![Linear Technology logo]

500MHz, 3nV/√Hz, $A_V \geq 10$ Operational Amplifier

FEATURES

- **Gain-Bandwidth: 500MHz**
- **Gain of 10 Stable Uncompensated**
- **Slew Rate: 200V/μs**
- Input Noise Voltage: 3nV/√Hz
- C-Load™ Op Amp Drives Capacitive Loads
- External Compensation Pin
- Maximum Input Offset Voltage: 300μV
- Maximum Input Bias Current: 300nA
- Maximum Input Offset Current: 300nA
- Minimum Output Swing Into 500Ω: ±12V
- Minimum DC Gain: 100V/mV, R_L = 500Ω
- 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 = 150Ω
- Differential Phase: 0.1°, A_V = 2, R_L = 150Ω

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.

*, LTC are registered trademarks and LT is a trademark of Linear Technology Corporation. C-Load is a trademark of Linear Technology Cortporation.
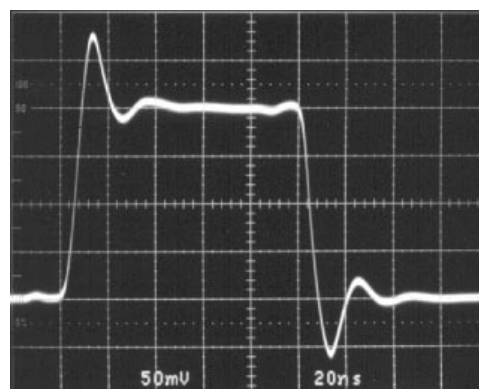
TYPICAL APPLICATION

A_V = 10 with Output Clamping
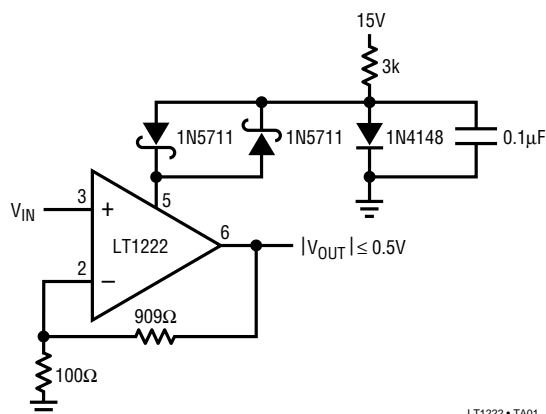
LT1222 • TA01

A_V = −1, C_C = 30pF Pulse Response

$R_F = R_G$ = 1k V_{IN} = 100mV
V_S = ±15V   f = 5MHz

LT1222 • TA02

![Linear Technology logo]

1

LT1222

ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage (V^+ to V^-) 36V
Differential Input Voltage .... ±6V
Input Voltage .... ±V_S
Output Short-Circuit Duration (Note 1) .... Indefinite
Specified Temperature Range
    LT1222C (Note 2) .... 0°C to 70°C
    LT1222M .... −55°C to 125°C

Operating Temperature Range
    LT1222C .... −40°C TO 85°C
    LT1222M .... −55°C to 125°C
Maximum Junction Temperature (See Below)
    Plastic Package .... 150°C
    Ceramic Package .... 175°C
Storage Temperature Range .... −65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
TOP VIEW NULL 8-LEAD TO-5 METAL CAN H PACKAGE NULL (1) (8) NULL −IN (2) (7) V^+ +IN (3) (6) V_{OUT} (4) (5) NC V^- T_{JMAX} = 175°C, θ_{JA} = 150°C/W	SPECIAL ORDER CONSULT FACTORY

	ORDER PART NUMBER
TOP VIEW NULL [1] 8 NULL −IN [2] 7 V^+ +IN [3] 6 V_{OUT} V^- [4] 5 NC J8 PACKAGE N8 PACKAGE 8-LEAD CERAMIC DIP 8-LEAD PLASTIC DIP S8 PACKAGE 8-LEAD PLASTIC SOIC T_{JMAX} = 175°C, θ_{JA} = 100°C/W (J) T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N) T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S)	LT1222CN8 LT1222MJ8 LT1222CS8
	S8 PART MARKING 1222

Consult factory for Industrial grade parts.

