National Semiconductor

Amplifiers

# LH0022/LH0022C High Performance FET Op Amp
# LH0042/LH0042C Low Cost FET Op Amp
# LH0052/LH0052C Precision FET Op Amp

## General Description

The LH0022/LH0042/LH0052 are a family of FET input operational amplifiers with very closely matched input characteristics, very high input impedance, and ultra-low input currents with no compromise in noise, common mode rejection ratio, open loop gain, or slew rate. The internally laser nulled LH0052 offers 500 microvolts maximum offset and 5 μV/°C offset drift. Input offset current is less than 500 femtoamps at room temperature and 500 pA maximum at 125°C. The LH0022 and LH0042 are not internally nulled but offer comparable matching characteristics. All devices in the family are internally compensated and are free of latch-up and unusual oscillation problems. The devices may be offset nulled with a single 10k trimpot with neglible effect in CMRR.

The LH0022, LH0042 and LH0052 are specified for operation over the −55°C to +125°C military temperature range. The LH0022C, LH0042C and LH0052C are specified for operation over the −25°C to +85°C temperature range.

## Features

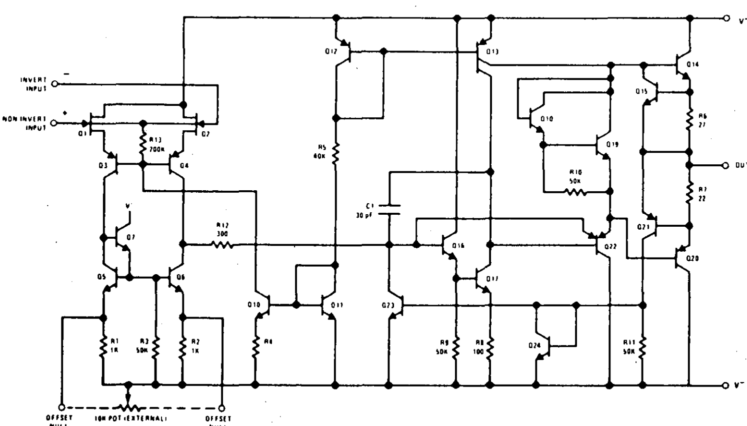
- Low input offset current—500 femtoamps max. (LH0052)
- Low input offset drift—5μV/°C max (LH0052)
- Low input offset voltage – 100 microvolts-typ.
- High open loop gain – 100 dB typ.
- Excellent slew rate – 3.0 V/μs typ.
- Internal 6 dB/octave frequency compensation
- Pin compatible with standard IC op amps (TO-5 package)

The LH0022/LH0042/LH0052 family of IC op amps are intended to fulfill a wide variety of applications for process control, medical instrumentation, and other systems requiring very low input currents and tightly matched input offsets. The LH0052 is particularly suited for long term high accuracy integrators and high accuracy sample and hold buffer amplifiers. The LH0022 and LH0042 provide low cost high performance for such applications as electrometer and photocell amplification, pico-ammeters, and high input impedance buffers.

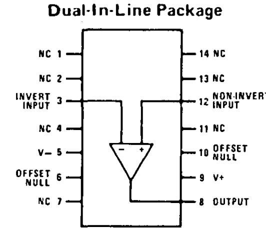
Special electrical parameter selection and custom built circuits are available on special request.

For additional application information and information on other National operational amplifiers, see *Available Linear Applications Literature.*

## Schematic and Connection Diagrams



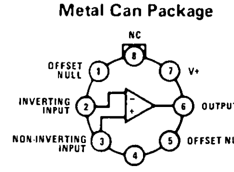

Dual-In-Line Package




TOP VIEW

**Order Number LH0022D, LH0022CD, LH0042D, LH0042CD, LH0052D or LH0052CD**
**See Package D14E**

Metal Can Package




TOP VIEW

**Order Number LH0022H, LH0022CH, LH0042H, LH0042CH, LH0052H or LH0052CH**
**See Package H08A**

*Previously Called NH0022/NH0022C

# Absolute Maximum Ratings

| | |
|---|---|
| Supply Voltage | ±22V |
| Power Dissipation (see graph) | 500 mW |
| Input Voltage (Note 1) | ±15V |
| Differential Input Voltage (Note 2) | ±30V |
| Voltage Between Offset Null and $V^-$ | ±0.5V |
| Short Circuit Duration | Continuous |
| Operating Temperature Range | |
| LH0022, LH0042, LH0052 | −55°C to +125°C |
| LH0022C, LH0042C, LH0052C | −25°C to +85°C |
| Storage Temperature Range | −65°C to +150°C |
| Lead Temperature (Soldering, 10 sec) | 300°C |

