LT1008

Picoamp Input Current, Microvolt Offset, Low Noise Op Amp

FEATURES

- Guaranteed Bias Current
  - T_A = 25°C: 100pA Max
  - T_A = –55°C to 125°C: 600pA Max
- Guaranteed Offset Voltage: 120µV Max
- Guaranteed Drift: 1.5µV/°C Max
- Low Noise, 0.1Hz to 10Hz: 0.5µV_{P-P}
- Guaranteed Low Supply Current: 600µA Max
- Guaranteed CMRR: 114dB Min
- Guaranteed PSRR: 114dB Min
- Guaranteed Voltage Gain with 5mA Load Current
- Available in 8-Lead PDIP and SO Packages

APPLICATIONS

- Precision Instrumentation
- Charge Integrators
- Wide Dynamic Range Logarithmic Amplifiers
- Light Meters
- Low Frequency Active Filters
- Standard Cell Buffers
- Thermocouple Amplifiers

DESCRIPTION

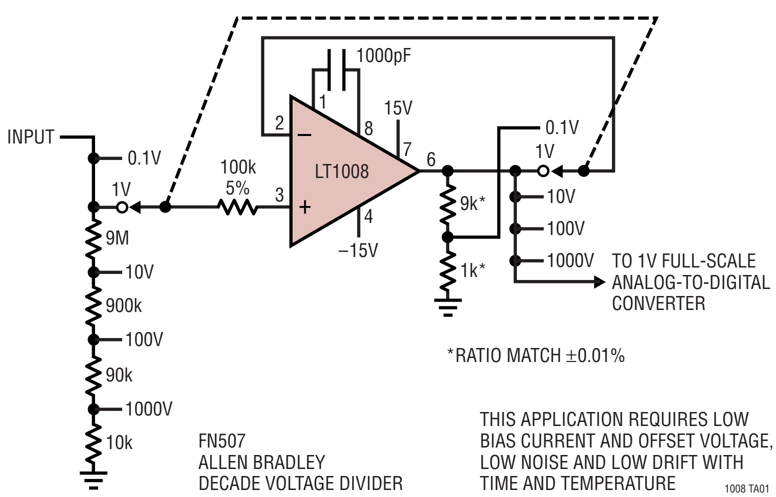
The LT®1008 is a universal precision operational amplifier that can be used in practically all precision applications. The LT1008 combines for the first time, picoampere bias currents (which are maintained over the full –55°C to 125°C temperature range), microvolt offset voltage (and low drift with time and temperature), low voltage and current noise, and low power dissipation. Extremely high common mode and power supply rejection ratios, and the ability to deliver 5mA load current with high voltage gain round out the LT1008's superb precision specifications.

The all around excellence of the LT1008 eliminates the necessity of the time consuming error analysis procedure of precision system design in many applications; the LT1008 can be stocked as the universal precision op amp.

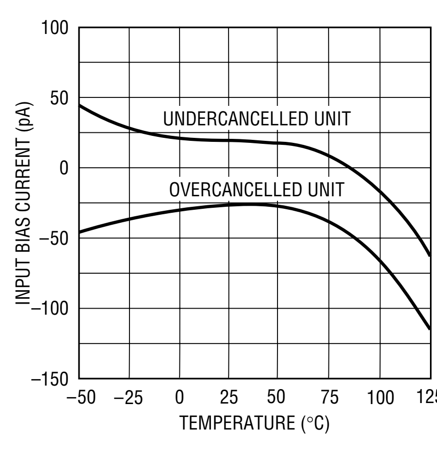
The LT1008 is externally compensated with a single capacitor for additional flexibility in shaping the frequency response of the amplifier. It plugs into and upgrades all standard LM108A/LM308A applications. For an internally compensated version with even lower offset voltage but otherwise similar performance see the LT1012.

TYPICAL APPLICATION

Input Amplifier for 4.5 Digit Voltmeter



Input Bias Current vs Temperature

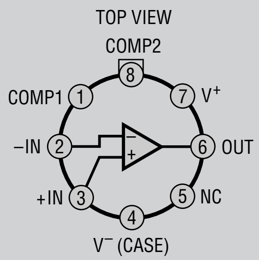


ABSOLUTE MAXIMUM RATINGS (Note 1)

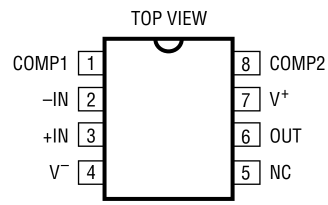
Supply Voltage .... ±20V
Differential Input Current (Note 2) .... ±10mA
Input Voltage .... ±20V
Output Short-Circuit Duration .... Indefinite
Storage Temperature Range .... –65°C to 150°C

Operating Temperature Range
LT1008M **(OBSOLETE)** .... –55°C to 125°C
LT1008C .... 0°C to 70°C
LT1008I .... –40°C to 85°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

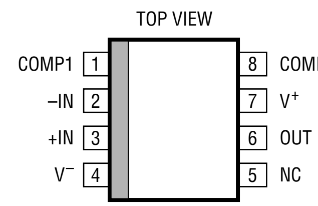


H PACKAGE
8-LEAD TO-5 METAL CAN
T_{JMAX} = 150°C, θ_{JA} = 150°C/W, θ_{JC} = 45°C/W



N8 PACKAGE
8-LEAD PDIP
T_{JMAX} = 150°C, θ_{JA} = 130°C/W

J8 PACKAGE 8-LEAD CERDIP
T_{JMAX} = 150°C, θ_{JA} = 100°C/W



S8 PACKAGE
8-LEAD PLASTIC SO
T_{JMAX} = 150°C, θ_{JA} = 190°C/W

ORDER PART NUMBER	ORDER PART NUMBER	ORDER PART NUMBER	ORDER PART NUMBER	S8 PART MARKING
LT1008MH LT1008CH	LT1008MJ8 LT1008CJ8	LT1008CN8 LT1008IN8	LT1008S8	1008

OBSOLETE PACKAGES
Consider N8 or S8 Package for Alternate Source

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.

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

SYMBOL	PARAMETER	CONDITIONS	LT1008M/I MIN	LT1008M/I TYP	LT1008M/I MAX	LT1008C MIN	LT1008C TYP	LT1008C MAX	UNITS
V_{OS}	Input Offset Voltage			30	120		30	120	µV
		(Note 3)		40	180		40	180	µV
	Long-Term Input Offset Voltage Stability			0.3			0.3		µV/Month
I_{OS}	Input Offset Current			30	100		30	100	pA
		(Note 3)		40	150		40	150	pA
I_B	Input Bias Current			±30	±100		±30	±100	pA
		(Note 3)		±40	±150		±40	±150	pA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.5			0.5		μV_{P-P}
	Input Noise Voltage Density	f_O = 10Hz (Note 4)		17	30		17	30	$nV/\sqrt{Hz}$
		f_O = 1000Hz (Note 5)		14	22		14	22	$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f_O = 10Hz		20			20		$fA/\sqrt{Hz}$
A_{VOL}	Large-Signal Voltage Gain	V_{OUT} = ±12V, $R_L \geq$ 10k	200	2000		200	2000		V/mV
		V_{OUT} = ±10V, $R_L \geq$ 2k	120	600		120	600		V/mV

ELECTRICAL CHARACTERISTICS $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1008M/I MIN	LT1008M/I TYP	LT1008M/I MAX	LT1008C MIN	LT1008C TYP	LT1008C MAX	UNITS
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	114	132		114	132		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2V$ to $\pm20V$	114	132		114	132		dB
	Input Voltage Range		±13.5	±14		±13.5	±14		V
V_{OUT}	Output Voltage Swing	$R_L = 10k$	±13	±14		±13	±14		V
	Slew Rate	$C_F = 30pF$	0.1	0.2		0.1	0.2		V/µs
I_S	Supply Current	(Note 3)		380	600		380	600	µA

