

# LT1222

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                                         |                |
|-----------------------------------------|----------------|
| Total Supply Voltage ( $V^+$ to $V^-$ ) | 36V            |
| Differential Input Voltage              | $\pm 6V$       |
| 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 ( <b>OBSOLETE</b> )             | -55°C to 125°C |

|                                          |                |
|------------------------------------------|----------------|
| Operating Temperature Range              |                |
| LT1222C                                  | -40°C TO 85°C  |
| LT1222I                                  | -40°C to 85°C  |
| LT1222M ( <b>OBSOLETE</b> )              | -55°C to 125°C |
| Maximum Junction Temperature (See Below) |                |
| Plastic Package                          | 150°C          |
| Ceramic Package ( <b>OBSOLETE</b> )      | 175°C          |
| Storage Temperature Range                | -65°C to 150°C |
| Lead Temperature (Soldering, 10 sec)     | 300°C          |

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| <p><b>H PACKAGE</b><br/>8-LEAD TO-5 METAL CAN<br/><math>T_{JMAX} = 175^\circ\text{C}</math>, <math>\theta_{JA} = 150^\circ\text{C/W}</math></p> | ORDER PART NUMBER             | <p><b>N8 PACKAGE</b><br/>8-LEAD PLASTIC DIP<br/><math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 130^\circ\text{C/W (N)}</math><br/><math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 190^\circ\text{C/W (S)}</math></p> <p><b>S8 PACKAGE</b><br/>8-LEAD PLASTIC SOIC<br/><math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 190^\circ\text{C/W (S)}</math></p> <p><b>J8 PACKAGE</b><br/>8-LEAD CERAMIC DIP<br/><math>T_{JMAX} = 175^\circ\text{C}</math>, <math>\theta_{JA} = 100^\circ\text{C/W (J)}</math></p> | ORDER PART NUMBER                   |
|                                                                                                                                                 | SPECIAL ORDER CONSULT FACTORY |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | LT1222CN8<br>LT1222CS8<br>LT1222IS8 |
|                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | S8 PART MARKING                     |
|                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1222<br>1222I                       |
| <p><b>OBSOLETE PACKAGE</b><br/>Consider the N8 or S8 Packages for Alternate Source</p>                                                          |                               | ORDER PART NUMBER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | LT1222MJ8                           |
|                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                     |

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

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

| SYMBOL    | PARAMETER                      | CONDITIONS                              | MIN | TYP      | MAX | UNITS                                |
|-----------|--------------------------------|-----------------------------------------|-----|----------|-----|--------------------------------------|
| $V_{OS}$  | Input Offset Voltage           | (Note 4)                                |     | 100      | 300 | $\mu V$                              |
| $I_{OS}$  | 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               | $V_{CM} = \pm 12V$<br>Differential      | 20  | 45<br>12 |     | $\text{M}\Omega$<br>$\text{k}\Omega$ |
| $C_{IN}$  | 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 5)                                | 150 | 200      |     | V/ $\mu\text{s}$                     |
|           | Full Power Bandwidth           | 10V Peak (Note 6)                       |     | 3.2      |     | MHz                                  |
| GBW       | Gain-Bandwidth                 | $f = 1\text{MHz}$                       |     | 500      |     | MHz                                  |

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# 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                                                                                                                       |     | 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%<br>10V Step, 0.01%                                                                                                       |     | 75<br>120    |      | ns<br>ns   |
|            | Differential Gain    | $A_V = 2$ , $C_C = 50pF$ , $f = 3.58MHz$ , $R_L = 150\Omega$ (Note 7)<br>$A_V = 10$ , $C_C = 0pF$ , $f = 3.58MHz$ , $R_L = 1k$ (Note 7) |     | 0.40<br>0.15 |      | %<br>%     |
|            | Differential Phase   | $A_V = 2$ , $C_C = 50pF$ , $f = 3.58MHz$ , $R_L = 150\Omega$ (Note 7)<br>$A_V = 10$ , $C_C = 0pF$ , $f = 3.58MHz$ , $R_L = 1k$ (Note 7) |     | 0.10<br>0.01 |      | DEG<br>DEG |
| $R_O$      | Output Resistance    | $A_V = 10$ , $f = 1MHz$                                                                                                                 |     | 0.1          |      | $\Omega$   |
| $I_S$      | Supply Current       |                                                                                                                                         |     | 8            | 10.5 | mA         |

