sup>(1)(3)</sup></b>				
Voltage Noise, $f = 0.1\text{Hz}$ to $10\text{Hz}$	$e_n$		17		$\mu\text{Vp-p}$
Voltage Noise Density, $f = 1\text{kHz}$			880		$\text{nV}/\sqrt{\text{Hz}}$
<b>GAIN</b>					
Initial <sup>(1)</sup>			1		V/V
Gain Error	$V_O = +0.5V$ to $+3.5V$		$\pm 0.01$	$\pm 0.075$	%
vs Temperature			$\pm 3$	$\pm 10$	$\text{ppm}/^\circ\text{C}$
Nonlinearity	$V_O = +0.5V$ to $+3.5V$		$\pm 0.001$		% of FSR
<b>FREQUENCY RESPONSE</b>					
Small Signal Bandwidth			100		kHz
Slew Rate			1		$V/\mu\text{s}$
Settling Time: 0.1%	$V_S = +5V$ , 3V Step		21		$\mu\text{s}$
0.01%	$V_S = +5V$ , 3V Step		25		$\mu\text{s}$
Overload Recovery	50% Input Overload		13		$\mu\text{s}$
<b>OUTPUT (<math>V_O</math>)</b>					
Voltage Output	$R_L = 100k\Omega$ $R_L = 10k\Omega$	$(V-) + 0.25$ $(V-) + 0.5$		$(V+) - 1$ $(V+) - 1.5$	V V
Output Current	$I_O$		$\pm 8$		mA
Short-Circuit Current	Continuous to Common		10		nF
Capacitive Load	Stable Operation				
<b>POWER SUPPLY</b>					
Operating Range, Single Supply		+2.7		+36	V
Quiescent Current	$V_{IN} = 0$ , $I_O = 0$		260	300	$\mu\text{A}$
<b>TEMPERATURE RANGE</b>					
Specified		-40		85	$^\circ\text{C}$
Operating		-55		125	$^\circ\text{C}$
Storage		-55		125	$^\circ\text{C}$
Thermal Resistance	$\theta_{JA}$ SO-8 Surface Mount		150		$^\circ\text{C}/W$

NOTES: (1) Overall difference amplifier configuration. Referred to input pins ( $V_{IN+}$  and  $V_{IN-}$ ), gain = 1V/V (2) Input offset voltage specification includes effects of amplifier's input bias and offset currents. (3) Includes effects of input current noise and thermal noise contribution of resistor network.

## 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, Continuous .....	±200V
Peak (0.1s) .....	±500V
Output Short Circuit to GND Duration .....	Continuous
Operating Temperature .....	-55°C to +125°C
Storage Temperature .....	-55°C to +125°C
Junction Temperature .....	+150°C
Lead Temperature (soldering, 10s) .....	+300°C

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

## PACKAGE/ORDERING INFORMATION

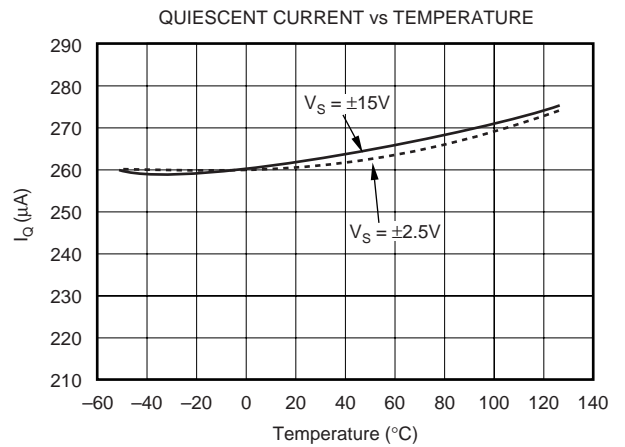
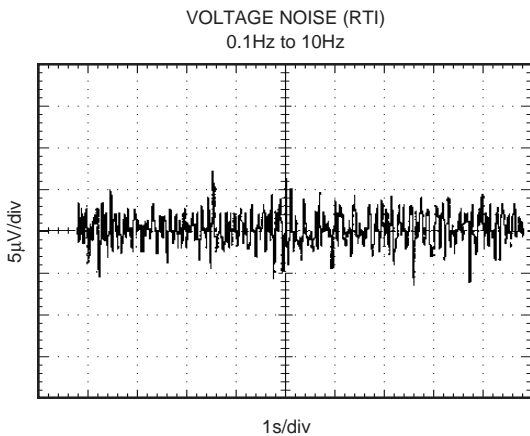
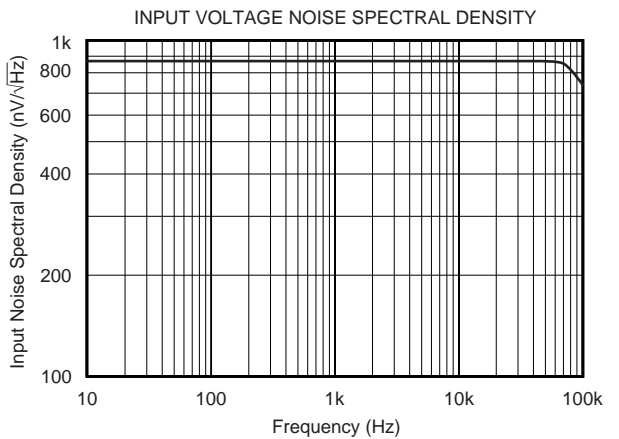
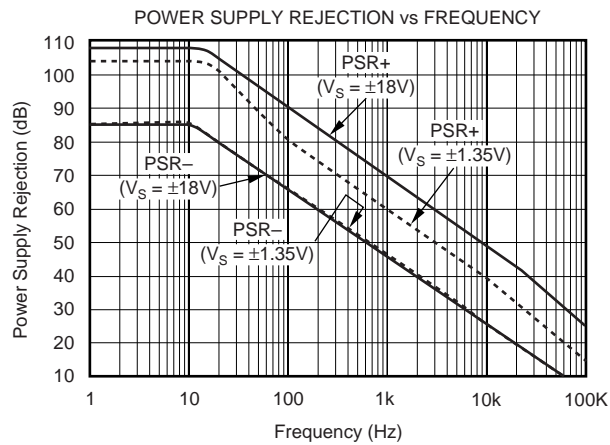
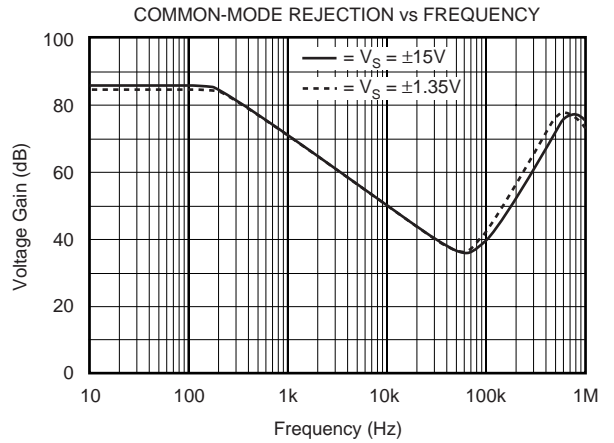
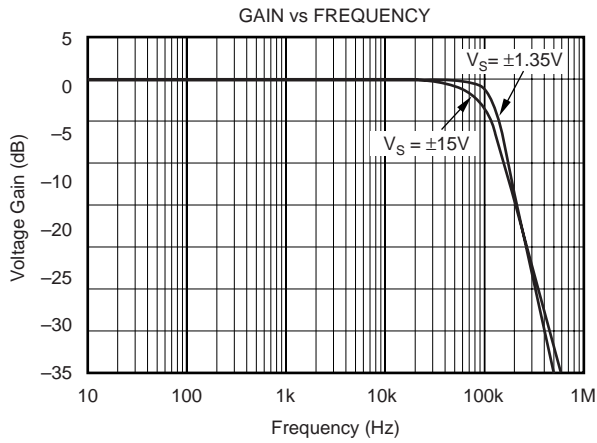
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER <sup>(1)</sup>	TRANSPORT MEDIA
INA148UA	SO-8	182	-40°C to +85°C	INA148UA	INA148UA	Rails
"	"	"	"	"	INA148UA/2K5	Tape and Reel

