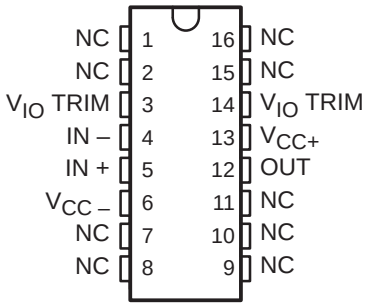
SLOS017C – D3195, FEBRUARY 1989 – REVISED JANUARY 1993

- **Maximum Equivalent Input Noise Voltage:**
  **3.8 nV/$\sqrt{\text{Hz}}$ at 1 kHz**
  **4.5 nV/$\sqrt{\text{Hz}}$ at 10 Hz**
- **Low Peak-to-Peak Equivalent Input Noise Voltage: 60 nV Typ From 0.1 Hz to 10 Hz**
- **Slew Rate (LT1037 and LT1037A):**
  **11 V/μs Min**

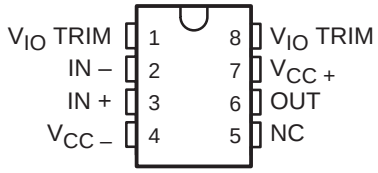
### LT1007A and LT1037A Specifications:

- **High Voltage Amplification:**
  **7 V/μV Min, $R_L$ = 2 kΩ**
  **3 V/μV Min, $R_L$ = 600 Ω**
- **Low Input Offset Voltage:**
  **25 μV Max**
- **Low Input Offset Voltage Temperature Coefficient: 0.6 μV/°C Max**
- **Common-Mode Rejection Ratio: 117 dB Min**

**DW PACKAGE**
**(TOP VIEW)**




**JG OR P PACKAGE**
**(TOP VIEW)**




NC – No internal connection

## description

These monolithic operational amplifiers feature extremely low-noise performance and out standing precision and speed specifications.The typical differential voltage amplification (at $T_A$ = 25°C) of these devices is an extremely high 20 V/μV driving a 2-kΩ load to ±12 V and 12 V/μV driving, a 600-Ω 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 greatly improved compared to equivalent grades of competing amplifiers.

**AVAILABLE OPTIONS**

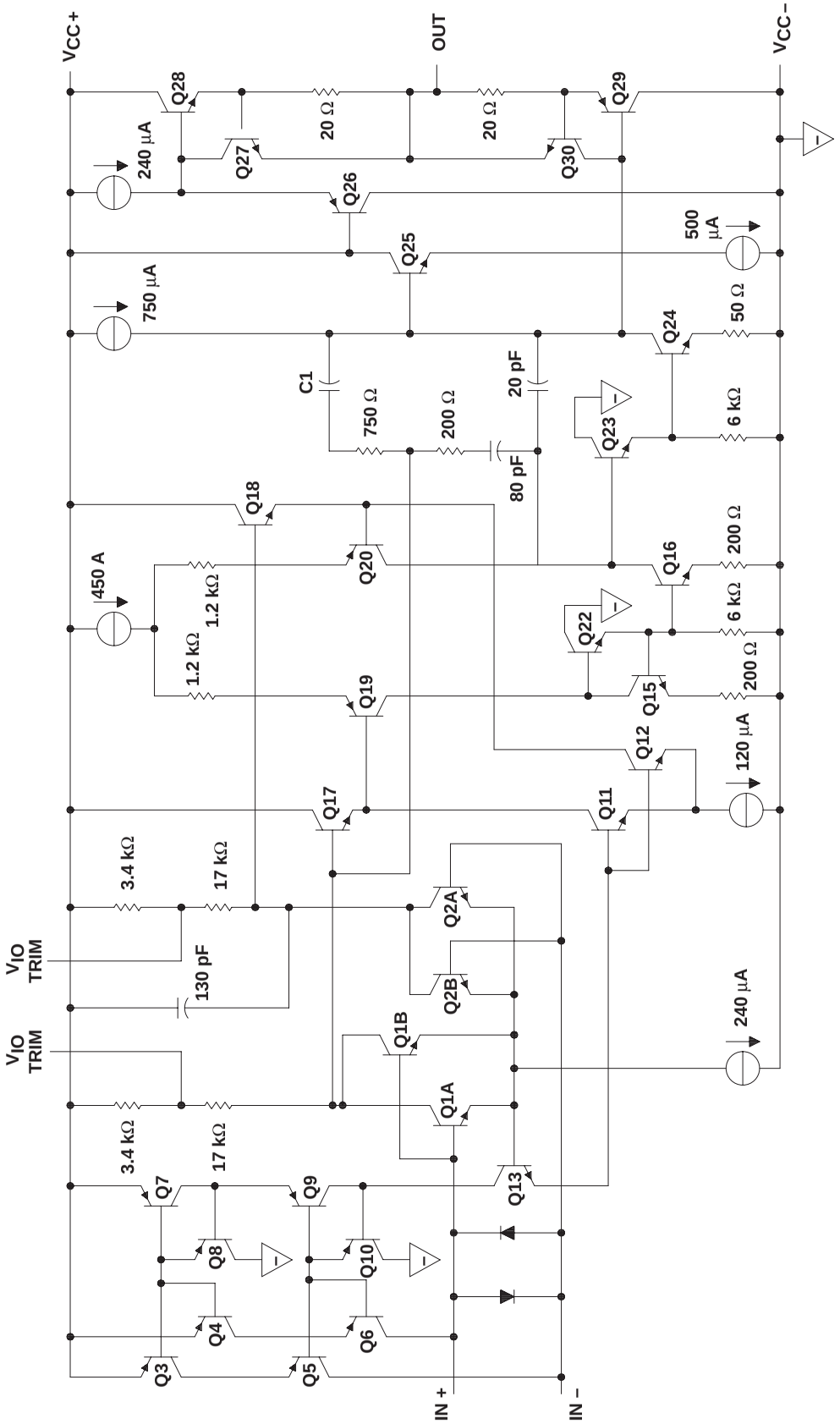
| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | |
|---|---|---|---|---|
| | | SMALL-OUTLINE (DW) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 60 μV | LT1007CDW | — | LT1007CP |
| | 25 μV | — | — | LT1007ACP |
| | 60 μV | LT1037CDW | — | LT1037CP |
| | 25 μV | — | — | LT1037ACP |
| –55°C to 125°C | 60 μV | — | LT1007MJG | LT1007MP |
| | 25 μV | — | LT1007AMJG | LT1007AMP |
| | 60 μV | — | LT1037MJG | LT1037MP |
| | 25 μV | — | LT1037AMJG | LT1037AMP |

The DW packages are available taped and reeled. Add the suffix R to the device type, (e.g.,LT1007CDWR).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 1993, Texas Instruments Incorporated

## schematic




C1 = 110 pF for LT1007
C1 = 12 pF for LT1037
All component values shown are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1) . . . . . 22 V
Supply voltage, $V_{CC-}$ . . . . . –22 V
Input voltage . . . . . $V_{CC\pm}$
Duration of output short circuit . . . . . Unlimited
Differential input current (see Note 2) . . . . . ±25 mA
Power dissipation . . . . . See Dissipation Rating Table
Operating free-air temperature range:
LT1007C, LT1007AC, LT1037C, LT1037AC . . . . . 0°C to 70°C
LT1007M, LT1007AM, LT1037M, LT1037AM . . . . . –55°C to 125°C
Storage temperature range . . . . . –65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: DW and P packages . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . . . 300°C

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. The inputs are protected by back-to-back diodes. Current limiting resistors are not used in order to achieve low noise. Excessive input current will flow if a differential input voltage in excess of approximately ±0.7 V is applied between the inputs, unless some limiting resistance is used.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|
| DW | 1025 mW | 8.2 mW/°C | 656 mW | N/A |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 210 mW |
| P | 1000 mW | 8 mW/°C | 640 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, $V_{CC+}$ | | 4 | 15 | 22 | 4 | 15 | 22 | V |
| Supply voltage, $V_{CC-}$ | | –4 | –15 | –22 | –4 | –15 | –22 | V |
| Input voltage, $V_I$ | $T_A = 25°C$ | ±11 | | | ±11 | | | V |
| | $T_A$ = full range | ±10.5 | | | ±10.3 | | | V |
| Operating free-air temperature, $T_A$ | | 0 | | 70 | –55 | | 125 | °C |

## electrical characteristics, $V_{CC\pm}$ = ±15 V

| PARAMETER | | TEST CONDITIONS | $T_A$ | LT1007C, LT1037C | | | LT1007AC, LT1037AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | See Note 3 | 25°C | | 20 | 60 | | 10 | 25 | µV |
| | | | 0°C to 70°C | | | 110 | | | 50 | |
| $\alpha_{VIO}$ | Average temperature coefficient of input offset voltage | | 0°C to 70°C | | | 1 | | | 0.6 | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 12 | 50 | | 7 | 30 | nA |
| | | | 0°C to 70°C | | | 70 | | | 40 | |
| $I_{IB}$ | Input bias current | | 25°C | | ±15 | ±55 | | ±10 | ±35 | nA |
| | | | 0°C to 70°C | | | ±75 | | | ±45 | |
| $V_{OM}$ | Peak output voltage swing | $R_L$ = 2 kΩ | 25°C | ±12.5 | ±13.5 | | ±13 | ±13.8 | | V |
| | | $R_L$ = 600 Ω | 25°C | ±10.5 | ±12.5 | | ±11 | ±12.5 | | |
| | | $R_L$ = 2 kΩ | 0°C to 70°C | ±12 | | | ±12.5 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $R_L \geq$ 2 kΩ, $V_O$ = ±12 V | 25°C | 5 | 20 | | 7 | 20 | | V/µV |
| | | $R_L \geq$ 1 Ω, $V_O$ = ±10 V | 25°C | 3.5 | 16 | | 5 | 16 | | |
| | | $R_L \geq$ 600 Ω, $V_O$ = ±10 V | 25°C | 2 | 12 | | 3 | 12 | | |
| | | $R_L \geq$ 2 kΩ, $V_O$ = ±10 V | 0°C to 70°C | 2.5 | | | 4 | | | |
| | | $R_L \geq$ 1 kΩ, $V_O$ = ±10 V | 0°C to 70°C | 2 | | | 2.5 | | | |
| $r_{i(CM)}$ | Common-mode input resistance | | 25°C | | 5 | | | 7 | | GΩ |
| $r_o$ | Open-loop output resistance | | 25°C | | 70 | | | 70 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = ±11 V | 25°C | 110 | 126 | | 117 | 130 | | dB |
| | | $V_{IC}$ = ±10.5 V | 0°C to 70°C | 106 | | | 114 | | | |
| $k_{SVR}$ | Supply voltage rejection ratio | $V_{CC\pm}$ = ±4 V to ±18 V | 25°C | 106 | 126 | | 110 | 130 | | dB |
| | | $V_{CC\pm}$ = ±4.5 V to ±18 V | 0°C to 70°C | 102 | | | 106 | | | |
| $P_D$ | Power dissipation | LT1007C, LT1007AC | 25°C | | 80 | 140 | | 80 | 120 | mW |
| | | LT1037C, LT1037AC | 25°C | | 85 | 140 | | 80 | 130 | |
| | | | 0°C to 70°C | | | 160 | | | 144 | |

NOTE 3: $V_{IO}$ measurements are performed by automatic test equipment approximately 0.5 seconds after application of power.