The ● denotes the specifications which apply over the temperature range  $0^\circ C \leq T_A \leq 70^\circ C$ , otherwise specifications are at  $T_A = 25^\circ C$ .  $V_S = \pm 15V$ ,  $V_{CM} = 0V$ , unless otherwise specified.

| SYMBOL    | PARAMETER                    | CONDITIONS                              | MIN | TYP | MAX | UNITS            |
|-----------|------------------------------|-----------------------------------------|-----|-----|-----|------------------|
| $V_{OS}$  | Input Offset Voltage         | (Note 4)                                | ●   | 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 5)                                | ●   | 150 | 200 | V/ $\mu s$       |
| $I_S$     | Supply Current               |                                         | ●   | 8   | 11  | mA               |

The ● denotes the specifications which apply over the temperature range  $-55^\circ C \leq T_A \leq 125^\circ C$  for LT1222M,  $-40^\circ C \leq T_A \leq 85^\circ C$  for LT1222I, otherwise specifications are at  $T_A = 25^\circ C$ .  $V_S = \pm 15V$ ,  $V_{CM} = 0V$ , unless otherwise specified.

| SYMBOL    | PARAMETER                    | CONDITIONS                                 | MIN    | TYP      | MAX      | UNITS              |
|-----------|------------------------------|--------------------------------------------|--------|----------|----------|--------------------|
| $V_{OS}$  | Input Offset Voltage         | (Note 4)                                   | ●      | 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                 | $R_L = 500\Omega$<br>$R_L = 1k$            | ●<br>● | 10<br>12 | 13<br>13 | $\pm V$<br>$\pm V$ |
| $I_{OUT}$ | Output Current               | $V_{OUT} = \pm 10V$<br>$V_{OUT} = \pm 12V$ | ●<br>● | 20<br>12 | 26<br>13 | mA<br>mA           |
| SR        | Slew Rate                    | (Note 5)                                   | ●      | 110      | 200      | V/ $\mu s$         |
| $I_S$     | 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  $0^\circ C$  to  $70^\circ C$  and is designed, characterized and expected to meet these extended temperature limits, but is not tested at  $-40^\circ C$  and  $85^\circ C$ . 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.

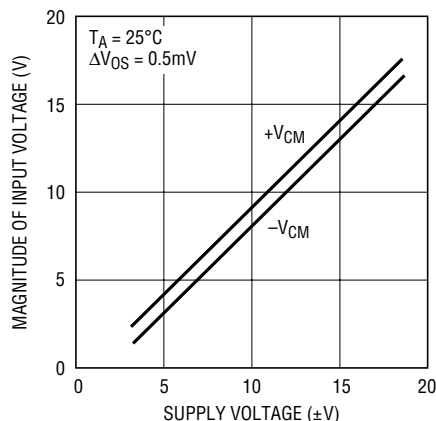
**Note 5:** Slew rate is measured between  $\pm 10V$  on an output swing of  $\pm 12V$ .

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

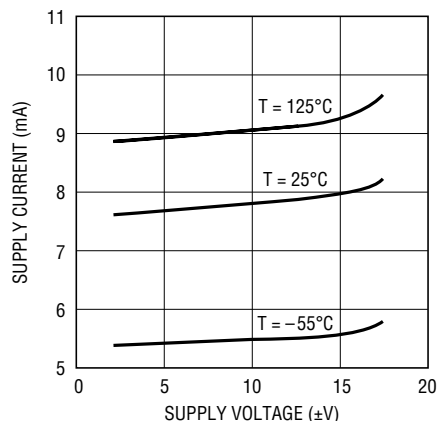
**Note 7:** Differential Gain and Phase are tested with five amps in series. Attenuators of  $1/Gain$  are used as loads.

## TYPICAL PERFORMANCE CHARACTERISTICS

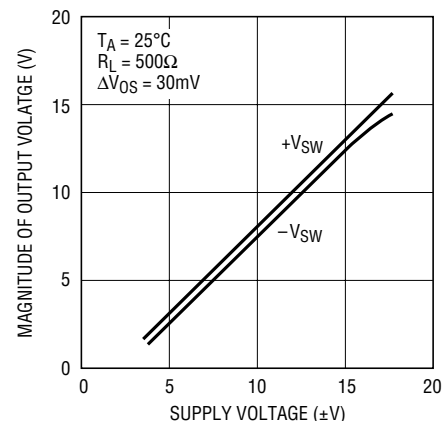
Input Common Mode Range vs Supply Voltage



