

# Over-The-Top Micropower, Rail-To-Rail Input and Output Op Amp

## FEATURES

- Operates with Inputs Above  $V^+$
- Rail-to-Rail Input and Output
- Micropower: 250μA Supply Current Max
- Operating Temperature Range:  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Gain-Bandwidth Product: 1.1MHz
- Slew Rate: 0.4V/μs
- Low Input Offset Voltage: 350μV Max
- Single Supply Input Range:  $-0.4\text{V}$  to  $44\text{V}$
- High Output Current: 25mA Min
- Specified on 3V, 5V and  $\pm 15\text{V}$  Supplies
- Output Shutdown
- Output Drives 4700pF with Output Compensation
- Reverse Battery Protection to 25V
- High Voltage Gain: 800V/mV
- High CMRR: 110dB
- Available in 8-Lead MSOP, PDIP and SO Packages; and a Tiny ( $3\text{mm} \times 3\text{mm} \times 0.8\text{mm}$ ) DFN Package

## APPLICATIONS

- Battery or Solar Powered Systems:
  - Portable Instrumentation
  - Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- MUX Amplifiers
- 4mA to 25mA Transmitters

## DESCRIPTION

The LT<sup>®</sup>1637 is a rugged op amp that operates on all single and split supplies with a total voltage of 2.7V to 44V. The LT1637 has a gain-bandwidth product of 1.1MHz while drawing less than 250μA of quiescent current. The LT1637 can be shut down, making the output high impedance and reducing the quiescent current to only 3μA. The LT1637 is reverse supply protected: it draws virtually no current for reverse supply up to 25V. The input range of the LT1637 includes both supplies and the output swings to both supplies. Unlike most micropower op amps, the LT1637 can drive heavy loads; its rail-to-rail output drives 25mA. The LT1637 is unity-gain stable into all capacitive loads up to 4700pF when optional 0.22μF and 150Ω compensation is used.

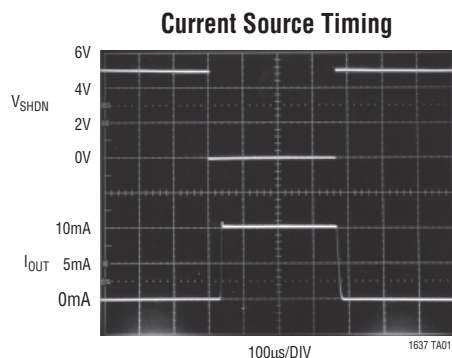
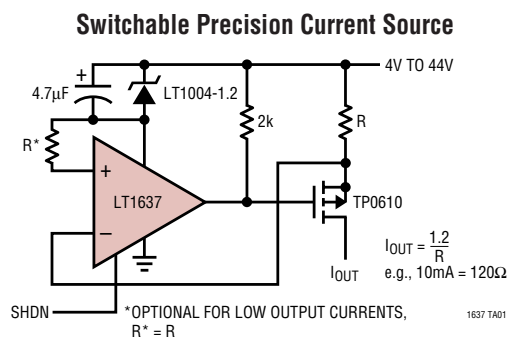
The LT1637 has a unique input stage that operates and remains high impedance when above the positive supply. The inputs take 44V both differential and common mode, even when operating on a 3V supply. Built-in resistors protect the inputs for faults below the negative supply up to 22V. There is no phase reversal of the output for inputs 5V below  $V_{EE}$  or 44V above  $V_{EE}$ , independent of  $V_{CC}$ .

The LT1637 op amp is available in the 8-pin MSOP, PDIP and SO packages. For space limited applications, the LT1637 is available in a  $3\text{mm} \times 3\text{mm} \times 0.8\text{mm}$  dual fine pitch leadless package (DFN).

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## TYPICAL APPLICATION

### Over-The-Top<sup>®</sup> Current Source with Shutdown

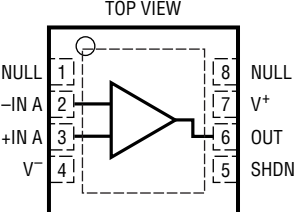
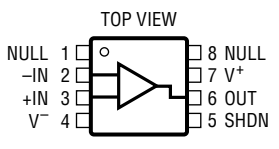
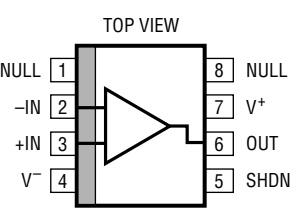


1637Id

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                                         |                                                |                                        |                                                |
|-----------------------------------------|------------------------------------------------|----------------------------------------|------------------------------------------------|
| Total Supply Voltage ( $V^+$ to $V^-$ ) | 44V                                            | Specified Temperature Range (Note 4)   |                                                |
| Input Differential Voltage              | 44V                                            | LT1637C/LT1637I                        | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| Input Current                           | $\pm 25\text{mA}$                              | LT1637H                                | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| Shutdown Pin Voltage Above $V^-$        | 32V                                            | LT1637MP                               | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| Shutdown Pin Current                    | $\pm 10\text{mA}$                              | Junction Temperature                   | $150^{\circ}\text{C}$                          |
| Output Short-Circuit Duration (Note 2)  | Continuous                                     | Junction Temperature (DD Package)      | $125^{\circ}\text{C}$                          |
| Operating Temperature Range (Note 3)    |                                                | Storage Temperature Range              | $-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$ |
| LT1637C/LT1637I                         | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  | Storage Temperature Range (DD Package) | $-65^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LT1637H                                 | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ | Lead Temperature (Soldering, 10 sec)   | $300^{\circ}\text{C}$                          |
| LT1637MP                                | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |                                        |                                                |

## PACKAGE/ORDER INFORMATION

|  <p>DD PACKAGE<br/>8-LEAD (3mm x 3mm) PLASTIC DFN<br/><math>T_{JMAX} = 125^{\circ}\text{C}</math>, <math>\theta_{JA} = 160^{\circ}\text{C/W}</math> (NOTE 2)<br/>UNDERSIDE METAL CONNECTED TO <math>V^-</math></p> |                  |  <p>MS8 PACKAGE<br/>8-LEAD PLASTIC MSOP<br/><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 250^{\circ}\text{C/W}</math></p> |                   |  <p>N8 PACKAGE      S8 PACKAGE<br/>8-LEAD PDIP      8-LEAD PLASTIC SO<br/><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 150^{\circ}\text{C/W}</math> (N8)<br/><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 190^{\circ}\text{C/W}</math> (S8)</p> |                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| ORDER PART NUMBER                                                                                                                                                                                                                                                                                   | DD PART* MARKING | ORDER PART NUMBER                                                                                                                                                                                                              | MS8 PART* MARKING | ORDER PART NUMBER                                                                                                                                                                                                                                                                                                                                                          | S8 PART MARKING                  |
| LT1637CDD<br>LT1637IDD                                                                                                                                                                                                                                                                              | LA<br>AK         | LT1637CMS8<br>LT1637IMS8                                                                                                                                                                                                       | LTIE<br>LTIE      | LT1637CN8<br>LT1637CS8<br>LT1637IN8<br>LT1637IS8<br>LT1637HS8<br>LT1637MPS8                                                                                                                                                                                                                                                                                                | 1637<br>1637I<br>1637H<br>1637MP |

\*The temperature grades are identified by a label on the shipping container. Consult factory for parts specified with wider operating temperature ranges.

## 3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the 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  $T_A = 25^{\circ}\text{C}$ .  $V_S = 3\text{V}$ ,  $0\text{V}$ ;  $V_S = 5\text{V}$ ,  $0\text{V}$ ;  $V_{SHDN} = V^-$ ,  $V_{CM} = V_{OUT} =$  half supply unless otherwise specified. (Note 4)

| SYMBOL   | PARAMETER            | CONDITIONS                                             | LT1637C/LT1637I |     |      | UNITS         |
|----------|----------------------|--------------------------------------------------------|-----------------|-----|------|---------------|
|          |                      |                                                        | MIN             | TYP | MAX  |               |
| $V_{OS}$ | Input Offset Voltage | N8, S8 Packages                                        |                 |     |      |               |
|          |                      | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$   | ●               | 100 | 350  | $\mu\text{V}$ |
|          |                      | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●               |     | 550  | $\mu\text{V}$ |
|          |                      |                                                        |                 |     | 700  | $\mu\text{V}$ |
|          |                      | MS8 Package                                            |                 |     |      |               |
|          |                      | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$   | ●               | 100 | 350  | $\mu\text{V}$ |
| $V_{OS}$ | Input Offset Voltage | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●               |     | 750  | $\mu\text{V}$ |
|          |                      |                                                        | ●               |     | 1100 | $\mu\text{V}$ |
|          |                      | DD Package                                             |                 |     |      |               |
|          |                      | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$   | ●               | 125 | 550  | $\mu\text{V}$ |
|          |                      | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●               |     | 950  | $\mu\text{V}$ |
|          |                      |                                                        |                 |     | 1100 | $\mu\text{V}$ |

