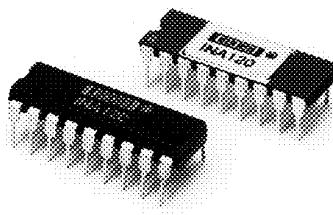




INA120



## Precision INSTRUMENTATION AMPLIFIER

### FEATURES

- **LOW OFFSET VOLTAGE: 25 $\mu$ V max**
- **LOW OFFSET VOLTAGE DRIFT: 0.25 $\mu$ V/ $^{\circ}$ C max**
- **PIN-STRAPPED GAINS: 1, 10, 100, 1000**
- **LOW GAIN DRIFT: 30ppm/ $^{\circ}$ C max at G = 100**
- **HIGH COMMON-MODE REJECTION: 106dB at 60Hz, G = 100**

### APPLICATIONS

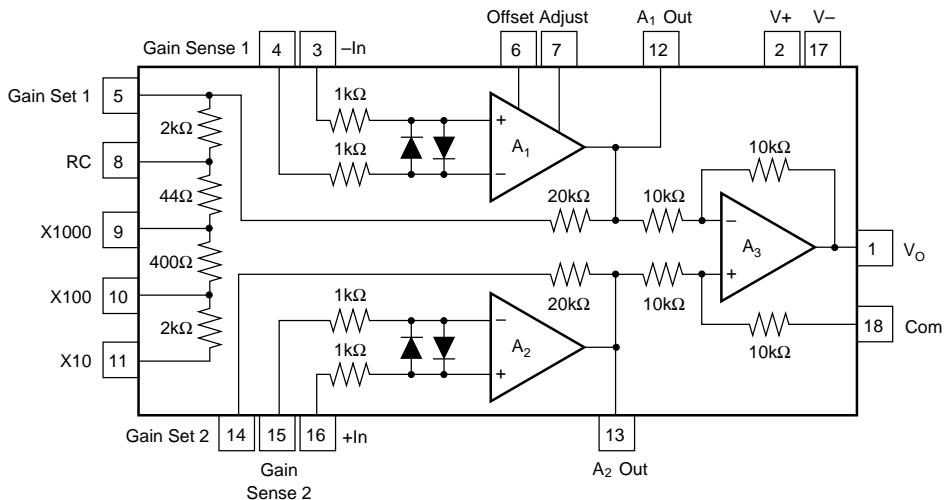
- **BRIDGE AMPLIFIER**
- **THERMOCOUPLE AMPLIFIER**
- **RTD SENSOR AMPLIFIER**
- **MEDICAL INSTRUMENTATION**
- **DATA ACQUISITION SYSTEM**
- **SWITCHED-GAIN AMPLIFIER**

### DESCRIPTION

The INA120 is a precision instrumentation amplifier ideal for accurate signal acquisition. It combines precision, protected-input operational amplifiers, laser-trimmed gain-setting resistors, and a high common-mode rejection difference amplifier on a single chip.

Simple pin-strapped connections set precise gains of 1, 10, 100 or 1000. External resistors can be used to set any gain from one to 5000. Gains can be digitally selected with an external multiplexer. Gain-sense connections on the INA120 maintain accuracy when using multiplexer or gain-switching circuitry. Low power dissipation and careful on-chip thermal management reduce warm-up drift and assure excellent long-term stability.

The INA120 is available in both plastic and ceramic 18-pin DIP packages, specified for the industrial temperature range.



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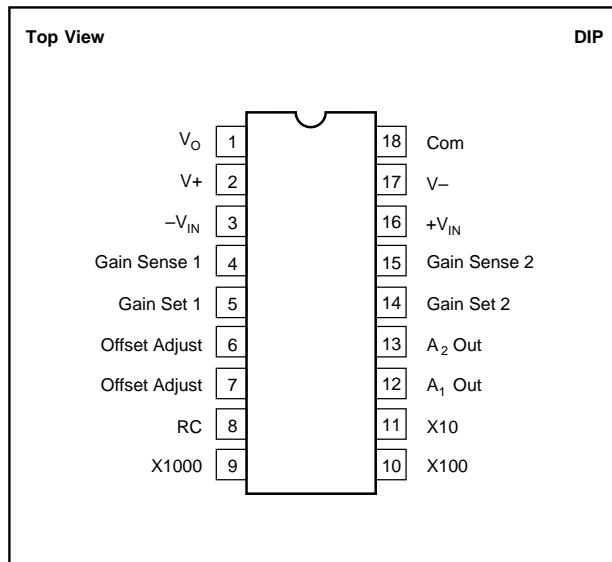
# SPECIFICATIONS