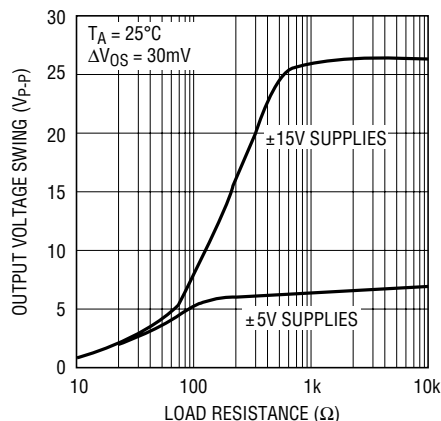
Supply Current vs Supply Voltage and Temperature



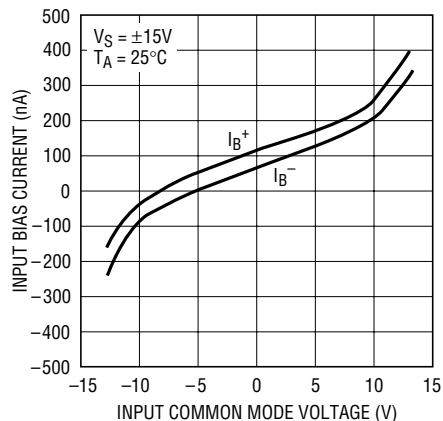
Output Voltage Swing vs Supply Voltage



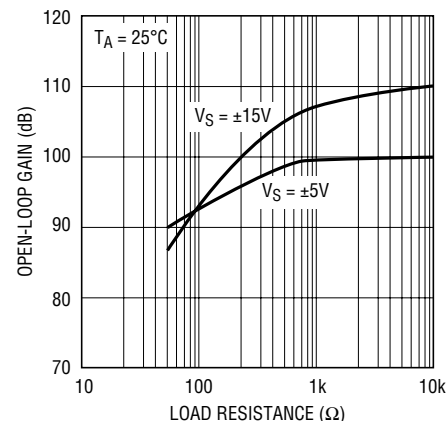
Output Voltage Swing vs Resistive Load



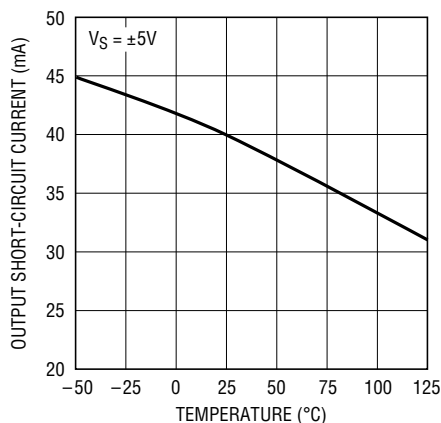
Input Bias Current vs Input Common Mode Voltage



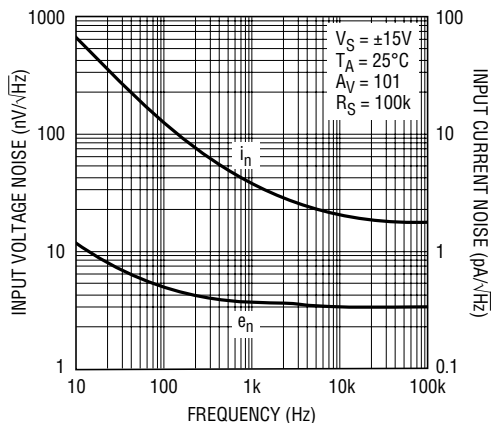
Open-Loop Gain vs Resistive Load



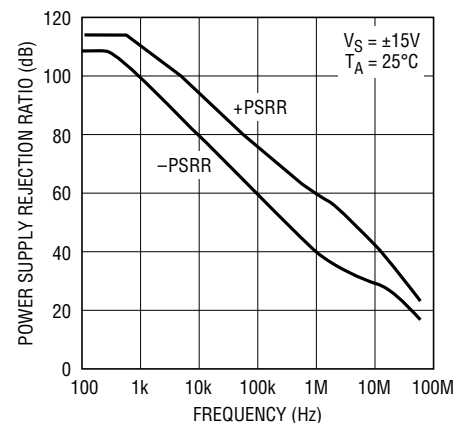
Output Short-Circuit Current vs Temperature