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 "INA148UA/2K5" will get a single 2500-piece Tape and Reel.

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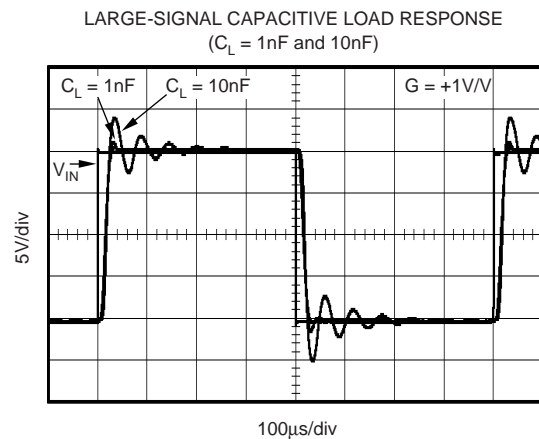
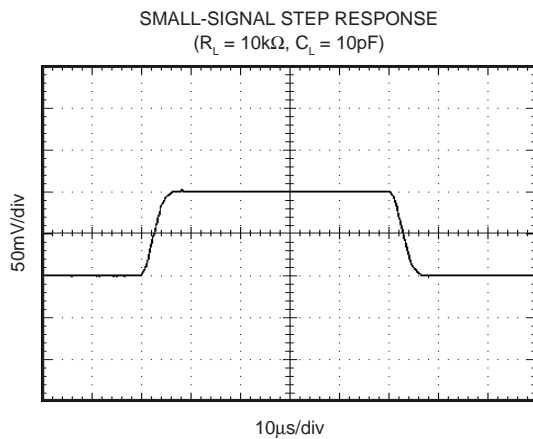
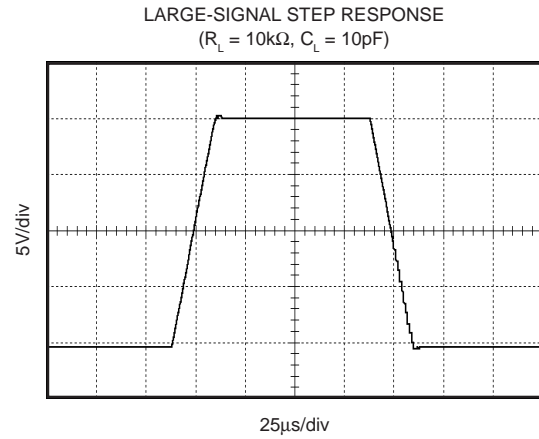
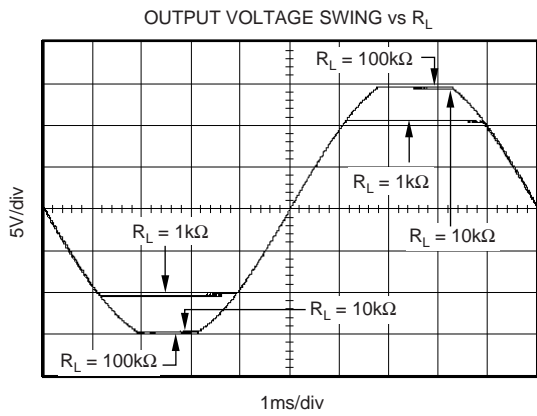
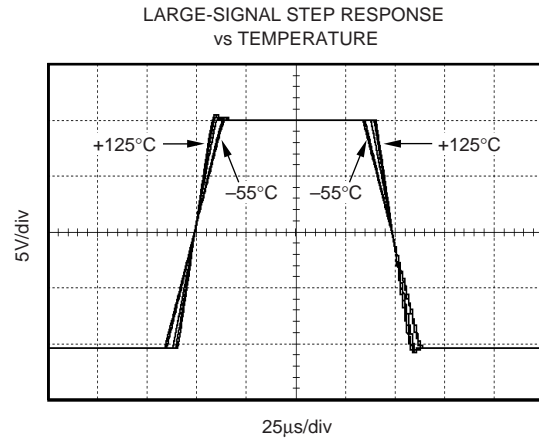
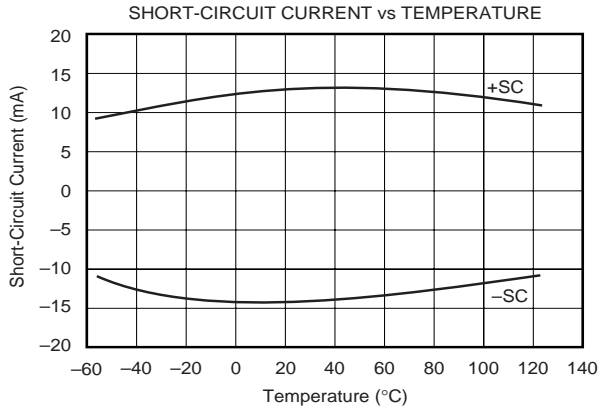
# TYPICAL PERFORMANCE CURVES

