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

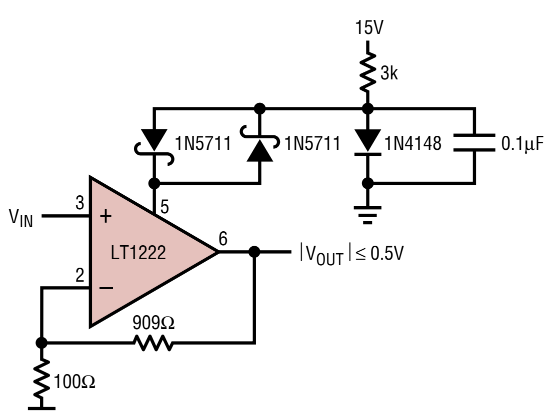
DESCRIPTION

The LT®1222 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.

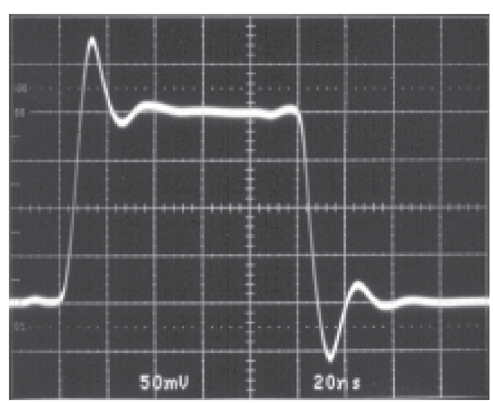
The LT1222 is a member of a family of fast, high performance amplifiers that employ Linear Technology Corporation's advanced complementary bipolar processing. For unity-gain stable applications the LT1220 can be used, and for gains of 4 or greater the LT1221 can be used.

TYPICAL APPLICATION

A_V = 10 with Output Clamping



A_V = −1, C_C = 30pF Pulse Response



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

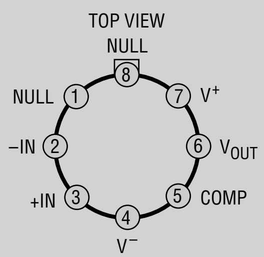
LT1222 • TA02

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-) 36V
Differential Input Voltage .... ±6V
Input Voltage .... $\pm V_S$
Output Short-Circuit Duration (Note 2) .... Indefinite
Specified Temperature Range
  LT1222C (Note 3) .... 0°C to 70°C
  LT1222I ....–40°C to 85°C
  LT1222M **(OBSOLETE)** .... –55°C to 125°C

Operating Temperature Range
  LT1222C .... –40°C TO 85°C
  LT1222I ....–40°C to 85°C
  LT1222M **(OBSOLETE)** .... –55°C to 125°C
Maximum Junction Temperature (See Below)
  Plastic Package .... 150°C
  Ceramic Package **(OBSOLETE)** .... 175°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

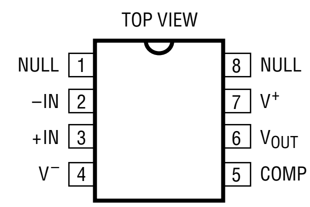


H PACKAGE
8-LEAD TO-5 METAL CAN
T_{JMAX} = 175°C, θ_{JA} = 150°C/W

OBSOLETE PACKAGE
Consider the N8 or S8 Packages for Alternate Source

ORDER PART NUMBER

SPECIAL ORDER CONSULT FACTORY



N8 PACKAGE 8-LEAD PLASTIC DIP
S8 PACKAGE 8-LEAD PLASTIC SOIC
T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S)

ORDER PART NUMBER

LT1222CN8
LT1222CS8
LT1222IS8

S8 PART MARKING

1222
1222I

J8 PACKAGE
8-LEAD CERAMIC DIP
T_{JMAX} = 175°C, θ_{JA} = 100°C/W (J)

ORDER PART NUMBER

LT1222MJ8

OBSOLETE PACKAGE
Consider the N8 or S8 Packages for Alternate Source

Consult LTC Marketing for parts specified with wider operating temperature ranges.