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

PARAMETER	CONDITIONS	INA120CG			INA120BG, BP			INA120AP			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
<b>GAIN</b>		1	$1 + (2R_F/R_G)$	1000	1	$1 + (2R_F/R_G)$	1000	1	$1 + (2R_F/R_G)$	1000	V/V
Range of Gain			0.01	0.05		0.01	0.05		0.02	0.1	%
Gain Equation		G = 1	0.05	0.1		0.05	0.2		0.1	0.2	%
Gain Error		G = 10	0.1	0.2		0.1	0.3		0.2	0.5	%
		G = 100	0.3	0.5		0.3	1		0.5	1	%
Gain Temp Coefficient		G = 1000	4	10		4	20		6	20	$\text{ppm}/^\circ\text{C}$
		G = 1	4	10		4	20		8	40	$\text{ppm}/^\circ\text{C}$
		G = 10	6	30		6	40		10	60	$\text{ppm}/^\circ\text{C}$
Nonlinearity		G = 100	22	50		22	50		40	100	$\text{ppm}/^\circ\text{C}$
		G = 1	0.001	0.005		0.001	0.01		0.001	0.01	% of FS
		G = 10	0.002	0.005		0.002	0.01		0.002	0.01	% of FS
		G = 100	0.004	0.01		0.004	0.02		0.004	0.02	% of FS
		G = 1000	0.008	0.05		0.008	0.1		0.008	0.1	% of FS
<b>OFFSET VOLTAGE</b>											
Initial Offset			(10+ 300/G)	(25+ 600/G)		(50+ 300/G)	(100+ 1000/G)		(50+ 600/G)	(200+ 2000/G)	$\mu\text{V}$
vs Temperature					(.25 + 10/G)						$\mu\text{V}/^\circ\text{C}$
vs Power Supply			$V_s = \pm 6\text{V}$ to $\pm 18\text{V}$		(1 + 20/G)(10 + 150/G)		(1 + 20/G)(20 + 250/G)		(1 + 20/G)(40 + 300/G)		$\mu\text{V}/\text{V}$
<b>INPUT BIAS CURRENT</b>											
Initial Bias Current				$\pm 7$	$\pm 20$		$\pm 7$	$\pm 20$		$\pm 20$	$\text{nA}$
vs Temperature				$\pm 0.2$	$\pm 10$		$\pm 0.2$	$\pm 20$		$\pm 0.2$	$\text{nA}/^\circ\text{C}$
Initial Offset Current				$\pm 5$			$\pm 5$			$\pm 10$	$\text{nA}$
vs Temperature				$\pm 0.2$			$\pm 0.2$			$\pm 0.2$	$\text{nA}/^\circ\text{C}$
Impedance: Differential				$10^{10} \parallel 3$			$10^{10} \parallel 3$			$10^{10} \parallel 3$	$\Omega \parallel \text{pF}$
Common-Mode				$10^{10} \parallel 3$			$10^{10} \parallel 3$			$10^{10} \parallel 3$	$\Omega \parallel \text{pF}$
<b>INPUT VOLTAGE RANGE</b>											
Range, Linear Response											
CMRR (DC, 1k $\Omega$ Source Imbalance)		G = 1	$\pm 10$	$\pm 12.5$		G = 10	$\pm 12.5$		G = 100	$\pm 12.5$	V
		G = 10	80	90		G = 100	74		G = 1000	70	$\text{dB}$
		G = 100	96	106		G = 1000	90		G = 1000	85	$\text{dB}$
		G = 1000	106	110		G = 1000	106		G = 1000	95	$\text{dB}$
											$\text{dB}$
<b>NOISE</b>											
Input Voltage Noise											
$f_B = 0.1\text{Hz}$ to $10\text{Hz}$		G = 1000	0.7			G = 1000	0.7		G = 1000	0.7	$\mu\text{V}$
Density: $f = 10\text{Hz}$		G = 1000	14			G = 1000	14		G = 1000	14	$\text{nV}/\sqrt{\text{Hz}}$
$f = 100\text{Hz}$			11				11			11	$\text{nV}/\sqrt{\text{Hz}}$
$f = 1000\text{Hz}$			10				10			10	$\text{nV}/\sqrt{\text{Hz}}$
Input Current Noise											
$f_B = 0.1\text{Hz}$ to $10\text{Hz}$			50				50			50	$\text{pAp-p}$
Density: $f = 10\text{Hz}$			1.8				1.8			1.8	$\text{pAp-p}/\sqrt{\text{Hz}}$
$f = 1\text{kHz}$			0.4				0.4			0.4	$\text{pAp-p}/\sqrt{\text{Hz}}$
Output Voltage Noise										8	$\mu\text{Vp-p}$
$f_B = 0.1\text{Hz}$ to $10\text{Hz}$											
<b>DYNAMIC RESPONSE</b>											
Small Signal Bandwidth (-3dB)		G = 1	2			G = 10	2		G = 100	2	$\text{MHz}$
		G = 10	200			G = 100	20		G = 1000	200	$\text{kHz}$
		G = 100	20			G = 1000	2		G = 1000	2	$\text{kHz}$
Slew Rate		G = 1000	0.4	0.6		G = 1000	0.6		G = 1000	0.6	$\text{V}/\mu\text{s}$
Settling Time to 0.01%		G = 1	24			G = 10	24		G = 100	24	$\mu\text{s}$
		G = 10	30			G = 100	30		G = 1000	30	$\mu\text{s}$
		G = 100	50			G = 1000	50		G = 1000	50	$\mu\text{s}$
		G = 1000	200			G = 1000	200		G = 1000	200	$\mu\text{s}$
Full Power Bandwidth, $G < 200$		$V_o = \pm 10\text{V}$ , $R_L = 2\text{k}\Omega$	9			$V_o = \pm 10\text{V}$ , $R_L = 2\text{k}\Omega$	9		$V_o = \pm 10\text{V}$ , $R_L = 2\text{k}\Omega$	9	$\mu\text{s}$
Overload Recovery		50% Overdrive	2			50% Overdrive	2		50% Overdrive	2	$\mu\text{s}$
<b>OUTPUT</b>											
Voltage, $R_L = 2\text{k}\Omega$		Over Temperature	$\pm 10.5$	$\pm 12.8$		Over Temperature	$\pm 10.5$	$\pm 12.8$		$\pm 10.5$	V
Current			5	15			5	15		5	$\text{mA}$
Short-Circuit Current				24				24		24	$\text{mA}$
Capacitive Load, Stable Operation				4000				4000		4000	$\text{pF}$
<b>POWER SUPPLY</b>											
Rated Voltage			$\pm 6$	$\pm 15$			$\pm 6$	$\pm 15$		$\pm 6$	V
Voltage Range				$\pm 2.7$				$\pm 2.7$		$\pm 2.7$	V
Supply Current											$\text{mA}$
<b>TEMPERATURE RANGE</b>											
Specification			-25				+85				$^\circ\text{C}$
Operation BP, AP				-40			-25				$^\circ\text{C}$
Operation CG, BG			-55				+85				$^\circ\text{C}$
Storage			-65				+125				$^\circ\text{C}$
				+150			-65				$^\circ\text{C}$
							+150				$^\circ\text{C}$
											$^\circ\text{C}$

See Absolute Maximum Table.

## PIN CONFIGURATION



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....	±18V
Input Voltage Range .....	(V+) +2 to (V-) -2V
Differential Input Voltage .....	Total V <sub>s</sub> +4V
Operating Temperature	
Ceramic G Package .....	-65°C to +150°C
Plastic P Package .....	-40°C to +125°C
Storage Temperature	
Ceramic G Package .....	-65°C to +150°C
Plastic P Package .....	-40°C to +125°C
Junction Temperature	
Ceramic G Package .....	+175°C
Plastic P Package .....	+125°C
Lead Temperature (soldering, 10s) .....	+300°C

## PACKAGE INFORMATION<sup>(1)</sup>

MODEL	PACKAGE	PACKAGE DRAWING NUMBER
INA120AP	18-Pin Plastic DIP	218
INA120BP	18-Pin Plastic DIP	218
INA120BG	18-Pin Ceramic DIP	158
INA120CG	18-Pin Ceramic DIP	158

