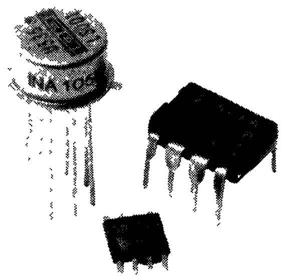
BURR-BROWN®



INA105

AVAILABLE IN DIE FORM

Precision Unity Gain DIFFERENTIAL AMPLIFIER

FEATURES

- CMR 86dB min over temp
- GAIN ERROR 0.01% max
- NONLINEARITY 0.001% max
- NO EXTERNAL ADJUSTMENTS REQUIRED
- EASY TO USE
- COMPLETE SOLUTION
- HIGHLY VERSATILE
- LOW COST
- TO-99 HERMETIC METAL, LOW COST PLASTIC DIP, AND SMALL OUTLINE PACKAGES

APPLICATIONS

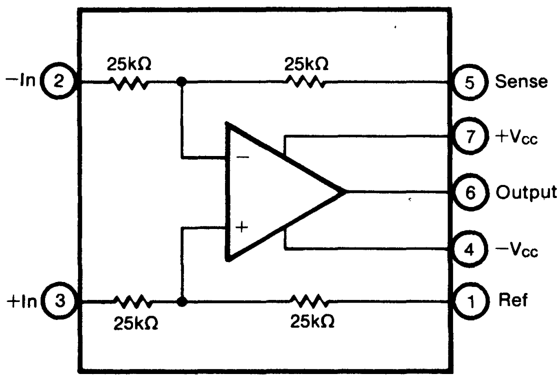
- DIFFERENTIAL AMPLIFIER
- BASIC INSTRUMENTATION AMPLIFIER BUILDING BLOCK
- UNITY-GAIN INVERTING AMPLIFIER
- GAIN-OF-1/2 AMPLIFIER
- NONINVERTING GAIN-OF-2 AMPLIFIER
- AVERAGE VALUE AMPLIFIER
- ABSOLUTE VALUE AMPLIFIER
- SUMMING AMPLIFIER
- SYNCHRONOUS DEMODULATOR
- CURRENT RECEIVER WITH COMPLIANCE TO RAILS
- 4mA to 20mA TRANSMITTER
- VOLTAGE-CONTROLLED CURRENT SOURCE
- ALL-PASS FILTERS

DESCRIPTION

The INA105 is a precision unity-gain differential amplifier. As a monolithic circuit, it offers high reliability at low cost. It consists of a premium grade operational amplifier and an on-chip precision resistor network.

As a special feature, the INA105 can drive 20mA from the positive supply. This simplifies construction of 4mA to 20mA current sources and transmitters.

The INA105 is completely self-contained and offers the user a highly versatile function. No adjustments to gain, offset, and CMR are necessary. This provides three important advantages: (1) lower initial design engineering time, (2) lower manufacturing assembly time and cost, and (3) easy cost-effective field repair of a precision circuit.



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PDS-617D

SPECIFICATIONS

ELECTRICAL

At +25°C, V_{CC} = ±15V unless otherwise noted.

		INA105AM			INA105BM			INA105KP/KU			
PARAMETER	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**UNITS**
GAIN											
Initial[1]			1			*			*		V/V
Error			0.005	0.01		*	*		0.01	0.025	%
vs Temperature			1	5		*	*		*		ppm/°C
Nonlinearity[2]			0.0002	0.001		*	*		*	*	%
OUTPUT											
Rated Voltage	I_O = +20mA, −5mA	10	12		*	*		*	*		V
Rated Current	E_O = 10V	+20, −5			*			*			mA
Impedance			0.01			*			*		Ω
Current Limit	To common		+40/−10			*			*		mA
Capacitive Load	Stable operation		1000			*			*		pF
INPUT											
Impedance[3]	Differential		50			*			*		kΩ
	Common-mode		50			*			*		kΩ
Voltage Range[4]	Differential	±10			*			*			V
	Common-mode	±20			*			*			V
Common-mode Rejection[5]	$T_A = T_{MIN}$ to T_{MAX}	80	90		86	100		72	*		dB
OFFSET VOLTAGE	RTO[6][7]										
Initial			50	250		*	*		*	500	µV
vs Temperature			5	20		5	10		*		µV/°C
vs Supply	$\pm V_{CC}$ = 6V to 18V		1	25		*	15		*	*	µV/V
vs Time			20			*			*		µV/mo
OUTPUT NOISE VOLTAGE	RTO[6][8]										
F_B = 0.01Hz to 10Hz			2.4			*			*		µV p-p
F_O = 10kHz			60			*			*		nV/√Hz
DYNAMIC RESPONSE											
Small Signal	−3dB		1			*			*		MHz
Full Power BW	V_O = 20V p-p	30	50		*	*		*	*		kHz
Slew Rate		2	3		*	*		*	*		V/µs
Settling Time, 0.1%	V_O = 10V step		4			*			*		µs
0.01%	V_O = 10V step		5			*			*		µs
0.01%	V_{CM} = 10V step, V_{DIFF} = 0V		1.5			*			*		µs
POWER SUPPLY											
Rated			±15			*			*		V
Voltage Range	Derated performance	±5		±18	*		*	*		*	V
Quiescent Current	V_{OUT} = 0V		±1.5	±2		*	*		*	*	mA
TEMPERATURE RANGE											
Specification		−25		+85	*		*	0		+70	°C
Operation		−55		+125	*		*	−25		+85	°C
Storage		−65		+150	*		*	−40		+85	°C

* Specification same as for INA105AM

NOTES. (1) Connected as difference amplifier (see Figure 4). (2) Nonlinearity is the maximum peak deviation from the best-fit straight line as a percent of full-scale peak-to-peak output (3) 25kΩ resistors are ratio matched but have ±20% absolute value. (4) Maximum input voltage without protection is 10V more than either ±15V supply (±25V) Limit I_{IN} to 1mA (5) With zero source impedance (see Maintaining CMR section). (6) Referred to output in unity-gain difference configuration. Note that this circuit has a gain of 2 for the operational amplifier's offset voltage and noise voltage. (7) Includes effects of amplifier's input bias and offset currents (8) Includes effects of amplifier's input current noise and thermal noise contribution of resistor network.

ABSOLUTE MAXIMUM RATINGS

Supply	±18V
Input Voltage Range	$\pm V_{CC}$
Operating Temperature Range: M	−55°C to +125°C
P, U	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (soldering 10 seconds) M, P	+300°C
Wave Soldering (3 seconds, max) U	+260°C
Output Short Circuit to Common	Continuous

ORDERING INFORMATION

Model	Package	Temperature Range
INA105AM	Metal TO-99	-25°C to +85°C
INA105BM	Metal TO-99	-25°C to +85°C
INA105KP	Plastic DIP	0°C to +70°C
INA105KU	Plastic SOIC	0°C to +70°C

BURN-IN SCREENING OPTION

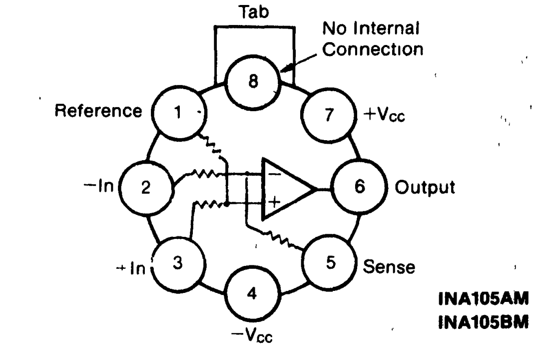
See text for details.

Model	Package	Burn-In Temp. (160h)[1]
INA105AM-BI	Metal TO-99	+125°C
INA105BM-BI	Metal TO-99	+125°C
INA105KP-BI	Plastic DIP	+85°C
INA105KU-BI	Plastic SOIC	+85°C

NOTE: (1) Or equivalent combination. See text

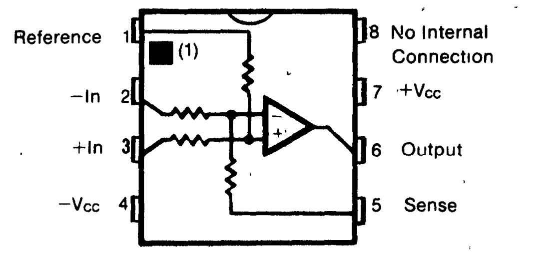
PIN DESIGNATIONS

TOP VIEW
TO-99



Case connected to −Vcc internally Make no connection

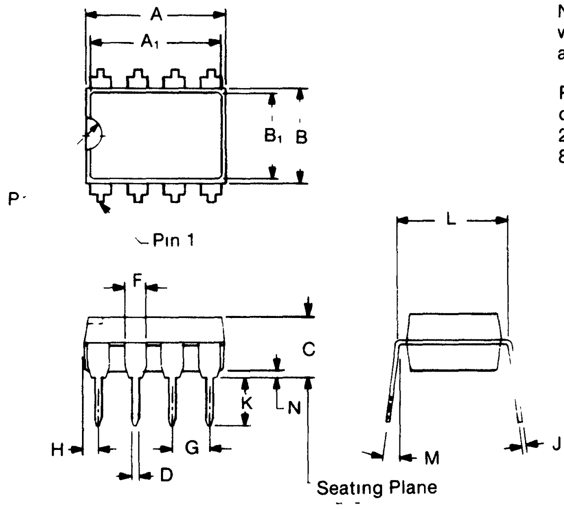
TOP VIEW
PLASTIC DIP AND SMALL OUTLINE
INA105