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

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 4)		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		$nV/\sqrt{Hz}$
i_n	Input Noise Current	f = 10kHz		2		$pA/\sqrt{Hz}$
R_{IN}	Input Resistance	V_{CM} = ±12V Differential	20	45 12		MΩ kΩ
C_{IN}	Input Capacitance			2		pF
	Input Voltage Range (Positive) Input Voltage Range (Negative)		12	14 –13	 –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 5)	150	200		V/µs
	Full Power Bandwidth	10V Peak (Note 6)		3.2		MHz
GBW	Gain-Bandwidth	f = 1MHz		500		MHz

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		43		%
	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 7) $A_V = 10$, $C_C = 0pF$, f = 3.58MHz, $R_L = 1k$ (Note 7)		0.40 0.15		% %
	Differential Phase	$A_V = 2$, $C_C = 50pF$, f = 3.58MHz, $R_L = 150\Omega$ (Note 7) $A_V = 10$, $C_C = 0pF$, f = 3.58MHz, $R_L = 1k$ (Note 7)		0.10 0.01		DEG DEG
R_O	Output Resistance	$A_V = 10$, f = 1MHz		0.1		Ω
I_S	Supply Current			8	10.5	mA

The ● denotes the specifications which apply over the temperature range 0°C ≤ T_A ≤ 70°C, otherwise specifications are at $T_A = 25°C$. $V_S = \pm15V$, $V_{CM} = 0V$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 4)	●		100	600	µV
	Input V_{OS} Drift		●		5		µV/°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		±V
I_{OUT}	Output Current	$V_{OUT} = \pm12V$	●	24	26		mA
SR	Slew Rate	(Note 5)	●	150	200		V/µs
I_S	Supply Current		●		8	11	mA

The ● denotes the specifications which apply over the temperature range –55°C ≤ T_A ≤ 125°C for LT1222M, –40°C ≤ T_A ≤ 85°C for LT1222I, otherwise specifications are at $T_A = 25°C$. $V_S = \pm15V$, $V_{CM} = 0V$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 4)	●		100	600	µV
	Input V_{OS} Drift		●		5		µV/°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	$R_L = 500\Omega$ $R_L = 1k$	● ●	10 12	13 13		±V ±V
I_{OUT}	Output Current	$V_{OUT} = \pm10V$ $V_{OUT} = \pm12V$	● ●	20 12	26 13		mA mA
SR	Slew Rate	(Note 5)	●	110	200		V/µs
I_S	Supply Current		●		8	11	mA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: A heat sink may be required when the output is shorted indefinitely.

Note 3: The LT1222C is guaranteed to meet specified performance from 0°C to 70°C and is designed, characterized and expected to meet these extended temperature limits, but is not tested at –40°C and 85°C. The LT1222I is guaranteed to meet the extended temperature limits.

Note 4: Input offset voltage is pulse tested and is exclusive of warm-up drift.

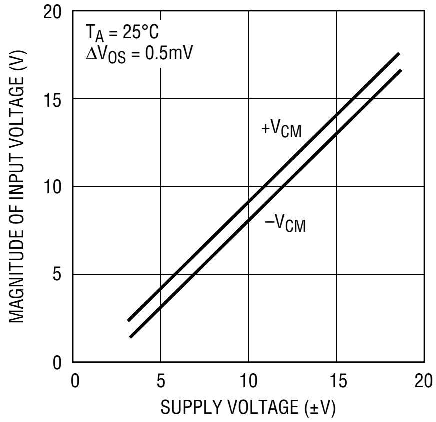
Note 5: Slew rate is measured between ±10V on an output swing of ±12V.

Note 6: FPBW = $SR/2\pi V_P$.

Note 7: Differential Gain and Phase are tested with five amps in series. Attenuators of 1/Gain are used as loads.