Input Noise Spectral Density

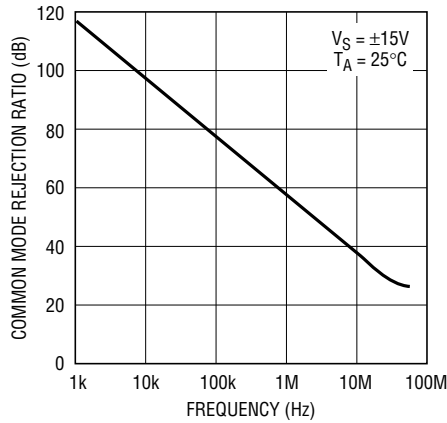


Power Supply Rejection Ratio vs Frequency



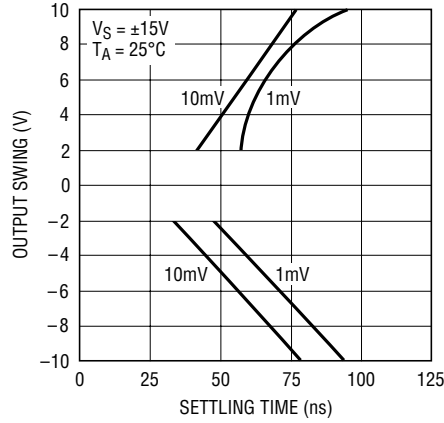
# TYPICAL PERFORMANCE CHARACTERISTICS

**Common Mode Rejection Ratio vs Frequency**



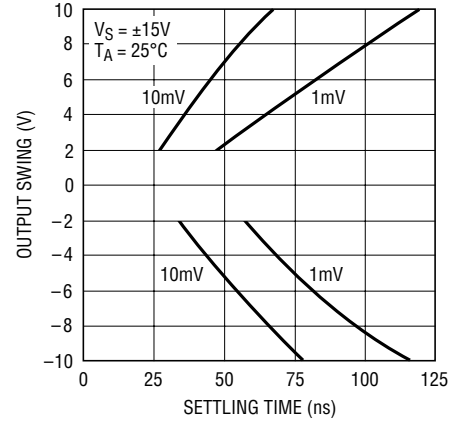
LT1222 • TPC10

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



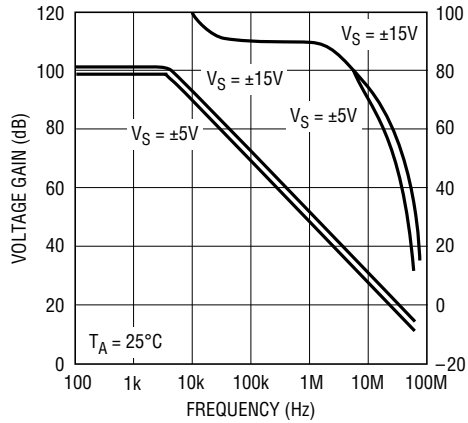
LT1222 • TPC11

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



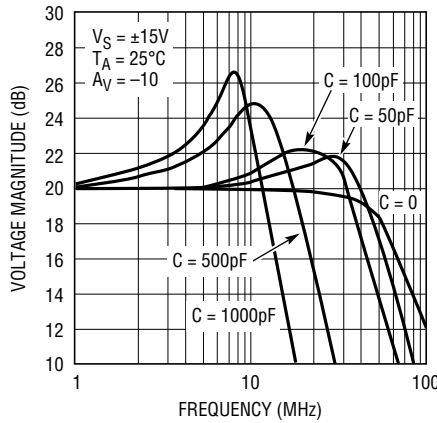
LT1222 • TPC12

**Voltage Gain and Phase vs Frequency**



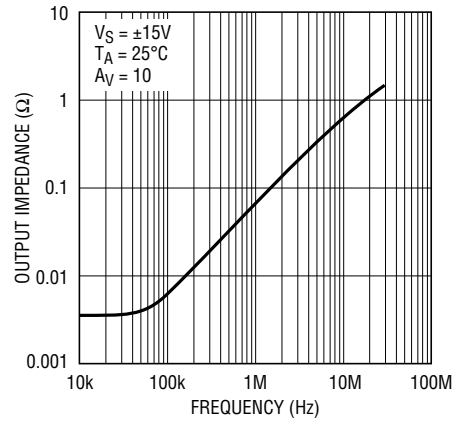
LT1222 • TPC13

**Frequency Response vs Capacitive Load**



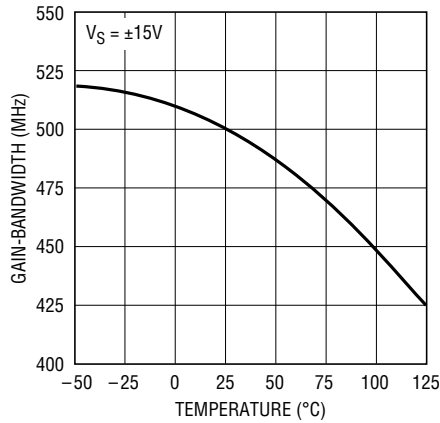
LT1222 • TPC14

**Closed-Loop Output Impedance vs Frequency**



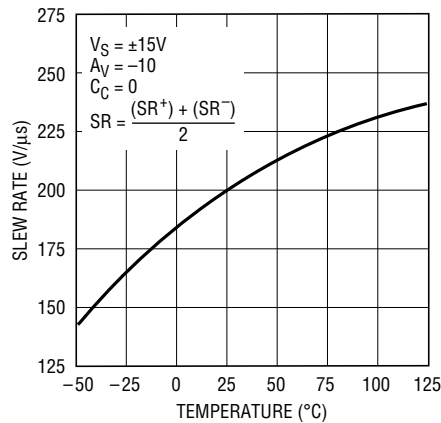
LT1222 • TPC15