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

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

2

ELECTRICAL CHARACTERISTICS

$V_S = \pm15V$, $T_A = 25°C$, $V_{CM} = 0V$, 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%			75		ns
		10V Step, 0.01%			120		ns
	Differential Gain	$A_V = 2$, $C_C = 50pF$, $f = 3.58MHz$, $R_L = 150\Omega$ (Note 6)			0.40		%
		$A_V = 10$, $C_C = 0pF$, $f = 3.58MHz$, $R_L = 1k$ (Note 6)			0.15		%
	Differential Phase	$A_V = 2$, $C_C = 50pF$, $f = 3.58MHz$, $R_L = 150\Omega$ (Note 6)			0.10		DEG
		$A_V = 10$, $C_C = 0pF$, $f = 3.58MHz$, $R_L = 1k$ (Note 6)			0.01		DEG
R_O	Output Resistance	$A_V = 10$, $f = 1MHz$			0.1		Ω
I_S	Supply Current				8	10.5	mA

$V_S = \pm15V$, $0°C \leq T_A \leq 70°C$, $V_{CM} = 0V$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 3)	●		100	600	μV
	Input V_{OS} Drift				5		$\mu V/°C$
I_{OS}	Input Offset Current		●		100	400	nA
I_B	Input Bias Current		●		100	400	nA
CMRR	Common-Mode Rejection Ratio	$V_{CM} = \pm12V$	●	100	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm5V$ to $\pm15V$	●	98	110		dB
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm10V$, $R_L = 500\Omega$	●	100	200		V/mV
V_{OUT}	Output Swing	$R_L = 500\Omega$	●	12	13		$\pm V$
I_{OUT}	Output Current	$V_{OUT} = \pm12V$	●	24	26		mA
SR	Slew Rate	(Note 4)	●	150	200		V/μs
I_S	Supply Current		●		8	11	mA

$V_S = \pm15V$, $-55°C \leq T_A \leq 125°C$, $V_{CM} = 0V$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 3)	●		100	600	μV
	Input V_{OS} Drift				5		$\mu V/°C$
I_{OS}	Input Offset Current		●		100	800	nA
I_B	Input Bias Current		●		100	1000	nA
CMRR	Common-Mode Rejection Ratio	$V_{CM} = \pm12V$	●	98	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm5V$ to $\pm15V$	●	98	110		dB
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm10V$, $R_L = 500\Omega$	●	50	200		V/mV
V_{OUT}	Output Swing	$R_L = 500\Omega$	●	10	13		$\pm V$
		$R_L = 1k$	●	12	13		$\pm V$
I_{OUT}	Output Current	$V_{OUT} = \pm10V$	●	20	26		mA
		$V_{OUT} = \pm12V$	●	12	13		mA
SR	Slew Rate	(Note 4)	●	110	200		V/μs
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 $-40°C$ to $85°C$, but are not tested nor guaranteed beyond $0°C$ to $70°C$. Industrial grade parts specified and tested over $-40°C$ to $85°C$ 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 $\pm10V$ on an output swing of $\pm12V$.

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

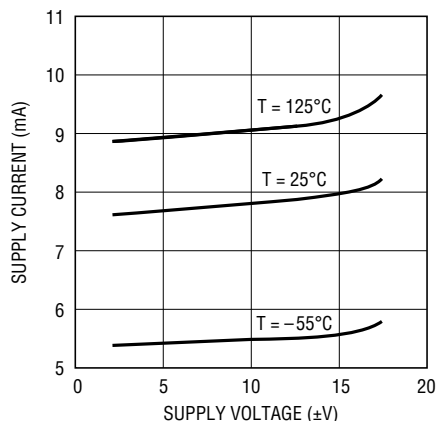**Note 6:** Differential Gain and Phase are tested with five amps in series. Attenuators of 1/Gain are used as loads.

LT1222

TYPICAL PERFORMANCE CHARACTERISTICS

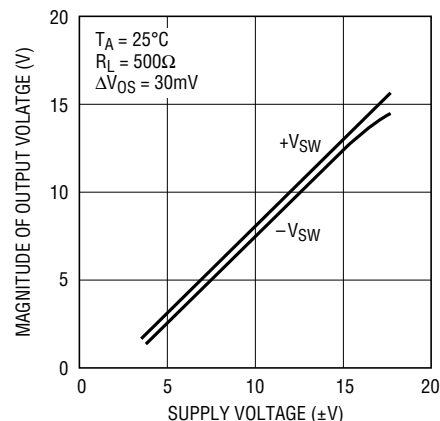### Input Common-Mode Range vs Supply Voltage