NOTE· (1) Peformance grade identifier box for small outline surface mount Blank indicates K grade Part is marked INA105U

MECHANICAL

"P" Package—Plastic DIP

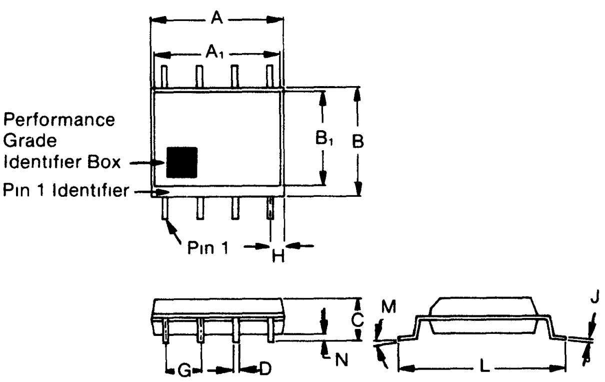


NOTE Leads in true position within 0 01" (0 25mm) R at MMC at seating plane

Pin material and plating composition conform to Method 2003 (solderability) of MIL-STD-883 (except paragraph 3 2)

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	355	400	9 03	10 16
A1	340	385	8 65	9 80
B	230	290	5 85	7 38
B1	200	250	5 09	6 36
C	120	200	3 05	5 09
D	015	023	0 38	0 59
F	030	070	0 76	1 78
G	100 BASIC		2 54 BASIC	
H	025	050	0 64	1 27
J	008	015	0 20	0.38
K	070	150	1 78	3 82
L	300 BASIC		7 63 BASIC	
M	0°	15°	0°	15°
N	010	030	0 25	0 76
P	025	050	0 64	1 27

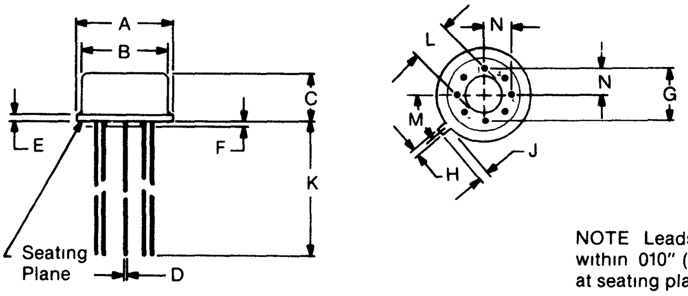
Small Outline Surface Mount



NOTE Leads in true position within 010" (25mm) R at MMC at seating plane

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	185	201	4.70	5 11
A1	178	201	4 52	5 11
B	146	162	3 71	4 11
B1	130	149	3 30	3 78
C	054	145	1 37	3 69
D	015	019	0 38	0 48
G	050 BASIC		1 27 BASIC	
H	018	026	0 46	0 66
J	008	012	0 20	0 30
L	220	252	5 59	6 40
M	0°	10°	0°	10°
N	000	012	0 00	0 30

TO-99 Package



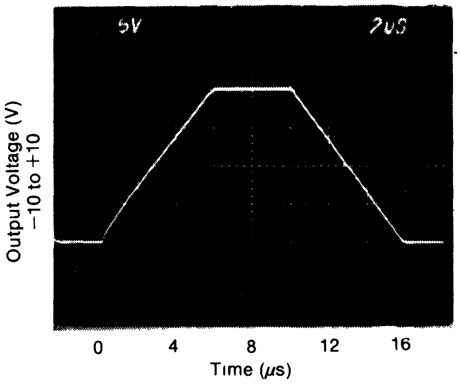
NOTE Leads in true position within 010" (25mm) R at MMC at seating plane

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	335	370	8 51	9 40
B	305	335	7 75	8 51
C	165	185	4 19	4 70
D	016	021	0 41	0 53
E	010	040	0 25	1 02
F	010	040	0 25	1 02
G	200 BASIC		5 08 BASIC	
H	028	034	0 71	0 86
J	029	045	0 74	1 14
K	500	—	12 7	—
L	110	160	2 79	4 06
M	45° BASIC		45° BASIC	
N	095	105	2 41	2 67

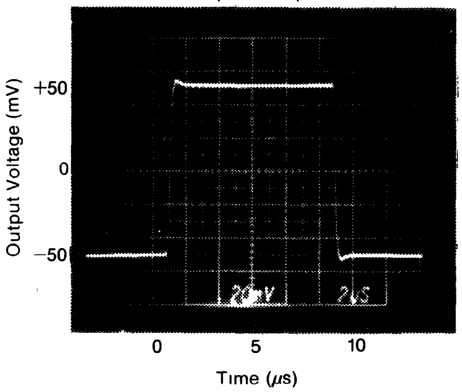
TYPICAL PERFORMANCE CURVES

$T_A = 25°C$, $\pm V_{CC} = 15VDC$ unless otherwise noted

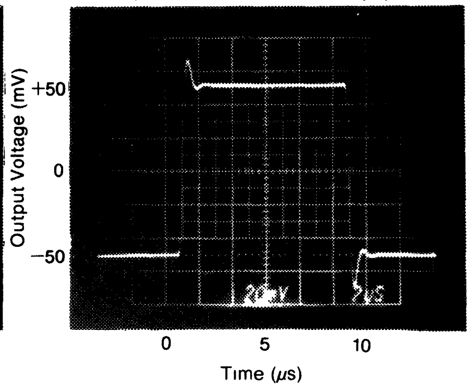
STEP RESPONSE



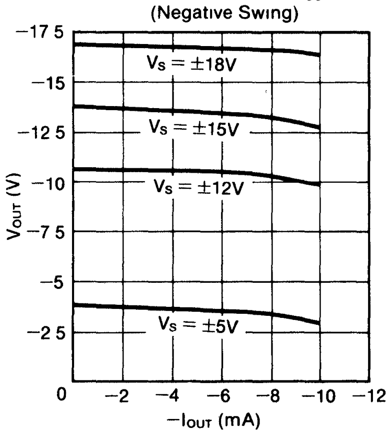
SMALL SIGNAL RESPONSE
(No Load)



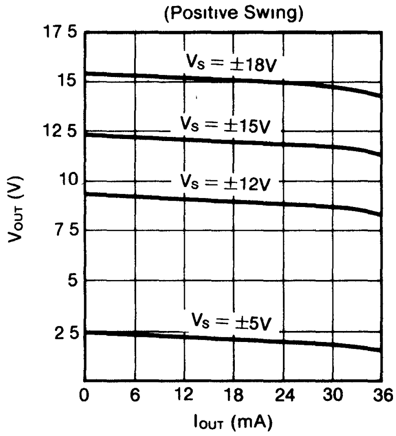
SMALL SIGNAL RESPONSE
($R_{LOAD} = \infty\Omega$, $C_{LOAD} = 1000pF$)



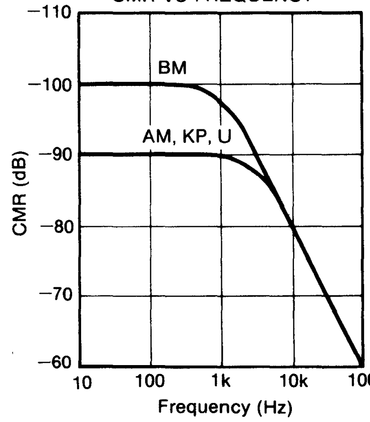
MAXIMUM V_{OUT} VS I_{OUT}
(Negative Swing)



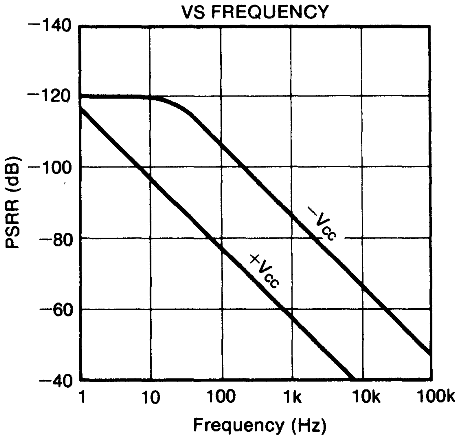
MAXIMUM V_{OUT} VS I_{OUT}
(Positive Swing)



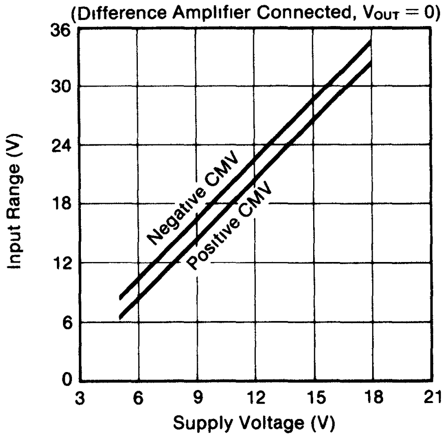
CMR VS FREQUENCY



POWER SUPPLY REJECTION
VS FREQUENCY



COMMON-MODE INPUT RANGE VS SUPPLY
(Difference Amplifier Connected, $V_{OUT} = 0$)



BURN-IN SCREENING

Burn-in screening is an option available for both the plastic- and ceramic-packaged INA105. Burn-in duration is 160 hours at the temperature shown below (or equivalent combination of time and temperature).

