



LT1222

500MHz,  $3\text{nV}/\sqrt{\text{Hz}}$ ,  $A_V \geq 10$   
Operational Amplifier

## FEATURES

- **Gain-Bandwidth: 500MHz**
- **Gain of 10 Stable Uncompensated**
- **Slew Rate: 200V/ $\mu\text{s}$**
- Input Noise Voltage:  $3\text{nV}/\sqrt{\text{Hz}}$
- C-Load™ Op Amp Drives Capacitive Loads
- External Compensation Pin
- Maximum Input Offset Voltage:  $300\mu\text{V}$
- Maximum Input Bias Current:  $300\text{nA}$
- Maximum Input Offset Current:  $300\text{nA}$
- Minimum Output Swing Into  $500\Omega$ :  $\pm 12\text{V}$
- Minimum DC Gain:  $100\text{V/mV}$ ,  $R_L = 500\Omega$
- Settling Time to 0.1%: 75ns, 10V Step
- Settling Time to 0.01%: 120ns, 10V Step
- Differential Gain: 0.4%,  $A_V = 2$ ,  $R_L = 150\Omega$
- Differential Phase:  $0.1^\circ$ ,  $A_V = 2$ ,  $R_L = 150\Omega$

## APPLICATIONS

- Wideband Amplifiers
- Buffers
- Active Filters
- Video and RF Amplification
- Cable Drivers
- 8-, 10-, 12-Bit Data Acquisition Systems

## DESCRIPTION

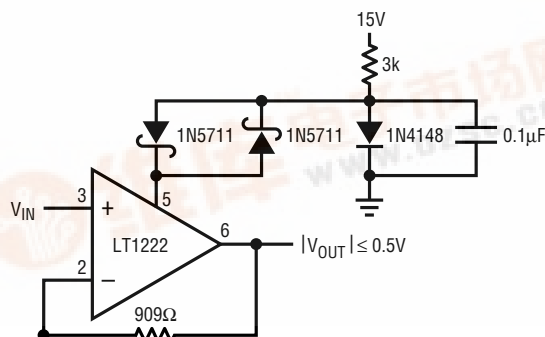
The LT1222 is a low noise, very high speed operational amplifier with superior DC performance. The LT1222 is stable in a noise gain of 10 or greater without compensation, or the part can be externally compensated for lower closed-loop gain at the expense of lower bandwidth and slew rate. It features reduced input offset voltage, lower input bias currents, lower noise and higher DC gain than devices with comparable bandwidth and slew rate. The circuit is a single gain stage that includes proprietary DC gain enhancement circuitry to obtain precision with high speed. The high gain and fast settling time make the circuit an ideal choice for data acquisition systems. The circuit is also capable of driving capacitive loads which makes it useful in buffer or cable driver applications. The compensation node can also be used to clamp the output swing.

The LT1222 is a member of a family of fast, high performance amplifiers that employ Linear Technology Corporation's advanced complementary bipolar processing. For unity-gain stable applications the LT1220 can be used, and for gains of 4 or greater the LT1221 can be used.

LT and LTC are registered trademarks and LT is a trademark of Linear Technology Corporation. C-Load is a trademark of Linear Technology Corporation.

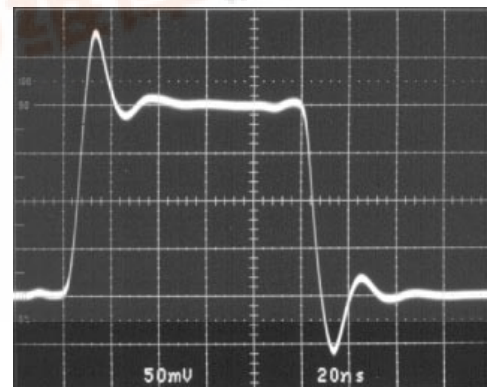
## TYPICAL APPLICATION

$A_V = 10$  with Output Clamping



LT1222 • TA01

$A_V = -1$ ,  $C_C = 30\text{pF}$  Pulse Response



$R_F = R_G = 1\text{k}\Omega$   
 $V_{IN} = 100\text{mV}$   
 $V_S = \pm 15\text{V}$   
 $f = 5\text{MHz}$

LT1222 • TA02



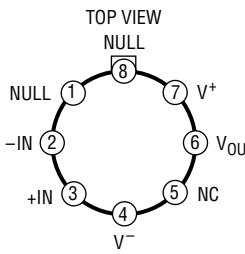
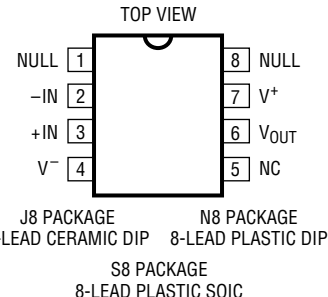
# LT1222

## ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage ( $V^+$  to  $V^-$ ) ..... 36V  
Differential Input Voltage .....  $\pm 6V$   
Input Voltage .....  $\pm V_S$   
Output Short-Circuit Duration (Note 1) ..... Indefinite  
Specified Temperature Range  
LT1222C (Note 2) .....  $0^\circ\text{C}$  to  $70^\circ\text{C}$   
LT1222M .....  $-55^\circ\text{C}$  to  $125^\circ\text{C}$

Operating Temperature Range  
LT1222C .....  $-40^\circ\text{C}$  TO  $85^\circ\text{C}$   
LT1222M .....  $-55^\circ\text{C}$  to  $125^\circ\text{C}$   
Maximum Junction Temperature (See Below)  
Plastic Package .....  $150^\circ\text{C}$   
Ceramic Package .....  $175^\circ\text{C}$   
Storage Temperature Range .....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$   
Lead Temperature (Soldering, 10 sec) .....  $300^\circ\text{C}$

## PACKAGE/ORDER INFORMATION

 <p>H PACKAGE 8-LEAD TO-5 METAL CAN <math>T_{JMAX} = 175^\circ\text{C}</math>, <math>\theta_{JA} = 150^\circ\text{C/W}</math></p>	ORDER PART NUMBER	 <p>J8 PACKAGE 8-LEAD CERAMIC DIP N8 PACKAGE 8-LEAD PLASTIC DIP S8 PACKAGE 8-LEAD PLASTIC SOIC <math>T_{JMAX} = 175^\circ\text{C}</math>, <math>\theta_{JA} = 100^\circ\text{C/W}</math> (J) <math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 130^\circ\text{C/W}</math> (N) <math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 190^\circ\text{C/W}</math> (S)</p>	ORDER PART NUMBER
	SPECIAL ORDER CONSULT FACTORY		LT1222CN8 LT1222MJ8 LT1222CS8
			S8 PART MARKING
			1222

Consult factory for Industrial grade parts.

## ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$ , $T_A = 25^\circ\text{C}$ , $V_{CM} = 0V$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{OS}$	Input Offset Voltage	(Note 3)		100	300	$\mu\text{V}$
$I_{OS}$	Input Offset Current			100	300	nA
$I_B$	Input Bias Current			100	300	nA
$e_n$	Input Noise Voltage	$f = 10\text{kHz}$		3		$\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Input Noise Current	$f = 10\text{kHz}$		2		$\text{pA}/\sqrt{\text{Hz}}$
$R_{IN}$	Input Resistance	$V_{CM} = \pm 12V$ Differential	20	45 12		$\text{M}\Omega$ $\text{k}\Omega$
$C_{IN}$	Input Capacitance			2		pF
	Input Voltage Range (Positive)		12	14		V
	Input Voltage Range (Negative)			-13	-12	V
CMRR	Common-Mode Rejection Ratio	$V_{CM} = \pm 12V$	100	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 5V$ to $\pm 15V$	98	110		dB
$A_{VOL}$	Large-Signal Voltage Gain	$V_{OUT} = \pm 10V$ , $R_L = 500\Omega$	100	200		V/mV
$V_{OUT}$	Output Swing	$R_L = 500\Omega$	12	13		$\pm V$
$I_{OUT}$	Output Current	$V_{OUT} = \pm 12V$	24	26		mA
SR	Slew Rate	(Note 4)	150	200		$\text{V}/\mu\text{s}$
	Full Power Bandwidth	10V Peak (Note 5)		3.2		MHz
GBW	Gain-Bandwidth	$f = 1\text{MHz}$		500		MHz

## ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$ , $T_A = 25^\circ C$ , $V_{CM} = 0V$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$t_r, t_f$	Rise Time, Fall Time	$A_V = 10$ , 10% to 90%, 0.1V		2.4		ns
	Overshoot	$A_V = 10$ , 0.1V		45		%
	Propagation Delay	$A_V = 10$ , 50% $V_{IN}$ to 50% $V_{OUT}$ , 0.1V		5.2		ns
$t_s$	Settling Time	10V Step, 0.1% 10V Step, 0.01%		75 120		ns ns
	Differential Gain	$A_V = 2$ , $C_C = 50pF$ , $f = 3.58MHz$ , $R_L = 150\Omega$ (Note 6) $A_V = 10$ , $C_C = 0pF$ , $f = 3.58MHz$ , $R_L = 1k$ (Note 6)		0.40 0.15		% %
	Differential Phase	$A_V = 2$ , $C_C = 50pF$ , $f = 3.58MHz$ , $R_L = 150\Omega$ (Note 6) $A_V = 10$ , $C_C = 0pF$ , $f = 3.58MHz$ , $R_L = 1k$ (Note 6)		0.10 0.01		DEG DEG
$R_O$	Output Resistance	$A_V = 10$ , $f = 1MHz$		0.1		$\Omega$
$I_S$	Supply Current			8	10.5	mA

$V_S = \pm 15V$ ,  $0^\circ C \leq T_A \leq 70^\circ C$ ,  $V_{CM} = 0V$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{OS}$	Input Offset Voltage	(Note 3)	●	100	600	$\mu V$
	Input $V_{OS}$ Drift			5		$\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●	100	400	nA
$I_B$	Input Bias Current		●	100	400	nA
CMRR	Common-Mode Rejection Ratio	$V_{CM} = \pm 12V$	●	100	120	dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 5V$ to $\pm 15V$	●	98	110	dB
$A_{VOL}$	Large-Signal Voltage Gain	$V_{OUT} = \pm 10V$ , $R_L = 500\Omega$	●	100	200	V/mV
$V_{OUT}$	Output Swing	$R_L = 500\Omega$	●	12	13	$\pm V$
$I_{OUT}$	Output Current	$V_{OUT} = \pm 12V$	●	24	26	mA
SR	Slew Rate	(Note 4)	●	150	200	V/ $\mu s$
$I_S$	Supply Current		●	8	11	mA

$V_S = \pm 15V$ ,  $-55^\circ C \leq T_A \leq 125^\circ C$ ,  $V_{CM} = 0V$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{OS}$	Input Offset Voltage	(Note 3)	●	100	600	$\mu V$
	Input $V_{OS}$ Drift			5		$\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●	100	800	nA
$I_B$	Input Bias Current		●	100	1000	nA
CMRR	Common-Mode Rejection Ratio	$V_{CM} = \pm 12V$	●	98	120	dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 5V$ to $\pm 15V$	●	98	110	dB
$A_{VOL}$	Large-Signal Voltage Gain	$V_{OUT} = \pm 10V$ , $R_L = 500\Omega$	●	50	200	V/mV
$V_{OUT}$	Output Swing	$R_L = 500\Omega$ $R_L = 1k$	● ●	10 12	13 13	$\pm V$ $\pm V$
$I_{OUT}$	Output Current	$V_{OUT} = \pm 10V$ $V_{OUT} = \pm 12V$	● ●	20 12	26 13	mA mA
SR	Slew Rate	(Note 4)	●	110	200	V/ $\mu s$
$I_S$	Supply Current		●	8	11	mA

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

**Note 1:** A heat sink may be required when the output is shorted indefinitely.

**Note 2:** Commercial parts are designed to operate over  $-40^\circ C$  to  $85^\circ C$ , but are not tested nor guaranteed beyond  $0^\circ C$  to  $70^\circ C$ . Industrial grade parts specified and tested over  $-40^\circ C$  to  $85^\circ C$  are available on special request. Consult factory.

