Picoamp Input Current, Microvolt Offset, Low Noise Op Amp

FEATURES

- OP-07 Type Performance
  at 1/8th of OP-07's Supply Current
  at 1/20th of OP-07's Bias and Offset Currents
- *Guaranteed* Offset Voltage 25μV Max
- *Guaranteed* Bias Current 100pA Max
- *Guaranteed* Drift 0.6μV/°C Max
- Low Noise, 0.1Hz to 10Hz 0.5μVp-p
- *Guaranteed* Low Supply Current 500μA Max
- *Guaranteed* CMRR 114dB Min
- *Guaranteed* PSRR 114dB Min
- *Guaranteed* Operation @ ±1.2V Supplies

APPLICATIONS

- Replaces OP-07 While Saving Power
- Precision Instrumentation
- Charge Integrators
- Wide Dynamic Range Logarithmic Amplifiers
- Light Meters
- Low Frequency Active Filters
- Thermocouple Amplifiers

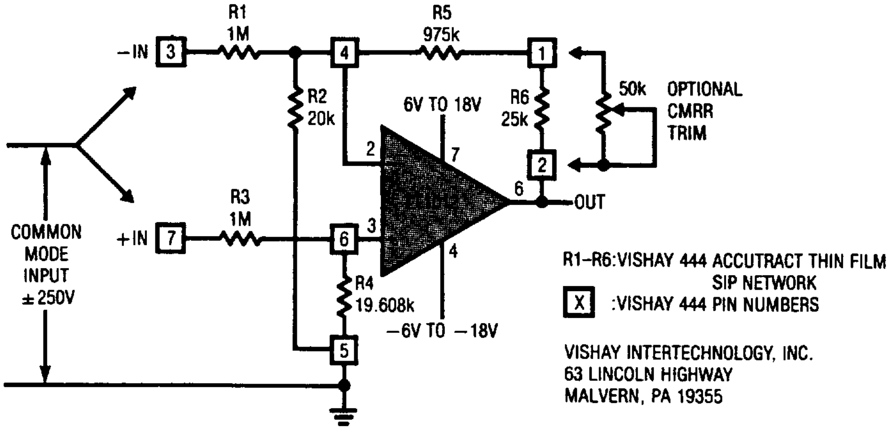
DESCRIPTION

The LT1012 is an internally compensated universal precision operational amplifier which can be used in practically all precision applications. The LT1012 combines picoampere bias currents (which are maintained over the full −55°C to 125°C temperature range), microvolt offset voltage (and low drift with time and temperature), low voltage and current noise, and low power dissipation. The LT1012 achieves precision operation on two Ni-Cad batteries with 1mW of power dissipation. Extremely high common mode and power supply rejection ratios, practically unmeasurable warm-up drift, and the ability to deliver 5mA load current with a voltage gain of one million round out the LT1012's superb precision specifications.

The all around excellence of the LT1012 eliminates the necessity of the time consuming error analysis procedure of precision system design in many applications; the LT1012 can be stocked as the universal internally compensated precision op amp.

Protected by U.S. patents 4,575,685 and 4,775,884

±250V Common Mode Range Instrumentation Amplifier ($A_V = 1$)

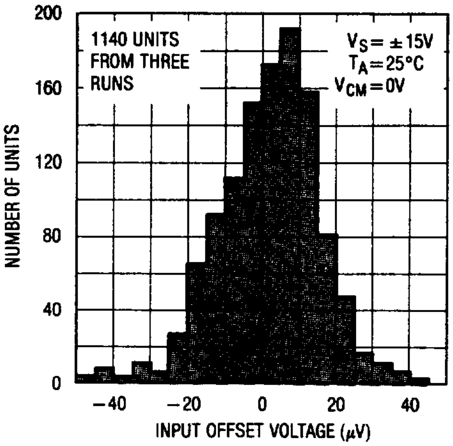


R1–R6: VISHAY 444 ACCUTRACT THIN FILM SIP NETWORK
X : VISHAY 444 PIN NUMBERS

VISHAY INTERTECHNOLOGY, INC.
63 LINCOLN HIGHWAY
MALVERN, PA 19355

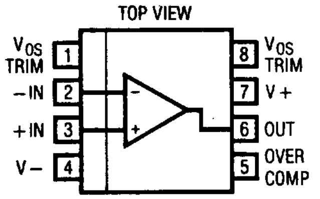
COMMON MODE REJECTION RATIO = 74dB (RESISTOR LIMITED)
WITH OPTIONAL TRIM = 130dB
OUTPUT OFFSET (TRIMMABLE TO ZERO) = 500μV
OUTPUT OFFSET DRIFT = 10μV/°C
INPUT RESISTANCE = 1M

Typical Distrubution of Input Offset Voltage

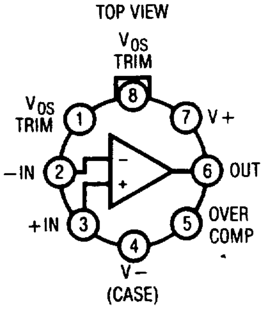
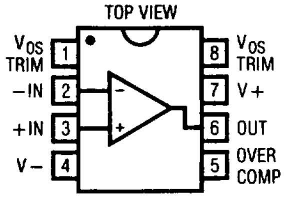


ABSOLUTE MAXIMUM RATINGS

Supply Voltage.............................. ± 20V
Differential Input Current (Note 1)..........± 10mA
Input Voltage...............................± 20V
Output Short Circuit Duration............Indefinite
Operating Temperature Range
  LT1012AM, LT1012M............– 55°C to 125°C
  LT1012AC, LT1012C,
    LT1012D, LT1012S8...............0°C to 70°C
Storage Temperature Range
  All Devices.....................– 65°C to 150°C
Lead Temperature (Soldering, 10 sec.)........300°C

	ORDER PART NUMBER
 SO PACKAGE 8-LEAD PLASTIC SOIC	LT1012S8
	PART MARKING
	1012

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
 H PACKAGE 8-LEAD TO-5 METAL CAN	LT1012AMH LT1012MH LT1012ACH LT1012CH LT1012DH
 N PACKAGE 8-LEAD PLASTIC DIP	LT1012ACN8 LT1012CN8 LT1012DN8

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V, V_{CM} = 0V, T_A = 25°C$, unless otherwise noted.

			LT1012AM/AC			LT1012M			LT1012C			
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage			8	25		8	35		10	50	µV
		(Note 2)		20	90		20	90		25	120	µV
	Long Term Input Offset Voltage Stability			0.3			0.3			0.3		µV/month
I_{OS}	Input Offset Current			15	100		15	100		20	150	pA
		(Note 2)		25	150		25	150		30	200	pA
I_B	Input Bias Current			± 25	± 100		± 25	± 100		± 30	± 150	pA
		(Note 2)		± 35	± 150		± 35	± 150		± 40	± 200	pA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.5			0.5			0.5		µVp-p
e_n	Input Noise Voltage Density	f_o = 10Hz (Note 3)		17	30		17	30		17	30	$nV/\sqrt{Hz}$
		f_o = 1000Hz (Note 4)		14	22		14	22		14	22	$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f_o = 10Hz		20			20			20		$fA/\sqrt{Hz}$
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = \pm 12V, R_L \geq 10k\Omega$	300	2000		300	2000		200	2000		V/mV
		$V_{OUT} = \pm 10V, R_L \geq 2k\Omega$	300	1000		200	1000		200	1000		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	114	132		114	132		110	132		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.2V$ to $\pm 20V$	114	132		114	132		110	132		dB
	Input Voltage Range		± 13.5	± 14.0		± 13.5	± 14.0		± 13.5	± 14.0		V
V_{OUT}	Output Voltage Swing	$R_L = 10k\Omega$	± 13	± 14		± 13	± 14		± 13	± 14		V
	Slew Rate		0.1	0.2		0.1	0.2		0.1	0.2		V/µsec
I_S	Supply Current			370	500		380	—		380	—	µA
		(Note 2)		380	600		380	600		380	600	µA