Plastic "-BI" models: +85°C
Ceramic "-BI" models: +125°C

All units are tested after burn-in to ensure that grade specifications are met. To order burn-in, add "-BI" to the base model number.

DISCUSSION OF PERFORMANCE

The INA105 is the new solution to a widely occurring problem—how to realize a very accurate unity-gain differential amplifier at low cost. Burr-Brown's solution is a reliable monolithic circuit including both operational amplifier and thin-film resistors on the chip. State-of-the-art laser-trimming techniques assure total error of less than ±0.015% (gain error, nonlinearity, offsets, and common-mode rejection).

The performance of the unity-gain differential amplifier circuit can mistakenly be taken for granted. The necessary resistor accuracy is difficult to achieve, especially over temperature. Two classical techniques employed for obtaining the necessary accuracy are either manual trimming or the use of available packaged matched and tracking resistor networks. Both are expensive compared to the cost of the complete INA105.

The INA105 provides the total solution. By using a computer-controlled laser-trimming procedure, both accuracy and low cost are guaranteed. This makes external adjustment of gain, CMR, and offset voltage unnecessary. The user can be assured of excellent accuracy over temperature due to the properties inherent in Burr-Brown's thin-film resistors.

Other advantages are also apparent. Design, purchasing, and inventory costs are reduced. Labor time in adjusting independent resistors is eliminated both during manufacturing and field repair. Best of all, expensive potentiometers are not required. This further enhances circuit reliability.

BASIC POWER SUPPLY AND SIGNAL CONNECTIONS

Figure 1 shows the proper connections for power supply and signal. Supplies should be decoupled with 1μF tantalum capacitors as close to the amplifier as possible. To avoid gain and CMR errors introduced by the external circuit, connect grounds as indicated, being sure to minimize ground resistance.

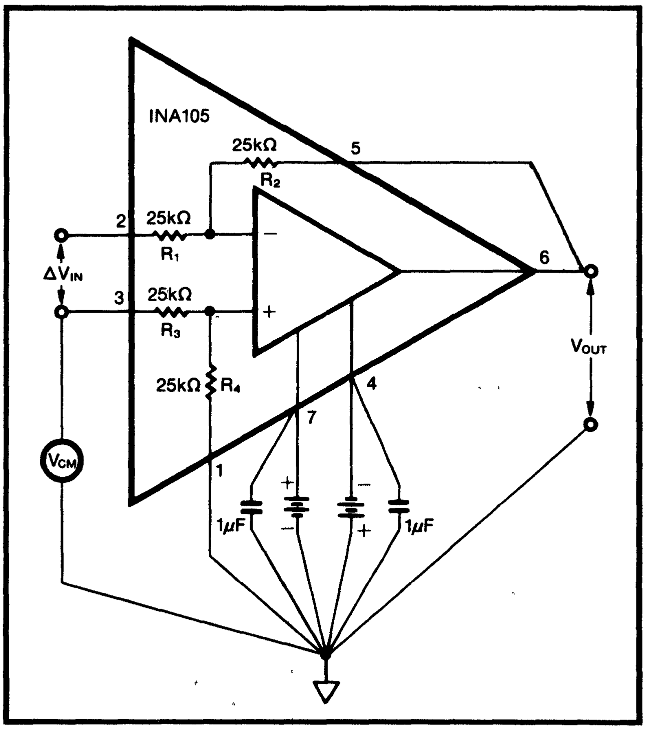


FIGURE 1. Basic Power Supply and Signal Connections.

OFFSET ADJUSTMENT

Figure 2 shows the offset adjustment circuit for the INA105. This circuit will allow ±300μV of adjustment and will not affect the gain accuracy or CMR.

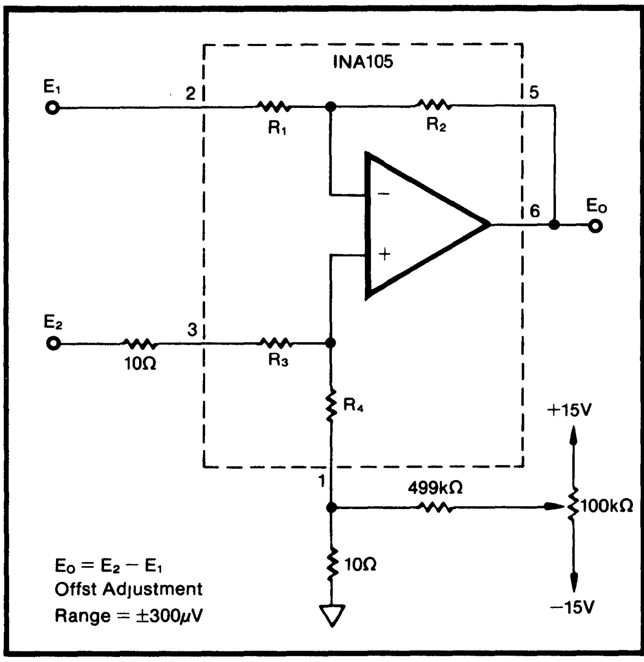


FIGURE 2. Offset Adjustment.

MAINTAINING COMMON-MODE REJECTION

Two factors are important in maintaining high CMR: (1) resistor matching and tracking (the internal INA105 circuitry does this for the user) and (2) source impedance including its imbalance.

Referring to Figure 1, the CMR depends upon the match of the internal R_4/R_3 ratio to the R_1/R_2 ratio. A CMR of 100dB requires resistor matching of 0.002%. To maintain 86dB, minimum CMR to +85°C, the resistor TCR tracking must be better than 2ppm/°C. These accuracies are difficult and expensive to reliably achieve with discrete components.

Any source impedance adds directly to the input resistors, R_1 and R_3, and will degrade DC and AC CMR. Likewise any wiring resistance adds directly to any of the precision difference resistors. A resistance of 0.5Ω (0.002% of 25kΩ) will degrade the 100dB CMR of the INA105; 5Ω will degrade the CMR to 80dB. Don't be tempted to interchange pins 1 and 3 or pins 2 and 5. The resistors in the INA105 are carefully matched to faithfully preserve the proper ratios. If they are switched, CMR and temperature drift performance will be degraded.

When input filters are used preceding an instrumentation amplifier (see Figure 5), care should also be taken to match RCs on the two input lines. For example, mismatched input filters for high frequencies will reduce the CMR at lower frequencies, e.g, 60Hz. Differential filters will not degrade AC CMR.

RESISTOR NOISE IN THE INA105

Figure 3 shows the model for calculating resistor noise in the INA105. Resistors have Johnson noise resulting from thermal agitation. The expression for this noise is:

$$E_{RMS} = \sqrt{4KTRB}$$

Where: K = Boltzman's constant (J/°K)
T = Absolute temperature (°K)
R = Resistance (Ω)
B = Bandwidth (Hz)

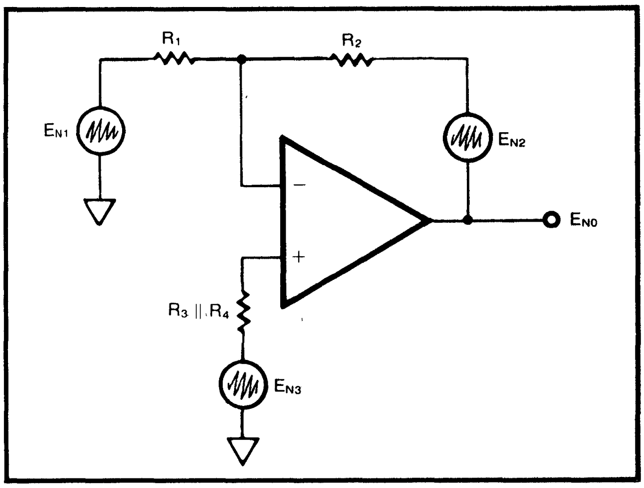


FIGURE 3. Resistor Noise Model.

At room temperature, this noise becomes:

$$E_N = 1.3^{-10}\sqrt{R} \qquad (V/\sqrt{Hz})$$

The three noise sources in Figure 2 are:

$$E_{N1} = 1.3^{-10}(R_2/R_1)\sqrt{R_1}$$
$$E_{N2} = 1.3^{-10}\sqrt{R_2}$$
$$E_{N3} = 1.3^{-10}(1 + R_2/R_1)\sqrt{R_3 \| R_4}$$

The output noise (given $R_1 = R_2 = R_3 = R_4 = 25k\Omega$) is:

$$E_{NO} = 2.6^{-10}\sqrt{R}$$
$$\boxed{E_{NO} = 41nV_{RMS}/\sqrt{Hz}}$$

For example,

E_{NO} within a
100Hz BW $= 410nV_{RMS}$
$= 2460nV_{P-P}$ with a crest factor of 6 (statistically includes 99.7% of all noise peak occurrences)

This is the noise due to the resistors alone. It is included in the noise specification of the INA105.