1637fd

## 3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the 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  $T_A = 25^{\circ}\text{C}$ .  $V_S = 3\text{V}$ ,  $0\text{V}$ ;  $V_S = 5\text{V}$ ,  $0\text{V}$ ;  $V_{\text{SHDN}} = V^-$ ,  $V_{\text{CM}} = V_{\text{OUT}} = \text{half supply unless otherwise specified. (Note 4)}$

| SYMBOL            | PARAMETER                            | CONDITIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            | LT1637C/LT1637I                       |                                |                  | UNITS                                                                                                                                        |
|-------------------|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------------|--------------------------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
|                   |                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            | MIN                                   | TYP                            | MAX              |                                                                                                                                              |
|                   | Input Offset Voltage Drift (Note 9)  | N8, S8 Packages, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$<br>MS8 Package, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$<br>DDPackage, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                                                                                                                                                                                                                                                  | ●<br>●<br>●                |                                       | 1<br>2<br>2                    | 3<br>6<br>6      | $\mu\text{V}/^{\circ}\text{C}$<br>$\mu\text{V}/^{\circ}\text{C}$<br>$\mu\text{V}/^{\circ}\text{C}$                                           |
| $I_{\text{OS}}$   | Input Offset Current                 | $V_{\text{CM}} = 44\text{V}$ (Note 5)                                                                                                                                                                                                                                                                                                                                                                                                                                                | ●<br>●                     |                                       | 0.4                            | 6.0<br>2.5       | nA<br>$\mu\text{A}$                                                                                                                          |
| $I_{\text{B}}$    | Input Bias Current                   | $V_{\text{CM}} = 44\text{V}$ (Note 5)<br>$V_S = 0\text{V}$                                                                                                                                                                                                                                                                                                                                                                                                                           | ●<br>●                     |                                       | 20<br>23<br>0.1                | 50<br>60         | nA<br>$\mu\text{A}$<br>nA                                                                                                                    |
|                   | Input Noise Voltage                  | 0.1Hz to 10Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            |                                       | 0.6                            |                  | $\mu\text{V}_{\text{P-P}}$                                                                                                                   |
| $e_n$             | Input Noise Voltage Density          | $f = 1\text{kHz}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                                       | 27                             |                  | $\text{nV}/\sqrt{\text{Hz}}$                                                                                                                 |
| $i_n$             | Input Noise Current Density          | $f = 1\text{kHz}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                            |                                       | 0.08                           |                  | $\text{pA}/\sqrt{\text{Hz}}$                                                                                                                 |
| $R_{\text{IN}}$   | Input Resistance                     | Differential<br>Common Mode, $V_{\text{CM}} = 0\text{V}$ to $44\text{V}$                                                                                                                                                                                                                                                                                                                                                                                                             |                            | 1<br>0.7                              | 2.6<br>1.4                     |                  | $\text{M}\Omega$<br>$\text{M}\Omega$                                                                                                         |
| $C_{\text{IN}}$   | Input Capacitance                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                            |                                       | 4                              |                  | pF                                                                                                                                           |
|                   | Input Voltage Range                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ●                          | 0                                     |                                | 44               | V                                                                                                                                            |
| CMRR              | Common Mode Rejection Ratio (Note 5) | $V_{\text{CM}} = 0\text{V}$ to $(V_{\text{CC}} - 1\text{V})$<br>$V_{\text{CM}} = 0\text{V}$ to $44\text{V}$ (Note 8)                                                                                                                                                                                                                                                                                                                                                                 | ●<br>●                     | 88<br>80                              | 110<br>98                      |                  | dB<br>dB                                                                                                                                     |
| $A_{\text{VOL}}$  | Large-Signal Voltage Gain            | $V_S = 3\text{V}$ , $V_0 = 500\text{mV}$ to $2.5\text{V}$ , $R_L = 10\text{k}$<br>$V_S = 3\text{V}$ , $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$V_S = 3\text{V}$ , $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$<br>$V_S = 5\text{V}$ , $V_0 = 500\text{mV}$ to $4.5\text{V}$ , $R_L = 10\text{k}$<br>$V_S = 5\text{V}$ , $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$<br>$V_S = 5\text{V}$ , $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ●<br>●<br>●<br>●<br>●<br>● | 150<br>100<br>75<br>300<br>200<br>150 | 400                            |                  | $\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$ |
| $V_{\text{OL}}$   | Output Voltage Swing LOW             | No Load<br>$I_{\text{SINK}} = 5\text{mA}$<br>$V_S = 5\text{V}$ , $I_{\text{SINK}} = 10\text{mA}$                                                                                                                                                                                                                                                                                                                                                                                     | ●<br>●<br>●                |                                       | 3<br>325<br>580                | 8<br>700<br>1300 | mV<br>mV<br>mV                                                                                                                               |
| $V_{\text{OH}}$   | Output Voltage Swing HIGH            | $V_S = 3\text{V}$ , No Load<br>$V_S = 3\text{V}$ , $I_{\text{SOURCE}} = 5\text{mA}$<br>$V_S = 5\text{V}$ , No Load<br>$V_S = 5\text{V}$ , $I_{\text{SOURCE}} = 10\text{mA}$                                                                                                                                                                                                                                                                                                          | ●<br>●<br>●<br>●           | 2.94<br>2.25<br>4.94<br>3.80          | 2.975<br>2.67<br>4.975<br>4.45 |                  | V<br>V<br>V<br>V                                                                                                                             |
| $I_{\text{SC}}$   | Short-Circuit Current (Note 2)       | $V_S = 3\text{V}$ , Short Output to Ground<br>$V_S = 3\text{V}$ , Short Output to $V_{\text{CC}}$<br>$V_S = 5\text{V}$ , Short Output to Ground<br>$V_S = 5\text{V}$ , Short Output to $V_{\text{CC}}$                                                                                                                                                                                                                                                                               |                            | 10<br>15<br>15<br>15                  | 14<br>45<br>22<br>60           |                  | mA<br>mA<br>mA<br>mA                                                                                                                         |
| PSRR              | Power Supply Rejection Ratio         | $V_S = 3\text{V}$ to $12.5\text{V}$ , $V_{\text{CM}} = V_0 = 1\text{V}$                                                                                                                                                                                                                                                                                                                                                                                                              | ●                          | 90                                    | 98                             |                  | dB                                                                                                                                           |
|                   | Minimum Supply Voltage               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ●                          |                                       |                                | 2.7              | V                                                                                                                                            |
|                   | Reverse Supply Voltage               | $I_S = -100\mu\text{A}$                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ●                          | 25                                    | 40                             |                  | V                                                                                                                                            |
| $I_S$             | Supply Current (Note 6)              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ●                          |                                       | 190                            | 250<br>295       | $\mu\text{A}$<br>$\mu\text{A}$                                                                                                               |
|                   | Supply Current, SHDN                 | $V_{\text{PIN5}} = 2\text{V}$ , No Load (Note 6)                                                                                                                                                                                                                                                                                                                                                                                                                                     | ●                          |                                       | 3                              | 12               | $\mu\text{A}$                                                                                                                                |
| $I_{\text{SHDN}}$ | Shutdown Pin Current                 | $V_{\text{PIN5}} = 0.3\text{V}$ , No Load (Note 6)<br>$V_{\text{PIN5}} = 2\text{V}$ , No Load (Note 5)<br>$V_{\text{PIN5}} = 3.3\text{V}$<br>$V_{\text{PIN5}} = 5\text{V}$                                                                                                                                                                                                                                                                                                           | ●<br>●                     |                                       | 0.2<br>1.0<br>2.5<br>4.3       | 15<br>5          | nA<br>$\mu\text{A}$<br>$\mu\text{A}$<br>$\mu\text{A}$                                                                                        |
|                   | Output Leakage Current, SHDN         | $V_{\text{PIN5}} = 2\text{V}$ , No Load (Note 6)                                                                                                                                                                                                                                                                                                                                                                                                                                     | ●                          |                                       | 0.02                           | 1                | $\mu\text{A}$                                                                                                                                |

## 3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the 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  $T_A = 25^{\circ}\text{C}$ .  $V_S = 3\text{V}$ ,  $0\text{V}$ ;  $V_S = 5\text{V}$ ,  $0\text{V}$ ;  $V_{\text{SHDN}} = V^-$ ,  $V_{\text{CM}} = V_{\text{OUT}} = \text{half supply unless otherwise specified. (Note 4)}$

| SYMBOL                | PARAMETER                          | CONDITIONS                                                        |   | LT1637C/LT1637I |      |     | UNITS                  |
|-----------------------|------------------------------------|-------------------------------------------------------------------|---|-----------------|------|-----|------------------------|
|                       |                                    |                                                                   |   | MIN             | TYP  | MAX |                        |
|                       | Maximum Shutdown Pin Current       | $V_{\text{PIN5}} = 32\text{V}$ , No Load (Note 5)                 | ● |                 | 20   | 150 | $\mu\text{A}$          |
| $t_{\text{ON}}$       | Turn-On Time                       | $V_{\text{PIN5}} = 5\text{V}$ to $0\text{V}$ , $R_L = 10\text{k}$ |   |                 | 45   |     | $\mu\text{s}$          |
| $t_{\text{OFF}}$      | Turn-Off Time                      | $V_{\text{PIN5}} = 0\text{V}$ to $5\text{V}$ , $R_L = 10\text{k}$ |   |                 | 3    |     | $\mu\text{s}$          |
| $t_{\text{SETTLING}}$ | Settling Time                      | $0.1\% A_V = 1$ , $\Delta V_O = 2\text{V}$                        |   |                 | 9    |     | $\mu\text{s}$          |
| GBW                   | Gain-Bandwidth Product<br>(Note 5) | $f = 10\text{kHz}$                                                |   | 650             | 1000 |     | $\text{kHz}$           |
|                       |                                    | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$              | ● | 550             |      |     | $\text{kHz}$           |
|                       |                                    | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$            | ● | 500             |      |     | $\text{kHz}$           |
| SR                    | Slew Rate<br>(Note 7)              | $A_V = -1$ , $R_L = \infty$                                       |   | 0.210           | 0.35 |     | $\text{V}/\mu\text{s}$ |
|                       |                                    | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$              | ● | 0.185           |      |     | $\text{V}/\mu\text{s}$ |
|                       |                                    | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$            | ● | 0.170           |      |     | $\text{V}/\mu\text{s}$ |