The ● indicates specifications which apply over the full operating temperature range of –55°C ≤ T_A ≤ 125°C for the LT1008M, –40°C ≤ T_A ≤ 85°C for the LT1008I and 0°C ≤ T_A ≤ 70°C for the LT1008C. $V_S = \pm15V$, $V_{CM} = 0V$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1008M/I MIN	LT1008M/I TYP	LT1008M/I MAX	LT1008C MIN	LT1008C TYP	LT1008C MAX	UNITS
V_{OS}	Input Offset Voltage		●		50	250		40	180	µV
		(Note 3)	●		60	320		50	250	µV
	Average Temperature Coefficient of Input Offset Voltage		●		0.2	1.5		0.2	1.5	µV/°C
I_{OS}	Input Offset Current		●		60	250		40	180	pA
		(Note 3)	●		80	350		50	250	pA
	Average Temperature Coefficient of Input Offset Current		●		0.4	2.5		0.4	2.5	pA/°C
I_B	Input Bias Current		●		±80	±600		±40	±180	pA
		(Note 3)	●		±150	±800		±50	±250	pA
	Average Temperature Coefficient of Input Bias Current		●		0.6	6		0.4	2.5	pA/°C
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm12V$, $R_L \geq 10k$	●	100	1000		150	1500		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	●	108	128		110	130		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2.5V$ to $\pm20V$	●	108	126		110	128		dB
	Input Voltage Range		●	±13.5			±13.5			V
V_{OUT}	Output Voltage Swing	$R_L = 10k$	●	±13	±14		±13	±14		V
I_S	Supply Current		●		400	800		400	800	µA

(LT1008S8 only) $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage			30	200	µV
		(Note 3)		40	250	µV
	Long-Term Input Offset Voltage Stability			0.3		µV/Month
I_{OS}	Input Offset Current			100	280	pA
		(Note 3)		120	380	pA
I_B	Input Bias Current			±100	±300	pA
		(Note 3)		±120	±400	pA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.5		μV_{P-P}
	Input Noise Voltage Density	$f_O = 10Hz$ (Note 5)		17	30	$nV/\sqrt{Hz}$
		$f_O = 1000Hz$ (Note 5)		14	22	$nV/\sqrt{Hz}$

ELECTRICAL CHARACTERISTICS (LT1008S8 only) $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
i_n	Input Noise Current Density	$f_O = 10Hz$		20		$fA/\sqrt{Hz}$
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm12V$, $R_L \geq 10k$ $V_{OUT} = \pm10V$, $R_L \geq 2k$	200 120	2000 600		V/mV V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	110	132		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2V$ to $\pm20V$	110	132		dB
	Input Voltage Range		±13.5	±14		V
V_{OUT}	Output Voltage Swing	$R_L = 10k$	±13	±14		V
	Slew Rate	$C_F = 30pF$	0.1	0.2		V/µs
I_S	Supply Current	(Note 3)		380	600	µA

(LT1008S8 only) The ● indicates specifications which apply over the full operating temperature range of $0°C \leq T_A \leq 70°C$. $V_S = \pm15V$, $V_{CM} = 0V$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	 (Note 3)	● ●		40 50	280 340	µV µV
	Average Temperature Coefficient of Input Offset Voltage		●		0.2	1.8	µV/°C
I_{OS}	Input Offset Current	 (Note 3)	● ●		120 140	380 500	pA pA
	Average Temperature Coefficient of Input Offset Current		●		0.4	4	pA/°C
I_B	Input Bias Current	 (Note 3)	● ●		±120 ±140	±420 ±550	pA pA
	Average Temperature Coefficient of Input Bias Current		●		0.4	5	pA/°C
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm12V$, $R_L \geq 10k$	●	150	1500		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13.5V$	●	108	130		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2.5V$ to $\pm20V$	●	108	128		dB
	Input Voltage Range		●	±13.5			V
V_{OUT}	Output Voltage Swing	$R_L = 10k$	●	±13	±14		V
I_S	Supply Current		●		400	800	µA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: Differential input voltages greater than 1V will cause excessive current to flow through the input protection diodes unless current limiting resistors are used.

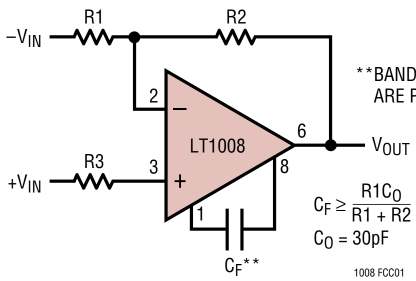
Note 3: These specifications apply for $\pm2V \leq V_S \leq \pm20V$ ($\pm2.5V \leq V_S \leq \pm20V$ over the temperature range) and $-13.5V \leq V_{CM} \leq 13.5V$ (for $V_S = \pm15V$).

Note 4: 10Hz noise voltage density is sample tested on every lot. Devices 100% tested at 10Hz are available on request.

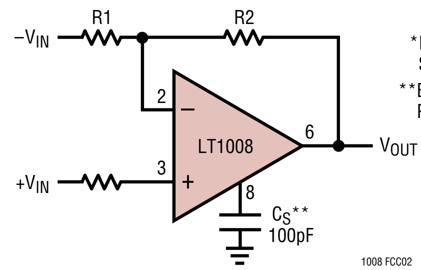
Note 5: This parameter is tested on a sample basis only.

FREQUENCY COMPENSATION CIRCUITS

Standard Compensation Circuit



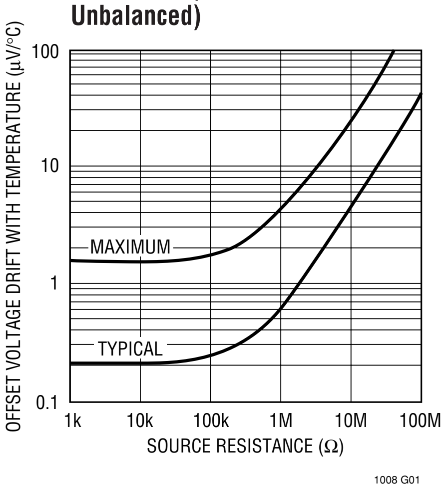
Alternate* Frequency Compensation



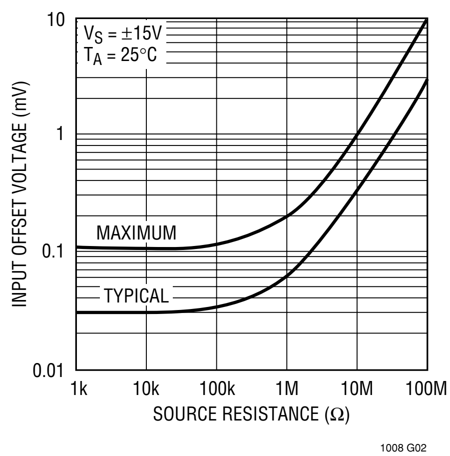
FOR $\frac{R2}{R1}$ > 200, NO EXTERNAL FREQUENCY COMPENSATION IS NECESSARY

TYPICAL PERFORMANCE CHARACTERISTICS

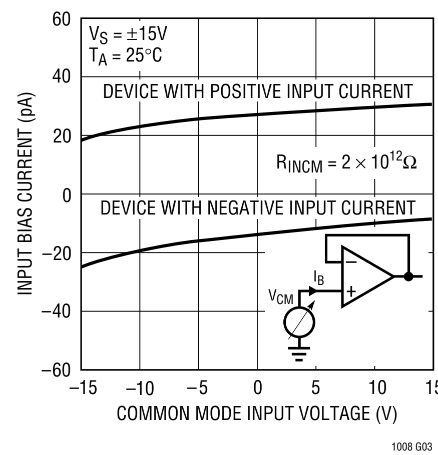
Offset Voltage Drift vs Source Resistance (Balanced or Unbalanced)