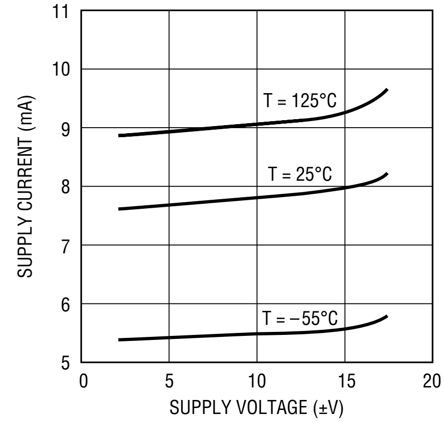
TYPICAL PERFORMANCE CHARACTERISTICS

Input Common Mode Range vs Supply Voltage



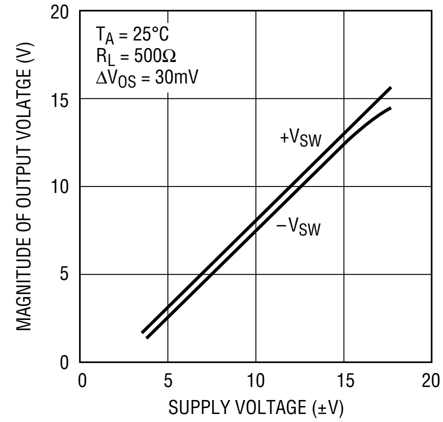
LT1222 • TPC01

Supply Current vs Supply Voltage and Temperature



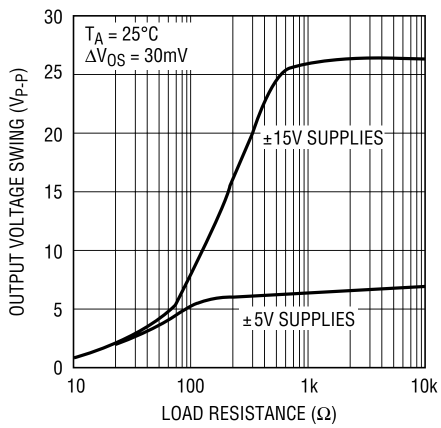
LT1222 • TPC02

Output Voltage Swing vs Supply Voltage



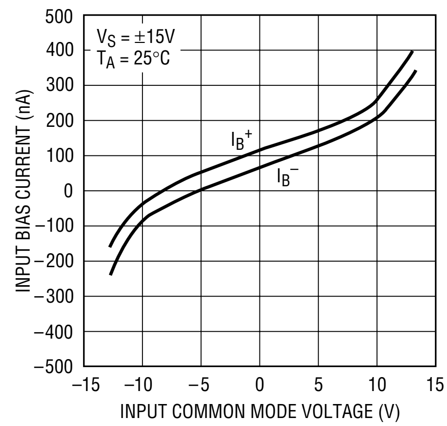
LT1222 • TPC03

Output Voltage Swing vs Resistive Load



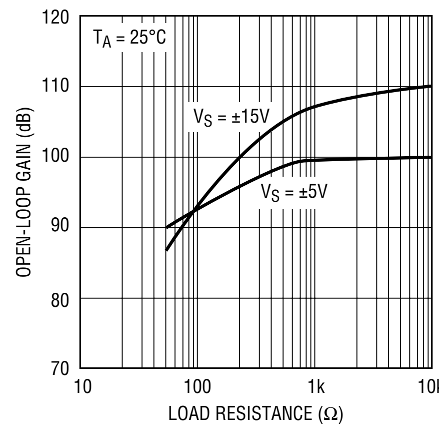
LT1222 • TPC04

Input Bias Current vs Input Common Mode Voltage



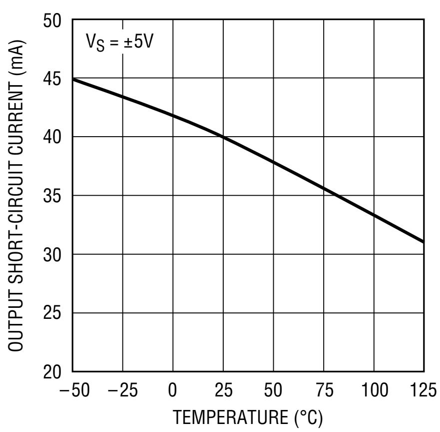
LT1222 • TPC05

Open-Loop Gain vs Resistive Load



