Low Noise, High Speed Precision Operational Amplifiers

FEATURES

- *Guaranteed* 4.5 nV/√Hz 10 Hz noise
- *Guaranteed* 3.8 nV/√Hz 1kHz noise
- 0.1 Hz to 10 Hz noise, 60 nV p-p, typical
- *Guaranteed* 7 million min. voltage gain, $R_L = 2k\Omega$
- *Guaranteed* 3 million min. voltage gain, $R_L = 600\Omega$
- *Guaranteed* 25μV max. offset voltage
- *Guaranteed* 0.6μV/°C max. drift with temperature
- *Guaranteed* 11V/μsec min. slew rate (LT1037)
- *Guaranteed* 117 dB min. CMRR

APPLICATIONS

- Low Noise Signal Processing
- Microvolt Accuracy Threshold Detection
- Strain Gauge Amplifiers
- Direct Coupled Audio Gain Stages
- Sine Wave Generators
- Tape Head Preamplifiers
- Microphone Preamplifiers

DESCRIPTION

The LT1007/LT1037 series features the lowest noise performance available to date for monolithic operational amplifiers: 2.5nV/√Hz wideband noise (less than the noise of a 400Ω resistor), 1/f corner frequency of 2Hz and 60nV peak to peak 0.1Hz to 10Hz noise. Low noise is combined with outstanding precision and speed specifications: 10μV offset voltage, 0.2μV/°C drift, 130 dB common-mode and power supply rejection, and 60MHz gain-bandwith-product on the decompensated LT1037, which is stable for closed loop gains of 5 or greater.

The voltage gain of the LT1007/1037 is an extremely high 20 million driving a 2kΩ load and 12 million driving a 600Ω load to ±10V.

In the design, processing, and testing of the device, particular attention has been paid to the optimization of the entire distribution of several key parameters. Consequently, the specifications of even the lowest cost grades (the LT1007C and the LT1037C) have been spectacularly improved compared to equivalent grades of competing amplifiers.

The sine wave generator application shown below utilizes the low noise and low distortion characteristics of the LT1037.

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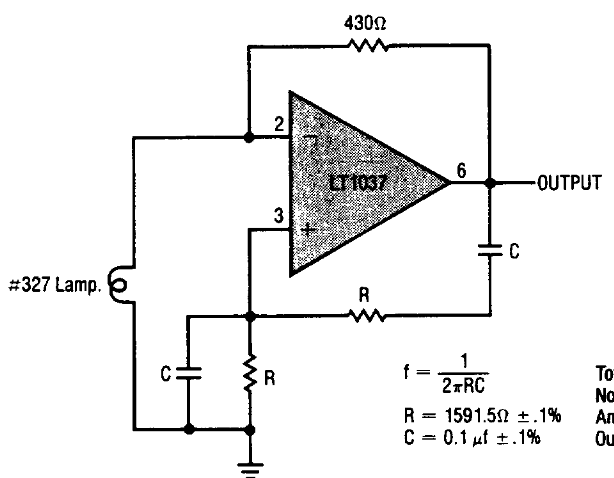
Ultra-Pure 1kHz Sine Wave Generator

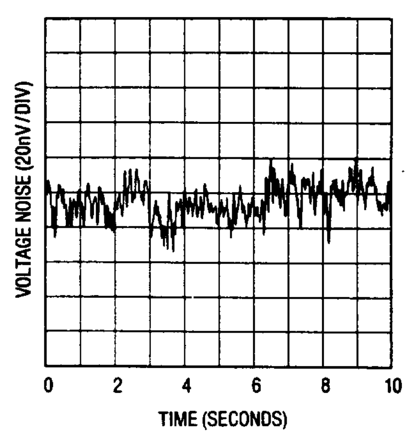


$f = \frac{1}{2\pi RC}$

R = 1591.5Ω ±.1%
C = 0.1μf ±.1%

Total Harmonic Distortion = < .0025%
Noise = < .0001%
Amplitude = ±8 volts
Output Frequency = 1.000kHz for values given ±.4%

0.1Hz to 10Hz Noise

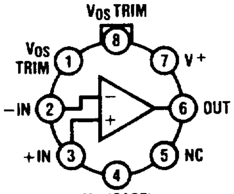


ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... ±22V
Input Voltage .... Equal to Supply Voltage
Output Short Circuit Duration .... Indefinite
Differential Input Current (Note 8)......... ±25mA
Lead Temperature (Soldering, 10 sec.)...... 300°C
Operating Temperature Range
  LT1007/1037AM, M.......... −55°C to 125°C
  LT1007/1037AC, C .... 0°C to 70°C
Storage Temperature Range
  All Devices.................. −65°C to 150°C

PACKAGE/ORDER INFORMATION

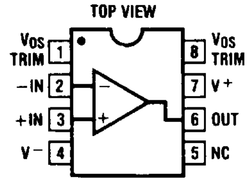
TOP VIEW



V−(CASE)
METAL CAN H PACKAGE

ORDER PART NUMBER	
LT1007AMH	LT1037AMH
LT1007MH	LT1037MH
LT1007ACH	LT1037ACH
LT1007CH	LT1037CH

TOP VIEW



HERMETIC DIP J8 PACKAGE
PLASTIC DIP N8 PACKAGE

LT1007AMJ8	LT1037AMJ8
LT1007MJ8	LT1037MJ8
LT1007ACJ8	LT1037ACJ8
LT1007CJ8	LT1037CJ8
LT1007ACN8	LT1037ACN8
LT1007CN8	LT1037CN8

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1007AM/AC LT1037AM/AC MIN	TYP	MAX	LT1007M/C LT1037M/C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 1)		10	25		20	60	μV
$\frac{\Delta V_{OS}}{\Delta Time}$	Long Term Input Offset Voltage Stability	(Notes 2 and 3)		0.2	1.0		0.2	1.0	μV/Mo
I_{OS}	Input Offset Current			7	30		12	50	nA
I_B	Input Bias Current			±10	±35		±15	±55	nA
e_n	Input Noise Voltage	0.1Hz to 10Hz (Notes 3 and 5)		0.06	0.13		0.06	0.13	μVp-p
	Input Noise Voltage Density	f_o = 10Hz (Notes 3 and 4) f_o = 1000Hz (Note 3)		2.8 2.5	4.5 3.8		2.8 2.5	4.5 3.8	nV/√Hz nV/√Hz
i_n	Input Noise Current Density	f_o = 10Hz (Notes 3 and 6) f_o = 1000Hz (Notes 3 and 6)		1.5 0.4	4.0 0.6		1.5 0.4	4.0 0.6	pA/√Hz pA/√Hz
	Input Resistance — Common Mode			7			5		GΩ
	Input Voltage Range		±11.0	±12.5		±11.0	±12.5		V
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 11V$	117	130		110	126		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 4V$ to $\pm 18V$	110	130		106	126		dB
A_{VOL}	Large Signal Voltage Gain	$R_L \geq 2k\Omega$, $V_O = \pm 12V$ $R_L \geq 1k\Omega$, $V_O = \pm 10V$ $R_L \geq 600\Omega$, $V_O = \pm 10V$	7.0 5.0 3.0	20.0 16.0 12.0		5.0 3.5 2.0	20.0 16.0 12.0		V/μV V/μV V/μV
V_{OUT}	Maximum Output Voltage Swing	$R_L \geq 2k\Omega$ $R_L \geq 600\Omega$	±13.0 ±11.0	±13.8 ±12.5		±12.5 ±10.5	±13.5 ±12.5		V V
SR	Slew Rate LT1007 LT1037	$R_L \geq 2k\Omega$ $A_{VCL} \geq 5$	1.7 11	2.5 15		1.7 11	2.5 15		V/μS V/μS
GBW	Gain-Bandwidth Product: LT1007 LT1037	f_o = 100kHz (Note 7) f_o = 10kHz (Note 7) ($A_{VCL} \geq 5$)	5.0 45	8.0 60		5.0 45	8.0 60		MHz MHz
Z_o	Open Loop Output Resistance	$V_O = 0$, $I_O = 0$		70			70		Ω
P_d	Power Dissipation LT1007 LT1037			80 80	120 130		80 85	140 140	mW mW

