

# Dual/Quad Over-The-Top Micropower Rail-to-Rail Input and Output Op Amps

## FEATURES

- **Low Input Offset Voltage: 500μV Max**
- **Output Swings to 10mV Max from V<sup>-</sup>**
- **Rail-to-Rail Input and Output**
- **Micropower: 50μA/Amplifier Max**
- Over-The-Top® Input Common Mode Range Extends 44V Above V<sup>-</sup>, Independent of V<sup>+</sup>
- Specified on 3V, 5V and ±15V Supplies
- High Output Current: 20mA
- Output Drives 10,000pF with Output Compensation
- Reverse Battery Protection to 18V
- No Supply Sequencing Problems
- High Voltage Gain: 1500V/mV
- High CMRR: 98dB
- No Phase Reversal
- Gain Bandwidth Product: 200kHz
- Tiny 3mm × 3mm × 0.8mm DFN Package

## APPLICATIONS

- Battery- or Solar-Powered Systems
  - Portable Instrumentation
  - Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- Micropower Active Filters
- 4mA to 20mA Transmitters

## DESCRIPTION

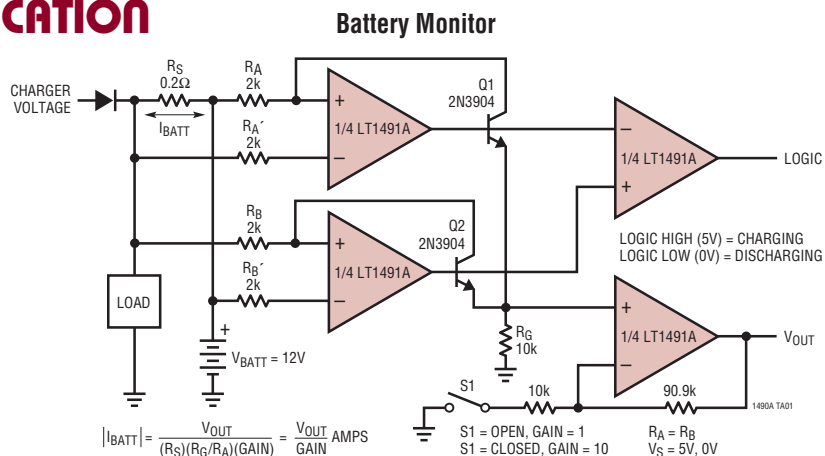
The LT®1490A/LT1491A are dual and quad op amps with a low input offset voltage of 500μV max. The LT1490A/LT1491A operate on all single and split supplies with a total voltage of 2V to 44V, drawing only 40μA of quiescent current per amplifier. These amplifiers are reverse supply protected; they draw virtually no current for reverse supply up to 18V. The input range of the LT1490A/LT1491A includes both supplies and the output swings to both supplies. Unlike most micropower op amps, the LT1490A/LT1491A can drive heavy loads; their rail-to-rail outputs drive 20mA. The LT1490A/LT1491A are unity-gain stable and drive all capacitive loads up to 10,000pF when optional 0.22μF and 150Ω compensation is used.

The LT1490A/LT1491A have a unique input stage that operates and remains high impedance when above the positive supply. The inputs take 44V both differential and common mode even when operating on a 3V supply. Built-in resistors protect the inputs for faults below the negative supply up to 15V. There is no phase reversal of the output for inputs 15V below V<sup>-</sup> or 44V above V<sup>-</sup>, independent of V<sup>+</sup>.

The LT1490A dual op amp is available in the 8-pin MSOP, PDIP and SO packages. For space limited applications LT1490A is available in a 3mm × 3mm × 0.8mm, dual fine pitch leadless package (DFN). The quad LT1491A is available in the 14-pin SO, PDIP and 5mm × 3mm × 0.8mm DFN packages.

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## TYPICAL APPLICATION



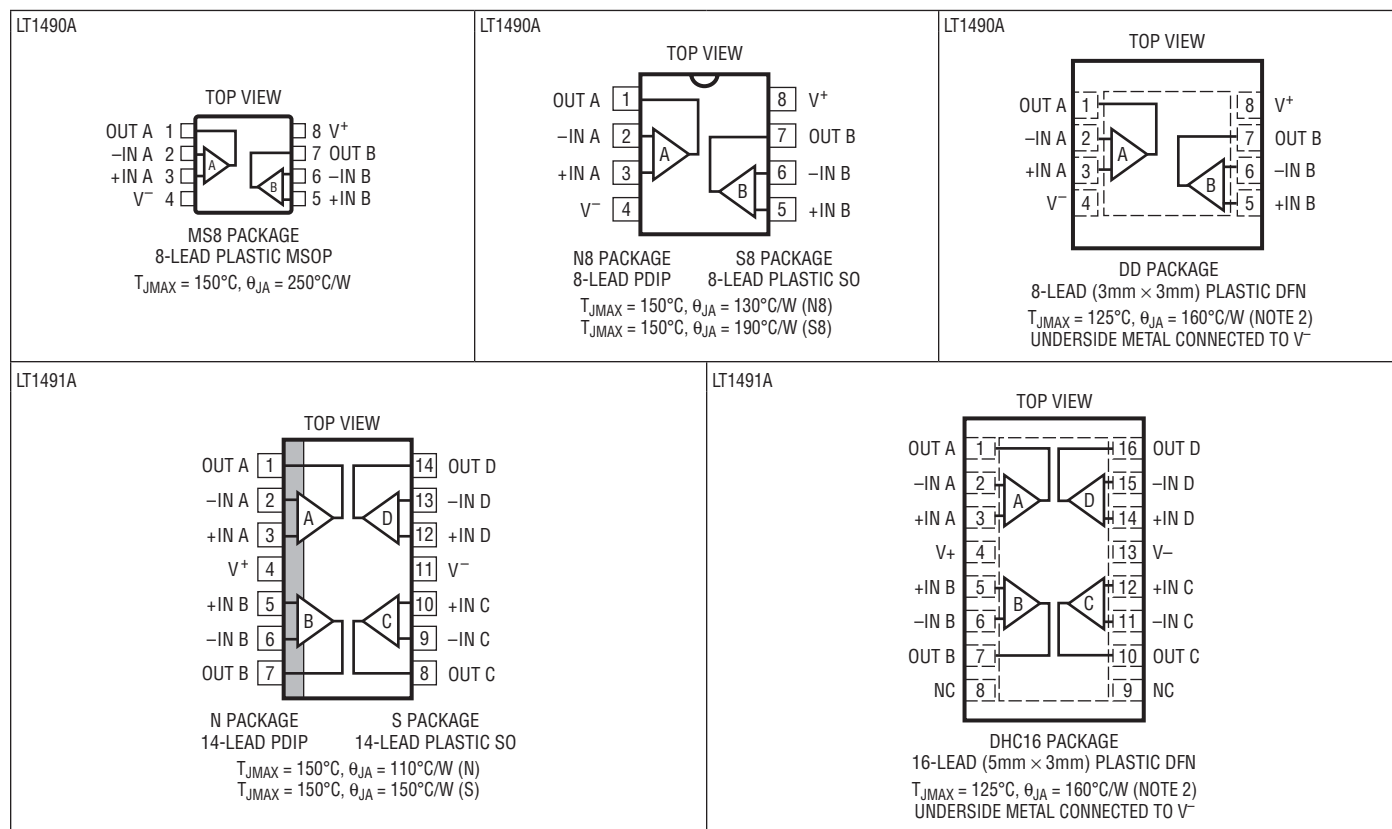
# LT1490A/LT1491A

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage ( $V_+$  to  $V_-$ ) ..... 44V  
 Differential Input Voltage ..... 44V  
 Input Current (Note 9) .....  $\pm 12\text{mA}$   
 Output Short-Circuit Duration (Note 2) ..... Continuous  
 Operating Temperature Range (Note 3)  
     LT1490AC/LT1491AC .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$   
     LT1490AI/LT1491AI .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$   
     LT1490AH/LT1491AH .....  $-40^\circ\text{C}$  to  $125^\circ\text{C}$

Specified Temperature Range (Note 4)  
     LT1490AC/LT1490AI .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$   
     LT1491AC/LT1491AI .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$   
     LT1490AH/LT1491AH .....  $-40^\circ\text{C}$  to  $125^\circ\text{C}$   
 Junction Temperature .....  $150^\circ\text{C}$   
 Junction Temperature (DD/DHC Package) .....  $125^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$   
 Storage Temperature Range  
     DD/DHC Package .....  $-65^\circ\text{C}$  to  $125^\circ\text{C}$   
 Lead Temperature (Soldering, 10 sec) .....  $300^\circ\text{C}$

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL     | PART MARKING* | PACKAGE DESCRIPTION             | SPECIFIED TEMPERATURE RANGE |
|------------------|-------------------|---------------|---------------------------------|-----------------------------|
| LT1490ACMS8#PBF  | LT1490ACMS8#TRPBF | LTNG          | 8-Lead Plastic MSOP             | 0°C to 70°C                 |
| LT1490AIMS8#PBF  | LT1490AIMS8#TRPBF | LTPU          | 8-Lead Plastic MSOP             | -40°C to 85°C               |
| LT1490AHMS8#PBF  | LT1490AHMS8#TRPBF | LTRK          | 8-Lead Plastic MSOP             | -40°C to 125°C              |
| LT1490ACS8#PBF   | LT1490ACS8#TRPBF  | 1490A         | 8-Lead Plastic SO               | 0°C to 70°C                 |
| LT1490AIS8#PBF   | LT1490AIS8#TRPBF  | 1490AI        | 8-Lead Plastic SO               | -40°C to 85°C               |
| LT1490AHS8#PBF   | LT1490AHS8#TRPBF  | 1490AH        | 8-Lead Plastic SO               | -40°C to 125°C              |
| LT1490ACN8#PBF   | LT1490ACN8#TRPBF  | LT1490ACN8    | 8-Lead PDIP                     | 0°C to 70°C                 |
| LT1490AIN8#PBF   | LT1490AIN8#TRPBF  | LT1490AIN8    | 8-Lead PDIP                     | -40°C to 85°C               |
| LT1490ACDD#PBF   | LT1490ACDD#TRPBF  | LAAH          | 8-Lead (3mm × 3mm) Plastic DFN  | 0°C to 70°C                 |
| LT1490AIDD#PBF   | LT1490AIDD#TRPBF  | LAAH          | 8-Lead (3mm × 3mm) Plastic DFN  | -40°C to 85°C               |
| LT1491ACS#PBF    | LT1491ACS#TRPBF   | LT1491ACS     | 14-Lead Plastic SO              | 0°C to 70°C                 |
| LT1491AIS#PBF    | LT1491AIS#TRPBF   | LT1491AIS     | 14-Lead Plastic SO              | -40°C to 85°C               |
| LT1491AHS#PBF    | LT1491AHS#TRPBF   | LT1491AHS     | 14-Lead Plastic SO              | -40°C to 125°C              |
| LT1491ACN#PBF    | LT1491ACN#TRPBF   | LT1491ACN     | 14-Lead PDIP                    | 0°C to 70°C                 |
| LT1491AIN#PBF    | LT1491AIN#TRPBF   | LT1491AIN     | 14-Lead PDIP                    | -40°C to 85°C               |
| LT1491ACDHC#PBF  | LT1491ACDHC#TRPBF | 1491A         | 16-Lead (5mm × 3mm) Plastic DFN | 0°C to 70°C                 |
| LT1491AIDHC#PBF  | LT1491AIDHC#TRPBF | 1491A         | 16-Lead (5mm × 3mm) Plastic DFN | -40°C to 85°C               |

