

# Micropower, Dual and Quad, Single Supply, Precision Op Amps

## FEATURES

- **Supply Current per Amplifier: 50 $\mu$ A Max**
- **Offset Voltage: 70 $\mu$ V Max**
- Offset Current: 250pA Max
- Voltage Noise: 0.6 $\mu$ V<sub>P-P</sub>, 0.1Hz to 10Hz
- Current Noise: 3pA<sub>P-P</sub>, 0.1Hz to 10Hz
- Offset Voltage Drift: 0.4 $\mu$ V/ $^{\circ}$ C
- Gain Bandwidth Product: 200kHz
- Slew Rate: 0.07V/ $\mu$ s
- Single Supply Operation
  - Input Voltage Range Includes Ground
  - Output Swings to Ground while Sinking Current
  - No Pull-Down Resistors Needed
- Output Sources and Sinks 5mA Load Current
- SO Package with Standard Pinout

## APPLICATIONS

- Battery or Solar-Powered Systems
  - Portable Instrumentation
  - Remote Sensor Amplifier
  - Satellite Circuitry
- Micropower Sample-and-Hold
- Thermocouple Amplifier
- Micropower Filters

## DESCRIPTION

The LT<sup>®</sup>2078 is a micropower dual op amp in 8-pin small outline, standard surface mount package, and LT2079 is a micropower quad op amp offered in the standard 14-pin surface mount package. Both devices are optimized for single supply operation at 5V.  $\pm$ 15V specifications are also provided.

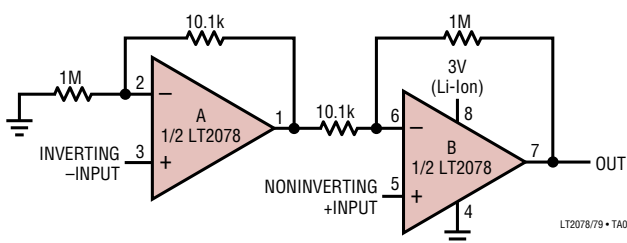
Micropower performance of competing devices is achieved at the expense of seriously degrading precision, noise, speed and output drive specifications. The design effort of the LT2078/LT2079 was concentrated on reducing supply current without sacrificing other parameters. The offset voltage achieved is the lowest on any dual or quad nonchopper stabilized op amp—micropower or otherwise. Offset current, voltage and current noise, slew rate and gain bandwidth product are all two to ten times better than on previous micropower op amps.

Both the LT2078/LT2079 can be operated from a single supply (as low as one lithium cell or two NiCd batteries). The input range goes below ground. The all NPN output stage swings to within a few millivolts of ground while sinking current—no power consuming pull-down resistors are needed. For applications requiring DIP packages refer to the LT1078/LT1079.

 LTC and LT are registered trademarks of Linear Technology Corporation.

## TYPICAL APPLICATION

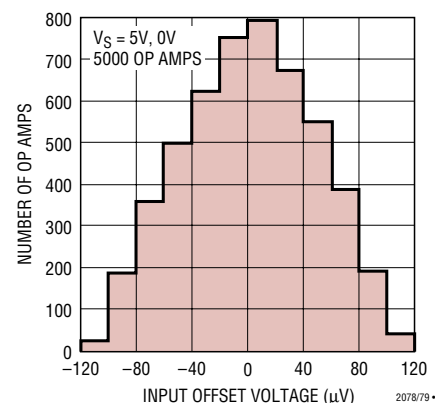
Single Battery, Micropower, Gain = 100, Instrumentation Amplifier



TYPICAL PERFORMANCE  
 INPUT OFFSET VOLTAGE = 40 $\mu$ V  
 INPUT OFFSET CURRENT = 0.2nA  
 TOTAL POWER DISSIPATION = 240 $\mu$ W  
 COMMON MODE REJECTION = 110dB (AMPLIFIER LIMITED)  
 GAIN BANDWIDTH PRODUCT = 200kHz

OUTPUT NOISE = 85 $\mu$ V<sub>P-P</sub> 0.1Hz TO 10Hz  
 = 300 $\mu$ V<sub>RMS</sub> OVER FULL BANDWIDTH  
 INPUT RANGE = 0.03V TO 1.8V  
 OUTPUT RANGE = 0.03V TO 2.3V  
 (0.3mV  $\leq$   $V_{IN+} - V_{IN-} \leq$  23mV)  
 OUTPUTS SINK CURRENT—NO PULL-DOWN RESISTORS

Distribution of Input Offset Voltage



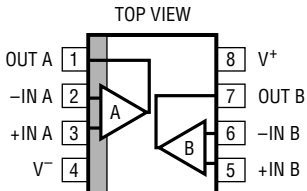
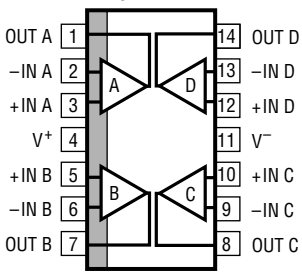
2078/79 • TA02  
20789fa

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage .....  $\pm 22\text{V}$   
 Differential Input Voltage .....  $\pm 30\text{V}$   
 Input Voltage ..... Equal to Positive Supply Voltage  
 ..... 5V Below Negative Supply Voltage  
 Output Short-Circuit Duration ..... Indefinite

Specified Temperature Range  
 Commercial .....  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$   
 Industrial .....  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$   
 Storage Temperature Range .....  $-65^{\circ}\text{C}$  to  $150^{\circ}\text{C}$   
 Lead Temperature (Soldering, 10 sec) .....  $300^{\circ}\text{C}$

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                                                                                                |                                                    |                                                                                                                                                                                                                                 |                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
|  <p>S8 PACKAGE<br/>8-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 190^{\circ}\text{C/W}</math></p> | ORDER PART NUMBER                                  |  <p>S PACKAGE<br/>14-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 150^{\circ}\text{C/W}</math></p> | ORDER PART NUMBER                              |
|                                                                                                                                                                                                                                | LT2078ACS8<br>LT2078AIS8<br>LT2078CS8<br>LT2078IS8 |                                                                                                                                                                                                                                 | LT2079ACS<br>LT2079AIS<br>LT2079CS<br>LT2079IS |
|                                                                                                                                                                                                                                | PART MARKING                                       |                                                                                                                                                                                                                                 |                                                |
|                                                                                                                                                                                                                                | 2078A 2078<br>2078AI 2078I                         |                                                                                                                                                                                                                                 |                                                |

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

## ELECTRICAL CHARACTERISTICS $V_S = 5\text{V}$ , $0\text{V}$ , $V_{CM} = 0.1\text{V}$ , $V_O = 1.4\text{V}$ , $T_A = 25^{\circ}\text{C}$ , unless otherwise noted.

| SYMBOL                                     | PARAMETER                                            | CONDITIONS (NOTE 2)                                            | LT2078AC/LT2078AI<br>LT2079AC/LT2079AI |              |           | LT2078C/LT2078I<br>LT2079C/LT2079I |              |            | UNITS                                                        |
|--------------------------------------------|------------------------------------------------------|----------------------------------------------------------------|----------------------------------------|--------------|-----------|------------------------------------|--------------|------------|--------------------------------------------------------------|
|                                            |                                                      |                                                                | MIN                                    | TYP          | MAX       | MIN                                | TYP          | MAX        |                                                              |
| $V_{OS}$                                   | Input Offset Voltage                                 | LT2078<br>LT2079                                               |                                        | 30<br>35     | 70<br>110 |                                    | 40<br>40     | 120<br>150 | $\mu\text{V}$<br>$\mu\text{V}$                               |
| $\frac{\Delta V_{OS}}{\Delta \text{Time}}$ | Long Term Input Offset Voltage Stability             |                                                                |                                        | 0.4          |           |                                    | 0.5          |            | $\mu\text{V/Mo}$                                             |
| $I_{OS}$                                   | Input Offset Current                                 |                                                                |                                        | 0.05         | 0.25      |                                    | 0.05         | 0.35       | nA                                                           |
| $I_B$                                      | Input Bias Current                                   |                                                                |                                        | 6            | 8         |                                    | 6            | 10         | nA                                                           |
| $e_n$                                      | Input Noise Voltage                                  | 0.1Hz to 10Hz (Note 3)                                         |                                        | 0.6          | 1.2       |                                    | 0.6          |            | $\mu\text{V}_{P-P}$                                          |
|                                            | Input Noise Voltage Density                          | $f_0 = 10\text{Hz}$ (Note 3)<br>$f_0 = 1000\text{Hz}$ (Note 3) |                                        | 29<br>28     | 45<br>37  |                                    | 29<br>28     |            | $\text{nV}/\sqrt{\text{Hz}}$<br>$\text{nV}/\sqrt{\text{Hz}}$ |
| $i_n$                                      | Input Noise Current                                  | 0.1Hz to 10Hz (Note 3)                                         |                                        | 2.3          | 4.0       |                                    | 2.3          |            | $\text{pA}_{P-P}$                                            |
|                                            | Input Noise Current Density                          | $f_0 = 10\text{Hz}$ (Note 3)<br>$f_0 = 1000\text{Hz}$          |                                        | 0.06<br>0.02 | 0.10      |                                    | 0.06<br>0.02 |            | $\text{pA}/\sqrt{\text{Hz}}$<br>$\text{pA}/\sqrt{\text{Hz}}$ |
|                                            | Input Resistance<br>Differential Mode<br>Common Mode | (Note 4)                                                       | 400                                    | 800<br>6     |           | 300                                | 800<br>6     |            | $\text{M}\Omega$<br>$\text{G}\Omega$                         |
|                                            | 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                          | $V_{CM} = 0\text{V}$ to $3.5\text{V}$                          | 95                                     | 110          |           | 92                                 | 108          |            | dB                                                           |
| PSRR                                       | Power Supply Rejection Ratio                         | $V_S = 2.3\text{V}$ to $12\text{V}$                            | 100                                    | 114          |           | 98                                 | 114          |            | dB                                                           |

20789fa

# ELECTRICAL CHARACTERISTICS $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, T_A = 25^\circ C$ , unless otherwise noted.