**Gain-Bandwidth vs Temperature**



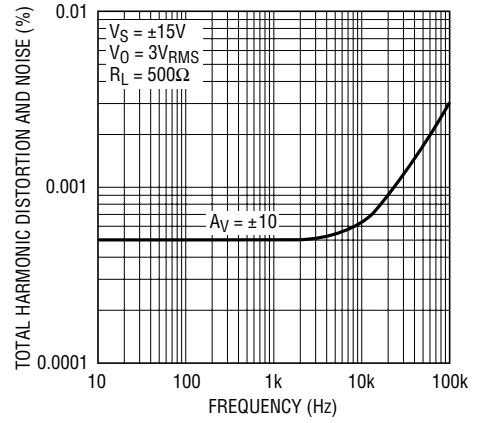
LT1222 • TPC16

**Slew Rate vs Temperature**



LT1222 • TPC17

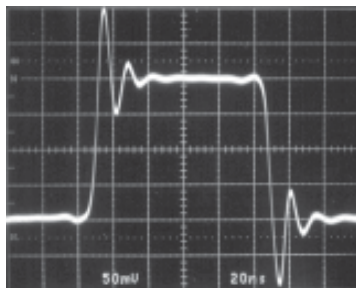
**Total Harmonic Distortion vs Frequency**



LT1222 • TPC18

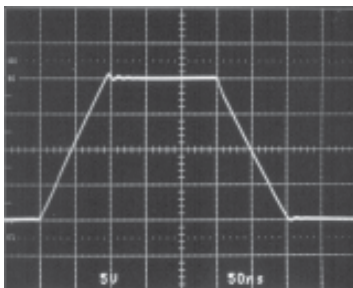
# TYPICAL PERFORMANCE CHARACTERISTICS

Small Signal,  $A_V = 10$



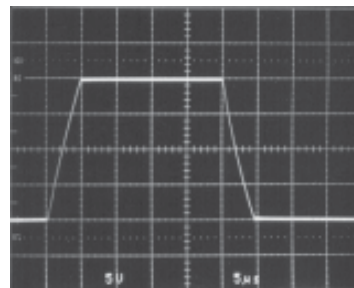
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 5MHz$  LT1222 • TPC19  
 $R_G = 100\Omega$   $V_{IN} = 20mV$

Large Signal,  $A_V = 10$



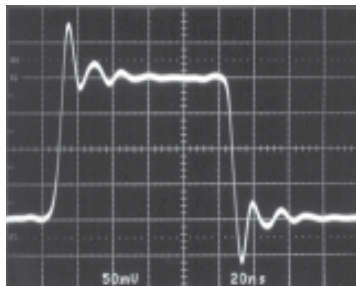
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 2MHz$  LT1222 • TPC20  
 $R_G = 100\Omega$   $V_{IN} = 2V$

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



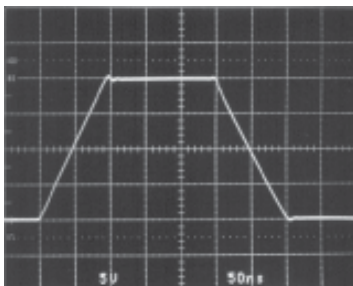
$R_F = 909\Omega$   $V_S = \pm 15V$   $f = 20kHz$  LT1222 • TPC21  
 $R_G = 100\Omega$   $V_{IN} = 2V$