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$, $V_{CM} = 0V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1012D			LT1012S8			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	 (Note 2)		12 25	60 —		15 25	120 180	μV μV
	Long Term Input Offset Voltage Stability			0.3			0.4		μV/month
I_{OS}	Input Offset Current	 (Note 2)		20 30	150 —		50 60	280 380	pA pA
I_B	Input Bias Current	 (Note 2)		±30 ±40	±150 —		±80 ±120	±300 ±400	pA pA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.5			0.5		μVp-p
e_n	Input Noise Voltage Density	$f_0 = 10Hz$ (Note 4) $f_0 = 1000Hz$ (Note 4)		17 14	30 22		17 14	30 22	$nV\sqrt{Hz}$ $nV\sqrt{Hz}$
i_n	Input Noise Current Density	$f_0 = 10Hz$		20			20		$fA/\sqrt{Hz}$
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = \pm 12V, R_L \geq 10k\Omega$ $V_{OUT} = \pm 10V, R_L \geq 2k\Omega$	200 200	2000 1000		200 120	2000 1000		V/mV V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	110	132		110	132		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.2V$ to $\pm 20V$	110	132		110	132		dB
	Input Voltage Range		±13.5	±14.0		±13.5	±14.0		V
V_{OUT}	Output Voltage Swing	$R_L = 10k\Omega$	±13	±14		±13	±14		V
	Slew Rate		0.1	0.2		0.1	0.2		V/μsec
I_S	Supply Current	(Note 2)		380	600		380	600	μA

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$, $V_{CM} = 0V$, $-55°C \leq T_A \leq 125°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1012AM			LT1012M			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	 (Note 2)	● ●		30 40	60 180		30 40	180 250	μV μV
	Average Temperature Coefficient of Input Offset Voltage		●		0.2	0.6		0.2	1.5	μV/°C
I_{OS}	Input Offset Current	 (Note 2)	● ●		30 70	250 350		30 70	250 350	pA pA
	Average Temperature Coefficient of Input Offset Current		●		0.3	2.5		0.3	2.5	pA/°C
I_B	Input Bias Current	 (Note 2)	● ●		±80 ±150	±600 ±800		±80 ±150	±600 ±800	pA pA
	Average Temperature Coefficient of Input Bias Current		●		0.6	6.0		0.6	6.0	pA/°C
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = \pm 12V, R_L \geq 10k\Omega$ $V_{OUT} = \pm 10V, R_L \geq 2k\Omega$	● ●	200 200	1000 600		150 100	1000 600		V/mV V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	●	110	128		108	128		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.5V$ to $\pm 20V$	●	110	126		108	126		dB
	Input Voltage Range		●	±13.5			±13.5			V
V_{OUT}	Output Voltage Swing	$R_L = 10k\Omega$	●	±13	±14		±13	±14		V
I_S	Supply Current		●		400	650		400	800	μA

The ● denotes the specifications which apply over the full operating temperature range.

Note 1: Differential input voltages greater than 1V will cause excessive current to flow through the input protection diodes unless limiting resistance is used.

Note 2: These specifications apply for $V_{MIN} \leq V_S \leq \pm 20V$ and $-13.5V \leq V_{CM} \leq 13.5V$ (for $V_S = \pm 15V$). $V_{MIN} = \pm 1.2V$ at 25°C, ±1.3V from 0°C to 70°C, ±1.5V from −55°C to 125°C.

Note 3: 10Hz noise voltage density is sample tested on every lot. Devices 100% tested at 10Hz are available on request.

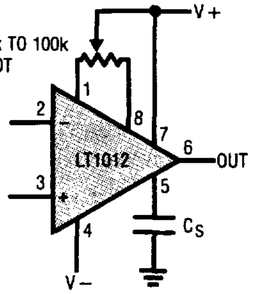
Note 4: This parameter is tested on a sample basis only.

ELECTRICAL CHARACTERISTICS $V_S = \pm15V, V_{CM} = 0V, 0°C \le T_A \le 70°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1012AC MIN	LT1012AC TYP	LT1012AC MAX	LT1012C MIN	LT1012C TYP	LT1012C MAX	UNITS
V_{OS}	Input Offset Voltage		●		20	60		20	100	μV
		(Note 2)	●		30	160		30	200	μV
	Average Temperature Coefficient of Input Offset Voltage		●		0.2	0.6		0.2	1.0	μV/°C
I_{OS}	Input Offset Current		●		25	230		35	230	pA
		(Note 2)	●		40	300		45	300	pA
	Average Temperature Coefficient of Input Offset Current		●		0.3	2.5		0.3	2.5	pA/°C
I_B	Input Bias Current		●		±35	±230		±35	±230	pA
		(Note 2)	●		±50	±300		±50	±300	pA
	Average Temperature Coefficient of Input Bias Current		●		0.3	2.5		0.3	2.5	pA/°C
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = \pm12V, R_L \ge 10k\Omega$	●	200	1500		150	1500		V/mV
		$V_{OUT} = \pm10V, R_L \ge 2k\Omega$	●	200	1000		150	800		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	●	110	130		108	130		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm1.3V$ to $\pm20V$	●	110	128		108	128		dB
	Input Voltage Range		●	±13.5			±13.5			V
V_{OUT}	Output Voltage Swing	$R_L = 10k\Omega$	●	±13	±14		±13	±14		V
I_S	Supply Current		●		400	600		400	800	μA

ELECTRICAL CHARACTERISTICS $V_S = \pm15V, V_{CM} = 0V, 0°C \le T_A \le 70°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1012D MIN	LT1012D TYP	LT1012D MAX	LT1012S8 MIN	LT1012S8 TYP	LT1012S8 MAX	UNITS
V_{OS}	Input Offset Voltage		●		25	140		30	200	μV
		(Note 2)	●		40	—		45	270	μV
	Average Temperature Coefficient of Input Offset Voltage		●		0.3	1.7		0.3	1.8	μV/°C
I_{OS}	Input Offset Current		●		35	380		60	380	pA
		(Note 2)	●		45	—		80	500	pA
	Average Temperature Coefficient of Input Offset Current		●		0.35	4.0		0.4	4.0	pA/°C
I_B	Input Bias Current		●		±50	±420		±100	±420	pA
		(Note 2)	●		±65	—		±150	±550	pA
	Average Temperature Coefficient of Input Bias Current		●		0.4	5.0		0.5	5.0	pA/°C
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = \pm12V, R_L \ge 10k\Omega$	●	150	1500		150	1500		V/mV
		$V_{OUT} = \pm10V, R_L \ge 2k\Omega$	●	150	800		100	800		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	●	108	130		108	130		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm1.3V$ to $\pm20V$	●	108	128		108	128		dB
	Input Voltage Range		●	±13.5			±13.5			V
V_{OUT}	Output Voltage Swing	$R_L = 10k\Omega$	●	±13	±14		±13	±14		V
I_S	Supply Current		●		400	800		400	800	μA



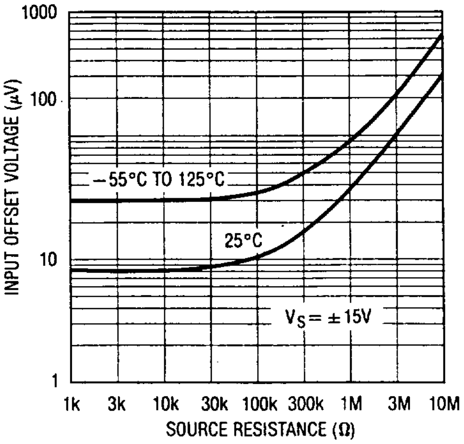
Optional Offset Nulling and Over-Compensation Circuits

Input offset voltage can be adjusted over a ±800μV range with a 5k to 100k potentiometer.