## $\pm 15\text{V}$ ELECTRICAL CHARACTERISTICS

The ● denotes the 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  $T_A = 25^{\circ}\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $V_{\text{CM}} = 0\text{V}$ ,  $V_{\text{OUT}} = 0\text{V}$ ,  $V_{\text{SHDN}} = V^-$  unless otherwise specified. (Note 4)

| SYMBOL           | PARAMETER                           | CONDITIONS                                                              |   | LT1637C/LT1637I |         |        | UNITS                          |
|------------------|-------------------------------------|-------------------------------------------------------------------------|---|-----------------|---------|--------|--------------------------------|
|                  |                                     |                                                                         |   | MIN             | TYP     | MAX    |                                |
| $V_{\text{OS}}$  | Input Offset Voltage                | N8, S8 Packages                                                         |   |                 | 100     | 450    | $\mu\text{V}$                  |
|                  |                                     | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                    | ● |                 |         | 650    | $\mu\text{V}$                  |
|                  |                                     | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                  | ● |                 |         | 800    | $\mu\text{V}$                  |
|                  |                                     | MS8 Package                                                             |   |                 | 100     | 450    | $\mu\text{V}$                  |
|                  |                                     | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                    | ● |                 |         | 800    | $\mu\text{V}$                  |
|                  |                                     | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                  | ● |                 |         | 1150   | $\mu\text{V}$                  |
|                  | Input Offset Voltage Drift (Note 9) | DD Package                                                              |   |                 | 125     | 650    | $\mu\text{V}$                  |
|                  |                                     | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                    | ● |                 |         | 1000   | $\mu\text{V}$                  |
|                  |                                     | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                  | ● |                 |         | 1150   | $\mu\text{V}$                  |
|                  |                                     | N8, S8 Packages, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | ● |                 | 1       | 3      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{\text{OS}}$  | Input Offset Current                | MS8 Package, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$     | ● |                 | 2       | 6      | $\mu\text{V}/^{\circ}\text{C}$ |
|                  |                                     | DD Package, $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$      | ● |                 | 2       | 6      | $\mu\text{V}/^{\circ}\text{C}$ |
|                  |                                     |                                                                         |   |                 |         |        |                                |
| $I_{\text{B}}$   | Input Bias Current                  |                                                                         | ● |                 | 17      | 50     | $\text{nA}$                    |
|                  | Input Noise Voltage                 | $0.1\text{Hz}$ to $10\text{Hz}$                                         |   |                 | 0.6     |        | $\mu\text{V}_{\text{P-P}}$     |
| $e_n$            | Input Noise Voltage Density         | $f = 1\text{kHz}$                                                       |   |                 | 27      |        | $\text{nV}/\sqrt{\text{Hz}}$   |
| $i_n$            | Input Noise Current Density         | $f = 1\text{kHz}$                                                       |   |                 | 0.08    |        | $\text{pA}/\sqrt{\text{Hz}}$   |
| $R_{\text{IN}}$  | Input Resistance                    | Differential                                                            |   | 1               | 3       |        | $\text{M}\Omega$               |
|                  |                                     | Common Mode, $V_{\text{CM}} = -15\text{V}$ to $14\text{V}$              |   |                 | 2200    |        | $\text{M}\Omega$               |
| $C_{\text{IN}}$  | Input Capacitance                   |                                                                         |   |                 | 4       |        | $\text{pF}$                    |
|                  | Input Voltage Range                 |                                                                         | ● | -15             |         | 29     | $\text{V}$                     |
| CMRR             | Common Mode Rejection Ratio         | $V_{\text{CM}} = -15\text{V}$ to $29\text{V}$                           | ● | 80              | 110     |        | $\text{dB}$                    |
| $A_{\text{VOL}}$ | Large-Signal Voltage Gain           | $V_O = \pm 14\text{V}$ , $R_L = 10\text{k}$                             |   | 100             | 400     |        | $\text{V}/\text{mV}$           |
|                  |                                     | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                    | ● | 75              |         |        | $\text{V}/\text{mV}$           |
|                  |                                     | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                  | ● | 50              |         |        | $\text{V}/\text{mV}$           |
| $V_{\text{OL}}$  | Output Voltage Swing LOW            | No Load                                                                 | ● |                 | -14.997 | -14.95 | $\text{V}$                     |
|                  |                                     | $I_{\text{SINK}} = 5\text{mA}$                                          | ● |                 | -14.680 | -14.25 | $\text{V}$                     |
|                  |                                     | $I_{\text{SINK}} = 10\text{mA}$                                         | ● |                 | -14.420 | -13.65 | $\text{V}$                     |

## ±15V ELECTRICAL CHARACTERISTICS

The ● denotes the 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  $T_A = 25^{\circ}\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $V_{CM} = 0\text{V}$ ,  $V_{OUT} = 0\text{V}$ ,  $V_{SHDN} = V^-$  unless otherwise specified. (Note 4)

| SYMBOL     | PARAMETER                       | CONDITIONS                                                                              |   | LT1637C/LT1637I |        |       | UNITS |
|------------|---------------------------------|-----------------------------------------------------------------------------------------|---|-----------------|--------|-------|-------|
|            |                                 |                                                                                         |   | MIN             | TYP    | MAX   |       |
| $V_{OH}$   | Output Voltage Swing HIGH       | No Load                                                                                 | ● | 14.9            | 14.967 |       | V     |
|            |                                 | $I_{SOURCE} = 5\text{mA}$                                                               | ● | 14.2            | 14.667 |       | V     |
|            |                                 | $I_{SOURCE} = 10\text{mA}$                                                              | ● | 13.7            | 14.440 |       | V     |
| $I_{SC}$   | Short-Circuit Current (Note 2)  | Short Output to GND                                                                     |   | ±25             | ±31.7  |       | mA    |
|            |                                 | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                                    | ● | ±20             |        |       | mA    |
|            |                                 | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                  | ● | ±15             |        |       | mA    |
| PSRR       | Power Supply Rejection Ratio    | $V_S = \pm 1.5\text{V}$ to $\pm 22\text{V}$                                             | ● | 90              | 115    |       | dB    |
|            | Minimum Supply Voltage          |                                                                                         | ● |                 |        | ±1.35 | V     |
| $I_S$      | Supply Current                  |                                                                                         | ● |                 | 230    | 300   | μA    |
|            |                                 |                                                                                         | ● |                 |        | 370   | μA    |
|            | Positive Supply Current, SHDN   | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                             | ● |                 | 6      | 40    | μA    |
| $I_{SHDN}$ | Shutdown Pin Current            | $V_{PIN5} = -21.7\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                           | ● |                 | 0.3    | 15    | nA    |
|            |                                 | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                             | ● |                 | 0.9    | 8     | μA    |
|            | Maximum Shutdown Pin Current    | $V_{PIN5} = 32\text{V}$ , $V_S = \pm 22\text{V}$                                        | ● |                 | 20     | 150   | μA    |
|            | Output Leakage Current, SHDN    | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                             | ● |                 | 0.02   | 2     | μA    |
| $V_L$      | Shutdown Pin Input Low Voltage  | $V_S = \pm 22\text{V}$                                                                  | ● | -21.7           | -21.6  |       | V     |
| $V_H$      | Shutdown Pin Input High Voltage | $V_S = \pm 22\text{V}$                                                                  | ● |                 | -20.8  | -20.0 | V     |
| $t_{ON}$   | Turn-On Time                    | $V_{PIN5} = -10\text{V}$ to $-15\text{V}$ , $R_L = 10\text{k}$                          |   |                 | 35     |       | μs    |
| $t_{OFF}$  | Turn-Off Time                   | $V_{PIN5} = -15\text{V}$ to $-10\text{V}$ , $R_L = 10\text{k}$                          |   |                 | 3      |       | μs    |
| GBW        | Gain-Bandwidth Product          | $f = 10\text{kHz}$                                                                      |   | 750             | 1100   |       | kHz   |
|            |                                 | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                                    | ● | 650             |        |       | kHz   |
|            |                                 | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                  | ● | 600             |        |       | kHz   |
| SR         | Slew Rate                       | $A_V = -1$ , $R_L = \infty$ , $V_0 = \pm 10\text{V}$ , Measure at $V_0 = \pm 5\text{V}$ |   | 0.225           | 0.4    |       | V/μs  |
|            |                                 | $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$                                    | ● | 0.200           |        |       | V/μs  |
|            |                                 | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$                                  | ● | 0.180           |        |       | V/μs  |