| SYMBOL    | PARAMETER                    | CONDITIONS (NOTE 1)                                                                 | LT2078AC/LT2078AI<br>LT2079AC/LT2079AI |                   |                 | LT2078C/LT2078I<br>LT2079C/LT2079I |                   |                 | UNITS          |
|-----------|------------------------------|-------------------------------------------------------------------------------------|----------------------------------------|-------------------|-----------------|------------------------------------|-------------------|-----------------|----------------|
|           |                              |                                                                                     | MIN                                    | TYP               | MAX             | MIN                                | TYP               | MAX             |                |
| $A_{VOL}$ | Large-Signal Voltage Gain    | $V_O = 0.03V$ to $4V$ , No Load<br>$V_O = 0.03V$ to $3.5V$ , $R_L = 50k$            | 200<br>150                             | 1000<br>600       |                 | 150<br>120                         | 1000<br>600       |                 | V/mV<br>V/mV   |
|           | Maximum Output Voltage Swing | Output Low, No Load<br>Output Low, $2k$ to GND<br>Output Low, $I_{SINK} = 100\mu A$ |                                        | 3.5<br>0.55<br>95 | 6<br>1.2<br>130 |                                    | 3.5<br>0.55<br>95 | 6<br>1.2<br>130 | mV<br>mV<br>mV |
|           |                              | Output High, No Load<br>Output High, $2k$ to GND                                    | 4.2<br>3.5                             | 4.4<br>3.9        |                 | 4.2<br>3.5                         | 4.4<br>3.9        |                 | V<br>V         |
| SR        | Slew Rate                    | $A_V = 1, V_S = \pm 2.5V$                                                           | 0.04                                   | 0.07              |                 | 0.04                               | 0.07              |                 | V/ $\mu s$     |
| GBW       | Gain Bandwidth Product       | $f_0 \leq 20kHz$                                                                    |                                        | 200               |                 |                                    | 200               |                 | kHz            |
| $I_S$     | Supply Current per Amplifier |                                                                                     |                                        | 38                | 50              |                                    | 39                | 55              | $\mu A$        |
|           | Channel Separation           | $\Delta V_{IN} = 3V, R_L = 10k, f \leq 10Hz$                                        |                                        | 110               |                 |                                    | 110               |                 | dB             |
|           | Minimum Supply Voltage       | (Note 5)                                                                            |                                        | 2.2               | 2.3             |                                    | 2.2               | 2.3             | V              |

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ C$ .  
 $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, -40^\circ C \leq T_A \leq 85^\circ C$  for I grades, unless otherwise noted.

| SYMBOL                           | PARAMETER                           | CONDITIONS                                                               |        | LT2078AI/LT2079AI |            |            | LT2078I/LT2079I |            |            | UNITS                                |
|----------------------------------|-------------------------------------|--------------------------------------------------------------------------|--------|-------------------|------------|------------|-----------------|------------|------------|--------------------------------------|
|                                  |                                     |                                                                          |        | MIN               | TYP        | MAX        | MIN             | TYP        | MAX        |                                      |
| $V_{OS}$                         | Input Offset Voltage                | LT2078<br>LT2079                                                         | ●<br>● |                   | 70<br>80   | 250<br>280 |                 | 95<br>100  | 370<br>400 | $\mu V$<br>$\mu V$                   |
| $\frac{\Delta V_{OS}}{\Delta T}$ | Input Offset Voltage Drift (Note 6) | LT2078<br>LT2079                                                         | ●<br>● |                   | 0.4<br>0.6 | 1.8<br>3.0 |                 | 0.5<br>0.6 | 2.5<br>3.5 | $\mu V/^\circ C$<br>$\mu V/^\circ C$ |
| $I_{OS}$                         | Input Offset Current                |                                                                          | ●      |                   | 0.07       | 0.70       |                 | 0.1        | 1.0        | nA                                   |
| $I_B$                            | Input Bias Current                  |                                                                          | ●      |                   | 7          | 10         |                 | 7          | 12         | nA                                   |
| CMRR                             | Common Mode Rejection Ratio         | $V_{CM} = 0.05V$ to $3.2V$                                               | ●      | 90                | 106        |            | 86              | 104        |            | dB                                   |
| PSRR                             | Power Supply Rejection Ratio        | $V_S = 3.1V$ to $12V$                                                    | ●      | 96                | 110        |            | 92              | 110        |            | dB                                   |
| $A_{VOL}$                        | Large-Signal Voltage Gain           | $V_O = 0.05V$ to $4V$ , No Load<br>$V_O = 0.05V$ to $3.5V$ , $R_L = 50k$ | ●<br>● | 110<br>80         | 600<br>400 |            | 80<br>60        | 600<br>400 |            | V/mV<br>V/mV                         |
|                                  | Maximum Output Voltage Swing        | Output Low, No Load<br>Output Low, $I_{SINK} = 100\mu A$                 | ●<br>● |                   | 4.5<br>125 | 8<br>170   |                 | 4.5<br>125 | 8<br>170   | mV<br>mV                             |
|                                  |                                     | Output High, No Load<br>Output High, $2k$ to GND                         | ●<br>● | 3.9<br>3.0        | 4.2<br>3.7 |            | 3.9<br>3.0      | 4.2<br>3.7 |            | V<br>V                               |
| $I_S$                            | Supply Current per Amplifier        |                                                                          | ●      |                   | 43         | 60         |                 | 45         | 70         | $\mu A$                              |

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ C$ .  
 $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, 0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted (Note 7)

| SYMBOL                           | PARAMETER                           | CONDITIONS              |        | LT2078AC/LT2079AC |            |            | LT2078C/LT2079C |            |            | UNITS                                |
|----------------------------------|-------------------------------------|-------------------------|--------|-------------------|------------|------------|-----------------|------------|------------|--------------------------------------|
|                                  |                                     |                         |        | MIN               | TYP        | MAX        | MIN             | TYP        | MAX        |                                      |
| $V_{OS}$                         | Input Offset Voltage                | LT2078<br>LT2079        | ●<br>● |                   | 50<br>60   | 150<br>180 |                 | 60<br>70   | 240<br>270 | $\mu V$<br>$\mu V$                   |
| $\frac{\Delta V_{OS}}{\Delta T}$ | Input Offset Voltage Drift (Note 6) | LT2078<br>LT2079        | ●<br>● |                   | 0.4<br>0.5 | 1.8<br>3.0 |                 | 0.5<br>0.6 | 2.5<br>3.5 | $\mu V/^\circ C$<br>$\mu V/^\circ C$ |
| $I_{OS}$                         | Input Offset Current                |                         | ●      |                   | 0.06       | 0.35       |                 | 0.06       | 0.50       | nA                                   |
| $I_B$                            | Input Bias Current                  |                         | ●      |                   | 6          | 9          |                 | 6          | 11         | nA                                   |
| CMRR                             | Common Mode Rejection Ratio         | $V_{CM} = 0V$ to $3.4V$ | ●      | 92                | 108        |            | 88              | 106        |            | dB                                   |
| PSRR                             | Power Supply Rejection Ratio        | $V_S = 2.6V$ to $12V$   | ●      | 98                | 112        |            | 95              | 112        |            | dB                                   |

# ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = 5\text{V}$ ,  $0\text{V}$ ,  $V_{CM} = 0.1\text{V}$ ,  $V_O = 1.4\text{V}$ ,  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , unless otherwise noted.

| SYMBOL    | PARAMETER                    | CONDITIONS                                                                                                  |        | LT2078AC/LT2079AC |            |     | LT2078C/LT2079C |            |     | UNITS         |
|-----------|------------------------------|-------------------------------------------------------------------------------------------------------------|--------|-------------------|------------|-----|-----------------|------------|-----|---------------|
|           |                              |                                                                                                             |        | MIN               | TYP        | MAX | MIN             | TYP        | MAX |               |
| $A_{VOL}$ | Large-Signal Voltage Gain    | $V_O = 0.05\text{V}$ to $4\text{V}$ , No Load<br>$V_O = 0.05\text{V}$ to $3.5\text{V}$ , $R_L = 50\text{k}$ | ●<br>● | 150<br>110        | 750<br>500 |     | 110<br>80       | 750<br>500 |     | V/mV<br>V/mV  |
|           | Maximum Output Voltage Swing | Output Low, No Load                                                                                         | ●      |                   | 4.0        | 7   |                 | 4.0        | 7   | mV            |
|           |                              | Output Low, $I_{SINK} = 100\mu\text{A}$                                                                     | ●      |                   | 105        | 150 |                 | 105        | 150 | mV            |
|           |                              | Output High, No Load                                                                                        | ●      | 4.1               | 4.3        |     | 4.1             | 4.3        |     | V             |
|           |                              | Output High, $2\text{k}$ to GND                                                                             | ●      | 3.3               | 3.8        |     | 3.3             | 3.8        |     | V             |
| $I_S$     | Supply Current per Amplifier |                                                                                                             | ●      |                   | 40         | 55  |                 | 42         | 63  | $\mu\text{A}$ |

$V_S = \pm 15\text{V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

| SYMBOL    | PARAMETER                    | CONDITIONS                                                                                |  | LT2078AC/LT2078AI<br>LT2079AC/LT2079AI |                          |            | LT2078C/LT2078I<br>LT2079C/LT2079I |                          |            | UNITS                          |
|-----------|------------------------------|-------------------------------------------------------------------------------------------|--|----------------------------------------|--------------------------|------------|------------------------------------|--------------------------|------------|--------------------------------|
|           |                              |                                                                                           |  | MIN                                    | TYP                      | MAX        | MIN                                | TYP                      | MAX        |                                |
| $V_{OS}$  | Input Offset Voltage         | LT2078<br>LT2079                                                                          |  |                                        | 50<br>60                 | 250<br>350 |                                    | 70<br>80                 | 350<br>450 | $\mu\text{V}$<br>$\mu\text{V}$ |
| $I_{OS}$  | Input Offset Current         |                                                                                           |  |                                        | 0.05                     | 0.25       |                                    | 0.05                     | 0.35       | nA                             |
| $I_B$     | Input Bias Current           |                                                                                           |  |                                        | 6                        | 8          |                                    | 6                        | 10         | 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  | $V_{CM} = 13.5\text{V}$ , $-15\text{V}$                                                   |  | 98                                     | 114                      |            | 95                                 | 114                      |            | dB                             |
| PSRR      | Power Supply Rejection Ratio | $V_S = 5\text{V}$ , $0\text{V}$ to $\pm 18\text{V}$                                       |  | 100                                    | 114                      |            | 98                                 | 114                      |            | dB                             |
| $A_{VOL}$ | Large-Signal Voltage Gain    | $V_O = \pm 10\text{V}$ , $R_L = 50\text{k}$<br>$V_O = \pm 10\text{V}$ , $R_L = 2\text{k}$ |  | 1000<br>400                            | 5000<br>1100             |            | 1000<br>300                        | 5000<br>1100             |            | V/mV<br>V/mV                   |
| $V_{OUT}$ | Maximum Output Voltage Swing | $R_L = 50\text{k}$<br>$R_L = 2\text{k}$                                                   |  | $\pm 13.0$<br>$\pm 11.0$               | $\pm 14.0$<br>$\pm 13.2$ |            | $\pm 13.0$<br>$\pm 11.0$           | $\pm 14.0$<br>$\pm 13.2$ |            | V<br>V                         |
| SR        | Slew Rate                    |                                                                                           |  | 0.06                                   | 0.10                     |            | 0.06                               | 0.10                     |            | V/ $\mu\text{s}$               |
| $I_S$     | Supply Current per Amplifier |                                                                                           |  |                                        | 46                       | 65         |                                    | 47                       | 75         | $\mu\text{A}$                  |