## electrical characteristics, $V_{CC\pm}$ = ±15 V

| PARAMETER | | TEST CONDITIONS | $T_A$ | LT1007M, LT1037M | | | LT1007AM, LT1037AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | See Note 3 | 25°C | | 20 | 60 | | 10 | 25 | µV |
| | | | –55°C to 125°C | | | 160 | | | 60 | |
| $\alpha_{VIO}$ | Average temperature coefficient of input offset voltage | | –55°C to 125°C | | | 1 | | | 0.6 | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 12 | 50 | | 7 | 30 | nA |
| | | | –55°C to 125°C | | | 85 | | | 50 | |
| $I_{IB}$ | Input bias current | | 25°C | | ±15 | ±55 | | ±10 | ±35 | nA |
| | | | –55°C to 125°C | | | ±95 | | | ±60 | |
| $V_{OM}$ | Peak output voltage swing | $R_L$ = 2 kΩ | 25°C | ±12.5 | ±13.5 | | ±13 | ±13.8 | | V |
| | | $R_L$ = 600 Ω | 25°C | ±10.5 | ±12.5 | | ±11 | ±12.5 | | |
| | | $R_L$ = 2 kΩ | –55°C to 125°C | ±12 | | | ±12.5 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $R_L \geq$ 2 kΩ, $V_O$ = ±12 V | 25°C | 5 | 20 | | 7 | 20 | | V/µV |
| | | $R_L \geq$ 1 kΩ, $V_O$ = ±10 V | 25°C | 3.5 | 16 | | 5 | 16 | | |
| | | $R_L \geq$ 600 Ω, $V_O$ = ±10 V | 25°C | 2 | 12 | | 3 | 12 | | |
| | | $R_L \geq$ 2 kΩ, $V_O$ = ±10 V | –55°C to 125°C | 2 | | | 3 | | | |
| | | $R_L \geq$ 1 kΩ, $V_O$ = ±10 V | –55°C to 125°C | 1.5 | | | 2 | | | |
| $r_{i(CM)}$ | Common-mode input resistance | | 25°C | | 5 | | | 7 | | GΩ |
| $r_o$ | Open-loop output resistance | | 25°C | | 70 | | | 70 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = ±11 V | 25°C | 110 | 126 | | 117 | 130 | | dB |
| | | $V_{IC}$ = ±10.3 V | –55°C to 125°C | 104 | | | 112 | | | |
| $k_{SVR}$ | Supply voltage rejection ratio | $V_{CC\pm}$ = ±4 V to ±18 V | 25°C | 106 | 126 | | 110 | 130 | | dB |
| | | $V_{CC\pm}$ = ±4.5 V to ±18 V | –55°C to 125°C | 100 | | | 104 | | | |
| $P_D$ | Power dissipation | LT1007M, LT1007AM | 25°C | | 80 | 140 | | 80 | 120 | mW |
| | | LT1037M, LT1037AM | 25°C | | 85 | 140 | | 80 | 130 | |
| | | | –55°C to 125°C | | | 170 | | | 150 | |

NOTE 3: $V_{IO}$ measurements are performed by automatic test equipment approximately 0.5 seconds after application of power.

## operating characteristics, $V_{CC\pm}$ = ±15 V, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | LT1007, LT1007A | | | LT1007, LT1007A | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate | $R_L \geq 2$ kΩ, $A_{VD} \geq 1$ (LT1007, LT1007A) | 1.7 | 2.5 | | 11 | 15 | | V/μs |
| | | $R_L \geq 2$ kΩ, $A_{VD} \geq 5$ (LT1037, LT1037A) | | | | | | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz, See Note 4 | | 0.06 | 0.13 | | 0.06 | 0.13 | μV |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | | 2.8 | 4.5 | | 2.8 | 4.5 | nV/√Hz |
| | | f = 1 kHz | | 2.5 | 3.8 | | 2.5 | 3.8 | |
| $I_n$ | Equivalent input noise current | f = 10 kHz, See Note 5 | | 1.5 | 4 | | 1.5 | 4 | pA/√Hz |
| | | f = 1 kHz, See Note 5 | | 0.4 | 0.6 | | 0.4 | 0.6 | |
| GBW | Gain bandwidth product | f = 100 kHz | 5 | 8 | | | | | MHz |
| | | f = 10 kHz, $A_V \geq 15$ | | | | 45 | 60 | | |

NOTES: 4. See the test circuit and frequency response curve for 0.1-Hz to 10-Hz noise (Figure 39) in the Applications Information section.
5. See the test circuit for current noise measurement (Figure 40) in the Applications Information section.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | vs Temperature | 1 |
| $\Delta V_{IO}$ | Change in input offset voltage | vs Time after power on<br>vs Time (long-term stability) | 2<br>3 |
| $I_{IO}$ | Input offset current | vs Temperature | 4 |
| $I_{IB}$ | Input bias current | vs Temperature<br>over common-mode range | 5<br>6 |
| | Common-mode limit voltage | vs Free-air temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage swing | vs Load resistance<br>vs Frequency | 8<br>9 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency<br>vs Frequency (LT1007)<br>vs Frequency (LT1037)<br>vs Temperature<br>vs Load resistance<br>vs Supply voltage<br>at 2 kΩ and 600 Ω | 10<br>11<br>12<br>13<br>14<br>15<br>16 |
| $V_{ID}$ | Differential input voltage | vs Output voltage | 16 |
| CMRR | Common-mode rejection ratio | vs Frequency | 17 |
| $k_{SVR}$ | Supply voltage rejection ratio | vs Frequency | 18 |
| SR | Slew rate | vs Free-air temperature (LT1007)<br>vs Free-air temperature (LT1037) | 19<br>20 |
| $\phi$ | Phase shift | vs Frequency (LT1007)<br>vs Frequency (LT1037) | 11<br>12 |
| $\phi_m$ | Phase margin | vs Free-air temperature (LT1007)<br>vs Free-air temperature (LT1037) | 19<br>20 |
| $V_n$ | Equivalent input noise voltage | vs Free-air temperature<br>vs Time (0.01-Hz to 1-Hz noise)<br>vs Frequency<br>vs Bandwidth<br>vs Supply voltage | 21<br>22<br>23<br>24<br>25 |
| $I_n$ | Equivalent input noise current<br>Total noise | vs Frequency<br>vs Source resistance | 26<br>27 |
| GBW | Gain bandwidth product | vs Free-air Temperature (LT1007)<br>vs Free-air Temperature (LT1037) | 19<br>20 |
| $I_{OS}$ | Short-circuit output current | vs Time (from short to GND) | 28 |
| $I_{CC}$ | Supply current | vs Supply voltage | 29 |
| $z_o$ | Closed-loop output impedance | vs Frequency | 30 |
| | Pulse response (LT1037) | Small-signal ($C_L$ = 15 pF)<br>Large-signal | 31<br>32 |
| | Pulse response (LT1007) | Small-signal ($C_L$ = 15 pF)<br>Large-signal | 33<br>34 |

