

# Micropower Precision, Dual/Quad CMOS Rail-to-Rail Input/Output Amplifiers

## FEATURES

- **Maximum Offset Voltage of 25 $\mu$ V (25°C)**
- **Maximum Offset Drift of 0.7 $\mu$ V/°C**
- **Maximum Input Bias:**  
     **1pA (25°C)**  
     **50pA ( $\leq$ 85°C)**
- Micropower: 54 $\mu$ A per Amp
- 95dB CMRR (Min)
- 100dB PSRR (Min)
- Input Noise Voltage Density: 16nV/ $\sqrt{\text{Hz}}$
- Rail-to-Rail Inputs and Outputs
- 2.7V to 5.5V Operation Voltage
- LTC6078 Available in 8-Lead MSOP and 10-Lead DFN Packages; LTC6079 Available in 16-Lead SSOP and DFN Packages

## APPLICATIONS

- Photodiode Amplifier
- High Impedance Sensor Amplifier
- Microvolt Accuracy Threshold Detection
- Instrumentation Amplifiers
- Battery Powered Applications

## DESCRIPTION

The LTC®6078/LTC6079 are dual/quad, low offset, low noise operational amplifiers with low power consumption and rail-to-rail input/output swing.

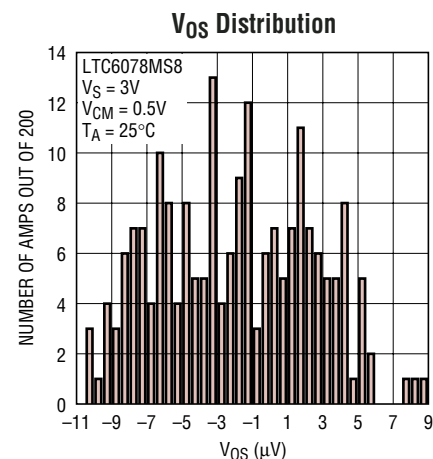
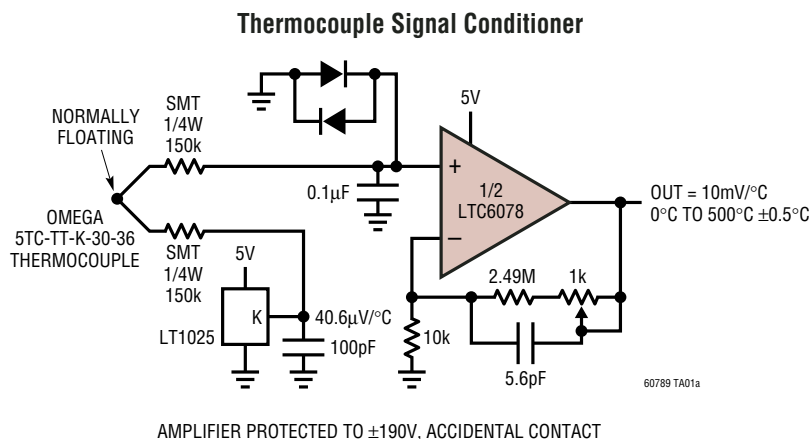
Input offset voltage is trimmed to less than 25 $\mu$ V and the CMOS inputs draw less than 50pA of bias current. The low offset drift, excellent CMRR, and high voltage gain make it a good choice for precision signal conditioning.

Each amplifier draws only 54 $\mu$ A current on a 3V supply. The micropower, rail-to-rail operation of the LTC6078/LTC6079 is well suited for portable instruments and single supply applications.

The LTC6078/LTC6079 are specified on power supply voltages of 3V and 5V from –40 to 125°C. The dual amplifier LTC6078 is available in 8-lead MSOP and 10-lead DFN packages. The quad amplifier LTC6079 is available in 16-lead SSOP and DFN packages.