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

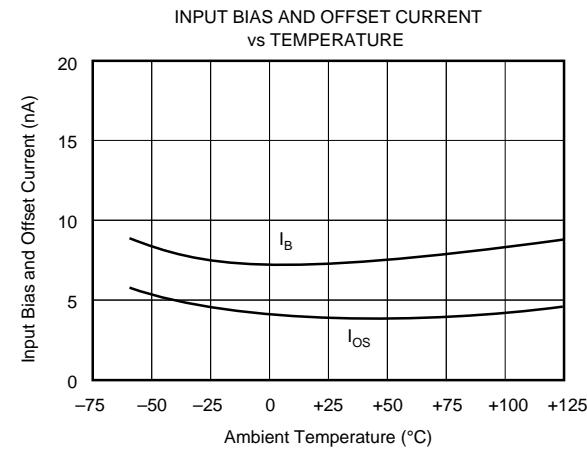
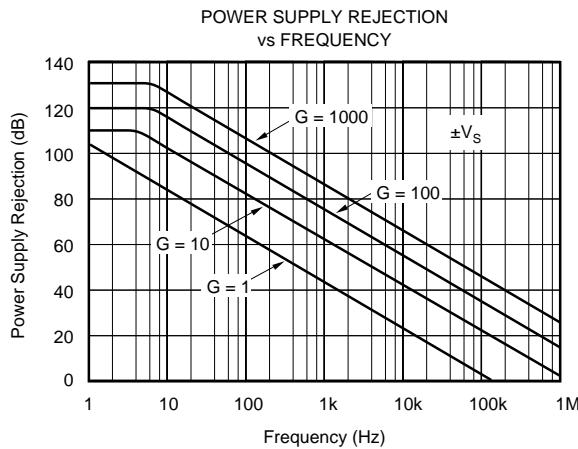
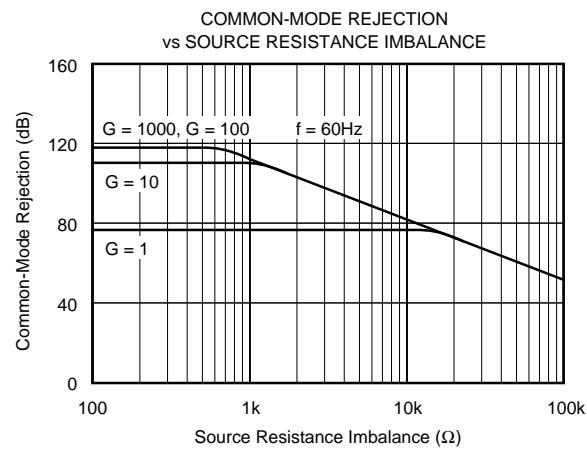
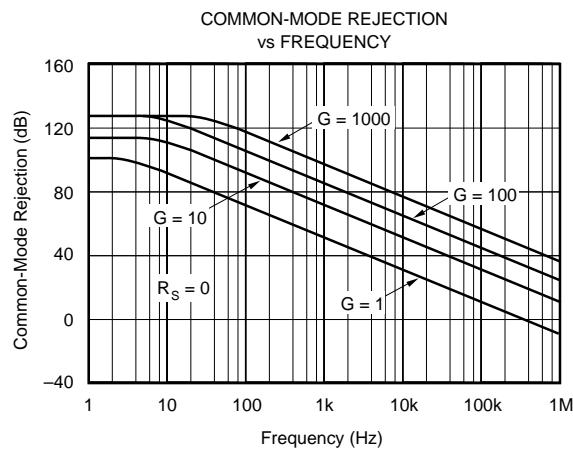
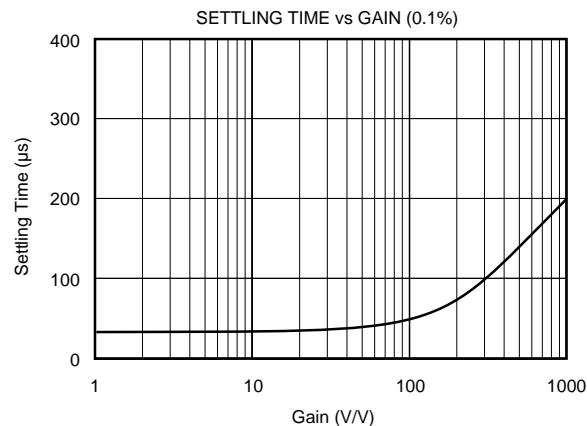
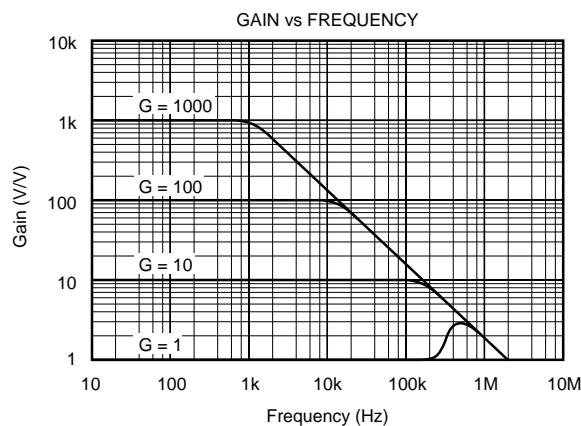
## ORDERING INFORMATION

MODEL	PACKAGE	TEMPERATURE RANGE
INA120AP	18-Pin Plastic DIP	-25°C to +85°C
INA120BP	18-Pin Plastic DIP	-25°C to +85°C
INA120BG	18-Pin Ceramic DIP	-25°C to +85°C
INA120CG	18-Pin Ceramic DIP	-25°C to +85°C