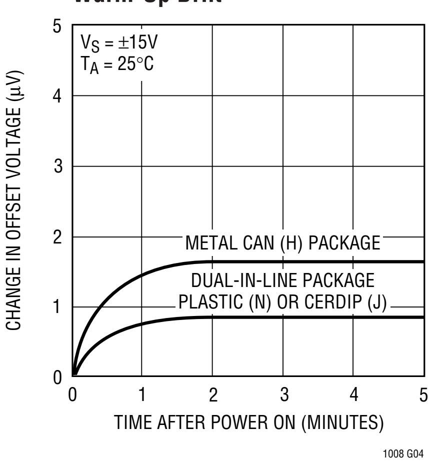
Offset Voltage vs Source Resistance (Balanced or Unbalanced)



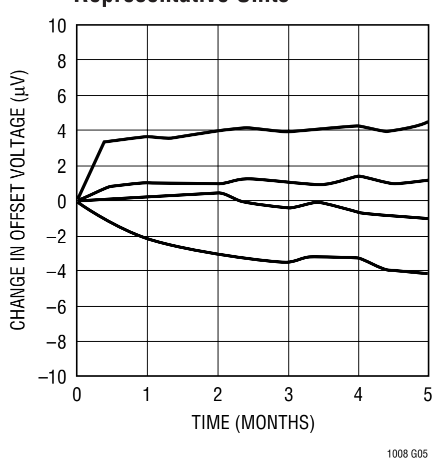
Input Bias Current vs Common Mode Range



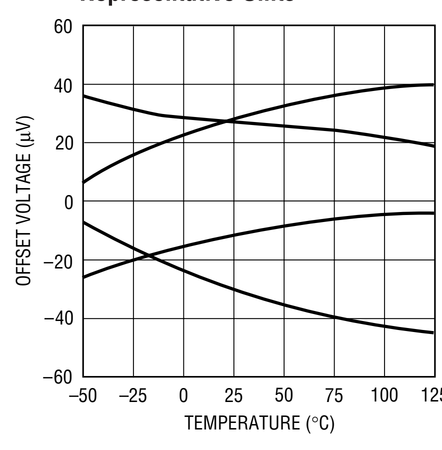
Warm-Up Drift



Long-Term Stability of Four Representative Units

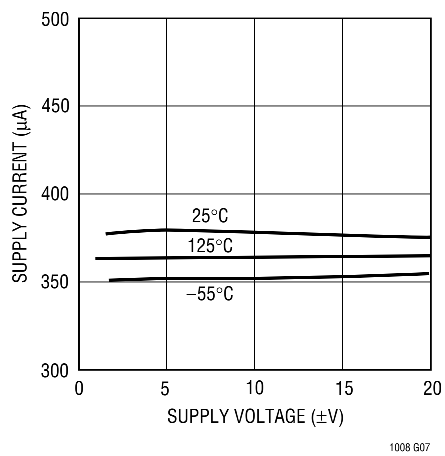


Offset Voltage Drift with Temperature of Four Representative Units

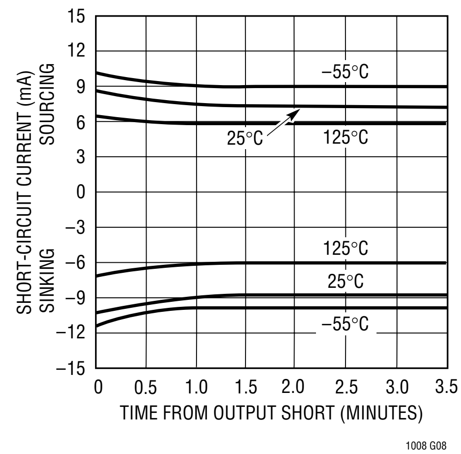


TYPICAL PERFORMANCE CHARACTERISTICS

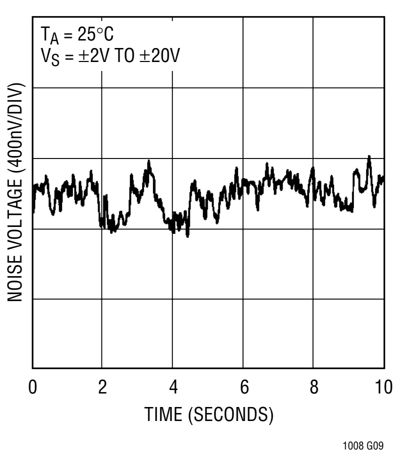
Supply Current vs Supply Voltage



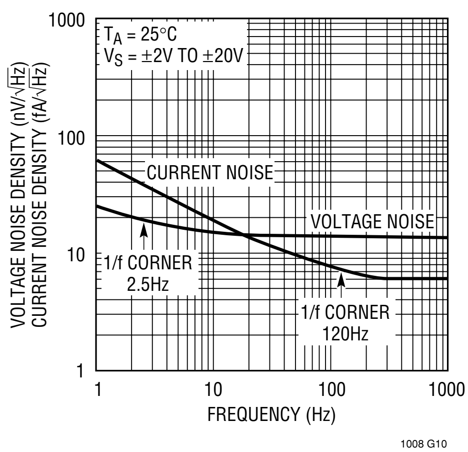
Output Short-Circuit Current vs Time



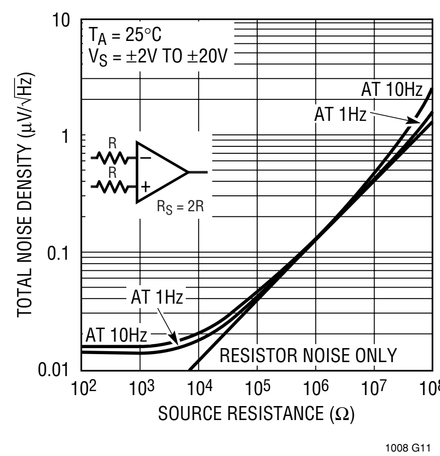
0.1Hz to 10Hz Noise



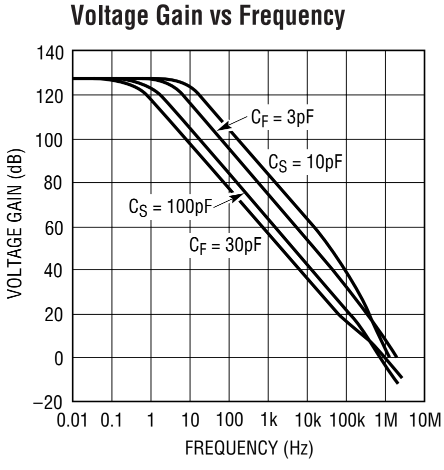
Noise Spectrum



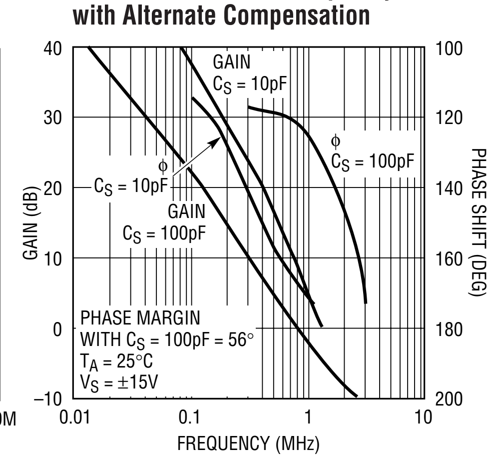
Total Noise vs Source Resistance



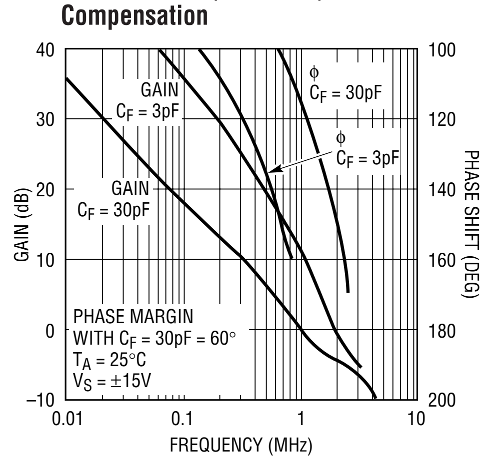
Voltage Gain vs Frequency



Gain, Phase Shift vs Frequency with Alternate Compensation

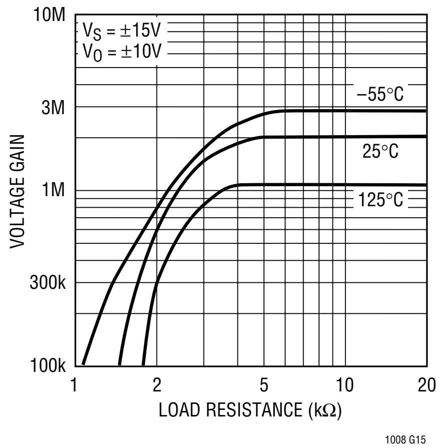


Gain, Phase Shift vs Frequency with Standard (Feedback) Compensation

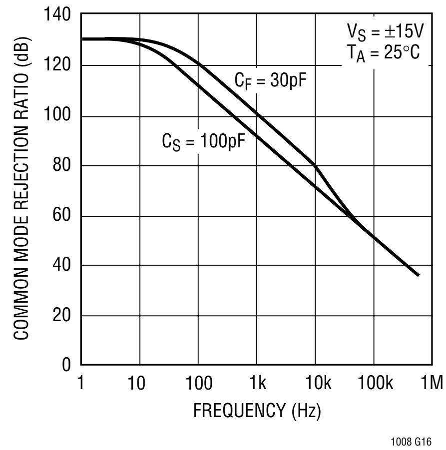


TYPICAL PERFORMANCE CHARACTERISTICS

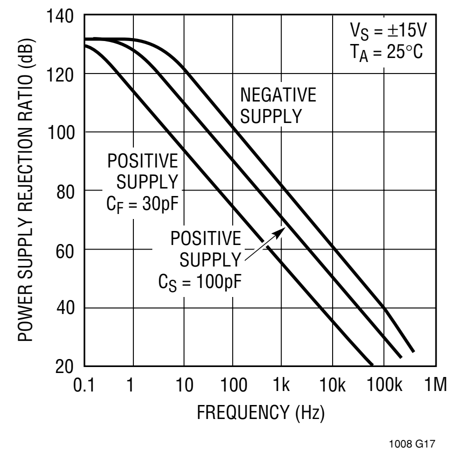
Voltage Gain vs Load Resistance



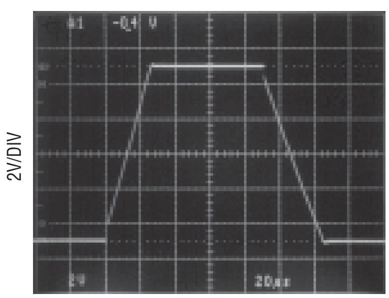
Common Mode Rejection vs Frequency



Power Supply Rejection vs Frequency