**Note 3:** Input offset voltage is pulse tested and is exclusive of warm-up drift.

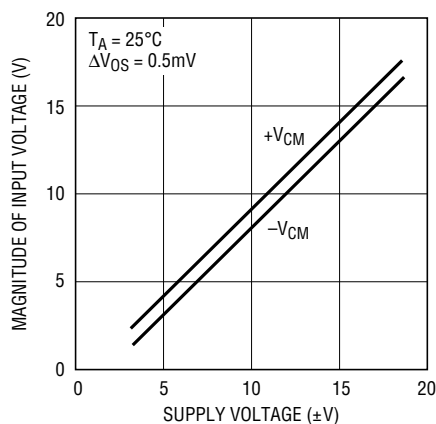
**Note 4:** Slew rate is measured between  $\pm 10V$  on an output swing of  $\pm 12V$ .

**Note 5:**  $FPBW = SR/2\pi V_p$ .

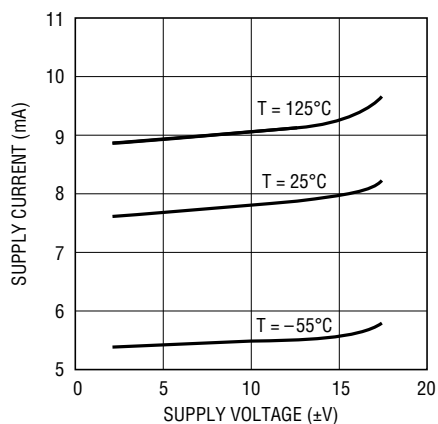
**Note 6:** Differential Gain and Phase are tested with five amps in series. Attenuators of 1/Gain are used as loads.

## TYPICAL PERFORMANCE CHARACTERISTICS

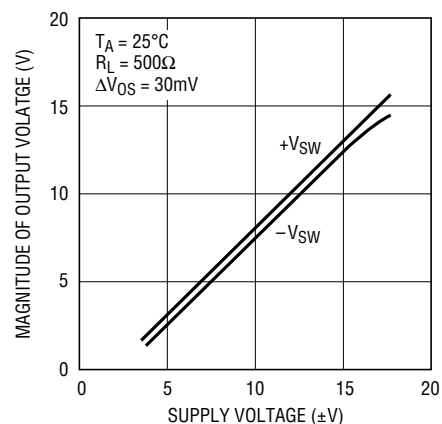
**Input Common-Mode Range vs Supply Voltage**



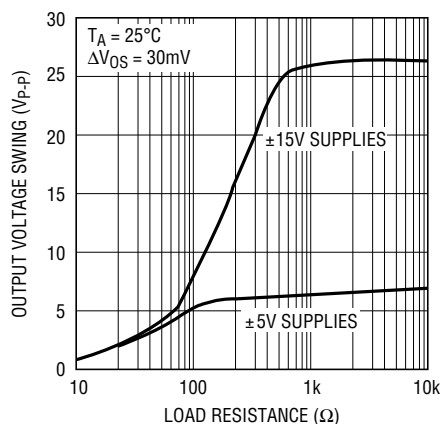
**Supply Current vs Supply Voltage and Temperature**



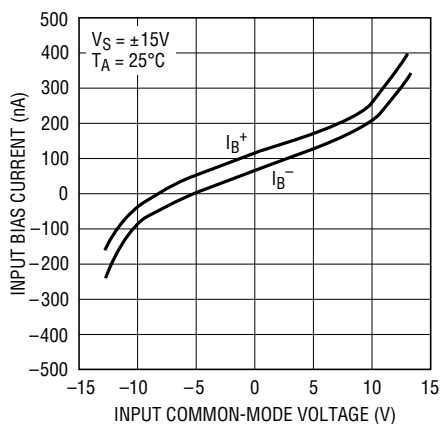
**Output Voltage Swing vs Supply Voltage**



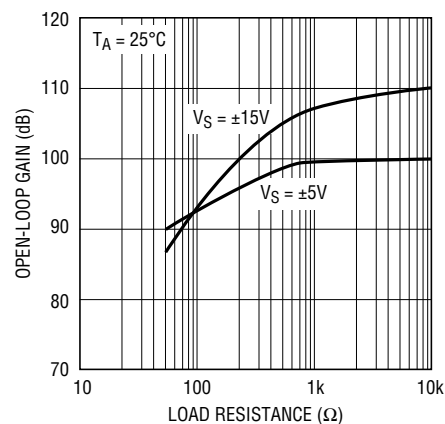
**Output Voltage Swing vs Resistive Load**



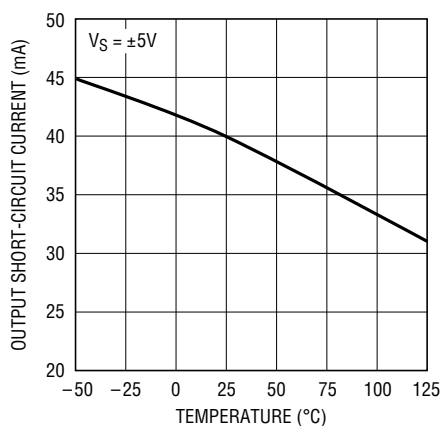
**Input Bias Current vs Input Common-Mode Voltage**



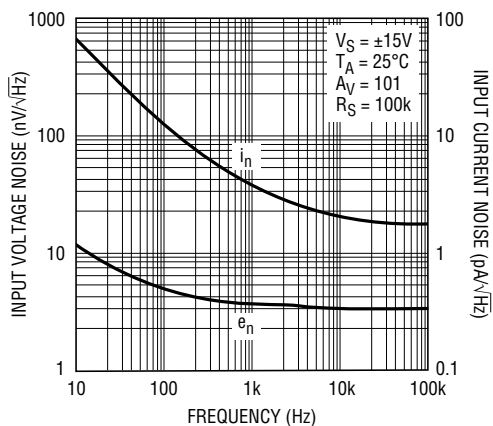
**Open-Loop Gain vs Resistive Load**



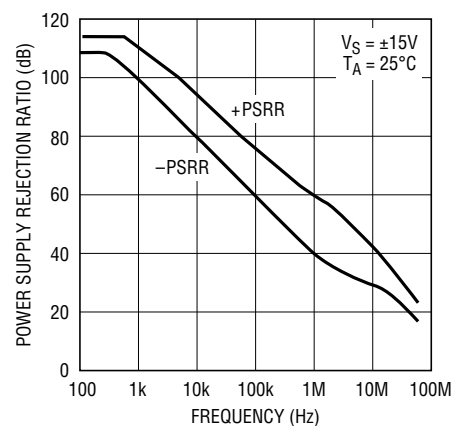
**Output Short-Circuit Current vs Temperature**



