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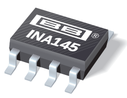


INA145

Programmable Gain DIFFERENCE AMPLIFIER

FEATURES

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

APPLICATIONS

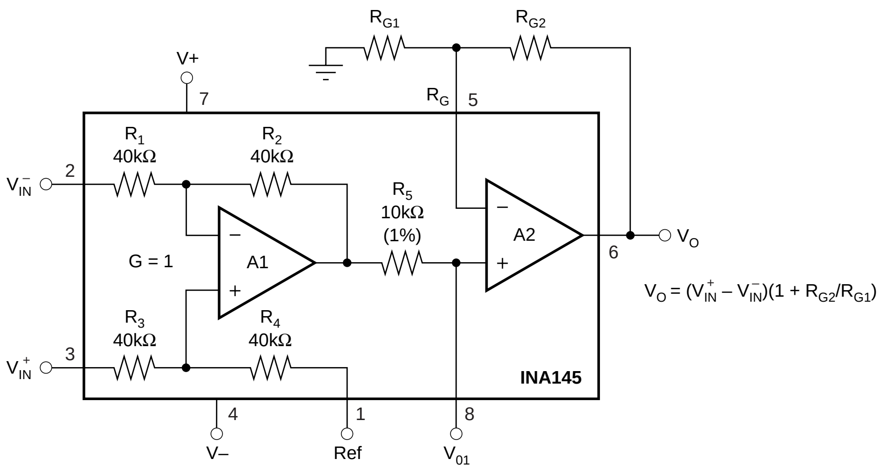
- CURRENT SHUNT MEASUREMENTS
- SENSOR AMPLIFIER
- DIFFERENTIAL LINE RECEIVER
- BATTERY POWERED SYSTEMS

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°C to +85°C.



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PDS-1567B

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SPECIFICATIONS: V_S = ±2.25V to ±18V

Boldface limits apply over the specified temperature range, T_A = –40°C to +85°C

At T_A = +25°C, G = 1, R_L = 10kΩ connected to ground and ref pin connected to ground unless otherwise noted.

PARAMETER		CONDITION	INA145UA			UNITS
			MIN	TYP	MAX	
OFFSET VOLTAGE, V_O		RTI[1, 2]				
Input Offset Voltage	V_{OS}	V_{CM} = V_O = 0V		±0.2	±1	mV
vs Temperature	**$\Delta V_{OS}/\Delta T$**			**See Typical Curve**		
vs Power Supply	PSRR	V_S = ±1.35V to ±18V		±20	±60	μV/V
vs Time				±0.3		μV/mo
Offset Voltage, V_{01}		RTI[1, 2]		±0.4		mV
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V_{CM}	(V_{IN}+) – (V_{IN}–) = 0V, V_O = 0V	2(V–)		2(V+) –2	V
Common-Mode Rejection	CMRR	V_{CM} = 2(V–) to 2(V+) – 2V, R_S = 0Ω	76	86		dB
Over Temperature		V_S = ±15V	**70**	**80**		dB
INPUT BIAS CURRENT[2]		V_{CM} = V_S/2				
Bias Current	I_B			±50		nA
Offset Current	I_{OS}			±5		nA
INPUT IMPEDANCE						
Differential (non-inverting input)				80		kΩ
Differential (inverting input)				27		kΩ
Common-Mode				40		kΩ
NOISE		RTI[1, 3]				
Voltage Noise, f = 0.1Hz to 10Hz				2		μVp-p
Voltage Noise Density, f = 1kHz	e_n			90		nV/√Hz
GAIN				G = 1 to 1000		
Gain Equation				G = 1 + R_{G2}/R_{G1}		V/V
Initial[1]				1		V/V
Gain Error		R_L = 100kΩ, V_O = (V–)+0.15 to (V+)–1, G = 1		±0.01	±0.1	%
vs Temperature		**R_L = 100kΩ, V_O = (V–)+0.25 to (V+)–1, G = 1**		**±2**	**±10**	ppm/°C
		R_L = 10kΩ, V_O = (V–)+0.3 to (V+)–1.25, G = 1		±0.01	±0.1	%
vs Temperature		**R_L = 10kΩ, V_O = (V–)+0.5 to (V+)–1.25, G = 1**		**±2**	**±10**	ppm/°C
Nonlinearity		R_L = 10kΩ, V_O = (V–)+0.3 to (V+)–1.25, G = 1		±0.0002	±0.005	% of FS
FREQUENCY RESPONSE						
Small Signal Bandwidth		G = 1		500		kHz
		G = 10		50		kHz
Slew Rate				0.45		V/μs
Settling Time, 0.1%		G = 1, 10V Step		40		μs
0.01%		G = 1, 10V Step		90		μs
Overload Recovery		50% Input Overload		40		μs
OUTPUT, V_O						
Voltage Output		R_L = 100kΩ, G = 1	(V–) + 0.15		(V+) – 1	V
Over Temperature		**R_L = 100kΩ, G = 1**	**(V–) + 0.25**		**(V+) – 1**	V
		R_L = 10kΩ, G = 1	(V–) + 0.3		(V+) – 1.25	V
Over Temperature		**R_L = 10kΩ, G = 1**	**(V–) + 0.5**		**(V+) – 1.25**	V
Short-Circuit Current		Continuous to Common		±15		mA
Capacitive Load		Stable Operation		1000		pF
POWER SUPPLY						
Specified Voltage Range, Dual Supplies			±2.25		±18	V
Operating Voltage Range			±1.35		±18	V
Quiescent Current		V_{IN} = 0, I_O = 0		±570	±700	μA
Over Temperature					**±800**	μA
TEMPERATURE RANGE						
Specified Range			–40		+85	°C
Operating Range			–55		+125	°C
Storage Range			–55		+125	°C
Thermal Resistance	θ_{JA}			150		°C/W

NOTES: (1) Referred to input pins (V_{IN}+ and V_{IN}–), Gain = 1V/V. Specified with 10kΩ 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.

SPECIFICATIONS: V_S = +5V Single Supply

Boldface limits apply over the specified temperature range, **T_A = –40°C to +85°C**

At T_A = +25°C, G = 1, R_L = 10kΩ connected to ground and ref pin connected to 2.5V unless otherwise noted.