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$  for I grades, unless otherwise noted.

| SYMBOL                           | PARAMETER                           | CONDITIONS                                          |        | LT2078AI/LT2079AI |            |            | LT2078I/LT2079I |            |            | UNITS                                                        |
|----------------------------------|-------------------------------------|-----------------------------------------------------|--------|-------------------|------------|------------|-----------------|------------|------------|--------------------------------------------------------------|
|                                  |                                     |                                                     |        | MIN               | TYP        | MAX        | MIN             | TYP        | MAX        |                                                              |
| $V_{OS}$                         | Input Offset Voltage                | LT2078<br>LT2079                                    | ●<br>● |                   | 90<br>100  | 430<br>500 |                 | 120<br>130 | 600<br>700 | $\mu\text{V}$<br>$\mu\text{V}$                               |
| $\frac{\Delta V_{OS}}{\Delta T}$ | Input Offset Voltage Drift (Note 6) | LT2078<br>LT2079                                    | ●<br>● |                   | 0.5<br>0.6 | 1.8<br>3.0 |                 | 0.6<br>0.7 | 2.5<br>3.8 | $\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$ |
| $I_{OS}$                         | Input Offset Current                |                                                     | ●      |                   | 0.07       | 0.70       |                 | 0.1        | 1.0        | nA                                                           |
| $I_B$                            | Input Bias Current                  |                                                     | ●      |                   | 7          | 10         |                 | 7          | 12         | nA                                                           |
| $A_{VOL}$                        | Large-Signal Voltage Gain           | $V_O = \pm 10\text{V}$ , $R_L = 5\text{k}$          | ●      | 200               | 700        |            | 150             | 700        |            | V/mV                                                         |
| CMRR                             | Common Mode Rejection Ratio         | $V_{CM} = 13\text{V}$ , $-14.9\text{V}$             | ●      | 92                | 110        |            | 88              | 110        |            | dB                                                           |
| PSRR                             | Power Supply Rejection Ratio        | $V_S = 5\text{V}$ , $0\text{V}$ to $\pm 18\text{V}$ | ●      | 96                | 110        |            | 92              | 110        |            | dB                                                           |
|                                  | Maximum Output Voltage Swing        | $R_L = 5\text{k}$                                   | ●      | $\pm 11.0$        | $\pm 13.5$ |            | $\pm 11.0$      | $\pm 13.5$ |            | V                                                            |
| $I_S$                            | Supply Current per Amplifier        |                                                     | ●      |                   | 52         | 80         |                 | 54         | 95         | $\mu\text{A}$                                                |

# ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = \pm 15\text{V}$ ,  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , unless otherwise noted (Note 7).

| SYMBOL                           | PARAMETER                              | CONDITIONS                                          |        | LT2078AC/LT2079AC |            |     | LT2078C/LT2079C |            |     | UNITS                                                        |
|----------------------------------|----------------------------------------|-----------------------------------------------------|--------|-------------------|------------|-----|-----------------|------------|-----|--------------------------------------------------------------|
|                                  |                                        |                                                     |        | MIN               | TYP        | MAX | MIN             | TYP        | MAX |                                                              |
| $V_{OS}$                         | Input Offset Voltage                   | LT2078<br>LT2079                                    | ●<br>● | 70<br>80          | 330<br>410 |     | 90<br>100       | 460<br>540 |     | $\mu\text{V}$<br>$\mu\text{V}$                               |
| $\frac{\Delta V_{OS}}{\Delta T}$ | Input Offset Voltage Drift<br>(Note 6) | LT2078<br>LT2079                                    | ●<br>● | 0.5<br>0.6        | 1.8<br>3.0 |     | 0.6<br>0.7      | 2.5<br>3.8 |     | $\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$ |
| $I_{OS}$                         | Input Offset Current                   |                                                     | ●      | 0.06              | 0.35       |     | 0.06            | 0.50       |     | nA                                                           |
| $I_B$                            | Input Bias Current                     |                                                     | ●      | 6                 | 9          |     | 6               | 11         |     | nA                                                           |
| $A_{VOL}$                        | Large-Signal Voltage Gain              | $V_O = \pm 10\text{V}$ , $R_L = 5\text{k}$          | ●      | 300               | 1200       |     | 250             | 1200       |     | V/mV                                                         |
| CMRR                             | Common Mode Rejection Ratio            | $V_{CM} = 13\text{V}$ , $-15\text{V}$               | ●      | 95                | 112        |     | 92              | 112        |     | dB                                                           |
| PSRR                             | Power Supply Rejection Ratio           | $V_S = 5\text{V}$ , $0\text{V}$ to $\pm 18\text{V}$ | ●      | 98                | 112        |     | 95              | 112        |     | dB                                                           |
|                                  | Maximum Output Voltage Swing           | $R_L = 5\text{k}$                                   | ●      | $\pm 11.0$        | $\pm 13.6$ |     | $\pm 11.0$      | $\pm 13.6$ |     | V                                                            |
| $I_S$                            | Supply Current per Amplifier           |                                                     | ●      | 49                | 73         |     | 50              | 85         |     | $\mu\text{A}$                                                |

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** Typical parameters are defined as the 60% yield of parameter distributions of individual amplifiers, i.e., out of 100 LT2079s (or 100 LT2078s) typically 240 op amps (or 120) will be better than the indicated specification.

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

**Note 4:** This parameter is guaranteed by design and is not tested.

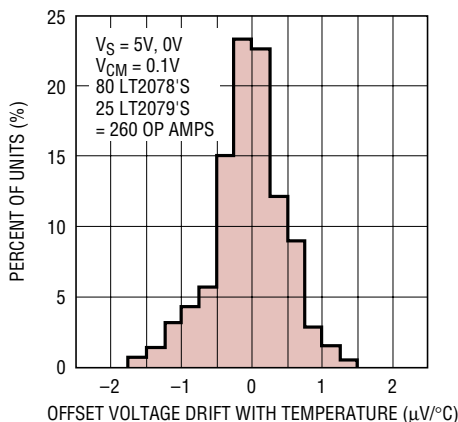
**Note 5:** Power supply rejection ratio is measured at the minimum supply voltage. The op amps actually work at 1.8V supply but with a typical offset skew of  $-300\mu\text{V}$ .

**Note 6:** This parameter is not 100% tested.

**Note 7:** The LT2078C/LT2079C are designed, characterized and expected to meet the industrial temperature limits, but are not tested at  $-40^\circ\text{C}$  and  $85^\circ\text{C}$ . I-grade parts are guaranteed.

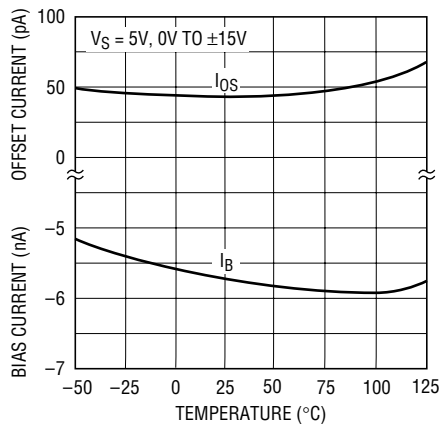
## TYPICAL PERFORMANCE CHARACTERISTICS

Distribution of Offset Voltage Drift with Temperature



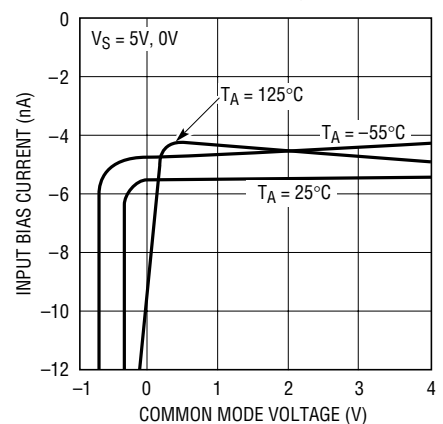
LT2078/79 • TPC01

Input Bias and Offset Currents vs Temperature



LT2078/79 • TPC02

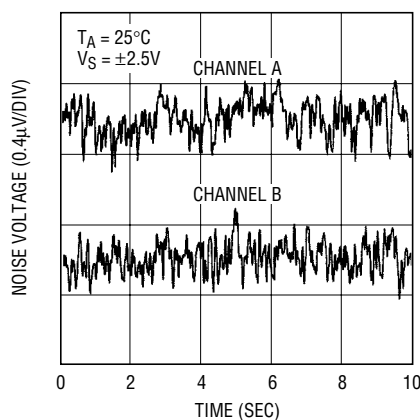
Input Bias Current vs Common Mode Voltage