## 3V AND 5V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for LT1637H and  $-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for LT1637MP.  $V_S = 3\text{V}, 0\text{V}$ ;  $V_S = 5\text{V}, 0\text{V}$ ;  $V_{CM} = V_{OUT} = \text{half supply unless otherwise specified. (Note 4)}$

| SYMBOL     | PARAMETER                            | CONDITIONS                                                               |   | LT1637H/LT1637MP |      |      | UNITS                          |
|------------|--------------------------------------|--------------------------------------------------------------------------|---|------------------|------|------|--------------------------------|
|            |                                      |                                                                          |   | MIN              | TYP  | MAX  |                                |
| $V_{OS}$   | Input Offset Voltage                 |                                                                          | ● |                  | 100  | 450  | $\mu\text{V}$                  |
|            | Input Offset Voltage Drift (Note 9)  |                                                                          | ● |                  | 3    | 10   | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{OS}$   | Input Offset Current                 | $V_{CM} = 44\text{V}$ (Note 5)                                           | ● |                  |      | 15   | nA                             |
|            |                                      |                                                                          | ● |                  |      | 10   | $\mu\text{A}$                  |
| $I_B$      | Input Bias Current                   | $V_{CM} = 44\text{V}$ (Note 5)                                           | ● |                  |      | 150  | nA                             |
|            |                                      |                                                                          | ● |                  |      | 100  | $\mu\text{A}$                  |
|            | Input Voltage Range                  |                                                                          | ● | 0.3              |      | 44   | V                              |
| CMRR       | Common Mode Rejection Ratio (Note 5) | $V_{CM} = 0.3\text{V}$ to $(V_{CC} - 1\text{V})$                         | ● | 72               |      |      | 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 $2.5\text{V}, R_L = 10\text{k}$ | ● | 150              | 400  |      | V/mV                           |
|            |                                      | $V_S = 5\text{V}, V_O = 500\text{mV}$ to $4.5\text{V}, R_L = 10\text{k}$ | ● | 20               | 800  |      | V/mV                           |
| $V_{OL}$   | Output Voltage Swing LOW             | No Load                                                                  | ● |                  |      | 15   | mV                             |
|            |                                      | $I_{SINK} = 5\text{mA}$                                                  | ● |                  |      | 900  | mV                             |
|            |                                      | $V_S = 5\text{V}, I_{SINK} = 10\text{mA}$                                | ● |                  |      | 1500 | mV                             |
| $V_{OH}$   | Output Voltage Swing HIGH            | $V_S = 3\text{V}$ , No Load                                              | ● | 2.90             |      |      | V                              |
|            |                                      | $V_S = 3\text{V}, I_{SOURCE} = 5\text{mA}$                               | ● | 2.05             |      |      | V                              |
|            |                                      | $V_S = 5\text{V}$ , No Load                                              | ● | 4.90             |      |      | V                              |
|            |                                      | $V_S = 5\text{V}, I_{SOURCE} = 10\text{mA}$                              | ● | 3.50             |      |      | V                              |
| PSRR       | Power Supply Rejection Ratio         | $V_S = 3\text{V}$ to $12.5\text{V}, V_{CM} = V_O = 1\text{V}$            | ● | 80               |      |      | dB                             |
|            | Minimum Supply Voltage               |                                                                          | ● | 2.7              |      |      | V                              |
|            | Reverse Supply Voltage               | $I_S = -100\mu\text{A}$                                                  | ● | 23               |      |      | V                              |
| $I_S$      | Supply Current                       | (Note 6)                                                                 | ● |                  | 190  | 250  | $\mu\text{A}$                  |
|            | Supply Current, SHDN                 | $V_{PIN5} = 2\text{V}$ , No Load (Note 6)                                | ● |                  |      | 400  | $\mu\text{A}$                  |
| $I_{SHDN}$ | Shutdown Pin Current                 | $V_{PIN5} = 0.3\text{V}$ , No Load (Note 6)                              | ● |                  |      | 15   | $\mu\text{A}$                  |
|            |                                      | $V_{PIN5} = 2\text{V}$ , No Load (Note 5)                                | ● |                  |      | 200  | nA                             |
|            | Output Leakage Current, SHDN         | $V_{PIN5} = 2\text{V}$ , No Load (Note 6)                                | ● |                  |      | 7    | $\mu\text{A}$                  |
|            | Maximum Shutdown Pin Current         | $V_{PIN5} = 32\text{V}$ , No Load (Note 5)                               | ● |                  |      | 5    | $\mu\text{A}$                  |
| GBW        | Gain-Bandwidth Product               | $f = 10\text{kHz}$ (Note 5)                                              | ● | 650              | 1000 |      | kHz                            |
|            |                                      |                                                                          | ● | 350              |      |      | kHz                            |
| SR         | Slew Rate                            | $A_V = -1, R_L = \infty$ (Note 7)                                        | ● | 0.210            | 0.35 |      | V/ $\mu\text{s}$               |
|            |                                      |                                                                          | ● | 0.1              |      |      | V/ $\mu\text{s}$               |

## ±15V ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range of  $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for LT1637H and  $-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for LT1637MP.  $V_S = \pm 15\text{V}$ ,  $V_{CM} = 0\text{V}$ ,  $V_{OUT} = 0\text{V}$ ,  $V_{SHDN} = V^-$ , unless otherwise specified. (Note 4)

| SYMBOL     | PARAMETER                           | CONDITIONS                                                                                 |   | LT1637H/LT1637MP |      |            | UNITS                                            |
|------------|-------------------------------------|--------------------------------------------------------------------------------------------|---|------------------|------|------------|--------------------------------------------------|
|            |                                     |                                                                                            |   | MIN              | TYP  | MAX        |                                                  |
| $V_{OS}$   | Input Offset Voltage                |                                                                                            | ● |                  | 100  | 550<br>3.4 | $\mu\text{V}$<br>$\text{mV}$                     |
|            | Input Offset Voltage Drift (Note 9) |                                                                                            | ● |                  | 3    | 11         | $\mu\text{V}/^{\circ}\text{C}$                   |
| $I_{OS}$   | Input Offset Current                |                                                                                            | ● |                  |      | 25         | nA                                               |
| $I_B$      | Input Bias Current                  |                                                                                            | ● |                  |      | 250        | nA                                               |
| CMRR       | Common Mode Rejection Ratio         | $V_{CM} = -14.7\text{V}$ to $29\text{V}$                                                   | ● | 72               |      |            | dB                                               |
| $A_{VOL}$  | Large-Signal Voltage Gain           | $V_O = \pm 14\text{V}$ , $R_L = 10\text{k}$                                                | ● | 100<br>4         | 400  |            | $\text{V}/\text{mV}$<br>$\text{V}/\text{mV}$     |
| $V_O$      | Output Voltage Swing                | No Load                                                                                    | ● |                  |      | $\pm 14.8$ | V                                                |
|            |                                     | $I_{OUT} = \pm 5\text{mA}$                                                                 | ● |                  |      | $\pm 14.0$ | V                                                |
|            |                                     | $I_{OUT} = \pm 10\text{mA}$                                                                | ● |                  |      | $\pm 13.4$ | V                                                |
| PSRR       | Power Supply Rejection Ratio        | $V_S = \pm 1.5\text{V}$ to $22\text{V}$                                                    | ● | 84               |      |            | dB                                               |
|            | Minimum Supply Voltage              |                                                                                            | ● | $\pm 1.35$       |      |            | V                                                |
| $I_S$      | Supply Current                      |                                                                                            | ● |                  | 230  | 300<br>500 | $\mu\text{A}$<br>$\mu\text{A}$                   |
|            | Positive Supply Current, SHDN       | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                                | ● |                  |      | 60         | $\mu\text{A}$                                    |
| $I_{SHDN}$ | Shutdown Pin Current                | $V_{PIN5} = -21.7\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                              | ● |                  |      | 200        | nA                                               |
|            |                                     | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                                | ● |                  |      | 10         | $\mu\text{A}$                                    |
|            | Maximum Shutdown Pin Current        | $V_{PIN5} = 32\text{V}$ , $V_S = \pm 22\text{V}$                                           | ● |                  |      | 200        | $\mu\text{A}$                                    |
|            | Output Leakage Current, SHDN        | $V_{PIN5} = -20\text{V}$ , $V_S = \pm 22\text{V}$ , No Load                                | ● |                  |      | 100        | $\mu\text{A}$                                    |
| $V_L$      | Shutdown Pin Input Low Voltage      | $V_S = \pm 22\text{V}$                                                                     | ● |                  |      | $-21.7$    | V                                                |
| $V_H$      | Shutdown Pin Input High Voltage     | $V_S = \pm 22\text{V}$                                                                     | ● | $-20$            |      |            | V                                                |
| GBW        | Gain-Bandwidth Product              | $f = 10\text{kHz}$                                                                         | ● | 750<br>400       | 1100 |            | $\text{kHz}$<br>$\text{kHz}$                     |
|            |                                     |                                                                                            | ● | 0.225<br>0.1     | 0.4  |            | $\text{V}/\mu\text{s}$<br>$\text{V}/\mu\text{s}$ |
| SR         | Slew Rate                           | $A_V = -1$ , $R_L = \infty$ , $V_O = \pm 10\text{V}$ ,<br>Measure at $V_O = \pm 5\text{V}$ | ● |                  |      |            |                                                  |

**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. The  $\theta_{JA}$  specified for the DD package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

**Note 3:** The LT1637C and LT1637I are guaranteed functional over the operating temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The LT1637H is guaranteed functional over the operating temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The LT1637MP is guaranteed functional over the operating temperature range  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**Note 4:** The LT1637C is guaranteed to meet specified performance from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The LT1637C is designed, characterized and expected to meet

specified performance from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  but is not tested or QA sampled at these temperatures. The LT1637I is guaranteed to meet specified performance from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The LT1637H is guaranteed to meet specified performance from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and the LT1637MP is guaranteed to meet specified performance from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**Note 5:**  $V_S = 5\text{V}$  limits are guaranteed by correlation to  $V_S = 3\text{V}$  and  $V_S = \pm 15\text{V}$  or  $V_S = \pm 22\text{V}$  tests.

**Note 6:**  $V_S = 3\text{V}$  limits are guaranteed by correlation to  $V_S = 5\text{V}$  and  $V_S = \pm 15\text{V}$  or  $V_S = \pm 22\text{V}$  tests.