PARAMETER		CONDITION	INA145UA MIN	TYP	MAX	UNITS
OFFSET VOLTAGE, V_O		RTI(1, 2)				
Input Offset Voltage	V_{OS}	V_{CM} = V_O = 2.5V		±0.35	±1	mV
vs Temperature	**$\Delta V_{OS}/\Delta T$**			**See Typical Curve**		
vs Power Supply Rejection Ratio	PSRR	V_S = ±1.35V to ±18V		±20	±60	µV/°C
vs Time				±0.3		µV/mo
Offset Voltage, V_{01}		RTI(1, 2)		±0.55		mV
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range(3)	V_{CM}	V_{IN}+ – V_{IN}– = 0V, V_O = 2.5V	–2.5		5.5	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = –2.5V to +5.5V, R_S = 0Ω	76	86		dB
Over Temperature				**80**		dB
INPUT BIAS CURRENT(2)						
Bias Current	I_B			±50		nA
Offset Current	I_{OS}			±5		nA
INPUT IMPEDANCE						
Differential (non-inverting input)				80		kΩ
Differential (inverting input)				27		kΩ
Common-Mode				40		kΩ
NOISE		RTI(1, 4)				
Voltage Noise, f = 0.1Hz to 10Hz				2		µVp-p
Voltage Noise Density, f = 1kHz	e_n			90		nV/√Hz
GAIN				G = 1 to 1000		V/V
Gain Equation				G = 1 + R_{G2}/R_{G1}		V/V
Initial(1)				1		V/V
Gain Error		R_L = 100kΩ, V_O = 0.15V to 4V, G = 1		±0.01	±0.1	%
vs Temperature		**R_L = 100kΩ, V_O = 0.25V to 4V, G = 1**		**±2**	**±10**	ppm/°C
		R_L = 10kΩ, V_O = 0.3V to 3.75V, G = 1		±0.01	±0.1	%
vs Temperature		**R_L = 10kΩ, V_O = 0.5V to 3.75V, G = 1**		**±2**	**±10**	ppm/°C
Nonlinearity		R_L = 10kΩ, V_O = +0.3 to +3.75, G = 1		±0.001	±0.005	% of FS
FREQUENCY RESPONSE						
Small Signal Bandwidth		G = 0.1		500		kHz
		G = 1		50		kHz
Slew Rate				0.45		V/µs
Settling Time, 0.1%		G = 1, 10V Step		40		µs
0.01%		G = 1, 10V Step		90		µs
Overload Recovery		50% Input Overload		40		µs
OUTPUT, V_O						
Voltage Output		R_L = 100kΩ, G = 1	0.15		4	V
Over Temperature		**R_L = 100kΩ, G = 1**	**0.25**		**4**	V
		R_L = 10kΩ, G = 1	0.3		3.75	V
Over Temperature		**R_L = 10kΩ, G = 1**	**0.5**		**3.75**	V
Short-Circuit Current		Continuous to Common		±15		mA
Capacitive Load		Stable Operation		1000		pF
POWER SUPPLY						
Specified Voltage Range, Single Supply			+4.5		+36	V
Operating Voltage Range			+2.7		+36	V
Quiescent Current		V_{IN} = 0, I_O = 0		550	700	µA
Over Temperature					**800**	µA
TEMPERATURE RANGE						
Specified Range			–40		+85	°C
Operating Range			–55		+125	°C
Storage Range			–55		+125	°C
Thermal Resistance	θ_{JA}			150		°C/W

NOTES: (1) Referred to input pins (V_{IN}+ and V_{IN}–), Gain = 1V/V. Specified with 10kΩ 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.

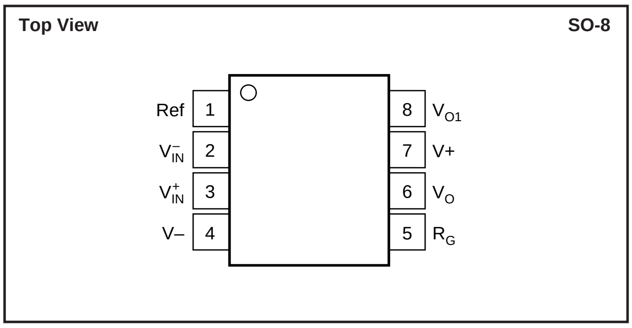
AMPLIFIER A1, A2 PERFORMANCE

Boldface limits apply over the specified temperature range, T_A = –40°C to +85°C

At T_A = +25°C, G = 1, R_L = 10kΩ connected to ground and ref pin connected to ground unless otherwise noted.

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

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, V+ to V–	36V
Signal Input Terminals, Voltage	±80V
Current	±1mA
Output Short Circuit (to ground)	Continuous
Operating Temperature	–55°C to +125°C
Storage Temperature	–55°C to +150°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+240°C

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

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.

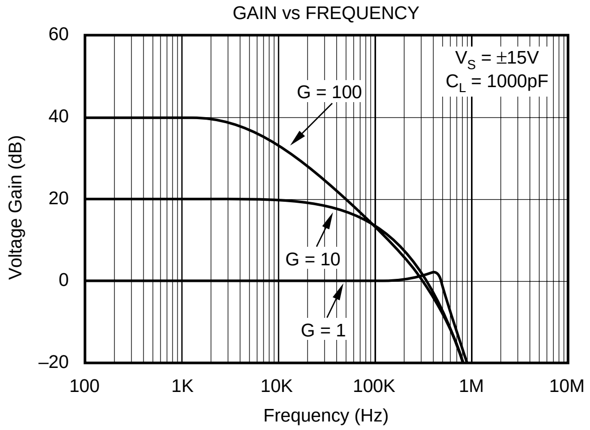
PACKAGE/ORDERING INFORMATION

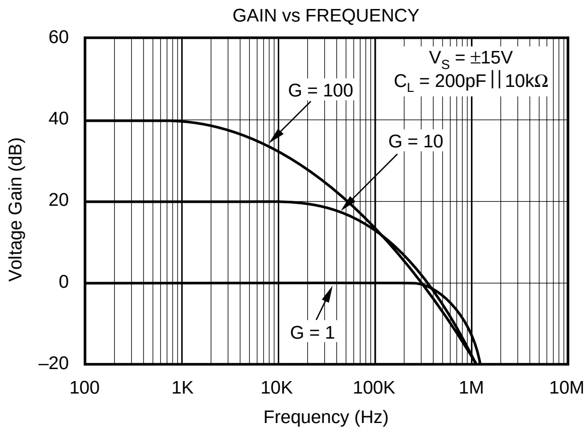
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER(1)	TRANSPORT MEDIA
INA145UA	SO-8	182	–40°C to +85°C	INA145UA	INA145UA	Rails
"	"	"	"	"	INA145UA/2K5	Tape and Reel