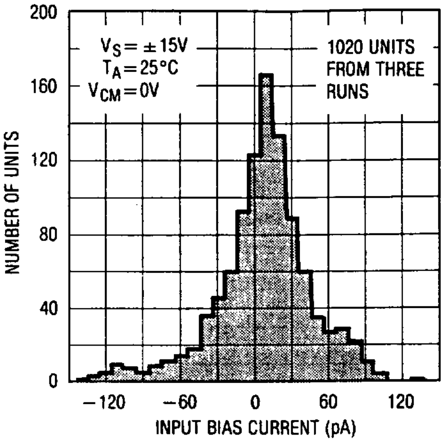
The LT1012 is internally compensated for unity gain stability. The over-compensation capacitor, C_S, can be used to improve capacitive load handling capability, to narrow noise bandwidth, or to stabilize circuits with gain in the feedback loop.

TYPICAL PERFORMANCE CHARACTERISTICS

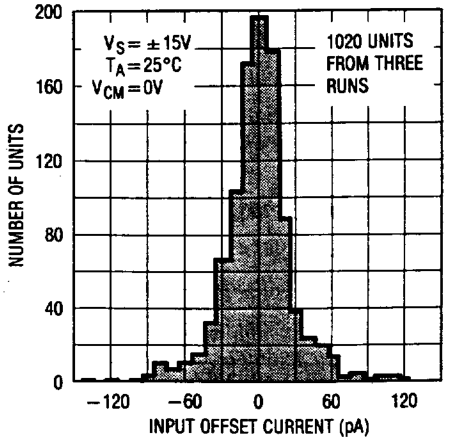
Offset Voltage vs Source Resistance (Balanced or Unbalanced)



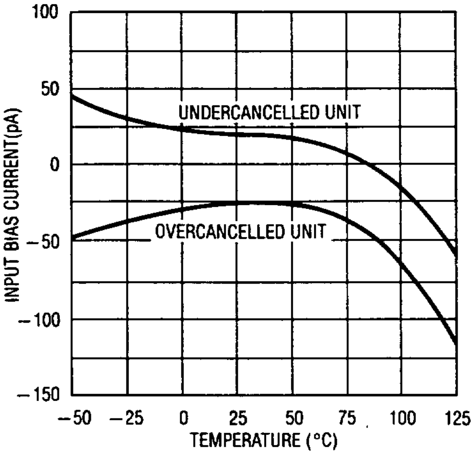
Typical Distribution of Input Bias Current



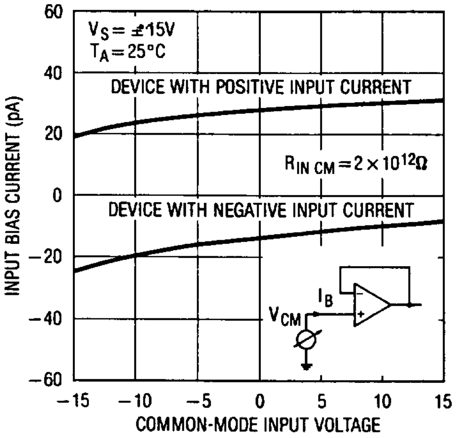
Typical Distribution of Input Offset Current



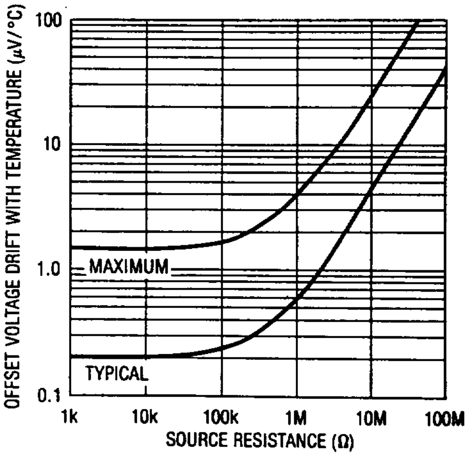
Input Bias Current vs Temperature



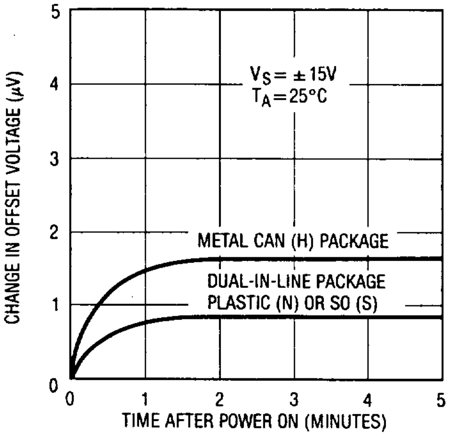
Input Bias Current Over Common Mode Range



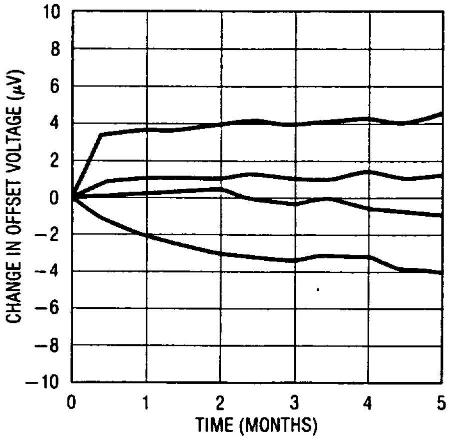
Offset Voltage Drift vs Source Resistance (Balanced or Unbalanced)