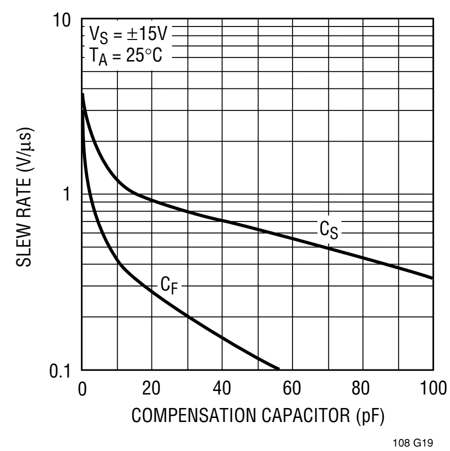


Large-Signal Transient Response

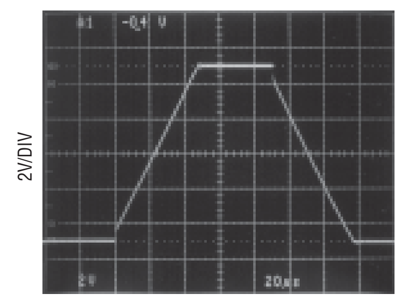


$A_V = 1$ 20µs/DIV 1008 G18
$C_S = 100pF$

Slew Rate vs Compensation Capacitance

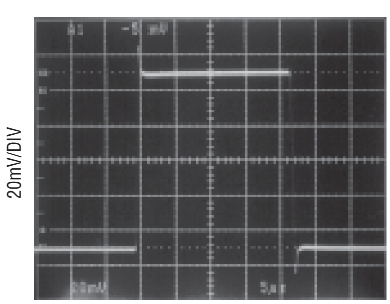


Large-Signal Transient Response



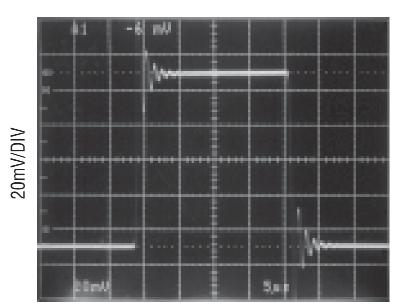
$A_V = 1$ 20µs/DIV 1008 G20
$C_F = 30pF$

Small-Signal Transient Response



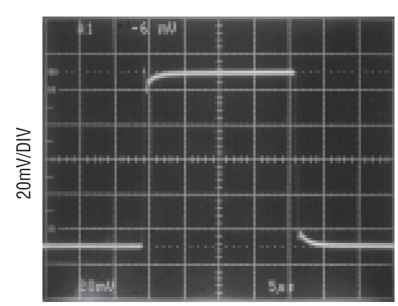
$A_V = 1$ 5µs/DIV 1008 G21
$C_S = 100pF$
$C_{LOAD} = 100pF$

Small-Signal Transient Response



$A_V = 1$ 5µs/DIV 1008 G22
$C_S = 100pF$
$C_{LOAD} = 600pF$

Small-Signal Transient Response



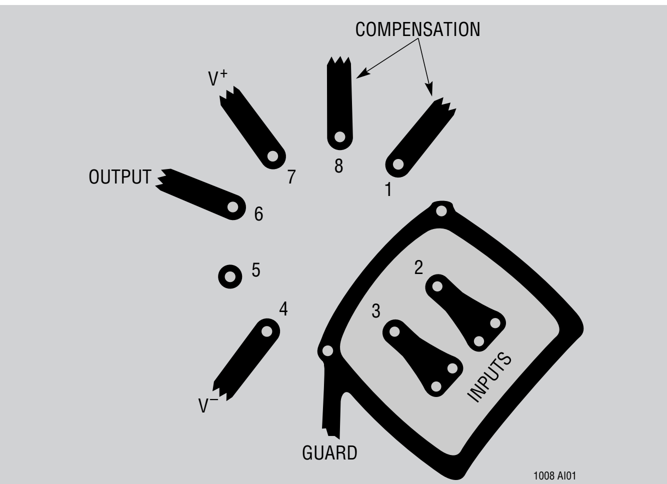
$A_V = 1$ 5µs/DIV 1008 G23
$C_F = 30pF$
$C_{LOAD} = 100pF$

APPLICATIONS INFORMATION

Achieving Picoampere/Microvolt Performance

In order to realize the picoampere—microvolt level accuracy of the LT1008, 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 noninverting 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 compensation terminals can affect offset voltage and drift with temperature.

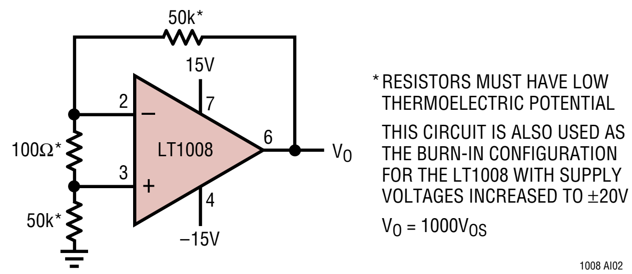


REFERENCE ONLY—OBSOLETE PACKAGE

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.

The LT1008 is specified over a wide range of power supply voltages from ±2V to ±18V. Operation with lower supplies is possible down to ±1.2V (two Ni-Cad batteries).