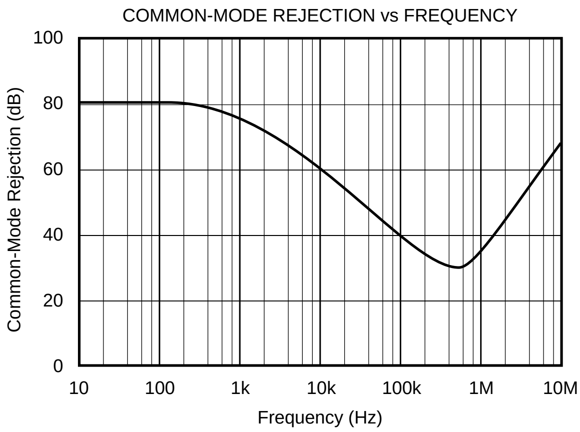
NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of "INA145UA/2K5" will get a single 2500-piece Tape and Reel.

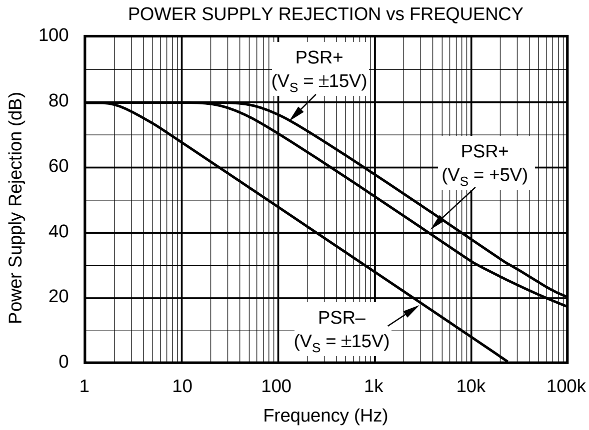
TYPICAL PERFORMANCE CURVES

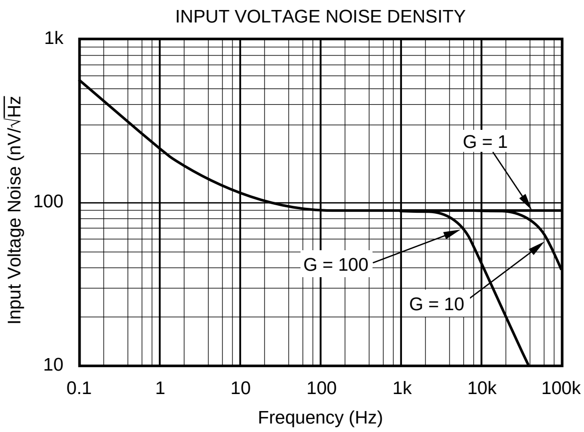
At T_A = +25°C, V_S = ±15V, G = 1, R_L = 10kΩ connected to ground and Ref pin connected to ground, unless otherwise noted.

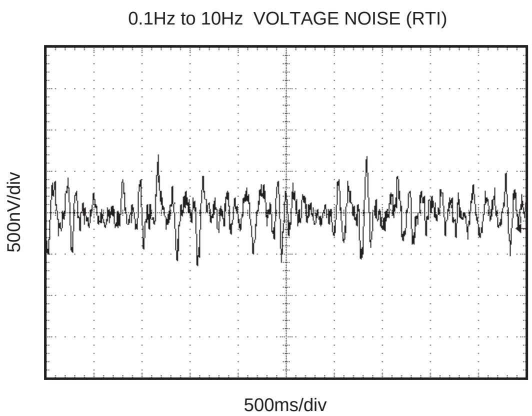








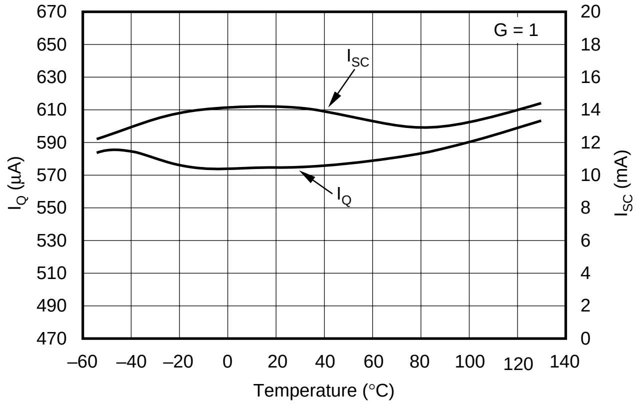




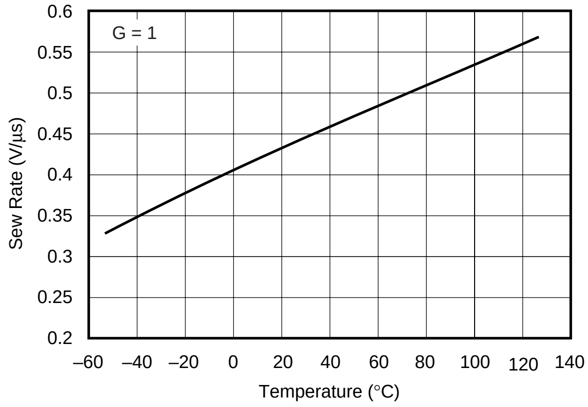
TYPICAL PERFORMANCE CURVES (Cont.)