Consult LTC Marketing for parts specified with wider operating temperature ranges. \*The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

# LT1490A/LT1491A

**ELECTRICAL CHARACTERISTICS** The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ , otherwise specifications are at  $T_A = 25^{\circ}\text{C}$ .  $V_S = 3\text{V}, 0\text{V}$ ;  $V_S = 5\text{V}, 0\text{V}$ ;  $V_{CM} = V_{OUT} = \text{half supply}$  unless otherwise noted. (Note 4)

| SYMBOL    | PARAMETER                            | CONDITIONS                                                                                                                                                   | LT1490AC/LT1491AC<br>LT1490AI/LT1491AI |       |       | UNITS                          |
|-----------|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------|-------|--------------------------------|
|           |                                      |                                                                                                                                                              | MIN                                    | TYP   | MAX   |                                |
| $V_{OS}$  | Input Offset Voltage (Note 5)        | LT1490A N, S Packages<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                      | ●                                      | 110   | 500   | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 700   | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 800   | $\mu\text{V}$                  |
|           |                                      | LT1490A MS8 Package, LT1491A N, S Packages<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●                                      | 220   | 1000  | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 1200  | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 1400  | $\mu\text{V}$                  |
|           |                                      | LT1490A DD, LT1491A DHC<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                    | ●                                      | 250   | 1200  | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 1400  | $\mu\text{V}$                  |
|           |                                      | ●                                                                                                                                                            |                                        |       | 1600  | $\mu\text{V}$                  |
|           | Input Offset Voltage Drift (Note 9)  | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                       | ●                                      | 2     | 4     | $\mu\text{V}/^{\circ}\text{C}$ |
|           |                                      | LT1490A DD, LT1491A DHC, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                              | ●                                      | 2     | 6     | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{OS}$  | Input Offset Current                 | ●                                                                                                                                                            |                                        | 0.2   | 0.8   | nA                             |
|           |                                      | ●                                                                                                                                                            |                                        |       | 0.8   | $\mu\text{A}$                  |
| $I_B$     | Input Bias Current                   | ●                                                                                                                                                            |                                        | 1     | 8     | nA                             |
|           |                                      | ●                                                                                                                                                            |                                        | 3     | 10    | $\mu\text{A}$                  |
|           |                                      | ●                                                                                                                                                            |                                        | 0.3   |       | nA                             |
|           | Input Bias Current Drift             | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                       | ●                                      | 2     |       | $\text{pA}/^{\circ}\text{C}$   |
|           | Input Noise Voltage                  | 0.1Hz to 10Hz                                                                                                                                                |                                        | 1     |       | $\mu\text{V}_{\text{p-p}}$     |
| $e_n$     | Input Noise Voltage Density          | $f = 1\text{kHz}$                                                                                                                                            |                                        | 50    |       | $\text{nV}/\sqrt{\text{Hz}}$   |
| $i_n$     | Input Noise Current Density          | $f = 1\text{kHz}$                                                                                                                                            |                                        | 0.015 |       | $\text{pA}/\sqrt{\text{Hz}}$   |
| $R_{IN}$  | Input Resistance                     | Differential                                                                                                                                                 |                                        | 6     | 17    | $\text{M}\Omega$               |
|           |                                      | Common Mode, $V_{CM} = 0\text{V}$ to $44\text{V}$                                                                                                            |                                        | 4     | 11    | $\text{M}\Omega$               |
| $C_{IN}$  | Input Capacitance                    |                                                                                                                                                              |                                        | 4.6   |       | pF                             |
|           | Input Voltage Range                  | ●                                                                                                                                                            | 0                                      |       | 44    | V                              |
| CMRR      | Common Mode Rejection Ratio (Note 6) | $V_{CM} = 0\text{V}$ to $V_{CC} - 1\text{V}$                                                                                                                 | ●                                      | 84    | 98    | dB                             |
|           |                                      | $V_{CM} = 0\text{V}$ to $44\text{V}$                                                                                                                         | ●                                      | 80    | 98    | dB                             |
| $A_{VOL}$ | Large-Signal Voltage Gain            | $V_S = 3\text{V}, V_O = 500\text{mV}$ to $2.5\text{V}, R_L = 10\text{k}$                                                                                     | ●                                      | 200   | 1500  | V/mV                           |
|           |                                      | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                                                                                                         | ●                                      | 133   |       | V/mV                           |
|           |                                      | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                       | ●                                      | 100   |       | V/mV                           |
|           |                                      | $V_S = 5\text{V}, V_O = 500\text{mV}$ to $4.5\text{V}, R_L = 10\text{k}$                                                                                     | ●                                      | 400   | 1500  | V/mV                           |
|           |                                      | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                                                                                                         | ●                                      | 250   |       | V/mV                           |
|           |                                      | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                       | ●                                      | 200   |       | V/mV                           |
| $V_{OL}$  | Output Voltage Swing Low             | $V_S = 3\text{V}$ , No Load                                                                                                                                  | ●                                      | 3     | 10    | mV                             |
|           |                                      | $V_S = 3\text{V}, I_{SINK} = 5\text{mA}$                                                                                                                     | ●                                      | 250   | 450   | mV                             |
|           |                                      | $V_S = 5\text{V}$ , No Load                                                                                                                                  | ●                                      | 3     | 10    | mV                             |
|           |                                      | $V_S = 5\text{V}, I_{SINK} = 5\text{mA}$                                                                                                                     | ●                                      | 250   | 500   | mV                             |
| $V_{OH}$  | Output Voltage Swing High            | $V_S = 5\text{V}, I_{SINK} = 10\text{mA}$                                                                                                                    |                                        | 330   | 500   | mV                             |
|           |                                      | $V_S = 3\text{V}$ , No Load                                                                                                                                  | ●                                      | 2.95  | 2.978 | V                              |
|           |                                      | $V_S = 3\text{V}, I_{SOURCE} = 5\text{mA}$                                                                                                                   | ●                                      | 2.55  | 2.6   | V                              |
|           |                                      | $V_S = 5\text{V}$ , No Load                                                                                                                                  | ●                                      | 4.95  | 4.978 | V                              |
| $I_{SC}$  | Short-Circuit Current (Note 2)       | $V_S = 5\text{V}, I_{SOURCE} = 10\text{mA}$                                                                                                                  | ●                                      | 4.30  | 4.6   | V                              |
|           |                                      | $V_S = 3\text{V}$ , Short to GND                                                                                                                             |                                        | 10    | 15    | mA                             |
|           |                                      | $V_S = 3\text{V}$ , Short to $V_{CC}$                                                                                                                        |                                        | 10    | 30    | mA                             |
|           |                                      | $V_S = 5\text{V}$ , Short to GND                                                                                                                             |                                        | 15    | 25    | mA                             |
|           |                                      | $V_S = 5\text{V}$ , Short to $V_{CC}$                                                                                                                        |                                        | 15    | 30    | mA                             |

# ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ , otherwise specifications are at  $T_A = 25^{\circ}\text{C}$ .  $V_S = 3\text{V}, 0\text{V}$ ;  $V_S = 5\text{V}, 0\text{V}$ ;  $V_{CM} = V_{OUT} = \text{half supply}$  unless otherwise noted. (Note 4)

| SYMBOL | PARAMETER                             | CONDITIONS                                                                                                                                    |             | LT1490AC/LT1491AC<br>LT1490AI/LT1491AI |      |          | UNITS                                                    |
|--------|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------------------|------|----------|----------------------------------------------------------|
|        |                                       |                                                                                                                                               |             | MIN                                    | TYP  | MAX      |                                                          |
| PSRR   | Power Supply Rejection Ratio          | $V_S = 2.5\text{V}$ to $12.5\text{V}$ , $V_{CM} = V_O = 1\text{V}$                                                                            | ●           | 84                                     | 98   |          | dB                                                       |
|        | Minimum Operating Supply Voltage      |                                                                                                                                               | ●           |                                        | 2    | 2.5      | V                                                        |
|        | Reverse Supply Voltage                | $I_S = -100\mu\text{A}$ per Amplifier                                                                                                         | ●           | 18                                     | 27   |          | V                                                        |
| $I_S$  | Supply Current per Amplifier (Note 7) |                                                                                                                                               | ●           |                                        | 40   | 50<br>55 | $\mu\text{A}$<br>$\mu\text{A}$                           |
| GBW    | Gain Bandwidth Product (Note 6)       | $f = 1\text{kHz}$<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$           | ●<br>●<br>● | 110<br>100<br>90                       | 180  |          | kHz<br>kHz<br>kHz                                        |
| SR     | Slew Rate (Note 8)                    | $A_V = -1$ , $R_L = \infty$<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●<br>●<br>● | 0.035<br>0.031<br>0.030                | 0.06 |          | V/ $\mu\text{s}$<br>V/ $\mu\text{s}$<br>V/ $\mu\text{s}$ |