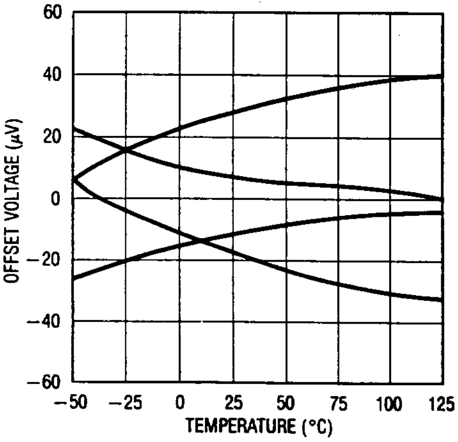
Warm-Up Drift



Long Term Stability of Four Representative Units

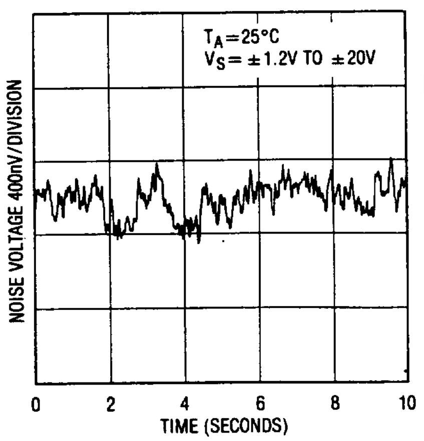


Offset Voltage Drift with Temperature of Four Representative Units

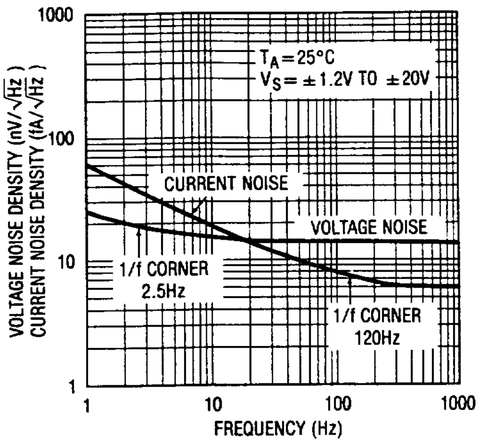


TYPICAL PERFORMANCE CHARACTERISTICS

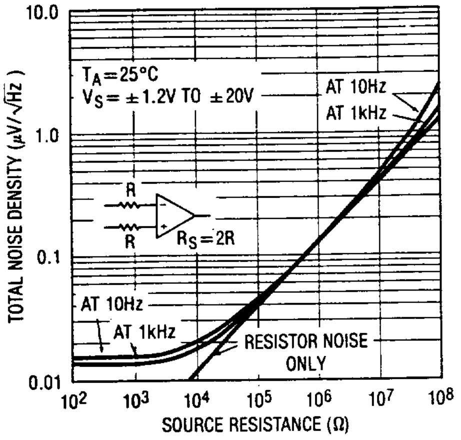
0.1Hz to 10Hz Noise



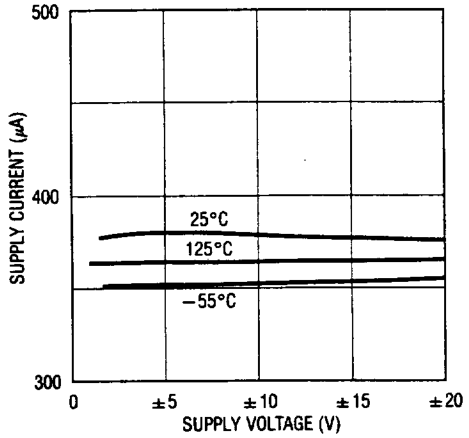
Noise Spectrum



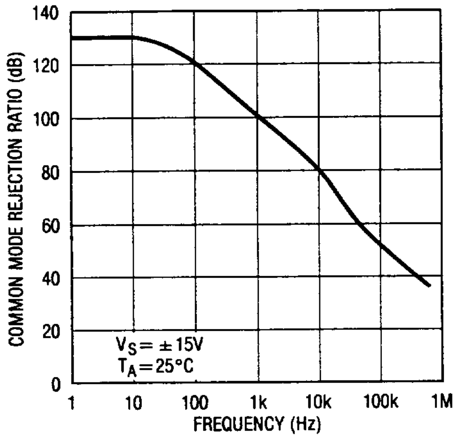
Total Noise vs Source Resistance



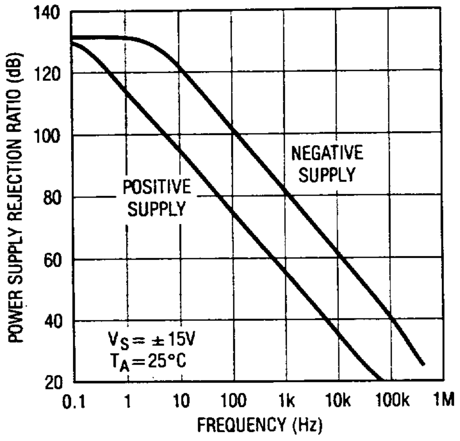
Supply Current vs Supply Voltage



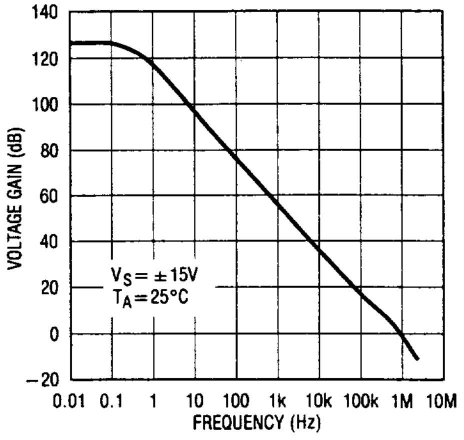
Common Mode Rejection vs Frequency



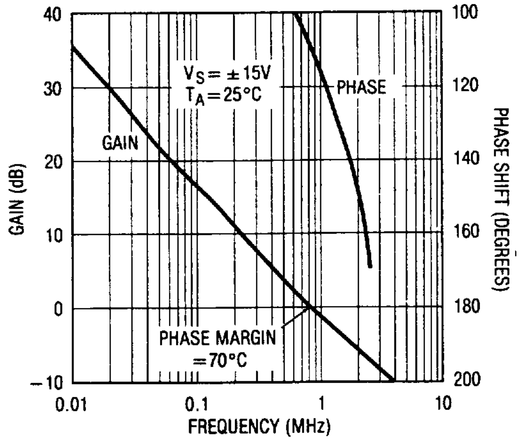
Power Supply Rejection vs Frequency



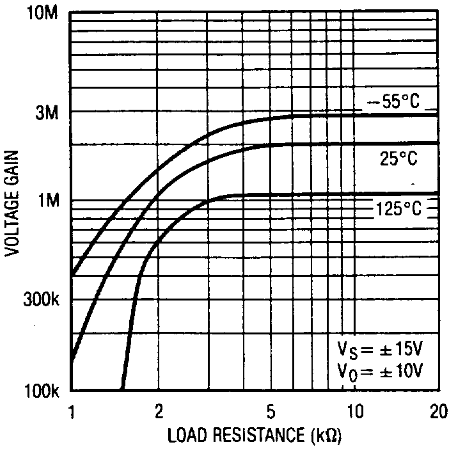
Voltage Gain vs Frequency



Gain, Phase Shift vs Frequency

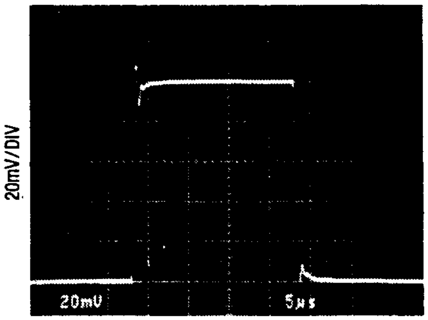


Voltage Gain vs Load Resistance



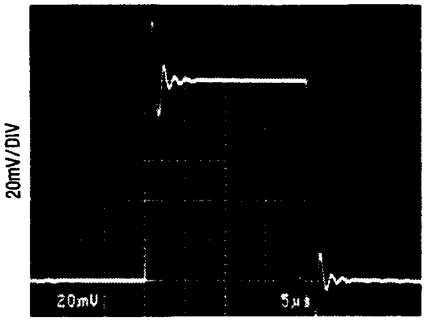
TYPICAL PERFORMANCE CHARACTERISTICS

Small Signal Transient Response



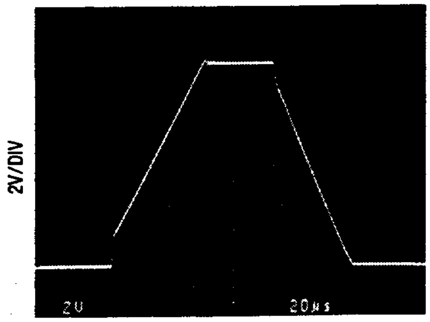
$A_V = +1$, $C_{LOAD} = 100pF$, 5µs/DIV

Small Signal Transient Response



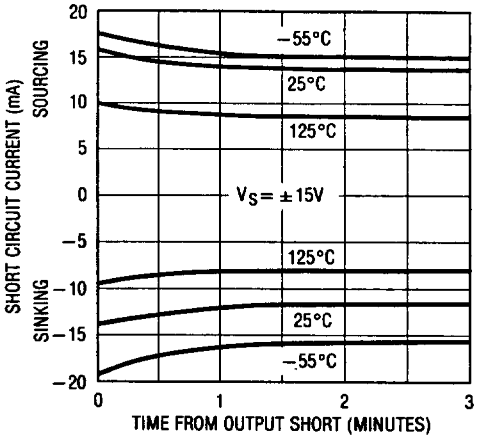
$A_V = +1$, $C_{LOAD} = 1000pF$, 5µs/DIV