At T_A = +25°C, V_S = ±15V, G = 1, R_L = 10kΩ connected to ground and Ref pin connected to ground, unless otherwise noted.

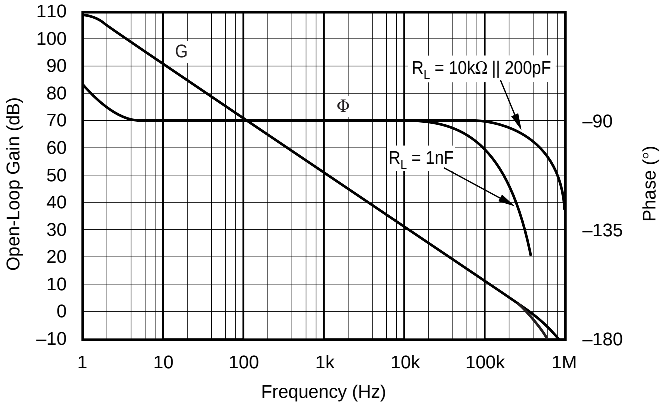
QUIESCENT CURRENT AND
SHORT-CIRCUIT CURRENT vs TEMPERATURE



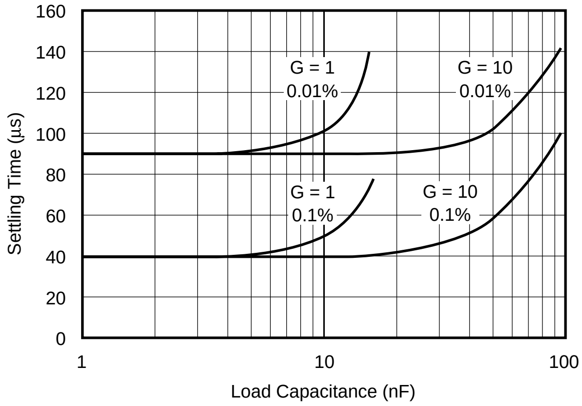
SLEW RATE vs TEMPERATURE



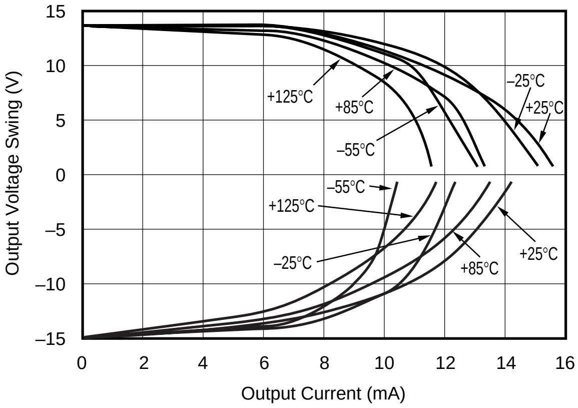
GAIN AND PHASE vs FREQUENCY
Op Amp A1 and A2



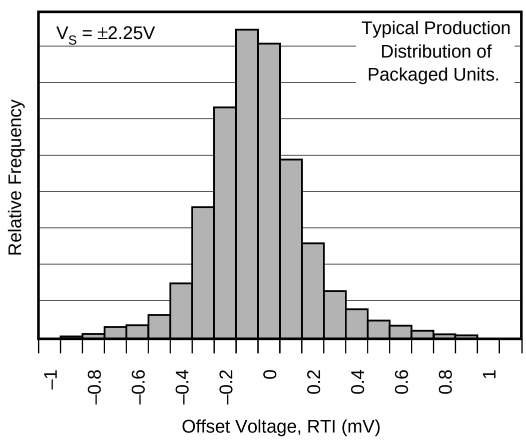
SETTLING TIME vs LOAD CAPACITANCE



MAXIMUM OUTPUT VOLTAGE SWING
vs OUTPUT CURRENT



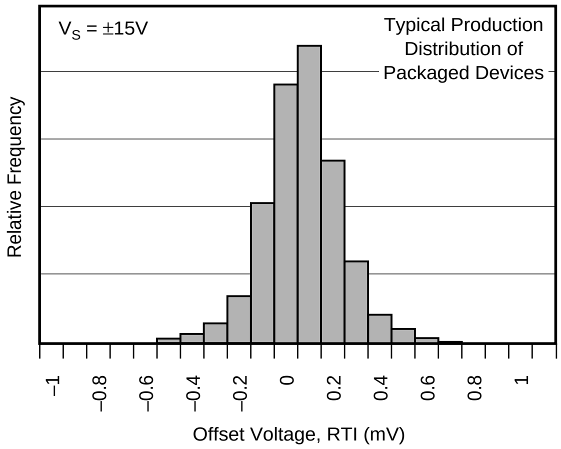
OFFSET VOLTAGE
PRODUCTION DISTRIBUTION



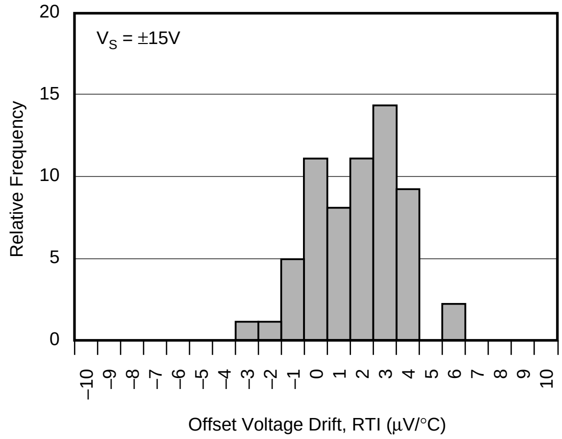
TYPICAL PERFORMANCE CURVES (Cont.)

At T_A = +25°C, V_S = ±15V, G = 1, R_L = 10kΩ connected to ground and Ref pin connected to ground, unless otherwise noted.