LINEAR TECHNOLOGY

ELECTRICAL CHARACTERISTICS $V_S = \pm15V$, $-55°C \leq T_A \leq 125°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1007AM/LT1037AM MIN	TYP	MAX	LT1007M/LT1037M MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 1)	●		25	60		50	160	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Input Offset Drift	(Note 9)	●		0.2	0.6		0.3	1.0	μV/°C
I_{OS}	Input Offset Current		●		15	50		20	85	nA
I_B	Input Bias Current		●		±20	±60		±35	±95	nA
	Input Voltage Range		●	±10.3	±11.5		±10.3	±11.5		V
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm10.3V$	●	112	126		104	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm4.5V$ to $\pm18V$	●	104	126		100	120		dB
A_{VOL}	Large Signal Voltage Gain	$R_L \geq 2k\Omega$, $V_o = \pm10V$ $R_L \geq 1k\Omega$, $V_o = \pm10V$	● ●	3.0 2.0	14.0 10.0		2.0 1.5	14.0 10.0		V/μV V/μV
V_{OUT}	Maximum Output Voltage Swing	$R_L \geq 2k\Omega$	●	±12.5	±13.5		±12.0	±13.5		V
P_d	Power Dissipation		●		100	150		100	170	mW

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ELECTRICAL CHARACTERISTICS $V_S = \pm15V$, $0°C \leq T_A \leq 70°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1007AC/LT1037AC MIN	TYP	MAX	LT1007C/LT1037C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 1)	●		20	50		35	110	μV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Input Offset Drift	(Note 9)	●		0.2	0.6		0.3	1.0	μV/°C
I_{OS}	Input Offset Current		●		10	40		15	70	nA
I_B	Input Bias Current		●		±14	±45		±20	±75	nA
	Input Voltage Range		●	±10.5	±11.8		±10.5	±11.8		V
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm10.5V$	●	114	126		106	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm4.5V$ to $\pm18V$	●	106	126		102	120		dB
A_{VOL}	Large Signal Voltage Gain	$R_L \geq 2k\Omega$, $V_o = \pm10V$ $R_L \geq 1k\Omega$, $V_o = \pm10V$	● ●	4.0 2.5	18.0 14.0		2.5 2.0	18.0 14.0		V/μV V/μV
V_{OUT}	Maximum Output Voltage Swing	$R_L \geq 2k\Omega$	●	±12.5	±13.6		±12.0	±13.6		V
P_d	Power Dissipation		●		90	144		90	160	mW

NOTES:

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

For MIL-STD components, please refer to LTC 883C data sheet for test listing and parameters.

Note 1: Input Offset Voltage measurements are performed by automatic test equipment approximately 0.5 seconds after application of power. AM and AC grades are guaranteed fully warmed up.

Note 2: Long Term Input Offset Voltage Stability refers to the average trend line of Offset Voltage vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 days are typically 2.5μV — refer to typical performance curve.

Note 3: This parameter is tested on a sample basis only.

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

Note 5: See the test circuit and frequency response curve for 0.1Hz to 10Hz tester in the Applications Information section.

Note 6: See the test circuit for current noise measurement in the Applications Information section.

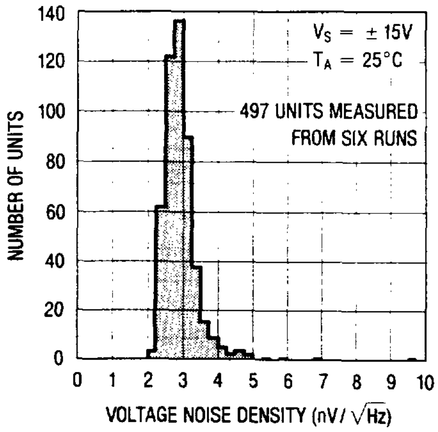
Note 7: This parameter is guaranteed by design and is not tested.

Note 8: The inputs are protected by back-to-back diodes. Current limiting resistors are not used in order to achieve low noise. If differential input voltage exceeds ±0.7V, the input current should be limited to 25mA.

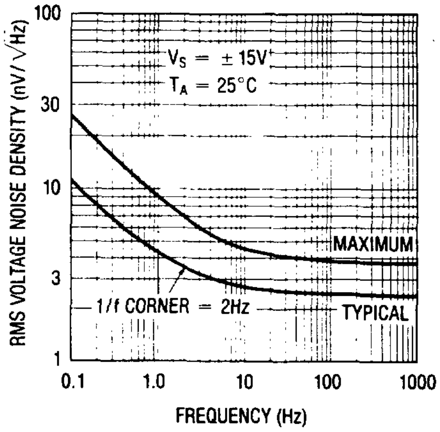
Note 9: The Average Input Offset Drift performance is within the specifications unnulled or when nulled with a pot having a range of 8kΩ to 20kΩ.

TYPICAL PERFORMANCE CHARACTERISTICS

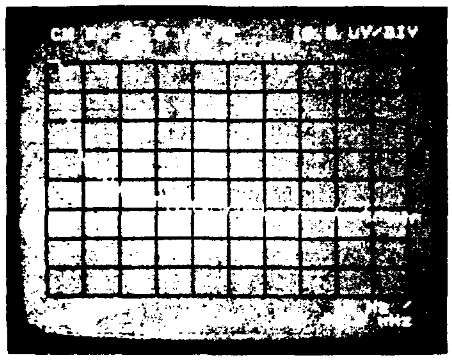
10Hz Voltage Noise Distribution



Voltage Noise vs Frequency

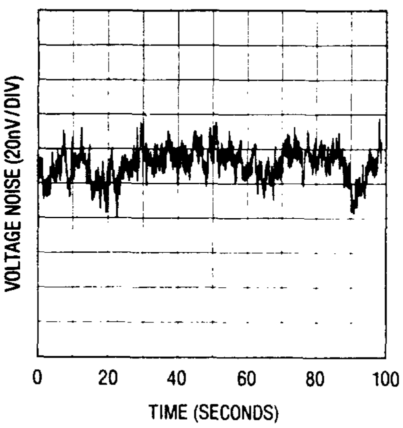


0.02 to 10Hz RMS Noise. Gain = 50,000 (Measured on HP3582 Spectrum Analyzer)

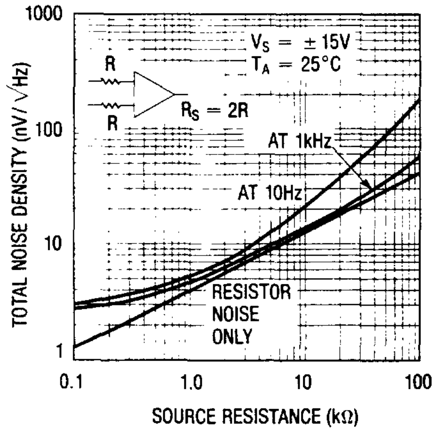


Marker at 2Hz (= 1/f corner) = $\frac{179\mu V/\sqrt{Hz}}{50,000} = 3.59\ \frac{nV}{\sqrt{Hz}}$