**Note 7:** 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.

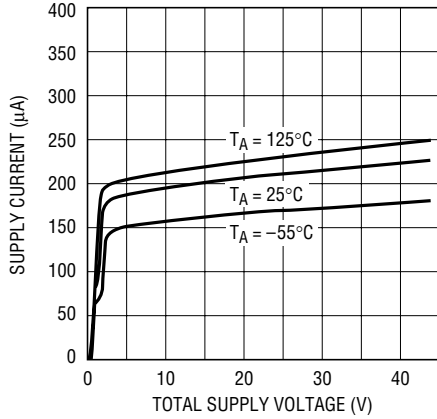
**Note 8:** This specification implies a typical input offset voltage of  $650\mu\text{V}$  at  $V_{CM} = 44\text{V}$  and a maximum input offset voltage of  $5.4\text{mV}$  at  $V_{CM} = 44\text{V}$ .

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



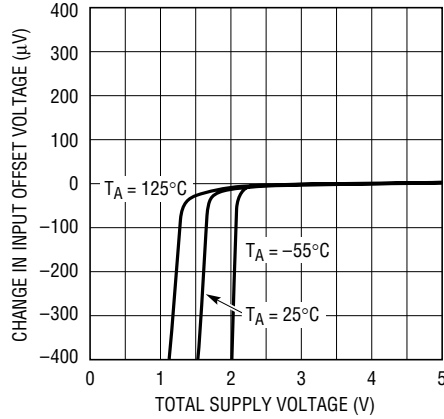
# TYPICAL PERFORMANCE CHARACTERISTICS

Supply Current vs Supply Voltage



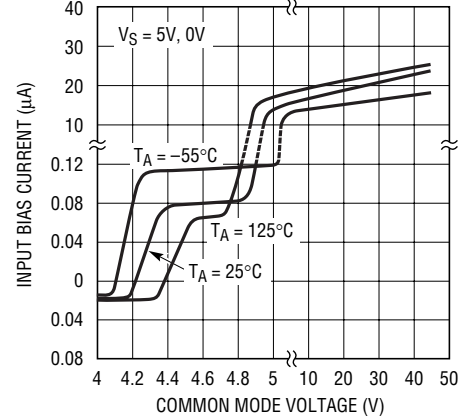
1637 G01

Minimum Supply Voltage



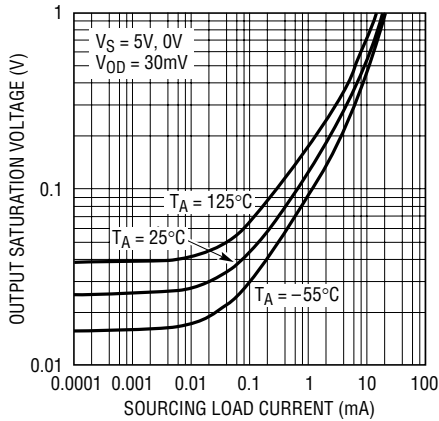
1637 G02

Input Bias Current vs Common Mode Voltage



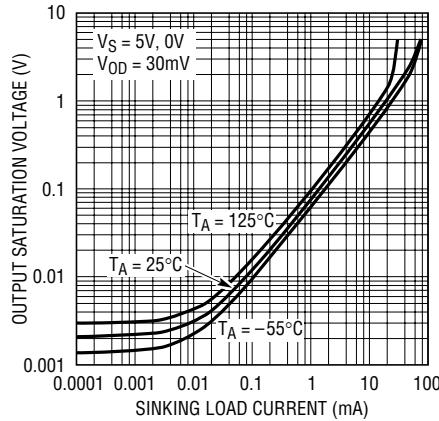
1637 G03

Output Saturation Voltage vs Load Current (Output High)



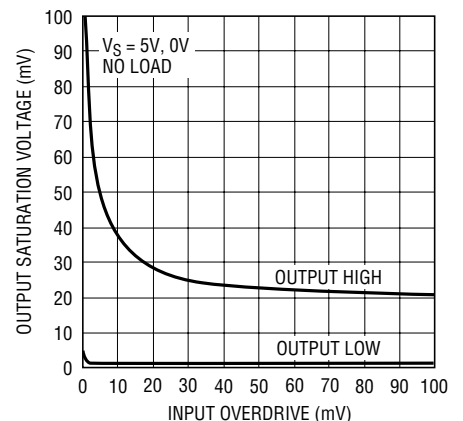
1637 G04

Output Saturation Voltage vs Load Current (Output Low)