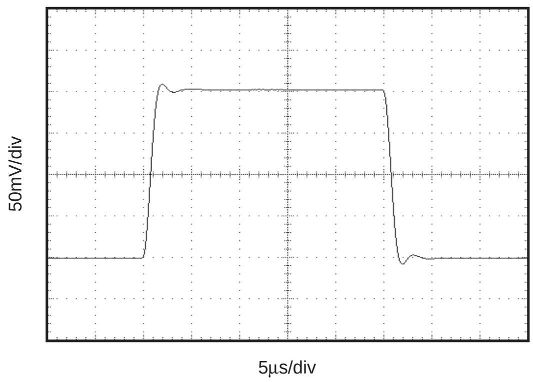
OFFSET VOLTAGE
PRODUCTION DISTRIBUTION



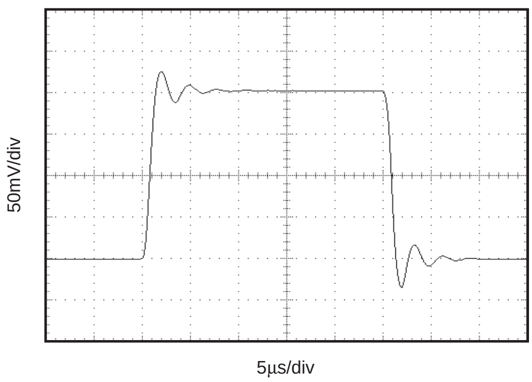
OFFSET VOLTAGE DRIFT
PRODUCTION DISTRIBUTION



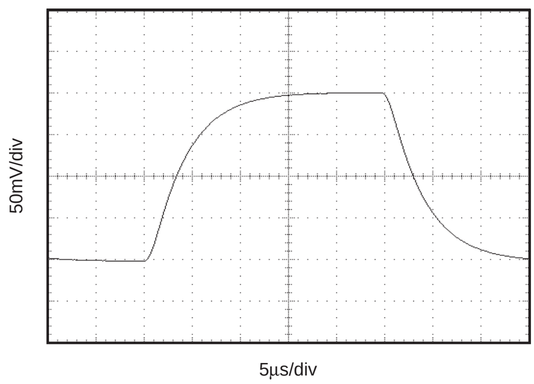
SMALL-SIGNAL STEP RESPONSE
(G = 1, R_L = 10kΩ, C_L = 200pF)



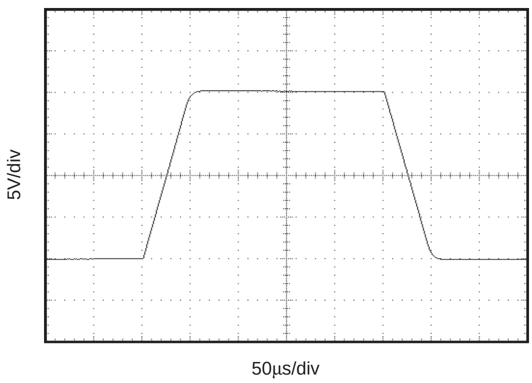
SMALL-SIGNAL STEP RESPONSE
(G = 1, C_L = 1000pF)



SMALL-SIGNAL STEP RESPONSE
(G = 10, C_L = 1000pF)



LARGE-SIGNAL STEP RESPONSE
(G = 10, R_L = 10kΩ, C_L = 200pF)



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 10kΩ resistor which is trimmed to ±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 ±2.25V to ±18V, with key parameters guaranteed over the temperature range –40°C to +85°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

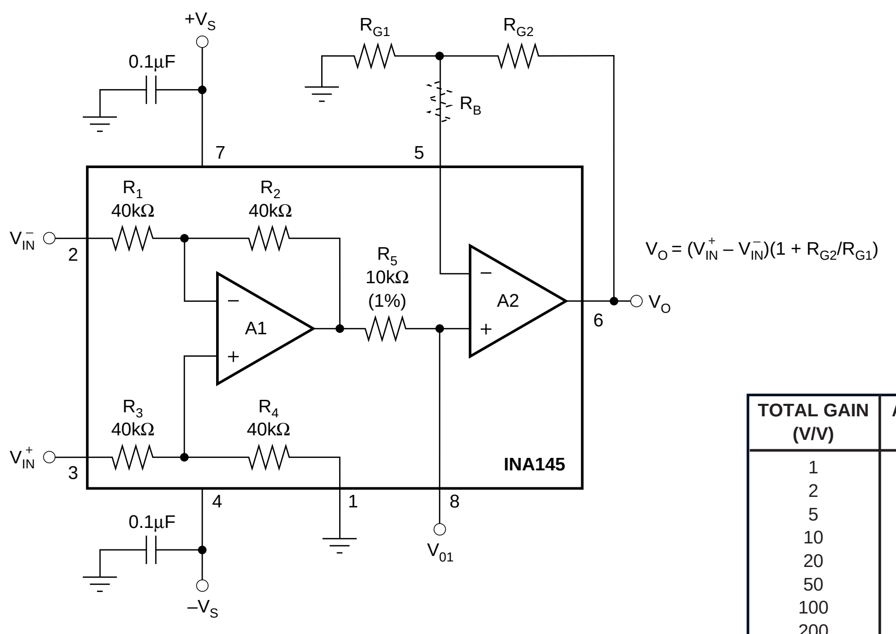
The gain of the INA145 is set by using two external resistors, R_{G1} and R_{G2}, according to the equation:

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

For a total gain of 1, A2 is connected as a buffer amplifier with no R_{G1}. A feedback resistor, R_{G2} = 10kΩ, 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 10kΩ 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+) – 1V.



		STANDARD 1% RESISTORS		
TOTAL GAIN (V/V)	A2 GAIN (V/V)	R_{G1} (W)	R_{G2} (W)	R_B (W)
1	1	(None)	10k	—
2	2	20k	20k	—
5	5	12.4k	49.9k	—
10	10	11.0k	100k	—
20	20	10.5k	200k	—
50	50	10.2k	499k	—
100	100	10.2k	1M	—
200	200	499	100k	9.53k
500	500	100	49.9k	10k
1000	1000	100	100k	10k

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 10Ω and a resistor added to the positive input terminal should be 10 times that, or 100Ω. 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 40kΩ. The source impedance at the two input terminals must be nearly equal to maintain good common-mode rejection. A 5Ω 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 300Ω 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 300Ω can cause a mismatch in the total resistor ratios, degrading CMR.