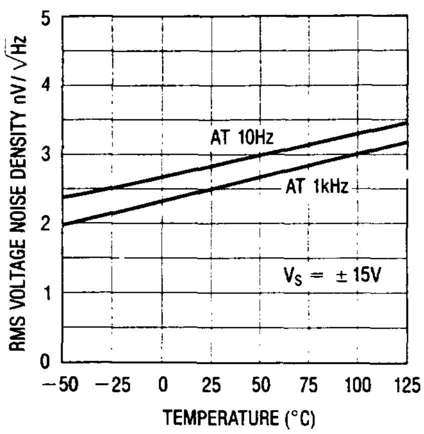
0.01 to 1Hz Peak to Peak Noise



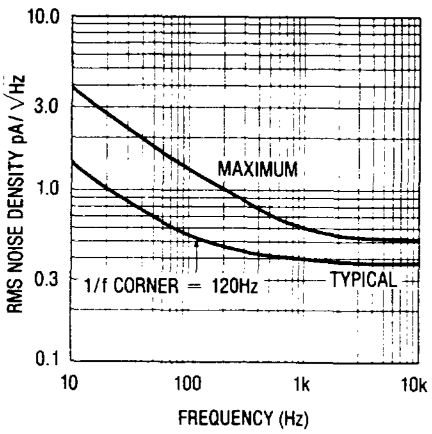
Total Noise vs Source Resistance



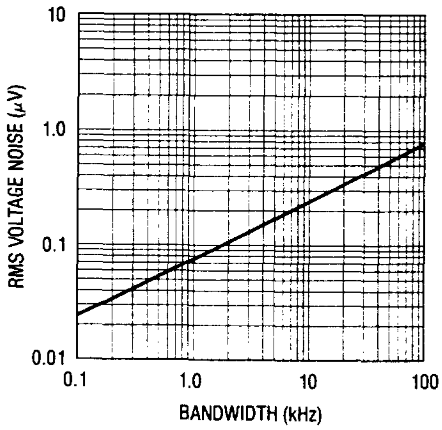
Voltage Noise vs Temperature



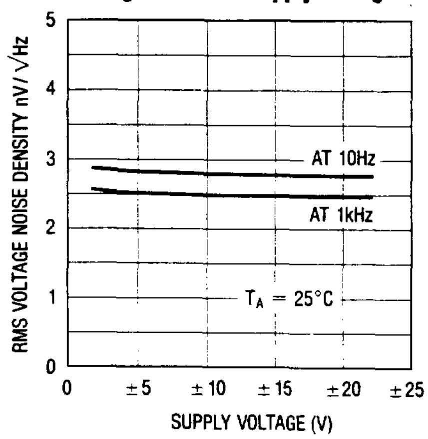
Current Noise vs Frequency



Wideband Voltage Noise (0.1Hz to Frequency Indicated)

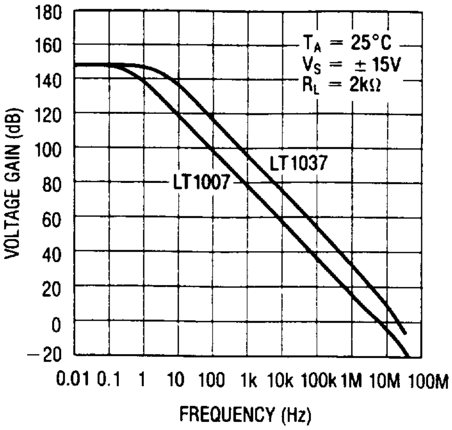


Voltage Noise vs Supply Voltage

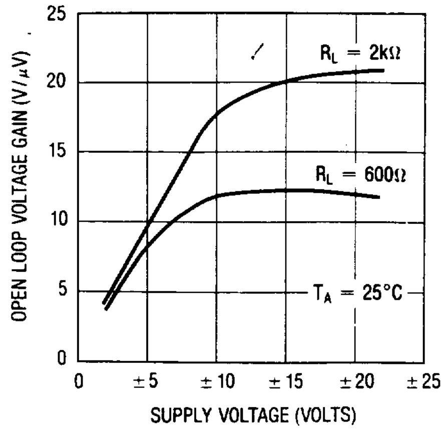


TYPICAL PERFORMANCE CHARACTERISTICS

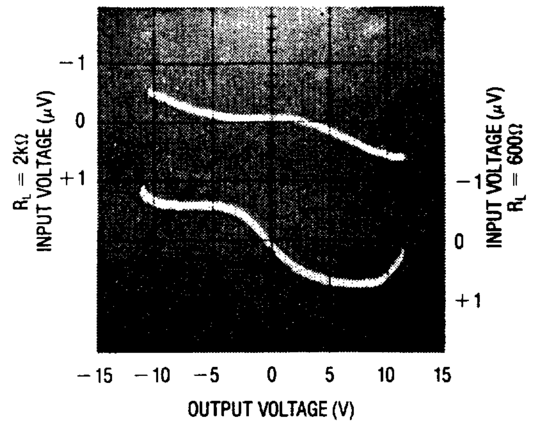
Voltage Gain vs Frequency



Voltage Gain vs Supply Voltage



Voltage Gain, R_L = 2K and 600Ω



MEASURED ON TEKTRONIX 178 LINEAR IC TESTER

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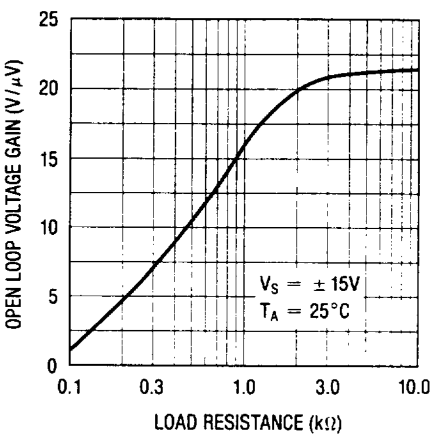
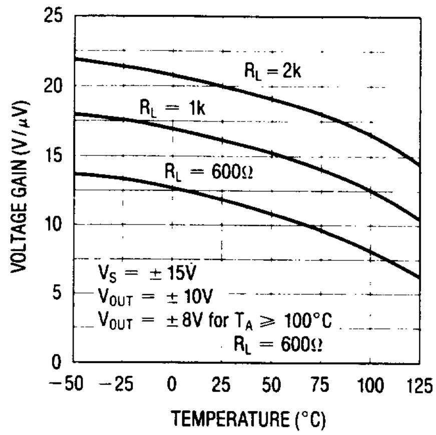
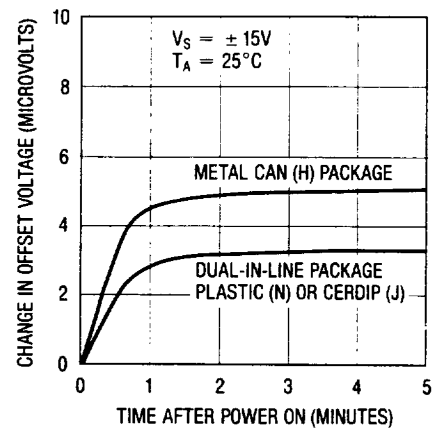
Voltage Gain vs Load Resistance