Test Circuit for Offset Voltage and Its Drift with Temperature



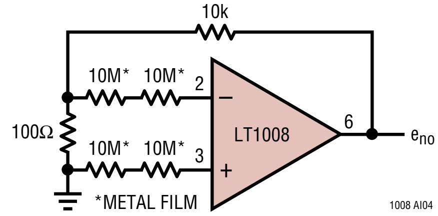
Noise Testing

The 0.1Hz to 10Hz peak-to-peak noise of the LT1008 is measured in the test circuit shown. The frequency response of this noise tester indicates that the 0.1Hz corner is defined by only one zero. The test time to measure 0.1Hz to 10Hz noise should not exceed 10 seconds, as this time limit acts as an additional zero to eliminate noise contributions from the frequency band below 0.1Hz.

A noise voltage density test is recommended when measuring noise on a large number of units. A 10Hz noise voltage density measurement will correlate well with a 0.1Hz to 10Hz peak-to-peak noise reading since both results are determined by the white noise and the location of the 1/f corner frequency.

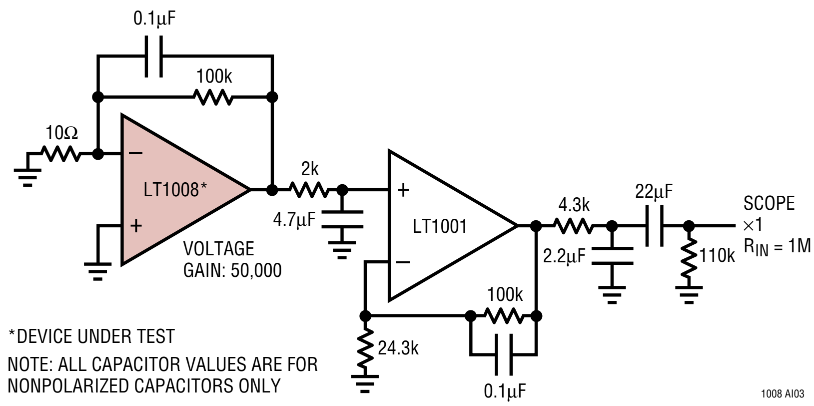
Current noise is measured in the circuit shown and calculated by the following formula where the noise of the source resistors is subtracted.

$$i_n = \frac{\left[e^2_{no} - (820nV)^2\right]^{1/2}}{40M\Omega \times 100}$$



APPLICATIONS INFORMATION

0.1Hz to 10Hz Noise Test Circuit



Frequency Compensation

The LT1008 is externally frequency compensated with a single capacitor. The two standard compensation circuits shown earlier are identical to the LM108A/LM308A frequency compensation schemes. Therefore, the LT1008 operational amplifiers can be inserted directly into LM108A/LM308A sockets, with similar AC and upgraded DC performance.

External frequency compensation provides the user with additional flexibility in shaping the frequency response of the amplifier. For example, for a voltage gain of ten and C_F = 3pF, a gain bandwidth product of 5MHz and slew rate of 1.2V/µs can be realized. For closed-loop gains in excess of 200, no external compensation is necessary, and slew rate increases to 4V/µs. The LT1008 can also be overcompensated (i.e., C_F > 30pF or C_S > 100pF) 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.

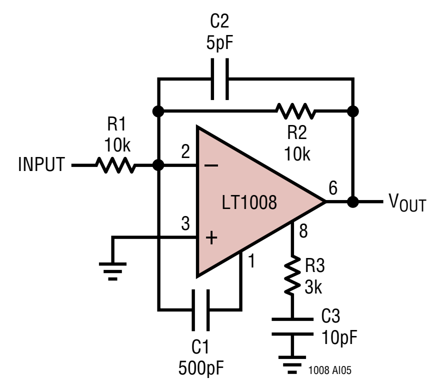
The availability of the compensation terminals permits the use of feedforward frequency compensation to enhance slew rate in low closed-loop gain configurations. The inverter slew rate is increased to 1.4V/µs. The voltage follower feedforward scheme bypasses the amplifier's gain stages and slews at nearly 10V/µs.

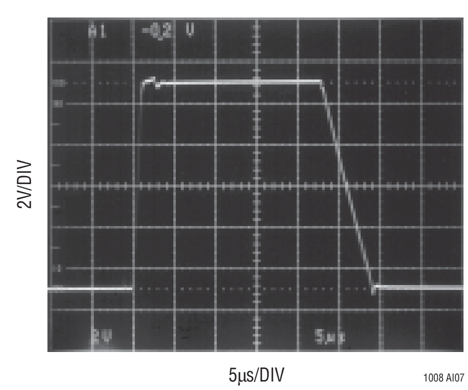
The inputs of the LT1008 are protected with back-to-back diodes. Current limiting resistors are not used, because the leakage of these resistors would prevent the realization of picoampere level bias currents at elevated temperatures.

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.

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.