# DC Electrical Characteristics for LH0022/LH0022C (Note 3)

| PARAMETER | CONDITIONS | LIMITS | | | | | | UNITS |
|---|---|---|---|---|---|---|---|---|
| | | LH0022 | | | LH0022C | | | |
| | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input Offset Voltage | $R_S \leq 100\ k\Omega$; $T_A = 25°C$, $V_S = \pm 15V$ | | 2.0 | 4.0 | | 3.5 | 6.0 | mV |
| | $R_S \leq 100\ k\Omega$, $V_S = \pm 15V$ | | | 5.0 | | | 7.0 | mV |
| Temperature Coefficient of Input Offset Voltage | $R_S \leq 100\ k\Omega$ | | 5 | 10 | | 5 | 15 | µV/°C |
| Offset Voltage Drift with Time | | | 3 | | | 4 | | µV/week |
| Input Offset Current | (Note 4) | | 0.2 | 2.0 | | 1.0 | 5.0 | pA |
| | | | | 2.0 | | | 0.5 | nA |
| Temperature Coefficient of Input Offset Current | | Doubles every 10°C | | | Doubles every 10°C | | | |
| Offset Current Drift with Time | | | 0.1 | | | 0.1 | | pA/week |
| Input Bias Current | (Note 4) | | 5 | 10 | | 10 | 25 | pA |
| | | | | 10 | | | 2.5 | nA |
| Temperature Coefficient of Input Bias Current | | Doubles every 10°C | | | Doubles every 10°C | | | |
| Differential Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Common Mode Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Input Capacitance | | | 4.0 | | | 4.0 | | pF |
| Input Voltage Range | $V_S = \pm 15V$ | ±12 | ±13.5 | | ±12 | ±13.5 | | V |
| Common Mode Rejection Ratio | $R_S \leq 10\ k\Omega$, $V_{IN} = \pm 10V$ | 80 | 90 | | 70 | 90 | | dB |
| Supply Voltage Rejection Ratio | $R_S \leq 10\ k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$ | 80 | 90 | | 70 | 90 | | dB |
| Large Signal Voltage Gain | $R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $T_A = 25°C$, $V_S = \pm 15V$ | 100 | 200 | | 75 | 160 | | V/mV |
| | $R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $V_S = \pm 15V$ | 50 | | | 50 | | | V/mV |
| Output Voltage Swing | $R_L = 1\ k\Omega$, $T_A = 25°C$, $V_S = \pm 15V$ | ±10 | ±12.5 | | ±10 | ±12 | | V |
| | $R_L = 2\ k\Omega$, $V_S = \pm 15V$ | ±10 | | | ±10 | | | V |
| Output Current Swing | $V_{OUT} = \pm 10V$, $T_A = 25°C$ | ±10 | ±15 | | ±10 | ±15 | | mA |
| Output Resistance | | | 75 | | | 75 | | Ω |
| Output Short Circuit Current | | | 25 | | | 25 | | mA |
| Supply Current | $V_S = \pm 15V$ | | 2.0 | 2.5 | | 2.4 | 2.8 | mA |
| Power Consumption | $V_S = \pm 15V$ | | | 75 | | | 85 | mW |