$T_A = 25°C$
$\Delta V_{OS} = 0.5mV$

$+V_{CM}$
$-V_{CM}$
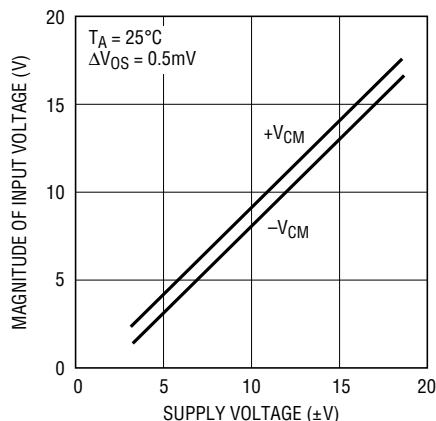
LT1222 • TPC01

Supply Current vs Supply Voltage and Temperature

$T = 125°C$
$T = 25°C$
$T = -55°C$

LT1222 • TPC02

Output Voltage Swing vs Supply Voltage

$T_A = 25°C$
$R_L = 500\Omega$
$\Delta V_{OS} = 30mV$

$+V_{SW}$
$-V_{SW}$

LT1222 • TPC03

Output Voltage Swing vs Resistive Load

$T_A = 25°C$
$\Delta V_{OS} = 30mV$

±15V SUPPLIES
±5V SUPPLIES
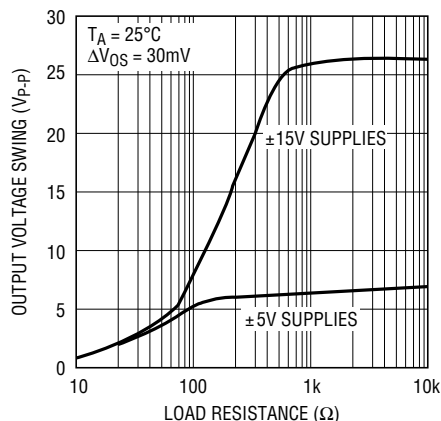
LT1222 • TPC04

Input Bias Current vs Input Common-Mode Voltage

$V_S = \pm15V$
$T_A = 25°C$

I_B^+
I_B^-
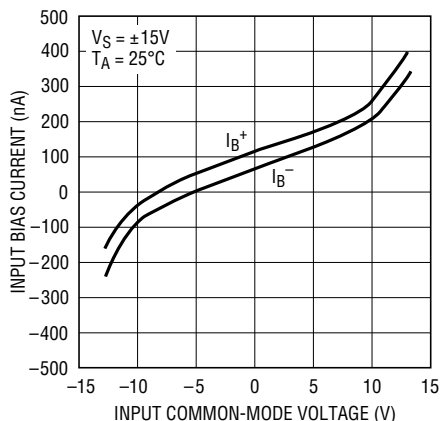
LT1222 • TPC05

Open-Loop Gain vs Resistive Load

$T_A = 25°C$

$V_S = \pm15V$
$V_S = \pm5V$
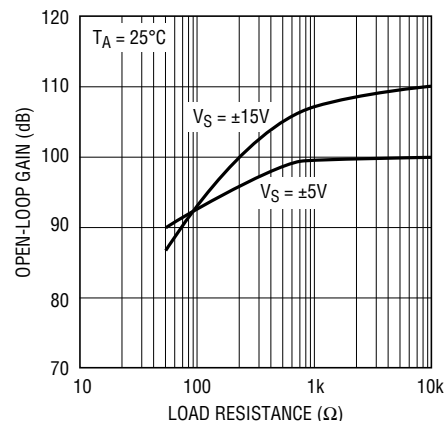
LT1222 • TPC06