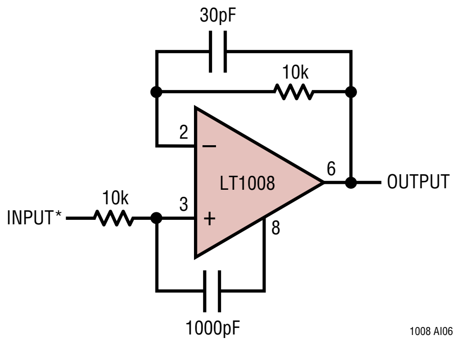
Inverter Feedforward Compensation



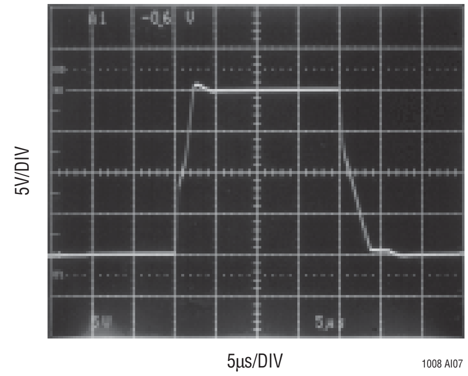


APPLICATIONS INFORMATION

Follower Feedforward Compensation

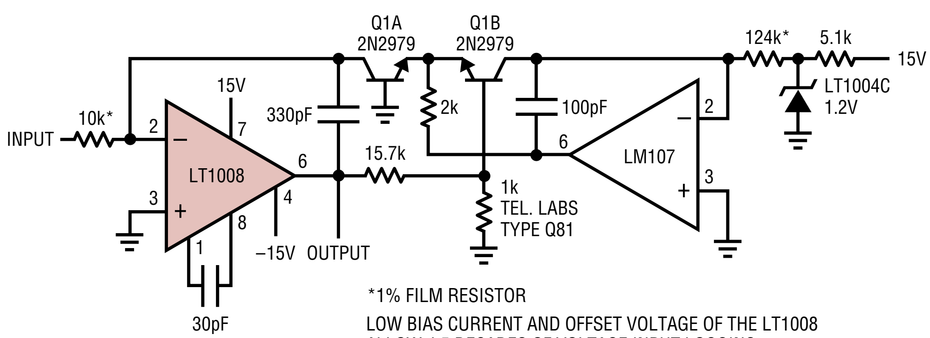


*SOURCE RESISTANCE ≤15k FOR STABILITY



TYPICAL APPLICATIONS

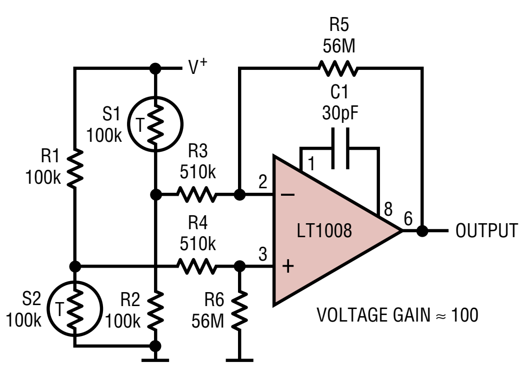
Logarithmic Amplifier



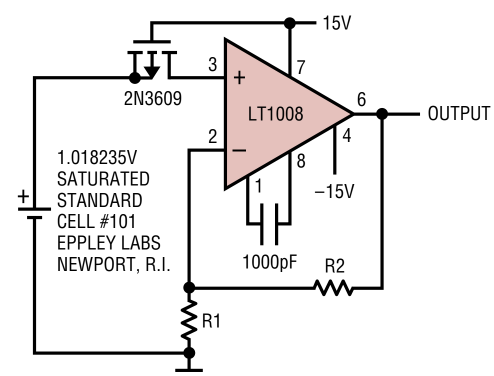
*1% FILM RESISTOR

LOW BIAS CURRENT AND OFFSET VOLTAGE OF THE LT1008 ALLOW 4.5 DECADES OF VOLTAGE INPUT LOGGING

Amplifier for Bridge Transducers



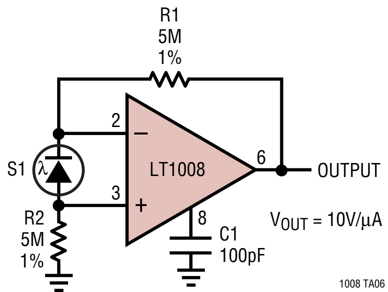
Saturated Standard Cell Amplifier



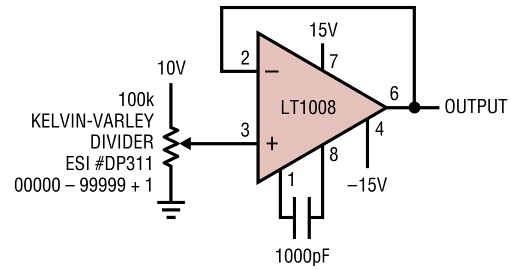
THE TYPICAL 30pA BIAS CURRENT OF THE LT1008 WILL DEGRADE THE STANDARD CELL BY ONLY 1ppm/YEAR. NOISE IS A FRACTION OF A ppm. UNPROTECTED GATE MOSFET ISOLATES STANDARD CELL ON POWER DOWN

TYPICAL APPLICATIONS

Amplifier for Photodiode Sensor



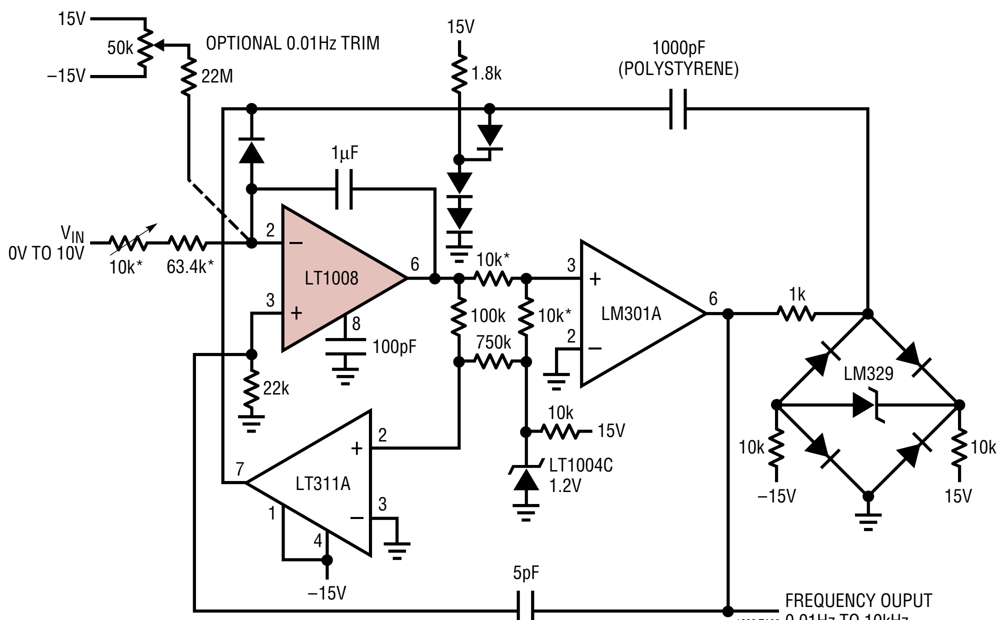
Five Decade Kelvin-Varley Divider Buffered by the LT1008



APPROXIMATE ERROR DUE TO NOISE, BIAS CURRENT, COMMON MODE REJECTION. VOLTAGE GAIN OF THE AMPLIFIER IS 1/5 OF A LEAST SIGNIFICANT BIT

The LT1008 integrator extends low frequency range. Total dynamic range is 0.01Hz to 10kHz (or 120dB) with 0.01% linearity.

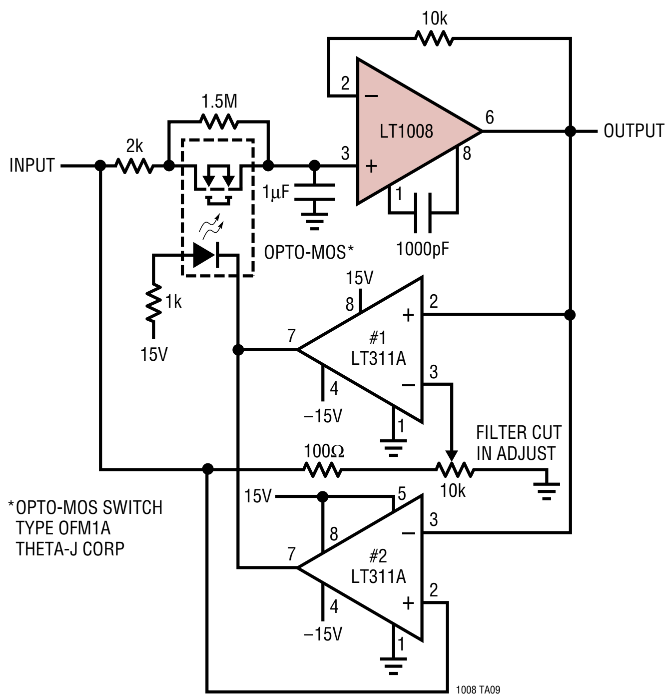
Extended Range Charge Pump Voltage to Frequency Converter