LT2078/79 • TPC03

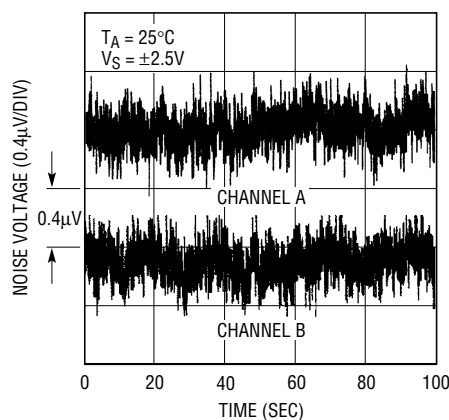
# TYPICAL PERFORMANCE CHARACTERISTICS

0.1Hz to 10Hz Noise



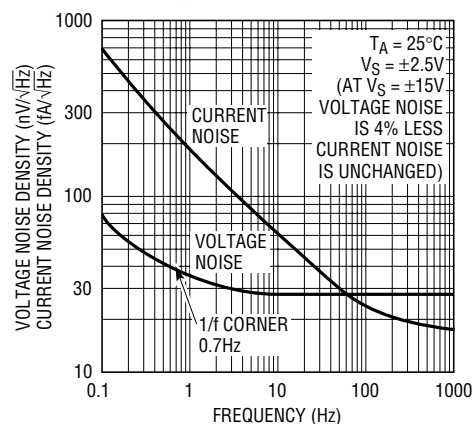
LT2078/79 • TPC04

0.01Hz to 10Hz Noise



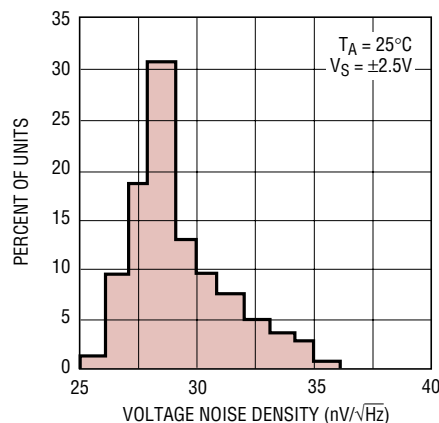
LT2078/79 • TPC05

Noise Spectrum



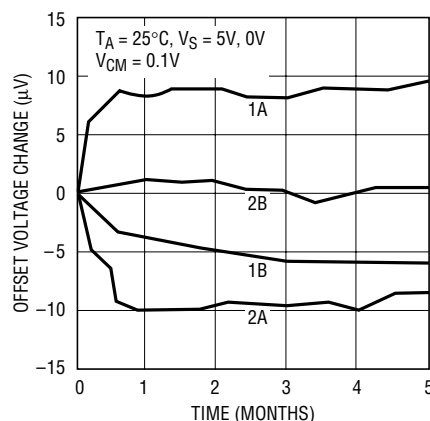
LT2078/79 • TPC06

10Hz Voltage Noise Distribution



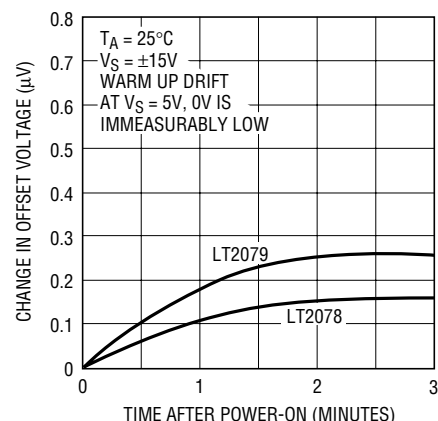
LT2078/79 • TPC07

Long Term Stability of Two Representative Units (LT2078)