Output Short-Circuit Current vs Temperature

$V_S = \pm5V$
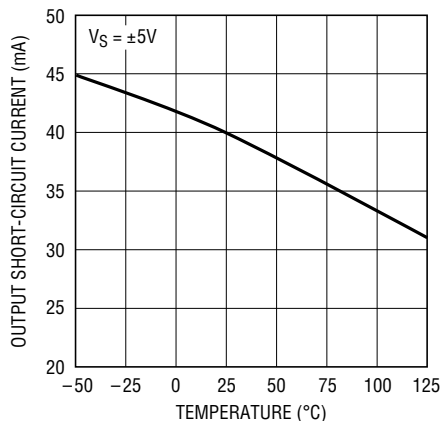
LT1222 • TPC07

Input Noise Spectral Density

$V_S = \pm15V$
$T_A = 25°C$
$A_V = 101$
$R_S = 100k$

i_n
e_n
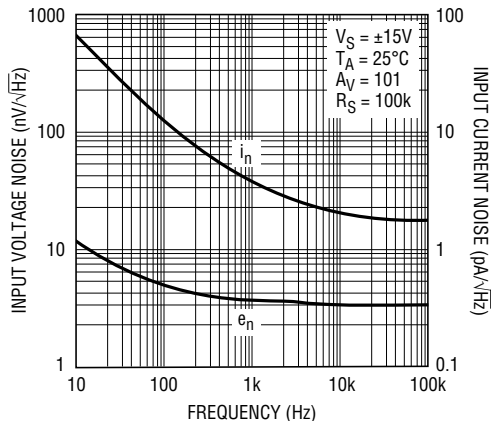
LT1222 • TPC08

Power Supply Rejection Ratio vs Frequency

$V_S = \pm15V$
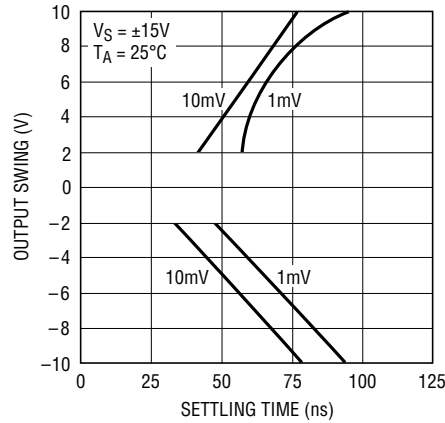$T_A = 25°C$

$+PSRR$
$-PSRR$

LT1222 • TPC09

4
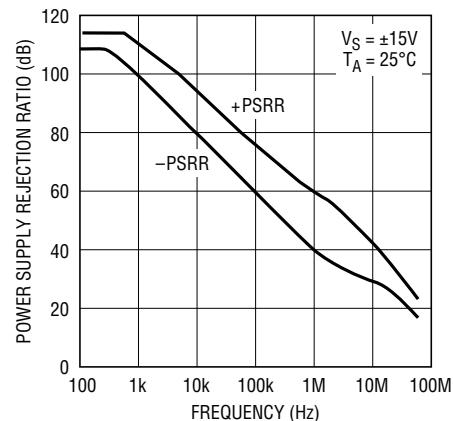
TYPICAL PERFORMANCE CHARACTERISTICS

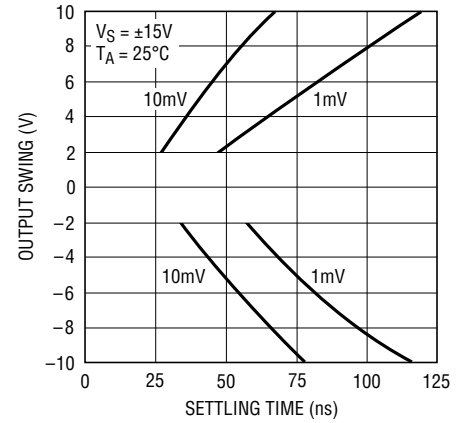### Common-Mode Rejection Ratio vs Frequency
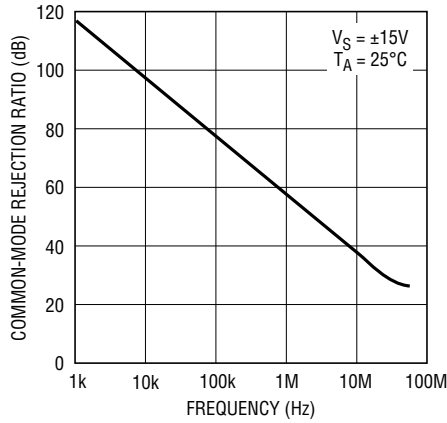
LT1222 • TPC10

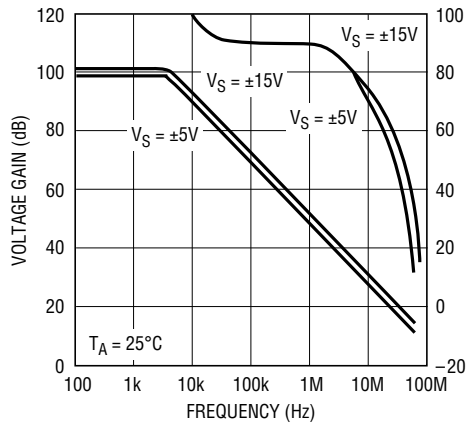### Output Swing and Error vs Settling Time (Noninverting)

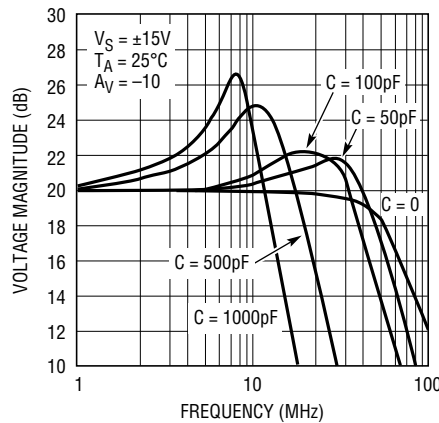LT1222 • TPC11

Output Swing and Error vs Settling Time (Inverting)
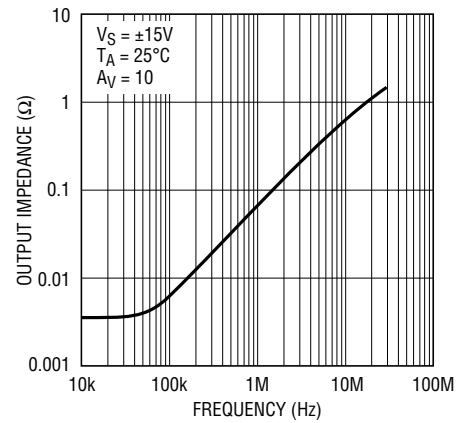