Small Signal,  $A_V = -10$



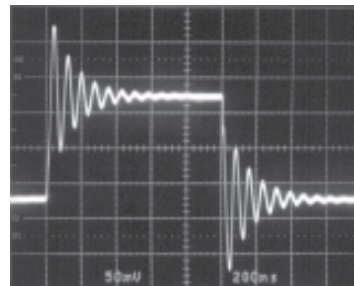
$R_F = 1k$   $V_S = \pm 15V$   $f = 5MHz$  LT1222 • TPC22  
 $R_G = 100\Omega (75)$   $V_{IN} = 20mV$

Large Signal,  $A_V = -10$



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

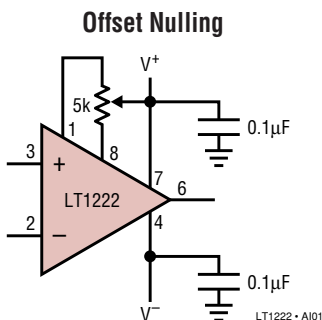
Small Signal,  $A_V = -10$ ,  
 $C_L = 1,000pF$



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

## 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.



## 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.

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## 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:

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

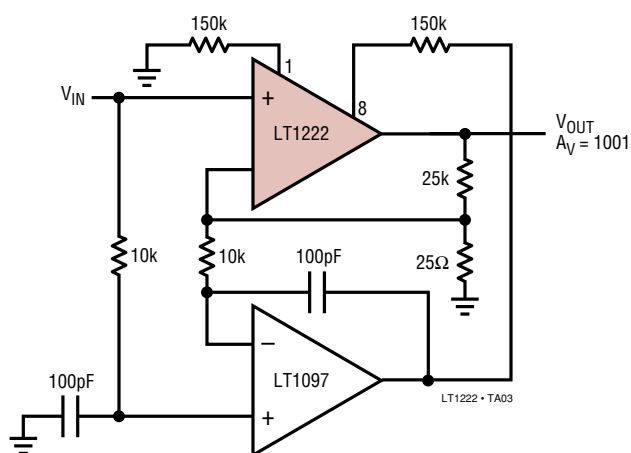
The slew rate is affected as follows:

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

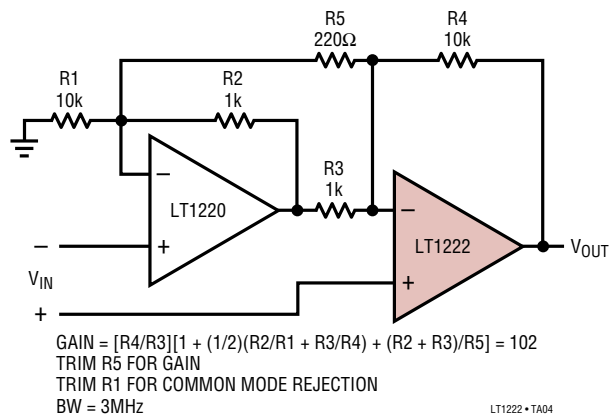
An example would be a gain of -10 (noise gain of 11) and  $C_C = 20pF$  which has 10.5MHz bandwidth and 46V/ $\mu$ s slew rate. It should be noted that the LT1222 is not stable in  $A_V = 1$  unless  $C_C = 50pF$  and a 1k resistor is used as the feedback resistor. The 1k and input capacitance increase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