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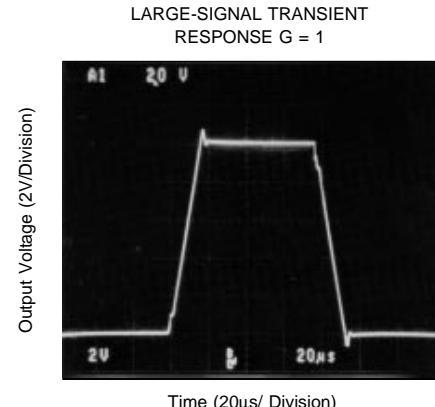
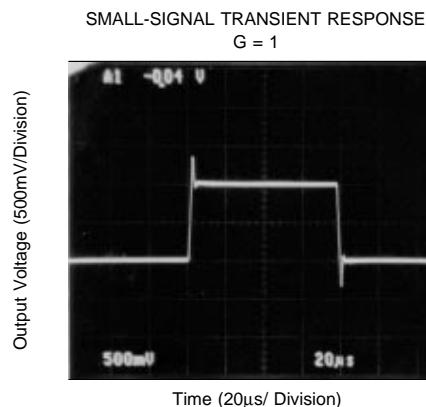
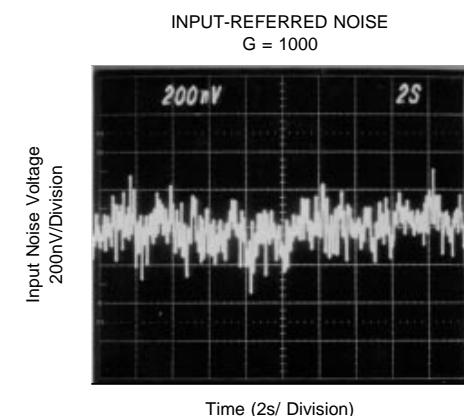
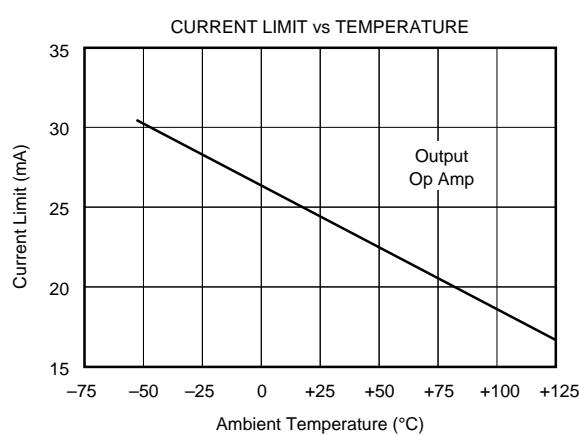
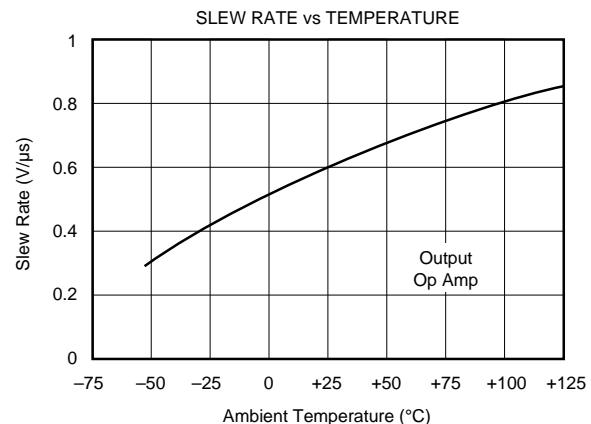
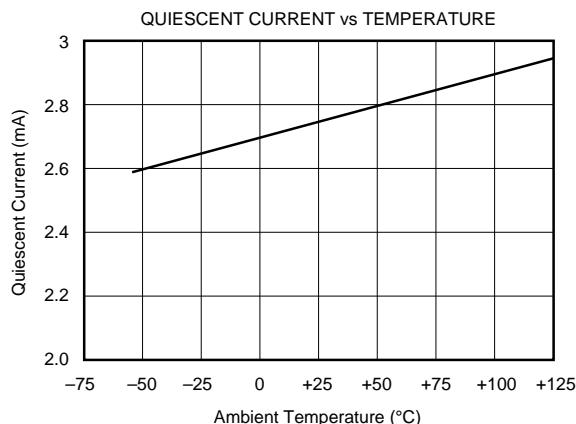
# TYPICAL PERFORMANCE CURVES

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



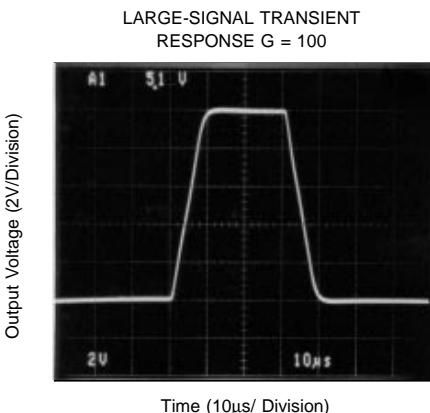
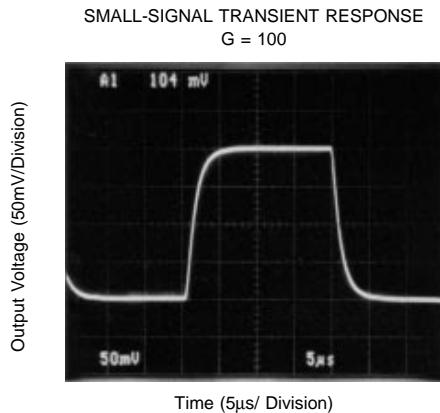
## TYPICAL PERFORMANCE CURVES (CONT)

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



## TYPICAL PERFORMANCE CURVES (CONT)

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



## APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA120. Applications with noisy or high impedance power supply lines may require decoupling capacitors close to the device pins as shown. The differential input voltage is applied to pins 16 and 3.

The output is referred to the output common reference terminal, pin 18. This terminal must have a low-impedance connection to ground. A resistance of  $1\Omega$  or greater in series with the common terminal could degrade common-mode rejection beyond the specified value.

### SETTING THE GAIN

Gains of 1, 10, 100 or 1000 can be configured by interconnecting the gain-set pins as shown in the table of Figure 1. These pin-strapped gains provide best gain accuracy and drift because they are determined by the ratios of accurately trimmed and matched on-chip resistors.

Digital gain control can be achieved using an analog multiplexer as shown in Figure 2. Since the switches are in series with the high impedance gain-sense connections, pins 4 and 15, their series resistance does not significantly affect gain error or drift. Gain error at  $G = 1$  is slightly higher than with direct pin connections shown in Figure 1. The gain is selected with a two-bit address,  $A_0$  and  $A_1$ . The Multiplexer Enable control is directly connected to  $V_+$  since a logic “low” on this line would cause the input amplifiers to run open-loop.

Other gains may be set by connecting an external resistor,  $R_G$ , as shown in Figure 3a. Gain accuracy using an external gain-setting resistor is a function of  $R_G$  and the internal  $20\text{k}\Omega$  resistors. The internal resistors are typically within  $\pm 0.2\%$  of nominal value and their drift under  $\pm 80\text{ppm}/^\circ\text{C}$ . Inaccuracy and drift of  $R_G$  will contribute additional gain error and drift.

Figure 3b shows an external gain-setting resistor connected in parallel with internal resistors. By forming a portion of the

effective  $R_G$  with internal resistors, gain accuracy and drift can be somewhat improved.

Connections available on the INA120 allow all input stage gain-setting resistors to be provided externally. A custom precision resistor network could be connected to provide the highest accuracy and lowest gain drift for non-standard gains. Impedance of this external network should be made close to that of the internal network for best performance.

