

## FEATURES

- Single Supply Operation
  - Input Voltage Range Extends to Ground
  - Output Swings to Ground while Sinking Current
- *Guaranteed* Offset Voltage  $50\mu\text{V}$  Max.
- *Guaranteed* Low Drift  $1.3\mu\text{V}/^\circ\text{C}$  Max.
- *Guaranteed* Offset Current  $0.5\text{nA}$  Max.
- *Guaranteed* High Gain
  - $5\text{mA}$  Load Current  $1.5$  Million Min.
  - $17\text{mA}$  Load Current  $0.8$  Million Min.
- *Guaranteed* Low Supply Current  $520\mu\text{A}$  Max.
- Supply Current can be Reduced by a Factor of 4
- Low Voltage Noise,  $0.1\text{Hz}$  to  $10\text{Hz}$   $0.55\mu\text{Vp-p}$
- Low Current Noise—  
 Better than OP-07  $0.07\text{pA}/\sqrt{\text{Hz}}$  at  $10\text{Hz}$
- High Input Impedance  $250\text{M}\Omega$  Min.
- *Guaranteed* Minimum Supply Voltage  $2.7\text{V}$  Min.

## APPLICATIONS

- Low Power Sample and Hold Circuits
- Battery Powered Precision Instrumentation
  - Strain Gauge Signal Conditioners
  - Thermocouple Amplifiers
- $4\text{mA}$ – $20\text{mA}$  Current Loop Transmitters
- Active Filters

## DESCRIPTION

The LT1006 is the first precision single supply operational amplifier. Its design has been optimized for single supply operation with a full set of specifications at  $5\text{V}$ . Specifications at  $\pm 15\text{V}$  are also provided.

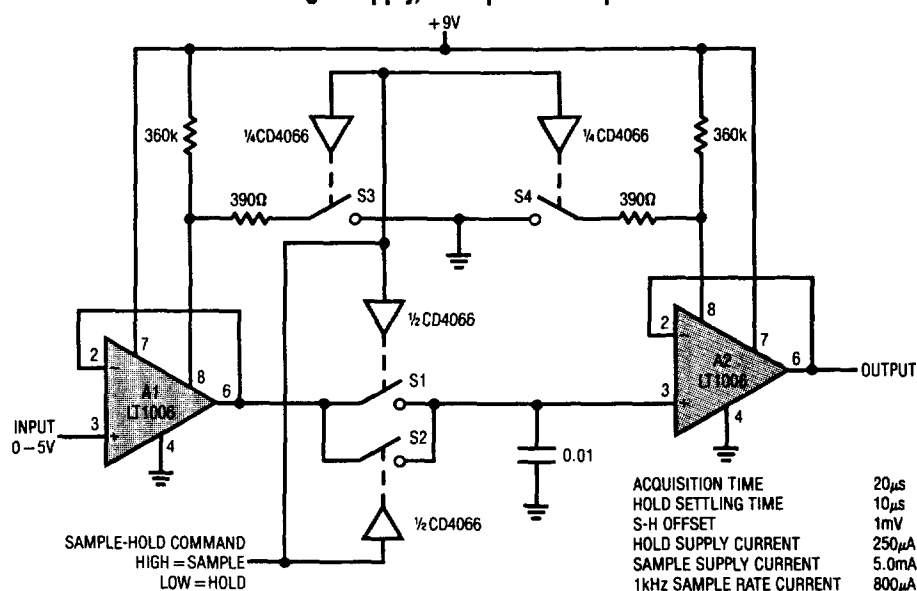
The LT1006 has low offset voltage of  $20\mu\text{V}$ , drift of  $0.2\mu\text{V}/^\circ\text{C}$ , offset current of  $120\text{pA}$ , gain of  $2.5$  million, common-mode rejection of  $114\text{dB}$ , and power supply rejection of  $126\text{dB}$ .

Although supply current is only  $340\mu\text{A}$ , a novel output stage can source or sink in excess of  $20\text{mA}$  while retaining high voltage gain. Common-mode input range includes ground to accommodate low ground-referenced inputs from strain gauges or thermocouples, and output can swing to within a few millivolts of ground. If higher slew rate (in excess of  $1\text{V}/\mu\text{s}$ ) or micropower operation (supply current down to  $90\mu\text{A}$ ) is required, the operating currents can be modified by connecting an external optional resistor to Pin 8.

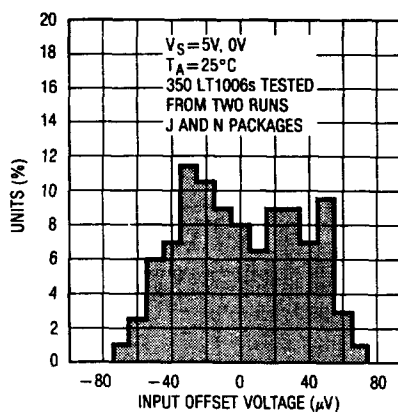
For similar single supply precision dual and quad op amps, please see the LT1013/LT1014 data sheet. For micropower dual and quad op amps, please see the LT1078/LT1079 data sheet.

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**LT1006 Single Supply, Micropower Sample and Hold**



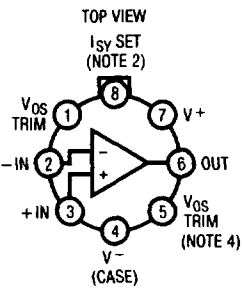
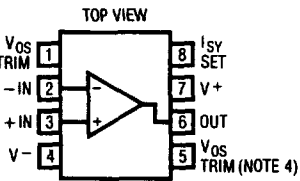
**Distribution of Input Offset Voltage**



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....  $\pm 22V$   
 Input Voltage ..... Equal to Positive Supply Voltage  
                                 ..... 5V Below Negative Supply Voltage  
 Differential Input Voltage..... 30V  
 Output Short Circuit Duration ..... Indefinite  
 Operating Temperature Range  
     LT1006AM, M .....  $-55^{\circ}C$  to  $125^{\circ}C$   
     LT1006AC, C .....  $0^{\circ}C$  to  $70^{\circ}C$   
 Storage Temperature Range  
     All Devices .....  $-65^{\circ}C$  to  $150^{\circ}C$   
 Lead Temperature (Soldering, 10 sec) .....  $300^{\circ}C$

## PACKAGE/ORDER INFORMATION

| TOP VIEW<br>I <sub>SY</sub> SET<br>(NOTE 2)                                                                                                           | ORDER PART<br>NUMBER                                            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
|                                                                                                                                                       | LT1006AMH<br>LT1006MH<br>LT1006ACH<br>LT1006CH                  |
|  <p>H8 PACKAGE TO-5 METAL CAN</p>                                   |                                                                 |
| TOP VIEW                                                                                                                                              | ORDER PART<br>NUMBER                                            |
|                                                                                                                                                       | LT1006AMJ8<br>LT1006MJ8<br>LT1006ACJ8<br>LT1006CJ8<br>LT1006CN8 |
|  <p>J8 PACKAGE<br/>HERMETIC DIP      N8 PACKAGE<br/>PLASTIC DIP</p> |                                                                 |

## ELECTRICAL CHARACTERISTICS $V_S = 5V$ , $V_{CM} = 0V$ , $V_{OUT} = 1.4V$ , $T_A = 25^{\circ}C$ , unless otherwise noted.