The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ , otherwise specifications are at  $T_A = 25^{\circ}\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $V_{CM} = 0\text{V}$ ,  $V_{OUT} = 0\text{V}$  unless otherwise noted. (Note 4)

| SYMBOL    | PARAMETER                           | CONDITIONS                                                                                                                                                    |             | LT1490AC/LT1491AC<br>LT1490AI/LT1491AI |              |                      | UNITS                                           |
|-----------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------------------|--------------|----------------------|-------------------------------------------------|
|           |                                     |                                                                                                                                                               |             | MIN                                    | TYP          | MAX                  |                                                 |
| $V_{OS}$  | Input Offset Voltage (Note 5)       | LT1490A N, S Packages<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                       | ●<br>●      |                                        | 150          | 700<br>950<br>1100   | $\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$ |
|           |                                     | LT1490A MS8 Package, LT1491A N, S Packages<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$  | ●<br>●      |                                        | 250          | 1200<br>1350<br>1500 | $\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$ |
|           |                                     | LT1490A DD, LT1491A DHC<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                     | ●<br>●      |                                        | 285          | 1400<br>1550<br>1700 | $\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$ |
|           | Input Offset Voltage Drift (Note 9) | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                        | ●           |                                        | 2            | 6                    | $\mu\text{V}/^{\circ}\text{C}$                  |
|           |                                     | LT1490A DD, LT1491A DHC, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                               | ●           |                                        | 2            | 7                    | $\mu\text{V}/^{\circ}\text{C}$                  |
| $I_{OS}$  | Input Offset Current                |                                                                                                                                                               | ●           |                                        | 0.2          | 0.8                  | nA                                              |
| $I_B$     | Input Bias Current                  |                                                                                                                                                               | ●           |                                        | 1            | 8                    | nA                                              |
|           | Input Bias Current Drift            | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                        | ●           |                                        | 5            |                      | pA/ $^{\circ}\text{C}$                          |
|           | Input Noise Voltage                 | 0.1Hz to 10Hz                                                                                                                                                 |             |                                        | 1            |                      | $\mu\text{V}_{P-P}$                             |
| $e_n$     | Input Noise Voltage Density         | $f = 1\text{kHz}$                                                                                                                                             |             |                                        | 50           |                      | nV/ $\sqrt{\text{Hz}}$                          |
| $i_n$     | Input Noise Current Density         | $f = 1\text{kHz}$                                                                                                                                             |             |                                        | 0.015        |                      | pA/ $\sqrt{\text{Hz}}$                          |
| $R_{IN}$  | Input Resistance                    | Differential<br>Common Mode, $V_{CM} = -15\text{V}$ to $14\text{V}$                                                                                           |             | 6                                      | 17<br>15000  |                      | M $\Omega$<br>M $\Omega$                        |
| $C_{IN}$  | Input Capacitance                   |                                                                                                                                                               |             |                                        | 4.6          |                      | pF                                              |
|           | Input Voltage Range                 |                                                                                                                                                               | ●           | -15                                    |              | 29                   | V                                               |
| CMRR      | Common Mode Rejection Ratio         | $V_{CM} = -15\text{V}$ to $29\text{V}$                                                                                                                        | ●           | 80                                     | 98           |                      | dB                                              |
| $A_{VOL}$ | Large-Signal Voltage Gain           | $V_O = \pm 14\text{V}$ , $R_L = 10\text{k}$<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●<br>●<br>● | 100<br>75<br>50                        | 250          |                      | V/mV<br>V/mV<br>V/mV                            |
| $V_O$     | Output Voltage Swing                | No Load                                                                                                                                                       | ●           | $\pm 14.9$                             | $\pm 14.978$ |                      | V                                               |
|           |                                     | $I_{OUT} = \pm 5\text{mA}$                                                                                                                                    | ●           | $\pm 14.5$                             | $\pm 14.750$ |                      | V                                               |
|           |                                     | $I_{OUT} = \pm 10\text{mA}$                                                                                                                                   | ●           | $\pm 14.5$                             | $\pm 14.670$ |                      | V                                               |

# LT1490A/LT1491A

**ELECTRICAL CHARACTERISTICS** The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ , otherwise specifications are at  $T_A = 25^{\circ}\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $V_{CM} = 0\text{V}$ ,  $V_{OUT} = 0\text{V}$  unless otherwise noted. (Note 4)

| SYMBOL   | PARAMETER                      | CONDITIONS                                                                                                                                                                                                    | LT1490AC/LT1491AC<br>LT1490AI/LT1491AI |          |          | UNITS                                                                      |
|----------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|----------|----------|----------------------------------------------------------------------------|
|          |                                |                                                                                                                                                                                                               | MIN                                    | TYP      | MAX      |                                                                            |
| $I_{SC}$ | Short-Circuit Current (Note 2) | Short to GND<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                | $\pm 20$<br>$\pm 15$<br>$\pm 10$       | $\pm 25$ |          | mA<br>mA<br>mA                                                             |
| PSRR     | Power Supply Rejection Ratio   | $V_S = \pm 1.25\text{V}$ to $\pm 22\text{V}$                                                                                                                                                                  | ● 88                                   | 98       |          | dB                                                                         |
| $I_S$    | Supply Current per Amplifier   |                                                                                                                                                                                                               | ●                                      | 50       | 70<br>85 | $\mu\text{A}$<br>$\mu\text{A}$                                             |
| GBW      | Gain Bandwidth Product         | $f = 1\text{kHz}$<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                           | ● 125<br>● 110<br>● 100                | 200      |          | kHz<br>kHz<br>kHz                                                          |
| SR       | Slew Rate                      | $A_V = -1$ , $R_L = \infty$ , $V_O = \pm 10\text{V}$ ,<br>Measured at $V_O = \pm 5\text{V}$<br>$0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ● 0.0375<br>● 0.0330<br>● 0.0300       | 0.07     |          | $\text{V}/\mu\text{s}$<br>$\text{V}/\mu\text{s}$<br>$\text{V}/\mu\text{s}$ |

The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$ ,  $V_S = 3\text{V}$ ,  $0\text{V}$ ;  $V_S = 5\text{V}$ ,  $0\text{V}$ ;  $V_{CM} = V_{OUT} = \text{half supply}$  unless otherwise noted. (Note 4)

| SYMBOL    | PARAMETER                            | CONDITIONS                                                                     | LT1490AH/LT1491AH |           |              | UNITS                                        |
|-----------|--------------------------------------|--------------------------------------------------------------------------------|-------------------|-----------|--------------|----------------------------------------------|
|           |                                      |                                                                                | MIN               | TYP       | MAX          |                                              |
| $V_{OS}$  | Input Offset Voltage (Note 5)        | LT1490AHS8                                                                     | ●                 | 110       | 500<br>2500  | $\mu\text{V}$<br>$\mu\text{V}$               |
|           |                                      | LT1490AHMS8, LT1491AHS                                                         | ●                 | 220       | 1000<br>3000 | $\mu\text{V}$<br>$\mu\text{V}$               |
|           | Input Offset Voltage Drift (Note 9)  |                                                                                | ●                 | 3         | 6            | $\mu\text{V}/^{\circ}\text{C}$               |
| $I_{OS}$  | Input Offset Current                 | $V_{CM} = 44\text{V}$ (Note 6)                                                 | ●<br>●            |           | 2<br>1.5     | nA<br>$\mu\text{A}$                          |
|           |                                      | $V_{CM} = 44\text{V}$ (Note 6)                                                 | ●<br>●            |           | 20<br>15     | nA<br>$\mu\text{A}$                          |
|           | Input Voltage Range                  |                                                                                | ●                 | 0.3       | 44           | V                                            |
| CMRR      | Common Mode Rejection Ratio (Note 6) | $V_{CM} = 0.3\text{V}$ to $V_{CC} - 1\text{V}$                                 | ●                 | 60        |              | dB                                           |
|           |                                      | $V_{CM} = 0.3\text{V}$ to $44\text{V}$                                         | ●                 | 74        |              | dB                                           |
| $A_{VOL}$ | Large-Signal Voltage Gain            | $V_S = 3\text{V}$ , $V_O = 500\text{mV}$ to $2.5\text{V}$ , $R_L = 10\text{k}$ | ●                 | 200<br>25 | 1500         | $\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$ |
|           |                                      | $V_S = 5\text{V}$ , $V_O = 500\text{mV}$ to $4.5\text{V}$ , $R_L = 10\text{k}$ | ●                 | 400<br>50 | 1500         | $\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$ |
| $V_{OL}$  | Output Voltage Swing Low             | $V_S = 3\text{V}$ , No Load                                                    | ●                 |           | 15           | mV                                           |
|           |                                      | $V_S = 3\text{V}$ , $I_{SINK} = 2.5\text{mA}$                                  | ●                 |           | 450          | mV                                           |
|           |                                      | $V_S = 5\text{V}$ , No Load                                                    | ●                 |           | 15           | mV                                           |
|           |                                      | $V_S = 5\text{V}$ , $I_{SINK} = 2.5\text{mA}$                                  | ●                 |           | 500          | mV                                           |
| $V_{OH}$  | Output Voltage Swing High            | $V_S = 3\text{V}$ , No Load                                                    | ●                 | 2.925     |              | V                                            |
|           |                                      | $V_S = 3\text{V}$ , $I_{SOURCE} = 5\text{mA}$                                  | ●                 | 2.350     |              | V                                            |
|           |                                      | $V_S = 5\text{V}$ , No Load                                                    | ●                 | 4.925     |              | V                                            |
|           |                                      | $V_S = 5\text{V}$ , $I_{SOURCE} = 10\text{mA}$                                 | ●                 | 4.100     |              | V                                            |
| PSRR      | Power Supply Rejection Ratio         | $V_S = 2.5\text{V}$ to $12.5\text{V}$ , $V_{CM} = V_O = 1\text{V}$             | ●                 | 80        |              | dB                                           |
|           | Minimum Operating Supply Voltage     |                                                                                | ●                 |           | 2.5          | V                                            |
|           | Reverse Supply Voltage               | $I_S = -100\mu\text{A}$ per Amplifier                                          | ●                 | 18        |              | V                                            |

# ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $V_{CM} = 0\text{V}$ ,  $V_{OUT} = 0\text{V}$  unless otherwise noted. (Note 4)

| SYMBOL    | PARAMETER                             | CONDITIONS                                     | LT1490AH/LT1491AH |      |              | UNITS                                            |
|-----------|---------------------------------------|------------------------------------------------|-------------------|------|--------------|--------------------------------------------------|
|           |                                       |                                                | MIN               | TYP  | MAX          |                                                  |
| $I_S$     | Supply Current per Amplifier (Note 7) | ●                                              |                   | 40   | 50<br>70     | $\mu\text{A}$<br>$\mu\text{A}$                   |
| GBW       | Gain Bandwidth Product (Note 6)       | $f = 1\text{kHz}$ ●                            | 110<br>60         | 180  |              | $\text{kHz}$<br>$\text{kHz}$                     |
| SR        | Slew Rate (Note 8)                    | $A_V = -1$ , $R_L = \infty$ ●                  | 0.035<br>0.015    | 0.06 |              | $\text{V}/\mu\text{s}$<br>$\text{V}/\mu\text{s}$ |
| $V_{OS}$  | Input Offset Voltage (Note 5)         | LT1490AHS8 ●                                   |                   | 150  | 700<br>2700  | $\mu\text{V}$<br>$\mu\text{V}$                   |
|           |                                       | LT1490AHMS8, LT1491AHS ●                       |                   | 250  | 1200<br>3200 | $\mu\text{V}$<br>$\mu\text{V}$                   |
|           | Input Offset Voltage Drift (Note 9)   | ●                                              |                   | 3    | 7            | $\mu\text{V}/^{\circ}\text{C}$                   |
| $I_{OS}$  | Input Offset Current                  | ●                                              |                   |      | 2            | $\text{nA}$                                      |
| $I_B$     | Input Bias Current                    | ●                                              |                   |      | 20           | $\text{nA}$                                      |
|           | Input Voltage Range                   | ●                                              | -14.7             |      | 29           | $\text{V}$                                       |
| CMRR      | Common Mode Rejection Ratio           | $V_{CM} = -14.7\text{V}$ to $29\text{V}$ ●     | 72                |      |              | $\text{dB}$                                      |
| $A_{VOL}$ | Large-Signal Voltage Gain             | $V_O = \pm 14\text{V}$ , $R_L = 10\text{k}$ ●  | 100<br>4          | 250  |              | $\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$     |
| $V_O$     | Output Voltage Swing                  | No Load ●                                      | $\pm 14.8$        |      |              | $\text{V}$                                       |
|           |                                       | $I_{OUT} = \pm 2.5\text{mA}$ ●                 | $\pm 14.3$        |      |              | $\text{V}$                                       |
| PSRR      | Power Supply Rejection Ratio          | $V_S = \pm 1.25\text{V}$ to $\pm 22\text{V}$ ● | 84                |      |              | $\text{dB}$                                      |
| $I_S$     | Supply Current per Amplifier          | ●                                              |                   | 50   | 70<br>95     | $\mu\text{A}$<br>$\mu\text{A}$                   |
| GBW       | Gain Bandwidth Product                | $f = 1\text{kHz}$ ●                            | 125<br>75         | 200  |              | $\text{kHz}$<br>$\text{kHz}$                     |
| SR        | Slew Rate                             | $A_V = -1$ , $R_L = \infty$ ●                  | 0.0375<br>0.02    | 0.07 |              | $\text{V}/\mu\text{s}$<br>$\text{V}/\mu\text{s}$ |

**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 to keep the junction temperature below absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. The  $\theta_{JA}$  specified for the DD and DHC package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

**Note 3:** The LT1490AC/LT1491AC and LT1490AI/LT1491AI are guaranteed functional over the operating temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The LT1490AH/LT1491AH are guaranteed functional over the operating temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**Note 4:** The LT1490AC/LT1491AC are guaranteed to meet specified performance from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The LT1490AC/LT1491AC are designed, characterized and expected to meet specified performance from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  but are not tested or QA sampled at these temperatures. The LT1490AI/LT1491AI are guaranteed to meet specified performance from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The LT1490AH/LT1491AH are guaranteed to meet specified performance from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**Note 5:** ESD (electrostatic discharge) sensitive device. Extensive use of ESD protection devices are used internal to the LT1490A/LT1491A. However, high electrostatic discharge can damage or degrade the device. Use proper ESD handling precautions.

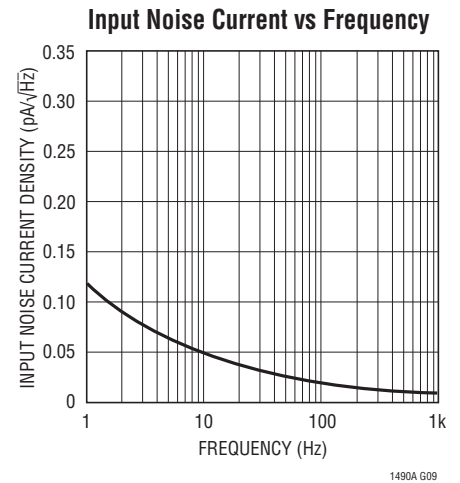
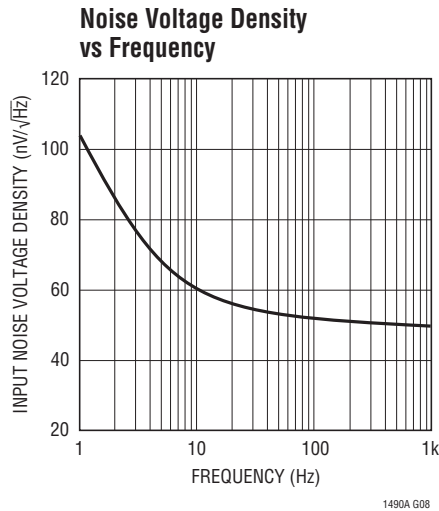
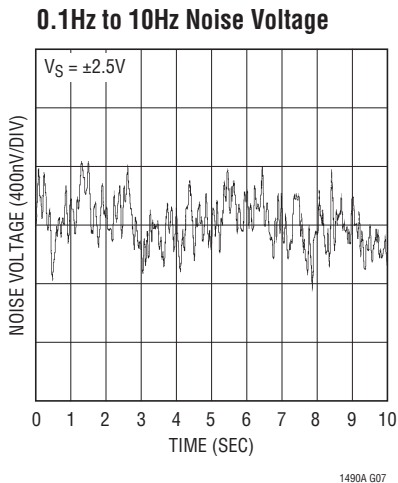
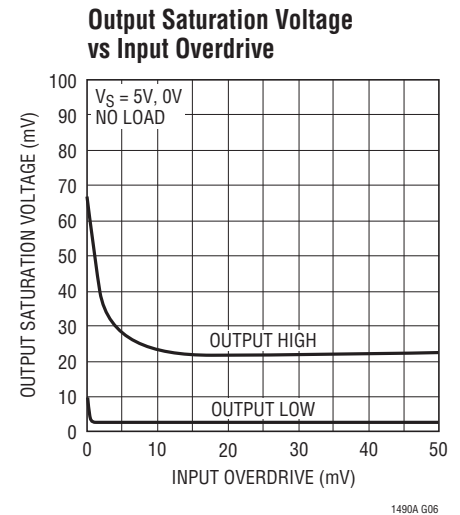
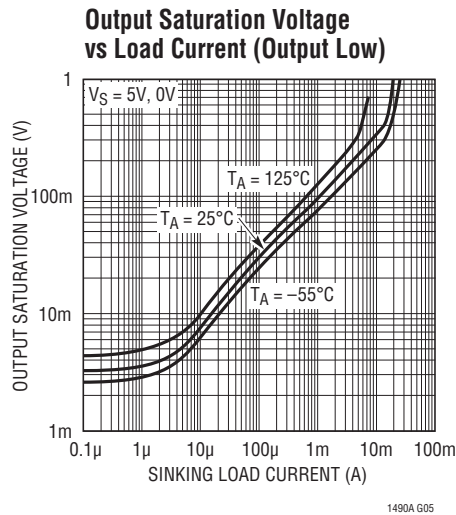
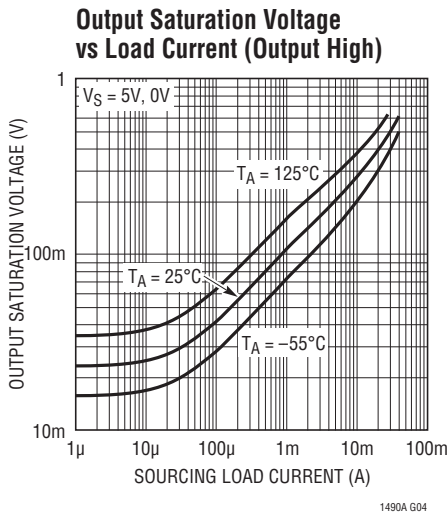
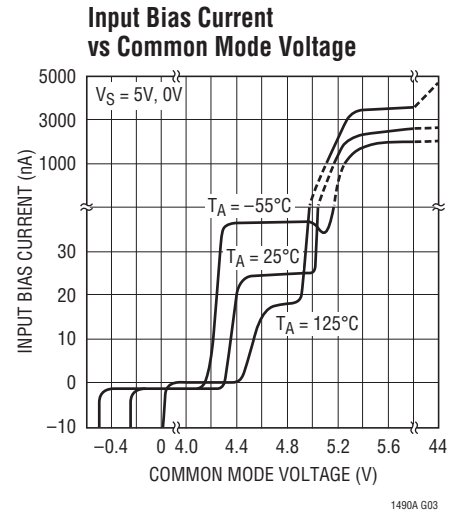
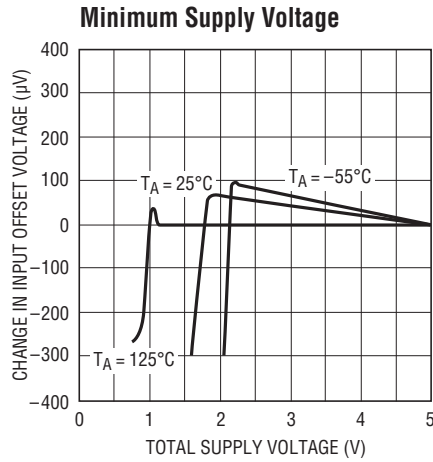
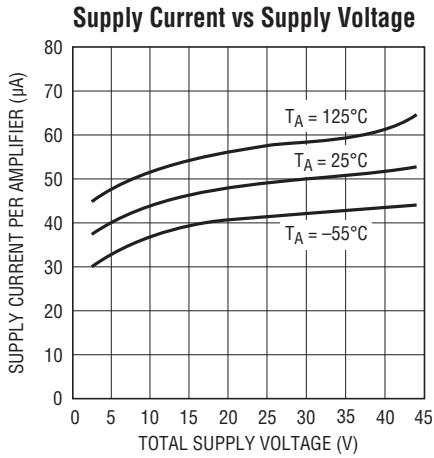
**Note 6:**  $V_S = 5\text{V}$  limits are guaranteed by correlation to  $V_S = 3\text{V}$  and  $V_S = \pm 15\text{V}$  tests.