APPLICATIONS CIRCUITS

The INA105 is ideally suited for a wide range of circuit functions. Figures 4 through 29 show many applications circuits ranging from difference amplifiers and single-ended gain blocks to average and absolute value amplifiers. It is ideal as a current-loop receiver. Also, since the positive output current drive has been extended, it serves uniquely as a current transmitter for ranges such as 4mA to 20mA. When using these applications recall that the internal 25kΩ resistors are ratio-matched but ±20% absolute.

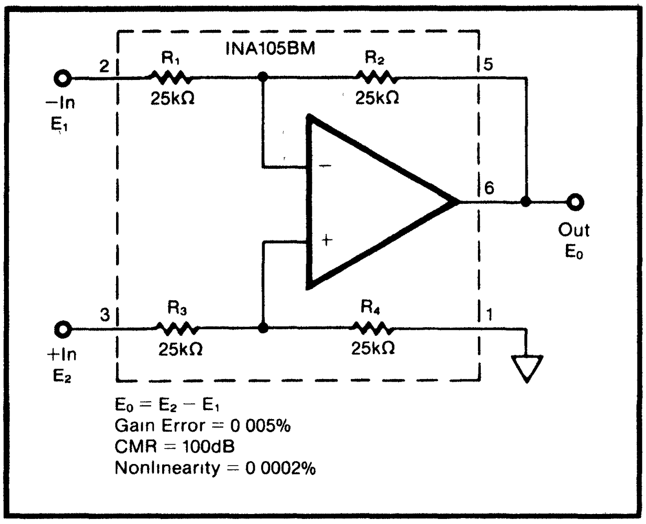
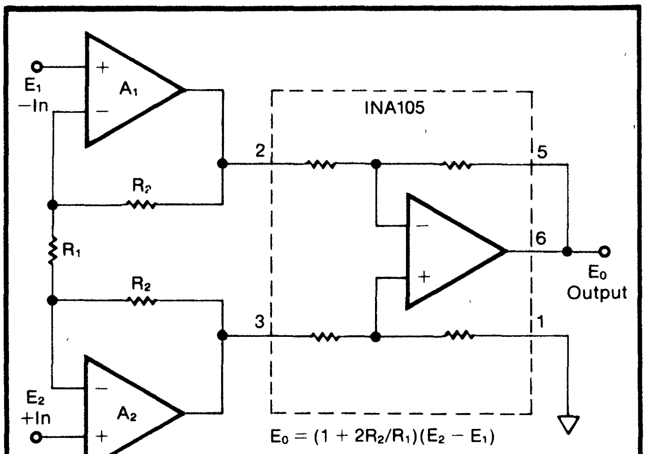


FIGURE 4. Precision Difference Amplifier.



For low source impedance applications, an input stage using OPA37 op amps will give the best low noise, offset, and temperature drift performance. At source impedances above about 10kΩ, the bias current noise of the OPA37 reacting with the input impedance begins to dominate the noise performance. For these applications, using the OPA111 or Dual OPA2111 FET input op amp will provide lower noise performance. For lower cost use the OPA121 plastic. To construct an electrometer use the OPA128.

A_1, A_2	R_1 (Ω)	R_2 (Ω)	Gain (V/V)	CMRR (dB)	Max I_B	Noise at 1kHz (nV/$\sqrt{Hz}$)
OPA37A	50.5	2.5k	100	128	40nA	4
OPA111B	202	10k	100	110	1pA	10
OPA128LM	202	10k	100	118	75fA	38

FIGURE 5. Precision Instrumentation Amplifier.

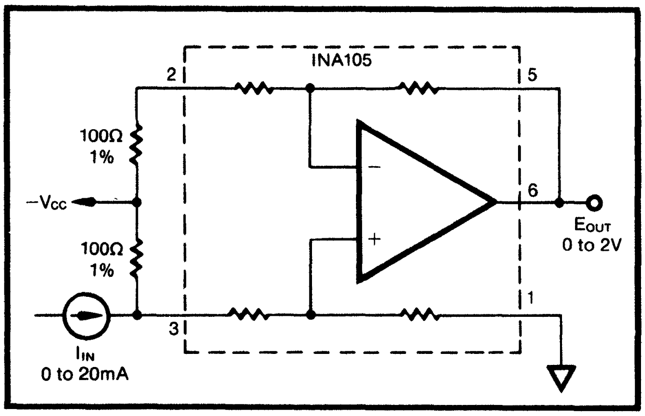


FIGURE 6. Current Receiver with Compliance to Rails.

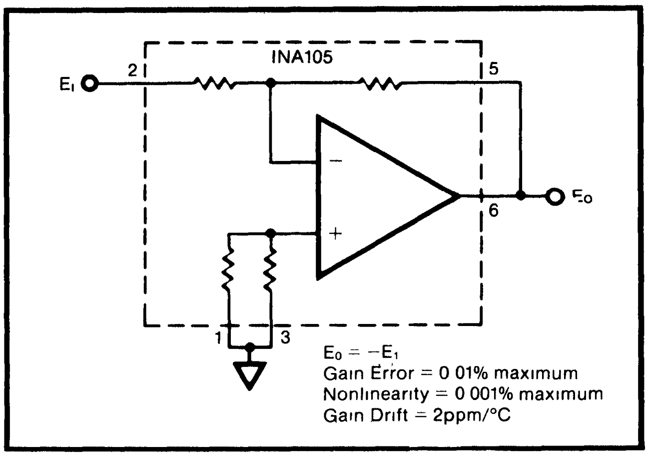


FIGURE 7. Precision Unity-Gain Inverting Amplifier.

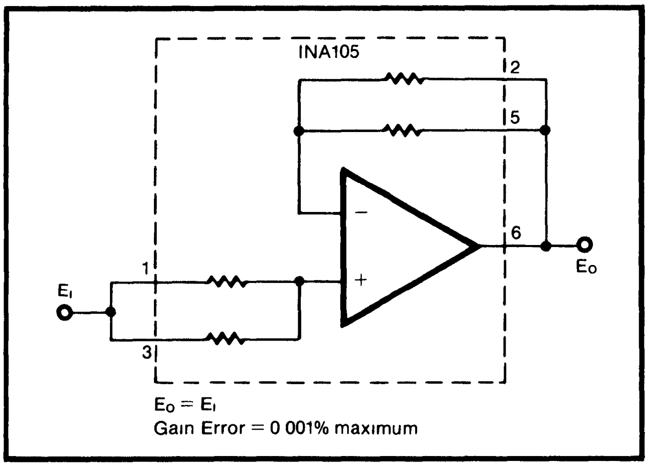


FIGURE 10. Precision Unity-Gain Buffer.

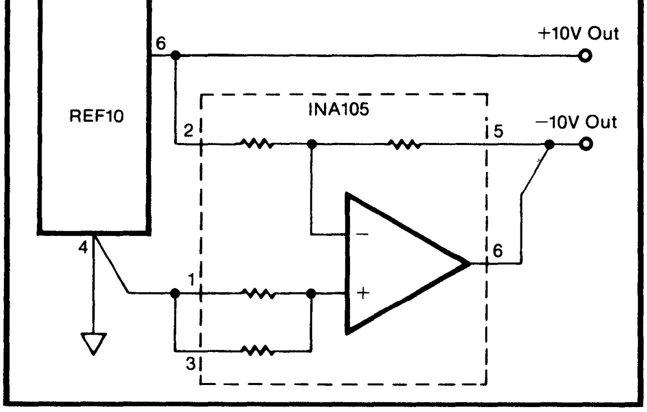


FIGURE 8. ±10V Precision Voltage Reference.

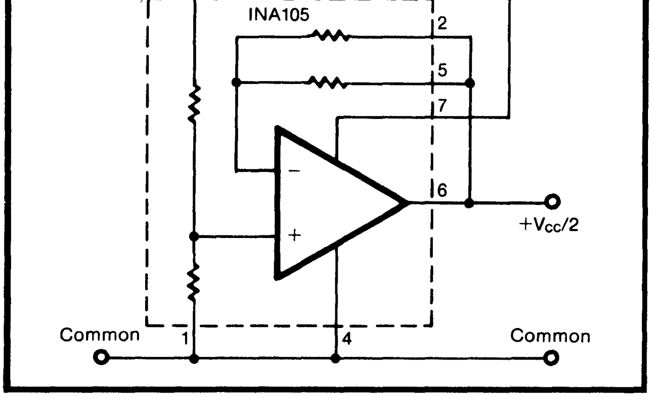


FIGURE 11. Pseudoground Generator.