### OFFSET TRIMMING

Many applications require no external offset voltage trimming. Figure 4 shows optional circuits for trimming offset voltage. Since the INA120 has two amplification stages, the offset voltage is comprised of two components—the input stage offset and output stage offset.

The input stage offset is equal to the combined offset of op amps  $A_1$  and  $A_2$ . This input stage offset dominates at high gain. When used in gains of 100 to 1000, it is often sufficient to adjust the input stage offset with a potentiometer connected to pins 6 and 7 as shown. Connect both inputs to ground and adjust for 0V at the output, pin 1. Do not use pins 6 and 7 to trim offset voltage at  $G = 1$  or to correct for offset in devices following the INA120 since this can cause excessive offset voltage drift.

At  $G = 1$ , offset is dominated by the output stage. Output stage offset can be trimmed by applying a correction voltage at the output reference terminal, pin 18. Low impedance must be maintained at this node to preserve the high CMR of the INA120. This is achieved by buffering the trim voltage with an op amp as shown.

At intermediate gains it may be necessary to provide both input stage and output stage offset adjustments. Again, ground both inputs. Connect a jumper between pins 9 and 11 (temporarily connects the INA120 in high gain) and adjust  $R_1$  for 0V at the output, pin 1. Then disconnect the jumper and adjust the output offset control for 0V output.

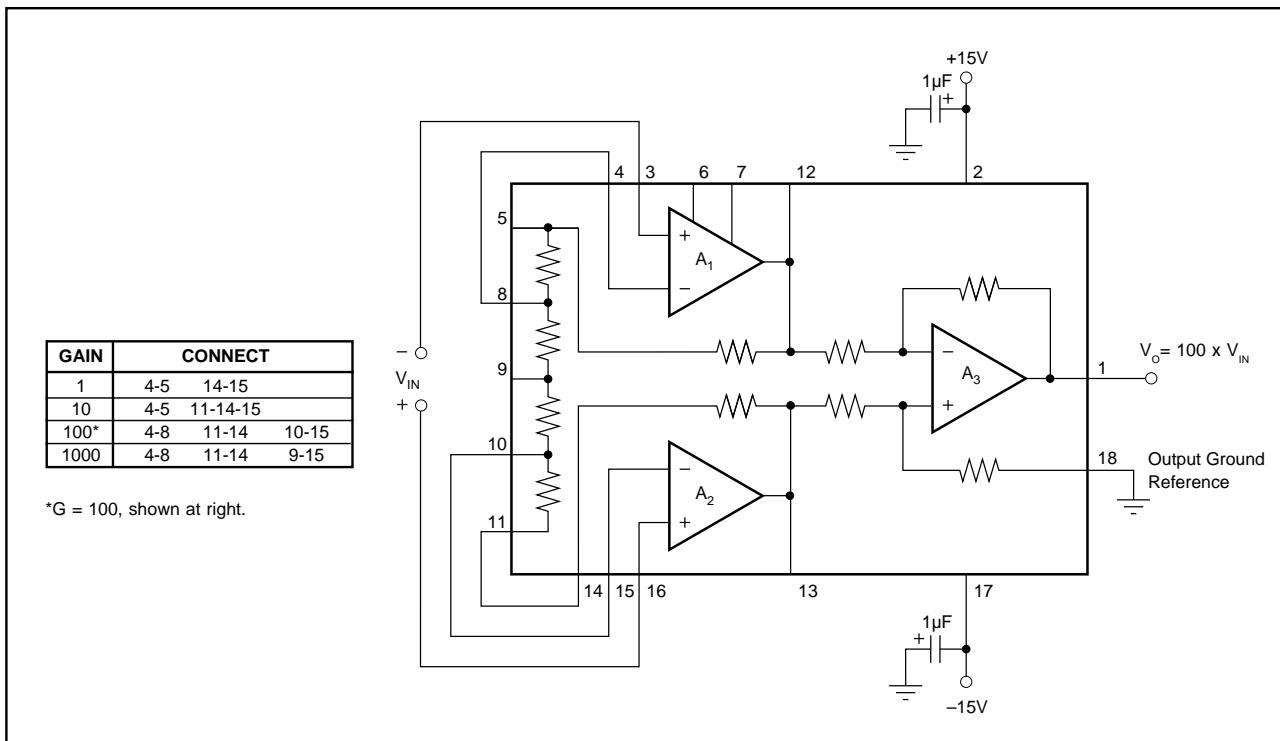


FIGURE 1. Basic Connection.