*1% METAL FILM RESISTOR
ALL DIODES 1N4148

TYPICAL APPLICATIONS

Precision, Fast Settling, Lowpass Filter

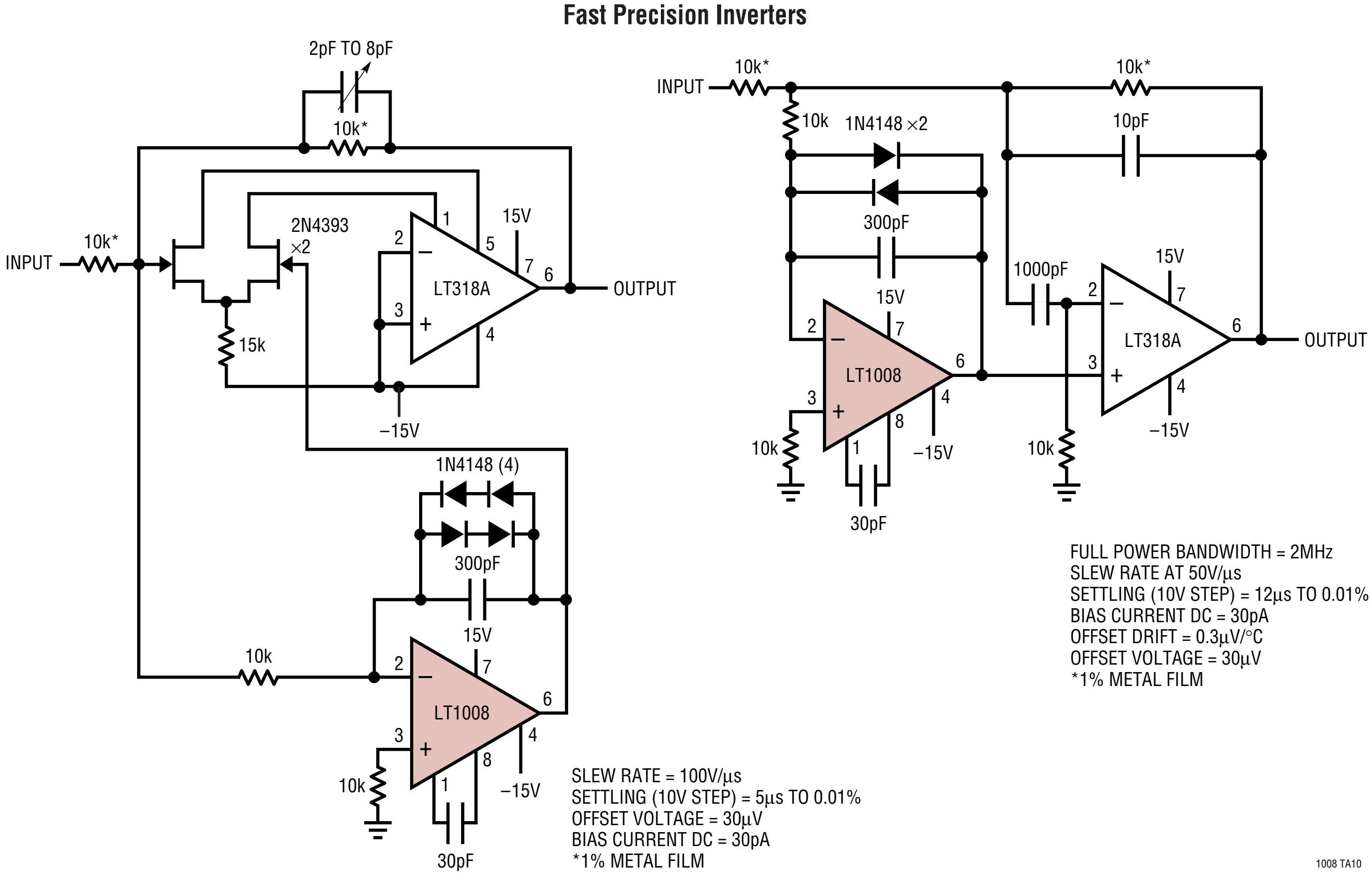


This circuit is useful where fast signal acquisition and high precision are required, as in electronic scales.

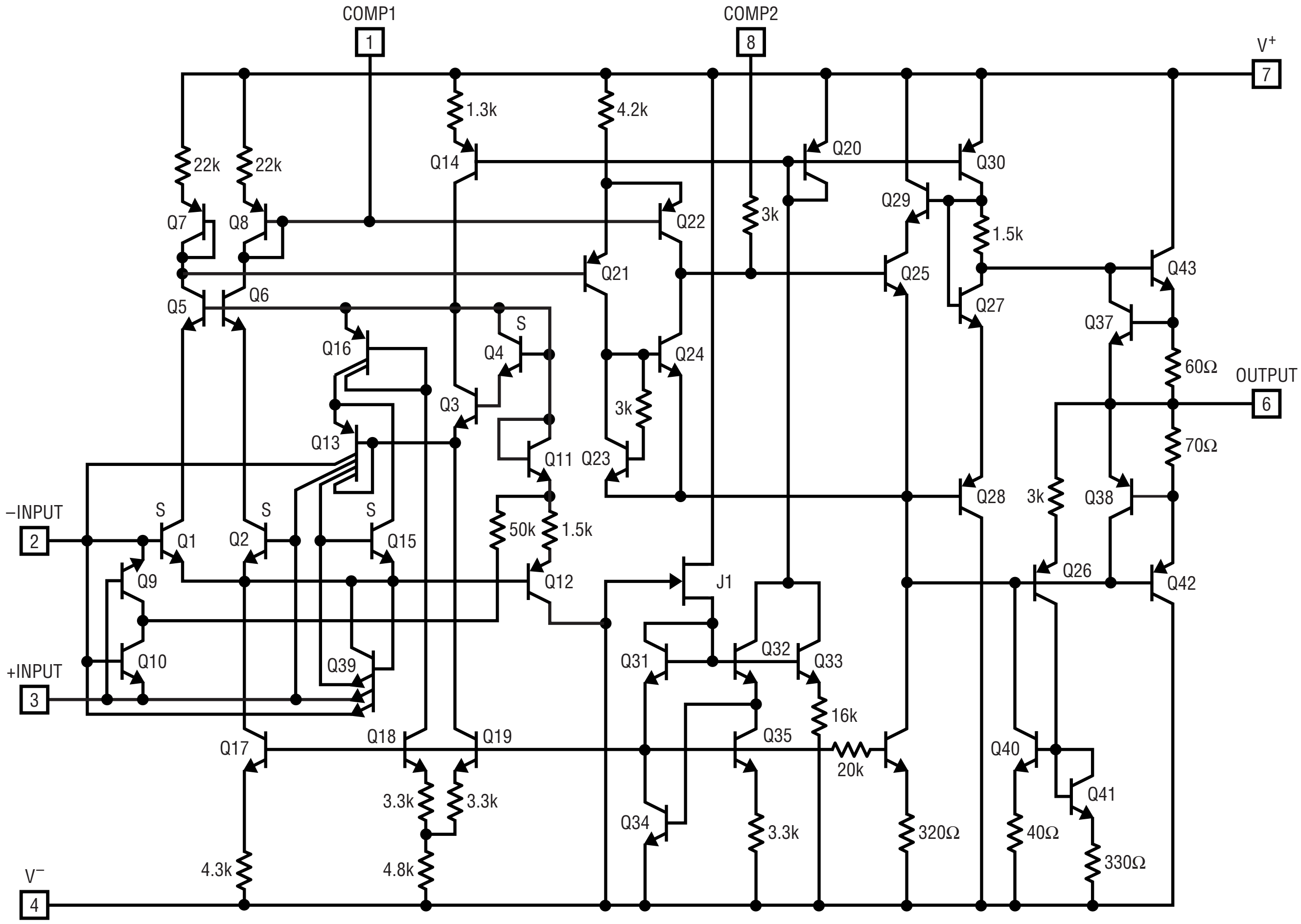
The filter's time constant is set by the 2k resistor and the 1μF capacitor until comparator 1 switches. The time constant is then set by the 1.5M resistor and the 1μF capacitor. Comparator 2 provides a quick reset.

The circuit settles to a final value three times as fast as a simple 1.5M-1μF filter with almost no DC error.