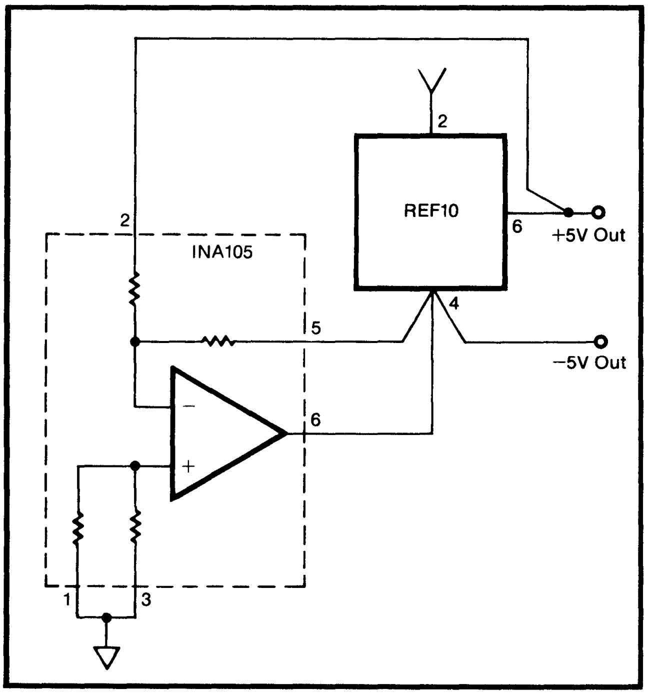


FIGURE 9. ±5V Precision Voltage Reference.

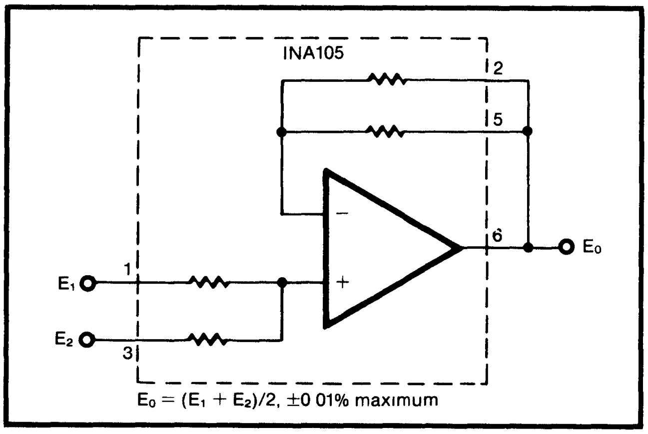


FIGURE 12. Precision Average Value Amplifier.

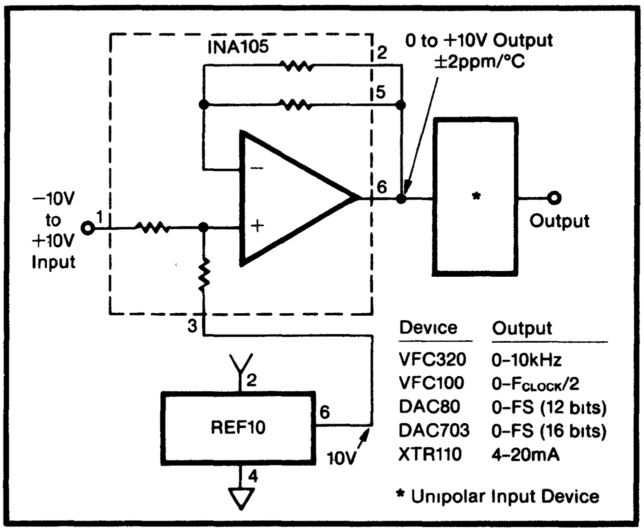


FIGURE 13. Precision Bipolar Offsetting.

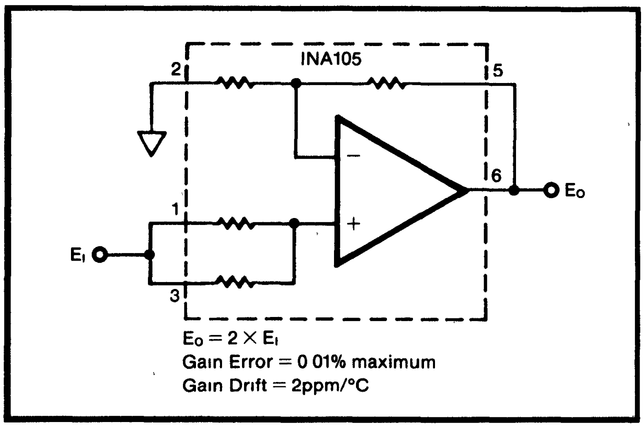


FIGURE 15. Precision (G = 2) Amplifier.

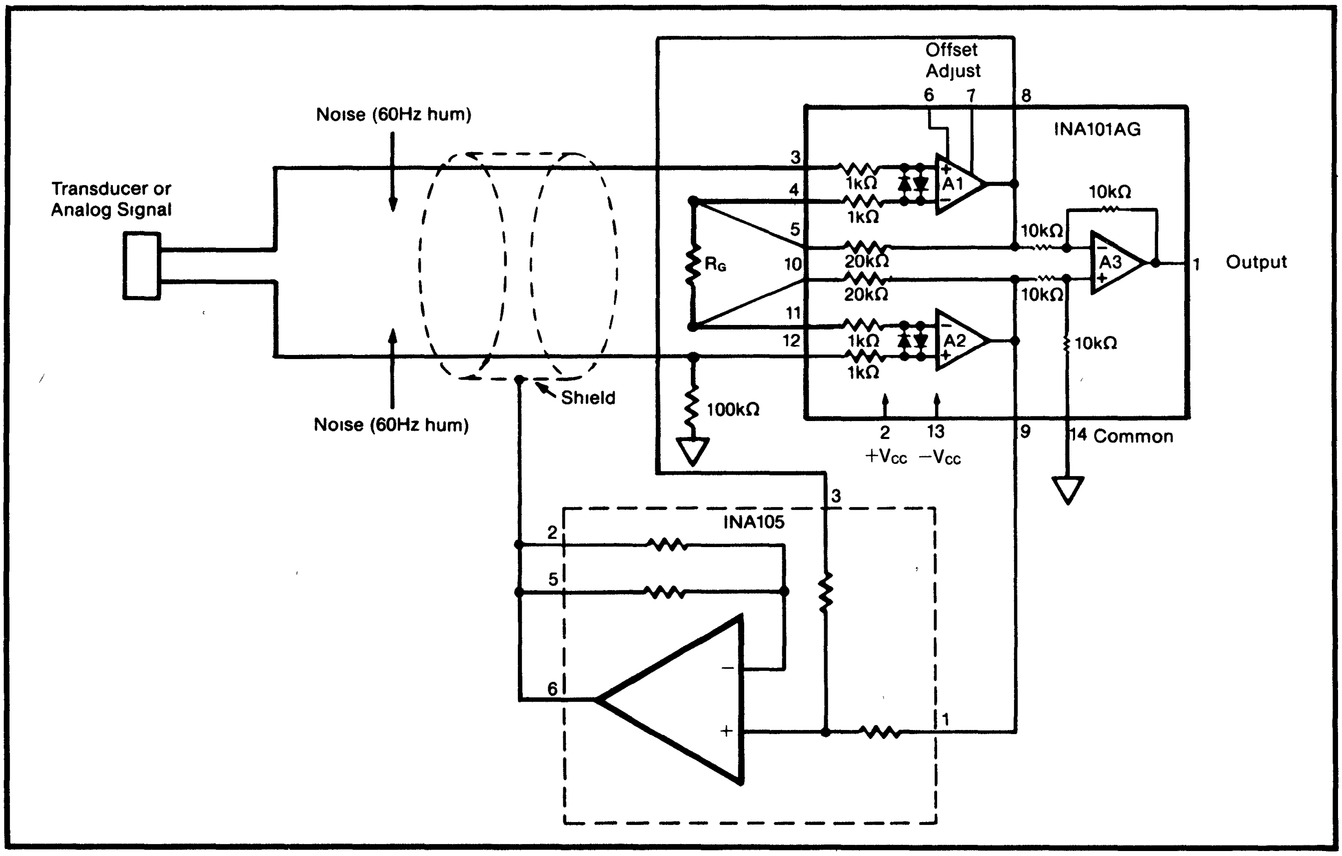


FIGURE 14. Instrumentation Amplifier Guard Drive Generator.

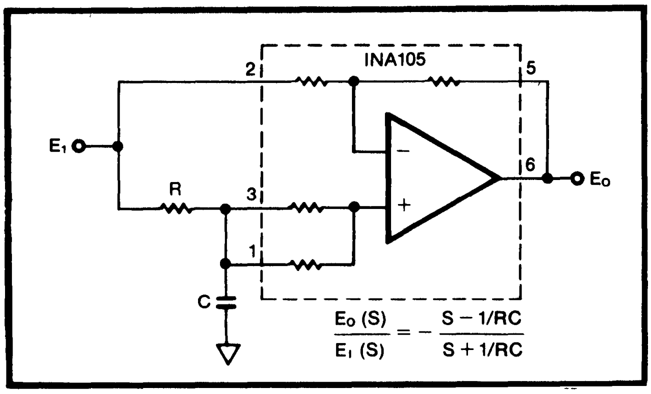


FIGURE 16. All-Pass Filter (provides unity gain and 0° to 180° phase shift output for frequencies of DC to ∞Hz).