**Input Noise Spectral Density**

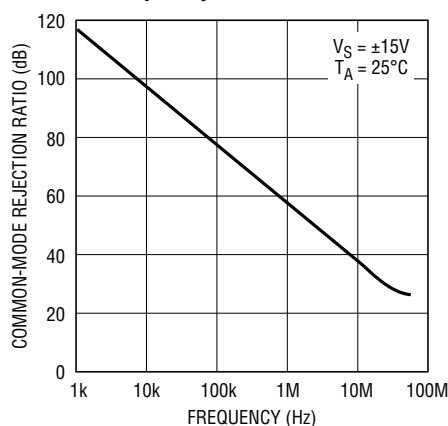


**Power Supply Rejection Ratio vs Frequency**



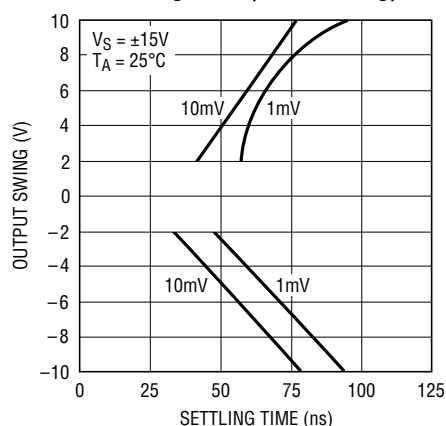
# TYPICAL PERFORMANCE CHARACTERISTICS

**Common-Mode Rejection Ratio vs Frequency**



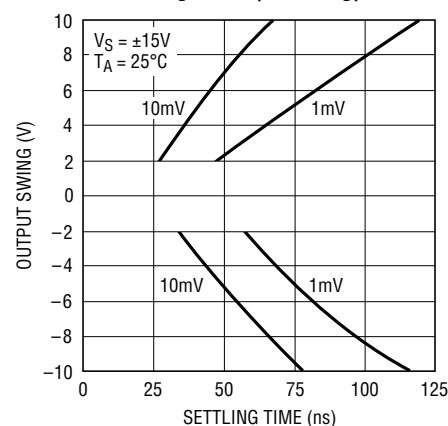
LT1222 • TPC10

**Output Swing and Error vs Settling Time (Noninverting)**



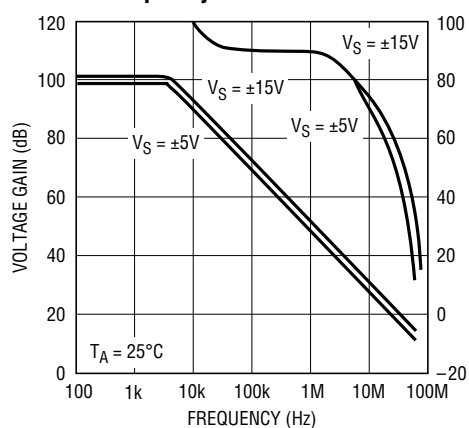
LT1222 • TPC11

**Output Swing and Error vs Settling Time (Inverting)**



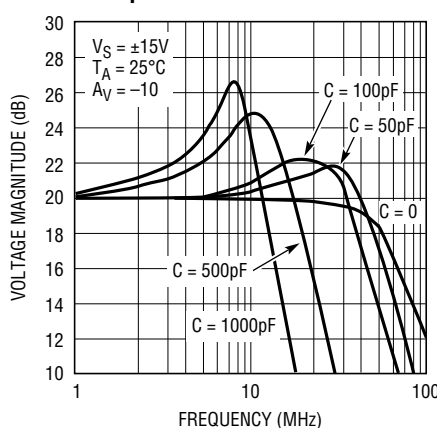
LT1222 • TPC12

**Voltage Gain and Phase vs Frequency**



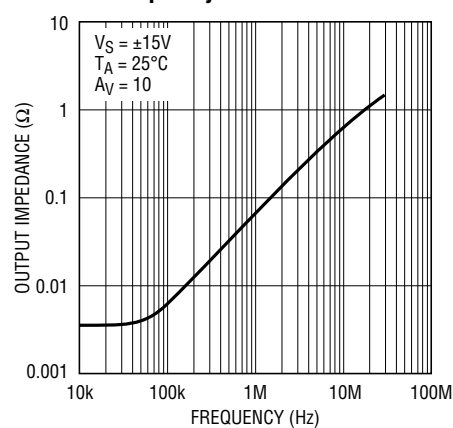
LT1222 • TPC13

**Frequency Response vs Capacitive Load**



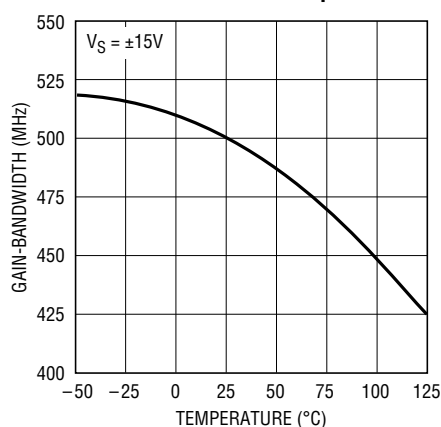
LT1222 • TPC14

**Closed-Loop Output Impedance vs Frequency**



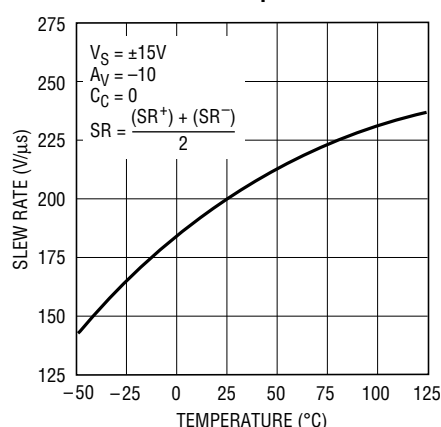
LT1222 • TPC15

**Gain-Bandwidth vs Temperature**



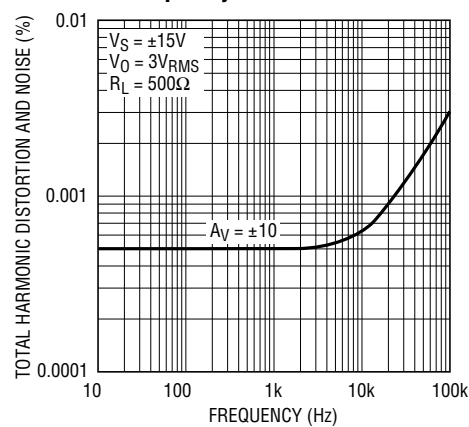
LT1222 • TPC16

**Slew Rate vs Temperature**



LT1222 • TPC17

**Total Harmonic Distortion vs Frequency**

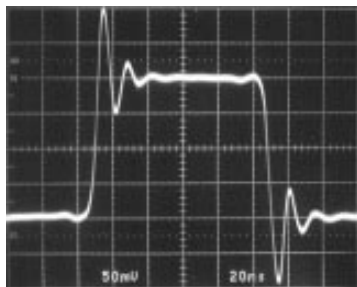


LT1222 • TPC18

# LT1222

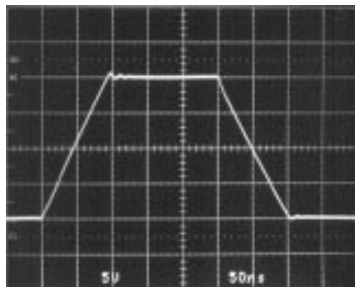
## TYPICAL PERFORMANCE CHARACTERISTICS

Small Signal,  $A_V = 10$



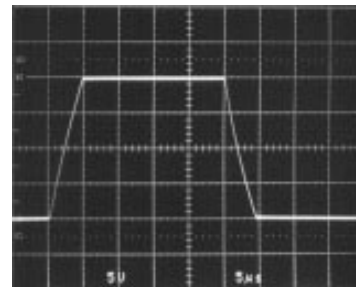
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 5MHz$   $R_G = 100\Omega$   $V_{IN} = 20mV$  LT1222 • TPC19

Large Signal,  $A_V = 10$



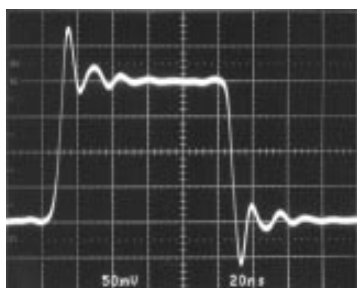
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 2MHz$   $R_G = 100\Omega$   $V_{IN} = 2V$  LT1222 • TPC20

Large Signal,  $A_V = 10$ ,  
 $C_L = 10,000pF$



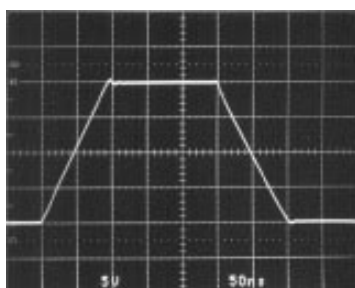
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 20kHz$   $R_G = 100\Omega$   $V_{IN} = 2V$  LT1222 • TPC21

Small Signal,  $A_V = -10$