## DC Electrical Characteristics for LH0042/LH0042C (Note 3)

| Parameter | Conditions | Limits | | | | | | Units |
|---|---|---|---|---|---|---|---|---|
| | | LH0042 | | | LH0042C | | | |
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Input Offset Voltage | $R_S \leq 100\,k\Omega$ | | 5.0 | 20 | | 6.0 | 20 | mV |
| Temperature Coefficient of Input Offset Voltage | $R_S \leq 100\,k\Omega$ | | 5.0 | | | 10 | | μV/°C |
| Offset Voltage Drift with Time | | | 7.0 | | | 10 | | μV/week |
| Input Offset Current | (Note 4) | | 1.0 | 5.0 | | 2.0 | 10 | pA |
| Temperature Coefficient of Input Offset Current | | Doubles every 10°C | | | Doubles every 10°C | | | |
| Offset Current Drift with Time | | | 0.1 | | | 0.1 | | pA/week |
| Input Bias Current | (Note 4) | | 10 | 25 | | 15 | 50 | pA |
| Temperature Coeffieient of Input Bias Current | | Doubles every 10°C | | | Doubles every 19°C | | | |
| Differential Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Common Mode Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Input Capacitance | | | 4.0 | | | 4.0 | | pF |
| Input Voltage Range | | ±12 | ±13.5 | | ±12 | ±13.5 | | V |
| Common Mode Rejection Ratio | $R_S \leq 10\,k\Omega$, $V_{IN} = \pm 10V$ | 70 | 86 | | 70 | 80 | | dB |
| Supply Voltage Rejection Ratio | $R_S \leq 10\,k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$ | 70 | 86 | | 70 | 80 | | dB |
| Large Signal Voltage Gain | $R_S \leq 2\,k\Omega$, $V_{OUT} = \pm 10V$ | 50 | 150 | | 25 | 100 | | V/mV |
| Output Voltage Swing | $R_L = 1\,k\Omega$, $T_A = 25°C$ | ±10 | ±12.5 | | ±10 | ±12 | | V |
| | $R_L = 2\,k\Omega$ | ±10 | | | ±10 | | | V |
| Output Current Swing | $V_{OUT} = \pm 10V$ | ±10 | ±15 | | ±10 | ±15 | | mA |
| Output Resistance | | | 75 | | | 75 | | Ω |
| Output Short Circuit Current | | | 20 | | | 20 | | mA |
| Supply Current | | | 2.5 | 3.5 | | 2.8 | 4.0 | mA |
| Power Consumption | | | | 105 | | | 120 | mW |

## DC Electrical Characteristics For LH0052/LH0052C (Note 3)

| Parameter | Conditions | Limits | | | | | | Units |
|---|---|---|---|---|---|---|---|---|
| | | LH0052 | | | LH0052C | | | |
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Input Offset Voltage | $R_S < 100\,k\Omega$, $V_S = +15V$, $T_A = 25°C$ | | 0.1 | 0.5 | | 0.2 | 1.0 | mV |
| | $R_S < 100\,k\Omega$, $V_S = \pm 15V$ | | | 1.0 | | | 1.5 | mV |
| Temperature Coefficient of Input Offset Voltage | $R_S \leq 100\,k\Omega$, $V_S = \pm 15V$ | | 2.0 | 5.0 | | 5.0 | 10 | μV/°C |
| Offset Voltage Drift with Time | | | 2.0 | | | 4.0 | | μV/week |
| Input Offset Current | (Note 4) | | 0.01 | 5.0 | | 0.02 | 1.0 | pA |
| | | | | 500 | | | 100 | pA |
| Temperature Coefficient of Input Offset Current | | Doubles every 10°C | | | Doubles every 10°C | | | |
| Offset Current Drift with Time | | <0.1 | | | <0.1 | | | pA/week |
| Input Bias Current | (Note 4) | | 0.5 | 2.5 | | 1.0 | 5.0 | pA |
| | | | | 2.5 | | | 0.5 | nA |
| Temperature Coefficient of Input Bias Current | | Doubles every 10°C | | | Doubles every 10°C | | | |
| Differential Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Common Mode Input Resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| Input Capacitance | | | 4.0 | | | 4.0 | | pF |
| Input Voltage Range | $V_S = \pm 15V$ | ±12 | ±13.5 | | ±12 | ±13.5 | | V |
| Common Mode Rejection Ratio | $R_S \leq 10\,k\Omega$, $V_{IN} = \pm 10V$ | 74 | 90 | | 70 | 90 | | dB |
| Supply Voltage Rejection Ratio | $R_S \leq 10\,k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$ | 74 | 90 | | 70 | 90 | | dB |
| Large Signal Voltage Gain | $R_L = 2\,K\Omega$, $V_{OUT} = \pm 10V$, $V_S = \pm 15V$, $T_A = 25°C$ | 100 | 200 | | 75 | 160 | | V/mV |
| | $R_L = 2\,k\Omega$, $V_{OUT} = \pm 10V$, $V_S = \pm 15V$ | 50 | | | 50 | | | V/mV |
| Output Voltage Swing | $R_L = 1\,k\Omega$, $T_A = 25°C$, $V_S = \pm 15V$ | ±10 | ±12.5 | | ±10 | ±12 | | V |
| | $R_L = 2\,k\Omega$, $V_S = \pm 15V$ | ±10 | | | ±10 | | | V |
| Output Current Swing | $V_{OUT} = \pm 10V$, $t_A = 25°C$ | ±10 | ±15 | | ±10 | ±15 | | mA |
| Output Resistance | | | 75 | | | 75 | | Ω |
| Output Short Circuit Current | | | 25 | | | 25 | | mA |
| Supply Current | $V_S = \pm 15V$ | | 3.0 | 3.5 | | 3.0 | 3.8 | mA |
| Power Consumption | $V_S = \pm 15V$ | | | 105 | | | 114 | mW |