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## TYPICAL APPLICATION



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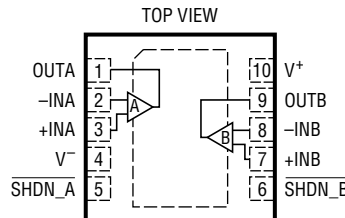
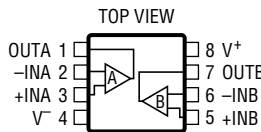
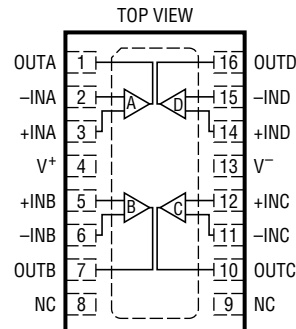
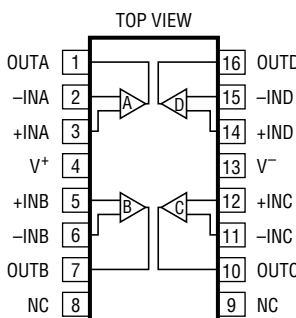
## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                               |                |
|-----------------------------------------------|----------------|
| Total Supply Voltage ( $V^+$ to $V^-$ ) ..... | 6V             |
| Input Voltage.....                            | $V^-$ to $V^+$ |
| Output Short Circuit Duration (Note 2) .....  | Indefinite     |
| Operating Temperature Range (Note 3)          |                |
| LTC6078C, LTC6079C .....                      | -40°C to 85°C  |
| LTC6078I, LTC6079I .....                      | -40°C to 85°C  |
| LTC6078H, LTC6079H.....                       | -40°C to 125°C |
| (Not Available in DFN Package)                |                |

|                                           |                |
|-------------------------------------------|----------------|
| Specified Temperature Range (Note 4)      |                |
| LTC6078C, LTC6079C .....                  | 0°C to 70°C    |
| LTC6078I, LTC6079I .....                  | -40°C to 85°C  |
| LTC6078H, LTC6079H.....                   | -40°C to 125°C |
| Junction Temperature                      |                |
| DFN Packages.....                         | 125°C          |
| All Other Packages.....                   | 150°C          |
| Storage Temperature Range                 |                |
| DFN Packages.....                         | -65°C to 125°C |
| All Other Packages.....                   | -65°C to 150°C |
| Lead Temperature (Soldering, 10 Sec)..... | 300°C          |

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           |                                                                                           |                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------------|
| <div><p>TOP VIEW</p><p>DD PACKAGE<br/>10-LEAD (3mm x 3mm) PLASTIC DFN<br/><math>T_{JMAX} = 125^{\circ}\text{C}</math>, <math>\theta_{JA} = 43^{\circ}\text{C/W}</math><br/>UNDERSIDE METAL CONNECTED TO <math>V^{-}</math></p></div>   | <div><p>TOP VIEW</p><p>MS8 PACKAGE<br/>8-LEAD PLASTIC MSOP<br/><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 200^{\circ}\text{C/W}</math></p></div>  | ORDER PART NUMBER                                                                         | DD PART MARKING*                                   |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | LTC6078CDD<br>LTC6078IDD                                                                  | LBBB<br>LBBB                                       |
| <div><p>TOP VIEW</p><p>DHC PACKAGE<br/>16-LEAD (5mm x 3mm) PLASTIC DFN<br/><math>T_{JMAX} = 125^{\circ}\text{C}</math>, <math>\theta_{JA} = 43^{\circ}\text{C/W}</math><br/>UNDERSIDE METAL CONNECTED TO <math>V^{-}</math></p></div> | <div><p>TOP VIEW</p><p>GN PACKAGE<br/>16-LEAD PLASTIC SSOP<br/><math>T_{JMAX} = 150^{\circ}\text{C}</math>, <math>\theta_{JA} = 110^{\circ}\text{C/W}</math></p></div> | ORDER PART NUMBER                                                                         | MS8 PART MARKING*                                  |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | LTC6078ACMS8<br>LTC6078CMS8<br>LTC6078AIMS8<br>LTC6078IMS8<br>LTC6078AHMS8<br>LTC6078HMS8 | LTAJZ<br>LTAJZ<br>LTAJZ<br>LTAJZ<br>LTAJZ<br>LTAJZ |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | ORDER PART NUMBER                                                                         | DHC PART MARKING*                                  |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | LTC6079CDHC<br>LTC6079IDHC                                                                | 6079<br>6079                                       |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | ORDER PART NUMBER                                                                         | GN PART MARKING                                    |
|                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                           | LTC6079CGN<br>LTC6079IGN<br>LTC6079HGN                                                    | 6079<br>6079I<br>6079H                             |