| SYMBOL                              | PARAMETER                                | CONDITIONS                                                                                                                                         | LT1006AM/AC |                              |                               | LT1006M/C  |                              |                               | UNITS                            |
|-------------------------------------|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------------------------|-------------------------------|------------|------------------------------|-------------------------------|----------------------------------|
|                                     |                                          |                                                                                                                                                    | MIN         | TYP                          | MAX                           | MIN        | TYP                          | MAX                           |                                  |
| $V_{OS}$                            | Input Offset Voltage                     |                                                                                                                                                    |             | 20                           | 50                            |            | 30                           | 80                            | $\mu V$                          |
| $\frac{\Delta V_{OS}}{\Delta Time}$ | Long Term Input Offset Voltage Stability |                                                                                                                                                    |             | 0.4                          |                               |            | 0.5                          |                               | $\mu V/Mo$                       |
| $I_{OS}$                            | Input Offset Current                     |                                                                                                                                                    |             | 0.12                         | 0.5                           |            | 0.15                         | 0.9                           | nA                               |
| $I_B$                               | Input Bias Current                       |                                                                                                                                                    |             | 9                            | 15                            |            | 10                           | 25                            | nA                               |
| $e_n$                               | Input Noise Voltage                      | 0.1Hz to 10Hz                                                                                                                                      |             | 0.55                         |                               |            | 0.55                         |                               | $\mu V_{p-p}$                    |
|                                     | Input Noise Voltage Density              | $f_o = 10Hz$ (Note 3)<br>$f_o = 1000Hz$ (Note 3)                                                                                                   |             | 23<br>22                     | 32<br>25                      |            | 23<br>22                     | 32<br>25                      | $nV/\sqrt{Hz}$<br>$nV/\sqrt{Hz}$ |
| $i_n$                               | Input Noise Current Density              | $f_o = 10Hz$                                                                                                                                       |             | 0.07                         |                               |            | 0.08                         |                               | $pA/\sqrt{Hz}$                   |
|                                     | Input Resistance                         | (Note 1)                                                                                                                                           |             |                              |                               |            |                              |                               |                                  |
|                                     | Differential Mode                        |                                                                                                                                                    | 180         | 400                          |                               | 100        | 300                          |                               | M $\Omega$                       |
|                                     | Common-Mode                              |                                                                                                                                                    |             | 5                            |                               |            | 4                            |                               | G $\Omega$                       |
|                                     | Input Voltage Range                      |                                                                                                                                                    | 3.5<br>0    | 3.8<br>-0.3                  |                               | 3.5<br>0   | 3.8<br>-0.3                  |                               | V<br>V                           |
| CMRR                                | Common-Mode Rejection Ratio              | $V_{CM} = 0V$ to $3.5V$                                                                                                                            | 100         | 114                          |                               | 97         | 112                          |                               | dB                               |
| PSRR                                | Power Supply Rejection Ratio             | $V_S = \pm 2V$ to $\pm 18V$ , $V_O = 0V$                                                                                                           | 106         | 126                          |                               | 103        | 124                          |                               | dB                               |
| $A_{VOL}$                           | Large Signal Voltage Gain                | $V_O = 0.03V$ to $4V$ , $R_L = 10k$<br>$V_O = 0.03V$ to $3.5V$ , $R_L = 2k$                                                                        | 1.0<br>0.5  | 2.5<br>2.0                   |                               | 0.7<br>0.3 | 2.0<br>1.8                   |                               | $V/\mu V$<br>$V/\mu V$           |
|                                     | Maximum Output Voltage Swing             | Output Low, No Load<br>Output Low, 600 $\Omega$ to GND<br>Output Low, $I_{SINK} = 1mA$<br>Output High, No Load<br>Output High, 600 $\Omega$ to GND |             | 15<br>5<br>220<br>4.0<br>3.4 | 25<br>10<br>350<br>4.4<br>4.0 |            | 15<br>5<br>220<br>4.0<br>3.4 | 25<br>10<br>350<br>4.4<br>4.0 | mV<br>mV<br>mV<br>V<br>V         |
| SR                                  | Slew Rate                                |                                                                                                                                                    | 0.25        | 0.4                          |                               | 0.25       | 0.4                          |                               | $V/\mu s$                        |
| $I_S$                               | Supply Current                           | $R_{SET} = \infty$<br>$R_{SET} = 180k$ Pin 8 to Pin 7 (Note 2)                                                                                     |             | 340<br>90                    | 520                           |            | 350<br>90                    | 570                           | $\mu A$<br>$\mu A$               |
|                                     | Minimum Supply Voltage                   |                                                                                                                                                    | 2.7         |                              |                               | 2.7        |                              |                               | V                                |

## ELECTRICAL CHARACTERISTICS

$V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, -55^\circ C \leq T_A \leq 125^\circ C$ , unless otherwise noted.

| SYMBOL                              | PARAMETER                    | CONDITIONS                                                        |        | LT1006AM |          |     | LT1006M |          |     | UNITS            |
|-------------------------------------|------------------------------|-------------------------------------------------------------------|--------|----------|----------|-----|---------|----------|-----|------------------|
|                                     |                              |                                                                   |        | MIN      | TYP      | MAX | MIN     | TYP      | MAX |                  |
| $V_{OS}$                            | Input Offset Voltage         |                                                                   | ●      |          | 40       | 180 |         | 60       | 250 | $\mu V$          |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Input Offset Voltage Drift   |                                                                   | ●      |          | 0.2      | 1.3 |         | 0.3      | 1.8 | $\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current         |                                                                   | ●      |          | 0.4      | 2.0 |         | 0.5      | 4.0 | nA               |
| $I_B$                               | Input Bias Current           |                                                                   | ●      |          | 13       | 25  |         | 16       | 40  | nA               |
| $A_{VOL}$                           | Large Signal Voltage Gain    | $V_O = 0.05V$ to $3.5V, R_L = 2k$                                 | ●      | 0.25     | 0.8      |     | 0.15    | 0.7      |     | $V/\mu V$        |
| CMRR                                | Common-Mode Rejection Ratio  | $V_{CM} = 0.1V$ to $3.2V$                                         | ●      | 90       | 103      |     | 87      | 102      |     | dB               |
| PSRR                                | Power Supply Rejection Ratio | $V_S = \pm 2V$ to $\pm 18V, V_O = 0V$                             | ●      | 100      | 117      |     | 97      | 116      |     | dB               |
|                                     | Maximum Output Voltage Swing | Output Low, $600\Omega$ to GND<br>Output High, $600\Omega$ to GND | ●<br>● | 3.2      | 6<br>3.8 | 15  | 3.1     | 6<br>3.8 | 18  | mV<br>V          |
| $I_S$                               | Supply Current               |                                                                   | ●      |          | 380      | 630 |         | 400      | 680 | $\mu A$          |

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## ELECTRICAL CHARACTERISTICS

$V_S = 5V, 0V, V_{CM} = 0V, V_O = 1.4V, 0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

| SYMBOL                              | PARAMETER                    | CONDITIONS                                                        |        | LT1006AC |          |     | LT1006C |            |            | UNITS                                |
|-------------------------------------|------------------------------|-------------------------------------------------------------------|--------|----------|----------|-----|---------|------------|------------|--------------------------------------|
|                                     |                              |                                                                   |        | MIN      | TYP      | MAX | MIN     | TYP        | MAX        |                                      |
| $V_{OS}$                            | Input Offset Voltage         | LT1006N8                                                          | ●<br>● |          | 30       | 110 |         | 45<br>50   | 160<br>190 | $\mu V$<br>$\mu V$                   |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Input Offset Voltage Drift   | LT1006N8                                                          | ●<br>● |          | 0.2      | 1.3 |         | 0.3<br>0.5 | 1.8<br>2.5 | $\mu V/^\circ C$<br>$\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current         |                                                                   | ●      |          | 0.25     | 1.2 |         | 0.3        | 2.5        | nA                                   |
| $I_B$                               | Input Bias Current           |                                                                   | ●      |          | 11       | 20  |         | 12         | 30         | nA                                   |
| $A_{VOL}$                           | Large Signal Voltage Gain    | $V_O = 0.04V$ to $3.5V, R_L = 2k$                                 | ●      | 0.35     | 1.3      |     | 0.25    | 1.2        |            | $V/\mu V$                            |
| CMRR                                | Common-Mode Rejection Ratio  | $V_{CM} = 0V$ to $3.4V$                                           | ●      | 96       | 109      |     | 92      | 108        |            | dB                                   |
| PSRR                                | Power Supply Rejection Ratio | $V_S = \pm 2V$ to $\pm 18V, V_O = 0V$                             | ●      | 101      | 120      |     | 97      | 118        |            | dB                                   |
|                                     | Maximum Output Voltage Swing | Output Low, $600\Omega$ to GND<br>Output High, $600\Omega$ to GND | ●<br>● | 3.3      | 6<br>3.9 | 13  | 3.2     | 6<br>3.9   | 13         | mV<br>V                              |
| $I_S$                               | Supply Current               |                                                                   | ●      |          | 350      | 570 |         | 360        | 620        | $\mu A$                              |

The ● denotes the specifications which apply over the full operating temperature range.