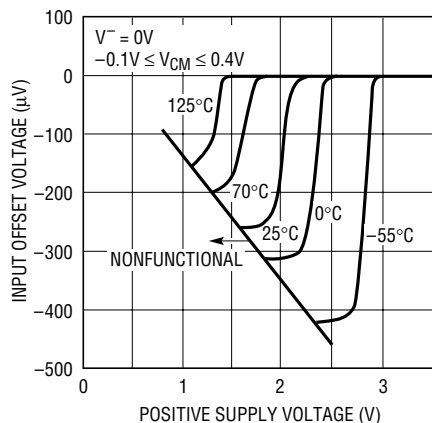
LT2078/79 • TPC08

Warm-Up Drift



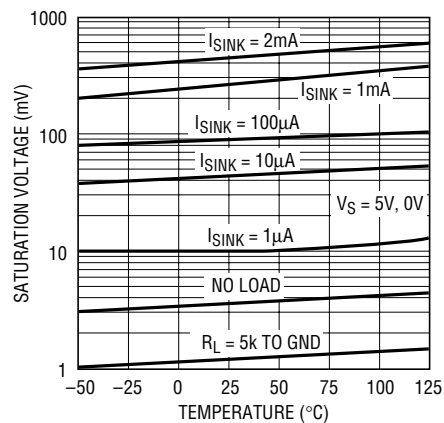
LT2078/79 • TPC09

Minimum Supply Voltage



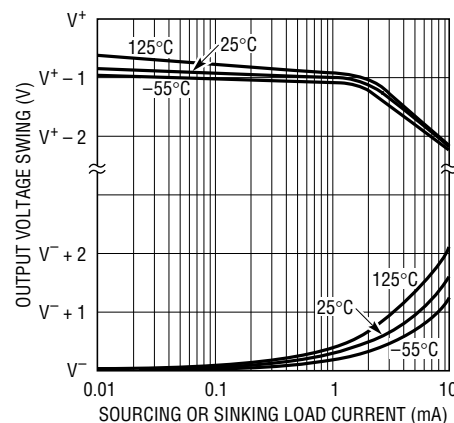
LT2078/79 • TPC10

Output Saturation vs Temperature vs Sink Current



LT2078/79 • TPC11

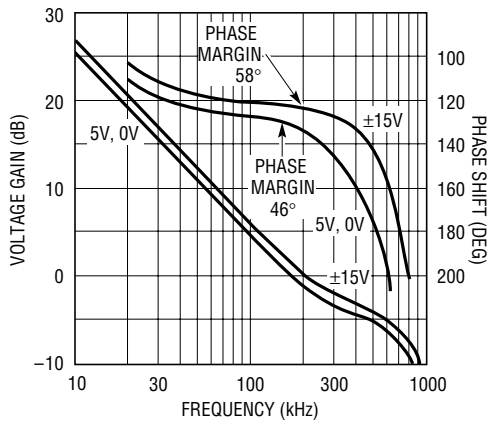
Output Voltage Swing vs Load Current



LT2078/79 • TPC11.5

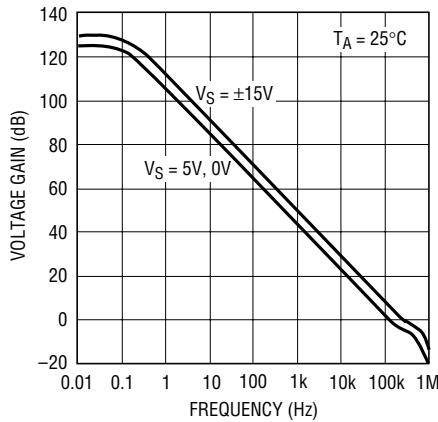
# TYPICAL PERFORMANCE CHARACTERISTICS

Gain, Phase vs Frequency



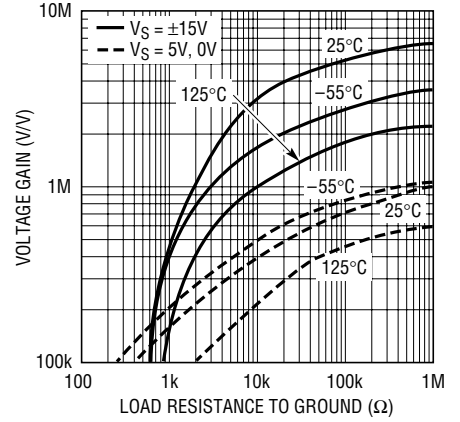
LT2078/79 • TPC12

Voltage Gain vs Frequency



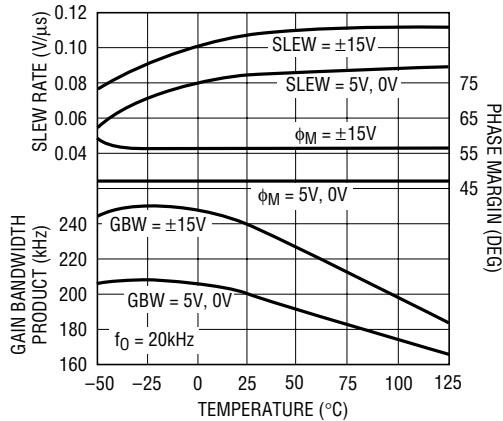
LT2078/79 • TPC13

Voltage Gain vs Load Resistance



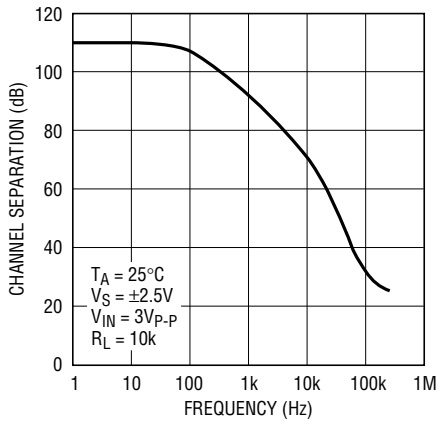
LT2078/79 • TPC14

Slew Rate, Gain Bandwidth Product and Phase Margin vs Temperature



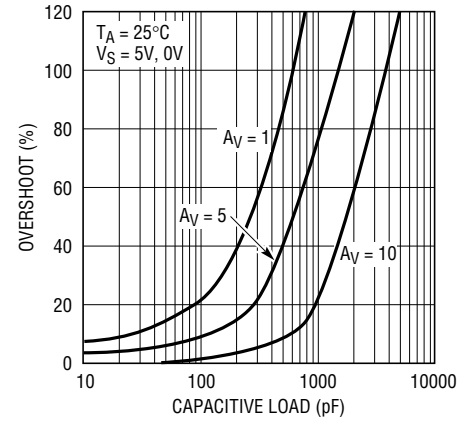
LT2078/79 • TPC15

Channel Separation vs Frequency



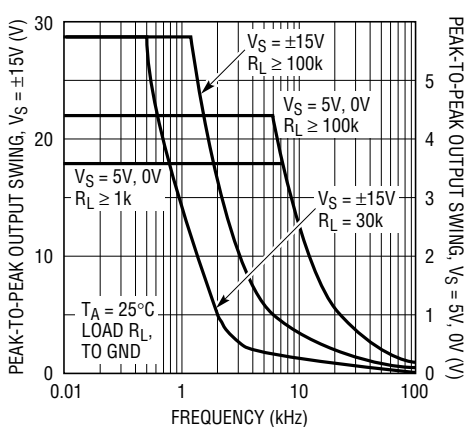
LT2078/79 • TPC16

Capacitive Load Handling



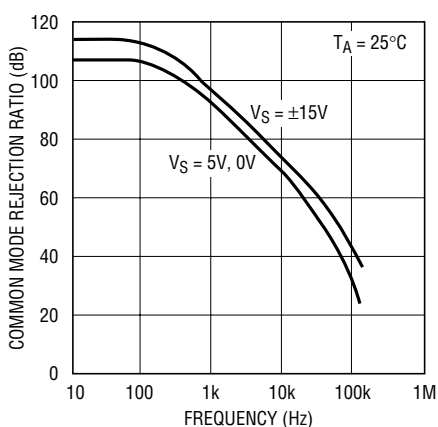
LT2078/79 • TPC17

Undistorted Output Swing vs Frequency



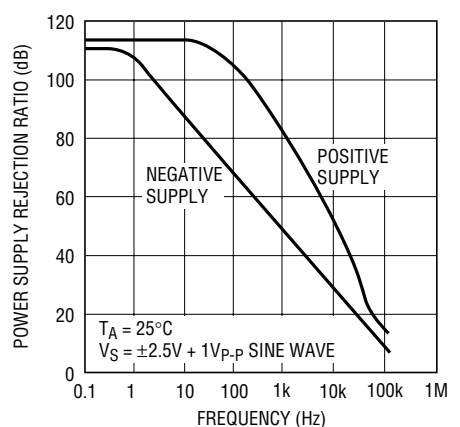
LT2078/79 • TPC18

Common Mode Rejection Ratio vs Frequency



LT2078/79 • TPC19

Power Supply Rejection Ratio vs Frequency

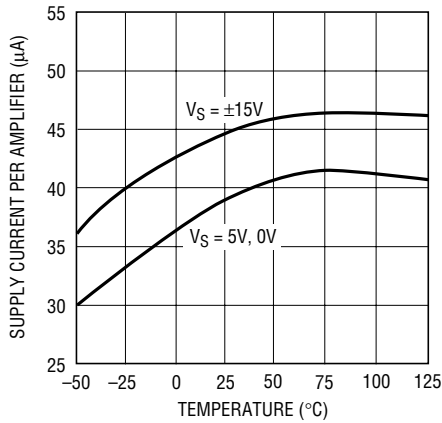


LT2078/79 • TPC20

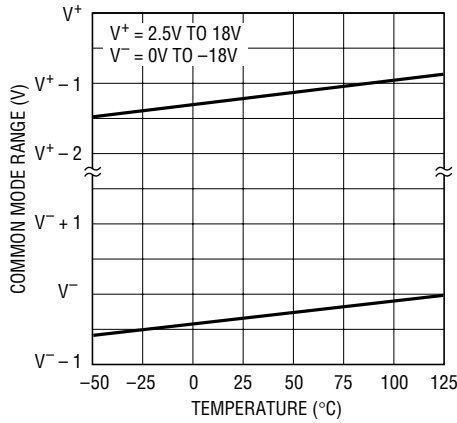


# TYPICAL PERFORMANCE CHARACTERISTICS

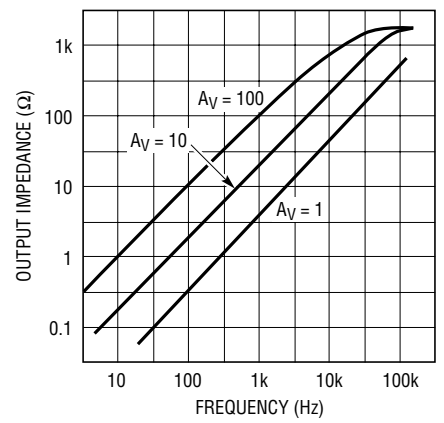
Supply Current vs Temperature



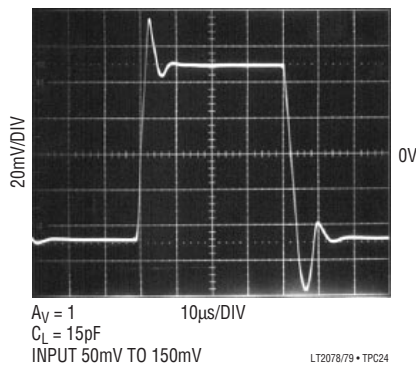
Common Mode Range vs Temperature



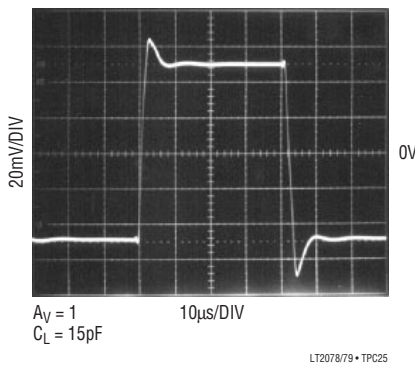
Closed-Loop Output Impedance



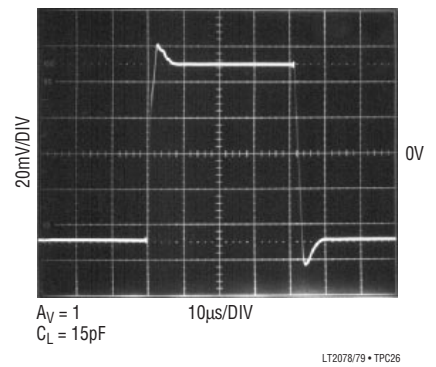
Small-Signal Transient Response  
 $V_S = 5V, 0V$



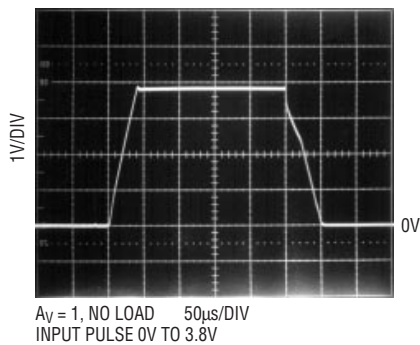
Small-Signal Transient Response  
 $V_S = \pm 2.5V$



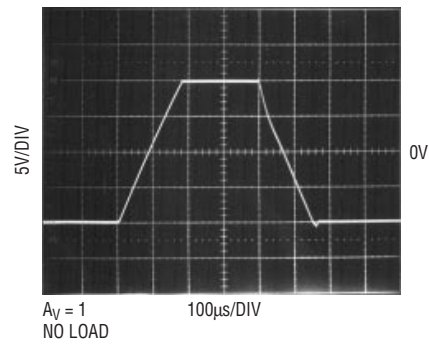
Small-Signal Transient Response  
 $V_S = \pm 15V$



Large-Signal Transient Response  
 $V_S = 5V, 0V$



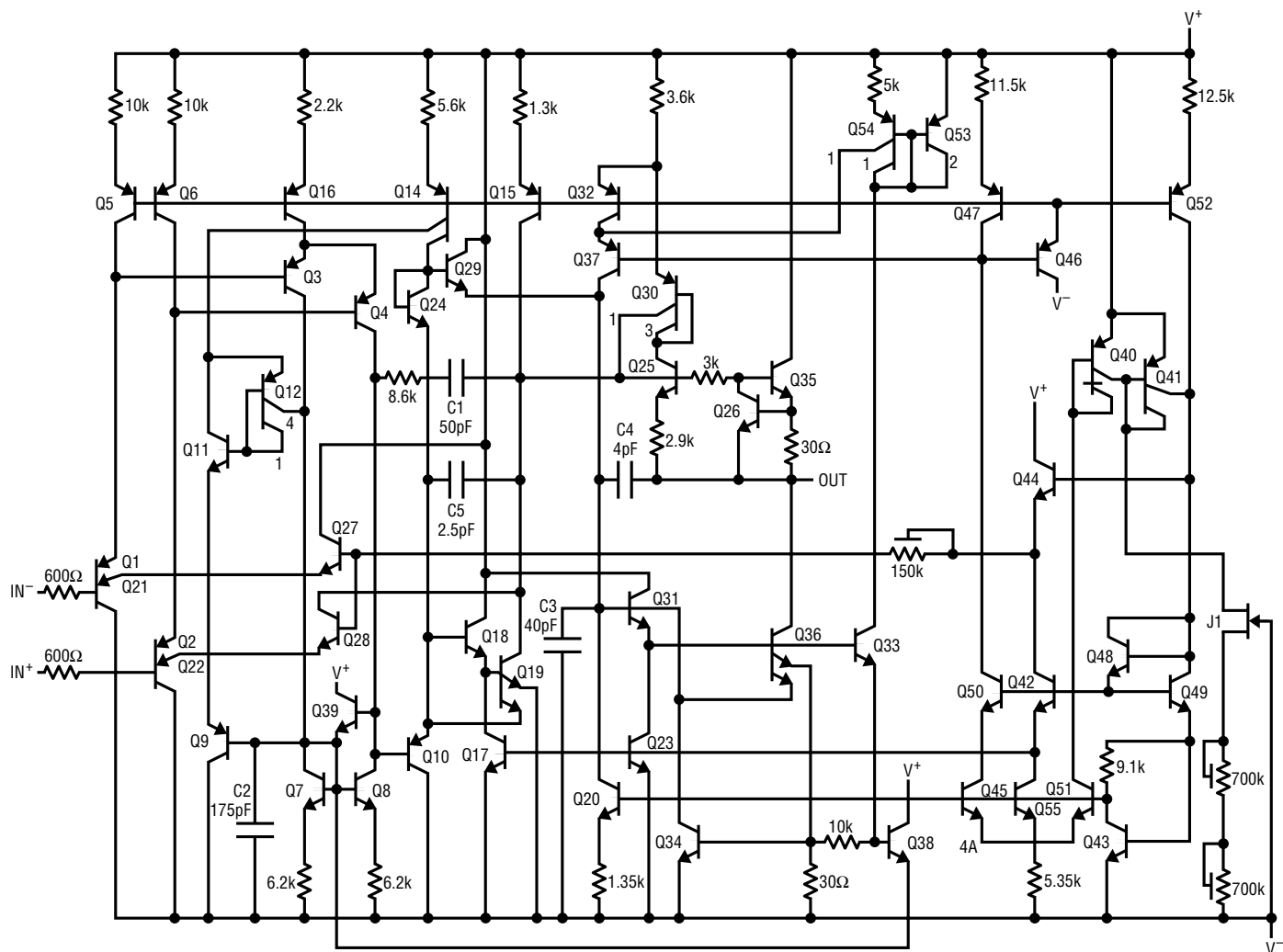
Large-Signal Transient Response  
 $V_S = \pm 15V$