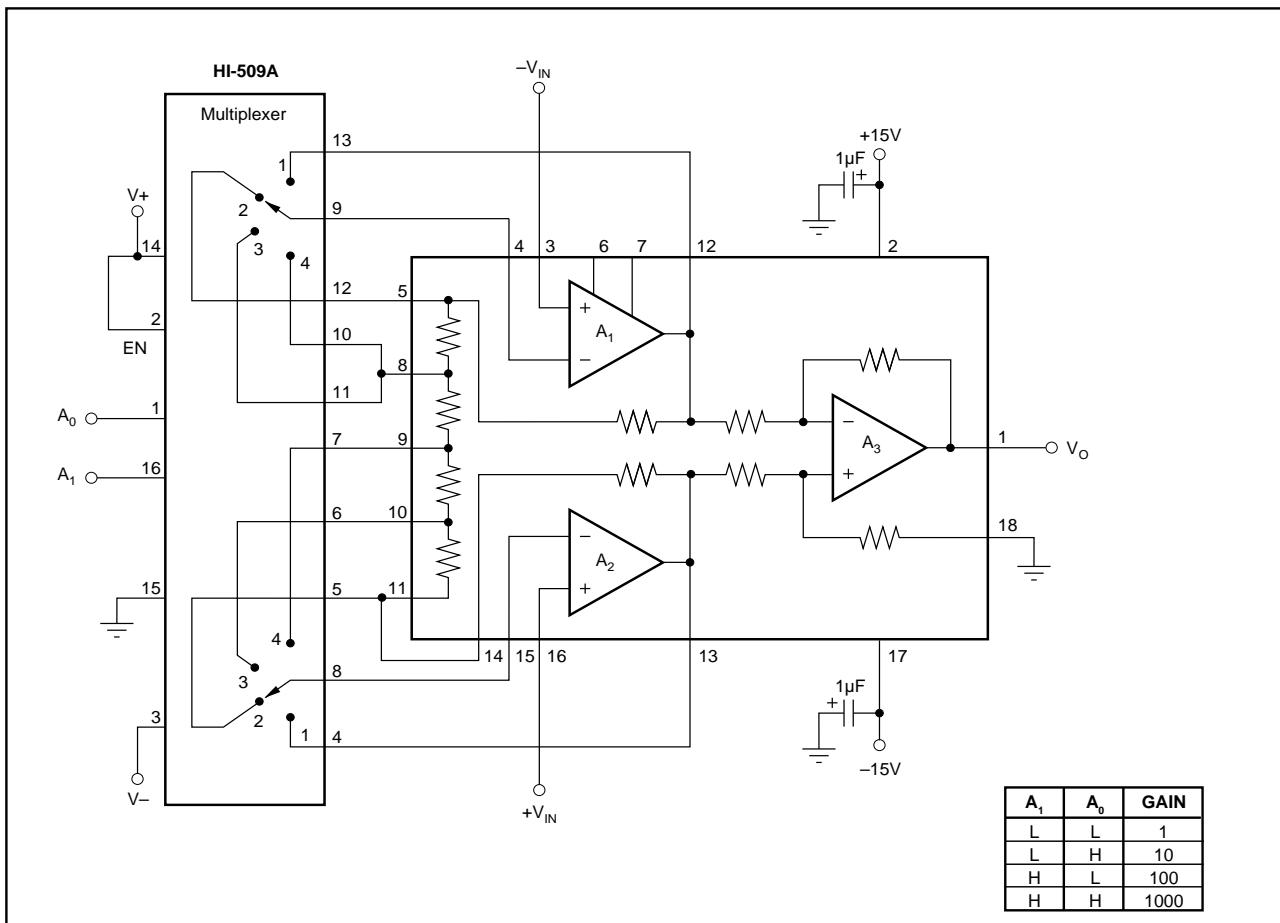


FIGURE 2. Digital Gain Control.

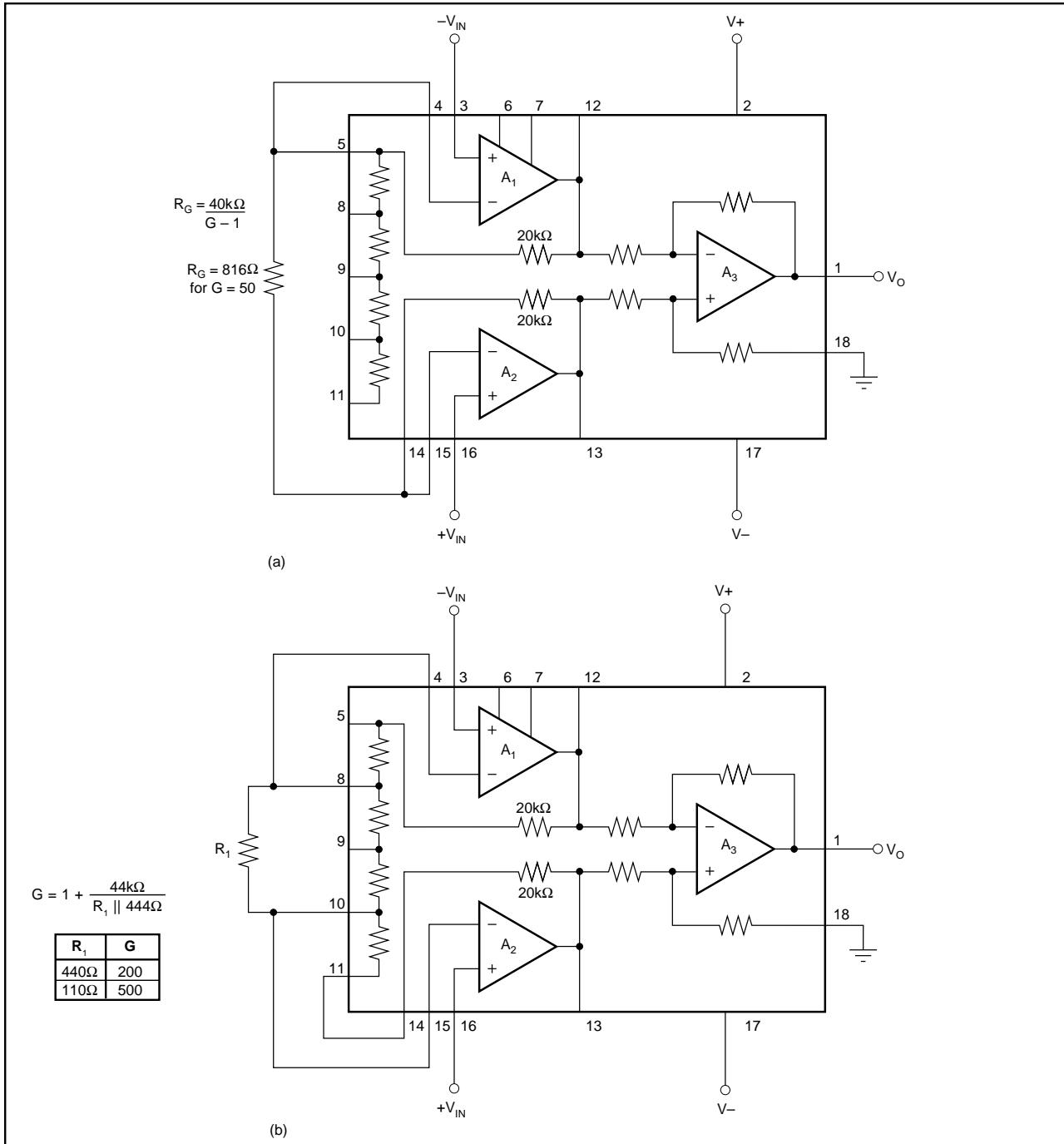


FIGURE 3. External Gain-Setting Resistors.

### INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA120 is extremely high—approximately  $10^{10}\Omega$ . This does not mean, however, that no current flows in the input terminals. The input bias current of the INA120 is typically  $\pm 10\text{nA}$  (it can be either polarity). 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 if the INA120 is to function. Figure 5 shows various provisions for an input bias current path. Without an appropriate current path, the inputs will float to a potential which

exceeds the common-mode range of the INA120 and the input amplifiers will saturate.

### INPUT PROTECTION

The inputs of the INA120 are protected for input voltages up to 2V beyond the power supply voltages. If the input can exceed these conditions, input clamp diodes should be provided as shown in Figure 6.  $R_s$  may not be required if the input cannot supply more than 100mA. If the input can supply larger currents, choose  $R_s$  according to the maximum source voltage, limiting current to under 100mA.