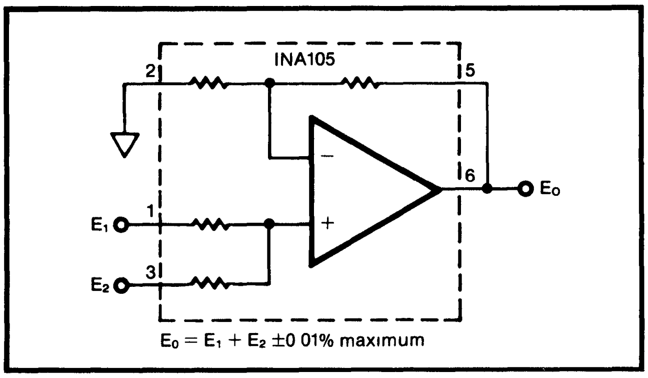


FIGURE 17. Precision Summing Amplifier.

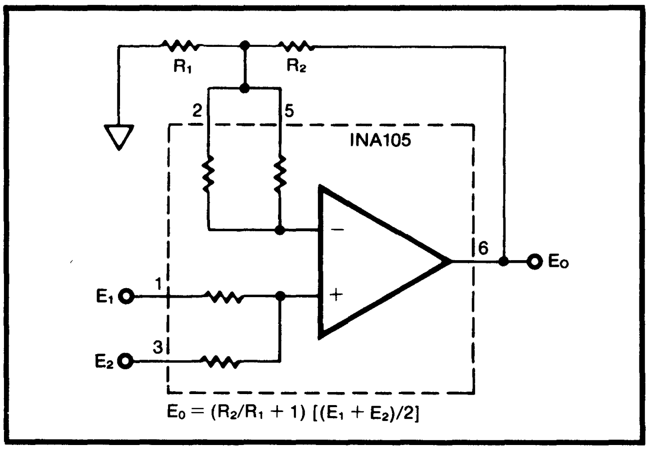


FIGURE 18. Precision Summing Amplifier with Gain.

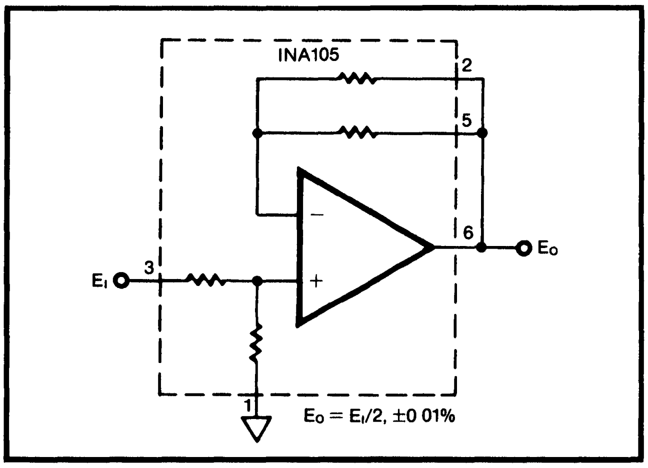


FIGURE 19. Precision (Gain = 1/2) Amplifier. Allows ±20V Input with ±15V Power Supplies.

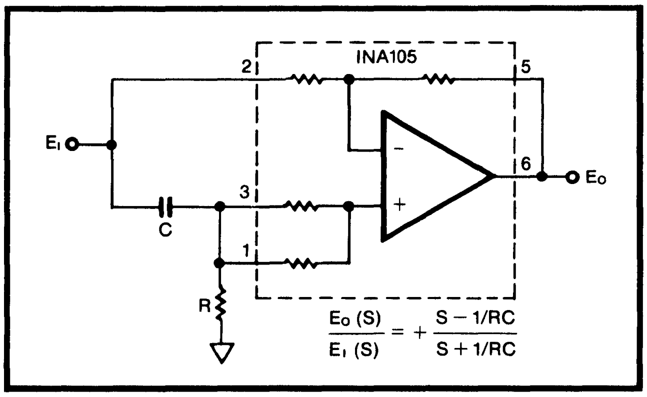


FIGURE 20. All-Pass Filter (provides unity gain and −180° to 0° phase shift output for frequencies of DC to ∞Hz).

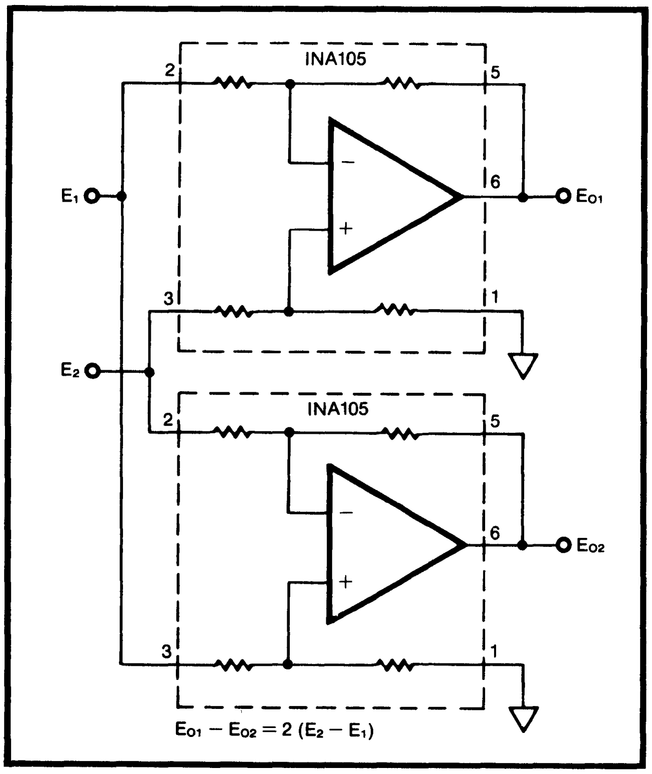


FIGURE 21. Differential Output Difference Amplifier.

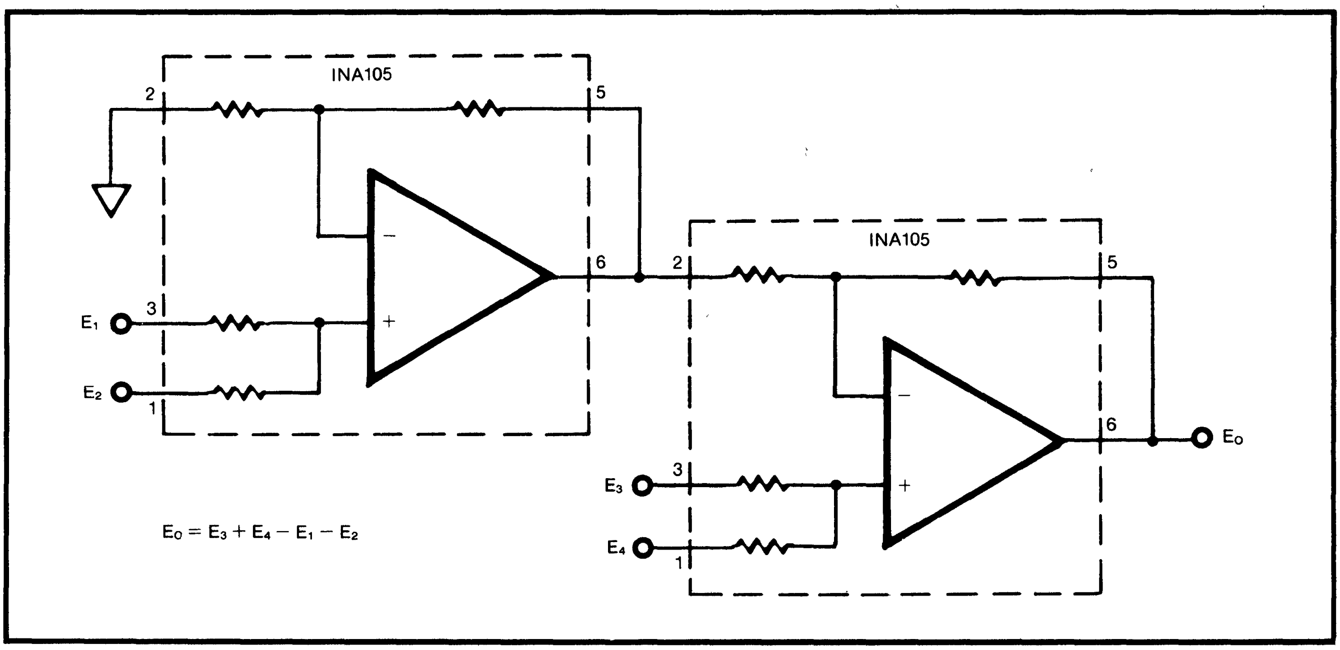


FIGURE 22. Precision Summing Instrumentation Amplifier.