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



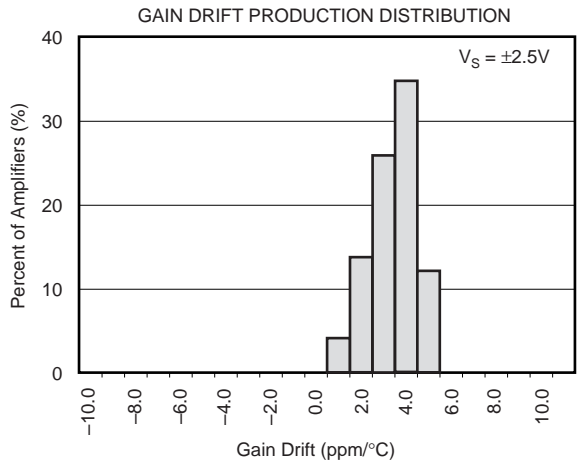
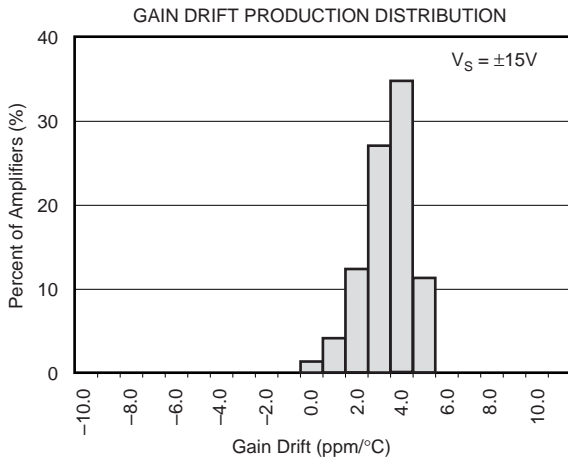
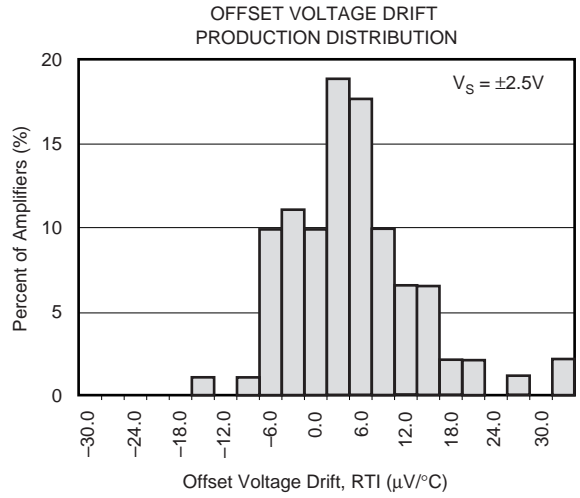
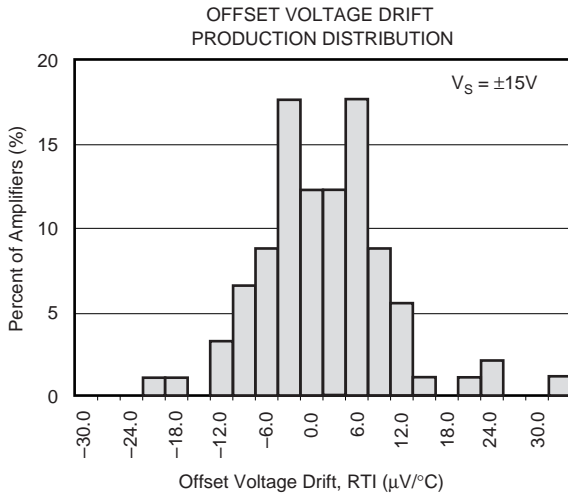
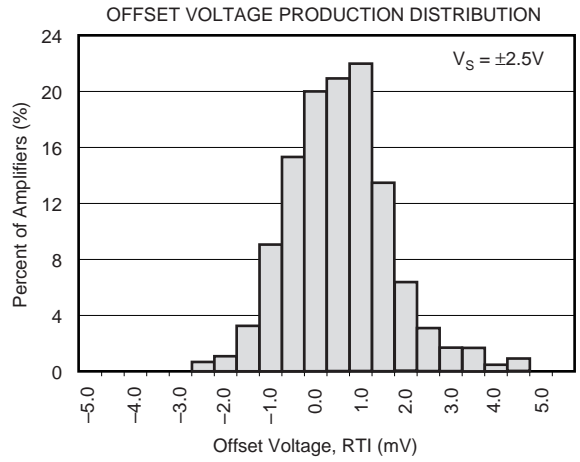
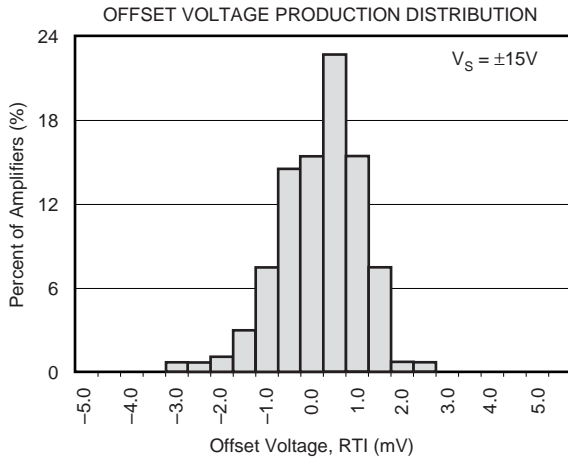
# TYPICAL PERFORMANCE CURVES (Cont.)