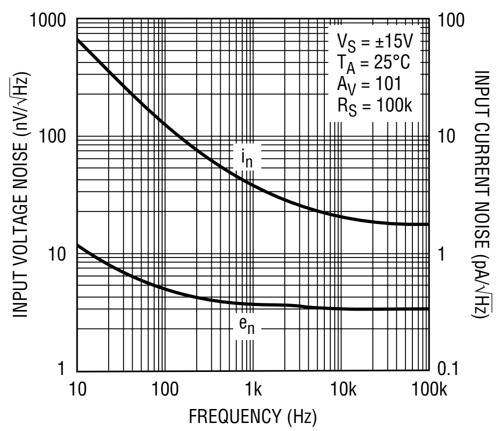
LT1222 • TPC06

Output Short-Circuit Current vs Temperature



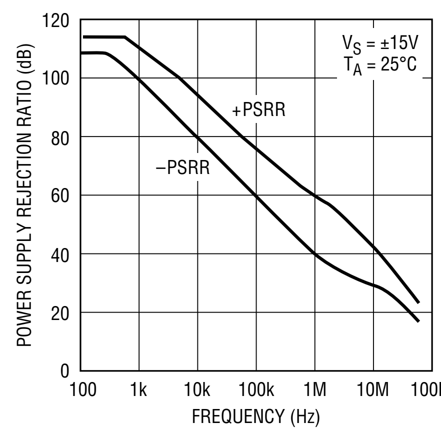
LT1222 • TPC07

Input Noise Spectral Density



LT1222 • TPC08

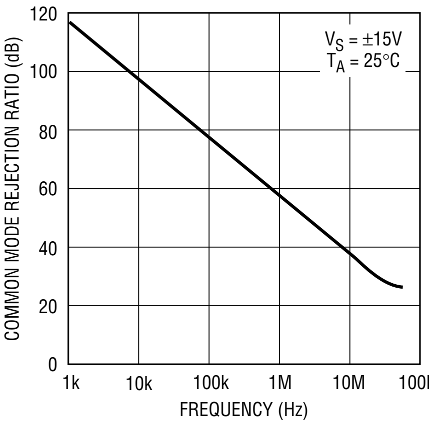
Power Supply Rejection Ratio vs Frequency



LT1222 • TPC09

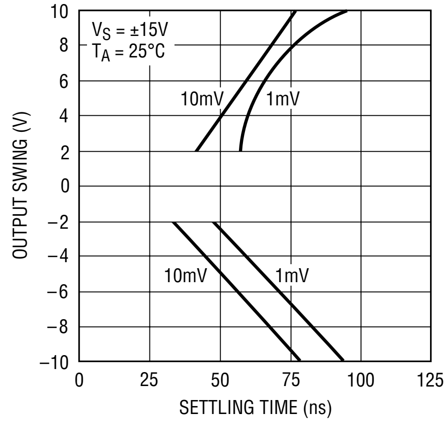
TYPICAL PERFORMANCE CHARACTERISTICS

Common Mode Rejection Ratio vs Frequency



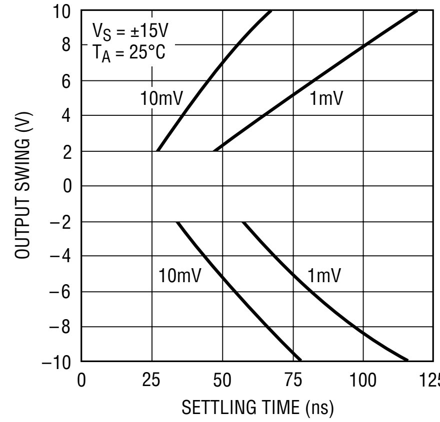
LT1222 • TPC10

Output Swing and Error vs Settling Time (Noninverting)



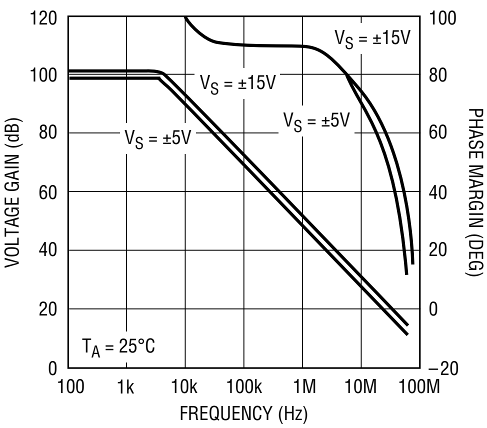
LT1222 • TPC11

Output Swing and Error vs Settling Time (Inverting)