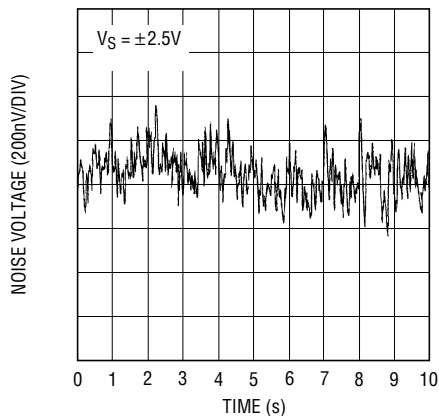
1637 G05

Output Saturation Voltage vs Input Overdrive



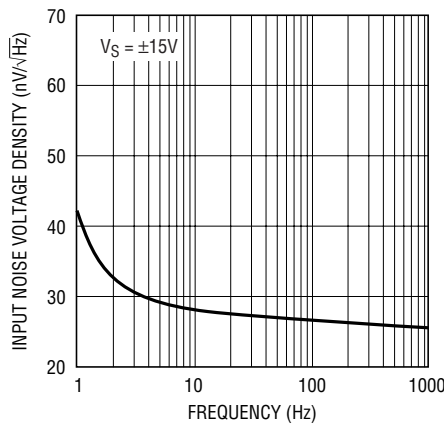
1637 G06

0.1Hz to 10Hz Noise Voltage



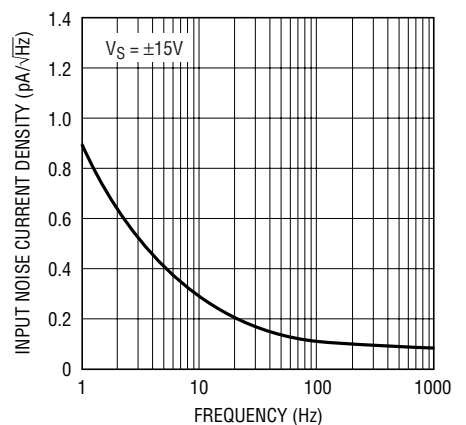
1637 G07

Noise Voltage Density vs Frequency



1637 G08

Input Noise Current vs Frequency

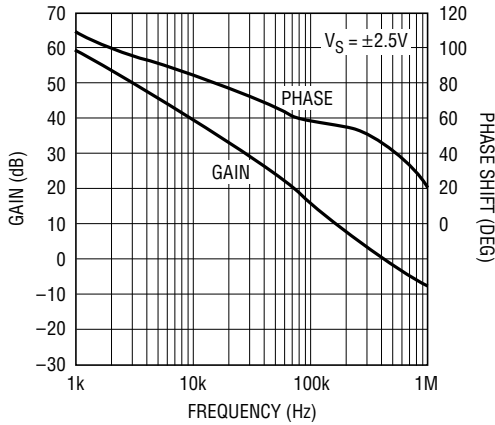


1637 G09



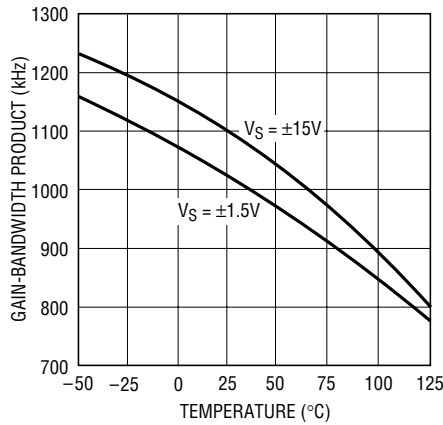
# TYPICAL PERFORMANCE CHARACTERISTICS

Open-Loop Gain and Phase Shift vs Frequency



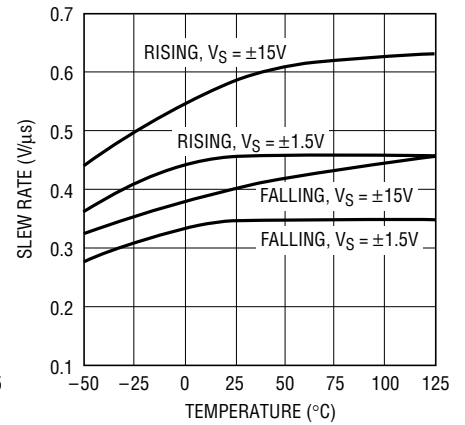
1637 G10

Gain-Bandwidth Product vs Temperature



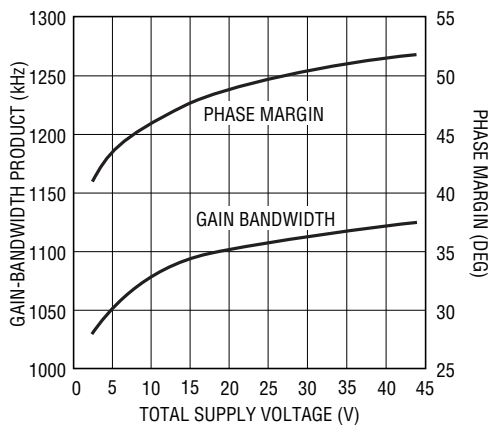
1637 G11

Slew Rate vs Temperature



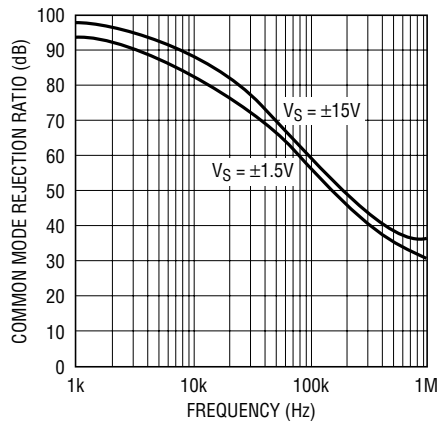
1637 G12

Gain-Bandwidth Product and Phase Margin vs Supply Voltage



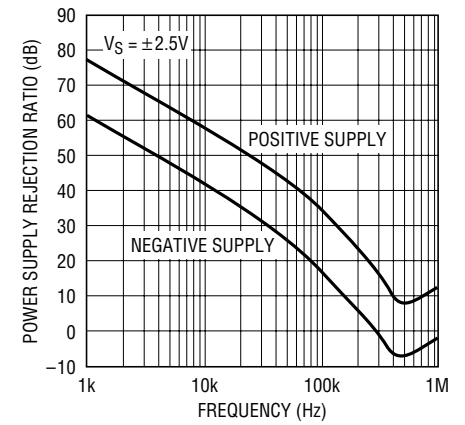
1637 G13

CMRR vs Frequency



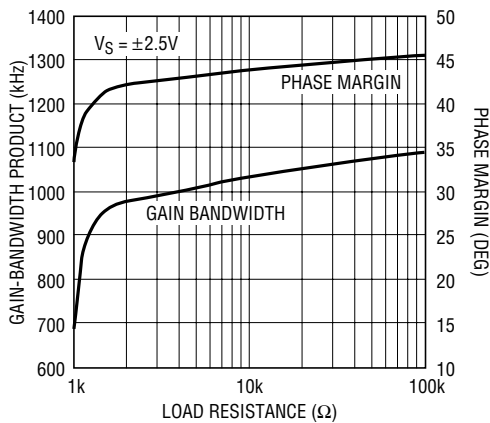
1637 G14

PSRR vs Frequency



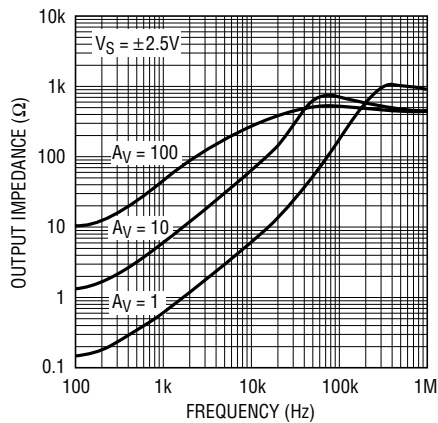
1637 G15

Gain-Bandwidth Product and Phase Margin vs Load Resistance



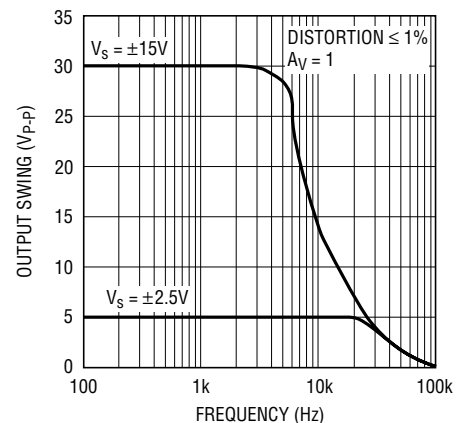
1637 G16

Output Impedance vs Frequency



1637 G17

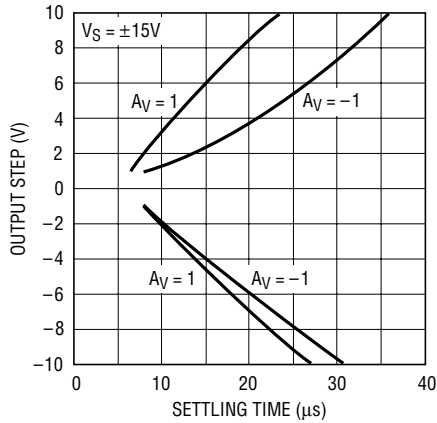
Undistorted Output Swing vs Frequency



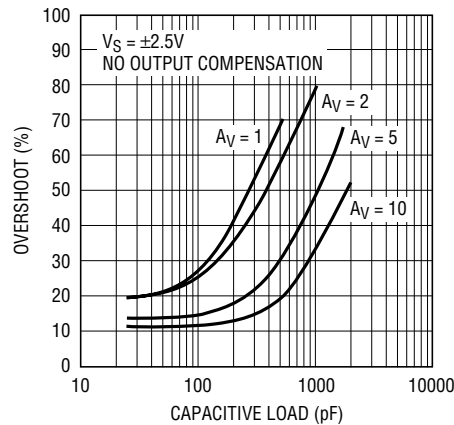
1637 G18

# TYPICAL PERFORMANCE CHARACTERISTICS

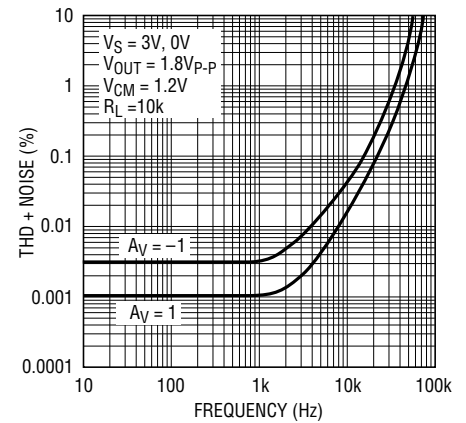
**Settling Time to 0.1%  
vs Output Step**



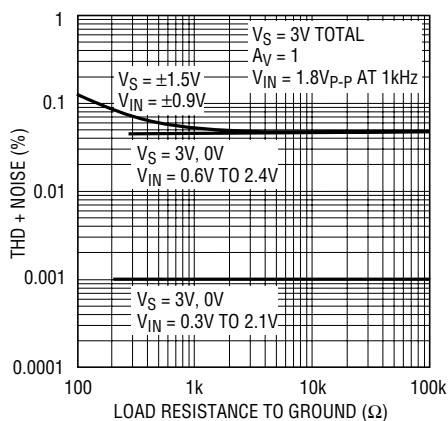
**Capacitive Load Handling,  
Overshoot vs Capacitive Load**



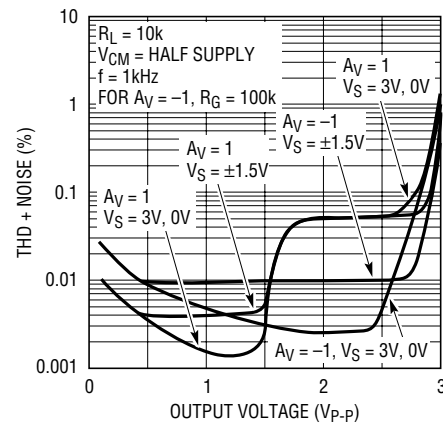
**Total Harmonic Distortion + Noise  
vs Frequency**



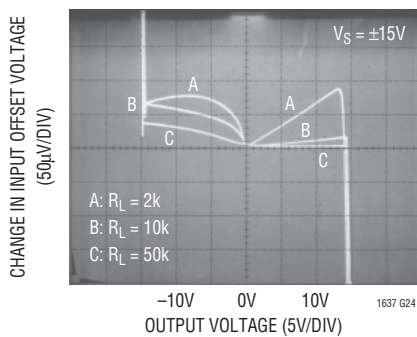
**Total Harmonic Distortion + Noise  
vs Load Resistance**



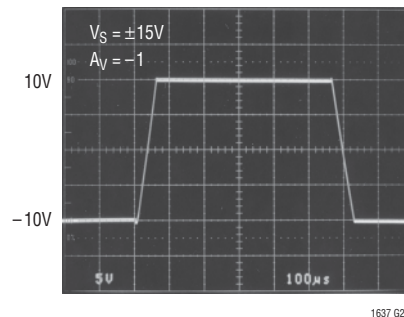
**Total Harmonic Distortion + Noise  
vs Output Voltage**



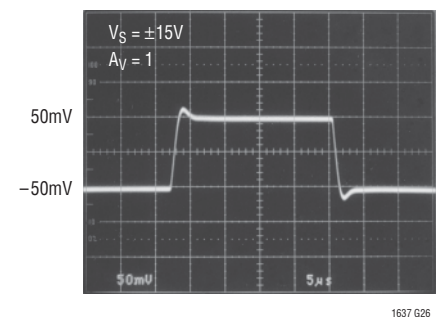
**Open-Loop Gain**



**Large-Signal Response**



**Small-Signal Response**



## APPLICATIONS INFORMATION

### Supply Voltage

The positive supply pin of the LT1637 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 LT1637 is protected against reverse battery voltages up to 25V. In the event a reverse battery condition occurs, the supply current is typically less than 1nA.

When operating the LT1637 on total supplies of 30V or more, the supply must not be brought up faster 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.  $5\Omega$  of resistance in the supply or the bypass capacitor will dampen the tuned circuit enough to limit the rise time.