## AC Electrical Characteristics For all amplifiers ($T_A = 25°C$, $V_S = \pm 15V$)

| PARAMETER | CONDITIONS | LIMITS LH0022/42/52 MIN | TYP | MAX | LH0022C/42C/52C MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| Slew Rate | Voltage Follower | 1.5 | 3.0 | | 1.0 | 3.0 | | V/μs |
| Large Signal Bandwidth | Voltage Follower | | 40 | | | 40 | | kHz |
| Small Signal Bandwidth | | | 1.0 | | | 1.0 | | MHz |
| Rise Time | | | 0.3 | 1.5 | | 0.3 | 1.5 | μs |
| Overshoot | | | 10 | 30 | | 15 | 40 | % |
| Settling Time (0.1 %) | $\Delta V_{IN} = 10V$ | | 4.5 | | | 4.5 | | μs |
| Overload Recovery | | | 4.0 | | | 4.0 | | μs |
| Input Noise Voltage | $R_S = 10\ k\Omega$, $f_o = 10\ Hz$ | | 150 | | | 150 | | $nV/\sqrt{Hz}$ |
| Input Noise Voltage | $R_S = 10\ k\Omega$, $f_o = 100\ Hz$ | | 55 | | | 55 | | $nV/\sqrt{Hz}$ |
| Input Noise Voltage | $R_S = 10\ k\Omega$, $f_o = 1\ kHz$ | | 35 | | | 35 | | $nV/\sqrt{Hz}$ |
| Input Noise Voltage | $R_S = 10\ k\Omega$, $f_o = 10\ kHz$ | | 30 | | | 30 | | $nV/\sqrt{Hz}$ |
| Input Noise Voltage | BW = 10 Hz to 10 kHz, $R_S = 10\ k\Omega$ | | 12 | | | 12 | | μVrms |
| Input Noise Current | BW = 10 Hz to 10 kHz | | <.1 | | | <.1 | | pArms |

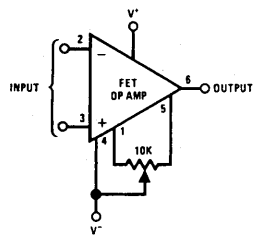
**Note 1:** For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

**Note 2:** Rating applies for minimum source resistance of 10 kΩ, for source resistances less than 10 kΩ, maximum differential input voltage is ±5V.

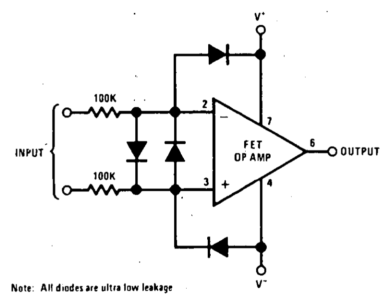
**Note 3:** Unless otherwise specified, these specifications apply for $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq +125°C$ for the LH0022 and LH0052 and $-25°C \leq T_A \leq +85°C$ for the LH0022C and LH0052C Typical values are given for $T_A = 25°C$.

**Note 4:** Input currents are a strong function of temperature. Due to high speed testing they are specified a junction temperature $T_j = 25°C$, self heating will cause an increase in current in manual tests.