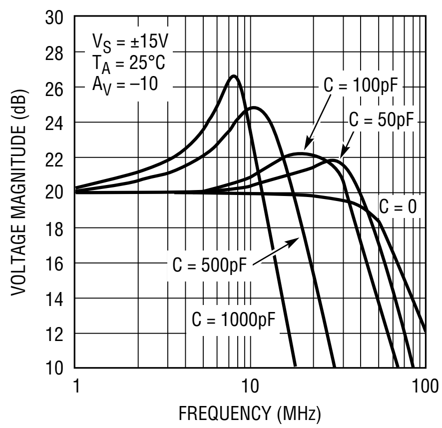
LT1222 • TPC12

Voltage Gain and Phase vs Frequency



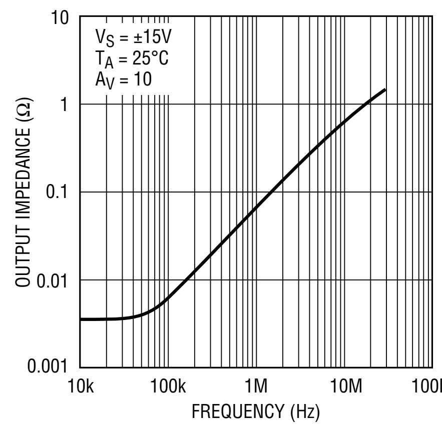
LT1222 • TPC13

Frequency Response vs Capacitive Load



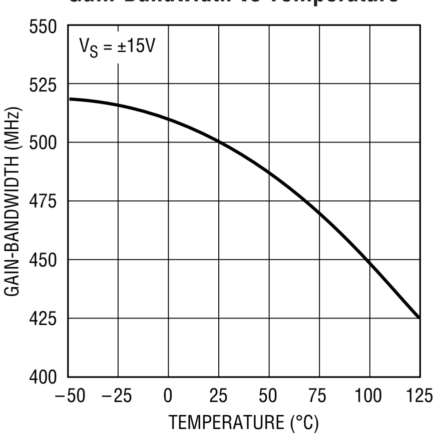
LT1222 • TPC14

Closed-Loop Output Impedance vs Frequency



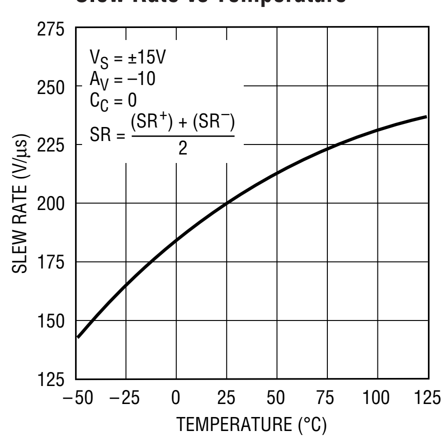
LT1222 • TPC15

Gain-Bandwidth vs Temperature



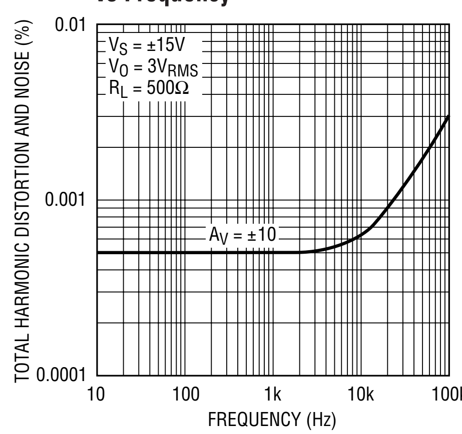
LT1222 • TPC16

Slew Rate vs Temperature



LT1222 • TPC17

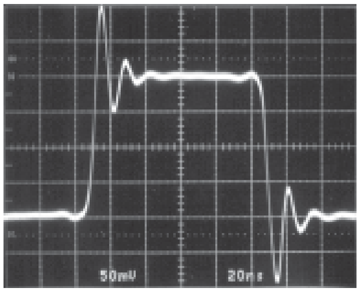
Total Harmonic Distortion vs Frequency



LT1222 • TPC18

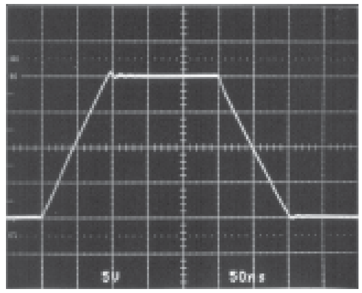
TYPICAL PERFORMANCE CHARACTERISTICS

Small Signal, A_V = 10



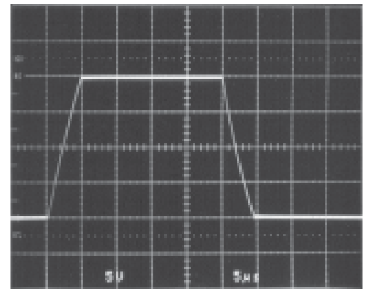
R_F = 909Ω V_S = ±15V f = 5MHz
R_G = 100Ω V_{IN} = 20mV
LT1222 • TPC19

Large Signal, A_V = 10



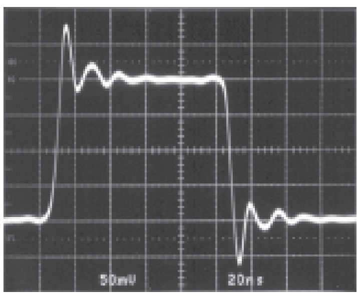
R_F = 909Ω V_S = ±15V f = 2MHz
R_G = 100Ω V_{IN} = 2V
LT1222 • TPC20

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



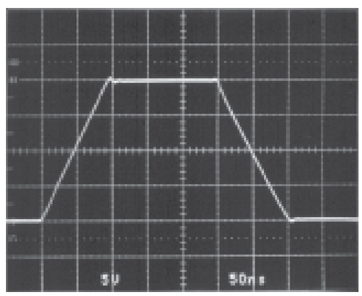
R_F = 909Ω V_S = ±15V f = 20kHz
R_G = 100Ω V_{IN} = 2V
LT1222 • TPC21