**Note 7:**  $V_S = 3\text{V}$  limits are guaranteed by correlation to  $V_S = 5\text{V}$  and  $V_S = \pm 15\text{V}$  tests.

**Note 8:** Guaranteed by correlation to slew rate at  $V_S = \pm 15\text{V}$  and GBW at  $V_S = 3\text{V}$  and  $V_S = \pm 15\text{V}$  tests.

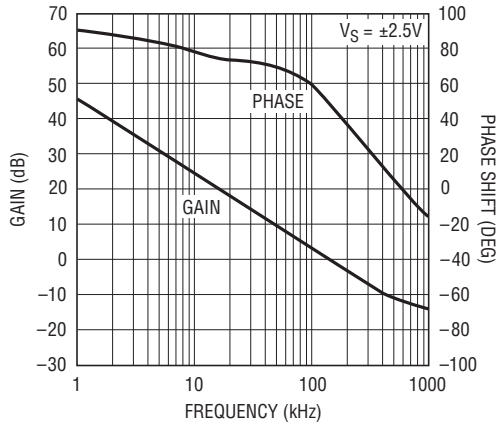
**Note 9:** This parameter is not 100% tested.

## TYPICAL PERFORMANCE CHARACTERISTICS



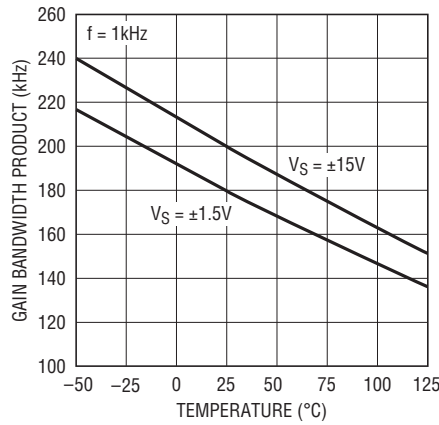
# TYPICAL PERFORMANCE CHARACTERISTICS

**Gain and Phase Shift vs Frequency**



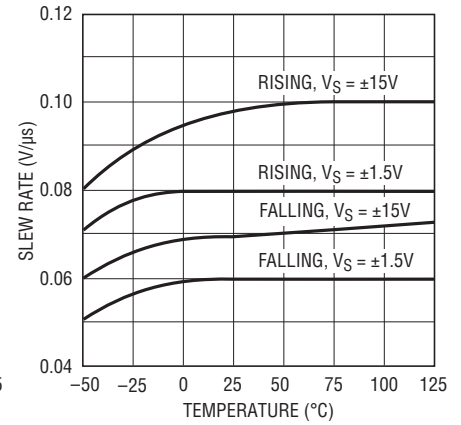
1490A G10

**Gain Bandwidth Product vs Temperature**



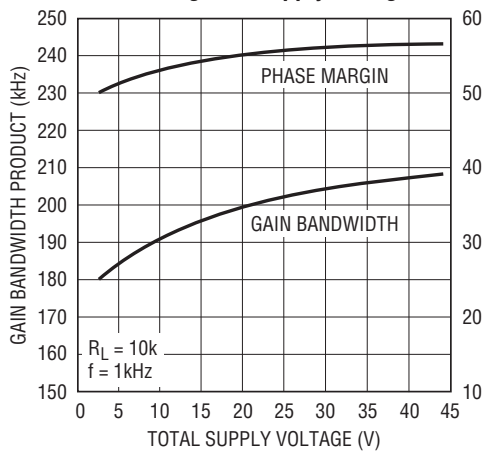
1490A G11

**Slew Rate vs Temperature**



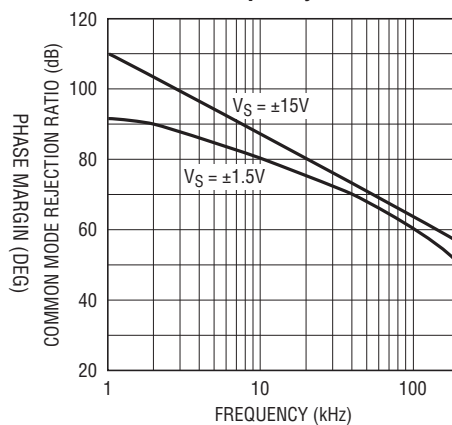
1490A G12

**Gain Bandwidth Product and Phase Margin vs Supply Voltage**



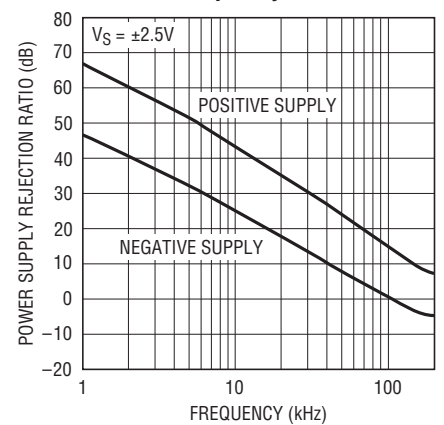
1490A G13

**CMRR vs Frequency**



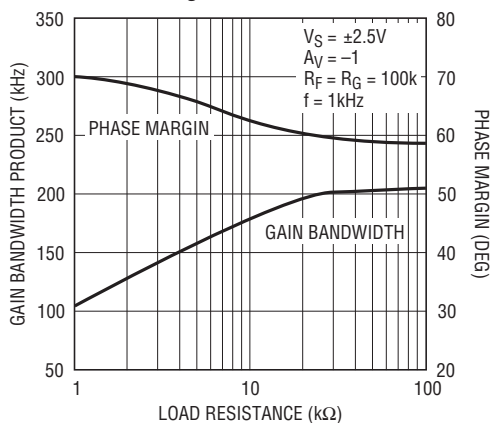
1490A G14

**PSRR vs Frequency**



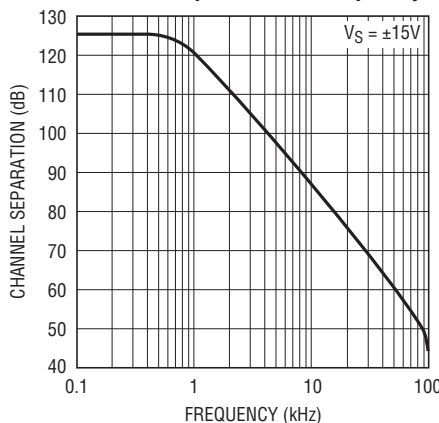
1490A G15

**Gain Bandwidth Product and Phase Margin vs Load Resistance**



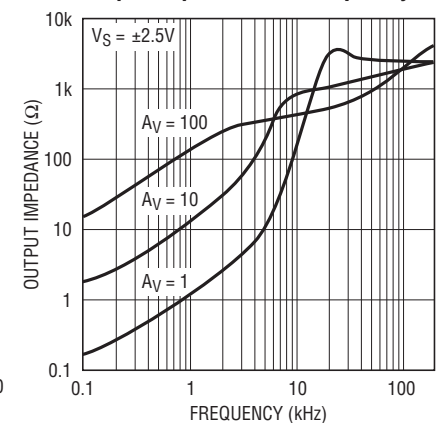
1490A G16

**Channel Separation vs Frequency**



1490A G17

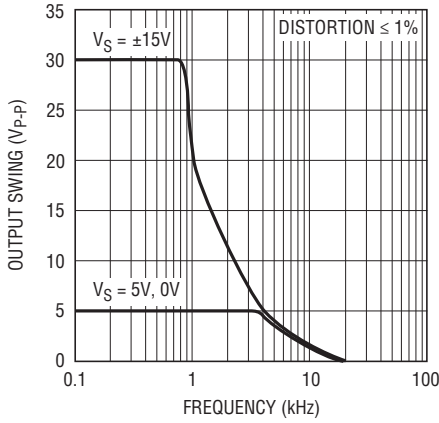
**Output Impedance vs Frequency**



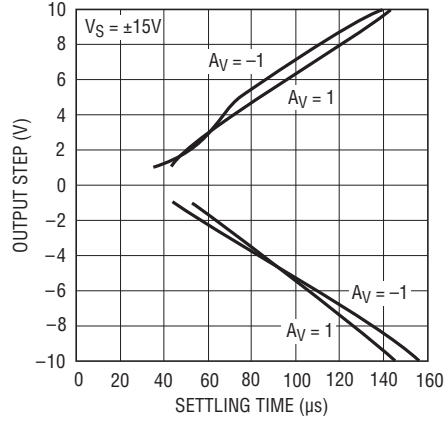
1490A G18

# TYPICAL PERFORMANCE CHARACTERISTICS

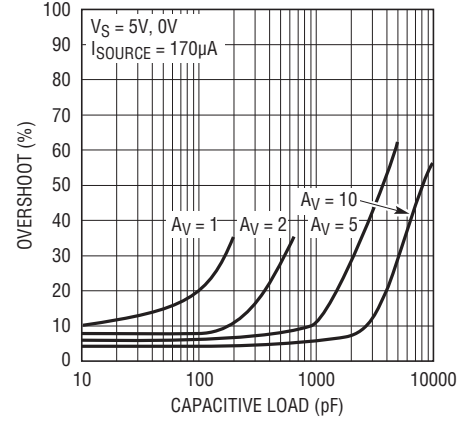
**Undistorted Output Swing vs Frequency**



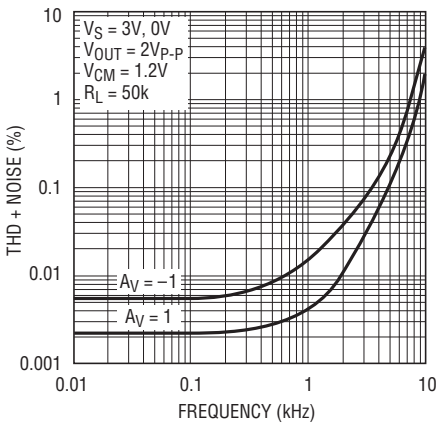
**Settling Time to 0.1% vs Output Step**



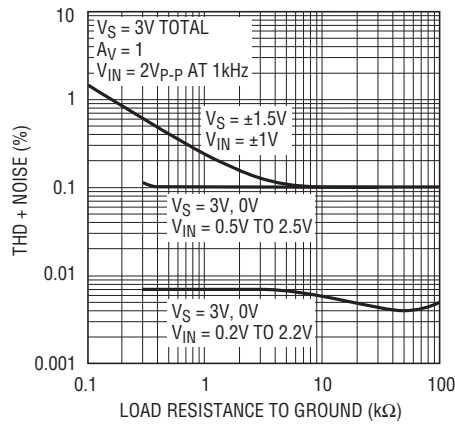
**Capacitive Load Handling, Overshoot vs Capacitive Load**