**Note 1:** This parameter is guaranteed by design and is not tested.

**Note 2:** Regular operation does not require an external resistor. In order to program the supply current for low power or high speed operation, connect an external resistor from Pin 8 to Pin 7 or from Pin 8 to Pin 4, respectively. Supply current specifications (for  $R_{SET} = 180k$ ) do not include current in  $R_{SET}$ .

**Note 3:** This parameter is tested on a sample basis only. All noise parameters are tested with  $V_S = \pm 2.5V, V_O = 0V$ .

**Note 4:** Optional offset nulling is accomplished with a potentiometer connected between the trim terminals and the wiper to  $V^-$ . A  $10k$  pot (providing a null range of  $\pm 6mV$ ) is recommended for minimum drift of nulled offset voltage with temperature. For increased trim resolution and accuracy, two fixed resistors can be used in conjunction with a smaller potentiometer. For example: two  $4.7k$  resistors tied to pins 1 and 5, with a  $500\Omega$  pot in the middle, will have a null range of  $\pm 150\mu V$ .

**ELECTRICAL CHARACTERISTICS**  $V_S = \pm 15V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

| SYMBOL    | PARAMETER                    | CONDITIONS                                                          | LT1006AM/AC    |                |      | LT1006M/C      |                |      | UNITS                  |
|-----------|------------------------------|---------------------------------------------------------------------|----------------|----------------|------|----------------|----------------|------|------------------------|
|           |                              |                                                                     | MIN            | TYP            | MAX  | MIN            | TYP            | MAX  |                        |
| $V_{OS}$  | Input Offset Voltage         |                                                                     |                | 30             | 100  |                | 50             | 180  | $\mu V$                |
| $I_{OS}$  | Input Offset Current         |                                                                     |                | 0.1            | 0.5  |                | 0.15           | 0.9  | nA                     |
| $I_B$     | Input Bias Current           |                                                                     |                | 7.5            | 12.0 |                | 8.0            | 20.0 | nA                     |
|           | Input Voltage Range          |                                                                     | 13.5<br>– 15.0 | 13.8<br>– 15.3 |      | 13.5<br>– 15.0 | 13.8<br>– 15.3 |      | V<br>V                 |
| CMRR      | Common-Mode Rejection Ratio  | $V_{CM} = +13.5V, -15V$                                             | 100            | 117            |      | 97             | 116            |      | dB                     |
| PSRR      | Power Supply Rejection Ratio | $V_S = \pm 2V$ to $\pm 18V$ , $V_O = 0V$                            | 106            | 126            |      | 103            | 124            |      | dB                     |
| $A_{VOL}$ | Large Signal Voltage Gain    | $V_O = \pm 10V$ , $R_L = 2k$<br>$V_O = \pm 10V$ , $R_L = 600\Omega$ | 1.5<br>0.8     | 5.0<br>1.5     |      | 1.2<br>0.5     | 4.0<br>1.0     |      | $V/\mu V$<br>$V/\mu V$ |
| $V_{OUT}$ | Maximum Output Voltage Swing | $R_L = 2k$                                                          | $\pm 13$       | $\pm 14$       |      | $\pm 12.5$     | $\pm 14$       |      | V                      |
| SR        | Slew Rate                    | $R_{SET} = \infty$<br>$R_{SET} = 390\Omega$ Pin 8 to Pin 4          | 0.25<br>1.0    | 0.4<br>1.2     |      | 0.25<br>1.0    | 0.4<br>1.2     |      | $V/\mu s$<br>$V/\mu s$ |
| $I_S$     | Supply Current               |                                                                     |                | 360            | 540  |                | 360            | 600  | $\mu A$                |

**ELECTRICAL CHARACTERISTICS**  $V_S = \pm 15V$ ,  $-55^\circ C \leq T_A \leq 125^\circ C$ , unless otherwise noted.

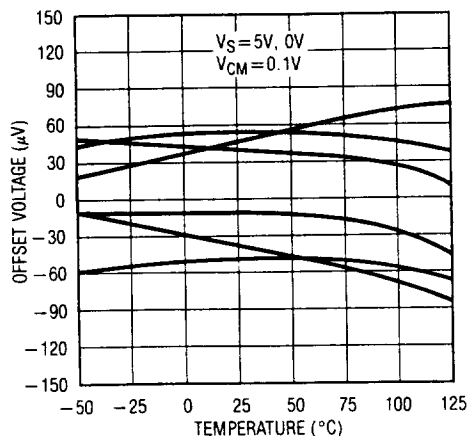
| SYMBOL                              | PARAMETER                    | CONDITIONS                               |   | LT1006AM |            |     | LT1006M    |            |     | UNITS            |
|-------------------------------------|------------------------------|------------------------------------------|---|----------|------------|-----|------------|------------|-----|------------------|
|                                     |                              |                                          |   | MIN      | TYP        | MAX | MIN        | TYP        | MAX |                  |
| $V_{OS}$                            | Input Offset Voltage         |                                          | ● |          | 80         | 320 |            | 110        | 460 | $\mu V$          |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Input Offset Voltage Drift   |                                          | ● |          | 0.5        | 2.2 |            | 0.6        | 2.8 | $\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current         |                                          | ● |          | 0.2        | 2.0 |            | 0.3        | 3.0 | nA               |
| $I_B$                               | Input Bias Current           |                                          | ● |          | 9          | 18  |            | 11         | 27  | nA               |
| $A_{VOL}$                           | Large Signal Voltage Gain    | $V_O = \pm 10V$ , $R_L = 2k$             | ● |          | 0.5        | 1.5 |            | 0.25       | 1.0 | $V/\mu V$        |
| CMRR                                | Common-Mode Rejection Ratio  | $V_{CM} = +13V, -14.9V$                  | ● |          | 97         | 114 |            | 94         | 113 | dB               |
| PSRR                                | Power Supply Rejection Ratio | $V_S = \pm 2V$ to $\pm 18V$ , $V_O = 0V$ | ● |          | 100        | 117 |            | 97         | 116 | dB               |
|                                     | Maximum Output Voltage Swing | $R_L = 2k$                               | ● | $\pm 12$ | $\pm 13.8$ |     | $\pm 11.5$ | $\pm 13.8$ |     | V                |
| $I_S$                               | Supply Current               |                                          | ● |          | 400        | 650 |            | 400        | 750 | $\mu A$          |