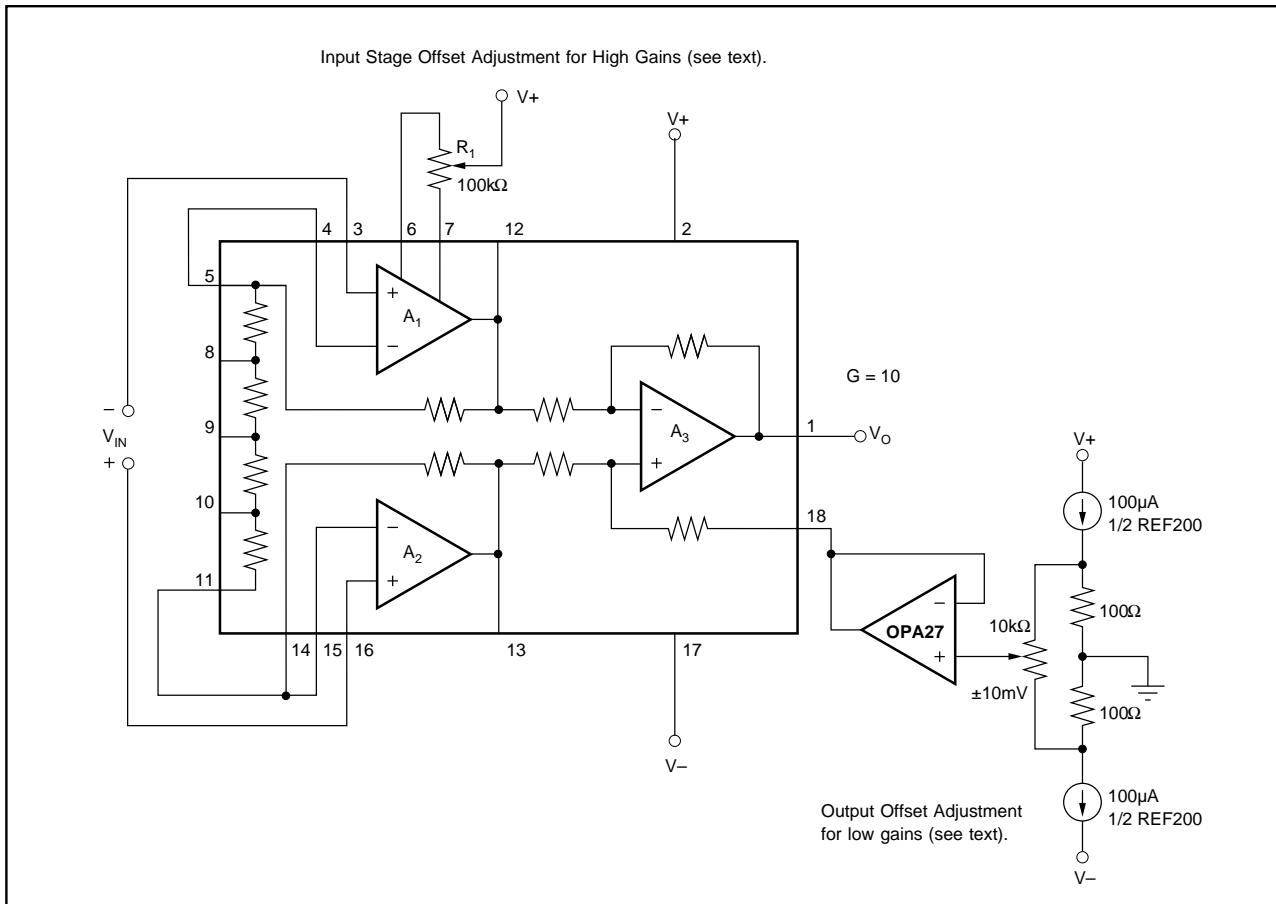


FIGURE 4. Offset Adjustment Circuits.

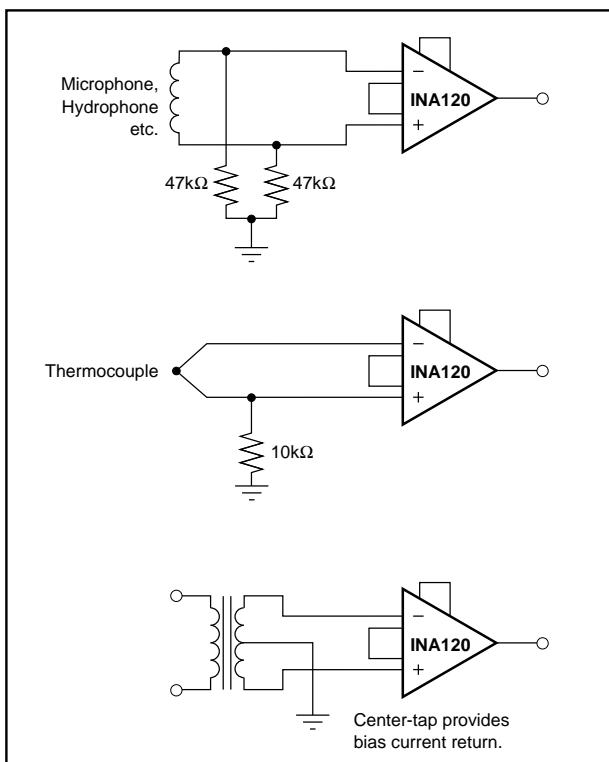


FIGURE 5. Providing an Input Bias Current Path.

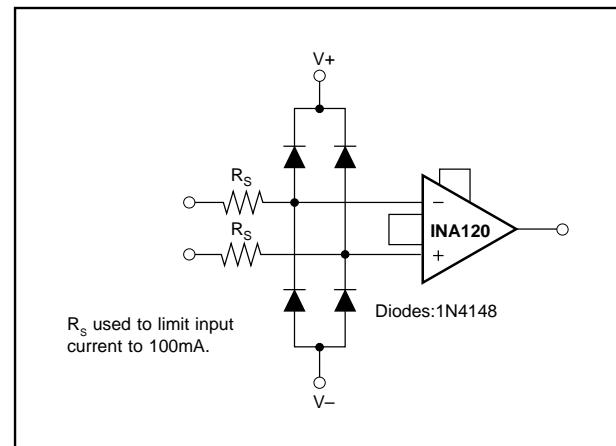


FIGURE 6. Input Protection Circuit.