Large Signal Transient Response

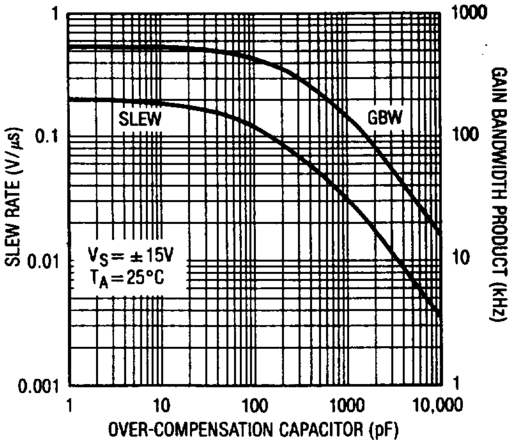


$A_V = +1$, 20µs/DIV

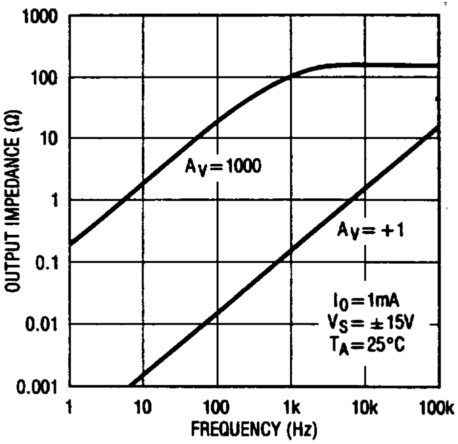
Output Short Circuit Current vs Time



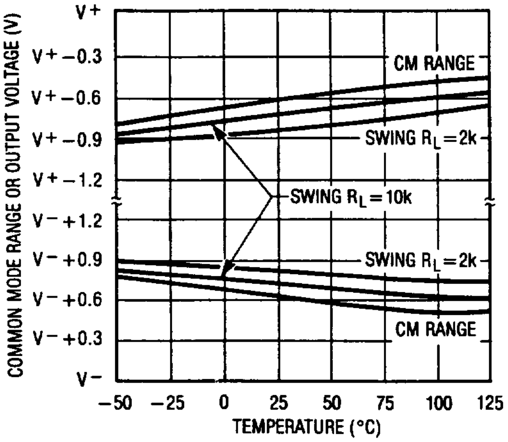
Slew Rate, Gain Bandwidth Product vs Over-Compensation Capacitor



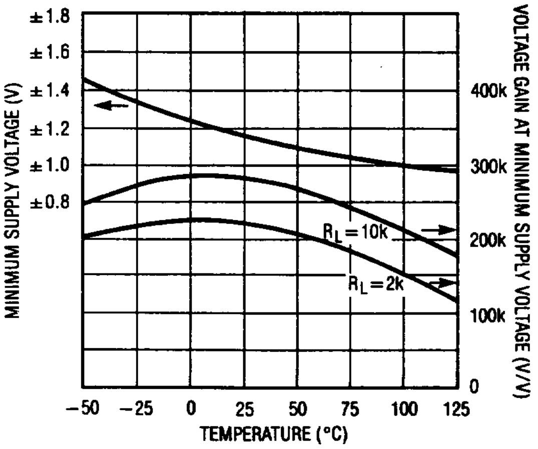
Closed Loop Output Impedance



Common Mode Range and Voltage Swing at Minimum Supply Voltage



Minimum Supply Voltage, Voltage Gain at V_{MIN}



APPLICATIONS INFORMATION

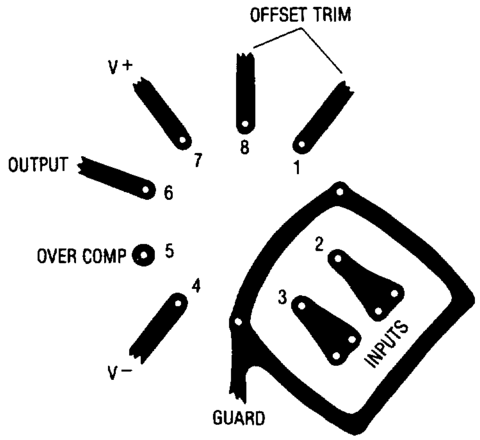
The LT1012 may be inserted directly into OP-07, LM11, 108A or 101A sockets with or without removal of external frequency compensation or nulling components. The LT1012 can also be used in 741, LF411, LF156 or OP-15 applications provided that the nulling circuitry is removed.

Although the OP-97 is a copy of the LT1012, the LT1012 directly replaces and upgrades OP-97 applications. The LT1012C and D have lower offset voltage and drift than the OP-97F. The LT1012A has lower supply current than the OP-97A/E. In addition, all LT1012 grades guarantee operation at ±1.2V supplies.

Achieving Picoampere/Microvolt Performance

In order to realize the picoampere/microvolt level accuracy of the LT1012, proper care must be exercised. For example, leakage currents in circuitry external to the op amp can significantly degrade performance. High quality insulation should be used (e.g. Teflon, Kel-F); cleaning of all insulating surfaces to remove fluxes and other residues will probably be required. Surface coating may be necessary to provide a moisture barrier in high humidity environments.

Board leakage can be minimized by encircling the input circuitry with a guard ring operated at a potential close to that of the inputs: in inverting configurations the guard ring should be tied to ground, in non-inverting connections to the inverting input at pin 2. Guarding both sides of the printed circuit board is required. Bulk leakage reduction depends on the guard ring width. Nanoampere level leakage into the offset trim terminals can affect offset voltage and drift with temperature.



Microvolt level error voltages can also be generated in the external circuitry. Thermocouple effects caused by temperature gradients across dissimilar metals at the contacts to the input terminals can exceed the inherent drift of the amplifier. Air currents over device leads should be minimized, package leads should be short, and the two input leads should be as close together as possible and maintained at the same temperature.

Noise Testing

For application information on noise testing and calculations, please see the LT1008 data sheet.

Frequency Compensation

The LT1012 can be overcompensated to improve capacitive load handling capability or to narrow noise bandwidth. In many applications, the feedback loop around the amplifier has gain (e.g. logarithmic amplifiers); overcompensation can stabilize these circuits with a single capacitor.

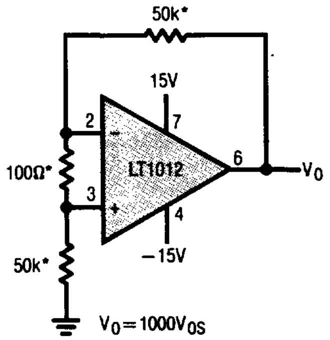
The availability of the compensation terminal permits the use of feedforward frequency compensation to enhance slew rate. The voltage follower feedforward scheme bypasses the amplifier's gain stages and slews at nearly 10V/μs.

The inputs of the LT1012 are protected with back-to-back diodes. Current limiting resistors are not used, because the leakage of these resistors would prevent the realization of picoampere level bias currents at elevated temperatures. In the voltage follower configuration, when the input is driven by a fast, large signal pulse (>1V), the input protection diodes effectively short the output to the input during slewing, and a current, limited only by the output short circuit protection will flow through the diodes.