**ELECTRICAL CHARACTERISTICS**  $V_S = \pm 15V$ ,  $0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

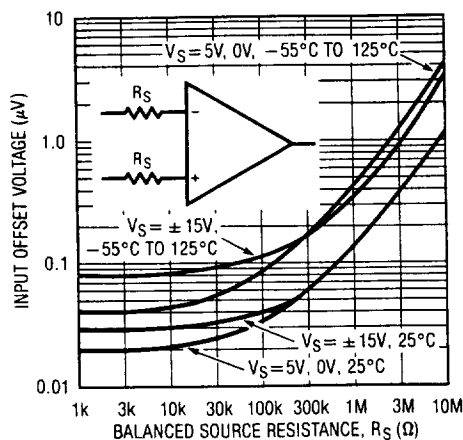
| SYMBOL                              | PARAMETER                    | CONDITIONS                               |        | LT1006AC   |            |     | LT1006C    |            |            | UNITS                                |
|-------------------------------------|------------------------------|------------------------------------------|--------|------------|------------|-----|------------|------------|------------|--------------------------------------|
|                                     |                              |                                          |        | MIN        | TYP        | MAX | MIN        | TYP        | MAX        |                                      |
| $V_{OS}$                            | Input Offset Voltage         | LT1006N8                                 | ●      |            | 50         | 200 |            | 75<br>80   | 300<br>330 | $\mu V$<br>$\mu V$                   |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Input Offset Voltage Drift   | LT1006N8                                 | ●<br>● |            | 0.5        | 2.2 |            | 0.6<br>0.7 | 2.8<br>3.5 | $\mu V/^\circ C$<br>$\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current         |                                          | ●      |            | 0.15       | 1.0 |            | 0.25       | 2.0        | nA                                   |
| $I_B$                               | Input Bias Current           |                                          | ●      |            | 8.0        | 15  |            | 10         | 23         | nA                                   |
| $A_{VOL}$                           | Large Signal Voltage Gain    | $V_O = \pm 10V$ , $R_L = 2k$             | ●      |            | 1.0        | 3.0 |            | 0.7        | 2.5        | $V/\mu V$                            |
| CMRR                                | Common-Mode Rejection Ratio  | $V_{CM} = 13V, -15V$                     | ●      |            | 98         | 116 |            | 94         | 114        | dB                                   |
| PSRR                                | Power Supply Rejection Ratio | $V_S = \pm 2V$ to $\pm 18V$ , $V_O = 0V$ | ●      |            | 101        | 120 |            | 97         | 118        | dB                                   |
|                                     | Maximum Output Voltage Swing | $R_L = 2k$                               | ●      | $\pm 12.5$ | $\pm 13.9$ |     | $\pm 11.5$ | $\pm 13.8$ |            | V                                    |
| $I_S$                               | Supply Current               |                                          | ●      |            | 370        | 600 |            | 380        | 660        | $\mu A$                              |

# TYPICAL PERFORMANCE CHARACTERISTICS

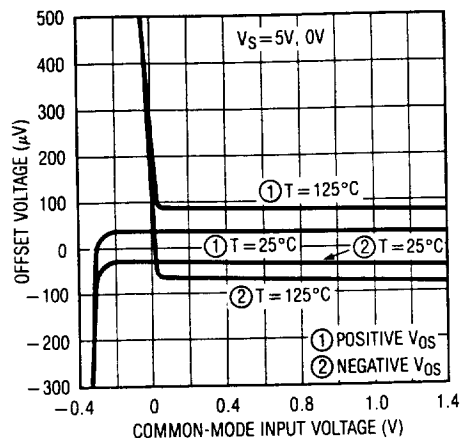
Offset Voltage Drift with Temperature of Representative Units



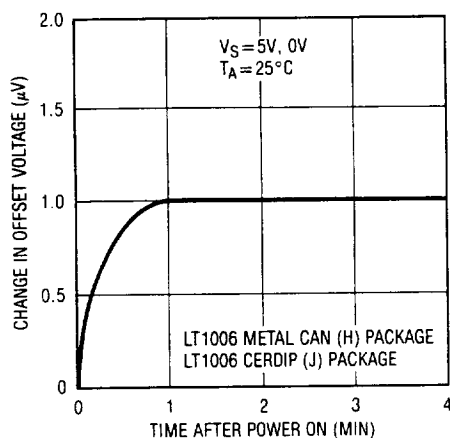
Offset Voltage vs Balanced Source Resistor



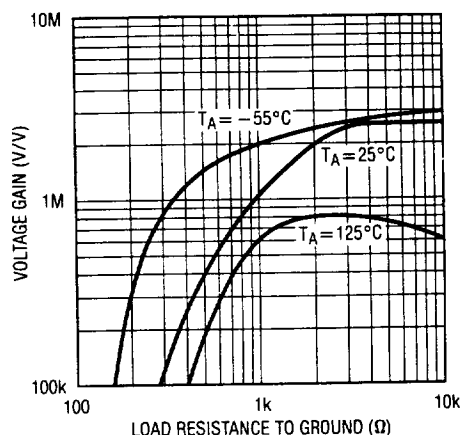
$V_{OS}$  vs Common-Mode Voltage vs Temperature



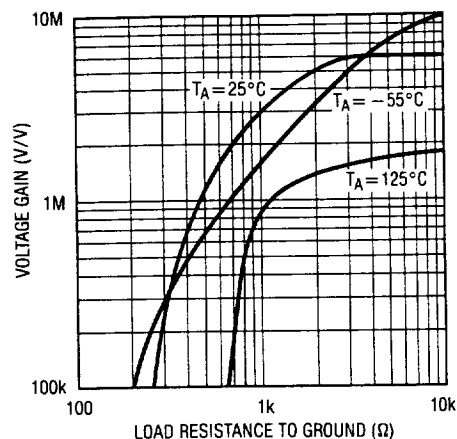
Warm-Up Drift



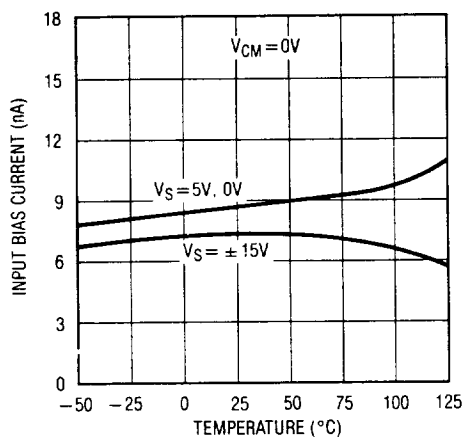
Voltage Gain vs Load Resistance,  $V_S = 5V, 0V$



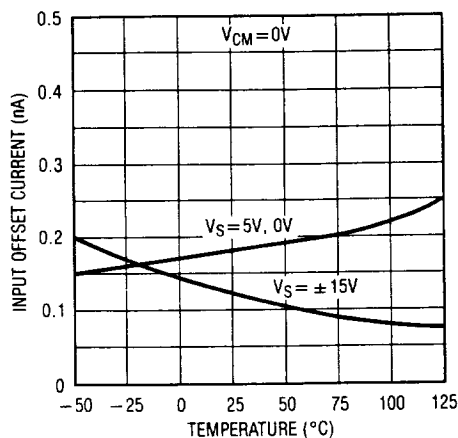
Voltage Gain vs Load Resistance with  $V_S = \pm 15V$