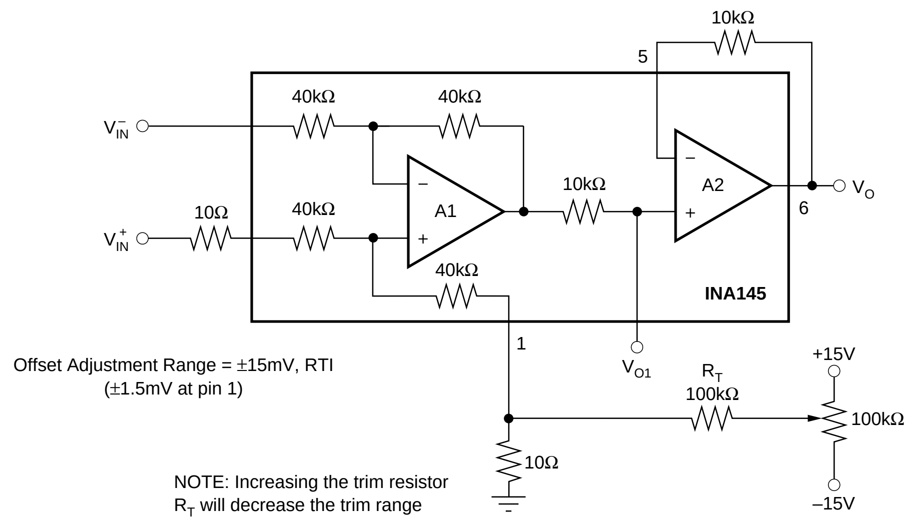
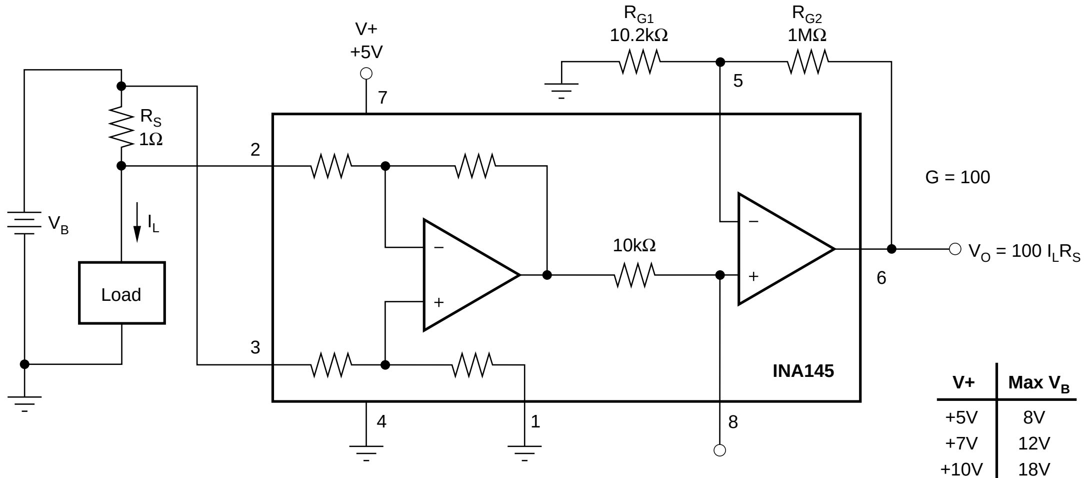


FIGURE 2. Optional Offset Trim Circuit.



V+	Max V_B
+5V	8V
+7V	12V
+10V	18V
+15V	28V

FIGURE 3. Measuring Current with Shunt Resistor.

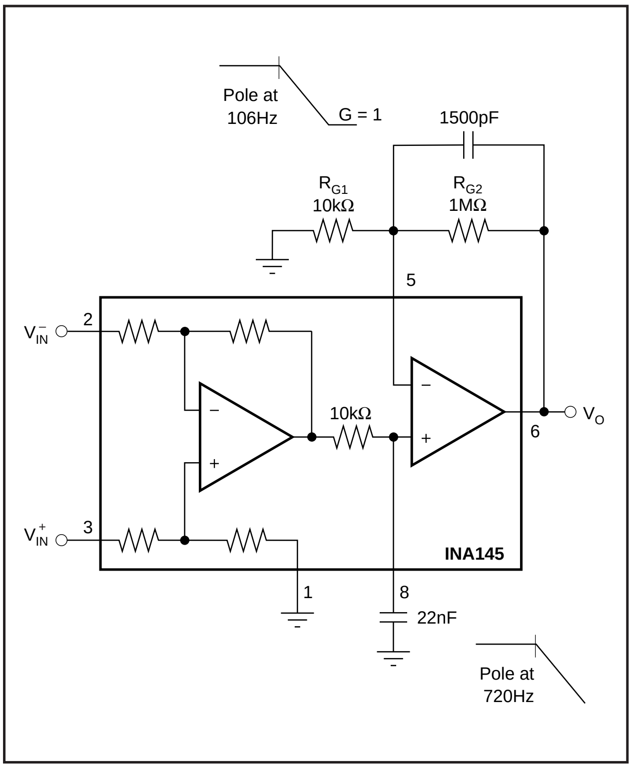


FIGURE 4. Noise Filtering.