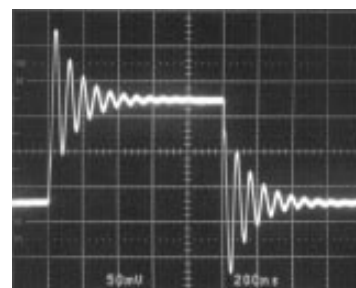
$R_F = 1k$   $V_S = \pm 15V$   $f = 5MHz$   $R_G = 100\Omega (75)$   $V_{IN} = 20mV$  LT1222 • TPC22

Large Signal,  $A_V = -10$



$R_F = 1k$   $V_S = \pm 15V$   $f = 2MHz$   $R_G = 100\Omega (75)$   $V_{IN} = 2V$  LT1222 • TPC23

Small Signal,  $A_V = -10$ ,  
 $C_L = 1,000pF$

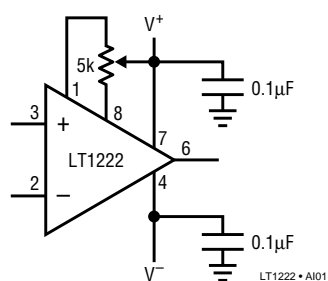


$R_F = 1k$   $V_S = \pm 15V$   $f = 500kHz$   $R_G = 100\Omega (75)$   $V_{IN} = 15mV$  LT1222 • TPC24

## APPLICATIONS INFORMATION

The LT1222 is stable in noise gains of 10 or greater and may be inserted directly into HA2520/2/5, HA2541/2/4, AD817, AD847, EL2020, EL2044 and LM6361 applications, provided that the nulling circuitry is removed and the amplifier configuration has a high enough noise gain. The suggested nulling circuit for the LT1222 is shown in the following figure.

Offset Nulling



LT1222 • A101

## Layout and Passive Components

The LT1222 amplifier is easy to apply and tolerant of less than ideal layouts. For maximum performance (for example, fast settling time) use a ground plane, short lead lengths and RF-quality bypass capacitors (0.01μF to 0.1μF). For high drive current applications use low ESR bypass capacitors (1μF to 10μF tantalum). Sockets should be avoided when maximum frequency performance is required. For more details see Design Note 50. Feedback resistors greater than 5k are not recommended because a pole is formed with the input capacitance which can cause peaking or oscillations. Stray capacitance on pin 5 should be minimized. Bias current cancellation circuitry is employed on the inputs of the LT1222 so the input bias current and input offset current have identical specifications. For this reason, matching the impedance on the inputs to reduce bias current errors is not necessary.