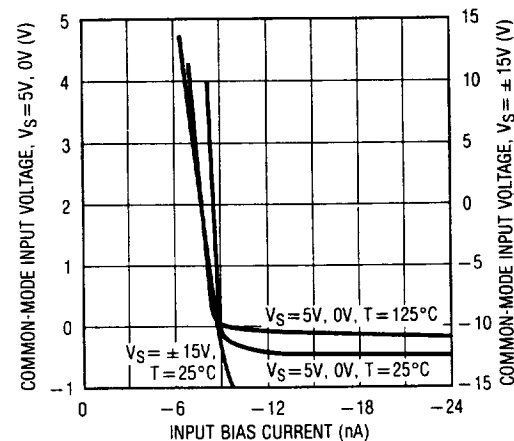
Input Bias Current vs Temperature



Input Offset Current vs Temperature

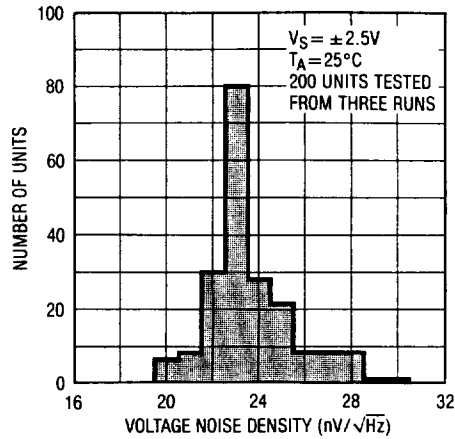


Input Bias Current vs Common-Mode Voltage

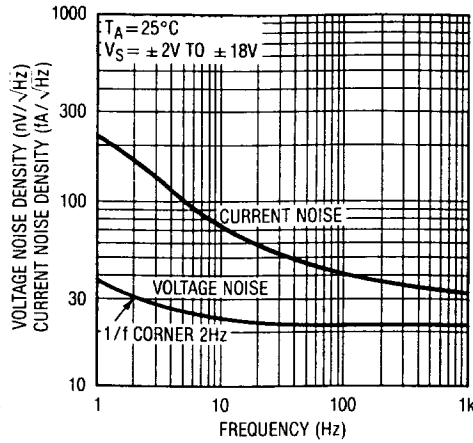


# TYPICAL PERFORMANCE CHARACTERISTICS

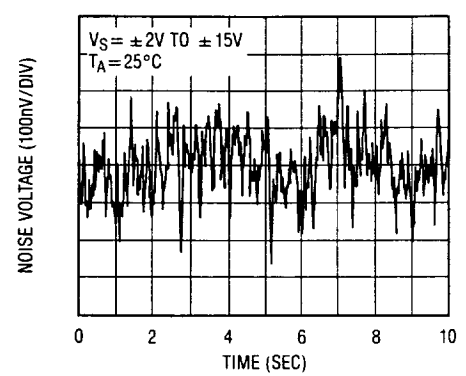
10Hz Voltage Noise Distribution



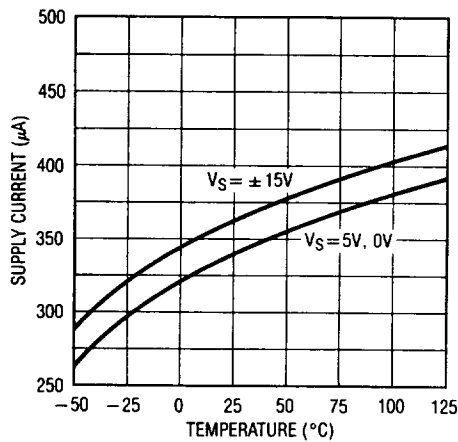
Noise Spectrum



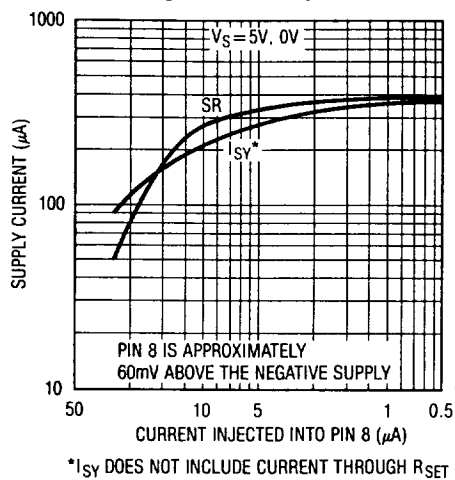
0.1Hz to 10Hz Noise



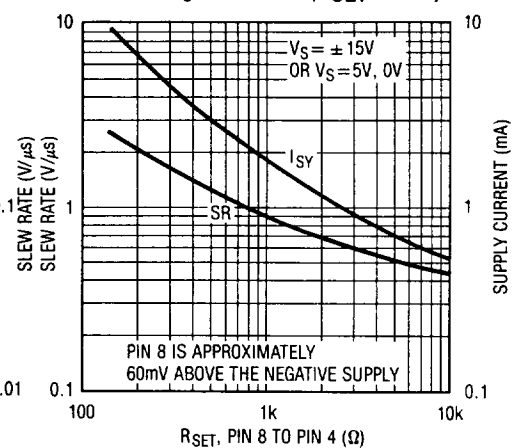
Supply Current vs Temperature



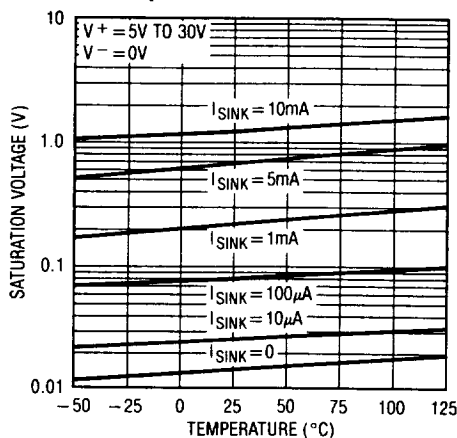
Reducing Power Dissipation



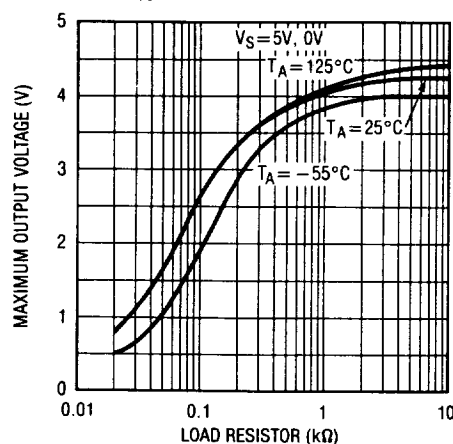
Increasing Slew Rate ( $R_{SET}$  to  $V^-$ )



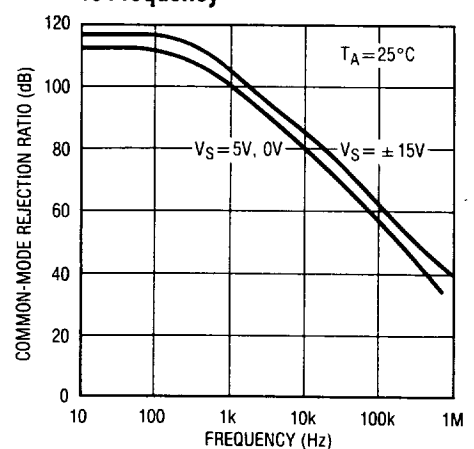
Output Saturation vs Sink Current vs Temperature