LT1222 • TPC12

Voltage Gain and Phase vs Frequency

LT1222 • TPC13

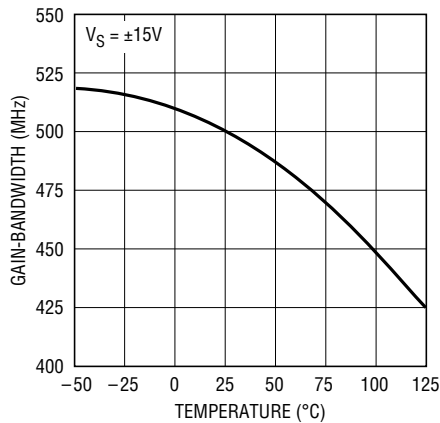### Frequency Response vs Capacitive Load

LT1222 • TPC14

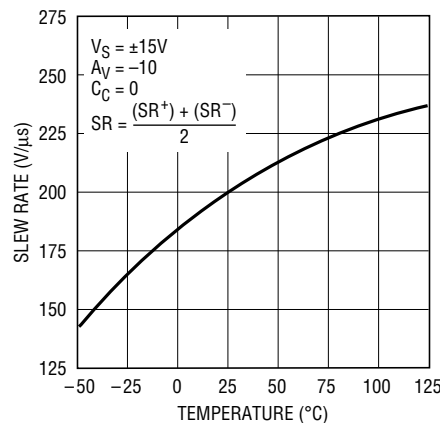### Closed-Loop Output Impedance vs Frequency
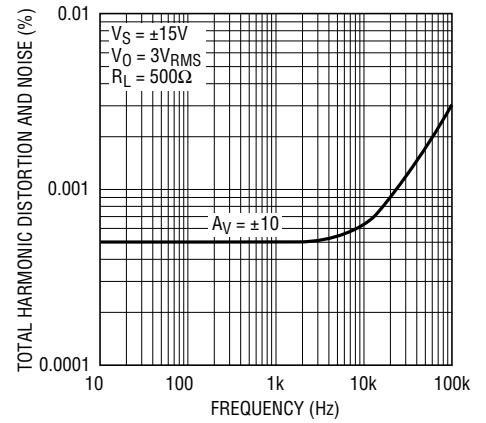

LT1222 • TPC15

Gain-Bandwidth vs Temperature
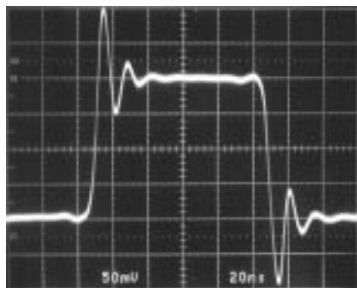

LT1222 • TPC16

Slew Rate vs Temperature

$$SR = \frac{(SR^+) + (SR^-)}{2}$$

LT1222 • TPC17

Total Harmonic Distortion vs Frequency

LT1222 • TPC18

5

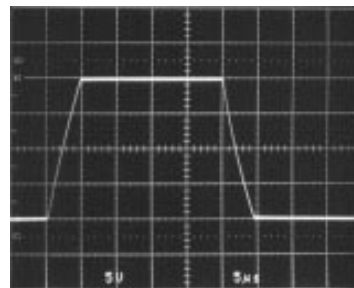# TYPICAL PERFORMANCE CHARACTERISTICS

Small Signal, A$_V$ = 10

R$_F$ = 909Ω   V$_S$ = ±15V   f = 5MHz
R$_G$ = 100Ω   V$_{IN}$ = 20mV

LT1222 • TPC19

Large Signal, A$_V$ = 10
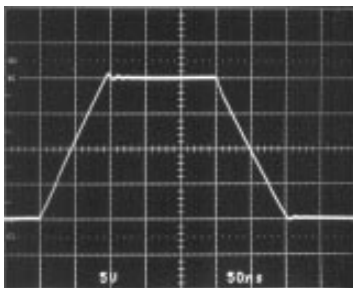
R$_F$ = 909Ω   V$_S$ = ±15V   f = 2MHz
R$_G$ = 100Ω   V$_{IN}$ = 2V

LT1222 • TPC20

**Large Signal, A$_V$ = 10,
C$_L$ = 10,000pF**

R$_F$ = 909Ω   V$_S$ = ±15V   f = 20kHz
R$_G$ = 100Ω   V$_{IN}$ = 2V

LT1222 • TPC21
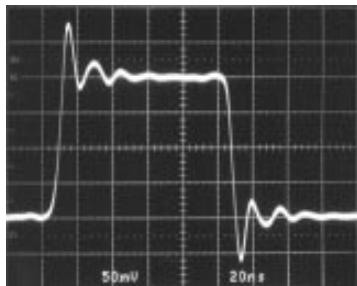
Small Signal, A$_V$ = −10