## TYPICAL CHARACTERISTICS†

**INPUT OFFSET VOLTAGE OF REPRESENTATIVE UNITS vs FREE-AIR TEMPERATURE**

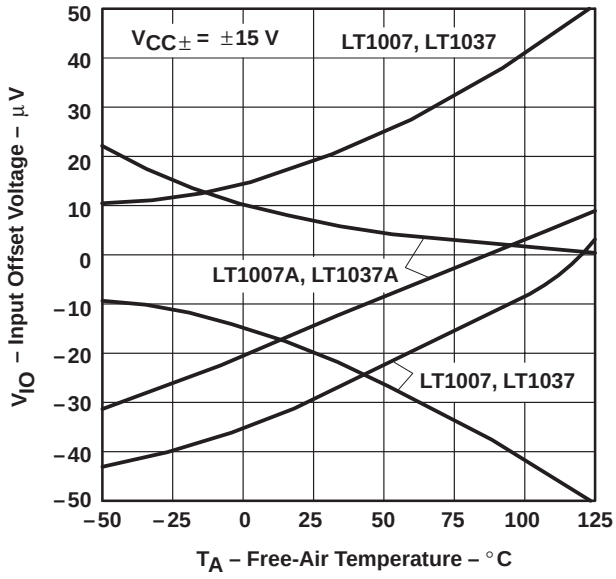



Figure 1

**INPUT OFFSET VOLTAGE vs TIME AFTER POWER ON**

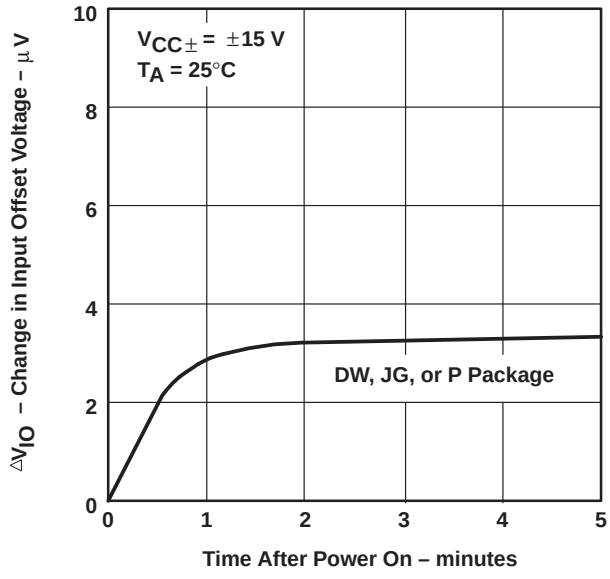



Figure 2

**LONG TERM STABILITY OF INPUT OFFSET VOLTAGE FOR FOUR REPRESENTATIVE UNITS**

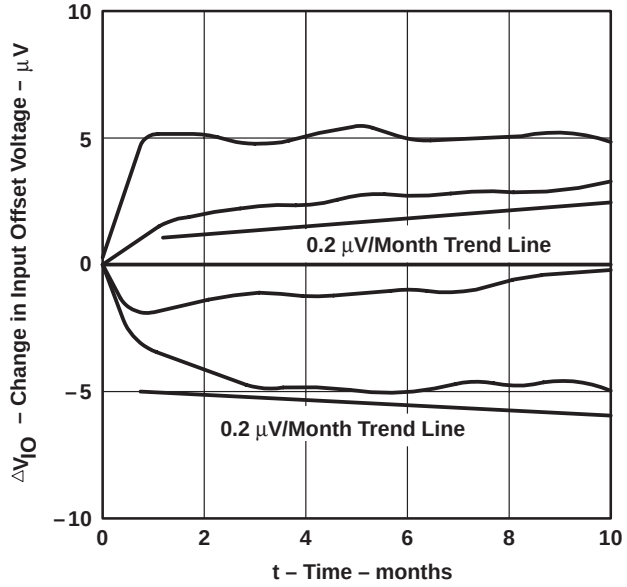



Figure 3

**INPUT OFFSET CURRENT vs TEMPERATURE**

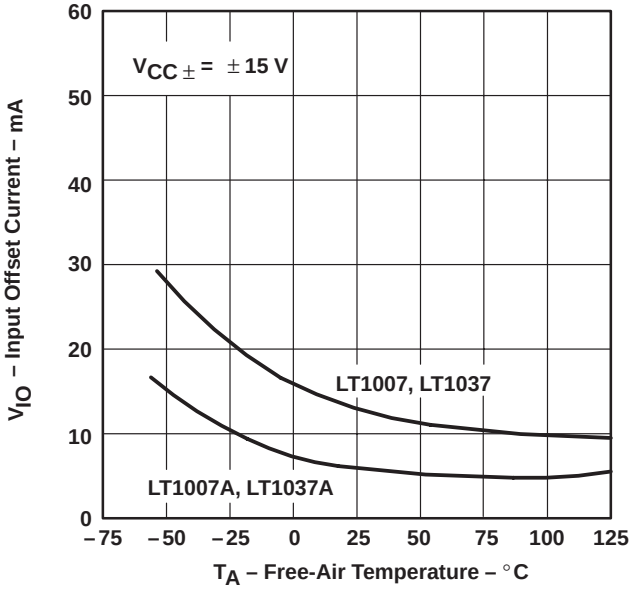



Figure 4

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE**

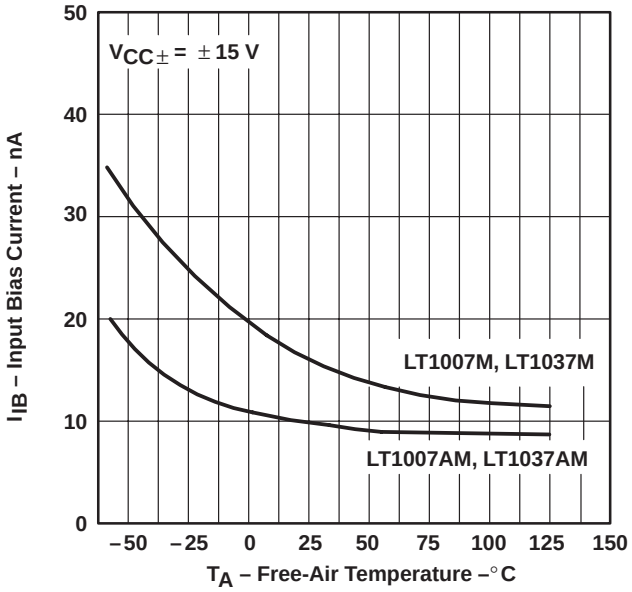



Figure 5

**INPUT BIAS CURRENT vs COMMON-MODE INPUT VOLTAGE**

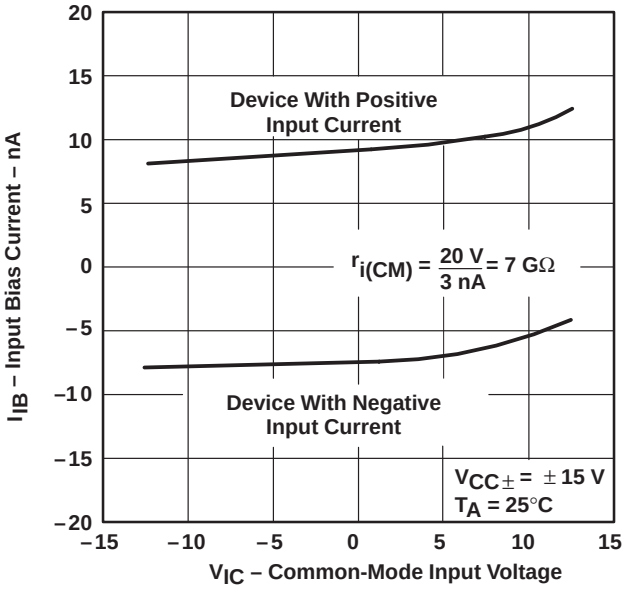



Figure 6

**COMMON-MODE INPUT VOLTAGE RANGE LIMITS vs FREE-AIR TEMPERATURE**

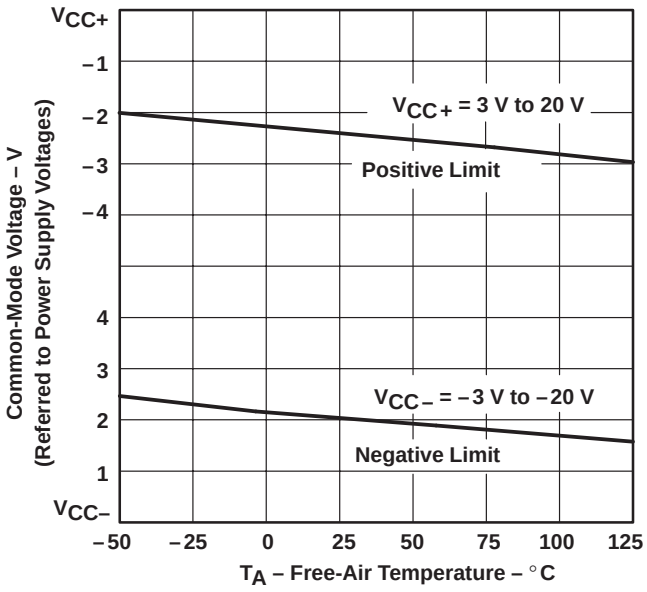



Figure 7

**PEAK OUTPUT VOLTAGE SWING vs LOAD RESISTANCE**

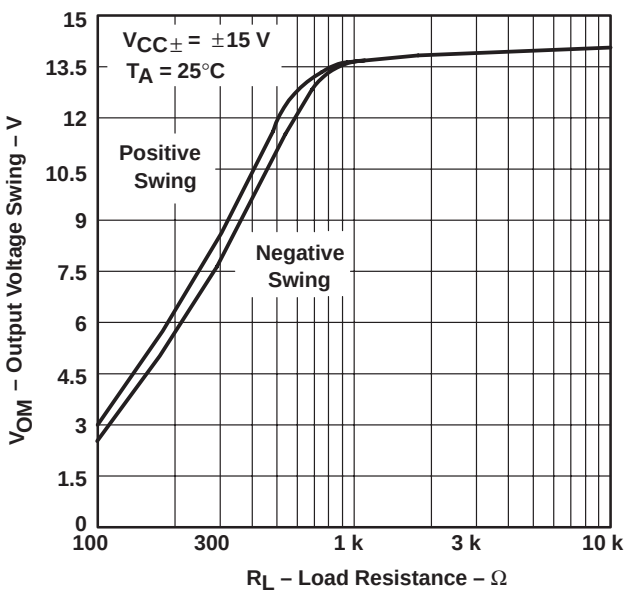



Figure 8

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

**PEAK-TO-PEAK OUTPUT VOLTAGE SWING vs FREQUENCY**

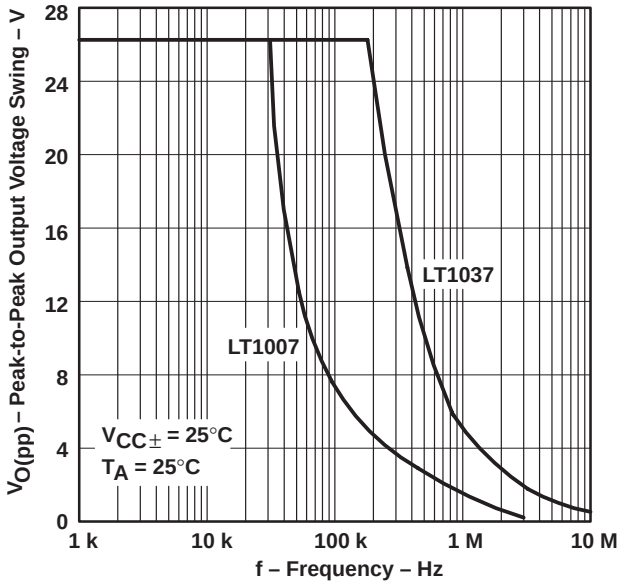



**Figure 9**

**DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY**

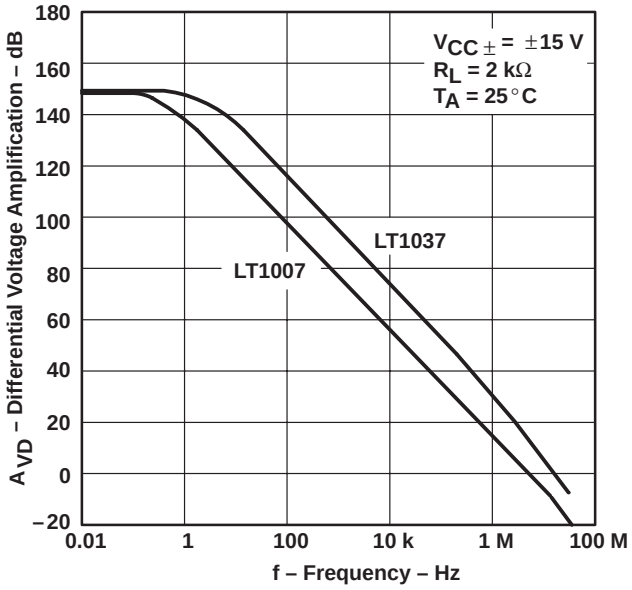