### Inputs

The LT1637 has 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 0.9V or more below  $V^+$ , the PNP input stage is active and the input bias current is typically  $-20\text{nA}$ . 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  $80\text{nA}$ . 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 LT1637 to operate with either or both of its inputs above  $V^+$ . At about 0.3V above  $V^+$  the NPN input transistor is fully saturated and the input bias current is typically  $23\mu\text{A}$  at room temperature. The input offset voltage is typically  $600\mu\text{V}$  when operating above  $V^+$ . The LT1637 will operate with its input 44V above  $V^-$  regardless of  $V^+$ .

The inputs are protected against excursions as much as 22V below  $V^-$  by an internal  $1.3\text{k}\Omega$  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 5V 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 LT1637 is affected by input overdrive as shown in the typical performance curves. When monitoring input voltages within 100mV of  $V^+$ , gain should be taken to keep the output from clipping.

The output of the LT1637 can be pulled up to 25V 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 LT1637 is 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 4700pF, 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 LT1637 switches 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 LT1637 should be operated single supply, with the output always sourcing current and with the input voltage swing between ground and  $(V^+ - 0.9\text{V})$ . See the Typical Performance Characteristics curves.

## APPLICATIONS INFORMATION

### Gain

The open-loop gain is less sensitive to load resistance 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.

### Shutdown

The LT1637 can be shut down two ways: using the shutdown pin or bringing  $V^+$  to within 0.5V of  $V^-$ . When  $V^+$  is brought to within 0.5V of  $V^-$  both the supply current and output leakage current drop to less than 10nA. When the shutdown pin is brought 1.2V above  $V^-$ , the supply current drops to about 3 $\mu$ A and the output leakage current is less than 1 $\mu$ A, independent of  $V^+$ . In either case the input bias current is less than 0.1nA (even if the inputs are 44V above the negative supply).

The shutdown pin can be taken up to 32V above  $V^-$ . The shutdown pin can be driven below  $V^-$ , however the pin current through the substrate diode should be limited with an external resistor to less than 10mA.

### Input Offset Nulling

The input offset voltage can be nulled by placing a 10k potentiometer between Pins 1 and 8 with its wiper to  $V^-$  (see Figure 1). The null range will be at least  $\pm 3$ mV.

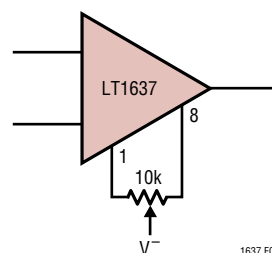
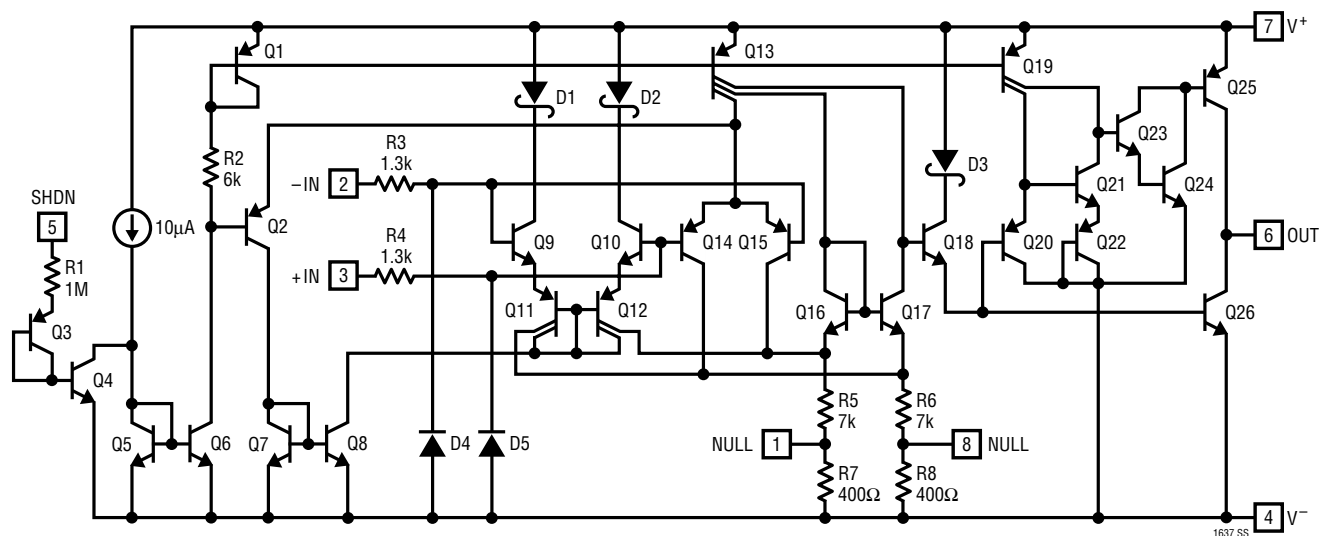


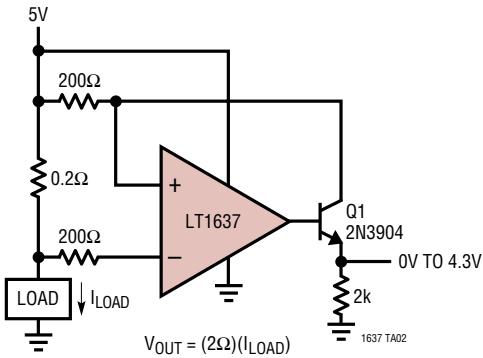
Figure 1. Input Offset Nulling

## SIMPLIFIED SCHEMATIC

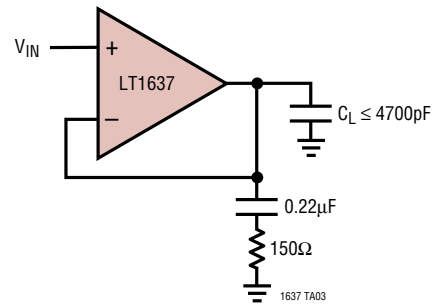


# TYPICAL APPLICATIONS

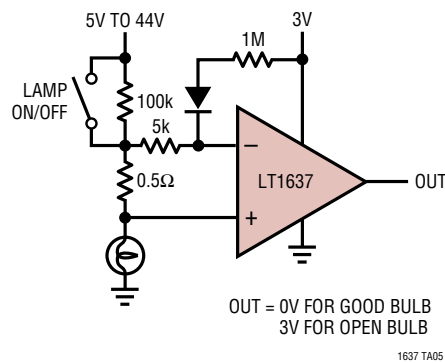
Positive Supply Rail Current Sense



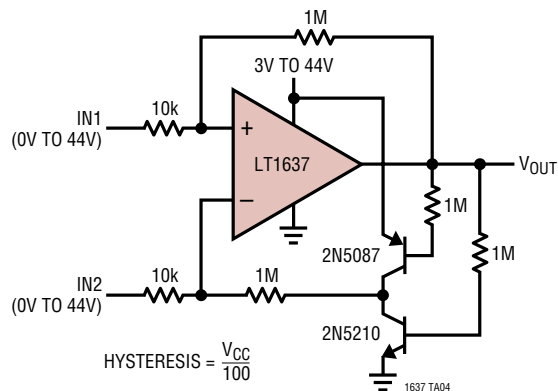
Optional Output Compensation for Capacitive Loads Greater Than 200pF