APPLICATIONS INFORMATION

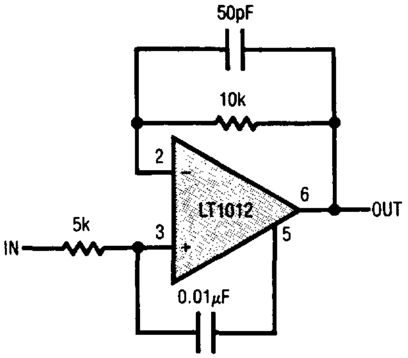
The use of a feedback resistor, as shown in the voltage follower feedforward diagram, is recommended because this resistor keeps the current below the short circuit limit, resulting in faster recovery and settling of the output.

Test Circuit for Offset Voltage and its Drift with Temperature

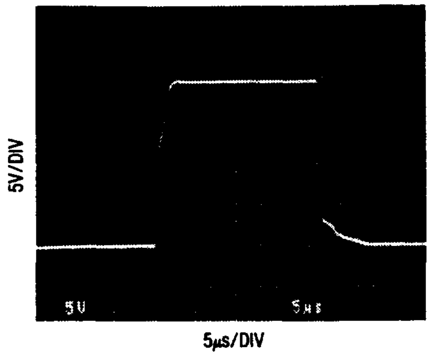


*RESISTORS MUST HAVE LOW THERMOELECTRIC POTENTIAL

Follower Feedforward Compensation

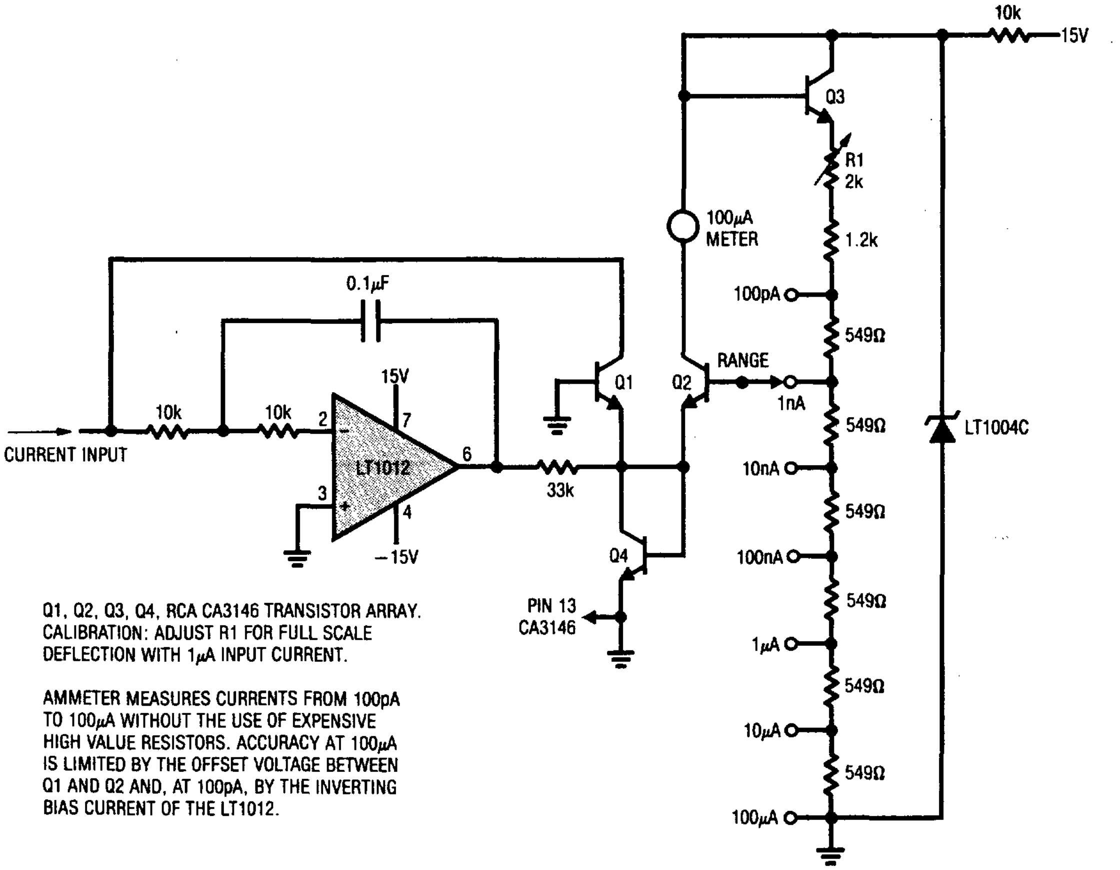


Pulse Response of Feedforward Compensation



TYPICAL APPLICATIONS

Ammeter with Six Decade Range

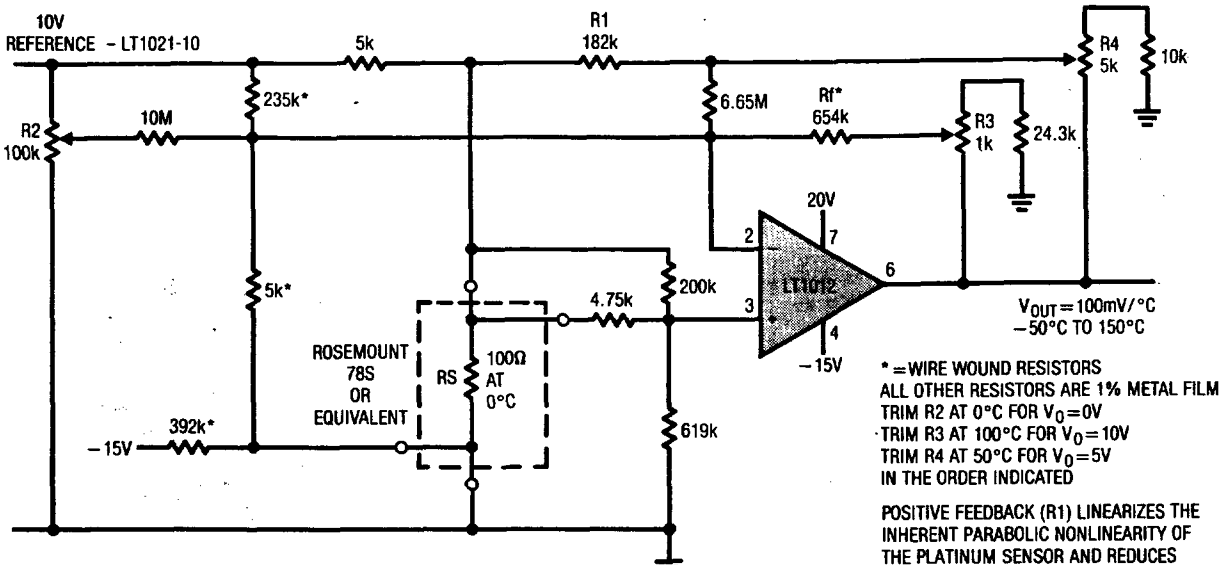


Q1, Q2, Q3, Q4, RCA CA3146 TRANSISTOR ARRAY.
CALIBRATION: ADJUST R1 FOR FULL SCALE DEFLECTION WITH 1µA INPUT CURRENT.

AMMETER MEASURES CURRENTS FROM 100pA TO 100µA WITHOUT THE USE OF EXPENSIVE HIGH VALUE RESISTORS. ACCURACY AT 100µA IS LIMITED BY THE OFFSET VOLTAGE BETWEEN Q1 AND Q2 AND, AT 100pA, BY THE INVERTING BIAS CURRENT OF THE LT1012.