**Figure 10**

**LT1007**
**DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY**

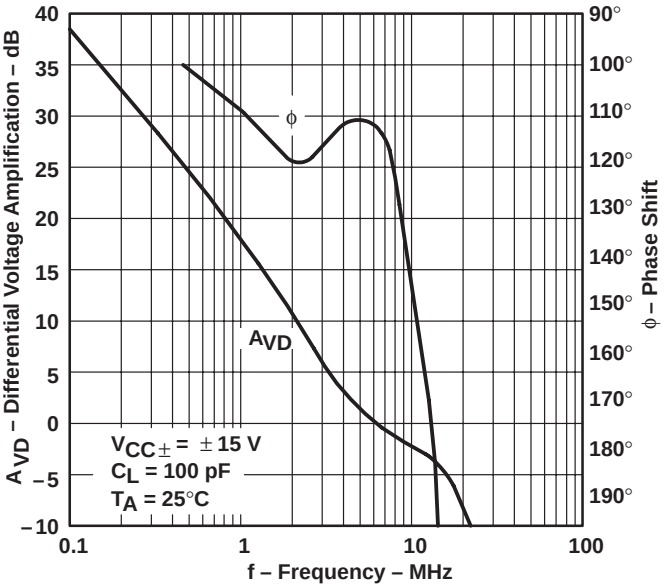



**Figure 11**

**LT1037**
**DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY**

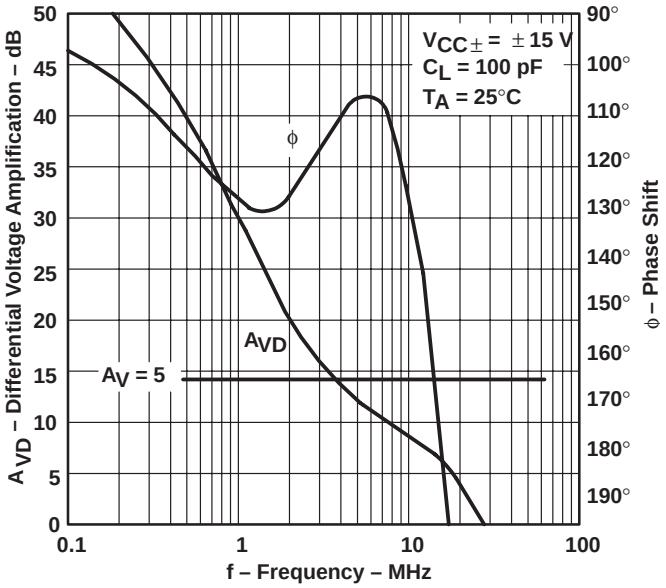



**Figure 12**

## TYPICAL CHARACTERISTICS†

**DIFFERNTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE**

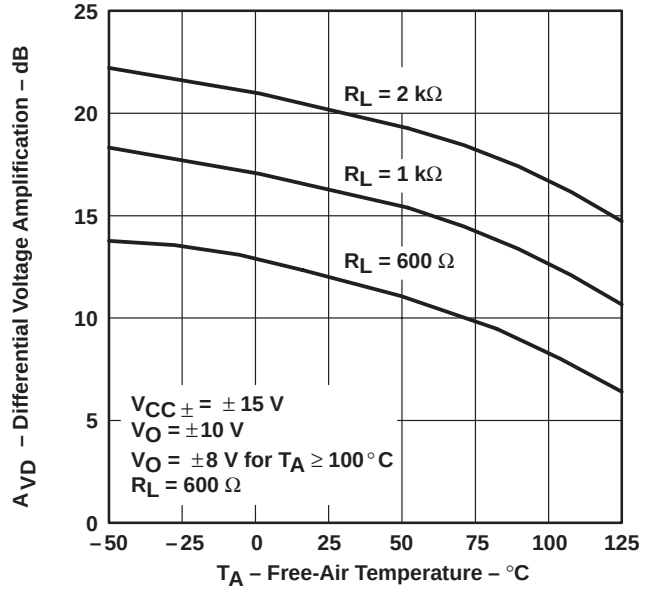



Figure 13

**DIFFERNTIAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE**

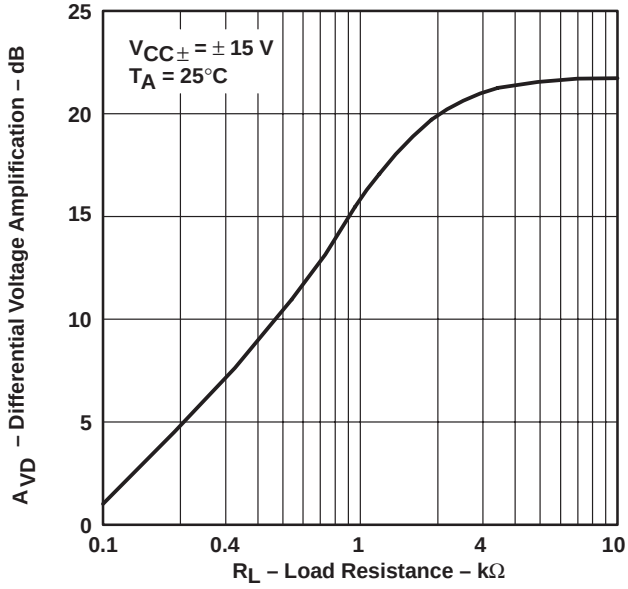



Figure 14

**DIFFERNTIAL VOLTAGE AMPLIFICATION vs SUPPLY VOLTAGE**

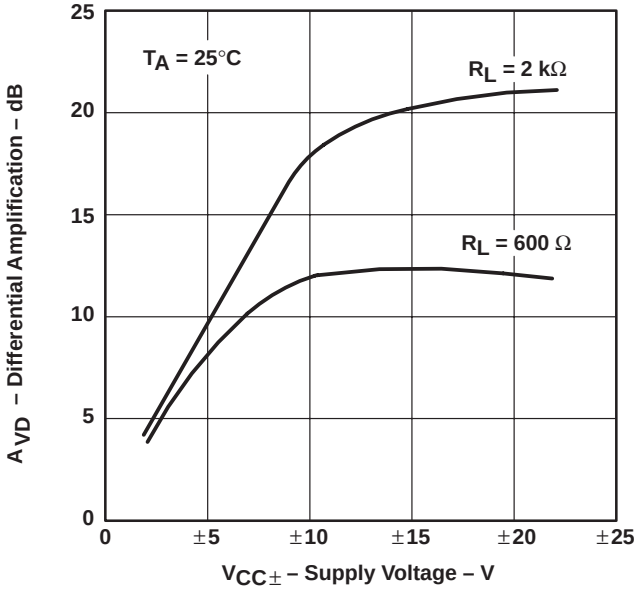



Figure 15

**DIFFERNTIAL INPUT VOLTAGE vs OUTPUT VOLTAGE**

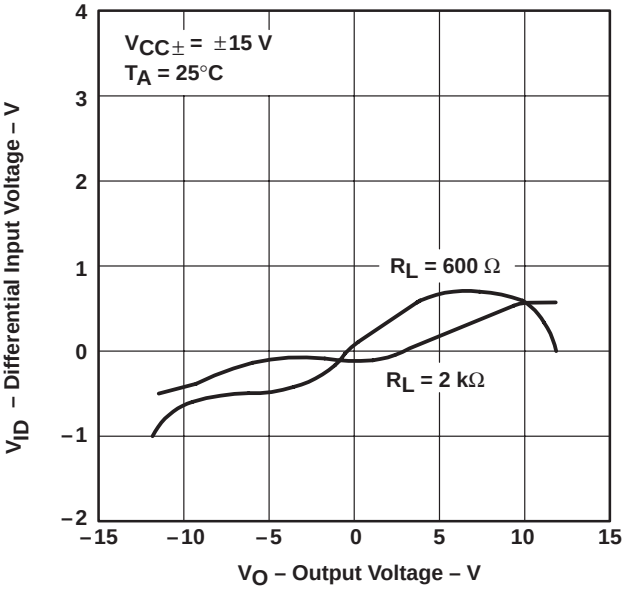



Figure 16

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

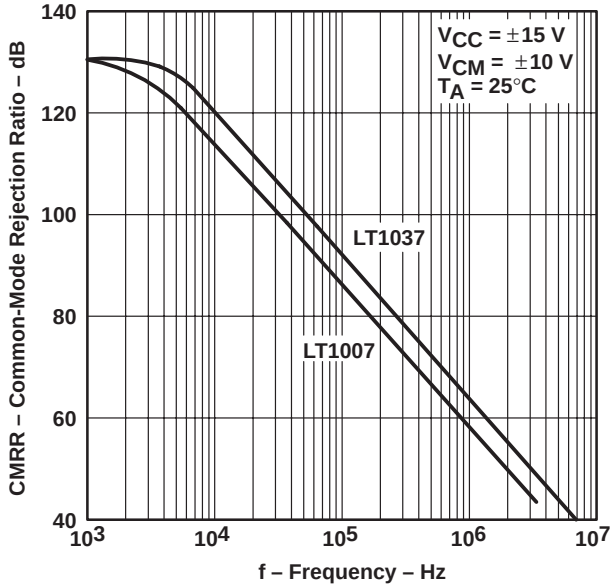



Figure 17

**SUPPLY VOLTAGE REJECTION RATIO vs FREQUENCY**

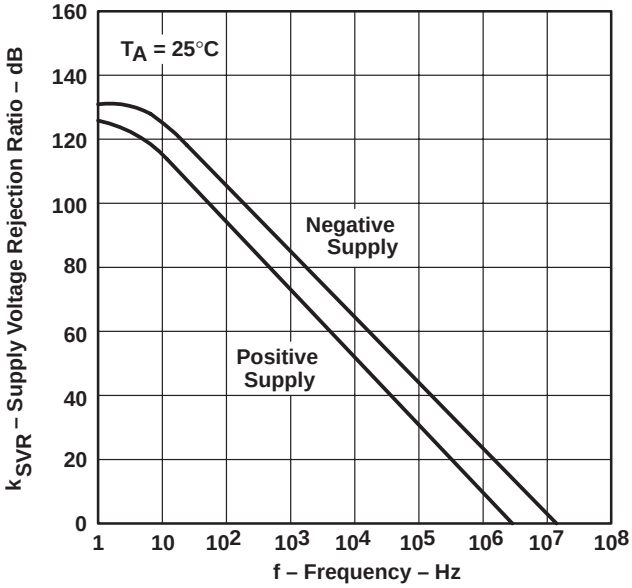



Figure 18

**LT1007**
**SLEW RATE, PHASE MARGIN AND GAIN BANDWIDTH PRODUCT vs FREE-AIR TEMPERATURE**

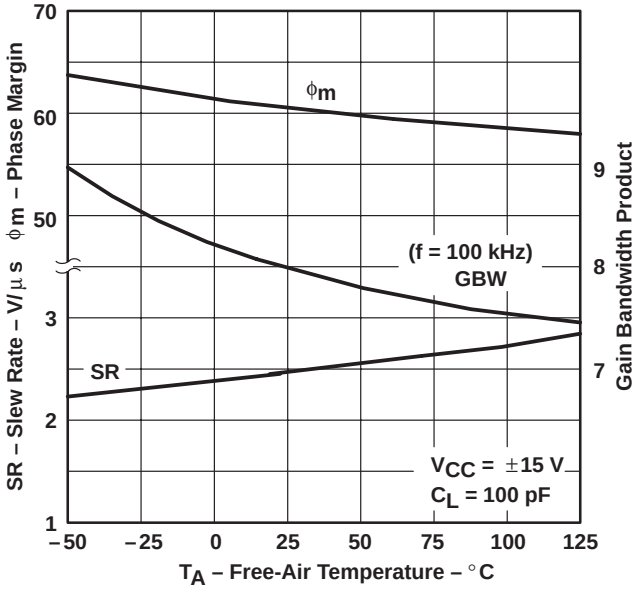



Figure 19