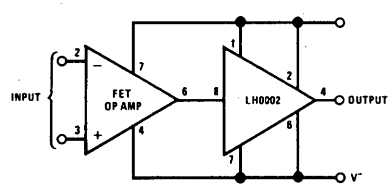
## Auxiliary Circuits (Shown for TO-5 pin out)




Offset Null

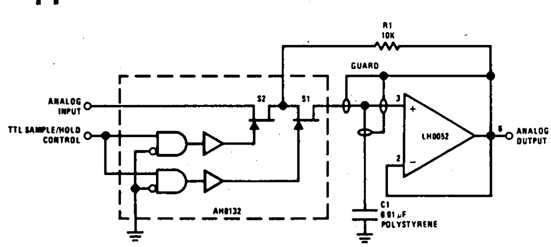



Protecting Inputs From ±150V Transients

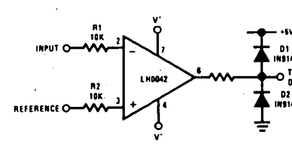



Boosting Output Drive to ±100 mA

## Typical Applications

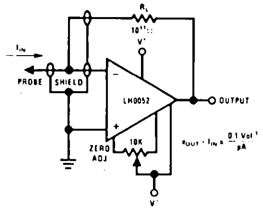



Low Drift Sample and Hold

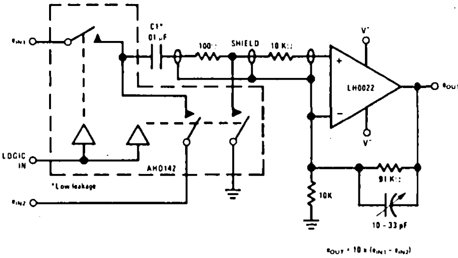



Precision Voltage Comparator

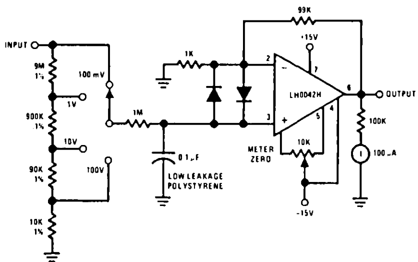
## Typical Applications (Cont'd)



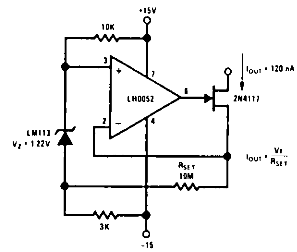

Picoamp Amplifier for pH Meters and Radiation Detectors



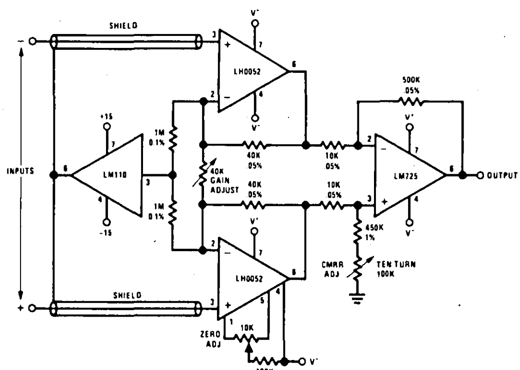

Precision Subtractor for Automatic Test Gear



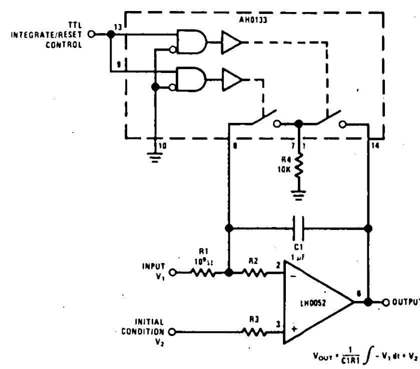

Sensitive Low Cost "VTVM"