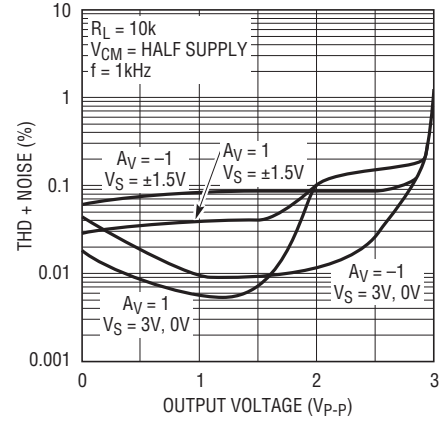
**Total Harmonic Distortion + Noise vs Frequency**



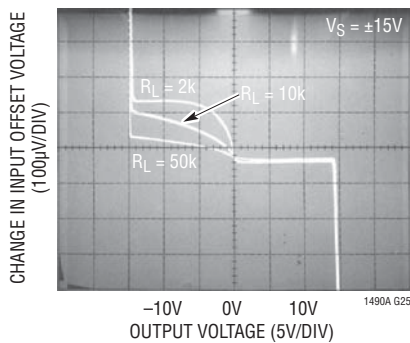
**Total Harmonic Distortion + Noise vs Load Resistance**



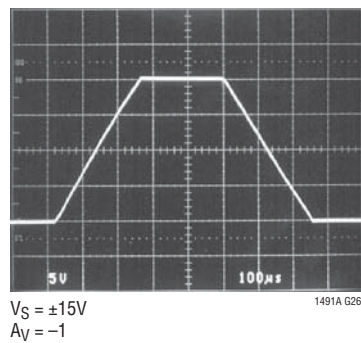
**Total Harmonic Distortion + Noise vs Output Voltage**



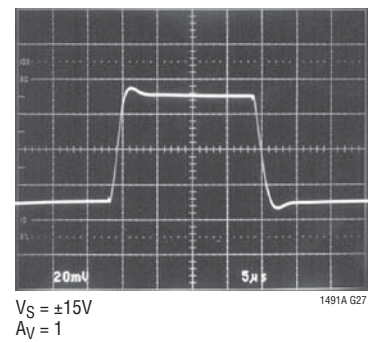
**Open-Loop Gain**



**Large-Signal Response**



**Small-Signal Response**



## APPLICATIONS INFORMATION

### Supply Voltage

The positive supply pin of the LT1490A/LT1491A should be bypassed with a small capacitor (about  $0.01\mu\text{F}$ ) within an inch of the pin. When driving heavy loads an additional  $4.7\mu\text{F}$  electrolytic capacitor should be used. When using split supplies, the same is true for the negative supply pin.

The LT1490A/LT1491A are protected against reverse battery voltages up to 18V. In the event a reverse battery condition occurs, the supply current is less than 1nA.

The LT1490A/LT1491A can be shut down by removing  $V^+$ . In this condition the input bias current is typically less than 0.5nA, even if the inputs are 44V above the negative supply.

When operating the LT1490A/LT1491A on total supplies of 20V or more, the supply must not rise to its final voltage in less than  $1\mu\text{s}$ . This is especially true if low ESR bypass capacitors are used. A series RLC circuit is formed from the supply lead inductance and the bypass capacitor. A resistance of  $7.5\Omega$  in the supply or in the bypass capacitor will dampen the tuned circuit enough to limit the rise time.

### Inputs

The LT1490A/LT1491A have two input stages, NPN and PNP (see the Simplified Schematic), resulting in three distinct operating regions as shown in the Input Bias Current vs Common Mode typical performance curve.

For input voltages about 0.8V or more below  $V^+$ , the PNP input stage is active and the input bias current is typically  $-1\text{nA}$ . When the input voltage is about 0.5V or less from  $V^+$ , the NPN input stage is operating and the input bias current is typically 25nA. Increases in temperature will cause the voltage at which operation switches from the PNP stage to the NPN stage to move towards  $V^+$ . The input offset voltage of the NPN stage is untrimmed and is typically  $600\mu\text{V}$ .

A Schottky diode in the collector of each NPN transistor of the NPN input stage allows the LT1490A/LT1491A to operate with either or both of their inputs above  $V^+$ . At about 0.3V above  $V^+$  the NPN input transistor is fully saturated and the input bias current is typically  $3\mu\text{A}$  at room temperature. The input offset voltage is typically  $700\mu\text{V}$  when operating above  $V^+$ . The LT1490A/LT1491A will operate with their inputs 44V above  $V^-$  regardless of  $V^+$ .

The inputs are protected against excursions as much as 15V below  $V^-$  by an internal 1k resistor in series with each input and a diode from the input to the negative supply. There is no output phase reversal for inputs up to 15V below  $V^-$ . There are no clamping diodes between the inputs and the maximum differential input voltage is 44V.

### Output

The output voltage swing of the LT1490A/LT1491A is affected by input overdrive as shown in the typical performance curves.

The output of the LT1490A/LT1491A can be pulled up to 18V beyond  $V^+$  with less than 1nA of leakage current, provided that  $V^+$  is less than 0.5V.

The normally reverse-biased substrate diode from the output to  $V^-$  will cause unlimited currents to flow when the output is forced below  $V^-$ . If the current is transient and limited to 100mA, no damage will occur.

The LT1490A/LT1491A are internally compensated to drive at least 200pF of capacitance under any output loading conditions. A  $0.22\mu\text{F}$  capacitor in series with a  $150\Omega$  resistor between the output and ground will compensate these amplifiers for larger capacitive loads, up to 10,000pF, at all output currents.

### Distortion

There are two main contributors of distortion in op amps: output crossover distortion as the output transitions from sourcing to sinking current and distortion caused by nonlinear common mode rejection. Of course, if the op amp is operating inverting there is no common mode induced distortion. When the LT1490A/LT1491A switch between input stages there is significant nonlinearity in the CMRR. Lower load resistance increases the output crossover distortion, but has no effect on the input stage transition distortion. For lowest distortion the LT1490A/LT1491A should be operated single supply, with the output always sourcing current and with the input voltage swing between ground and  $(V^+ - 0.8\text{V})$ . See the Typical Performance Characteristics curves.

## APPLICATIONS INFORMATION

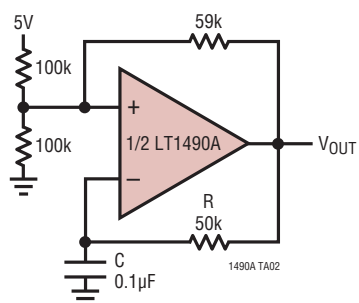
### Gain

The open-loop gain is almost independent of load when the output is sourcing current. This optimizes performance

in single supply applications where the load is returned to ground. The typical performance photo of Open-Loop Gain for various loads shows the details.

## TYPICAL APPLICATIONS

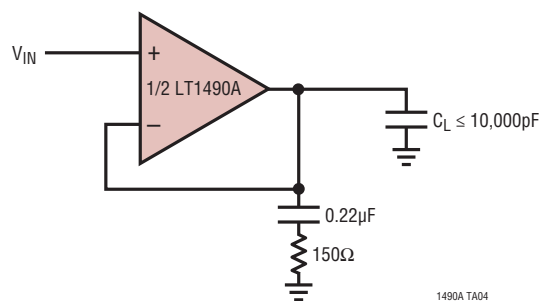
**Square Wave Oscillator**



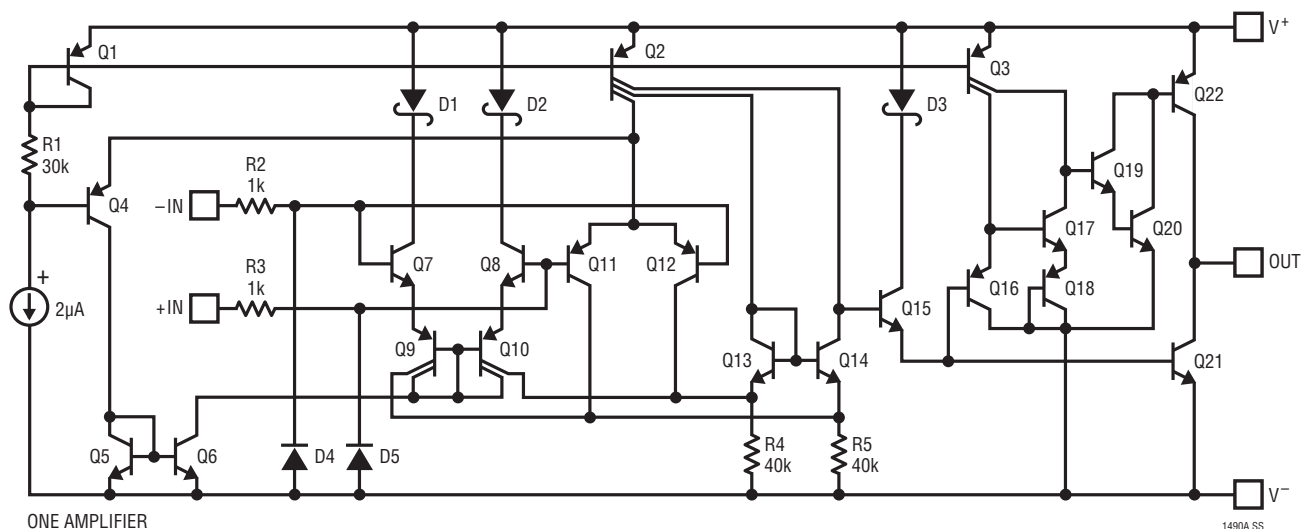
$$f = \frac{1}{2RC}$$

$V_{OUT} = 5V_{P-P}$  WITH 5V SUPPLY  
 $I_S = 200\mu A$   
 AT  $V_S = 5V$ ,  $R = 50k$ ,  $C = 1nF$   
 OUTPUT IS 5kHz SLEW LIMITED TRIANGLE WAVE