Maximum Output Swing vs Load Resistor

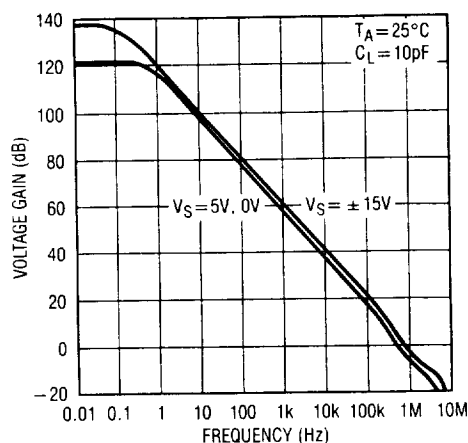


Common-Mode Rejection Ratio vs Frequency

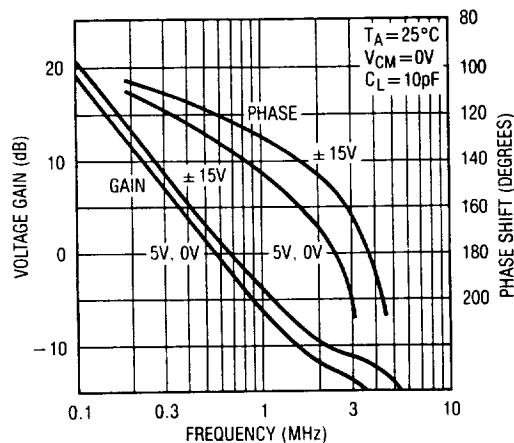


# TYPICAL PERFORMANCE CHARACTERISTICS

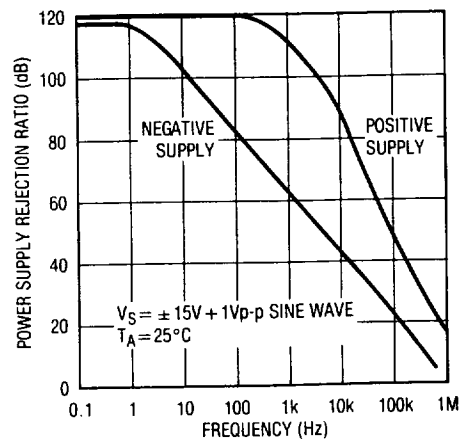
Voltage Gain vs Frequency



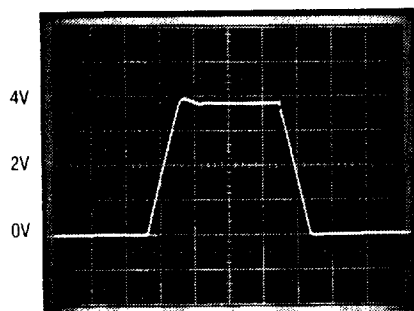
Gain, Phase vs Frequency



Power Supply Rejection Ratio vs Frequency



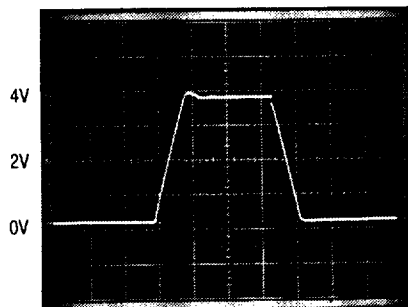
Large Transient Response,  
VS = 5V, 0V



10μs/DIV

AV = 1  
RL = 4.7k TO 5V  
INPUT = 0V TO 3.8V

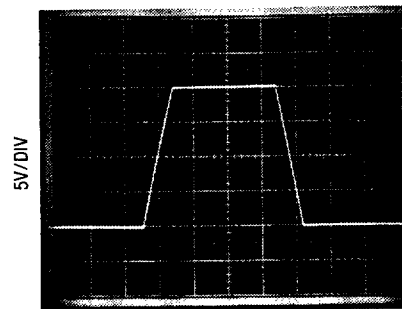
Large Signal Transient Response,  
VS = 5V, 0V



10μs/DIV

AV = 1  
RL = 4.7k TO GROUND  
INPUT = 0V TO 3.8V

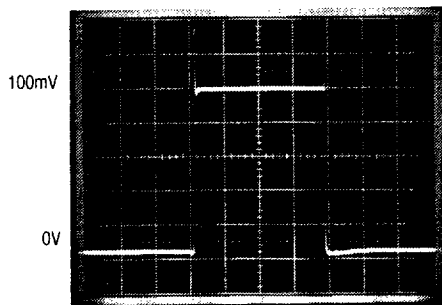
Large Signal Transient Response,  
VS = ±15V



50μs/DIV

AV = 1

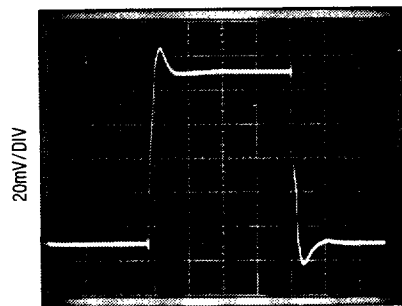
Small Signal Transient Response,  
VS = 5V, 0V



20μs/DIV

AV = 1  
CL = 10pF  
RL = 600Ω TO GND  
INPUT = 0V TO 100mV PULSE

Small Signal Transient Response,  
VCC = ±2.5V to ±15V



2μs/DIV

AV = 1  
CL = 10pF

2

## APPLICATIONS INFORMATION

The LT1006 is fully specified for single supply operation, i.e., when the negative supply is 0V. Input common-mode range includes ground; the output swings within a few millivolts of ground. Single supply operation, however, can create special difficulties, both at the input and at the output. The LT1006 has specific circuitry which addresses these problems.

At the input, the driving signal can fall below 0V—inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, two distinct problems can occur on previous single supply designs, such as the LM124, LM158, OP-20, OP-21, OP-220, OP-221, OP-420:

a) When the input is more than a diode drop below ground, unlimited current will flow from the substrate ( $V^-$  terminal) to the input. This can destroy the unit. On the LT1006, the  $400\Omega$  resistors, in series with the input (see schematic diagram), protect the devices even when the input is 5V below ground.

b) When the input is more than 400mV below ground (at  $25^\circ\text{C}$ ), the input stage saturates (transistors Q3 and Q4)

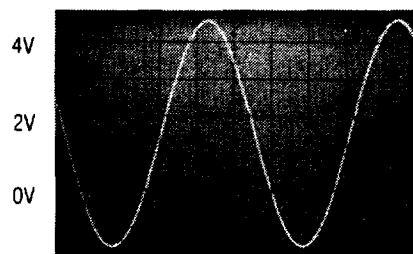
and phase reversal occurs at the output. This can cause lock-up in servo systems. Due to a unique phase reversal protection circuitry (Q21, Q22, Q27, Q28), the LT1006's output does not reverse, as illustrated below, even when the inputs are at  $-1.5\text{V}$ .

At the output, the aforementioned single supply designs either cannot swing to within 600mV of ground (OP-20) or cannot sink more than a few microamperes while swinging to ground (LM124, LM158). The LT1006's all-NPN output stage maintains its low output resistance and high gain characteristics until the output is saturated.

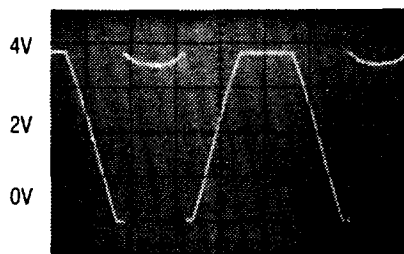
In dual supply operations, the output stage is crossover distortion-free.

Since the output cannot go exactly to ground, but can only approach ground to within a few millivolts, care should be exercised to ensure that the output is not saturated. For example, a 1mV input signal will cause the amplifier to set up in its linear region in the gain 100 configuration shown below, but is not enough to make the amplifier function properly in the voltage follower mode.

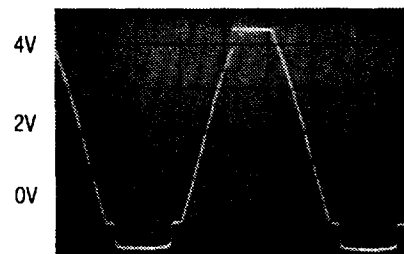
**Voltage Follower with Input Exceeding the Negative Common-Mode Range ( $V_S = 5\text{V}, 0\text{V}$ )**



6Vp-p INPUT,  $-1.5\text{V TO } 4.5\text{V}$

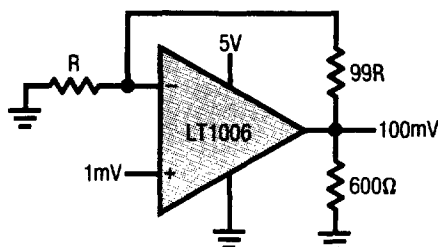


LM324, LM358, OP-20, OP-21  
EXHIBIT OUTPUT PHASE  
REVERSAL

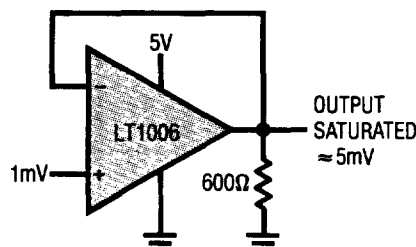


LT1006  
NO PHASE REVERSAL

**Gain 100 Amplifier**



**Voltage Follower**

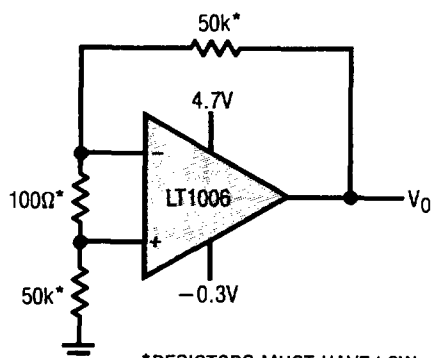




## APPLICATIONS INFORMATION

In automated production testing the output is forced to 1.4V by the test loop; offset voltage is measured with a common-mode voltage of zero and the negative supply at zero (Pin 4). Without the test loop, these exact conditions cannot be achieved. The test circuit shown ensures that the output will never saturate even with worst-case offset voltages ( $-250\mu\text{V}$  over the  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  range). The effective common-mode input is 0.3V with respect to the negative supply. As indicated by the common-mode rejection specifications the difference is only a few microvolts between the two methods of offset voltage measurement.