R$_F$ = 1k   V$_S$ = ±15V   f = 5MHz
R$_G$ = 100Ω (75)   V$_{IN}$ = 20mV

LT1222 • TPC22

Large Signal, A$_V$ = −10
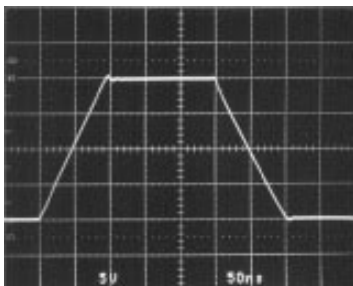
R$_F$ = 1k   V$_S$ = ±15V   f = 2MHz
R$_G$ = 100Ω (75)   V$_{IN}$ = 2V

LT1222 • TPC23

**Small Signal, A$_V$ = −10,
C$_L$ = 1,000pF**
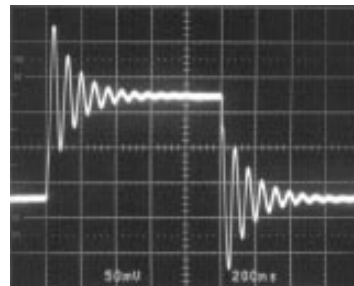
R$_F$ = 1k   V$_S$ = ±15V   f = 500kHz
R$_G$ = 100Ω (75)   V$_{IN}$ = 15mV

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 • AI01
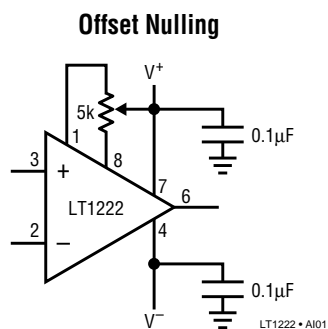
Layout and Passive Components

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.

6

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 ±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/μs 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., 75Ω) 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 vresus –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 $C_C = 20$pF which has 10.5MHz bandwidth and 46V/μs slew rate. It should be noted that the LT1222 is not stable in $A_V = 1$ unless $C_C = 50$pF and a 1k resistor is used as the feedback resistor. The 1k and input capacitance increase the noise gain at frequency to aid stability.

7

TYPICAL APPLICATIONS

V$_{OS}$ Null Loop
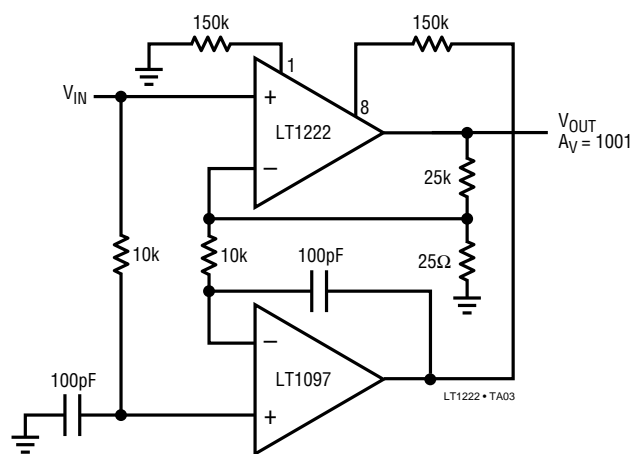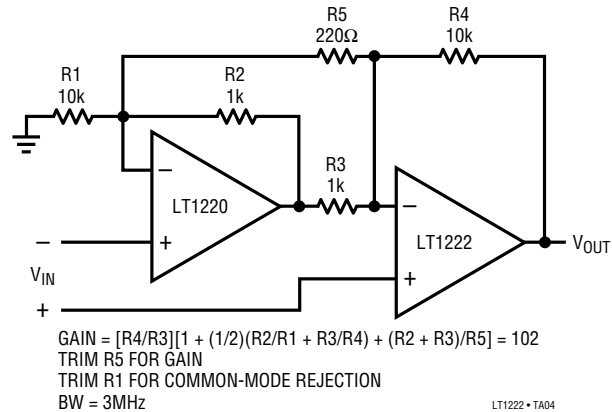
V$_{IN}$

150k

150k

LT1222

1

8

V$_{OUT}$
A$_V$ = 1001

25k

25Ω

10k

10k

100pF

100pF

LT1097

LT1222 • TA03

Two Op Amp Instrumemtation Amplifier

R5
220Ω

R4
10k

R1
10k

R2
1k

R3
1k

LT1220

LT1222

V$_{OUT}$

V$_{IN}$

GAIN = [R4/R3][1 + (1/2)(R2/R1 + R3/R4) + (R2 + R3)/R5] = 102
TRIM R5 FOR GAIN
TRIM R1 FOR COMMON-MODE REJECTION
BW = 3MHz