## APPLICATIONS INFORMATION

### Output Clamping

Access to the internal compensation node at pin 5 allows the output swing of the LT1222 to be clamped. An example is shown on the first page of this data sheet. The compensation node is approximately one diode drop above the output and can source or sink 1.2mA. Back-to-back Schottky diodes clamp pin 5 to a diode drop above ground so the output is clamped to  $\pm 0.5V$  (the drop of the Schottkys at 1.2mA). The diode reference is bypassed for good AC response. This circuit is useful for amplifying the voltage at false sum nodes used in settling time measurements.

### Capacitive Loading

The LT1222 is stable with capacitive loads. This is accomplished by sensing the load induced output pole and adding compensation at the amplifier gain node. As the capacitive load increases, both the bandwidth and phase margin decrease. There will be peaking in the frequency domain as shown in the curve of Frequency Response vs Capacitive Load. The small-signal transient response will have more overshoot as shown in the photo of the small-signal response with 1000pF load. The large-signal response with a 10,000pF load shows the output slew rate being limited to 4V/ $\mu s$  by the short-circuit current. The LT1222 can drive coaxial cable directly, but for best pulse fidelity a resistor of value equal to the characteristic impedance of the cable (i.e., 75 $\Omega$ ) should be placed in series with the output. The other end of the cable should be terminated with the same value resistor to ground.

### Compensation

The LT1222 has a typical gain-bandwidth product of 500MHz which allows it to have wide bandwidth in high gain configurations (i.e., in a gain of 100, it will have a bandwidth of about 5MHz). For added flexibility the amplifier frequency response may be adjusted by adding capacitance from pin 5 to ground. The compensation capacitor

may be used to reduce overshoot, to allow the amplifier to be used in lower noise gains, or simply to reduce bandwidth. Table 1 shows gain and compensation capacitor versus  $-3dB$  bandwidth, maximum frequency peaking and small-signal overshoot.

Table 1

$A_V$	$C_C$ (pF)	$f_{-3dB}$ (MHz)	Max Peaking (dB)	Overshoot (%)
-1	30	99	4.2	36
-1	50	70	0.9	13
-1	82	32	0	0
-1	150	13	0	0
5	10	140	3.8	35
5	20	100	0	5
5	30	34	0	1
5	50	15	0	0
10	0	150	9.5	45
10	5	111	0.2	10
10	10	40	0	2
10	20	17	0	0
20	0	82	0.1	10
20	5	24	0	0
20	10	14	0	0

For frequencies  $< 10MHz$  the frequency response of the amplifier is approximately:

$$f = 1/[2\pi \times 53\Omega \times (C_C + 6pF) \times (\text{Noise Gain})]$$

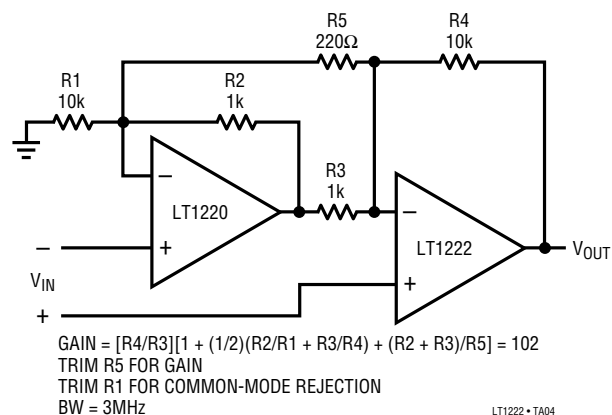
The slew rate is affected as follows:

$$SR = 1.2mA/(C_C + 6pF)$$

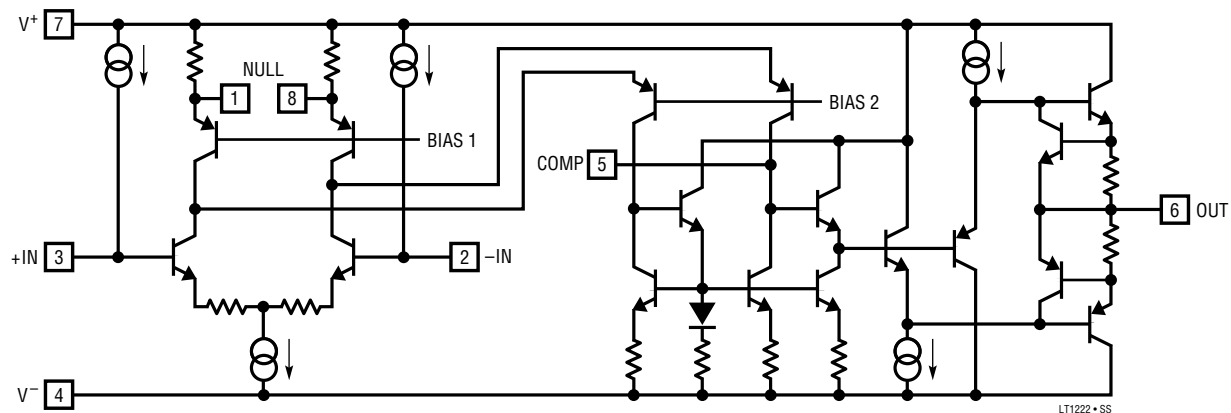
An example would be a gain of  $-10$  (noise gain of 11) and  $C_C = 20pF$  which has 10.5MHz bandwidth and 46V/ $\mu s$  slew rate. It should be noted that the LT1222 is not stable in  $A_V = 1$  unless  $C_C = 50pF$  and a 1k resistor is used as the feedback resistor. The 1k and input capacitance increase the noise gain at frequency to aid stability.