**LT1037**
**SLEW RATE, PHASE MARGIN AND GAIN BANDWIDTH PRODUCT vs FREE-AIR TEMPERATURE**

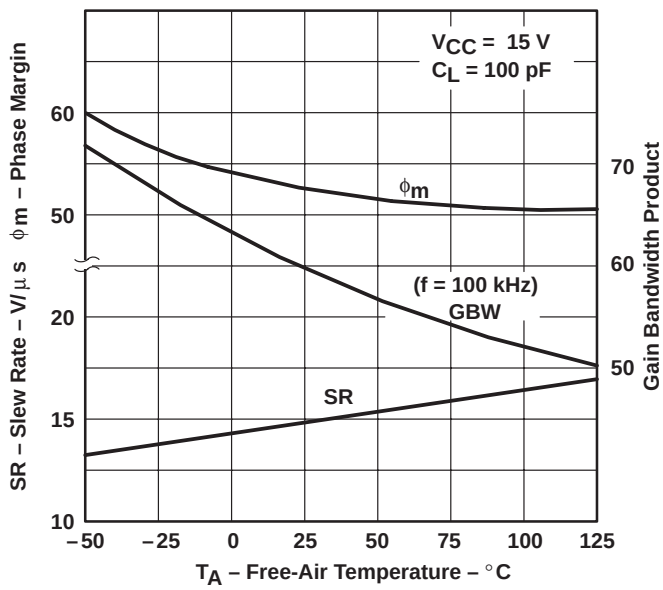



Figure 20

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**EQUIVALENT INPUT NOISE VOLTAGE vs FREE-AIR TEMPERATURE**

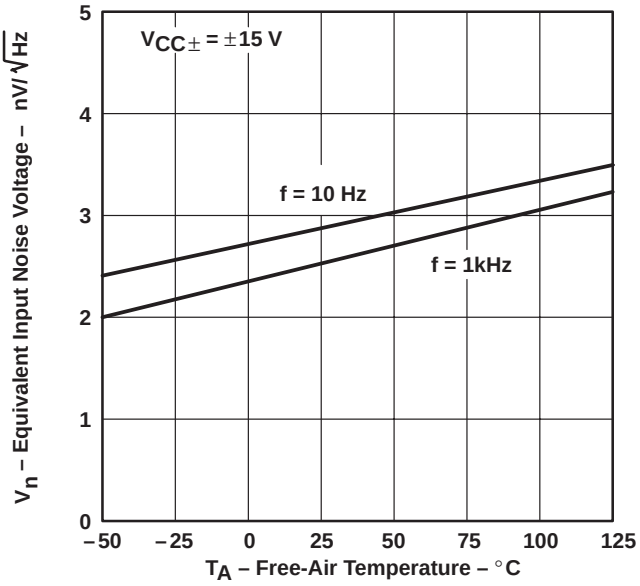



Figure 21

**EQUIVALENT INPUT NOISE VOLTAGE OVER A 100-SECOND TIME PERIOD**

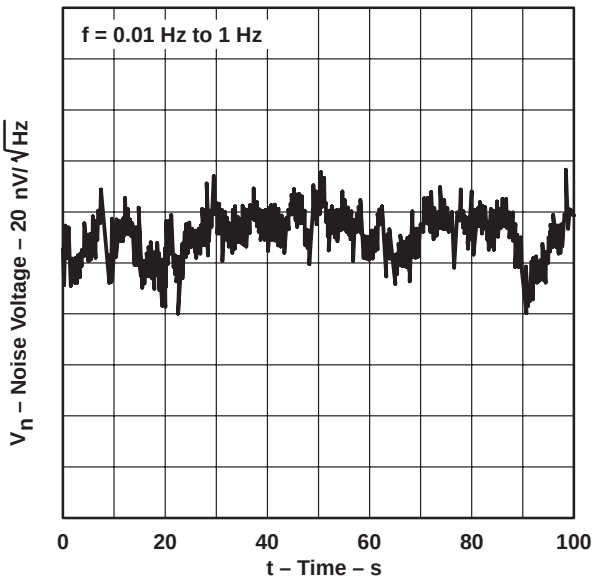



Figure 22

**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**

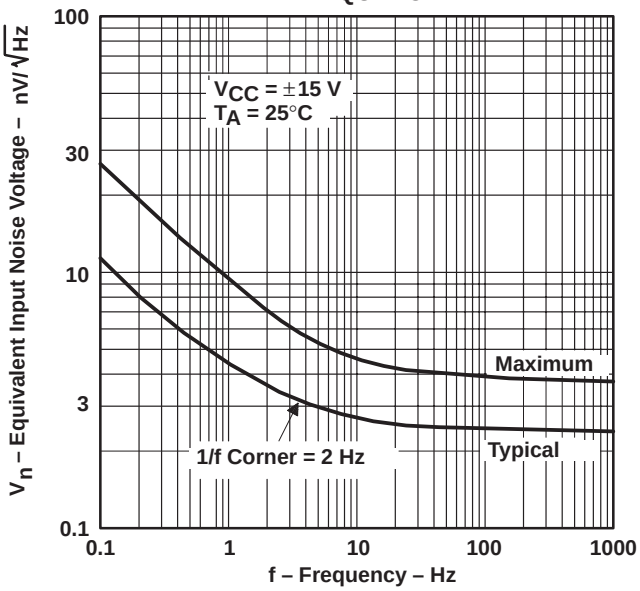



Figure 23

**BROADBAND NOISE VOLTAGE 0.1 Hz TO INDICATED FREQUENCY**

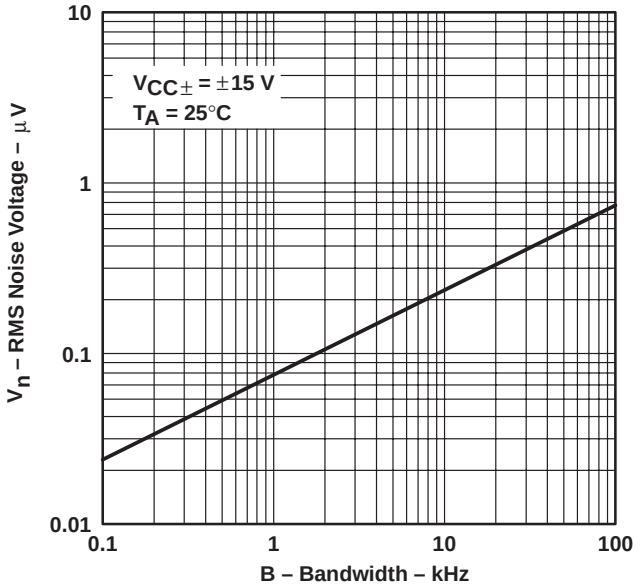



Figure 24

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**EQUIVALENT INPUT NOISE VOLTAGE vs SUPPLY VOLTAGE**

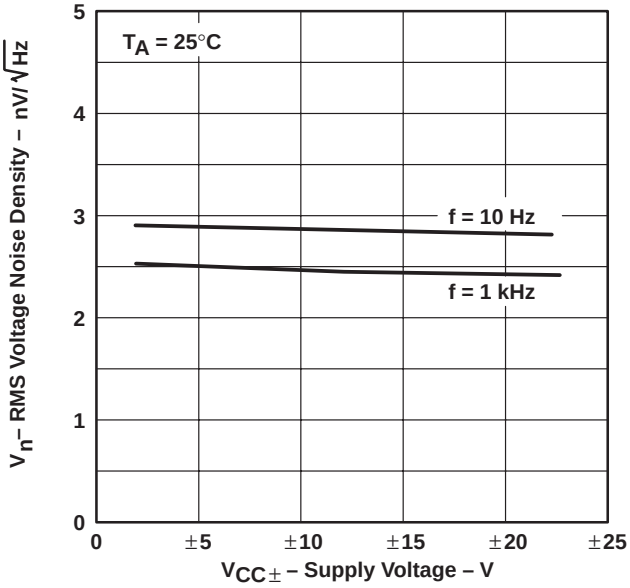



Figure 25

**EQUIVALENT INPUT NOISE CURRENT vs FREQUENCY**

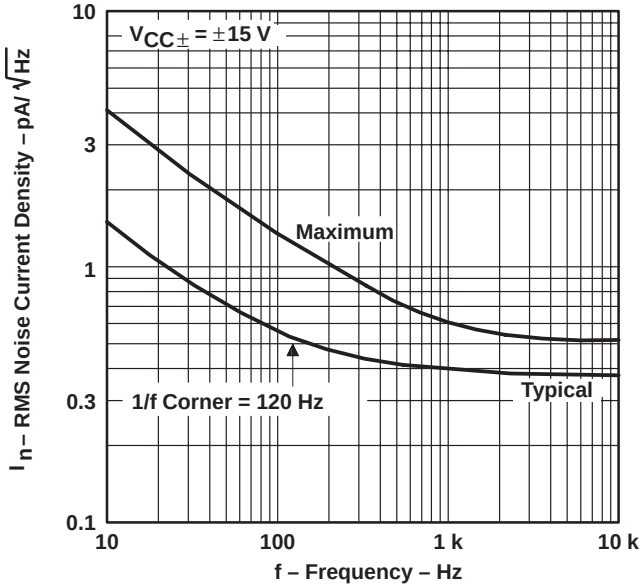



Figure 26

**TOTAL NOISE VOLTAGE vs SOURCE RESISTANCE**

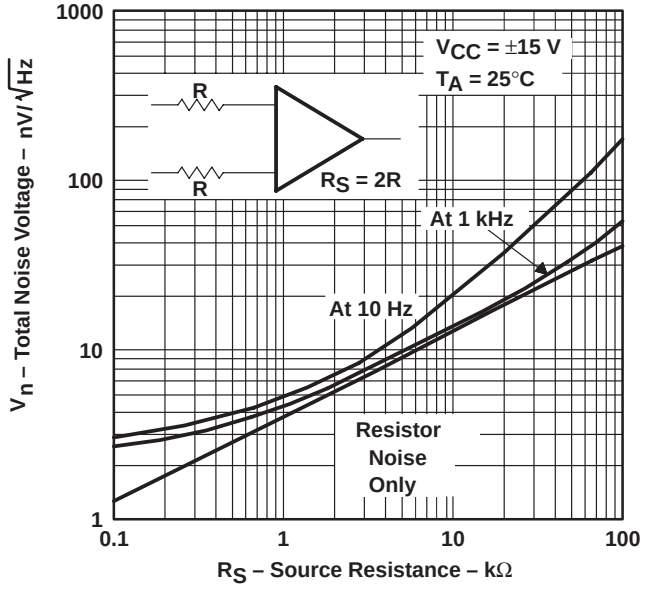



Figure 27

**SHORT-CIRCUIT OUTPUT CURRENT vs ELAPSED TIME**

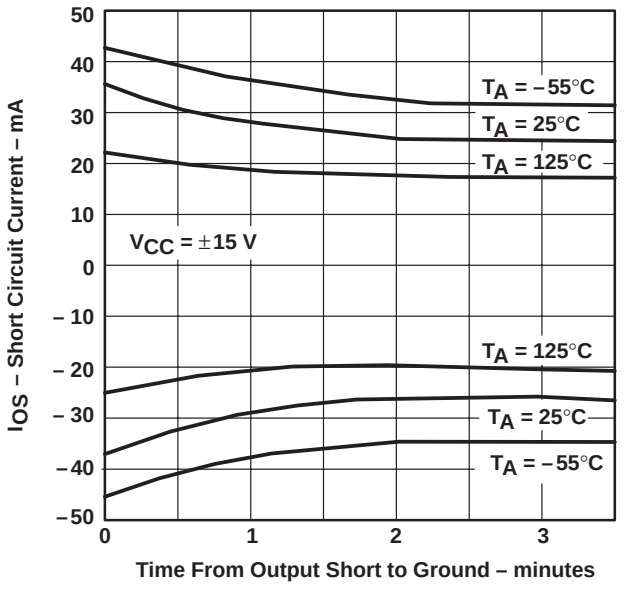



Figure 28

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**SUPPLY CURRENT vs SUPPLY VOLTAGE**