Fast Precision Inverters

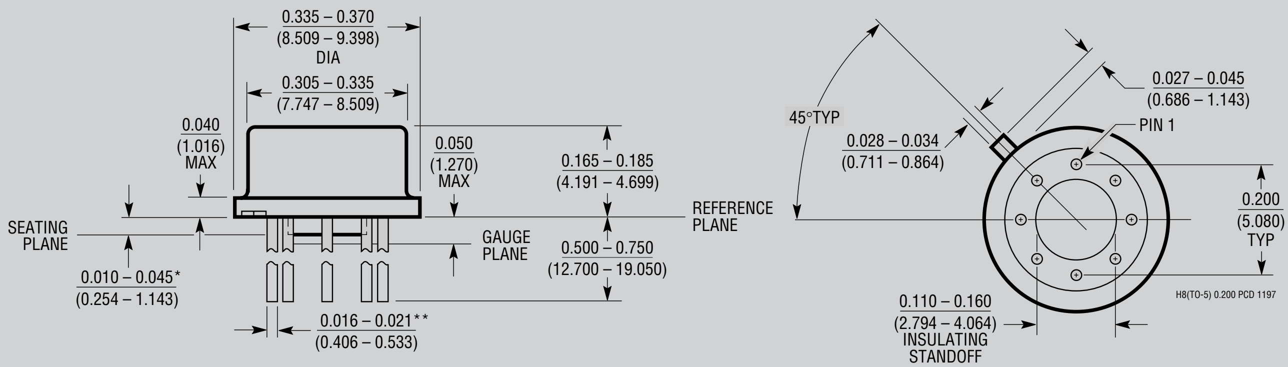


SCHEMATIC DIAGRAM



PACKAGE DESCRIPTION

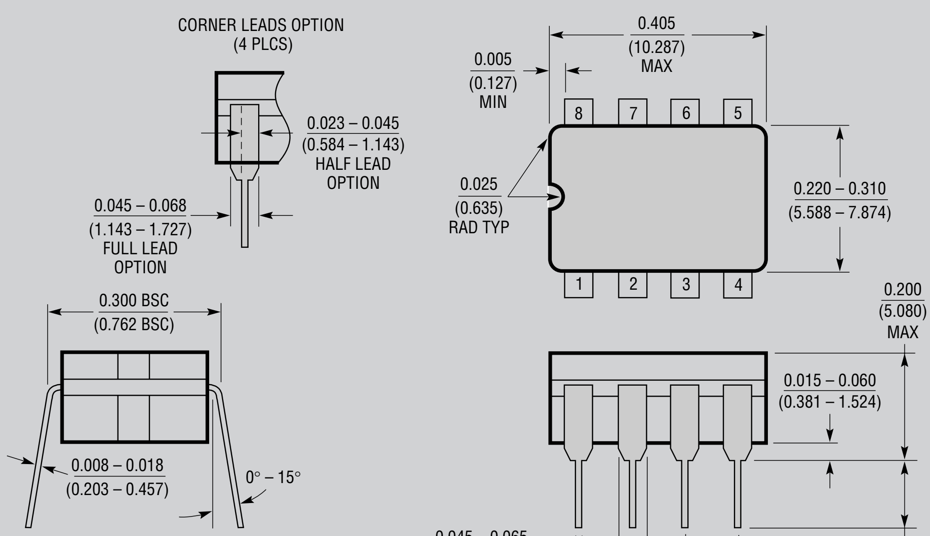
H Package
8-Lead TO-5 Metal Can (.200 Inch PCD)
(Reference LTC DWG # 05-08-1320)



*LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND 0.045" BELOW THE REFERENCE PLANE

**FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS 0.016 – 0.024 (0.406 – 0.610)

J8 Package
8-Lead CERDIP (Narrow .300 Inch, Hermetic)
(Reference LTC DWG # 05-08-1110)

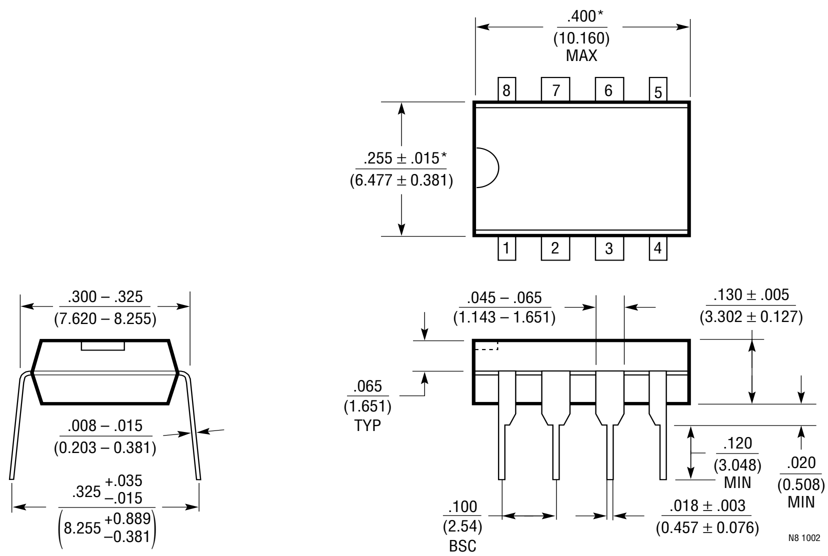


NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP/PLATE OR TIN PLATE LEADS

OBSOLETE PACKAGES

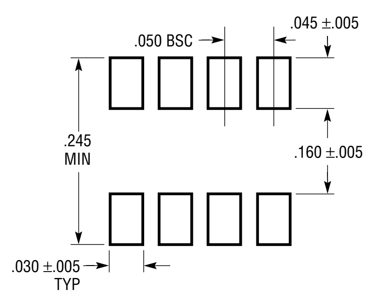
PACKAGE DESCRIPTION

N8 Package
8-Lead PDIP (Narrow .300 Inch)
(Reference LTC DWG # 05-08-1510)

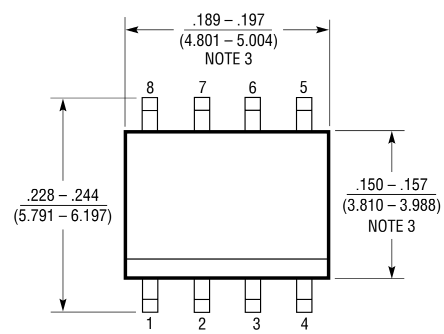


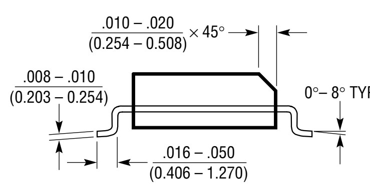
NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

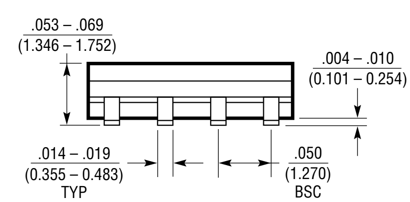
S8 Package
8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610)



RECOMMENDED SOLDER PAD LAYOUT







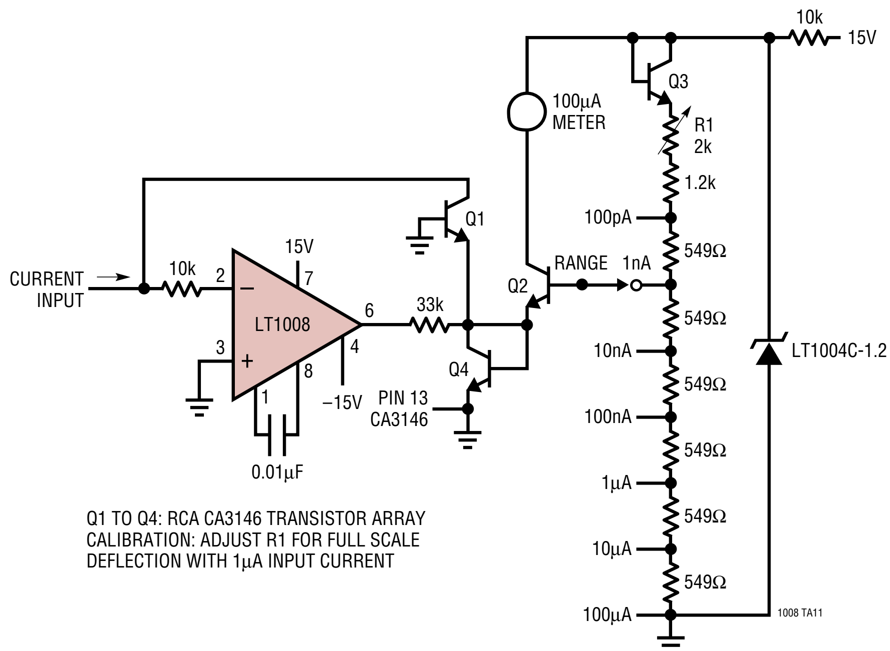
NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

TYPICAL APPLICATION

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 LT1008.

Ammeter with Six Decade Range



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1012	Picoamp Input Current, Microvolt Offset, Low Noise Op Amp	Internally Compensated LT1008
LT1112	Dual Low Power, Precision, Picoamp Input Op Amp	Dual LT1012
LT1880	SOT-23, Rail-to-Rail Output, Picoamp Input Current Precision Op Amp	Single SOT-23 Version of LT1884
LT1881/LT1882	Dual and Quad Rail-to-Rail Output, Picoamp Input Precision Op Amps	Dual/Quad C_{LOAD} Stable
LT1884/LT1885	Dual and Quad Rail-to-Rail Output, Picoamp Input Precision Op Amps	Dual/Quad Faster LT1881/LT1882

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