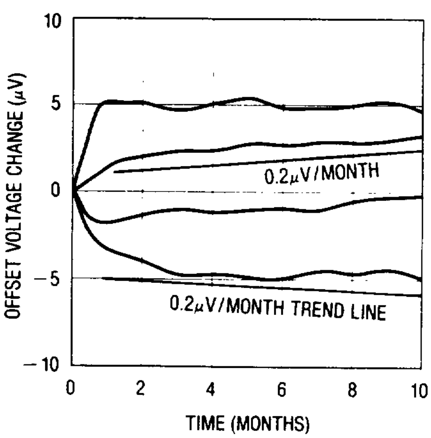
Voltage Gain vs Temperature



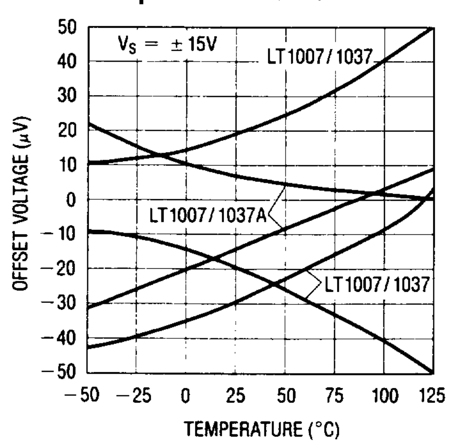
Warm-Up Drift



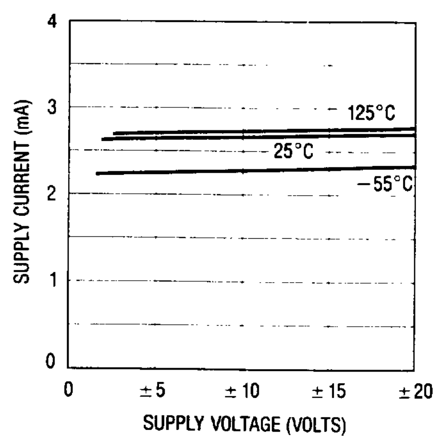
Long Term Stability of Four Representative Units



Offset Voltage Drift with Temperature of Representative Units

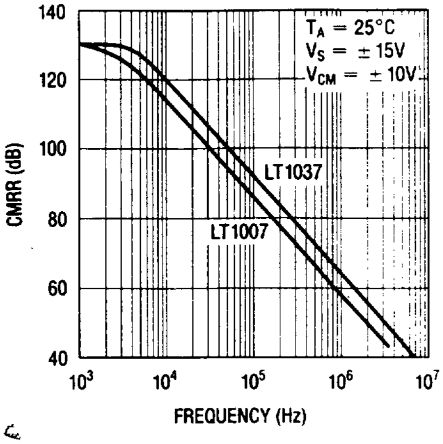


Supply Current vs Supply Voltage

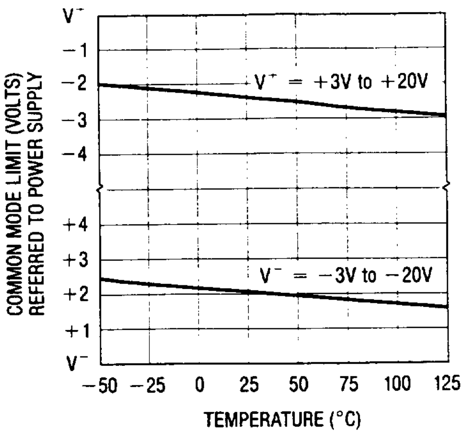


TYPICAL PERFORMANCE CHARACTERISTICS

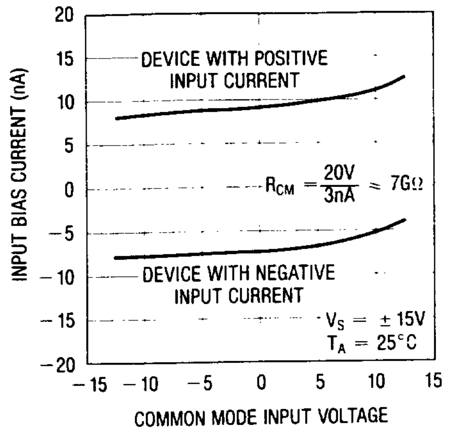
Common Mode Rejection vs Frequency



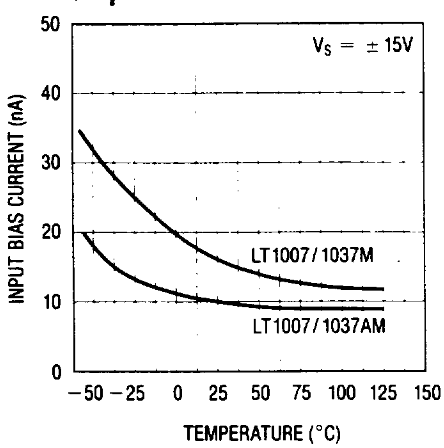
Common Mode Limit vs Temperature



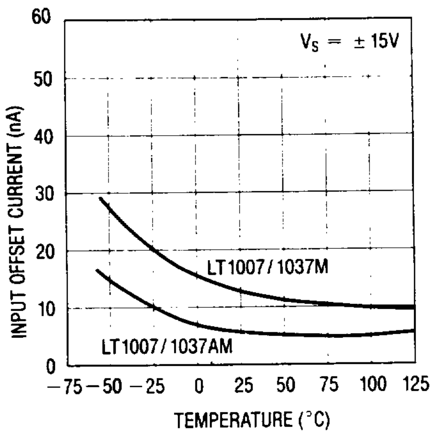
Input Bias Current Over the Common Mode Range