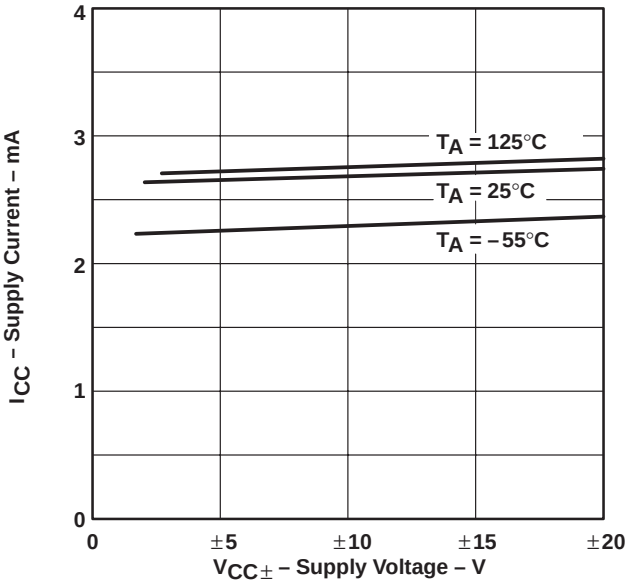



Figure 29

**CLOSED-LOOP OUTPUT IMPEDANCE vs FREQUENCY**

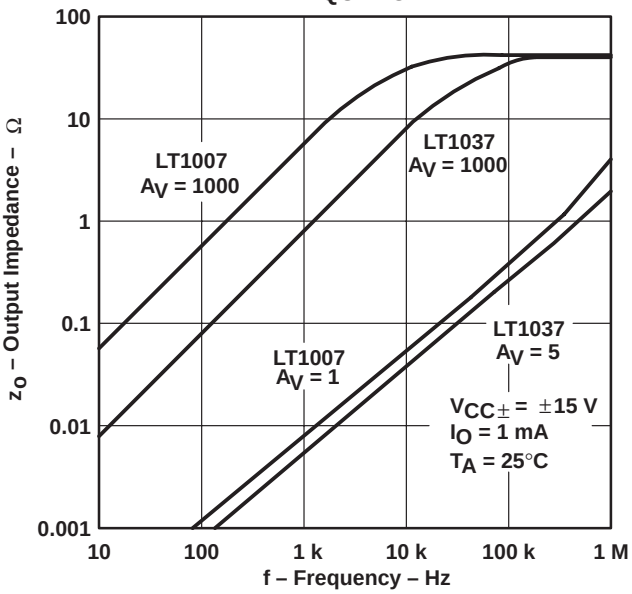



Figure 30

**LT1037 VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE**

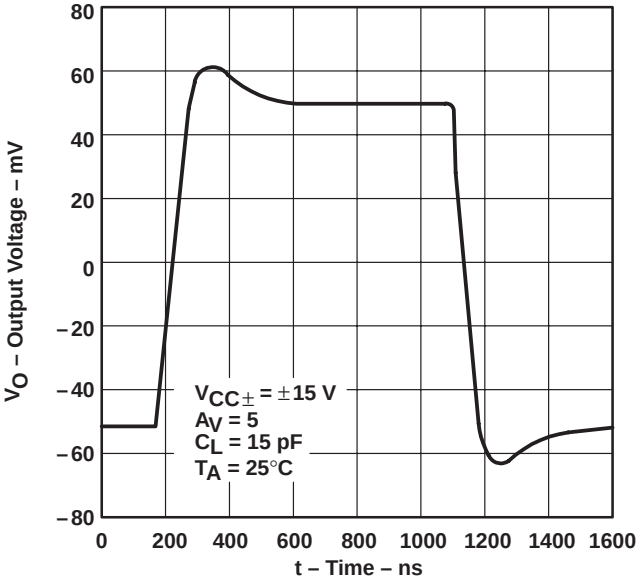



Figure 31

**LT1037 VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE**

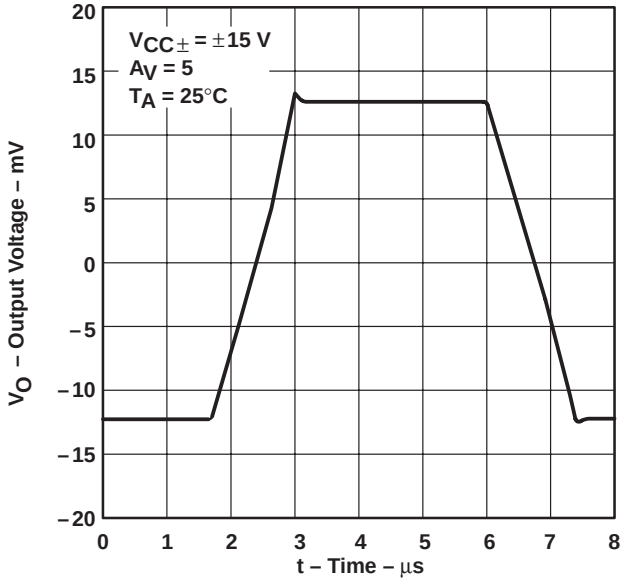



Figure 32

† Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

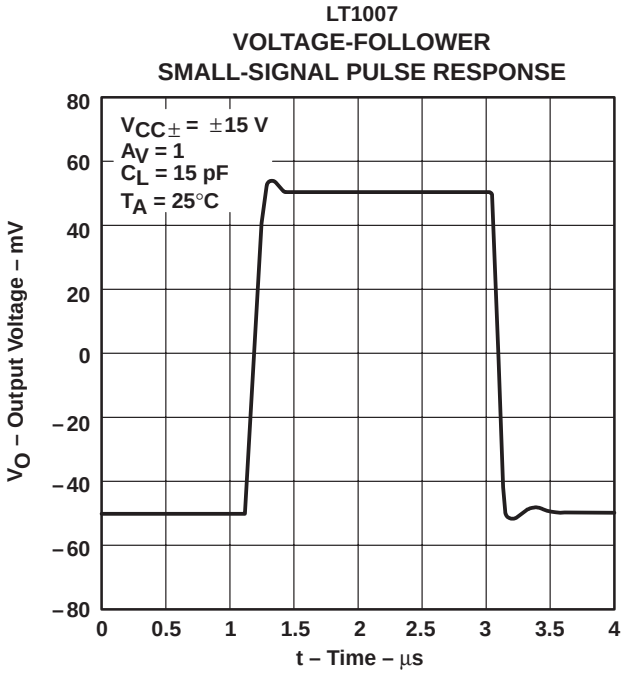



Figure 33

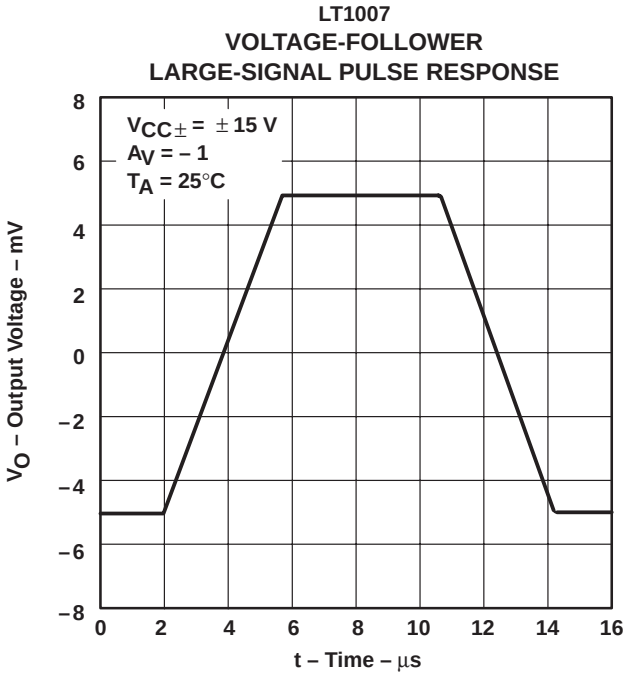



Figure 34

## APPLICATION INFORMATION

### general

The LT1007- and LT1037-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 and LT1037 may be fitted to μA741 sockets by removing or modifying external nulling components.

### offset voltage adjustment

The input offset voltage and its change with temperature of the LT1007 and LT1037 are permanently trimmed to a low level at wafer testing . However, if further adjustment of $V_{IO}$ is necessary, the use of a 10-kΩ nulling potentiometer, as shown in Figure 35, will not degrade drift with temperature. Trimming to a value other than zero creates a drift of $V_{IO}$/300 μV/°C (e.g., if $V_{IO}$ is adjusted to 300 μV, the change in temperature coefficient will be 1 μV/°C).

The adjustment range with a 10-kΩ potentiometer is approximately ±2.5 mV. If a smaller adjustment range is needed, the sensitivity and resolution of the nulling can be improved by using a smaller potentiometer in conjunction with fixed resistors. The example in Figure 36 has an approximate null range of ±200 μV.

### offset voltage and drift

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

## APPLICATION INFORMATION

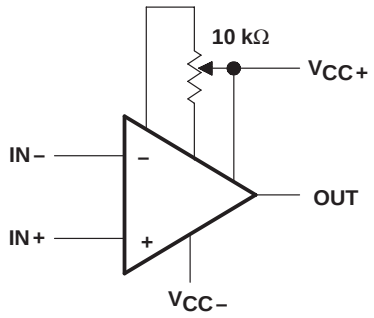



**Figure 35. Standard Adjustment**

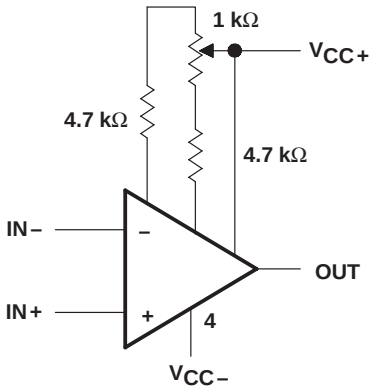


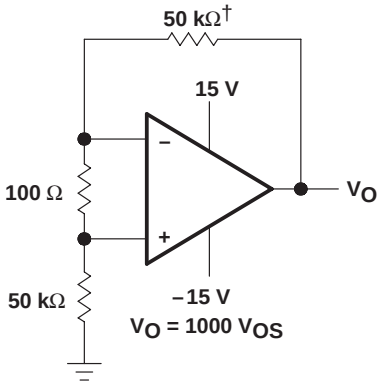

**Figure 36. Improved Sensitivity Adjustment**

The circuit shown in Figure 37 can be used to measure offset voltage. In addition, with the supply voltages increased to ± 20 V, it can be used as the burn-in configuration for the LT1007 and LT1037.