**Test Circuit for Offset Voltage and Offset Drift with Temperature**



\*RESISTORS MUST HAVE LOW THERMOELECTRIC POTENTIAL.

\*\*THIS CIRCUIT IS ALSO USED AS THE BURN-IN CONFIGURATION, WITH SUPPLY VOLTAGES INCREASED TO  $\pm 20\text{V}$ .

$V_O = 1000V_{OS}$

### Low Supply Operation

The minimum guaranteed supply voltage for proper operation of the LT1006 is 2.7V. Typical supply current at this voltage is  $320\mu\text{A}$ , therefore power dissipation is only  $860\mu\text{W}$ .

### Noise Testing

For application information on noise testing and calculations, please see the LT1007 or LT1028 data sheet.

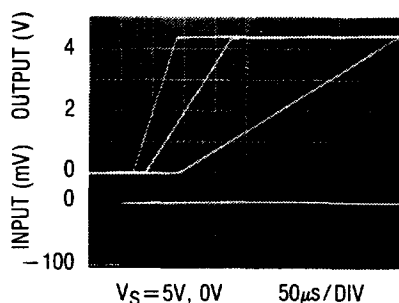
### Supply Current Programming

Connecting an optional external resistor to Pin 8 changes the biasing of the LT1006 in order to increase its speed or to decrease its power consumption. If higher slew rate is required, connect the external resistor from Pin 8 to Pin 4 [see performance curves for Increasing Slew Rate ( $R_{SET}$  to  $V^-$ )]. For lower power consumption, inject a current into Pin 8 (which is approximately 60mV above  $V^-$ ) as shown on the Reducing Power Dissipation plot. This can be accomplished by connecting  $R_{SET}$  to the positive supply, or to save additional power, by obtaining the injected current from a low voltage battery.

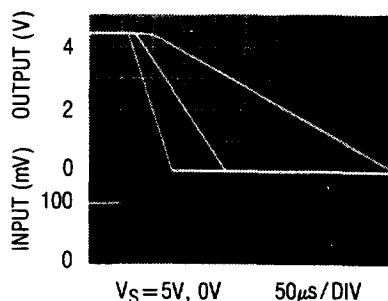
### Comparator Applications

The single supply operation of the LT1006 and its ability to swing close to ground while sinking current lends itself to use as a precision comparator with TTL compatible output.

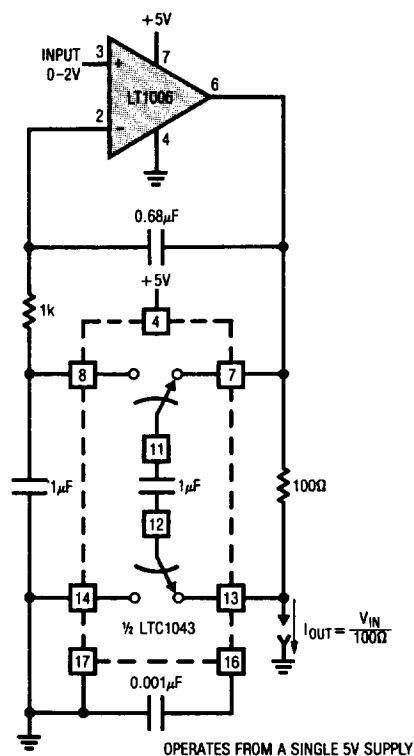
**Comparator Rise Response Time to 10mV, 5mV, 2mV Overdrives**



**Comparator Fall Response Time to 10mV, 5mV, 2mV Overdrives**



### Voltage Controlled Current Source with Ground Referred Input and Output



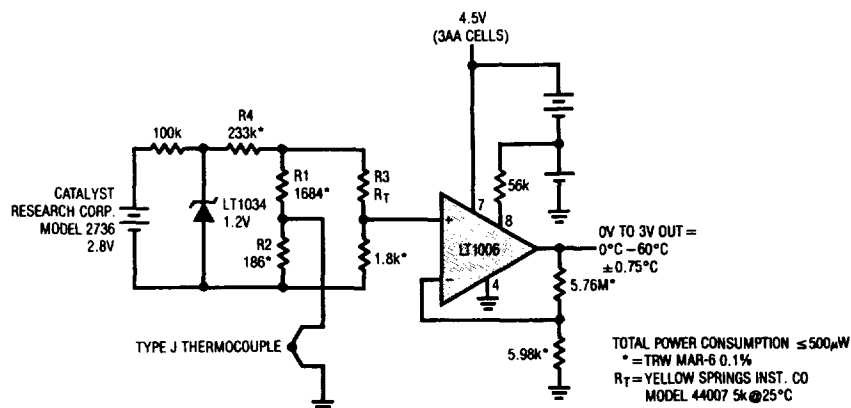
INPUT 0V - 5V  
 120k\*\* TYP  
 20k 1MHz TRIM  
 200k\*  
 3.1k\*  
 100Hz TRIM  
 220k\*\* TYP  
 2k  
 2μF  
 0.33μF  
 A1 LT1006  
 9V  
 470k  
 47k  
 0.01μF  
 3pF  
 12k  
 Q8 2N3906  
 1N4148  
 STRAY CAPACITANCE  
 Q7  
 TRIGGER  
 10μF  
 74C90  
 11 12 14  
 +100  
 74C90  
 11 12 14  
 +100  
 Q1  
 Q2  
 Q3  
 Q4  
 LT1004-2.5  
 LT1004-1.2  
 OUTPUT 0MHz - 1MHz  
 100pF (POLYSTYRENE)  
 CHARGE PUMP  
 REFERENCE SWITCH  
 REFERENCE  
 LM334  
 2k\*  
 9V

\* = 1% METAL FILM  
 \*\* = 1% METAL FILM, SELECTED  
 = 2N3904  
 = 74C14

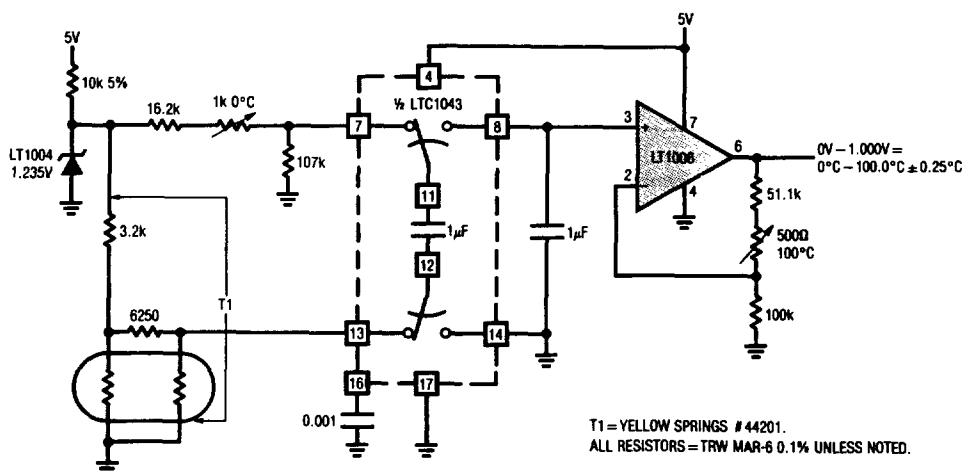
0.12% LINEARITY  
 280μA QUIESCENT CURRENT  
 680μA AT 1MHz