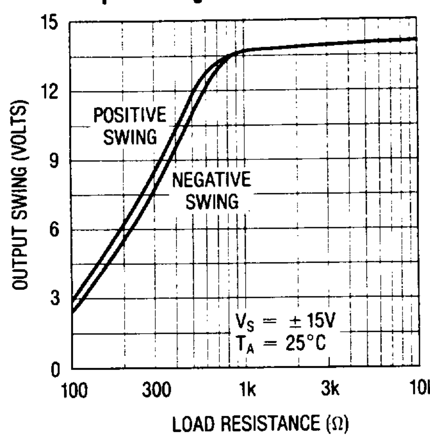
Input Bias Current vs Temperature



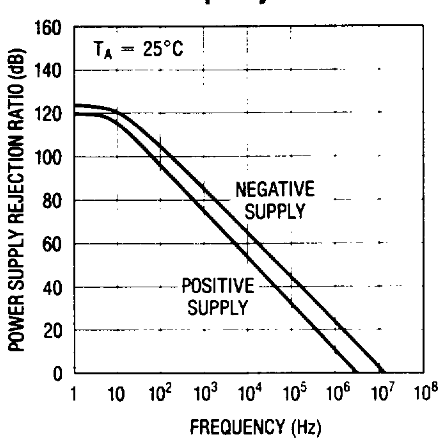
Input Offset Current vs Temperature



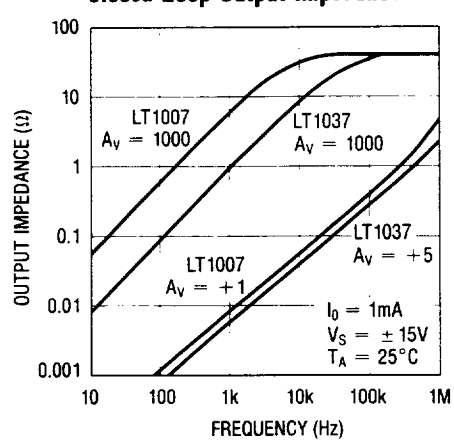
Output Swing vs Load Resistance



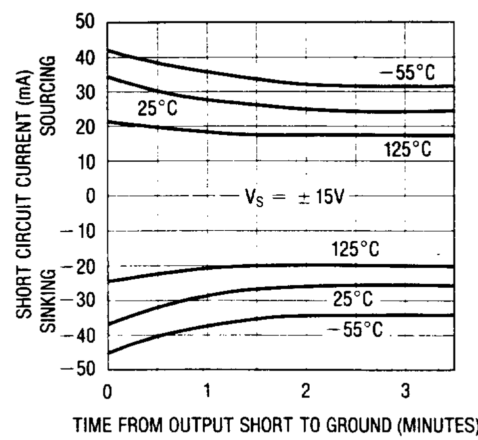
PSRR vs Frequency



Closed Loop Output Impedance



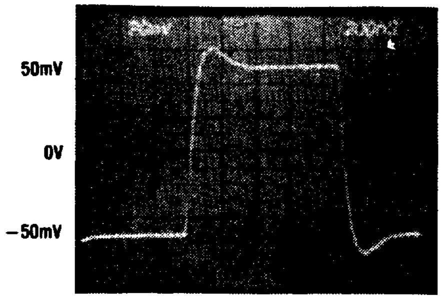
Output Short Circuit Current vs Time



LINEAR TECHNOLOGY

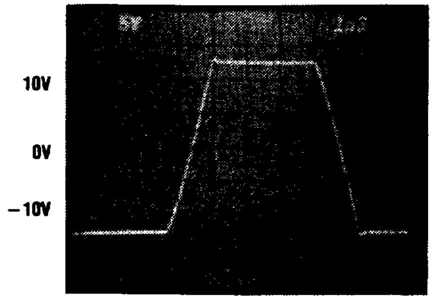
TYPICAL PERFORMANCE CHARACTERISTICS

LT1037 Small Signal Transient Response



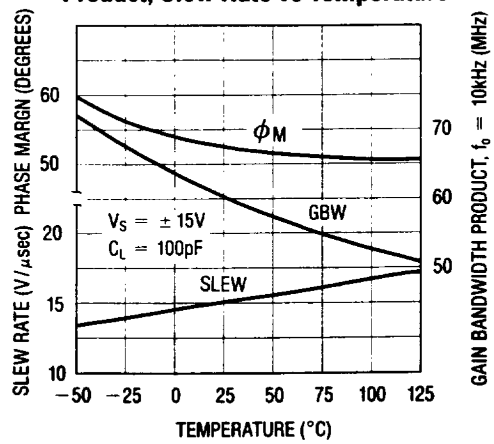
$A_{VCL} = +5$, $V_S = \pm 15V$
$C_L = 15pF$

LT1037 Large Signal Response



$A_{VCL} = +5$, $V_S = \pm 15V$

LT1037 Phase Margin, Gain Bandwidth Product, Slew Rate vs Temperature



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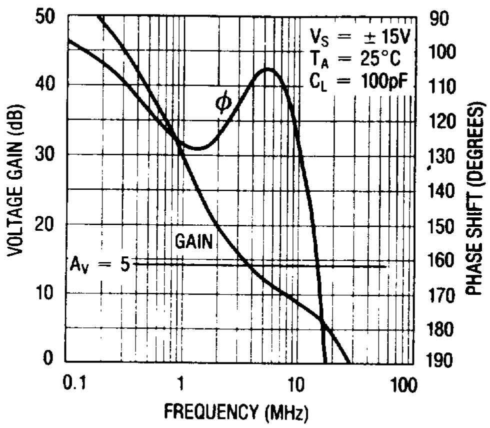
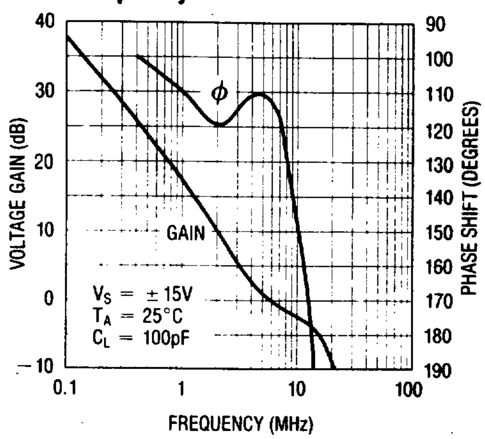
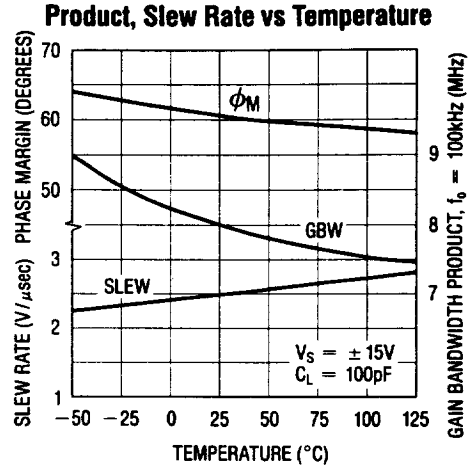
LT1037 Gain, Phase Shift vs Frequency



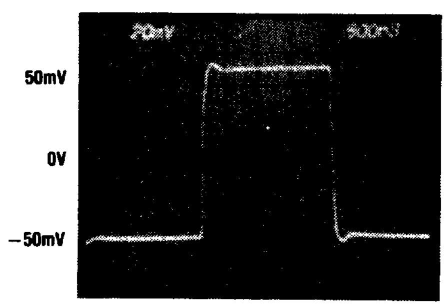
LT1007 Gain, Phase Shift vs Frequency



LT1007 Phase Margin, Gain-Bandwidth Product, Slew Rate vs Temperature

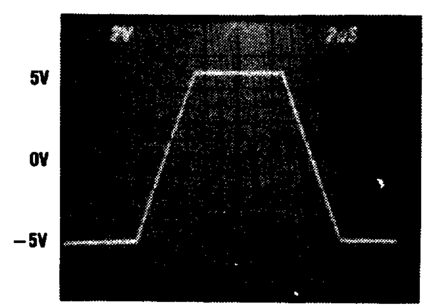


LT1007 Small Signal Transient Response



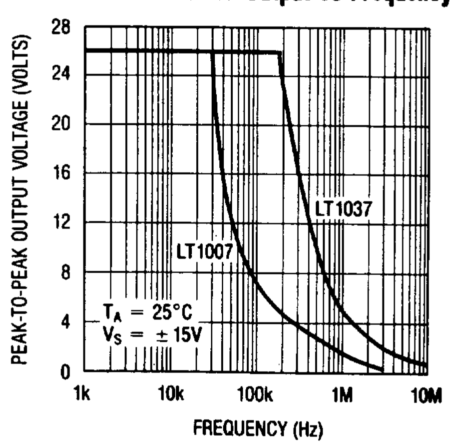
$A_{VCL} = +1$, $V_S = \pm 15V$
$C_L = 15pF$

LT1007 Large Signal Response



$A_{VCL} = -1$, $V_S = \pm 15V$

Maximum Undistorted Output vs Frequency



APPLICATIONS INFORMATION

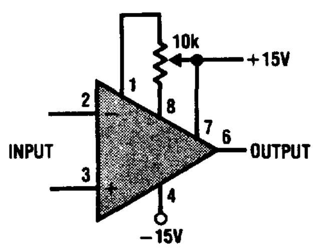
General

The LT1007/1037 series devices may be inserted directly into OP-07, OP-27, OP-37, and 5534 sockets with or without removal of external compensation or nulling components. In addition, the LT1007/1037 may be fitted to 741 sockets with the removal or modification of external nulling components.

Offset Voltage Adjustment

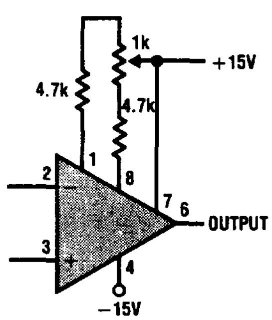
The input offset voltage of the LT1007/1037 and its drift with temperature, are permanently trimmed at wafer testing to a low level. However, if further adjustment of V_{OS} is necessary, the use of a 10k nulling potentiometer will not degrade drift with temperature. Trimming to a value other than zero creates a drift of $(V_{OS}/300)\ \mu V/°C$, e.g., if V_{OS} is adjusted to $300\mu V$, the change in drift will be $1\mu V/°C$.