## TYPICAL APPLICATIONS

## Two Op Amp Instrumentation Amplifier



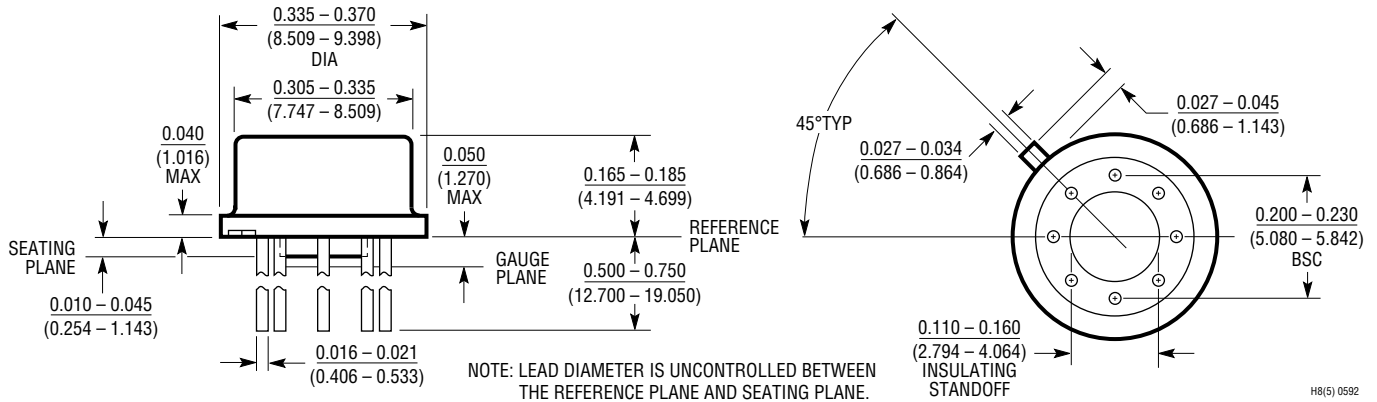
## SIMPLIFIED SCHEMATIC



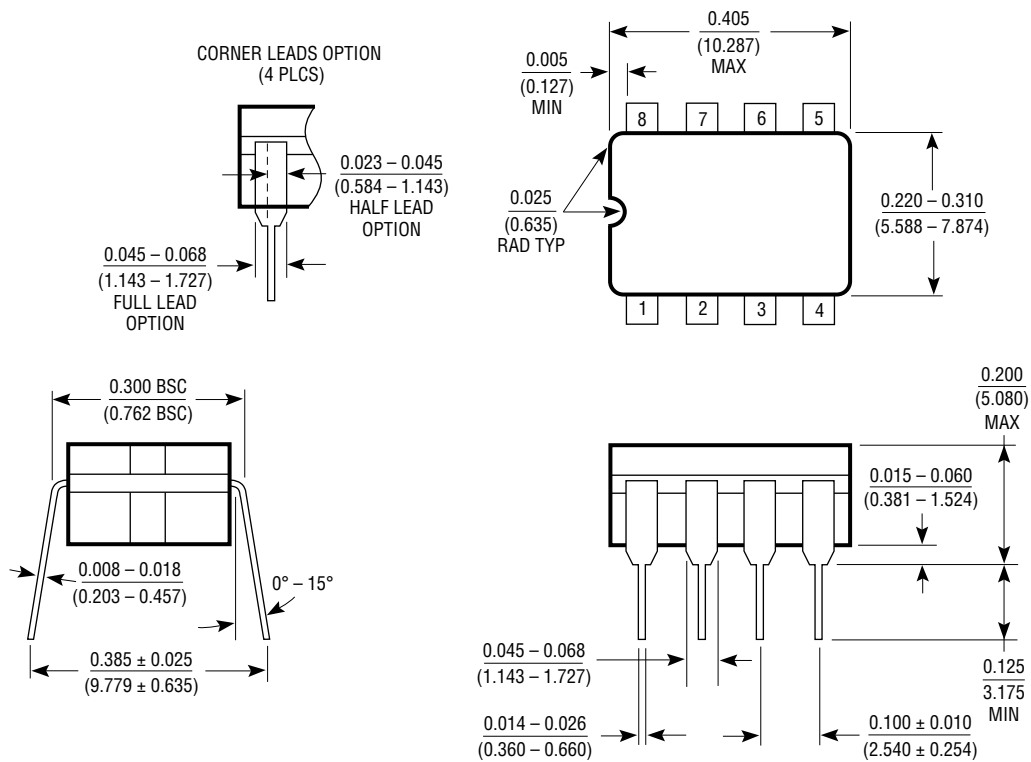
# **PACKAGE DESCRIPTION**

Dimensions in inches (millimeters) unless otherwise noted.