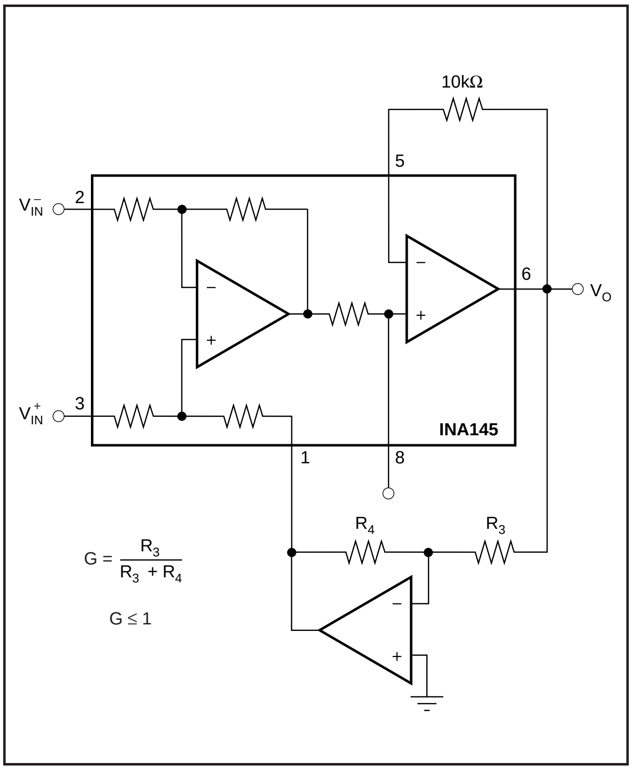


FIGURE 5. Creating Gains Less Than Unity.

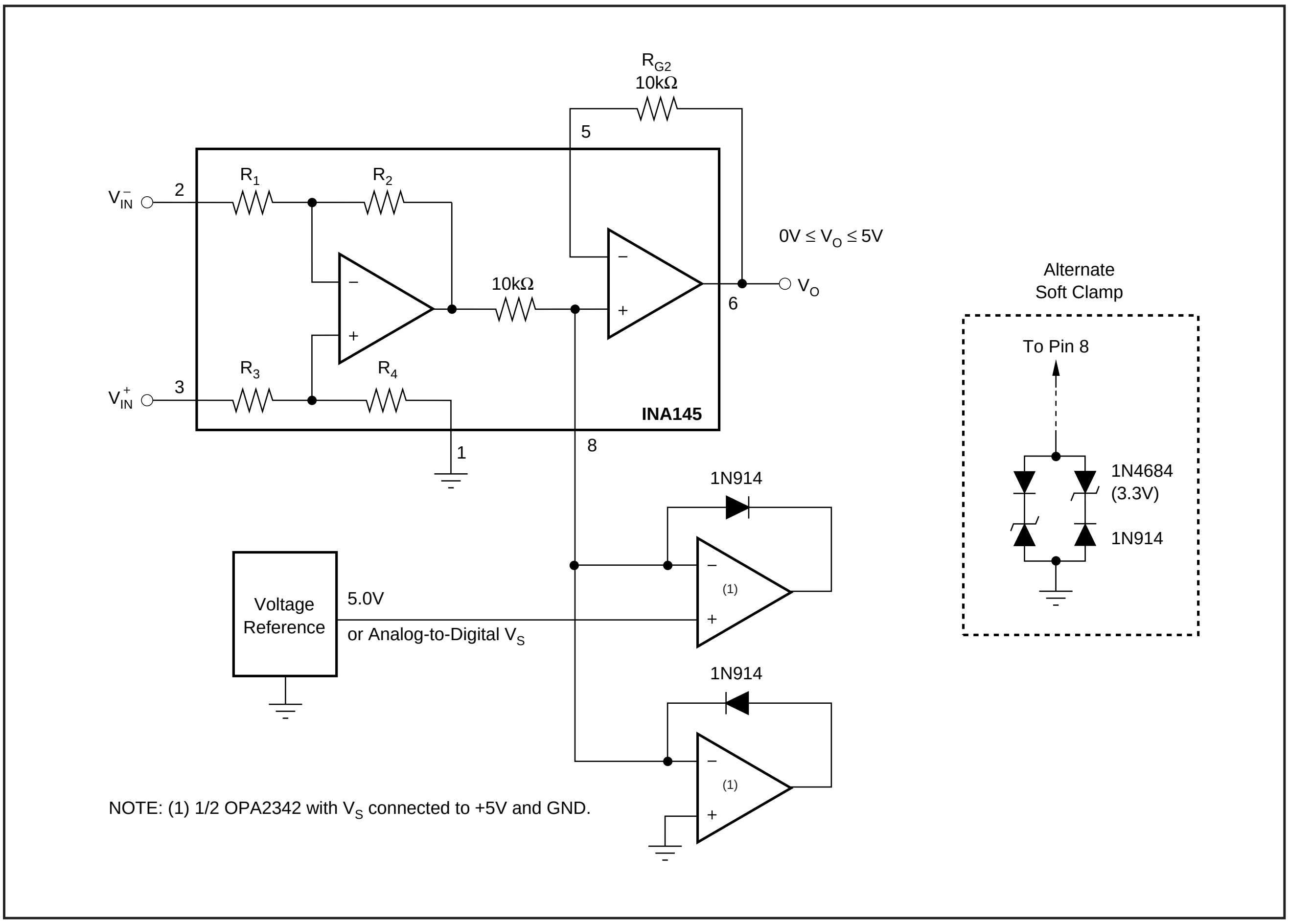


FIGURE 6. Clamp Circuits.

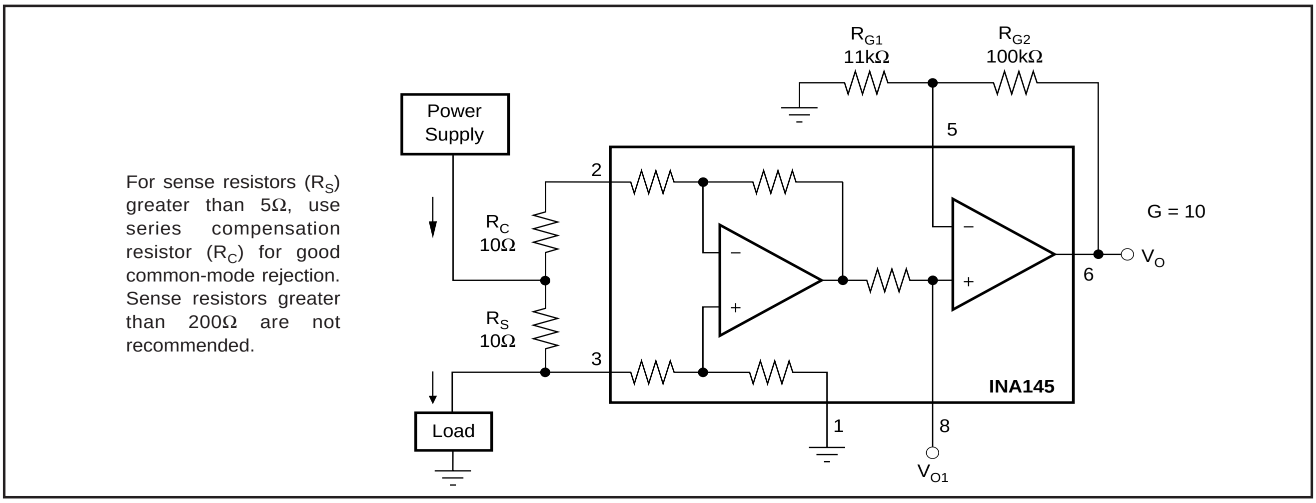


FIGURE 7. Current Monitor, G = 1.