TYPICAL APPLICATIONS

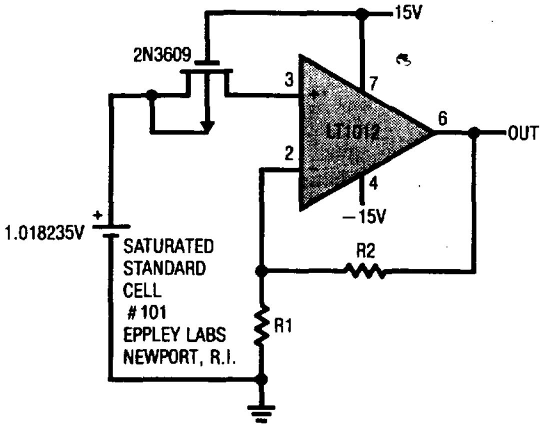
Kelvin-Sensed Platinum Temperature Sensor Amplifier



* = WIRE WOUND RESISTORS
ALL OTHER RESISTORS ARE 1% METAL FILM
TRIM R2 AT 0°C FOR V_O = 0V
TRIM R3 AT 100°C FOR V_O = 10V
TRIM R4 AT 50°C FOR V_O = 5V
IN THE ORDER INDICATED

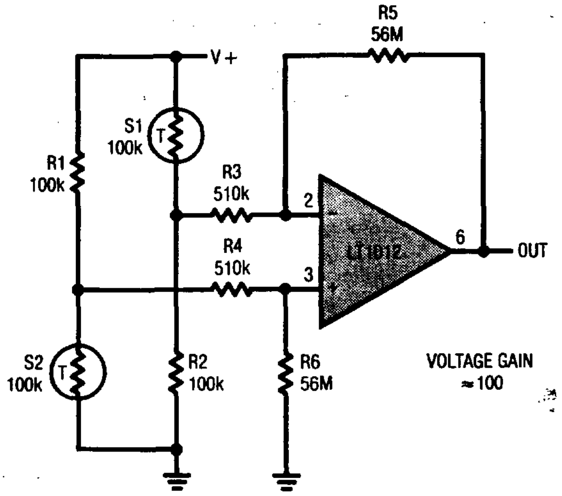
POSITIVE FEEDBACK (R1) LINEARIZES THE INHERENT PARABOLIC NONLINEARITY OF THE PLATINUM SENSOR AND REDUCES ERRORS FROM 1.2°C TO 0.004°C OVER THE –50°C TO 150°C RANGE

Saturated Standard Cell Amplifier

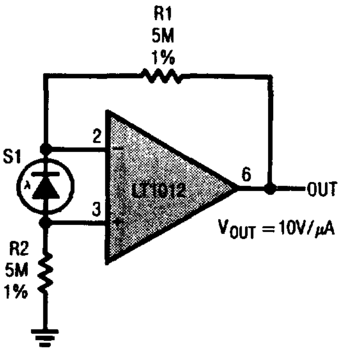


THE TYPICAL 30pA BIAS CURRENT OF THE LT1012 WILL DEGRADE THE STANDARD CELL BY ONLY 1ppm/YEAR. NOISE IS A FRACTION OF A ppm. UNPROTECTED GATE MOSFET ISOLATES STANDARD CELL ON POWER DOWN.

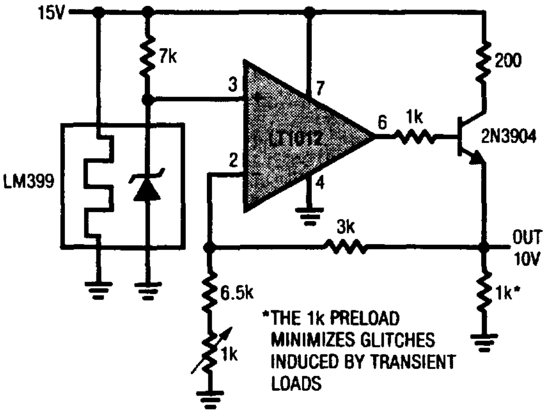
Amplifier for Bridge Transducers



Amplifier for Photodiode Sensor



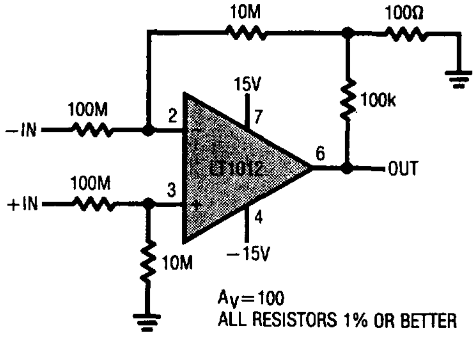
Buffered Reference for A to D Converters



*THE 1k PRELOAD MINIMIZES GLITCHES INDUCED BY TRANSIENT LOADS

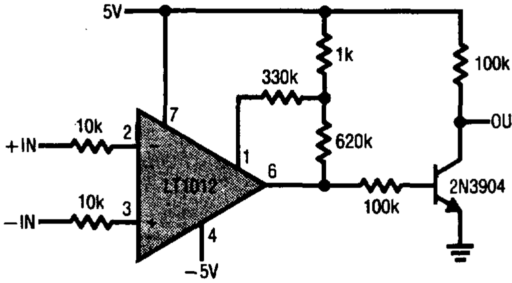
TYPICAL APPLICATIONS

Instrumentation Amplifier with ±100V Common Mode Range

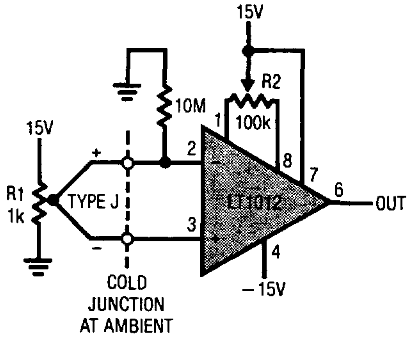


$A_V = 100$
ALL RESISTORS 1% OR BETTER

Low Power Comparator with <10μV Hysteresis

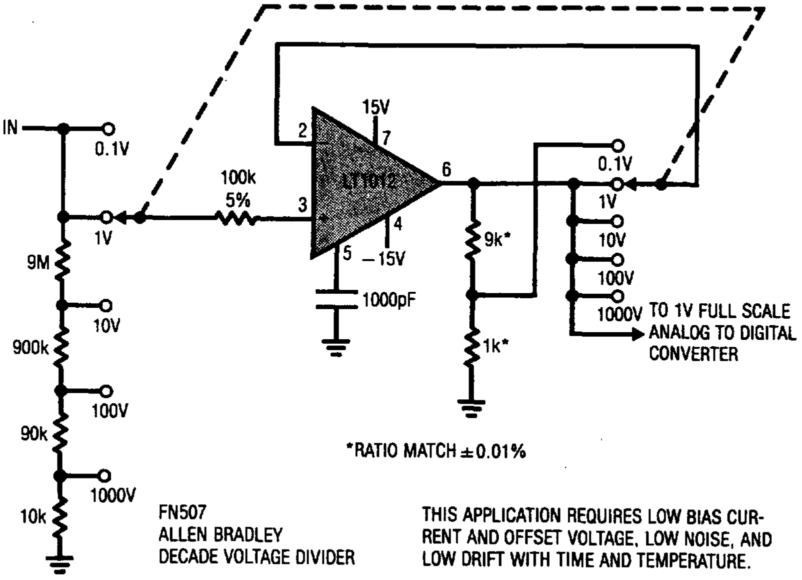


Air Flow Detector



MOUNT R1 IN AIRFLOW.
ADJUST R2 SO OUTPUT
GOES HIGH WHEN AIRFLOW
STOPS.