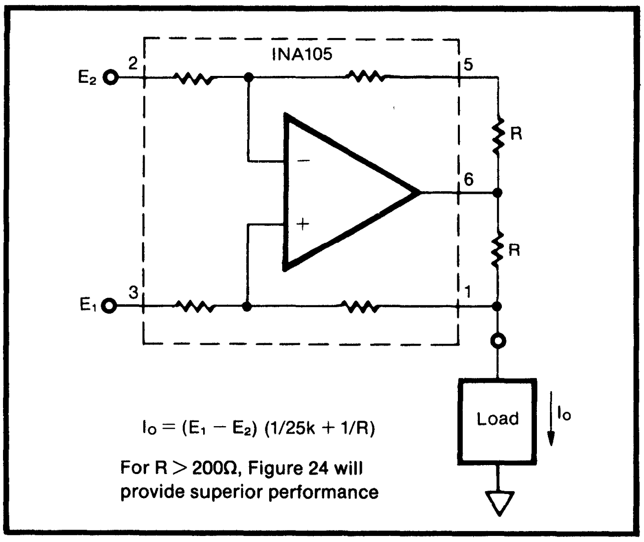


FIGURE 23. Precision Voltage-to-Current Converter with Differential Inputs.

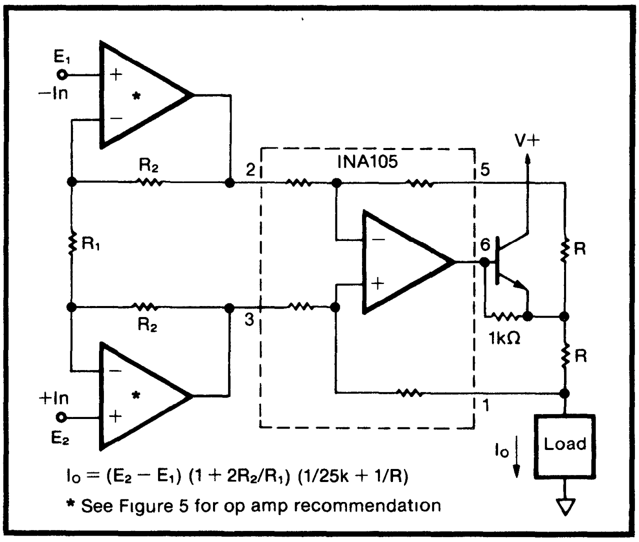


FIGURE 25. Precision Voltage-Controlled Current Source with Buffered Differential Inputs and Gain.

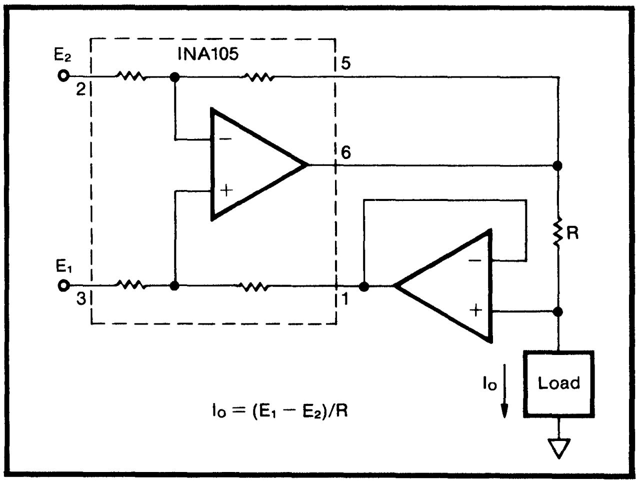


FIGURE 24. Differential Input Voltage-to-Current Converter for Low I_{OUT}.

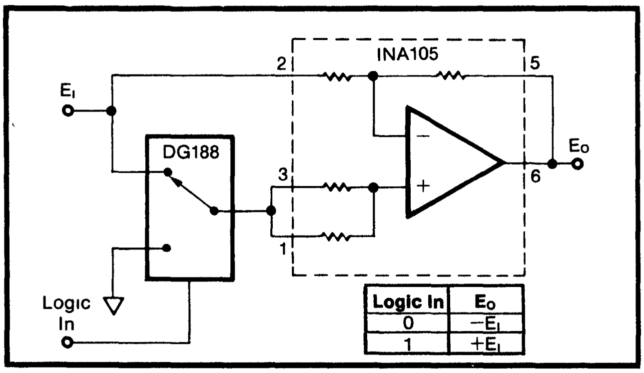


FIGURE 26. Digitally Controlled Gain of ±1 Amplifier.

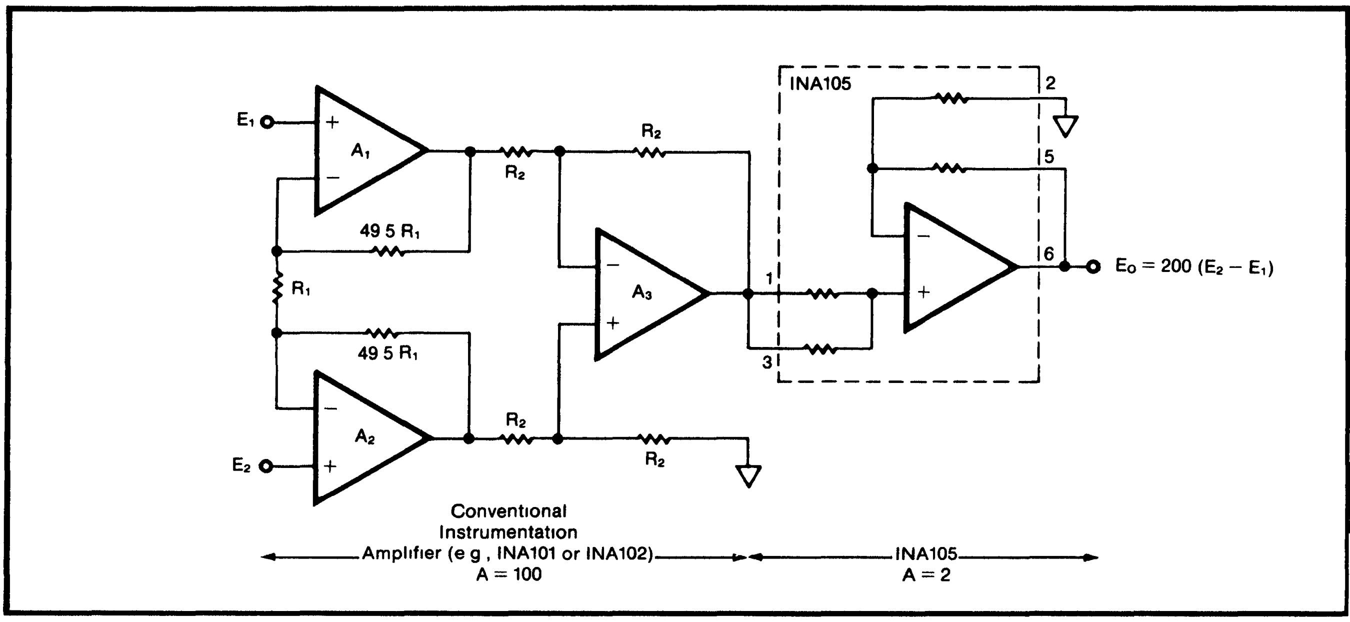


FIGURE 27. Boosting Instrumentation Amplifier Common-Mode Range From ±5V to ±7.5V with 10V Full-Scale Output.

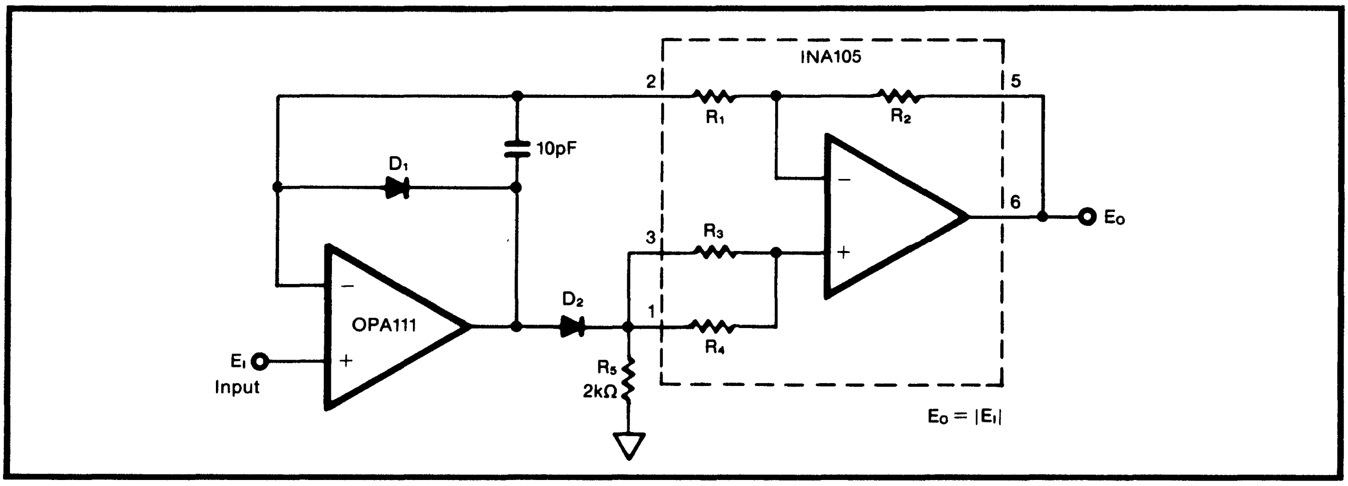


FIGURE 28. Precision Absolute Value Buffer.