# SIMPLIFIED SCHEMATIC

1/2 LT2078, 1/4 LT2079



LT2078/79 • SIMPLIFIED SCHEM

## APPLICATIONS INFORMATION

The LT2078/LT2079 devices are fully specified with  $V^+ = 5V$ ,  $V^- = 0V$ ,  $V_{CM} = 0.1V$ . This set of operating conditions appears to be the most representative for battery powered micropower circuits. Offset voltage is internally trimmed to a minimum value at these supply voltages. When 9V or 3V batteries or  $\pm 2.5V$  dual supplies are used, bias and offset current changes will be minimal. Offset voltage changes will be just a few microvolts as given by the PSRR and CMRR specifications. For example, if  $PSRR = 114dB (=2\mu V/V)$ , at 9V the offset voltage change will be  $8\mu V$ . Similarly,  $V_S = \pm 2.5V$ ,  $V_{CM} = 0V$  is equivalent to a common mode voltage change of 2.4V or a  $V_{OS}$  change of  $7\mu V$  if  $CMRR = 110dB (3\mu V/V)$ .

A full set of specifications is also provided at  $\pm 15V$  supply voltages for comparison with other devices and for completeness.

### Single Supply Operation

The LT2078/LT2079 is quite tolerant of power supply bypassing. In some applications requiring faster settling time the positive supply pin of the LT2078/LT2079 should be bypassed with a small capacitor (about  $0.1\mu F$ ). The same is true for the negative supply pin when using split supplies.

The LT2078/LT2079 are fully specified for single supply operation, i.e., when the negative supply is 0V. Input common mode range goes below ground and the output swings within a few millivolts of ground while sinking current. All competing micropower op amps either cannot swing to within 600mV of ground (OP-20, OP-220, OP-420) or need a pull-down resistor connected to the output to swing to ground (OP-90, OP-290, OP-490, HA5141/42/44). This difference is critical because in many applications these competing devices cannot be operated as micropower op amps and swing to ground simultaneously.

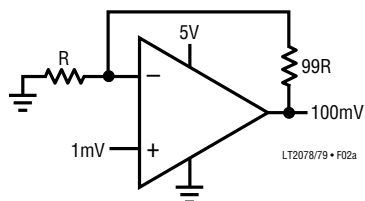


Figure 1a. Gain 100 Amplifier

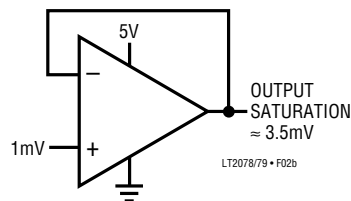


Figure 1b. Voltage Follower

As an example, consider the instrumentation amplifier shown on the front page. When the common mode signal is low and the output is high, amplifier A has to sink current. When the common mode signal is high and the output low, amplifier B has to sink current. The competing devices require a 12k pull-down resistor at the output of amplifier A and a 15k at the output of B to handle the specified signals. (The LT2078 does not need pull-down resistors.) When the common mode input is high and the output is high these pull-down resistors draw  $300\mu A$  ( $150\mu A$  each), which is excessive for micropower applications.

The instrumentation amplifier is by no means the only application requiring current sinking capability. In seven of the nine single supply applications shown in this data sheet the op amps have to be able to sink current. In two of the applications the first amplifier has to sink only the 6nA input bias current of the second op amp. The competing devices, however, cannot even sink 6nA without a pull-down resistor

Since the output of the LT2078/LT2079 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 in Figure 1, but is not enough to make the amplifier function properly in the voltage follower mode.

Single supply operation can also create difficulties 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 (1 and 2), OP-90/290/490 (2 only):

## APPLICATIONS INFORMATION

1. 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 LT2078/LT2079, resistors in series with the input protect the devices even when the input is 5V below ground.
2. When the input is more than 400mV below ground (at 25°C), the input stage saturates and phase reversal occurs at the output. This can cause lockup in servo systems. Due to a unique phase reversal protection circuitry, the LT2078/LT2079 output does not reverse, as illustrated in Figure 2, even when the inputs are at  $-1V$ .

### Distortion

There are two main contributors of distortion in op amps: distortion caused by nonlinear common mode rejection and output crossover distortion as the output transitions from sourcing to sinking current. The common mode

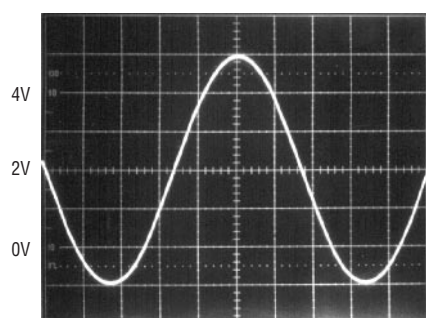
rejection of the LT2078/LT2079 is very good, typically 108dB. Therefore, as long as the input operates in the normal common mode range, there will be very little common mode induced distortion. If the op amp is operating inverting there is no common mode induced distortion. Crossover distortion will increase as the output load resistance decreases. For the lowest distortion the LT2078/LT2079 should be operated with the output always sourcing current, this is usually accomplished by putting a resistor from the output to  $V^-$ . In an inverting configuration with no load, the output will source and sink current through the feedback resistor. High value feedback resistors will reduce crossover distortion and maintain micropower operation.

### Matching Specifications

In many applications the performance of a system depends on the matching between two op amps, rather than

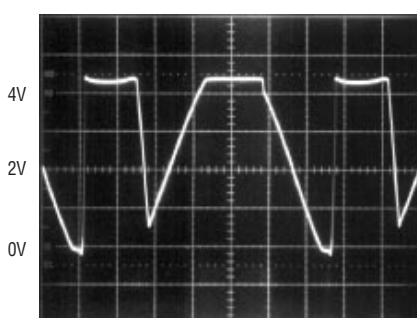
Table 1

|                                         |        | LT2078AC/LT2079AC/LT2078AI/LT2079AI |           | LT2078C/LT2079C/LT2078I/LT2079I |           | UNITS             |
|-----------------------------------------|--------|-------------------------------------|-----------|---------------------------------|-----------|-------------------|
| PARAMETER                               |        | 50% YIELD                           | 98% YIELD | 50% YIELD                       | 98% YIELD |                   |
| $V_{OS}$ Match, $\Delta V_{OS}$         | LT2078 | 30                                  | 110       | 50                              | 190       | $\mu V$           |
|                                         | LT2079 | 40                                  | 150       | 50                              | 250       | $\mu V$           |
| Temperature Coefficient $\Delta V_{OS}$ |        | 0.5                                 | 1.2       | 0.6                             | 1.8       | $\mu V/^{\circ}C$ |
| Average Noninverting $I_B$              |        | 6                                   | 8         | 6                               | 10        | nA                |
| Match of Noninverting $I_B$             |        | 0.12                                | 0.4       | 0.15                            | 0.5       | nA                |
| CMRR Match                              |        | 120                                 | 100       | 117                             | 97        | dB                |
| PSRR Match                              |        | 117                                 | 105       | 117                             | 102       | dB                |



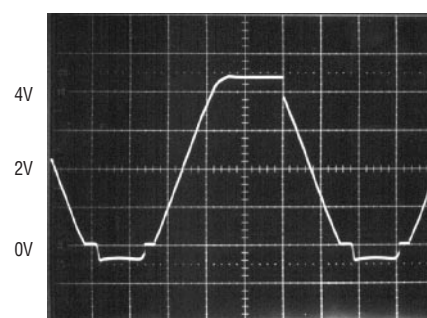
6Vp-p INPUT  
-1V TO 5V

LT2078/79 • F01a



OP-90 EXHIBITS OUTPUT PHASE REVERSAL

LT2078/79 • F01b



LT2078/LT2079 NO PHASE REVERSAL

LT2078/79 • F01c

Figure 2. Voltage Follower with Input Exceeding the Negative Common Mode Range ( $V_S = 5V$ ,  $0V$ )

## APPLICATIONS INFORMATION

the individual characteristics of the two devices, the two and three op amp instrumentation amplifier configurations shown in this data sheet are examples. Matching characteristics are not 100% tested on the LT2078/LT2079.

Some specifications are guaranteed by definition. For example, 70 $\mu$ V maximum offset voltage implies that mismatch cannot be more than 140 $\mu$ V. 95dB (= 17.5 $\mu$ V/V) CMRR means that worst-case CMRR match is 89dB (= 35 $\mu$ V/V). However, Table 1 can be used to estimate the

expected matching performance at  $V_S = 5V$ , 0V between the two sides of the LT2078, and between amplifiers A and D, and between amplifiers B and C of the LT2079.

### Comparator Applications

The single supply operation of the LT2078/LT2079 and its ability to swing close to ground while sinking current lends itself to use as a precision comparator with TTL compatible output.