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



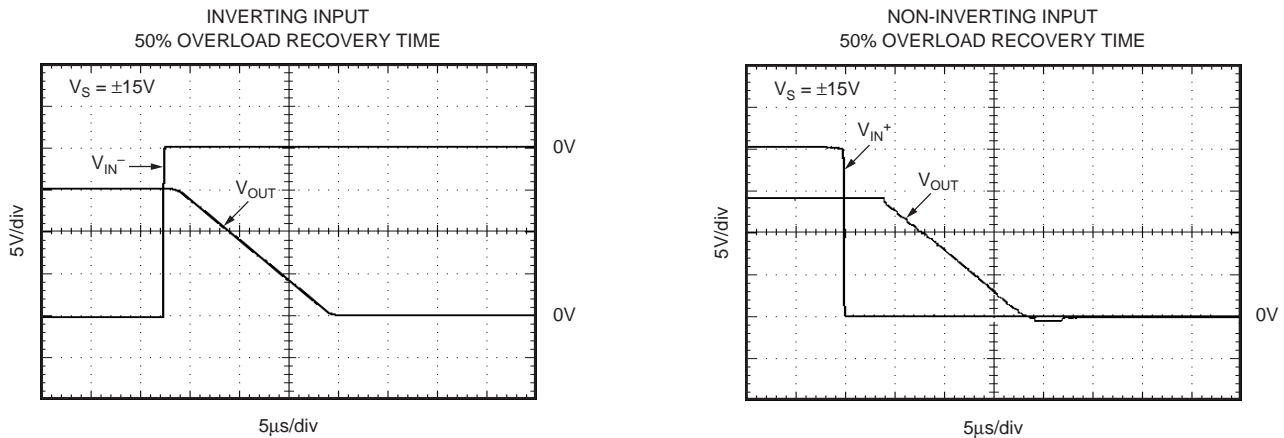
# TYPICAL PERFORMANCE CURVES (Cont.)

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



# TYPICAL PERFORMANCE CURVES (Cont.)

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



## APPLICATION INFORMATION

The INA148 is a unity gain difference amplifier with a high common-mode input voltage range. A basic diagram of the circuit and pin connections is shown in Figure 1.

To achieve its high common-mode voltage range, the INA148 features a precision laser-trimmed thin-film resistor network with a 20:1 input voltage divider ratio. High input voltages are thereby reduced in amplitude, allowing the internal op amp to “see” input voltages that are within its linear operating range. A “Tee” network in the op amp feedback network places the amplifier in a gain of 20V/V, thus restoring the circuit’s overall gain to unity (1V/V).

External voltages can be summed into the amplifier’s output by using the Ref pin, making the differential amplifier a highly versatile design tool. Voltages on the Ref pin will also influence the INA148’s common-mode voltage range.

In accordance with good engineering practice for linear integrated circuits, the INA148’s power-supply bypass

capacitors should be connected as close to pins 4 and 7 as practicable. Ceramic or tantalum types are recommended for use as bypass capacitors.

The input impedances are unusually high for a difference amplifier and this should be considered when routing input signal traces on a PC board. Avoid placing digital signal traces near the difference amplifier’s input traces to minimize noise pickup.

## OPERATING VOLTAGE

The INA148 is specified for  $\pm 15\text{V}$  and  $\pm 5\text{V}$  dual supplies and  $+5\text{V}$  single supplies. The INA148 can be operated with single or dual supplies with excellent performance.

The INA148 is fully characterized for supply voltages from  $\pm 1.35\text{V}$  to  $\pm 18\text{V}$  and over temperatures of  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ . Parameters that vary significantly with operating voltage, load conditions, or temperature are shown in the Typical Performance Curves section.

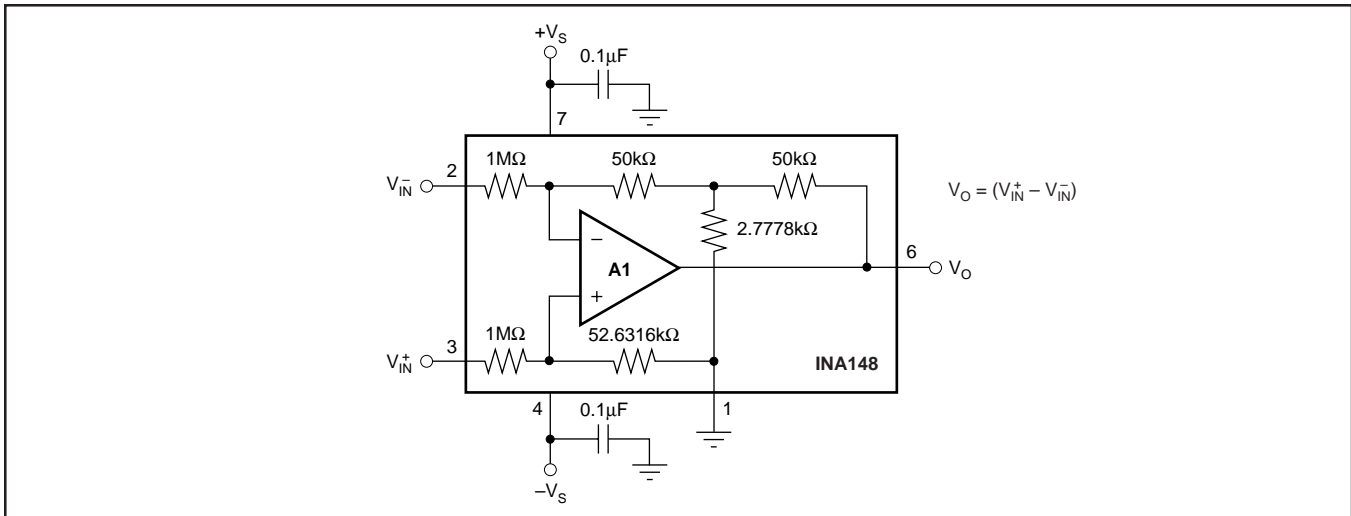


FIGURE 1. Basic Circuit Connections.