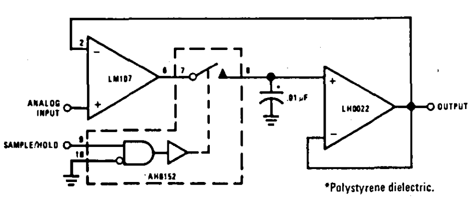

Ultra Low Level Current Source



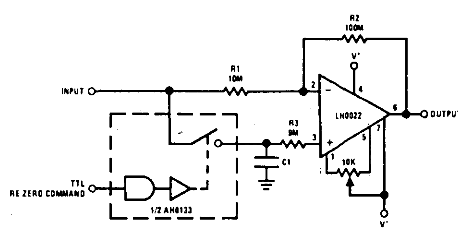

True Instrumentation Amplifier




Precision Integrator



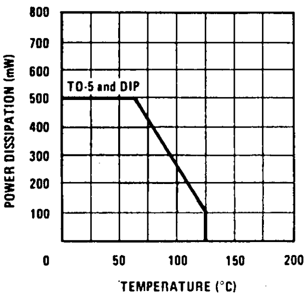

Precision Sample and Hold



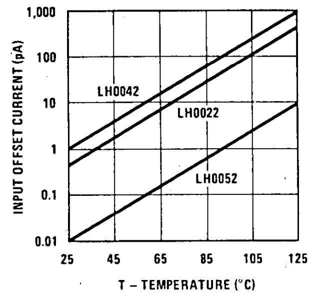

Re-Zeroing Amplifier

# Typical Performance Characteristics

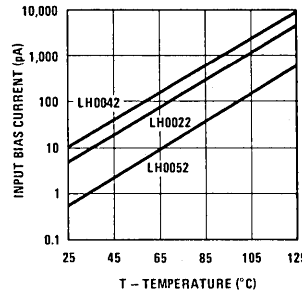
**Maximum Power Dissipation**



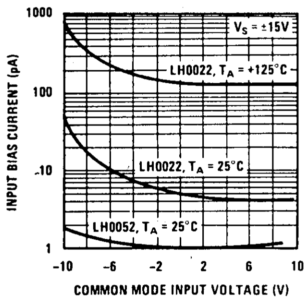

**Input Offset Current vs Temperature**



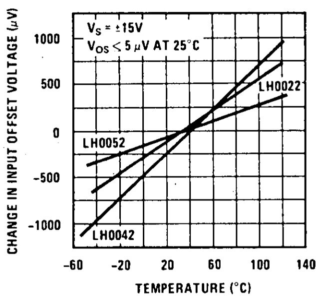

**Input Bias Current vs Temperature**



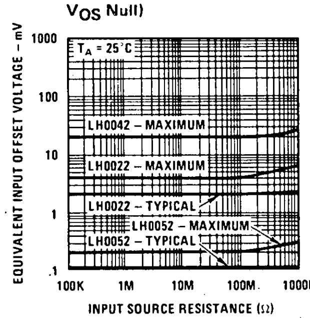

**Input Bias Current vs Input Voltage**



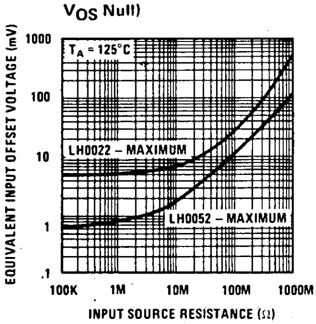

**Input Offset Voltage vs Temperature**



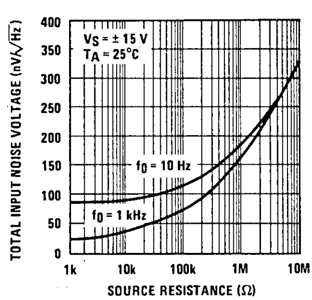

**Offset Error (Without $V_{OS}$ Null)**



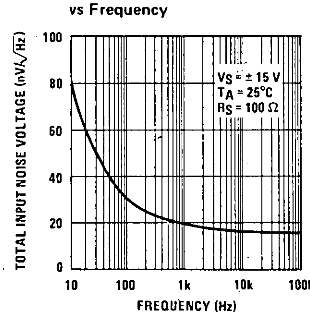

**Offset Error (Without $V_{OS}$ Null)**



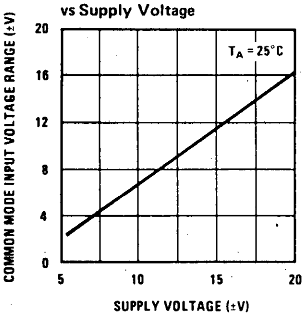

**Total Input Noise Voltage* vs Source Resistance**



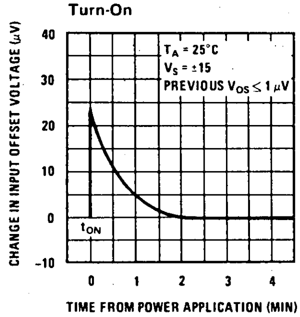

**Total Input Noise Voltage* vs Frequency**



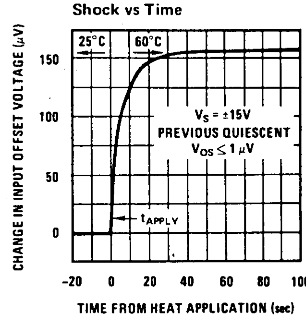