Standard Adjustment



The adjustment range with a 10k pot is approximately ±2.5mV. If less adjustment range is needed, the sensitivity and resolution of the nulling can be improved by using a smaller pot in conjunction with fixed resistors. The example has an approximate null range of ±200μV.

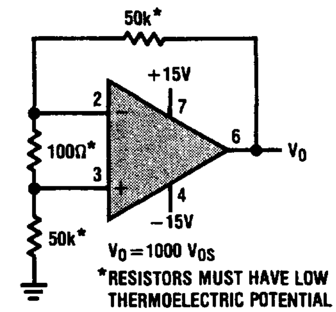
Improved Sensitivity Adjustment



Offset Voltage and Drift

Thermocouple effects, caused by temperature gradients across dissimilar metals at the contacts to the input terminals, can exceed the inherent drift of the amplifier unless proper care is exercised. Air currents should be minimized, package leads should be short, the two input leads should be close together and maintained at the same temperature.

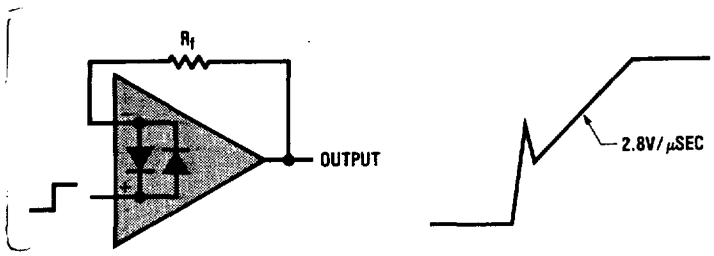
The circuit shown to measure offset voltage is also used as the burn-in configuration for the LT1007/1037, with the supply voltages increased to ±20V.



Test Circuit for Offset Voltage and Offset Voltage Drift with Temperature

Unity Gain Buffer Applications (LT1007 Only)

When $R_f \leq 100\Omega$ and the input is driven with a fast, large signal pulse (>1V), the output waveform will look as shown in the pulsed operation diagram.



During the fast feedthrough-like portion of the output, the input protection diodes effectively short the output to the input and a current, limited only by the output short circuit protection, will be drawn by the signal generator. With $R \geq 500\Omega$, the output is capable of handling the current requirements ($I_L \leq 20mA$ at 10V) and the amplifier stays in its active mode and a smooth transition will occur.

As with all operational amplifiers when $R_f > 2k\Omega$, a pole will be created with R_f and the amplifier's input capacitance, creating additional phase shift and reducing the phase margin. A small capacitor (20pF to 50pF) in parallel with R_f will eliminate this problem.

APPLICATIONS INFORMATION — NOISE

Noise Testing

The 0.1Hz to 10Hz peak-to-peak noise of the LT1007/1037 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.

Measuring the typical 60nV peak-to-peak noise performance of the LT1007/1037 requires special test precautions:

(a) The device should be warmed up for at least five minutes. As the op amp warms up, its offset voltage changes typically 3μV due to its chip temperature increasing 10°C to 20°C from the moment the power supplies are turned on. In the 10 second measurement interval these temperature-induced effects can easily exceed tens of nanovolts.

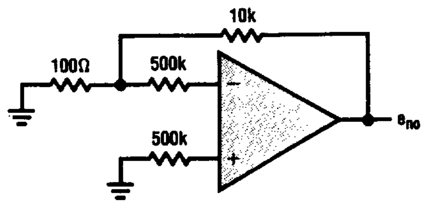
(b) For similar reasons, the device must be well shielded from air currents to eliminate the possibility of thermoelectric effects in excess of a few nanovolts, which would invalidate the measurements.

(c) Sudden motion in the vicinity of the device can also "feedthrough" to increase the observed noise.

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:

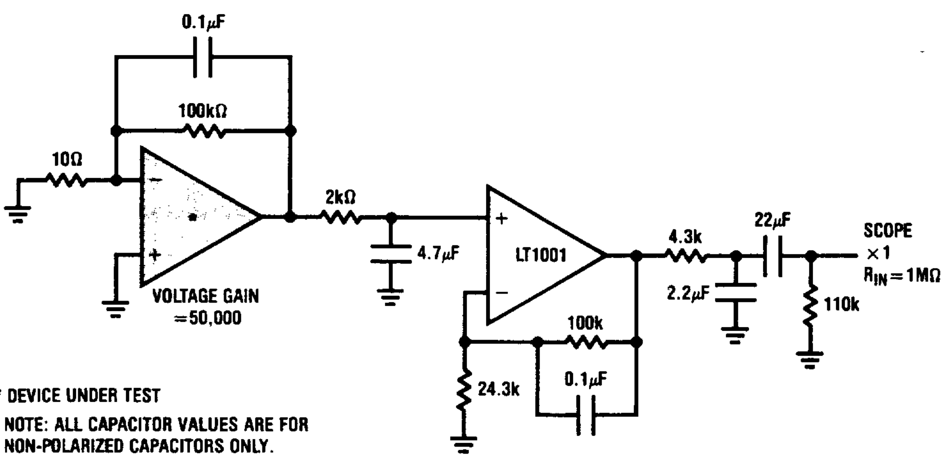
$$i_n = \frac{\left[e_{no}^2 - (130nV)^2\right]^{1/2}}{1M\Omega \times 100}$$



The LT1007/1037 achieves its low noise, in part, by operating the input stage at 120μA versus the typical 10μA of most other op amps. Voltage noise is inversely proportional while current noise is directly proportional to the square root of the stage current. Therefore the LT1007/1037's current noise will be relatively high. At low frequencies, the low 1/f current noise corner frequency (≈120Hz) minimizes current noise to some extent.

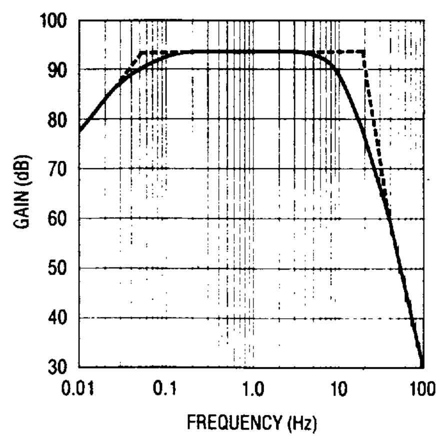
In most practical applications, however, current noise will not limit system performance. This is illustrated in

0.1Hz to 10Hz Noise Test Circuit



* DEVICE UNDER TEST
NOTE: ALL CAPACITOR VALUES ARE FOR NON-POLARIZED CAPACITORS ONLY.

0.1Hz to 10Hz p-p Noise Tester Frequency Response



the total noise versus source resistance plot, where total noise = $[(\text{voltage noise})^2 + (\text{current noise} \times R_S)^2 + (\text{resistor noise})^2]^{1/2}$

Three regions can be identified as a function of source resistance:

(i) $R_S \leq 400\Omega$. Voltage noise dominates

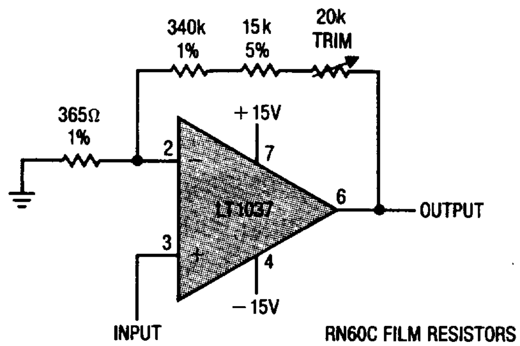
(ii) $400\Omega \leq R_S \leq 50k\Omega$ at 1kHz, $400\Omega \leq R_S \leq 8k\Omega$ at 10Hz — Resistor noise dominates

(iii) $R_S > 50k\Omega$ at 1kHz, $R_S > 8k\Omega$ at 10Hz — Current noise dominates

Clearly the LT1007/1037 should not be used in region (iii), where total system noise is at least six times higher than the voltage noise of the op amp, i.e., the low voltage noise specification is completely wasted.