## THE GAIN EQUATION

An internal on-chip resistor network sets the overall differential gain of the INA148 to precisely 1V/V. It's output is in accordance with the equation:

$$V_{OUT} = (V_{IN}^{+} - V_{IN}^{-}) + V_{REF} \quad (1)$$

## COMMON-MODE RANGE

The 20:1 input resistor ratio of the INA148 provides an input common-mode range that extends well beyond its power supply rails.

The exact input voltage range depends on the amplifier's power-supply voltage and the voltage applied to the Ref terminal (pin 1). Typical input voltage ranges at different power supply voltages can be found in the applications circuits section.

## OFFSET TRIM

The INA148 is laser-trimmed for low offset voltage and drift. Most applications will require no external offset adjustment.

Since a voltage applied to the reference (Ref) pin (pin 1) will be summed directly into the amplifier's output signal, this technique can be used to null the amplifier's input offset voltage. Figure 2 shows an optional circuit for trimming the offset voltage.

To maintain high common-mode rejection (CMR), the source impedance of any signal applied to the Ref terminal should be very low ( $\leq 5\Omega$ ).

A source impedance of only 10Ω at the Ref pin will reduce the INA148's CMR to approximately 74dB. High CMR can be restored if a resistor is added in series with the amplifier's positive input terminal (pin 3). This resistor should be 19 times the source impedance that drives the Ref pin. For example, if the Ref pin sees a source impedance of 10Ω, a resistor of 190Ω should be added in series with pin 3.

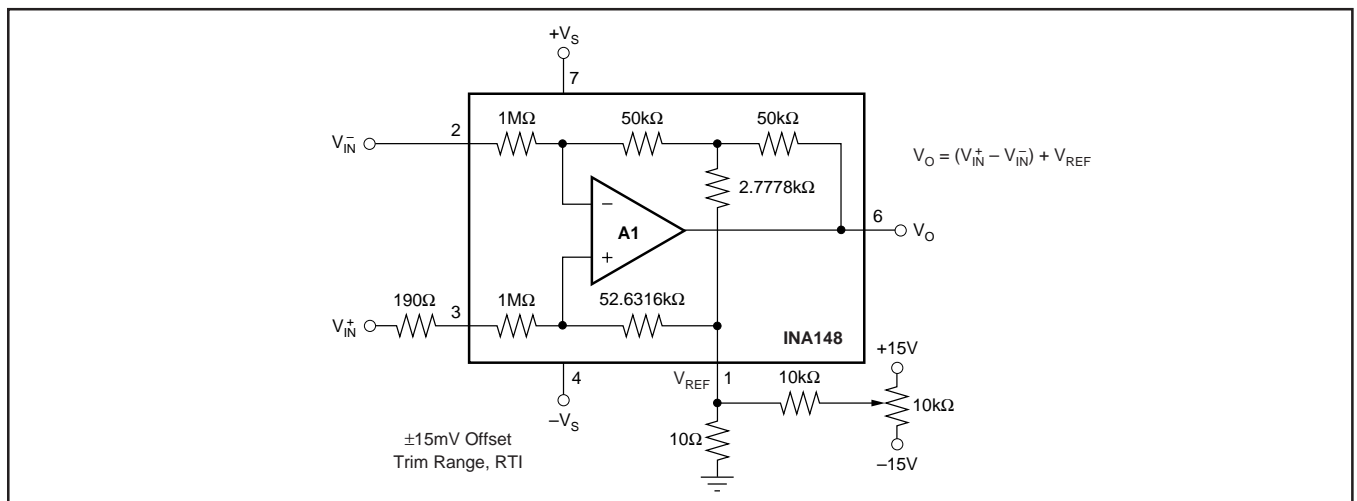


FIGURE 2. Optional Offset Trim Voltage.

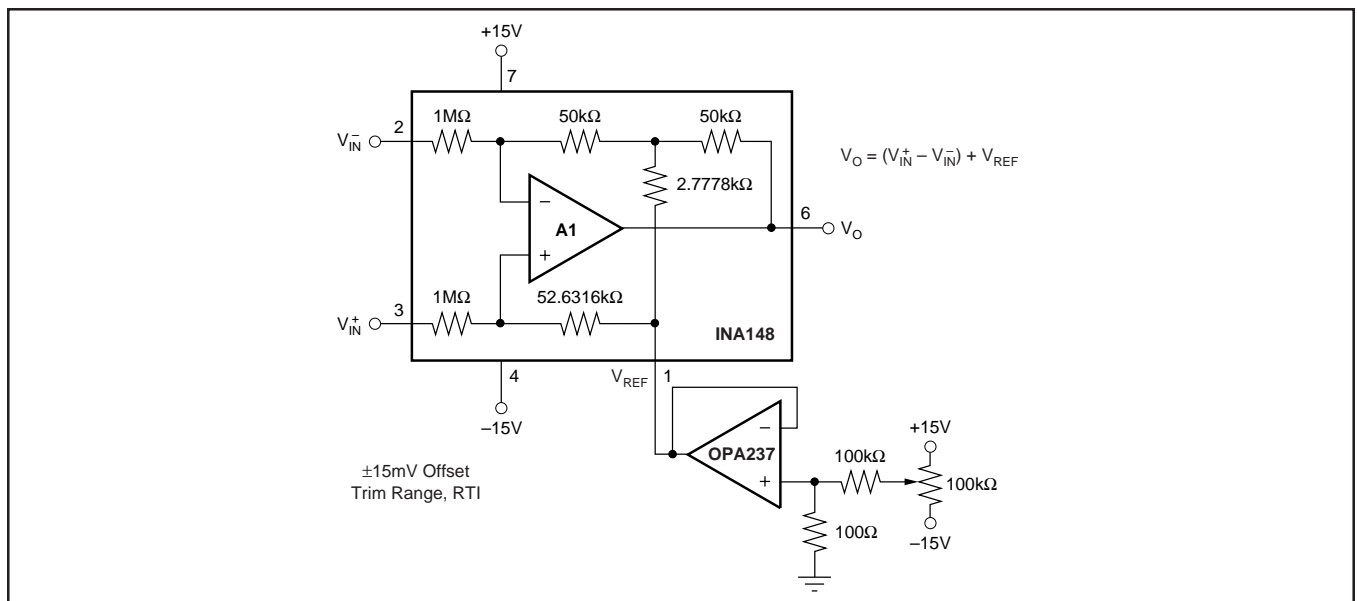


FIGURE 3. Preferred Offset Trim Circuit.