**Optional Output Compensation for Capacitive Loads Greater Than 200pF**



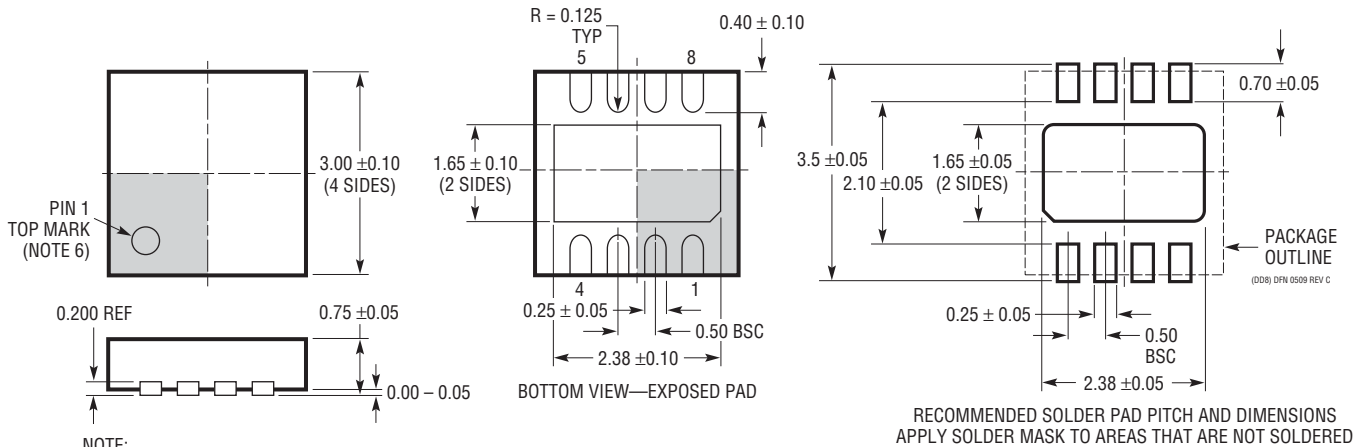
## SIMPLIFIED SCHEMATIC



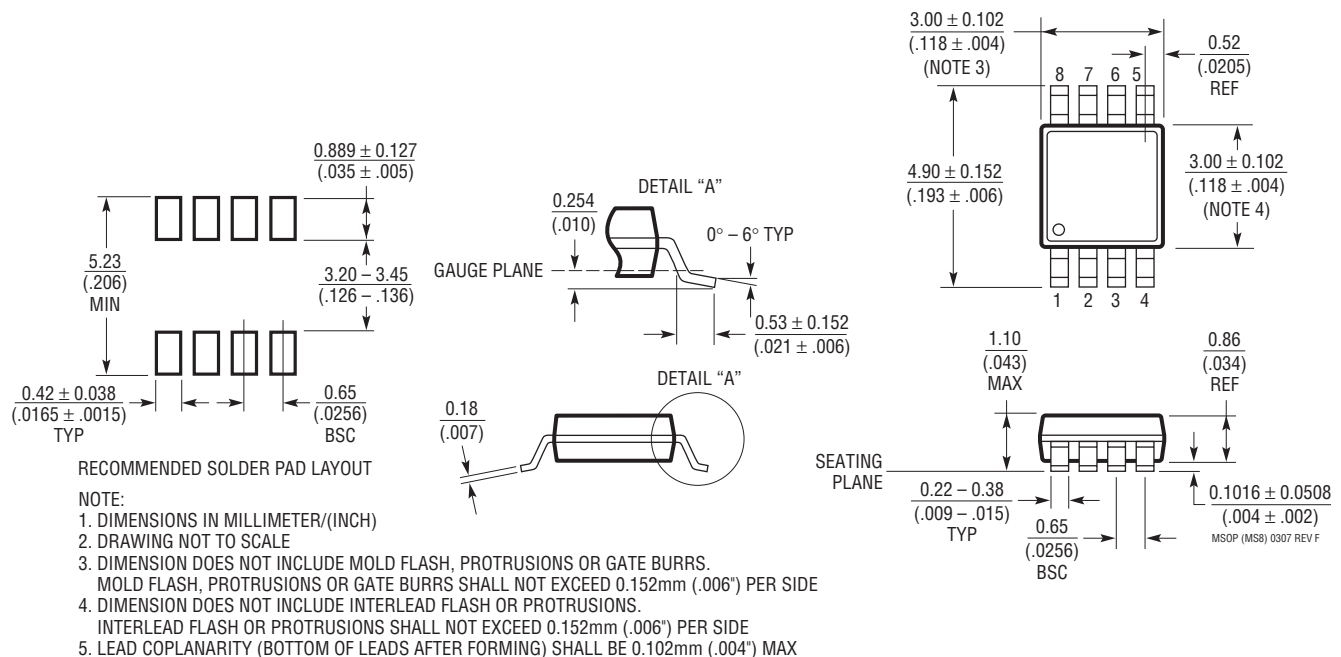
# PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

## DD Package 8-Lead Plastic DFN (3mm × 3mm) (Reference LTC DWG # 05-08-1698 Rev C)



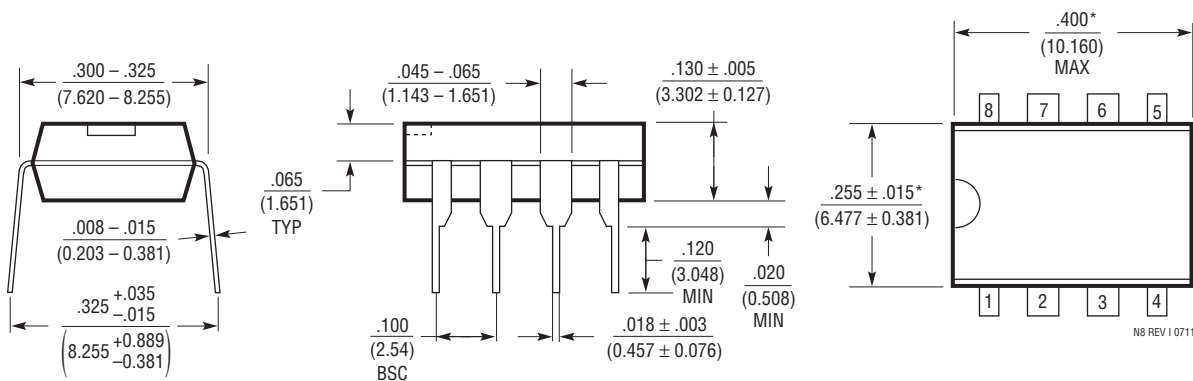
## MS8 Package 8-Lead Plastic MSOP (Reference LTC DWG # 05-08-1660 Rev F)



## PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

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

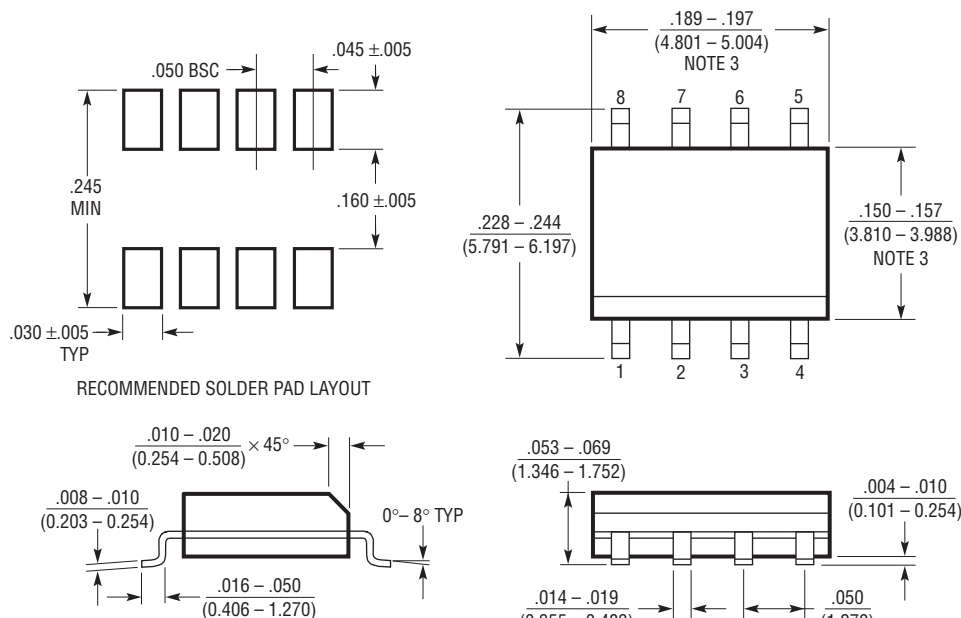


NOTE:

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)

### 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

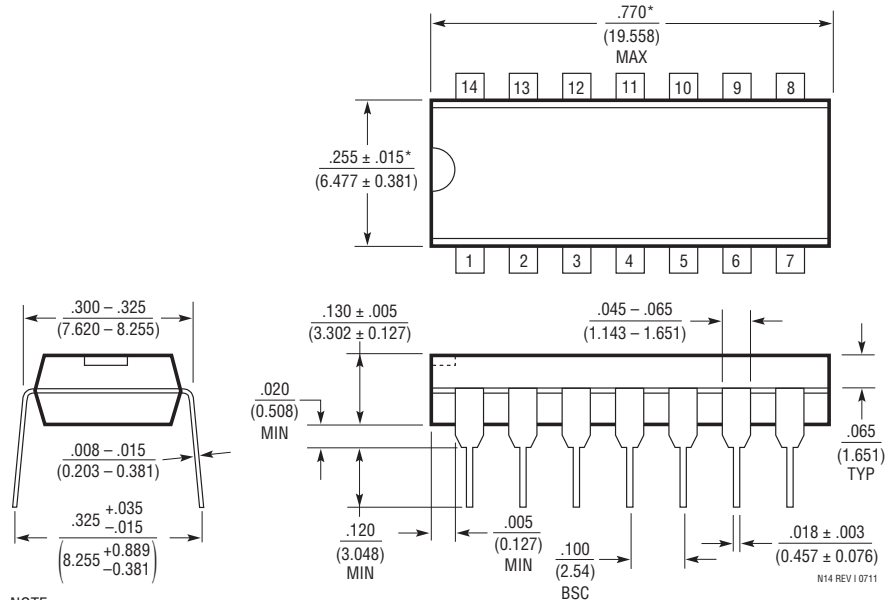
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