## **H8 Package 8-Lead TO-5 Metal Can**



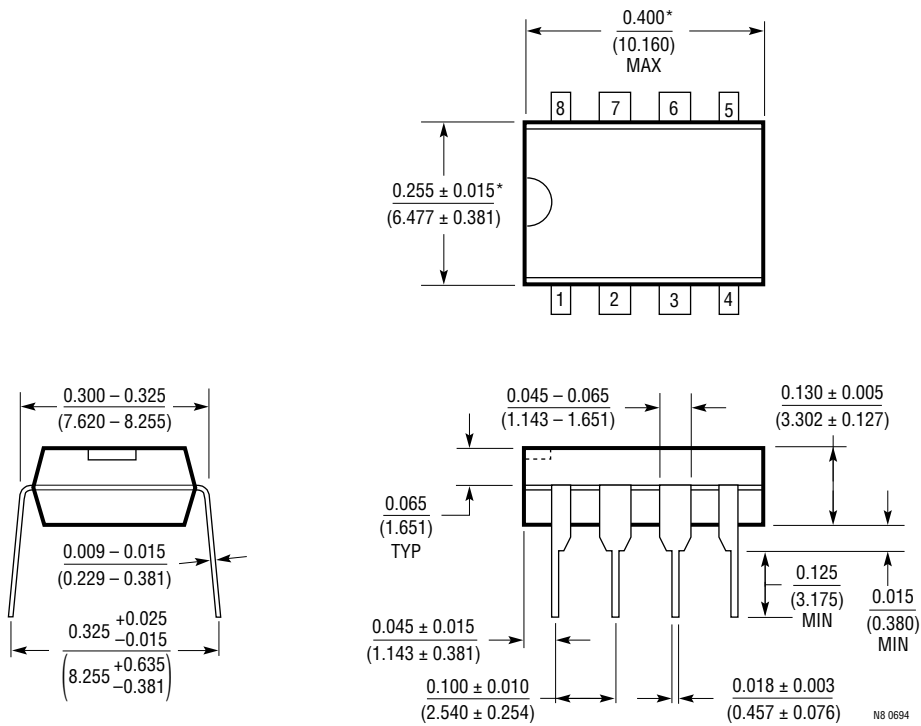
## **J8 Package 8-Lead Ceramic Dip**



LT1222

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

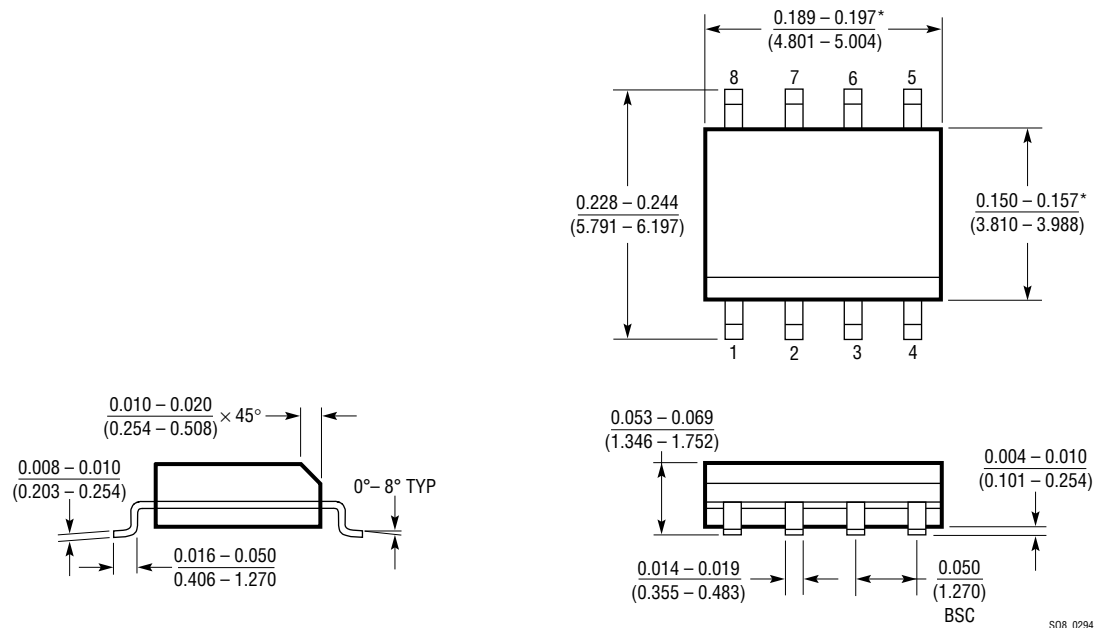
**N8 Package  
8-Lead Plastic Dip**



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTURSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm).

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

**S8 Package  
8-Lead Plastic SOIC**



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCH (0.15mm).

## U.S. Area Sales Offices

### NORTHEAST REGION

**Linear Technology Corporation**  
3220 Tillman Drive, Suite 120  
Bensalem, PA 19020  
Phone: (215) 638-9667  
FAX: (215) 638-9764

### Linear Technology Corporation

266 Lowell St., Suite B-8  
Wilmington, MA 01887  
Phone: (508) 658-3881  
FAX: (508) 658-2701

### SOUTHEAST REGION

**Linear Technology Corporation**  
17060 Dallas Parkway  
Suite 208  
Dallas, TX 75248  
Phone: (214) 733-3071  
FAX: (214) 380-5138

### CENTRAL REGION

**Linear Technology Corporation**  
Chesapeake Square  
229 Mitchell Court, Suite A-25  
Addison, IL 60101  
Phone: (708) 620-6910  
FAX: (708) 620-6977

### SOUTHWEST REGION

**Linear Technology Corporation**  
22141 Ventura Blvd.  
Suite 206  
Woodland Hills, CA 91364  
Phone: (818) 703-0835  
FAX: (818) 703-0517

### NORTHWEST REGION

**Linear Technology Corporation**  
782 Sycamore Dr.  
Milpitas, CA 95035  
Phone: (408) 428-2050  
FAX: (408) 432-6331

## International Sales Offices

### FRANCE

**Linear Technology S.A.R.L.**  
Immeuble "Le Quartz"  
58 Chemin de la Justice  
92290 Chateaufort Malabry  
France  
Phone: 33-1-41079555  
FAX: 33-1-46314613

### GERMANY

**Linear Technolgy GmbH**  
Untere Hauptstr. 9  
D-85386 Eching  
Germany  
Phone: 49-89-3197410  
FAX: 49-89-3194821

### JAPAN

**Linear Technology KK**  
5F YZ Bldg.  
4-4-12 Iidabashi, Chiyoda-Ku  
Tokyo, 102 Japan  
Phone: 81-3-3237-7891  
FAX: 81-3-3237-8010

### KOREA

**Linear Technology Korea Branch**  
Namsong Building, #505  
Itaewon-Dong 260-199  
Yongsan-Ku, Seoul  
Korea  
Phone: 82-2-792-1617  
FAX: 82-2-792-1619

### SINGAPORE

**Linear Technology Pte. Ltd.**  
507 Yishun Industrial Park A  
Singapore 2776  
Phone: 65-753-2692  
FAX: 65-754-4113

### TAIWAN

**Linear Technology Corporation**  
Rm. 801, No. 46, Sec. 2  
Chung Shan N. Rd.  
Taipei, Taiwan, R.O.C.  
Phone: 886-2-521-7575  
FAX: 886-2-562-2285

### UNITED KINGDOM

**Linear Technology (UK) Ltd.**  
The Coliseum, Riverside Way  
Camberley, Surrey GU15 3YL  
United Kingdom  
Phone: 44-276-677676  
FAX: 44-276-64851

## World Headquarters

**Linear Technology Corporation**  
1630 McCarthy Blvd.  
Milpitas, CA 95035-7487  
Phone: (408) 432-1900  
FAX: (408) 434-0507