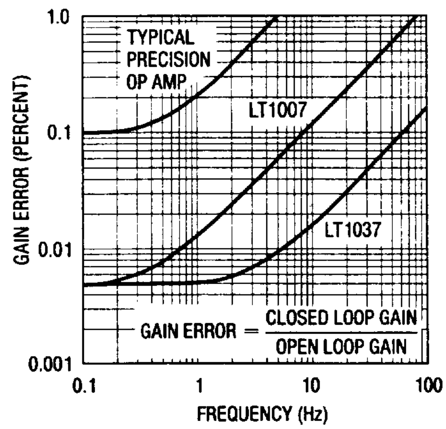
TYPICAL APPLICATIONS

Gain 1000 Amplifier with 0.01% Accuracy, DC to 5Hz

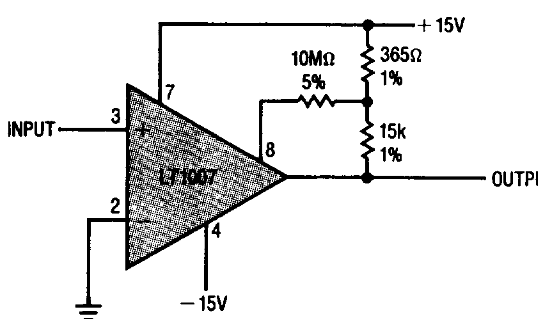


The high gain and wide bandwidth of the LT1037 and (LT1007) is useful in low frequency high closed loop gain amplifier applications. A typical precision Op Amp may have an open loop gain of one million with 500kHz bandwidth. As the gain error plot shows, this device is capable of 0.1% amplifying accuracy up to 0.3Hz only. Even instrumentation range signals can vary at a faster rate. The LT1037's "gain precision — bandwidth product" is 200 times higher, as shown.

Gain Error vs Frequency Closed Loop Gain = 1000



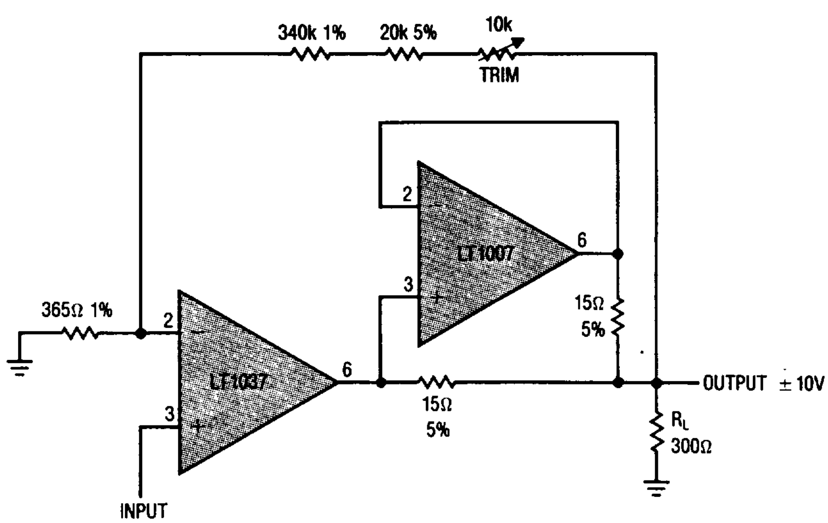
Microvolt Comparator with Hysteresis



Positive feedback to one of the nulling terminals creates approximately 5μV of hysteresis. Output can sink 16mA.

Input offset voltage is typically changed less than 5μV due to the feedback.

Precision Amplifier Drives 300Ω Load to ±10V

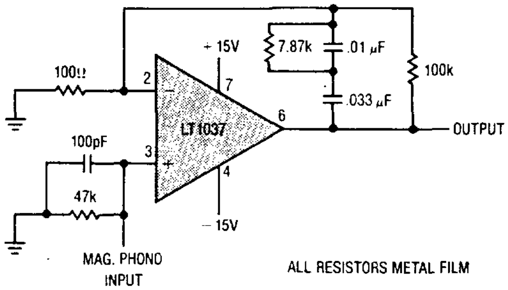


The addition of the LT1007 doubles the amplifier's output drive to ±33mA. Gain accuracy is 0.02%, slightly degraded compared to above because of self heating of the LT1037 under load.