Input Amplifier for 4 1/2 Digit Voltmeter



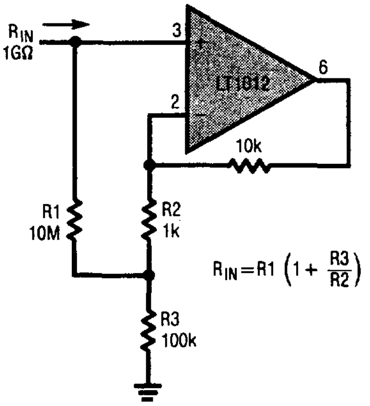
TO 1V FULL SCALE ANALOG TO DIGITAL CONVERTER

*RATIO MATCH ±0.01%

FN507
ALLEN BRADLEY
DECADE VOLTAGE DIVIDER

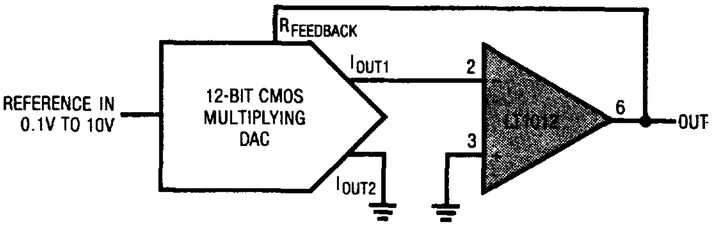
THIS APPLICATION REQUIRES LOW BIAS CURRENT AND OFFSET VOLTAGE, LOW NOISE, AND LOW DRIFT WITH TIME AND TEMPERATURE.

Resistor Multiplier



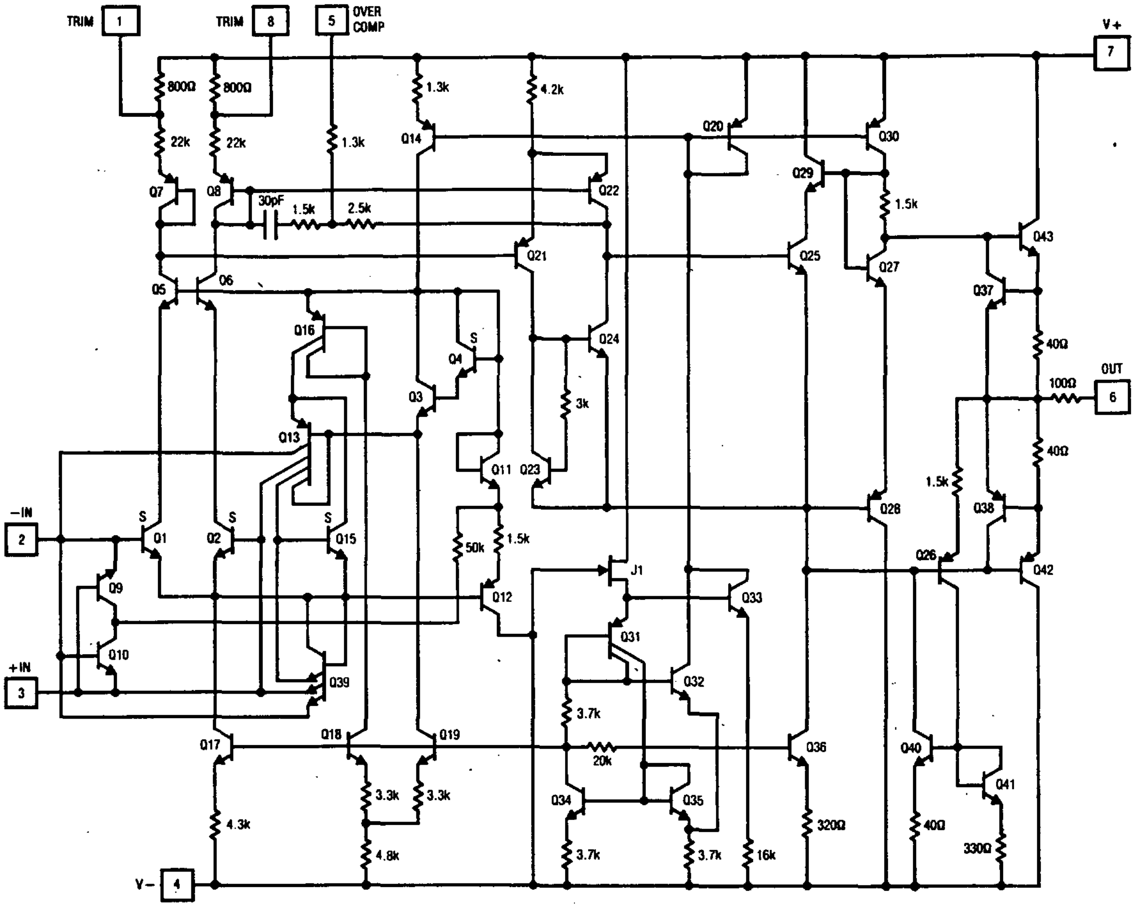
$R_{IN} = R1\left(1 + \frac{R3}{R2}\right)$

"No Trims" 12-Bit Multiplying DAC Output Amplifier



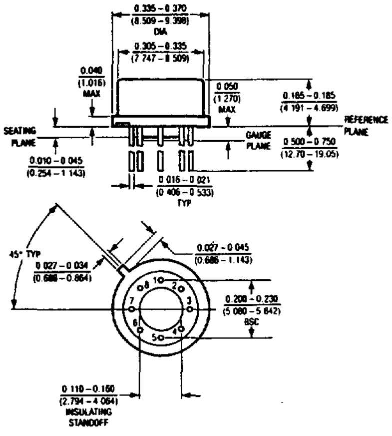
WHEN THE REFERENCE INPUT DROPS TO 0.1V,
THE LEAST SIGNIFICANT BIT DECREASES TO
THE MICROVOLT/PICOAMPERE RANGE.

SCHEMATIC DIAGRAM



PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

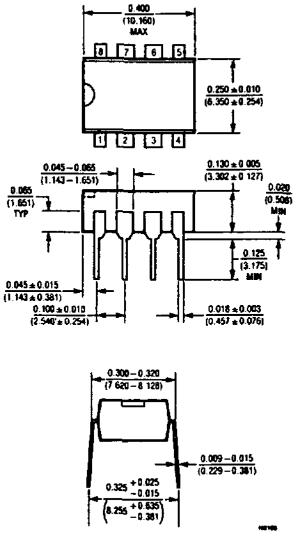
H Package
8-Lead TO-5 Metal Can



NOTE: LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND SEATING PLANE.

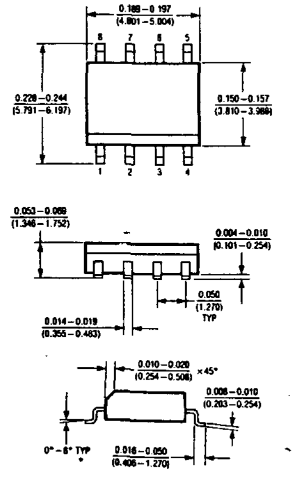
T_{JMAX}	θ_{JA}	θ_{JC}
150°C	150°C/W	45°C/W

N Package
8-Lead Plastic DIP



T_{JMAX}	θ_{JA}
100°C	130°C/W

SO Package
8-Lead Plastic SOIC



NOTES
1. PKG MATERIAL: PLASTIC
2. LEAD MATERIAL: A-42, TIN PLATED

T_{JMAX}	θ_{JA}
100°C	170°C/W