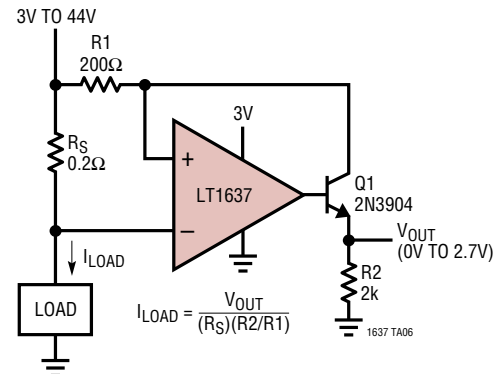
Lamp Outage Detector



Over-The-Top Comparator with Hysteresis

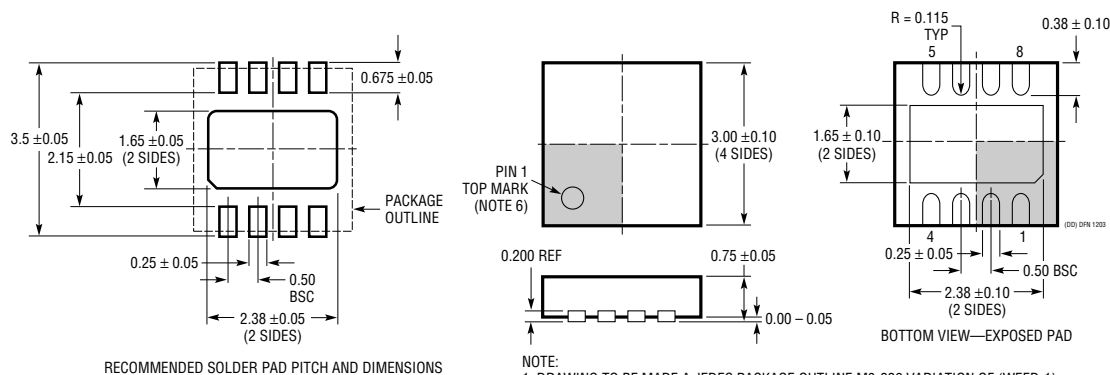


Over-The-Top Current Sense

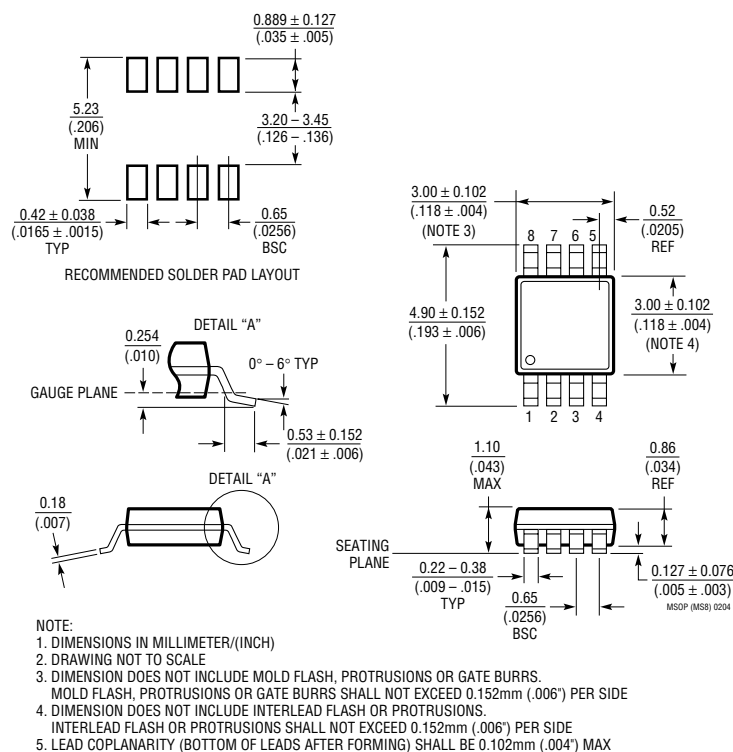


## PACKAGE DESCRIPTION

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

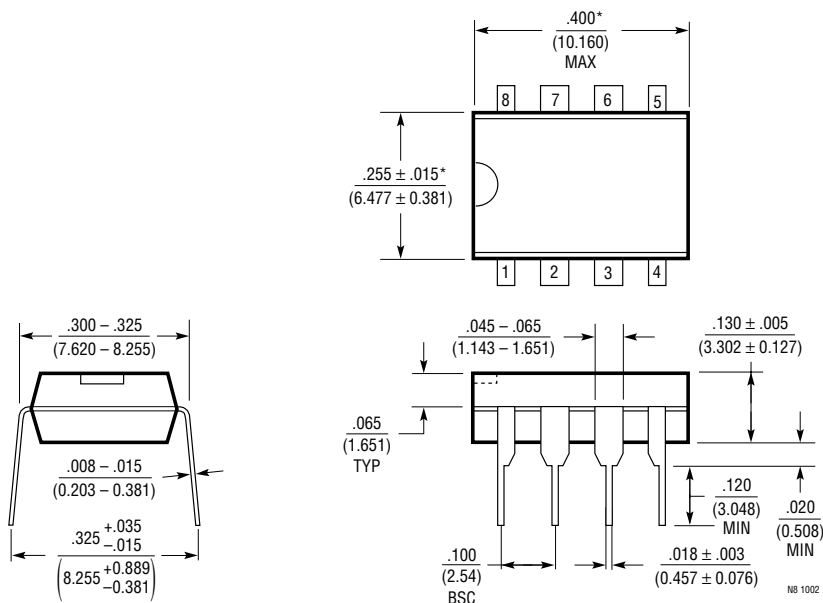


### MS8 Package 8-Lead Plastic MSOP (Reference LTC DWG # 05-08-1660)

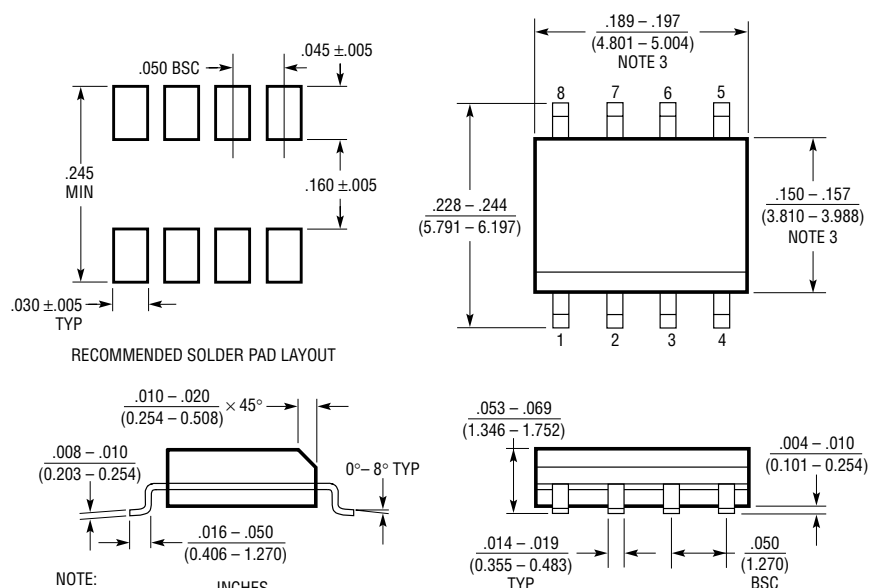


## PACKAGE DESCRIPTION

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



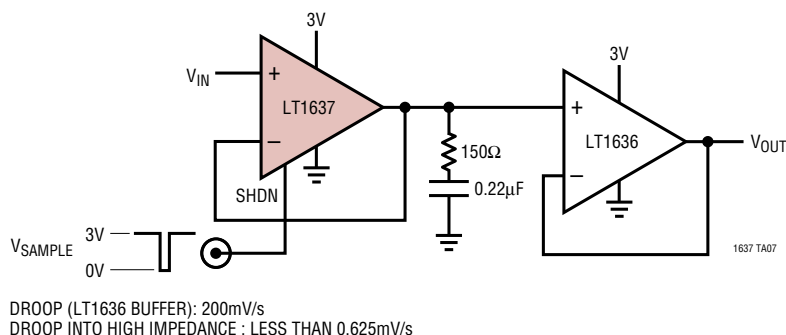
### S8 Package 8-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



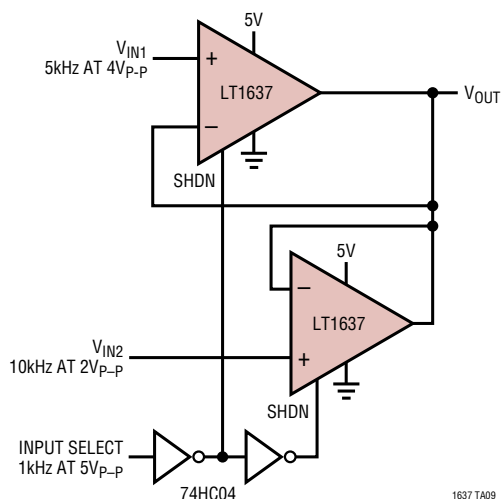


## TYPICAL APPLICATIONS

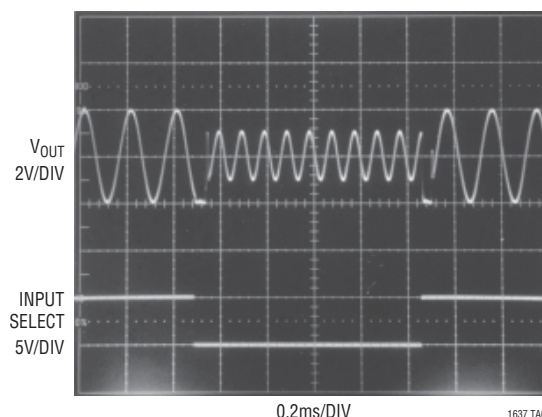
### Sample-and-Hold



### MUX Amplifier



### MUX Amplifier Waveforms



## RELATED PARTS

| PART NUMBER                    | DESCRIPTION                                                                     | COMMENTS                                                                                                              |
|--------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| LT1078/LT1079<br>LT2078/LT2079 | Dual/Quad 55μA Max, Single Supply, Precision Op Amps                            | Input/Output Common Mode Includes Ground, 70μV $V_{OS(MAX)}$ and 2.5μV/°C Drift (Max), 200kHz GBW, 0.07V/μs Slew Rate |
| LT1178/LT1179<br>LT2178/LT2179 | Dual/Quad 17μA Max, Single Supply, Precision Op Amps                            | Input/Output Common Mode Includes Ground, 70μV $V_{OS(MAX)}$ and 4μV/°C Drift (Max), 85kHz GBW, 0.04V/μs Slew Rate    |
| LT1366/LT1367                  | Dual/Quad Precision, Rail-to-Rail Input and Output Op Amps                      | 475μV $V_{OS(MAX)}$ , 500V/mV $A_{VOL(MIN)}$ , 400kHz GBW                                                             |
| LT1490/LT1491                  | Dual/Quad Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amps        | Single Supply Input Range: -0.4V to 44V, Micropower 50μA per Amplifier, Rail-to-Rail Input and Output, 200kHz GBW     |
| LT1636                         | Single Over-The-Top Micropower Rail-to-Rail Input and Output Op Amp             | 55μA 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/μs Slew Rate, 230μA Supply Current per Amplifier                                                                 |
| LT1782                         | Micropower, Over-The-Top, SOT-23, Rail-to-Rail Input and Output Op Amp          | SOT-23, 800μV $V_{OS(MAX)}$ , $I_S$ = 55μA (Max), Gain-Bandwidth = 200kHz, Shutdown Pin                               |
| LT1783                         | 1.2MHz, Over-The-Top, Micropower, Rail-to-Rail Input and Output Op Amp          | SOT-23, 800μV $V_{OS(MAX)}$ , $I_S$ = 300μA (Max), Gain-Bandwidth = 1.2MHz, Shutdown Pin                              |

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