# TYPICAL APPLICATIONS

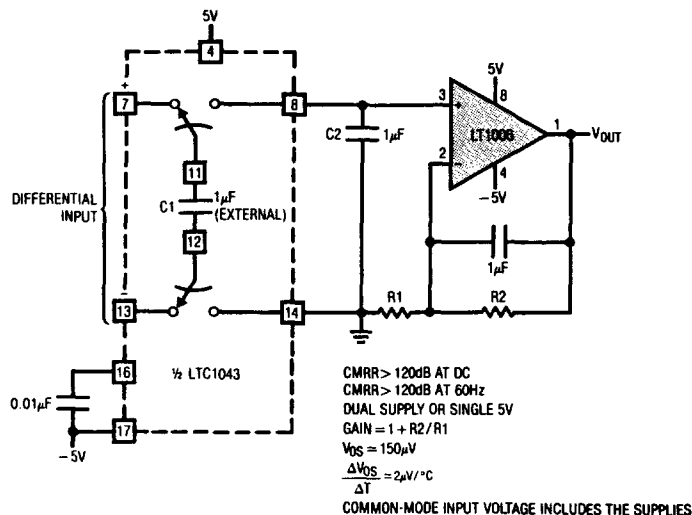
## Micropower Thermocouple Signal Conditioner with Cold Junction Compensation



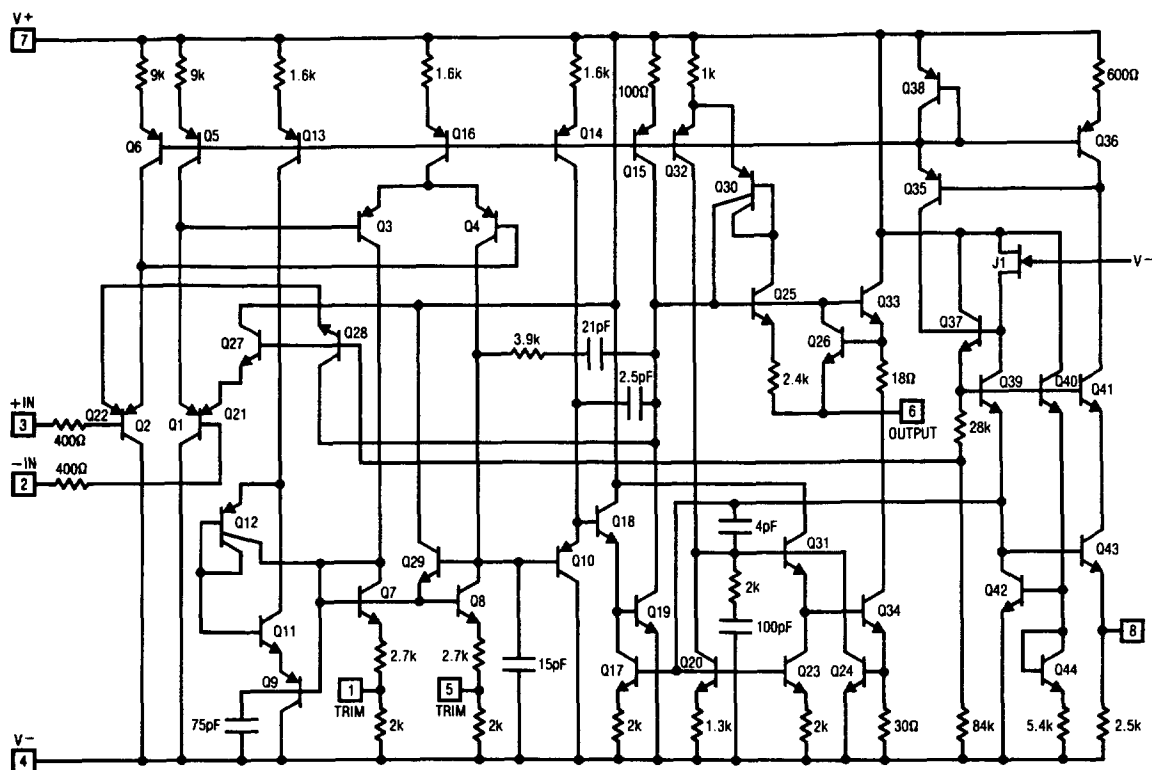
## Linear Thermometer



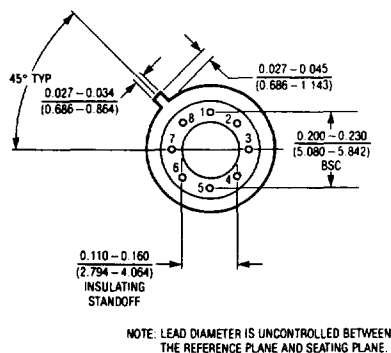
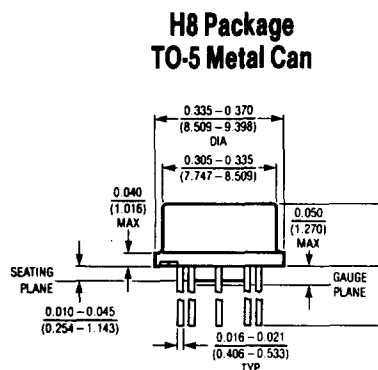
## ± 5V Precision Instrumentation Amplifier



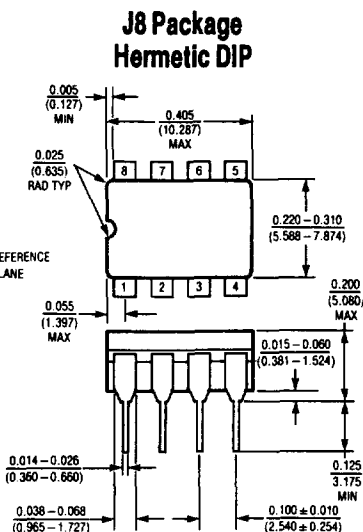
# LT1006 SCHEMATIC DIAGRAM



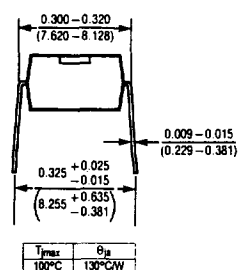
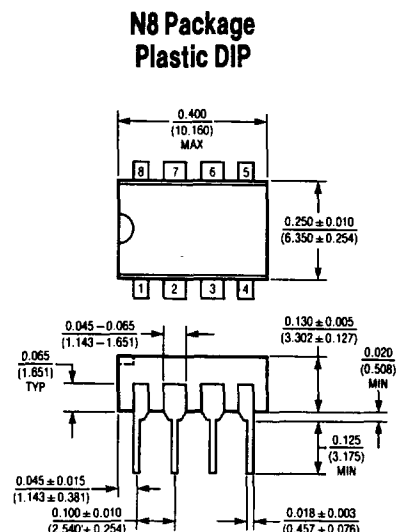
## PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.



| $T_{max}$ | $\theta_{JA}$ | $\theta_{JC}$ |
|-----------|---------------|---------------|
| 150°C     | 150°C/W       | 45°C/W        |



| $T_{max}$ | $\theta_{JA}$ |
|-----------|---------------|
| 150°C     | 100°C/W       |



| $T_{max}$ | $\theta_{JA}$ |
|-----------|---------------|
| 100°C     | 130°C/W       |