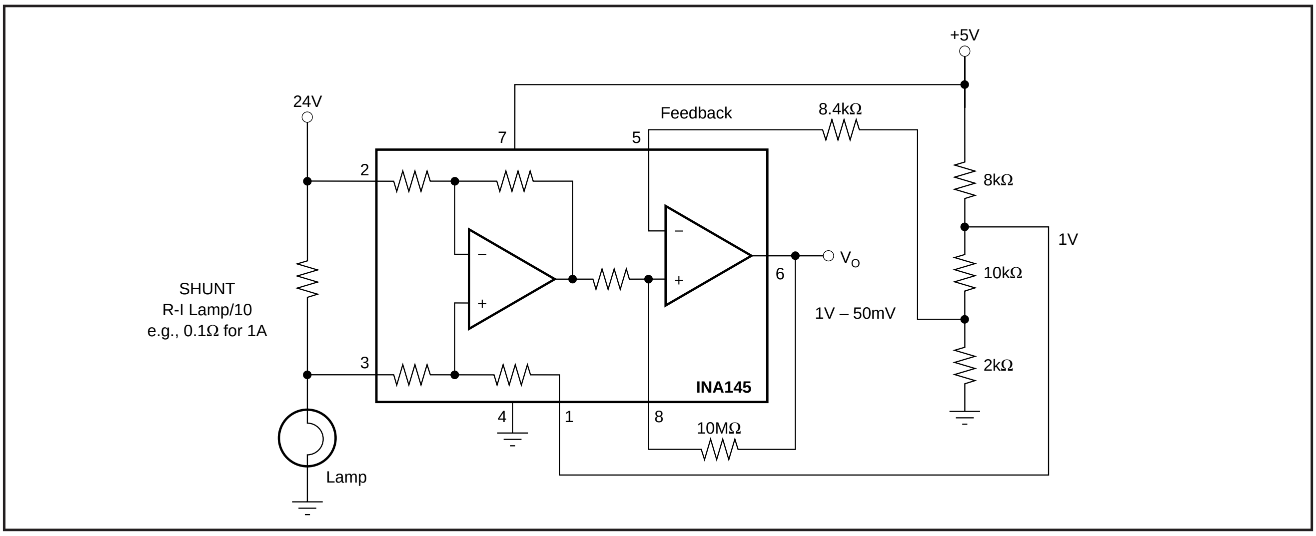


FIGURE 8. Comparator Output with Optional Hysteresis Application to Sense Lamp Burn-Out.

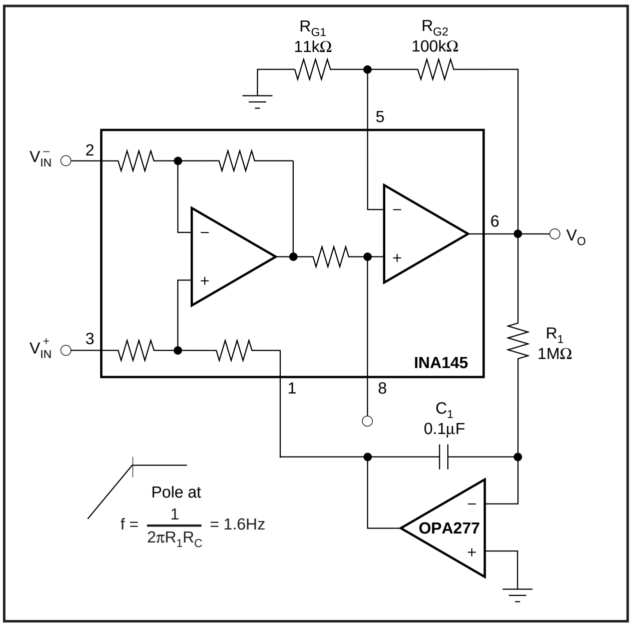


FIGURE 9. AC Coupling (DC Restoration).

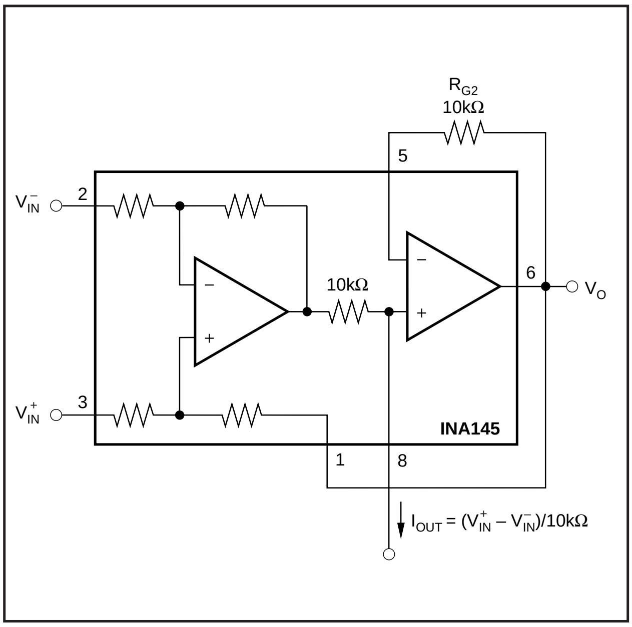


FIGURE 10. Precision Current Source.