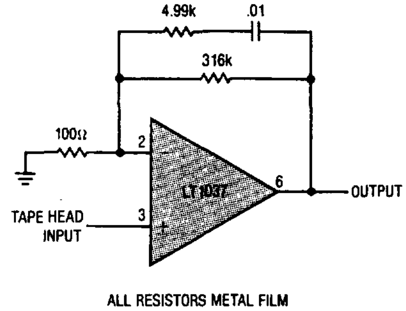
LINEAR TECHNOLOGY

TYPICAL APPLICATIONS

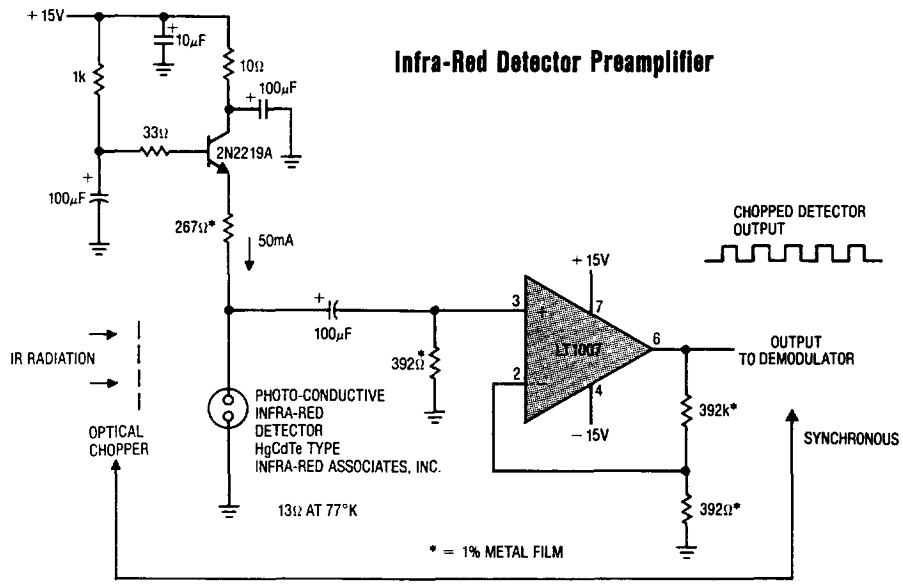
Phono Preamplifier



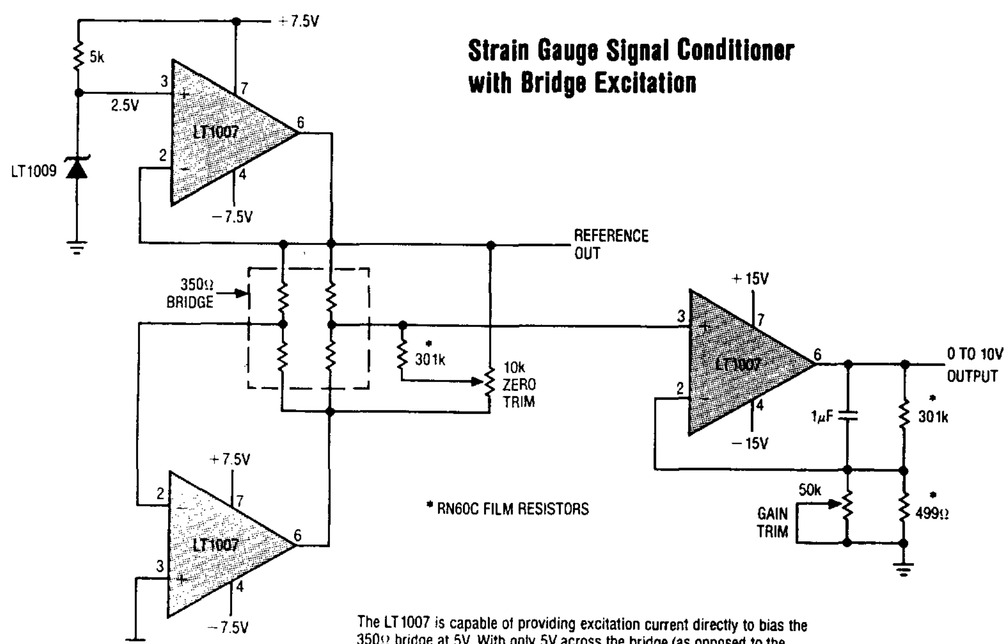
Tape Head Amplifier



Infra-Red Detector Preamplifier

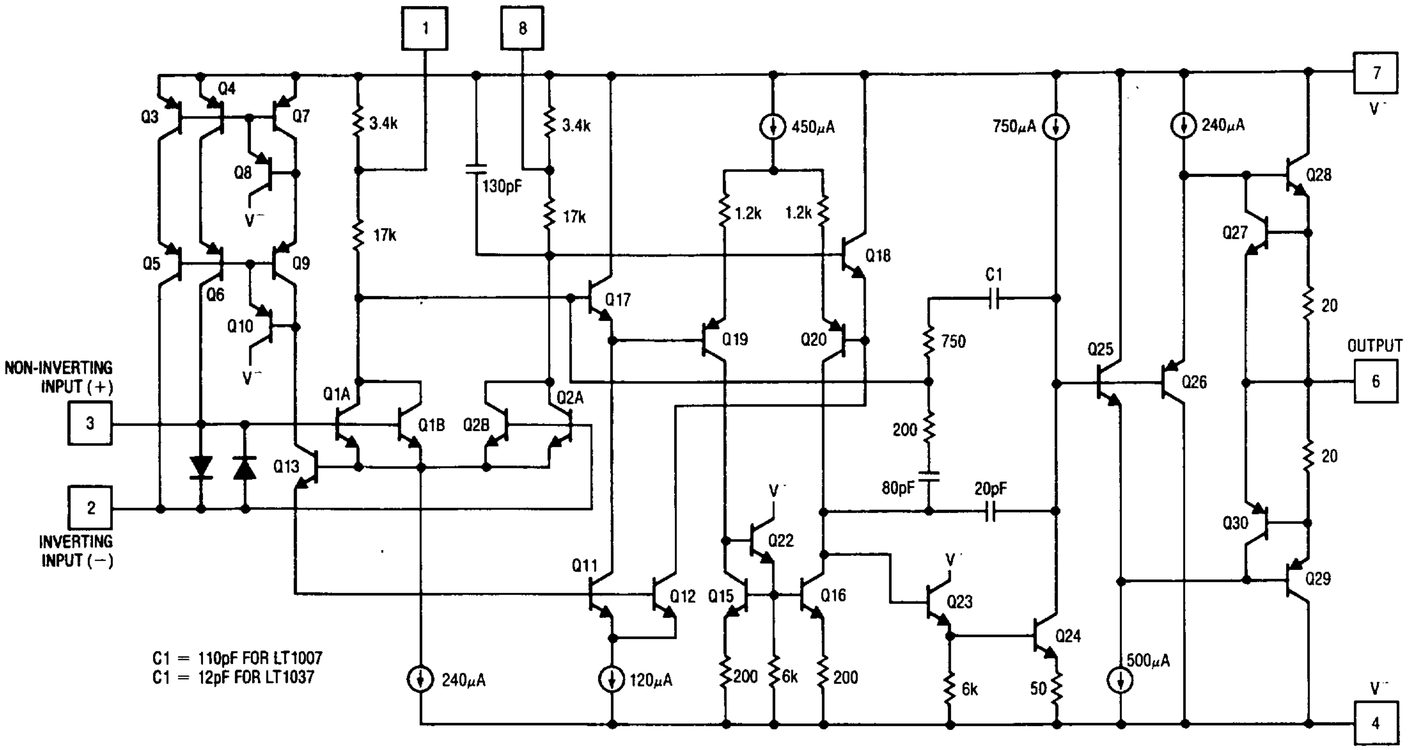


Strain Gauge Signal Conditioner with Bridge Excitation



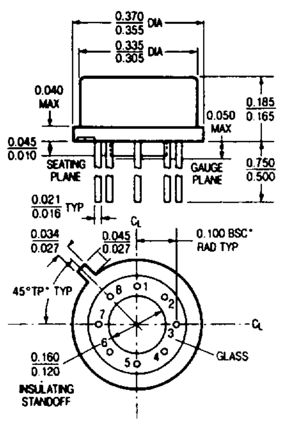
The LT1007 is capable of providing excitation current directly to bias the 350Ω bridge at 5V. With only 5V across the bridge (as opposed to the usual 10V) total power dissipation and bridge warm-up drift is reduced. The bridge output signal is halved, but the LT1007 can amplify the reduced signal accurately.

SCHEMATIC DIAGRAM



PACKAGE DESCRIPTION

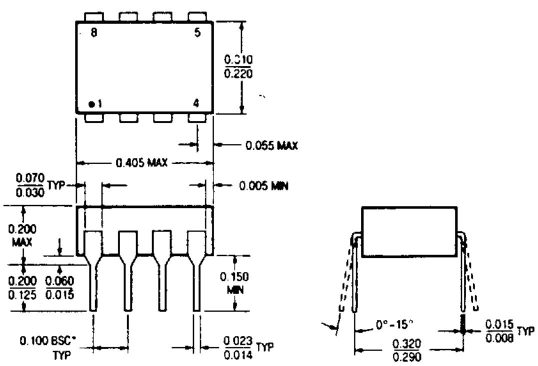
H Package
Metal Can



NOTE: DIMENSIONS IN INCHES

$T_j$max	Θ_{ja}	Θ_{jc}
150°C	150°C/W	45°C/W

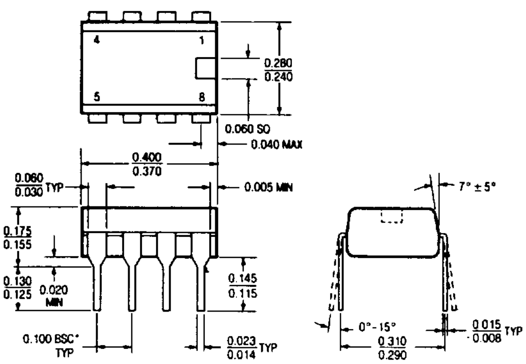
J8 Package
8 Lead Hermetic Dip



NOTE: DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED.
*LEADS WITHIN 0.007 OF TRUE POSITION (TP) AT GAUGE PLANE

$T_j$max	Θ_{ja}
150°C	100°C/W

N8 Package
8 Lead Plastic



NOTE: DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED.
*LEADS WITHIN 0.007 OF TRUE POSITION (TP) AT GAUGE PLANE.

$T_j$max	Θ_{ja}
100°C	130°C/W