Small Signal, A_V = –10



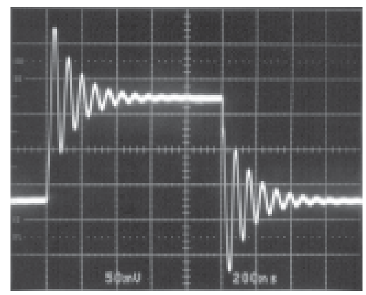
R_F = 1k V_S = ±15V f = 5MHz
R_G = 100Ω (75) V_{IN} = 20mV
LT1222 • TPC22

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

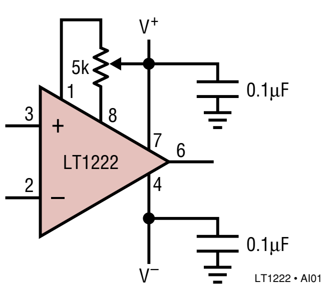


R_F = 1k V_S = ±15V f = 500kHz
R_G = 100Ω (75) V_{IN} = 15mV
LT1222 • TPC24

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



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 ±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:

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

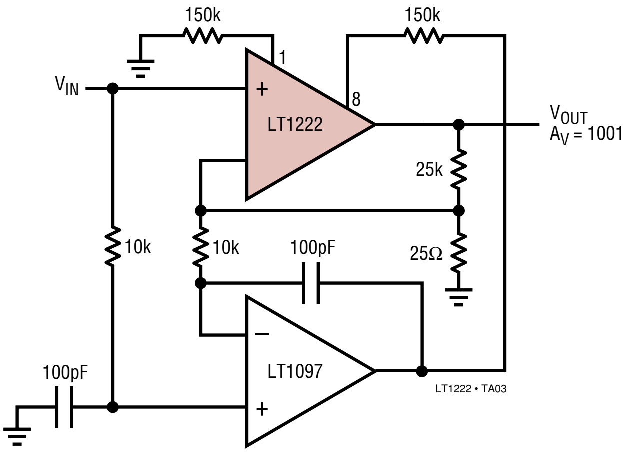
The slew rate is affected as follows:

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

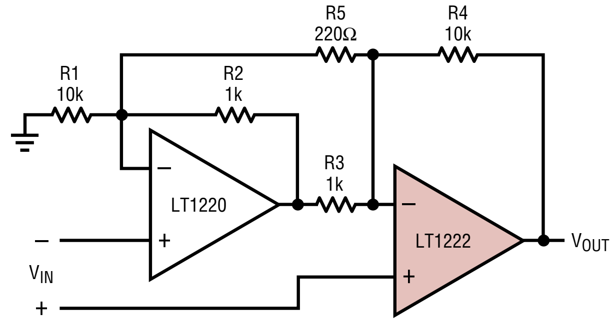
An example would be a gain of –10 (noise gain of 11) and C_C = 20pF which has 10.5MHz bandwidth and 46V/µs slew rate. It should be noted that the LT1222 is not stable in A_V = 1 unless C_C = 50pF and a 1k resistor is used as the feedback resistor. The 1k and input capacitance increase the noise gain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