Preferably, the offset trim voltage applied to the Ref pin should be buffered with an amp such as an OPA237 (see Figure 3). In this case, the op amp output impedance is low enough that no external resistor is needed to maintain the INA148's excellent CMR.

### INPUT IMPEDANCE

The input resistor network determines the impedance of each of the INA148's inputs. It is approximately  $1\text{M}\Omega$ . Unlike an instrumentation amplifier, signal source impedances at the two input terminals must be nearly equal to maintain good common-mode rejection.

A mismatch between the two inputs' source impedances will cause a differential amplifier's common-mode rejection to be degraded. With a source impedance imbalance of only  $500\Omega$ , CMR can fall to approximately 66dB.

Figure 4 shows a common application—measuring power supply current through a shunt resistor ( $R_S$ ). A shunt resistor creates an unbalanced source resistance condition that can degrade a differential amplifier's common mode rejection.

Unless the shunt resistor is less than approximately  $100\Omega$ , an additional equal compensating resistor ( $R_C$ ) is recommended to maintain input balance and high CMR.

Source impedances (or shunts) greater than  $5\text{k}\Omega$  are not recommended, even if they are "perfectly" compensated. This is because the internal resistor network is laser-trimmed for accurate voltage divider ratios, but not necessarily to absolute values. Input resistors are shown as  $1\text{M}\Omega$ , however, this is only their nominal value.

In practice, the input resistors' absolute values may vary by as much as 30 percent. The two input resistors match to about 5 percent, so adding compensating resistors greater than  $5\text{k}\Omega$  can cause a serious mismatch in the resulting resistor network voltage divider ratios, thus degrading CMR.

Attempts to extend the INA148 input voltage range by adding external resistors is not recommended for the reasons just described in the last paragraph. CMR will suffer a serious degradation unless the resistors are carefully trimmed for CMR and gain. This is an iterative adjustment and can be tedious and time consuming.

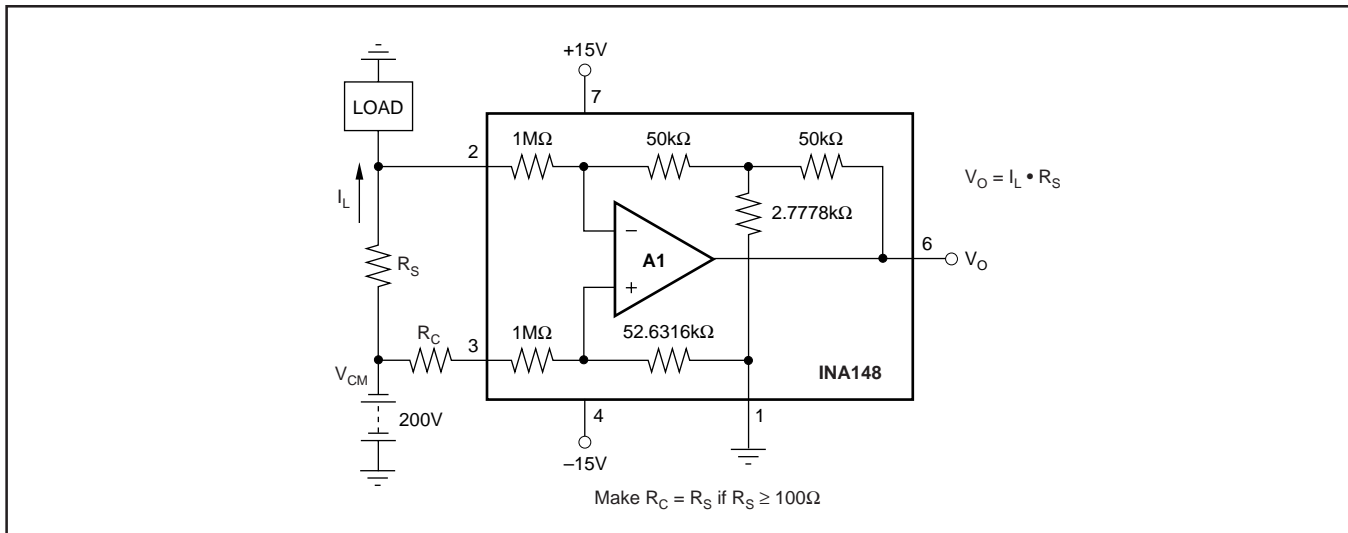


FIGURE 4. Shunt-Resistor Current Measurement Circuit.

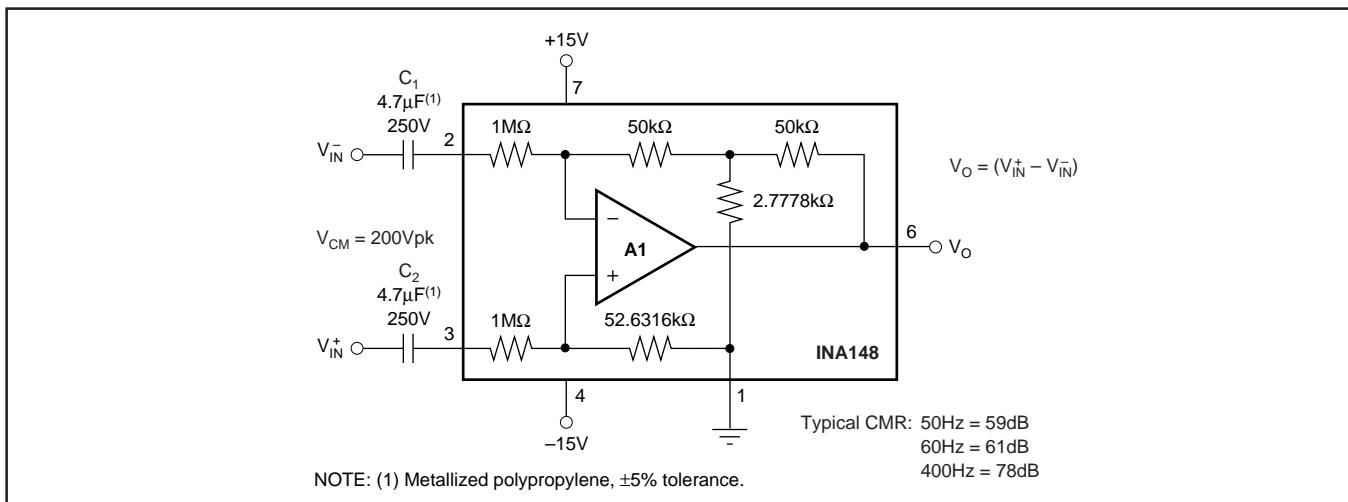


FIGURE 5. AC-Coupled Difference Amplifier.