## TYPICAL APPLICATIONS

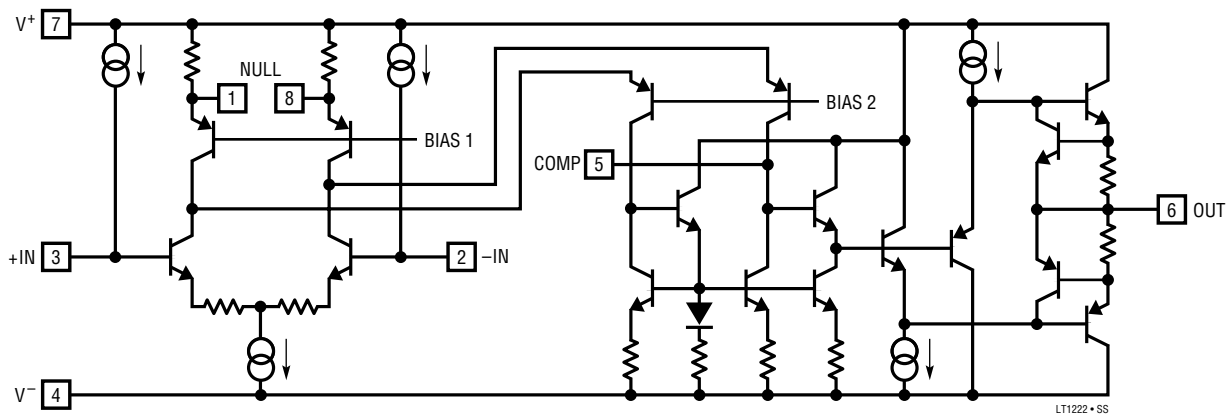
### $V_{OS}$ Null Loop



### Two Op Amp Instrumentation Amplifier

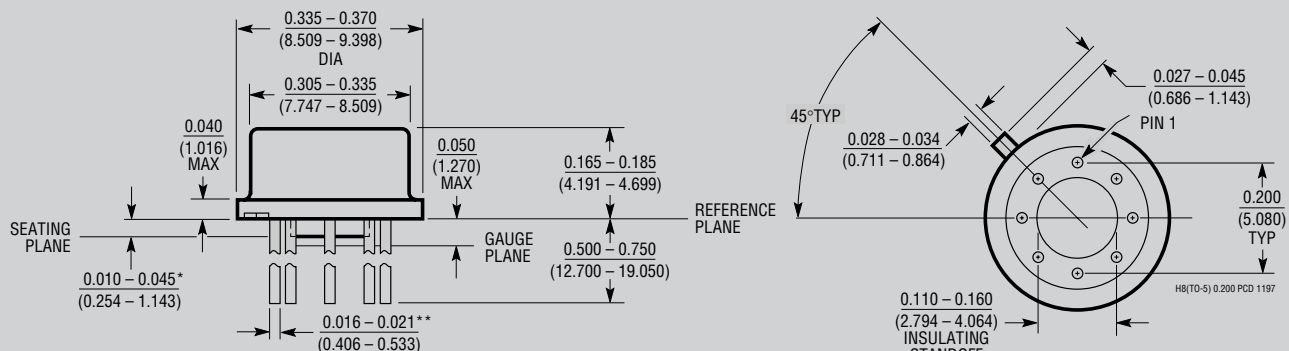


## SIMPLIFIED SCHEMATIC



# PACKAGE DESCRIPTION

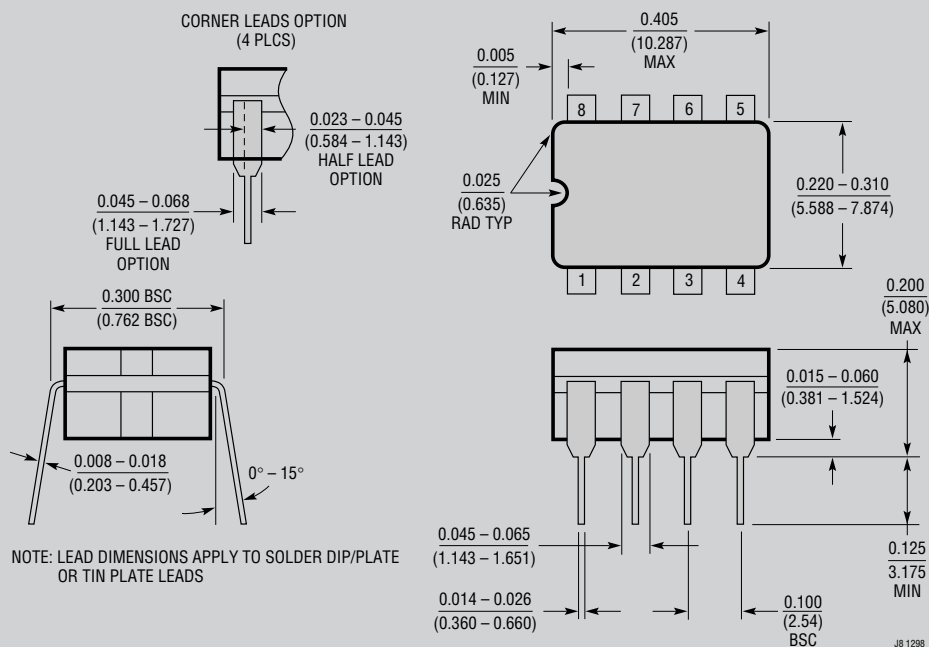
## H Package 8-Lead TO-5 Metal Can (.200 Inch PCD) (Reference LTC DWG # 05-08-1320)