LT1222 • TA04

SIMPLIFIED SCHEMATIC

V$^+$ 7

NULL

1

8

BIAS 1

BIAS 2

COMP 5

2 −IN

+IN 3

6 OUT

V$^-$ 4

LT1222 • SS
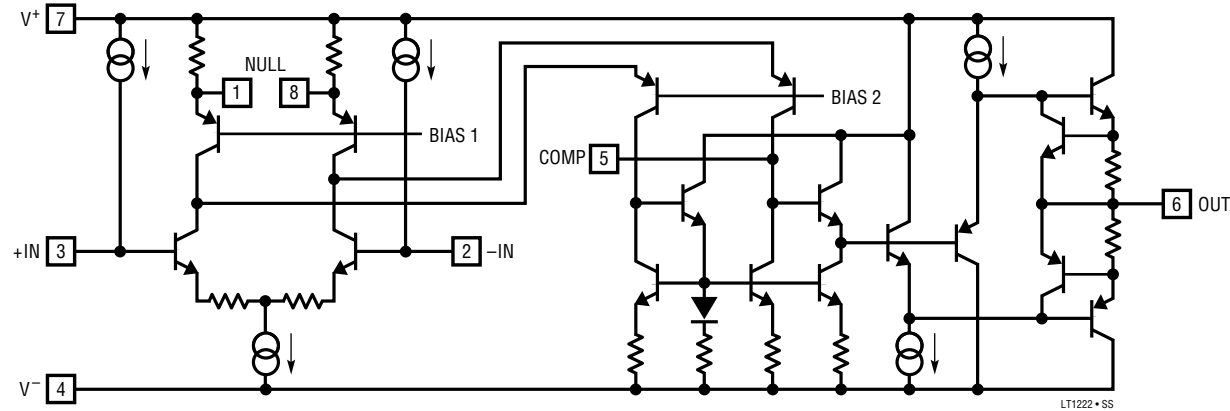
PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

H8 Package
8-Lead TO-5 Metal Can

0.335 – 0.370
(8.509 – 9.398)
DIA

0.305 – 0.335
(7.747 – 8.509)

0.040
(1.016)
MAX

0.050
(1.270)
MAX

0.165 – 0.185
(4.191 – 4.699)

REFERENCE
PLANE

SEATING
PLANE

GAUGE
PLANE

0.500 – 0.750
(12.700 – 19.050)

0.010 – 0.045
(0.254 – 1.143)

0.016 – 0.021
(0.406 – 0.533)

NOTE: LEAD DIAMETER IS UNCONTROLLED BETWEEN
THE REFERENCE PLANE AND SEATING PLANE.

45°TYP

0.027 – 0.034
(0.686 – 0.864)

0.027 – 0.045
(0.686 – 1.143)

0.200 – 0.230
(5.080 – 5.842)
BSC

0.110 – 0.160
(2.794 – 4.064)
INSULATING
STANDOFF

H8(5) 0592

J8 Package
8-Lead Ceramic Dip

CORNER LEADS OPTION
(4 PLCS)

0.023 – 0.045
(0.584 – 1.143)
HALF LEAD
OPTION

0.045 – 0.068
(1.143 – 1.727)
FULL LEAD
OPTION

0.405
(10.287)
MAX

0.005
(0.127)
MIN

0.025
(0.635)
RAD TYP

0.220 – 0.310
(5.588 – 7.874)

0.300 BSC
(0.762 BSC)

0.008 – 0.018
(0.203 – 0.457)

0° – 15°

0.385 ± 0.025
(9.779 ± 0.635)

0.200
(5.080)
MAX

0.015 – 0.060
(0.381 – 1.524)

0.045 – 0.068
(1.143 – 1.727)

0.014 – 0.026
(0.360 – 0.660)

0.100 ± 0.010
(2.540 ± 0.254)

0.125
3.175
MIN

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

J8 0694

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9

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

N8 Package
8-Lead Plastic Dip

0.400*
(10.160)
MAX

8 7 6 5

0.255 ± 0.015*
(6.477 ± 0.381)

1 2 3 4

0.300 – 0.325
(7.620 – 8.255)

0.045 – 0.065
(1.143 – 1.651)

0.130 ± 0.005
(3.302 ± 0.127)

0.065
(1.651)
TYP

0.009 – 0.015
(0.229 – 0.381)

$0.325 {}^{+0.025}_{-0.015}$

$\left(8.255 {}^{+0.635}_{-0.381}\right)$

0.045 ± 0.015
(1.143 ± 0.381)

0.100 ± 0.010
(2.540 ± 0.254)

0.018 ± 0.003
(0.457 ± 0.076)