**Common Mode Input Voltage vs Supply Voltage**




**Stabilization Time of Input Offset Voltage from Power Turn-On**



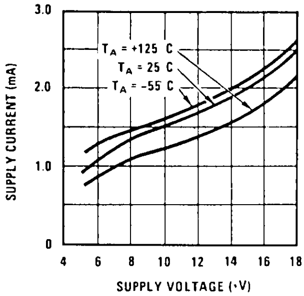

**Change in Input Offset Voltage Due to Thermal Shock vs Time**



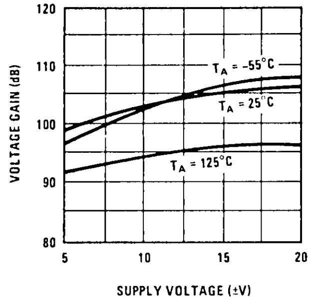

*Noise Voltage Includes Contribution from Source Resistance

## Typical Performance Characteristics (Cont'd)

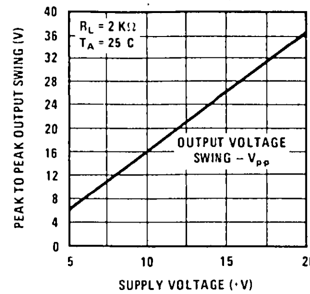
**Supply Voltage vs Supply Current**



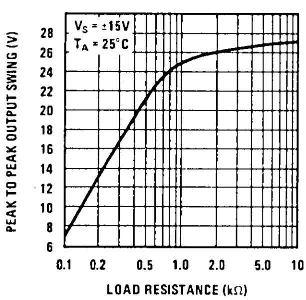

**Voltage Gain**



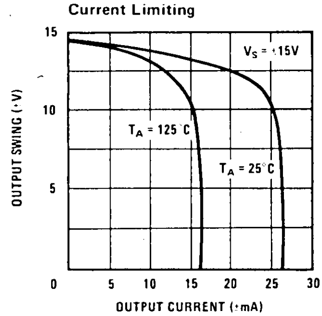

**Output Swing vs Supply Voltage**



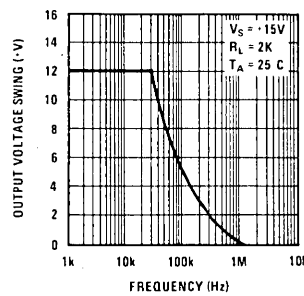

**Output Voltage Swing vs Load Resistance**



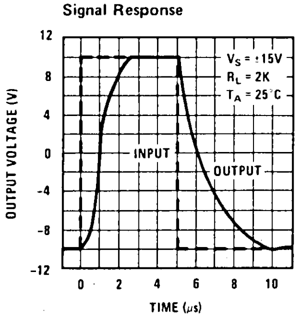

**Current Limiting**



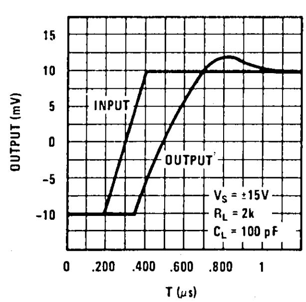

**Output Voltage Swing vs Frequency**



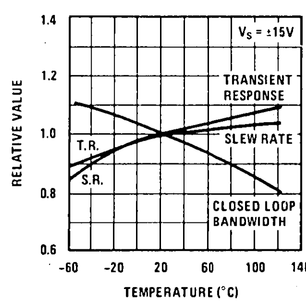

**Voltage Follower Large Signal Response**



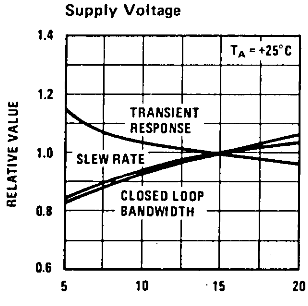

**Transient Response**



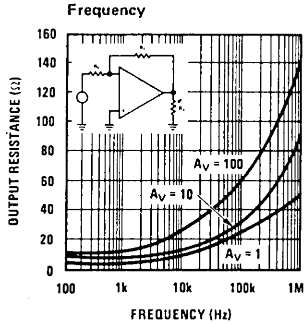

**Frequency Characteristics vs Ambient Temperature**




**Frequency Characteristics vs Supply Voltage**




**Output Resistance vs Frequency**




**Open Loop Transfer Characteristics vs Frequency**