When $R_F \leq 100\ \Omega$ and the input is driven with a fast large-signal pulse (> 1 V), the output waveform will be as shown in Figure 38.

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, is drawn by the signal generator. When $R_F$ is $\geq 500\ \Omega$, the output is capable of handling the current requirements ($I_L \leq 20$ mA at 10 V), the amplifier stays in its active mode, and a smooth transition occurs.

When $R_F$ is > 2 kΩ, 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 (20 pF to 50 pF) in parallel with $R_F$ will eliminate this problem.




† Resistors must have low thermoelectric potential

**Figure 37. Test Circuit for Offset Voltage and Offset Voltage Drift With Temperature**

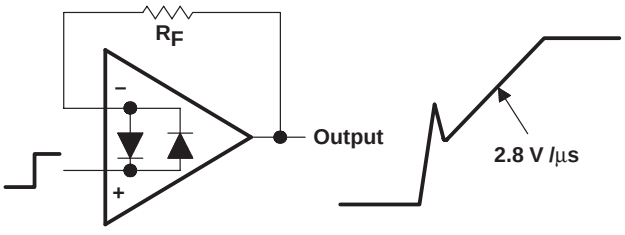
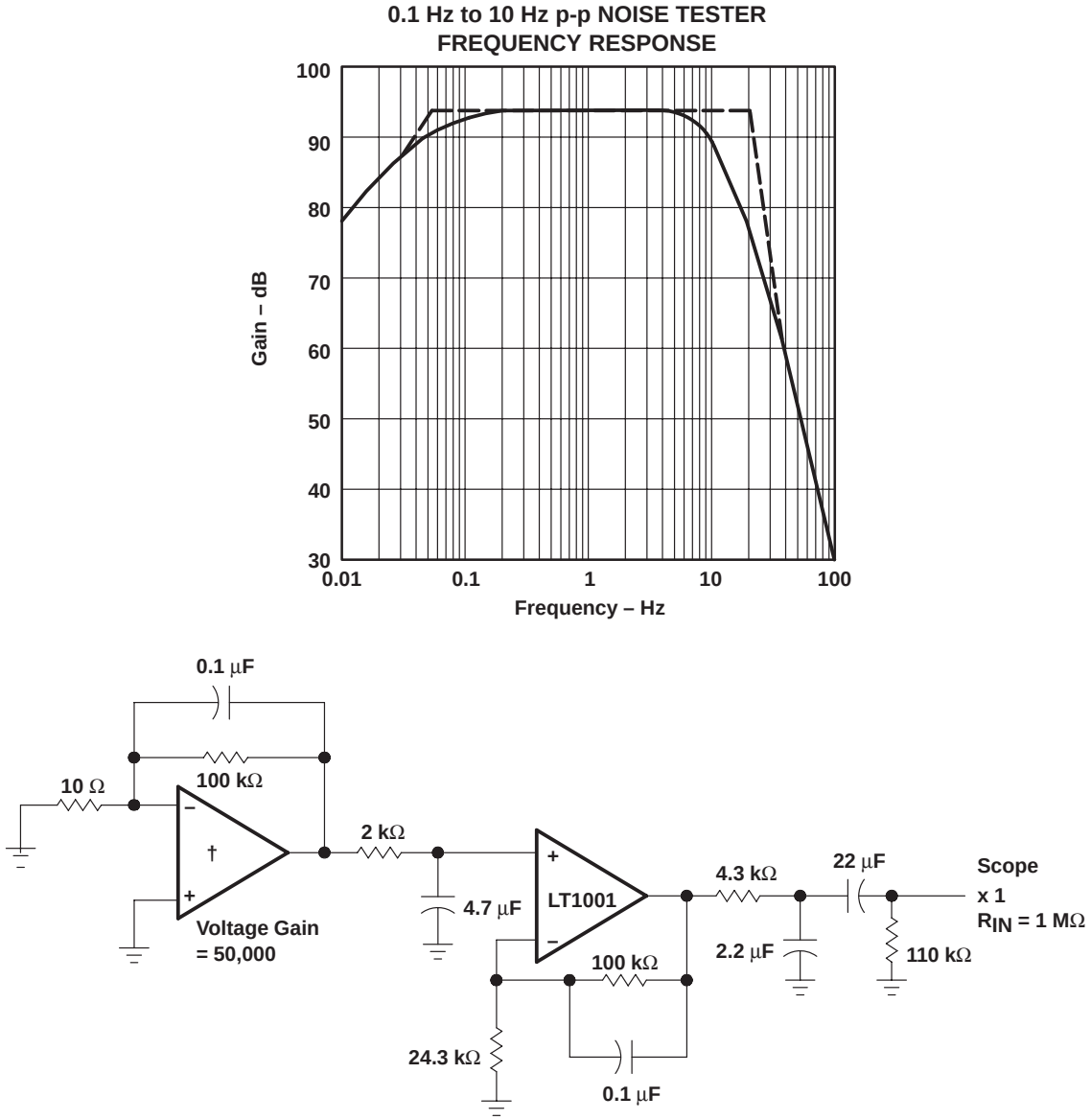



**Figure 38. Pulse Operation**

## APPLICATION INFORMATION

### noise testing

Figure 39 shows a test circuit for 0.1-Hz to 10-Hz peak-to-peak noise measurement of the LT1007 and LT1037. The frequency response of this noise tester indicates that eeethe 0.1 Hz corner is defined by only one zero. Because the time limit acts as an additional zero to eliminate noise contributions from the frequency band below 0.1 Hz, the test time to measure 0.1-Hz to 10-Hz noise should not exceed 10 seconds.




† Device under test
NOTE: All capacitor values are for non-polarized capacitors only.

**Figure 39. 0.1-Hz To 10-Hz Noise Test Circuit**

## APPLICATION INFORMATION

Special test precautions are required to measure the typical 60-nV peak-to-peak noise performance of the LT1007 and LT1037:

1. The device should be warmed up for at least five minutes. As the operational amplifier warms up, the offset voltage typically changes 3 μV, due to the 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.
2. The device must be well shielded from air currents to eliminate thermoelectric effects. In excess of a few nanovolts, thermoelectric effects would invalidate the measurements.
3. Sudden motion in the vicinity of the device can produce a feedthrough effect that increases observed noise.

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

Figure 40 shows a circuit that measures noise current and presents the formula for calculating noise current.

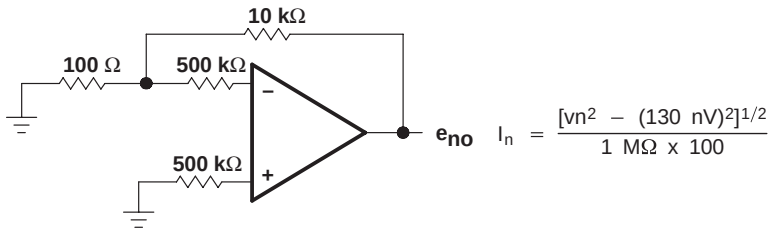



**Figure 40. Noise Test Circuit**

The LT1007 and LT1037 achieve low noise, in part, by operating the input stage at 120 μA versus the typical 10 μA for most other operational amplifiers. Voltage noise is directly proportional to the square root of the stage current; therefore, the LT1007 and LT1037 noise current is relatively high. At low frequencies, the low 1/f current-noise corner frequency (≈120 Hz) minimizes noise current to some extent.

In most practical applications, however, noise current will not limit system performance; this is illustrated in Figure 27, where:

$$\text{total noise} = [(\text{noise voltage})^2(\text{noise current} \times R_S)^2 + (\text{resistor noise})^2]^{1/2}$$

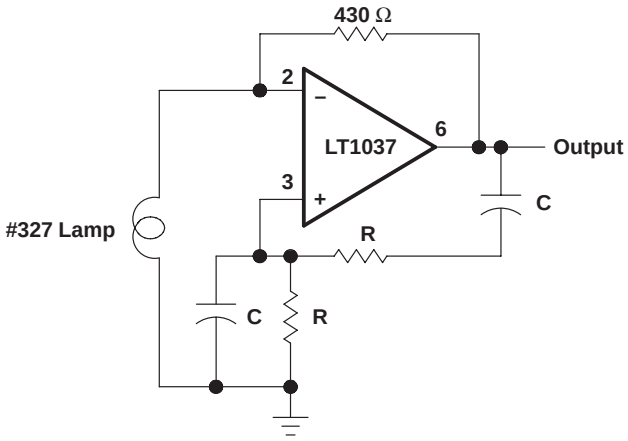
Three regions can be identified as a function of source resistance:

| | | |
|---|---|---|
| (i) | $R_S \leq 400\ \Omega$ | Voltage noise dominates in region (i) |
| (ii) | $R_S = 400\ \Omega$ to 50 kΩ at 1 kHz<br>$R_S = 400\ \Omega$ to 8 kΩ at 10 kHz | Resistor noise dominates in region (ii) |
| (iii) | $R_S > 50\ \Omega$ at 1 kHz<br>$R_S > 8$ kΩ at 10 Hz | Current noise dominates in region (iii) |

The LT1007 and LT1037 should not be used in region (iii) where total system noise is at least six times higher than the noise voltage of the operational amplifier (i.e., the low-voltage noise specification is completely wasted).

## APPLICATION INFORMATION

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




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

R =1591.5Ω ±0.1 %
C = 0.1 μF ±0.1 %

TOTAL HARMONIC DISTORTION ≤ 0.0025%
NOISE ≤ 0.001%
AMPLITUDE = ±8 V
OUTPUT FREQUENCY = 1.000 kHz FOR VALUES GIVEN ±0.4%

**Figure 41. Ultra-Pure 1-kHz Sine-Wave Generator**

**EQUIVALENT INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD**

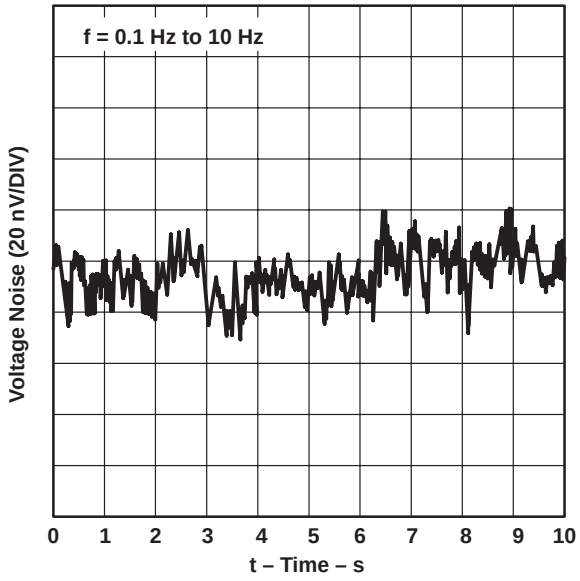
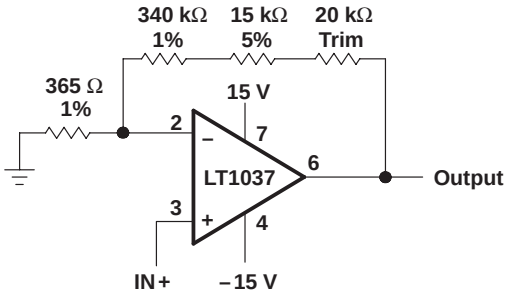



**Figure 42**




RN60C Film Resistors

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 operational amplifier may have an open loop gain of one million with 500 kHz bandwidth. As the gain error plot shows, this device is capable of 0.1% amplifying accuracy up to 0.3 Hz only. Even instrumentation range signals can vary at a faster rate. The LT1037's gain precision – bandwidth product is 200 times higher, as shown.