S08 0303

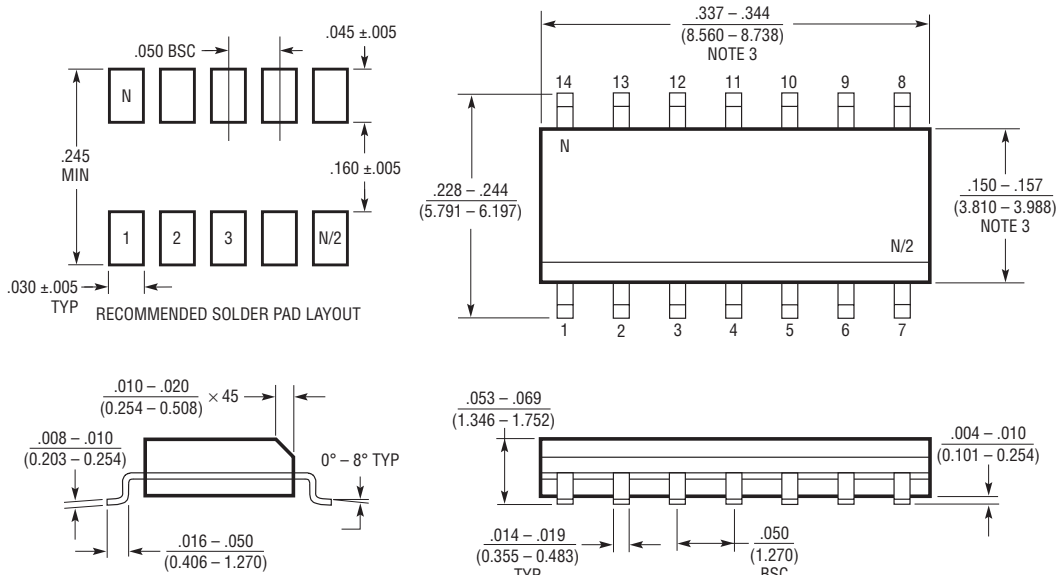
# PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

## N Package 14-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510 Rev I)



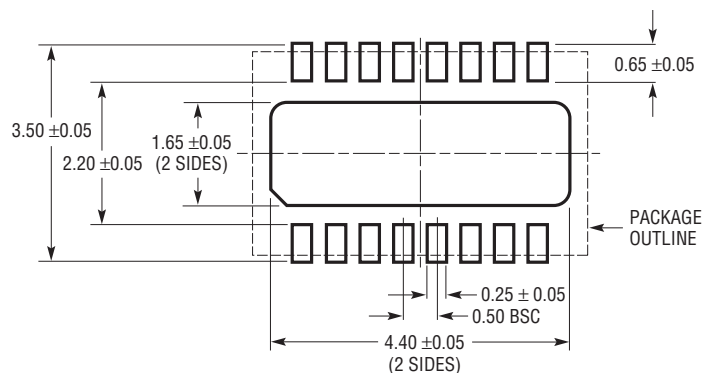
## S Package 14-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



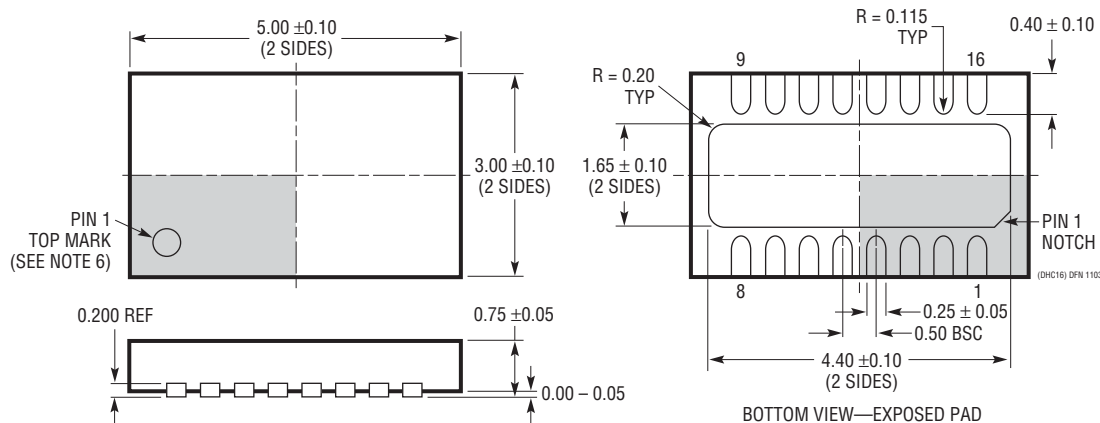
## PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

### DHC Package 16-Lead Plastic DFN (5mm × 3mm) (Reference LTC DWG # 05-08-1706)



#### RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS



#### NOTE:

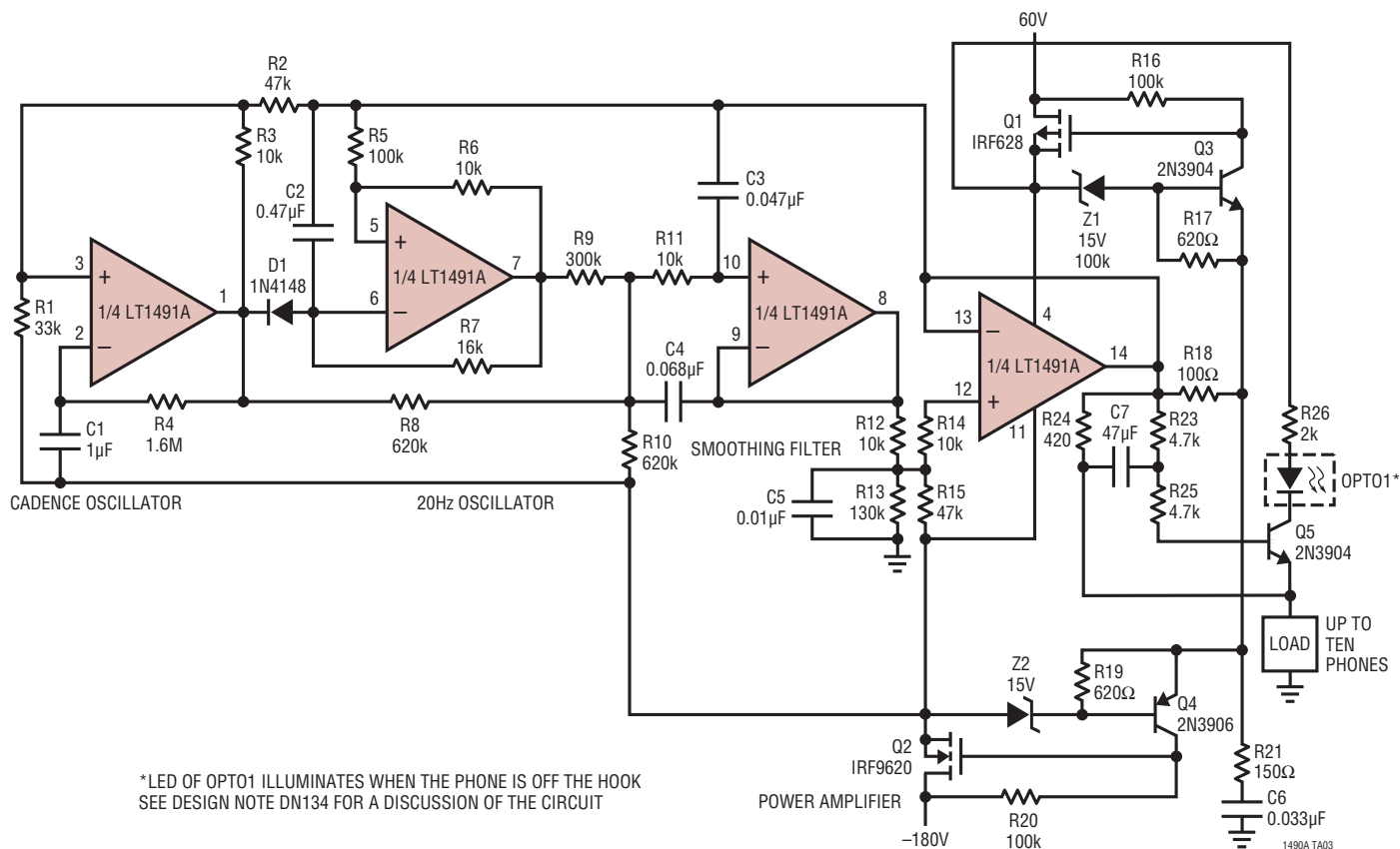
1. DRAWING PROPOSED TO BE MADE VARIATION OF VERSION (WJED-1) IN JEDEC PACKAGE OUTLINE MO-229
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

**REVISION HISTORY** (Revision history begins at Rev C)

| REV | DATE  | DESCRIPTION                                                        | PAGE NUMBER |
|-----|-------|--------------------------------------------------------------------|-------------|
| C   | 10/10 | Changed units from mV to V for $V_O$ in Electrical Characteristics | 7           |
|     |       | Updated package drawings                                           | 13-16       |
| D   | 12/11 | Revised Order Information                                          | 3           |

## TYPICAL APPLICATION

Ring-Tone Generator



\*LED OF OPTO1 ILLUMINATES WHEN THE PHONE IS OFF THE HOOK  
SEE DESIGN NOTE DN134 FOR A DISCUSSION OF THE CIRCUIT

## RELATED PARTS

| PART NUMBER   | DESCRIPTION                                                                     | COMMENTS                                                                                                                   |
|---------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| LT1366/LT1367 | Dual/Quad Precision, Rail-to-Rail Input and Output Op Amps                      | 475 $\mu$ V $V_{OS(MAX)}$ , 500V/mV $A_{VOL(MIN)}$ , 400kHz GBW                                                            |
| LT1636        | Single Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp             | 55 $\mu$ A Supply Current, $V_{CM}$ Extends 44V Above $V_{EE}$ , Independent of $V_{CC}$ , MSOP Package, Shutdown Function |
| LT1638/LT1639 | Dual/Quad 1.2MHz Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amps | 0.4V/ $\mu$ s Slew Rate, 230 $\mu$ A Supply Current per Amplifier                                                          |
| LT1782        | Micropower, Over-The-Top, SOT-23, Rail-to-Rail Input and Output Op Amp          | SOT-23, 800 $\mu$ V $V_{OS(MAX)}$ , $I_S$ = 55 $\mu$ A (Max), Gain-Bandwidth = 200kHz, Shutdown Pin                        |
| LT1783        | 1.2MHz, Over-The-Top, Micropower, Rail-to-Rail Input and Output Op Amp          | SOT-23, 800 $\mu$ V $V_{OS(MAX)}$ , $I_S$ = 300 $\mu$ A (Max), Gain-Bandwidth = 1.2MHz, Shutdown Pin                       |