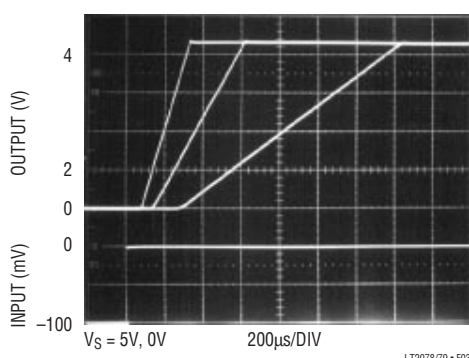


Figure 3. Comparator Rise Response  
Time to 10mV, 5mV, 2mV Overdrives

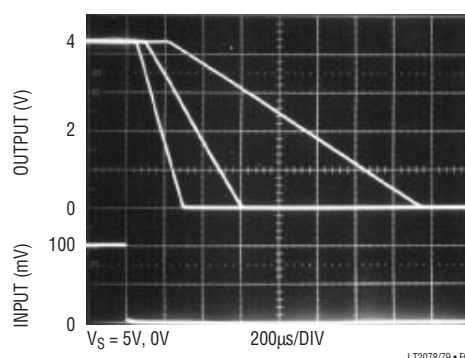
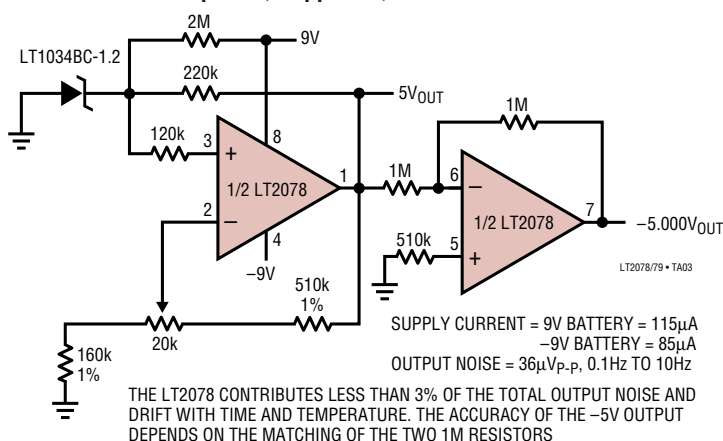


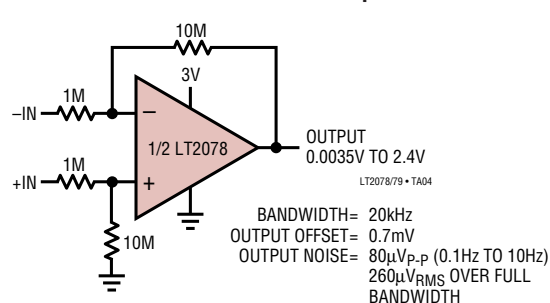
Figure 4. Comparator Fall Response  
Time to 10mV, 5mV, 2mV Overdrives

## TYPICAL APPLICATIONS

### Micropower, 10ppm/°C, $\pm 5V$ Reference



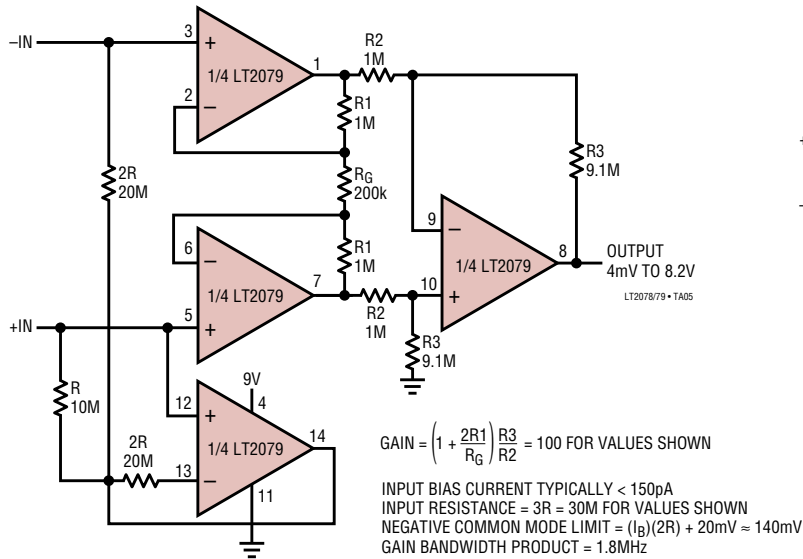
### Gain of 10 Difference Amplifier



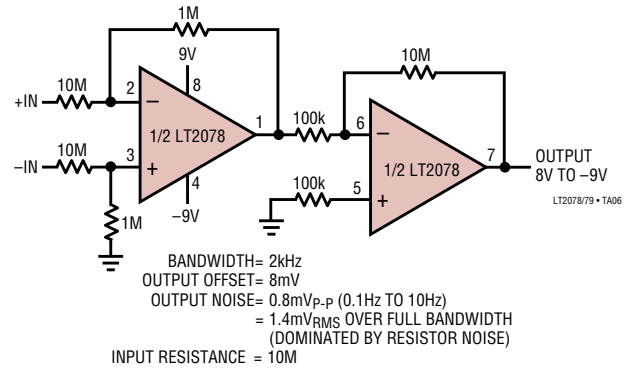
THE USEFULNESS OF DIFFERENCE AMPLIFIERS IS LIMITED BY THE FACT THAT THE INPUT RESISTANCE IS EQUAL TO THE SOURCE RESISTANCE. THE PICOAMPERE OFFSET CURRENT AND LOW CURRENT NOISE OF THE LT2078 ALLOWS THE USE OF 1M SOURCE RESISTORS WITHOUT DEGRADATION IN PERFORMANCE. IN ADDITION, WITH MEGOHM RESISTORS MICROPOWER OPERATION CAN BE MAINTAINED

## TYPICAL APPLICATIONS

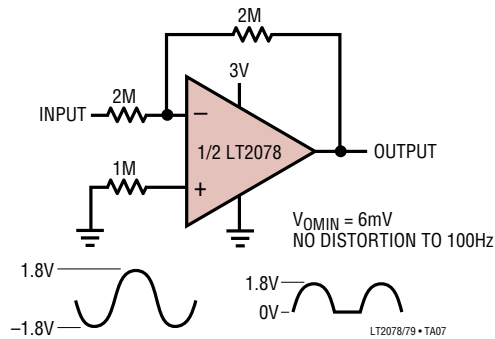
**Picoampere Input Current, Triple Op Amp Instrumentation Amplifier with Bias Current Cancellation**



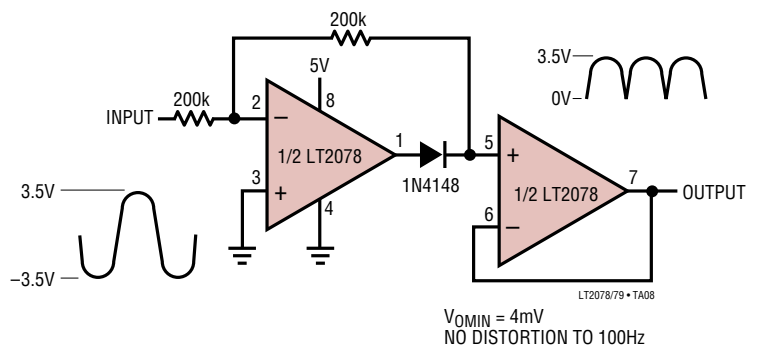
**85V, -100V Common Mode Range Instrumentation Amplifier ( $A_V = 10$ )**