**Figure 43. Gain 1000 Amplifier With 0.01% Accuracy, DC to 5 Hz**

## APPLICATION INFORMATION

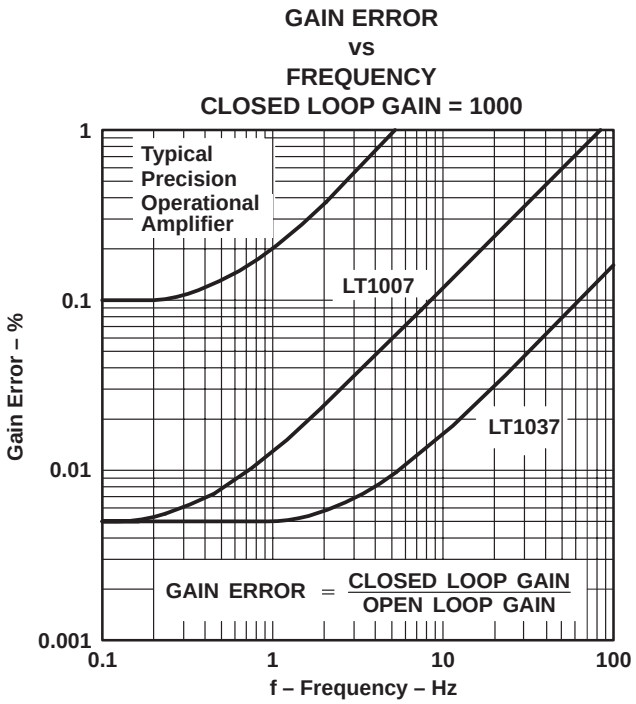
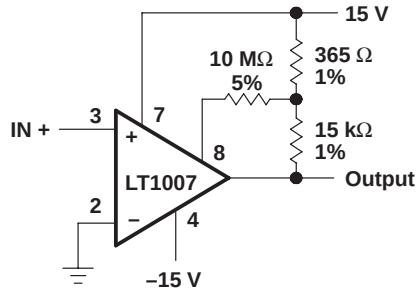


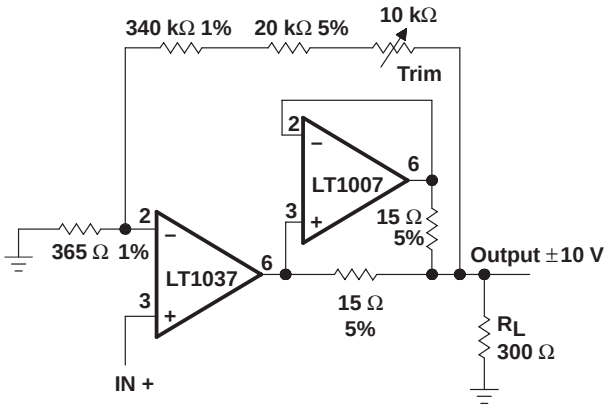

**Figure 44.**




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

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

**Figure 45. Microvolt Comparator With Hysteresis**




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

**Figure 46. Precision Amplifier Drives 300-Ω Load to ± 10 V**

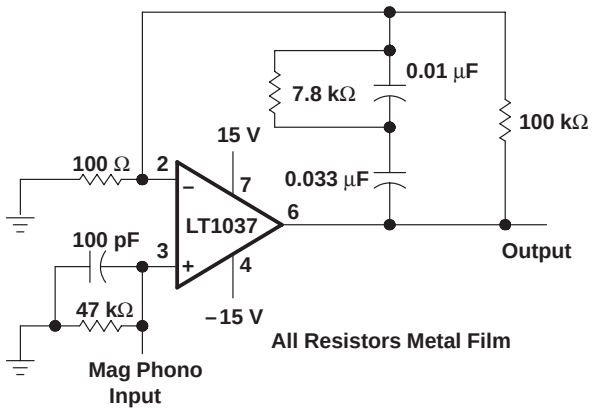



**Figure 47. Phono Preamplifier**

## APPLICATION INFORMATION

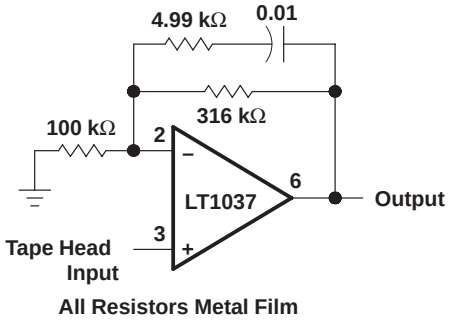



**Figure 48. Tape Head Amplifier**

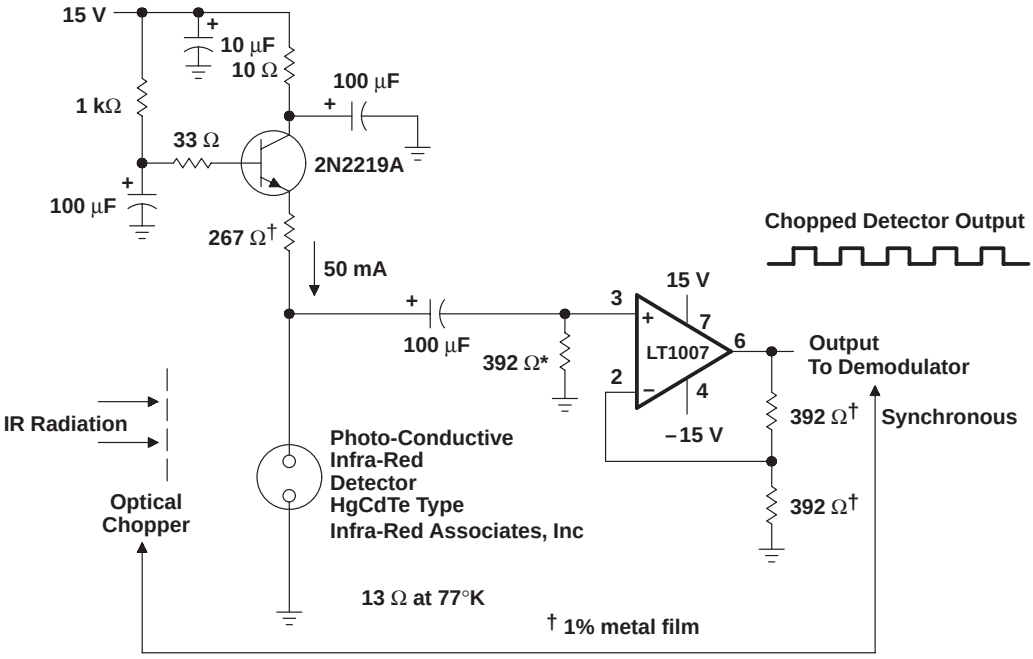
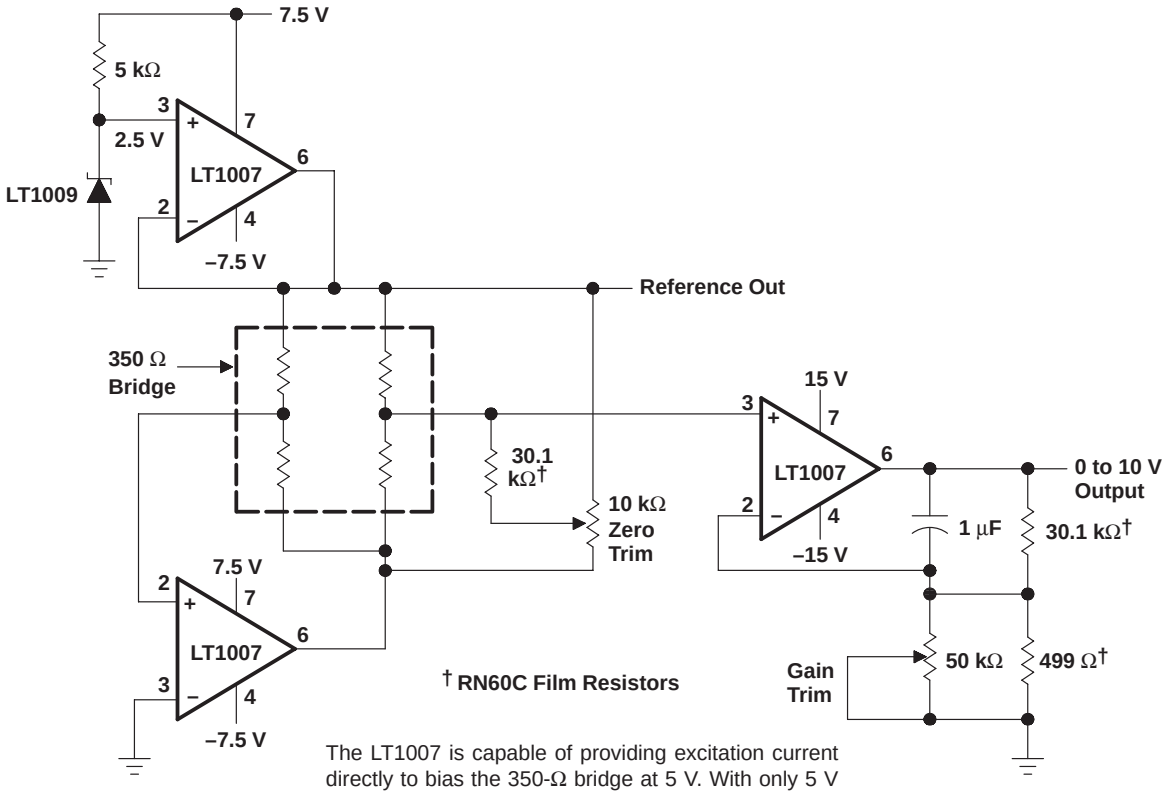



**Figure 49. Infra-Red Detector Preamplifier**

## APPLICATION INFORMATION




The LT1007 is capable of providing excitation current directly to bias the 350-Ω bridge at 5 V. With only 5 V across the bridge (as opposed to the usual 10 V) 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.

**Figure 50. Strain Gauge Signal Conditioner With Bridge Excitation**

## IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.

Copyright © 1999, Texas Instruments Incorporated