TYPICAL APPLICATIONS

V_{OS} Null Loop

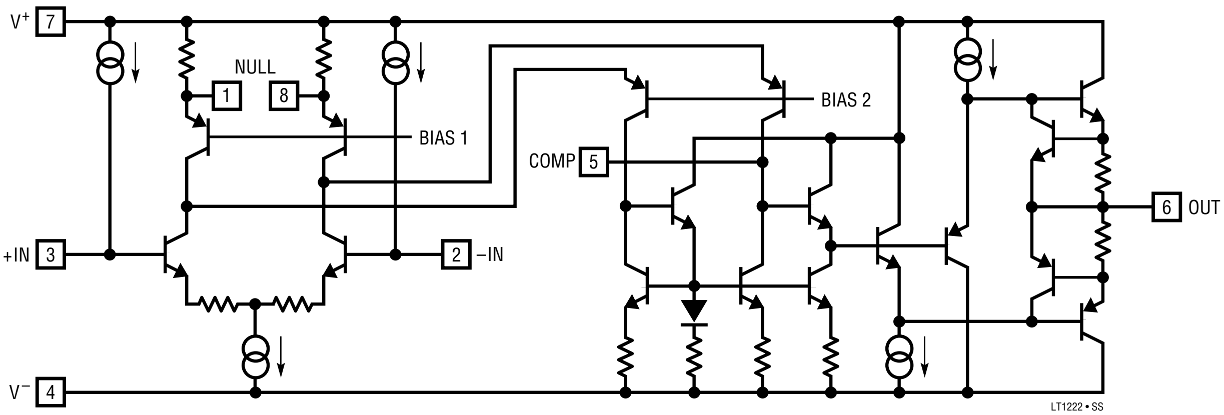


Two Op Amp Instrumemtation Amplifier



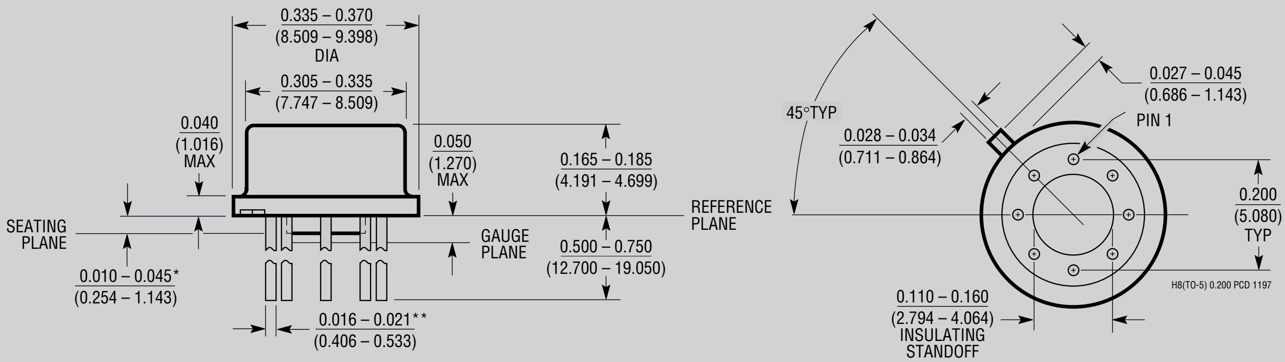
GAIN = [R4/R3][1 + (1/2)(R2/R1 + R3/R4) + (R2 + R3)/R5] = 102
TRIM R5 FOR GAIN
TRIM R1 FOR COMMON MODE REJECTION
BW = 3MHz

SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

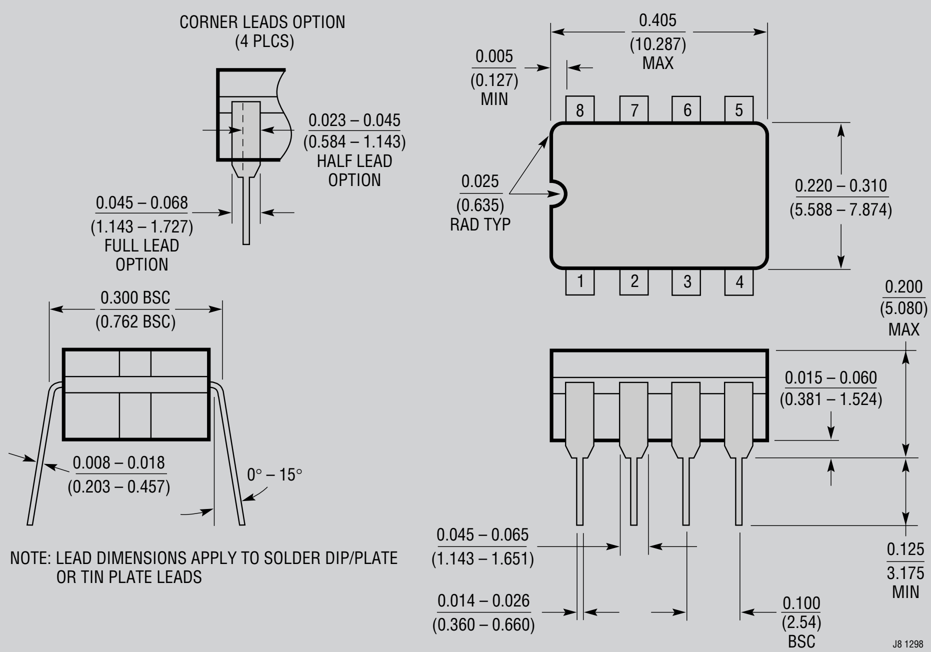
H Package
8-Lead TO-5 Metal Can (.200 Inch PCD)
(Reference LTC DWG # 05-08-1320)



*LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND 0.045" BELOW THE REFERENCE PLANE

**FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS $\frac{0.016 - 0.024}{(0.406 - 0.610)}$

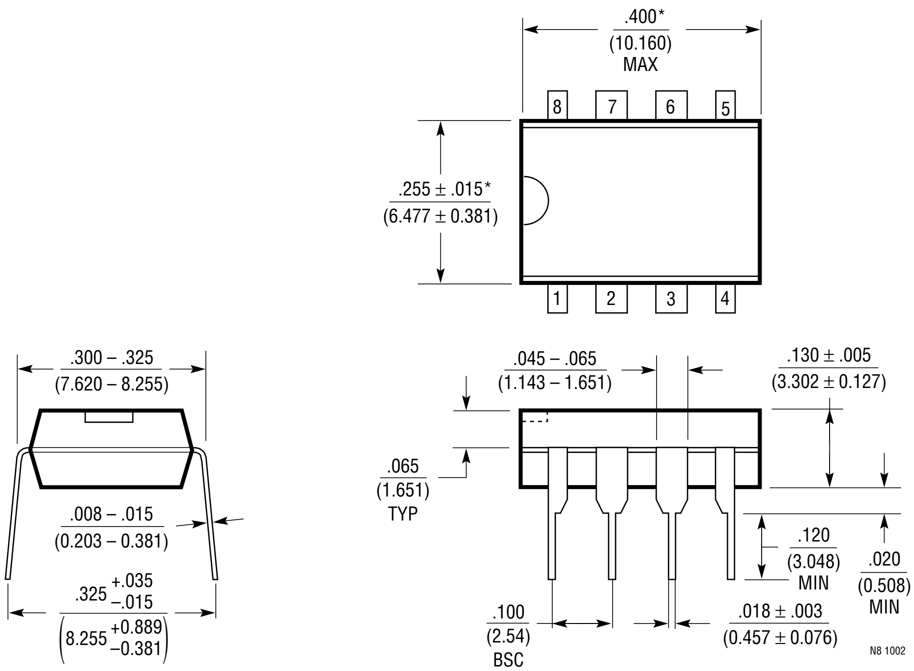
J8 Package
8-Lead CERDIP (Narrow .300 Inch, Hermetic)
(Reference LTC DWG # 05-08-1110)



OBSOLETE PACKAGES

PACKAGE DESCRIPTION

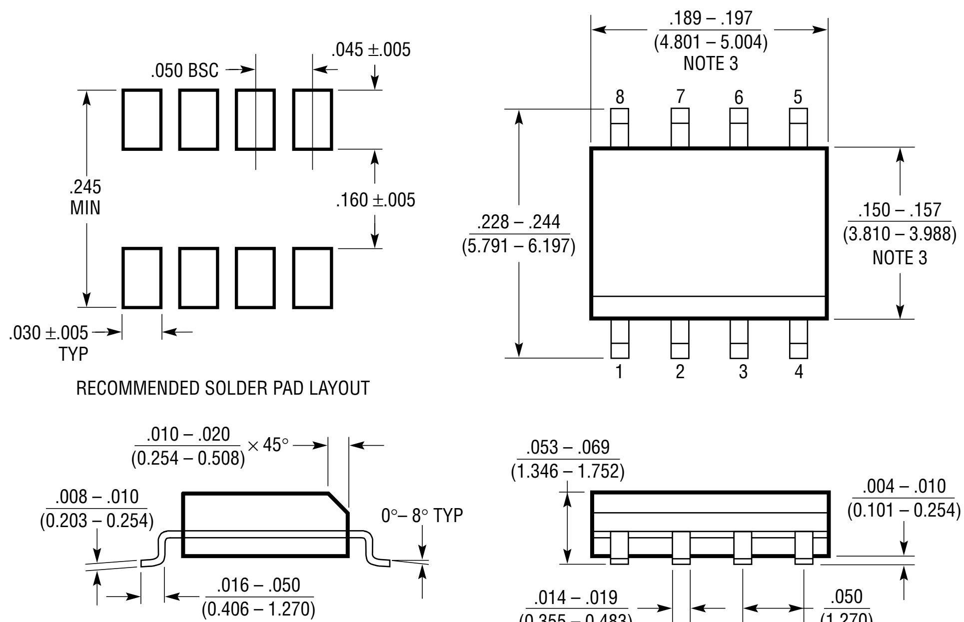
N8 Package
8-Lead PDIP (Narrow .300 Inch)
(Reference LTC DWG # 05-08-1510)



NOTE:
1. DIMENSIONS ARE INCHES / MILLIMETERS
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

PACKAGE DESCRIPTION

S8 Package
8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610)



NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1220	45MHz, 250V/µs Amplifier	Unity Gain Stable Version of the LT1222
LT1221	150MHz, 250V/µs Amplifier	$A_V \geq 4$ Version of the LT1222

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