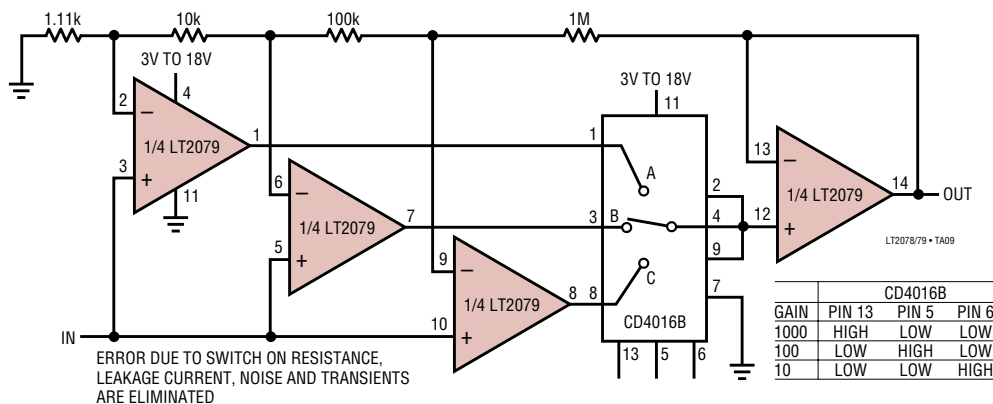
**Half-Wave Rectifier**



**Absolute Value Circuit (Full-Wave Rectifier)**

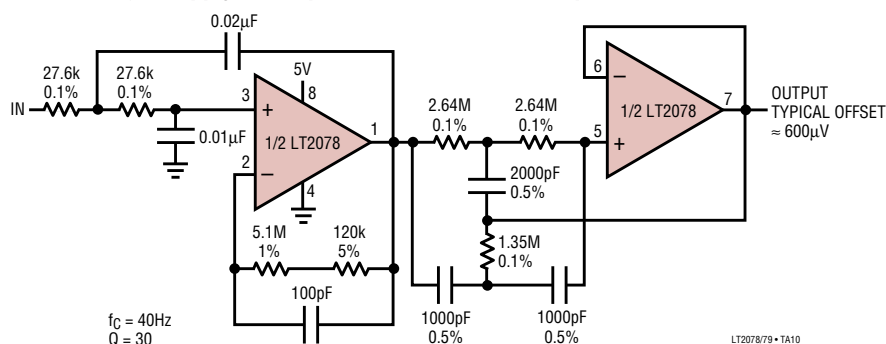


**Programmable Gain Amplifier (Single Supply)**

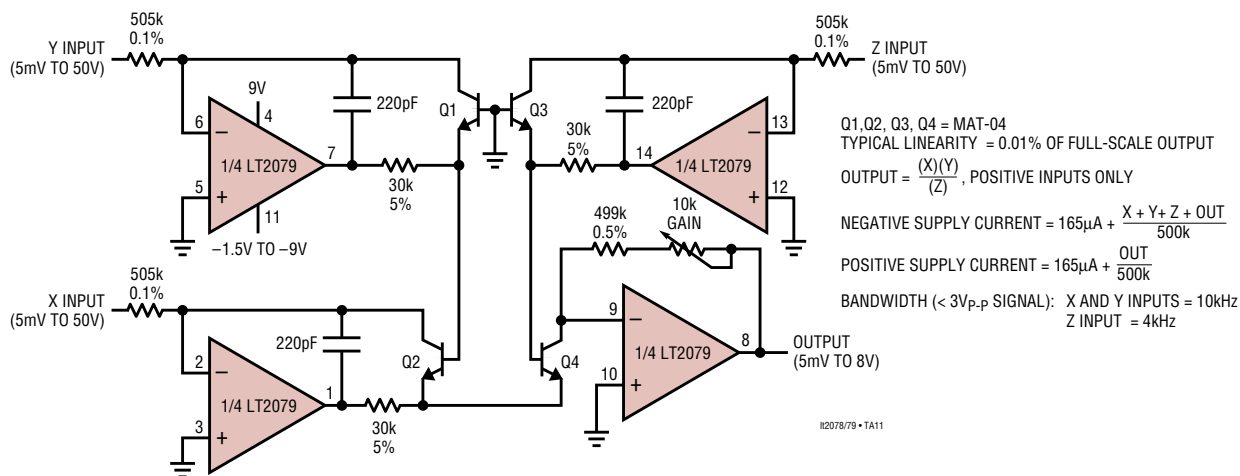


## TYPICAL APPLICATIONS

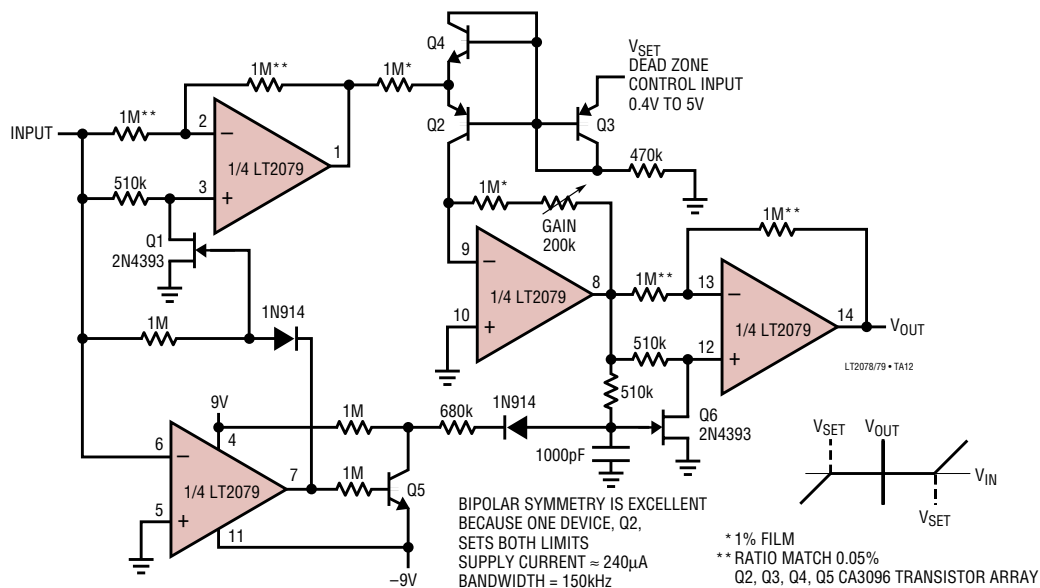
## Single Supply, Micropower, Second Order Lowpass Filter with 60Hz Notch



## Micropower Multiplier/Divider

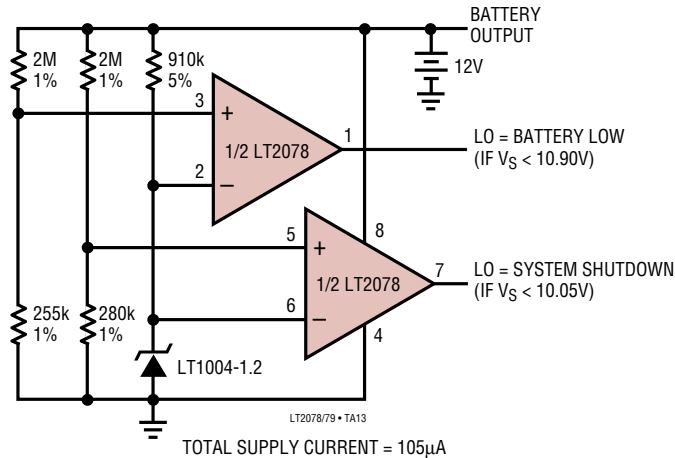


## Micropower Dead Zone Generator



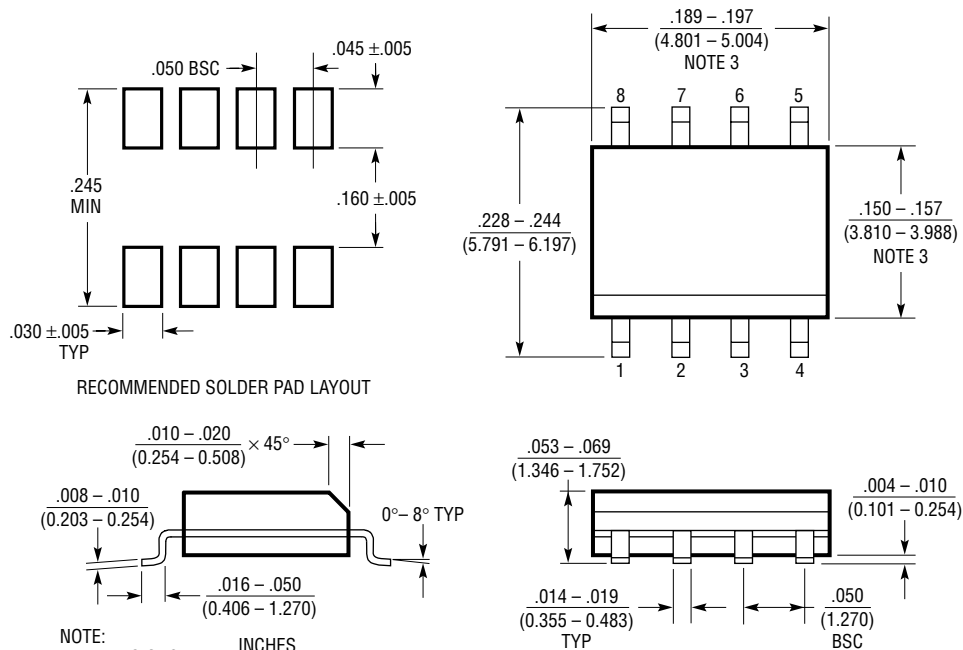
## TYPICAL APPLICATIONS

### Lead-Acid Low-Battery Detector with System Shutdown



## PACKAGE DESCRIPTION

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



S08 0303



The image contains three mechanical drawings of a 14-pin package:

- Top View:** Shows the package layout with dimensions:
  - Pin pitch:  $.050 \text{ BSC}$
  - Pin width:  $.045 \pm .005$
  - Pin height:  $.245 \text{ MIN}$
  - Pin 1 offset:  $.030 \pm .005 \text{ TYP}$
  - Pin 1 to N/2 distance:  $.228 - .244$  (5.791 - 6.197)
  - Pin 1 to N/2 distance (mm):  $.150 - .157$  (3.810 - 3.968) NOTE 3
  - Pin 1 to N/2 distance (mm) alternative:  $.160 \pm .005$
  - Label: RECOMMENDED SOLDER PAD LAYOUT
- Side View:** Shows the package profile with dimensions:
  - Pin width:  $.053 - .069$  (1.346 - 1.752)
  - Pin height:  $.008 - .010$  (0.203 - 0.254)
  - Pin 1 to N/2 distance:  $.016 - .050$  (0.406 - 1.270)
  - Pin 1 to N/2 distance (mm):  $.014 - .019$  (0.355 - 0.483) TYP
  - Pin 1 to N/2 distance (mm) alternative:  $.050$  (1.270) BSC
  - Pin 1 to N/2 distance (mm) alternative:  $.004 - .010$  (0.101 - 0.254)
  - Pin 1 to N/2 distance (mm) alternative:  $0^\circ - 8^\circ \text{ TYP}$
- Detail View:** Shows the package profile with dimensions:
  - Pin width:  $.010 - .020$  (0.254 - 0.508)  $\times 45^\circ$
  - Pin height:  $.008 - .010$  (0.203 - 0.254)
  - Pin 1 to N/2 distance:  $.016 - .050$  (0.406 - 1.270)
  - Pin 1 to N/2 distance (mm):  $.014 - .019$  (0.355 - 0.483) TYP
  - Pin 1 to N/2 distance (mm) alternative:  $.050$  (1.270) BSC
  - Pin 1 to N/2 distance (mm) alternative:  $.004 - .010$  (0.101 - 0.254)
  - Pin 1 to N/2 distance (mm) alternative:  $0^\circ - 8^\circ \text{ TYP}$

**NOTE:**

1. DIMENSIONS IN INCHES (MILLIMETERS)
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm).

S14 0502

## TYPICAL APPLICATION

3V (LITHIUM)

LT1004-1.2

1/2 LT2078

1 8 3 2 4

13k\*

12.3k\*

10k\*

50k

5°C TRIM

1k\*\*

1k\*\*

1k\*\*

1k AT 0°C

1μF

1/2 LT2078

6 7 5

1.21m\* (SELECT AT 110°C)

1μF

43.2k\*\*

5k

220°C TRIM

0.02V to 2.2V<sub>OUT</sub> = 2°C to 220°C ±0.1°C

LT2078/79 • TA14

R<sub>P</sub> = ROSEMOUNT 118MF

\*\* = TRW MAR-6 0.1%

\* = 1% METAL FILM

## RELATED PARTS

| PART NUMBER   | DESCRIPTION                                                 | COMMENTS                                                                                                                 |
|---------------|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| LT1178/LT1179 | Dual/Quad 17µA Max, Single Supply Precision Op Amps         | 70µV V <sub>OS</sub> Max and 2.5µV/°C Drift Max, 85kHz GBW, 0.04V/µs Slew Rate, Input/Output Common Mode Includes Ground |
| LT1211/LT1212 | 14MHz, 7V/µs Single Supply Dual and Quad Precision Op Amps  | 275µV V <sub>OS</sub> Max, 6µV/°C Drift Max Input Voltage Range Includes Ground                                          |
| LT1490/LT1491 | Dual/ Quad Micropower Rail-to-Rail Input and Output Op Amps | Single Supply Input Range: -0.4V to 44V, Micropower 50µA Amplifier, Rail-to-Rail Input and Output, 200kHz GBW            |
| LT2178/LT2179 | Dual/Quad 17µA Max, Single Supply Precision Op Amps         | SO-8 and 14-Lead Standard Pinout, 70µV V <sub>OS</sub> Max, 85kHz GBW                                                    |