0.125
(3.175)
MIN

0.015
(0.380)
MIN

N8 0694
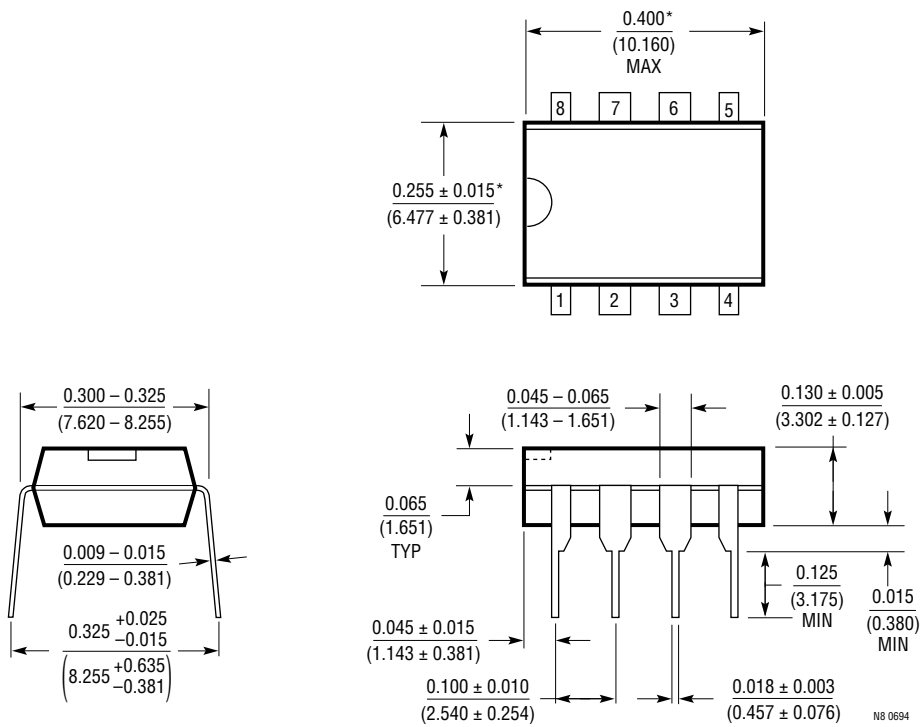
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
 MOLD FLASH OR PROTURSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm).

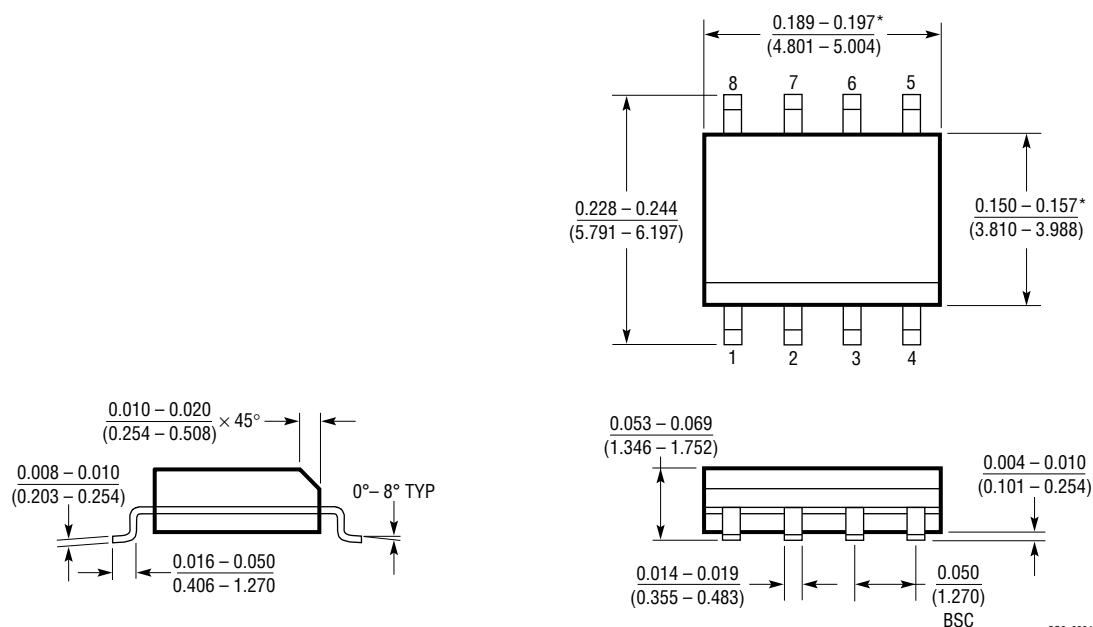# PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

**S8 Package
8-Lead Plastic SOIC**

$\dfrac{0.189 - 0.197^*}{(4.801 - 5.004)}$

8 7 6 5

$\dfrac{0.228 - 0.244}{(5.791 - 6.197)}$

$\dfrac{0.150 - 0.157^*}{(3.810 - 3.988)}$

1 2 3 4

$\dfrac{0.010 - 0.020}{(0.254 - 0.508)} \times 45°$

$\dfrac{0.008 - 0.010}{(0.203 - 0.254)}$

0°– 8° TYP

$\dfrac{0.016 - 0.050}{0.406 - 1.270}$

$\dfrac{0.053 - 0.069}{(1.346 - 1.752)}$

$\dfrac{0.004 - 0.010}{(0.101 - 0.254)}$

$\dfrac{0.014 - 0.019}{(0.355 - 0.483)}$

$\dfrac{0.050}{(1.270)}$
BSC

SO8 0294

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

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