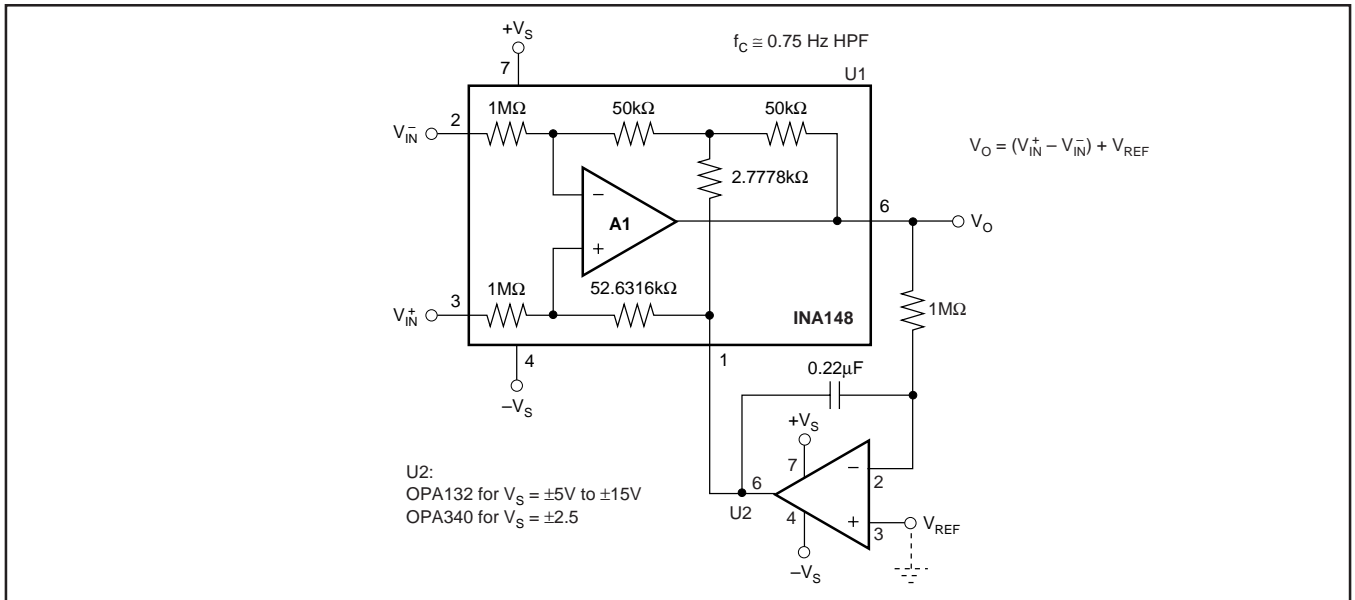


FIGURE 6. Quasi-AC-Coupled Differential Amplifier.

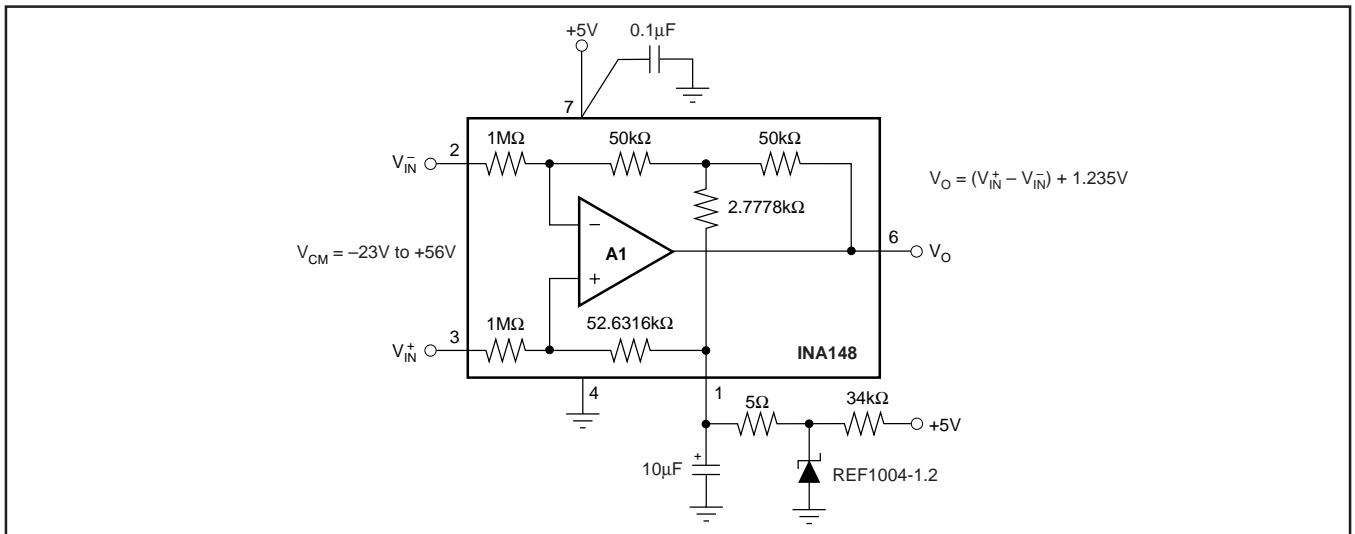


FIGURE 7. Single-Supply Differential Amplifier.