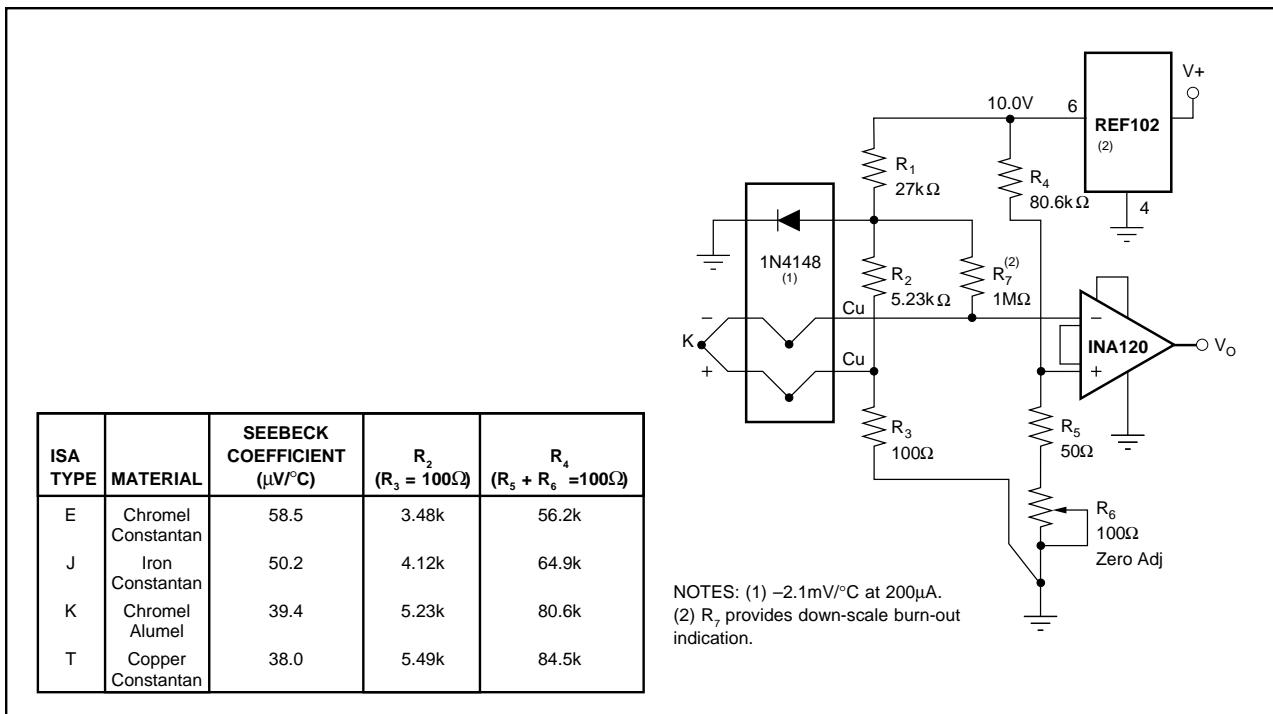


FIGURE 7. Thermocouple Amplifier With Cold Junction Compensation.

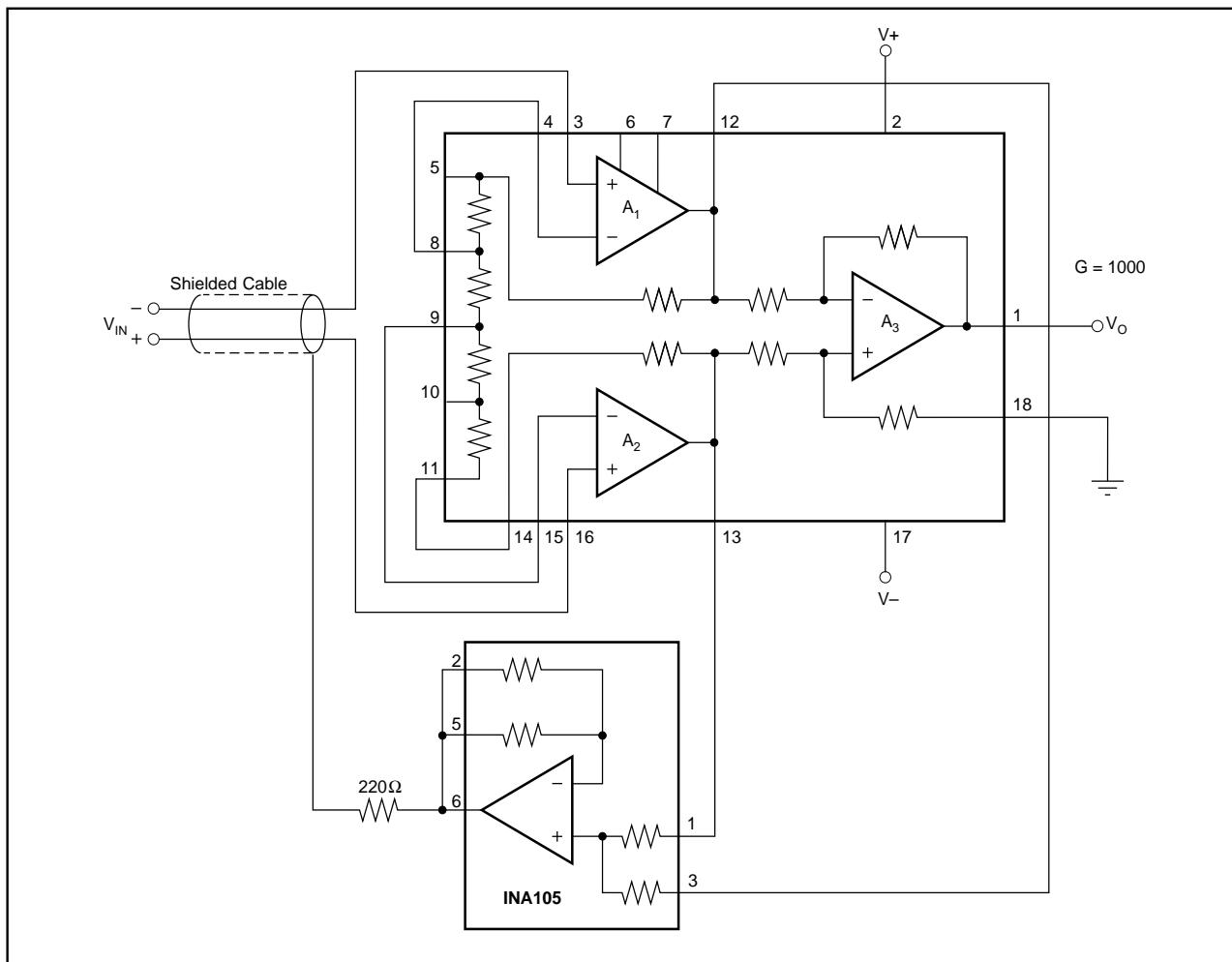


FIGURE 8. Guard Drive Circuit.

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INA120

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