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

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

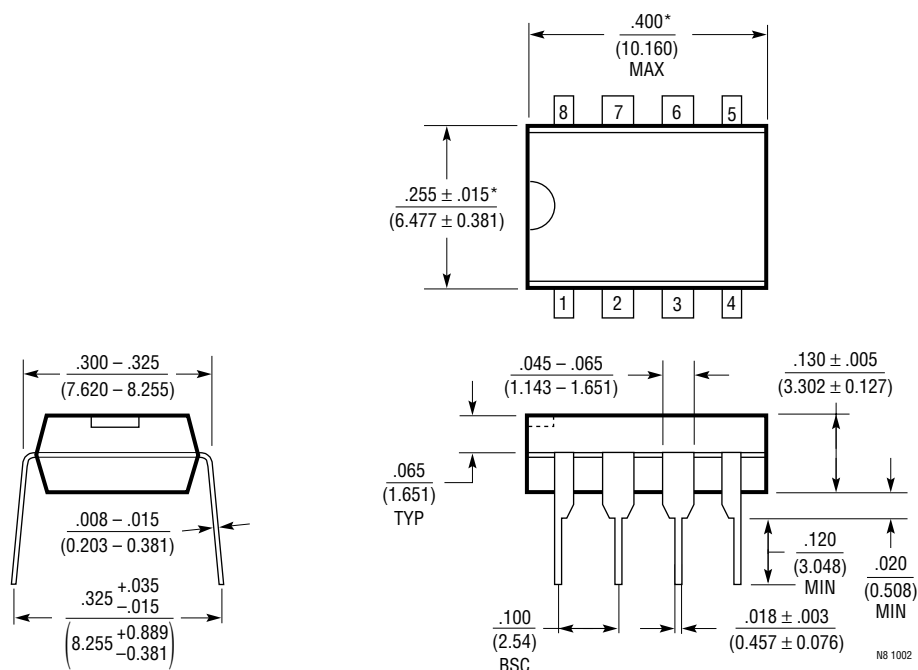
## J8 Package 8-Lead CERP (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



## OBSOLETE PACKAGES

## PACKAGE DESCRIPTION

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

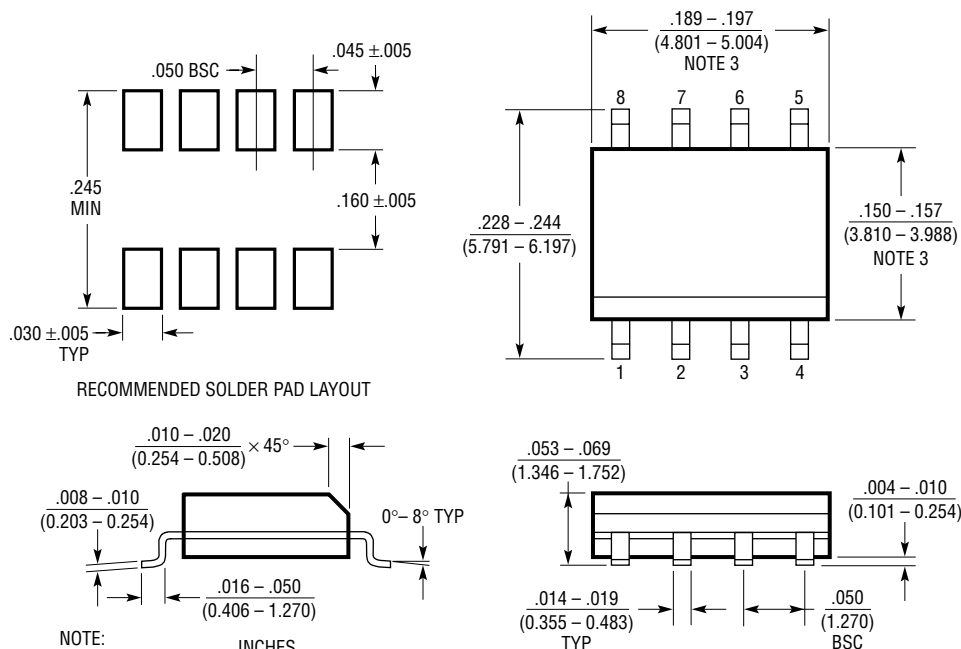


NOTE:  
1. DIMENSIONS ARE  $\frac{\text{INCHES}}{\text{MILLIMETERS}}$

\*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)

S08 0303

# LT1222

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## RELATED PARTS

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

1222fc