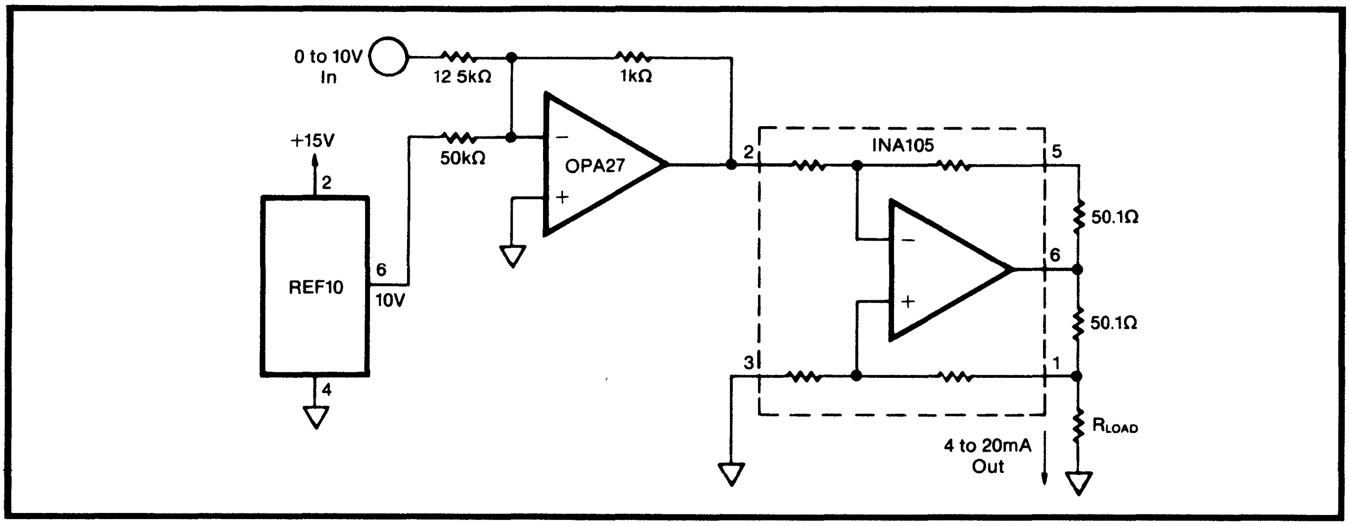


FIGURE 29. Precision 4-20mA Current Transmitter.

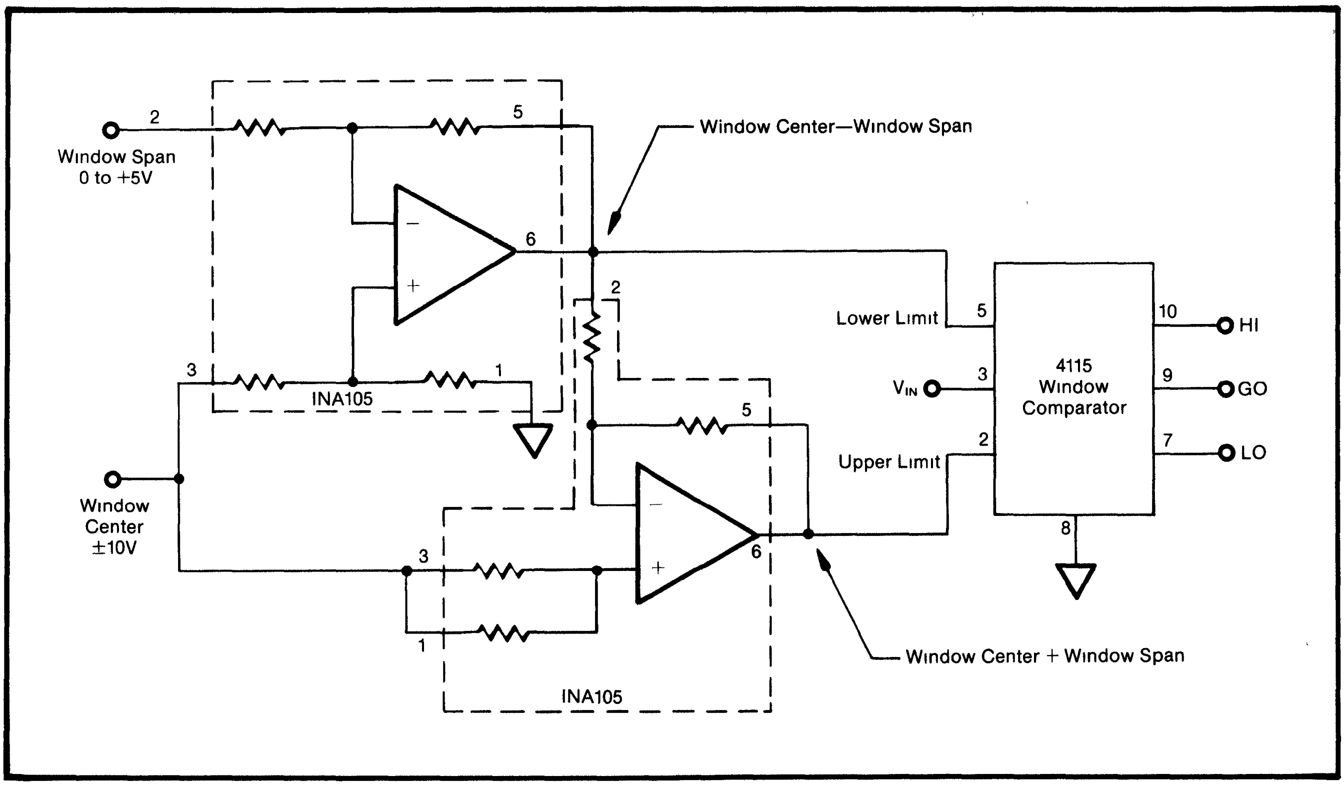


FIGURE 30. Window Comparator with Window Span and Window Center Inputs.

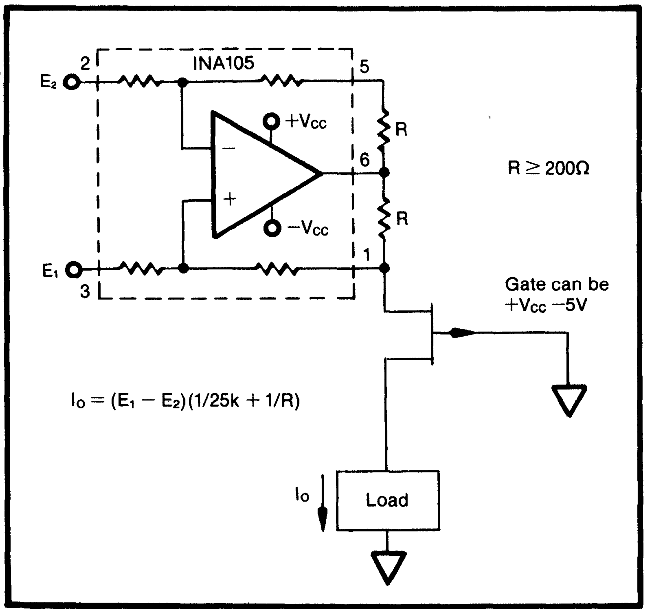


FIGURE 31. Isolating Current Source.

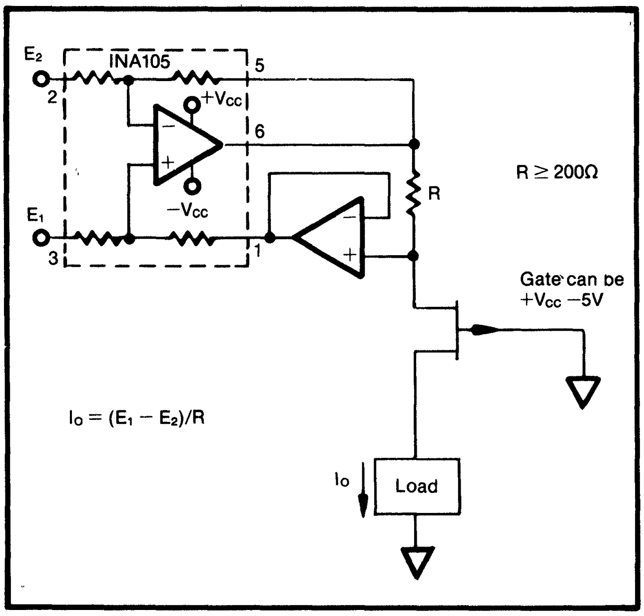


FIGURE 32. Isolating Current Source with Buffering Amplifier for Greater Accuracy.