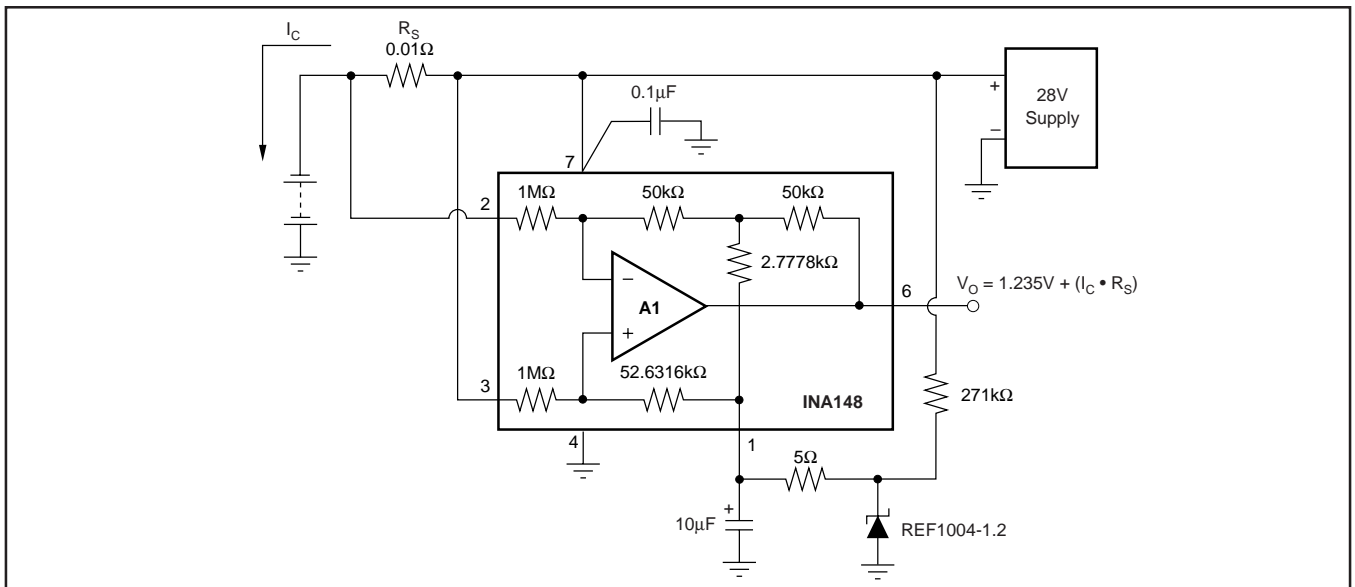


FIGURE 8. Battery Monitor Circuit.

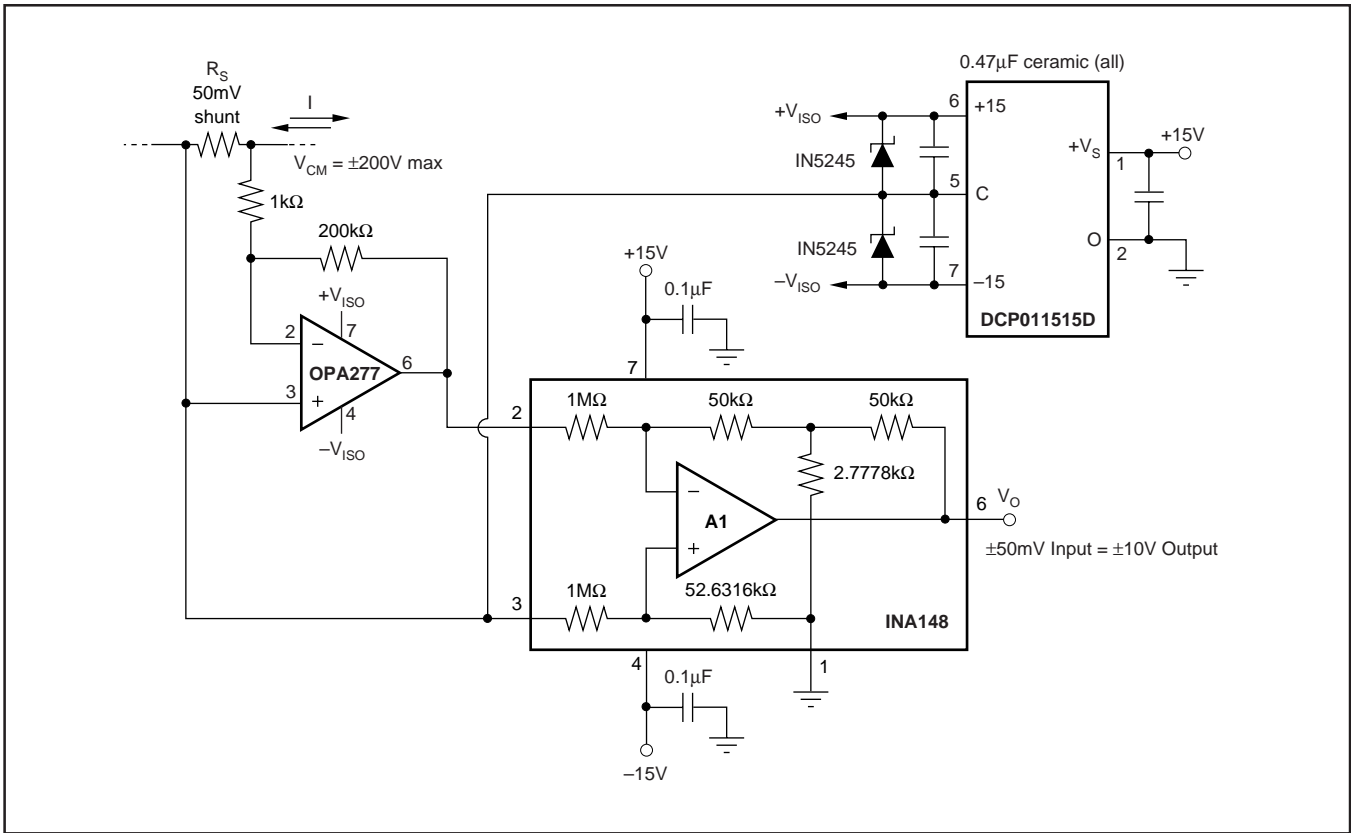


FIGURE 9. 50mV Current Shunt Amplifier with  $\pm 200V$  Common-Mode Voltage Range.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
INA148UA	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA148UA/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA148UA/2K5G4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR
INA148UAG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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**TAPE AND REEL INFORMATION**



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



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA148UA/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)
INA148UA/2K5	SOIC	D	8	2500	346.0	346.0	29.0

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