Order Options Tape and Reel: Add #TR  
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF  
Lead Free Part Marking: <http://www.linear.com/leadfree/>

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

\*The temperature grades and parametric grades are identified by a label on the shipping container.

**ELECTRICAL CHARACTERISTICS** The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . Test conditions are  $V^+ = 3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = 0.5\text{V}$  unless otherwise noted.

| SYMBOL                          | PARAMETER                                                   | CONDITIONS                                                                       | C, I SUFFIXES |           |           | H SUFFIX |           |           | UNITS                        |
|---------------------------------|-------------------------------------------------------------|----------------------------------------------------------------------------------|---------------|-----------|-----------|----------|-----------|-----------|------------------------------|
|                                 |                                                             |                                                                                  | MIN           | TYP       | MAX       | MIN      | TYP       | MAX       |                              |
| $V_{\text{OS}}$                 | Offset Voltage (Note 5)                                     | LTC6078MS8, LTC6078AMS8, LTC6079GN                                               |               |           |           |          |           |           | $\mu\text{V}$                |
|                                 |                                                             | $V_{\text{CM}} = 0.5\text{V}, 2.5\text{V}$                                       |               | $\pm 7$   | $\pm 25$  |          | $\pm 7$   | $\pm 25$  | $\mu\text{V}$                |
|                                 |                                                             | LTC6078DD, LTC6079DHC                                                            |               | $\pm 7$   | $\pm 30$  |          |           |           | $\mu\text{V}$                |
|                                 |                                                             | LTC6078AMS8                                                                      | ●             | $\pm 20$  | $\pm 70$  |          | $\pm 25$  | $\pm 95$  | $\mu\text{V}$                |
|                                 |                                                             | LTC6078MS8                                                                       | ●             | $\pm 25$  | $\pm 97$  |          | $\pm 30$  | $\pm 135$ | $\mu\text{V}$                |
|                                 |                                                             | LTC6079GN                                                                        | ●             | $\pm 30$  | $\pm 115$ |          | $\pm 35$  | $\pm 165$ | $\mu\text{V}$                |
|                                 |                                                             | LTC6078DD                                                                        | ●             | $\pm 30$  | $\pm 120$ |          |           |           | $\mu\text{V}$                |
|                                 |                                                             | LTC6079DHC                                                                       | ●             | $\pm 35$  | $\pm 150$ |          |           |           | $\mu\text{V}$                |
| $\Delta V_{\text{OS}}/\Delta T$ | Input Offset Voltage Drift (Note 5)                         | LTC6078AMS8                                                                      | ●             | $\pm 0.2$ | $\pm 0.7$ |          | $\pm 0.2$ | $\pm 0.7$ | $\mu\text{V}/^\circ\text{C}$ |
|                                 |                                                             | LTC6078MS8                                                                       | ●             |           | $\pm 1.1$ |          |           | $\pm 1.1$ | $\mu\text{V}/^\circ\text{C}$ |
|                                 |                                                             | LTC6078DD, LTC6079GN                                                             | ●             | $\pm 0.3$ | $\pm 1.4$ |          | $\pm 0.3$ | $\pm 1.4$ | $\mu\text{V}/^\circ\text{C}$ |
|                                 |                                                             | LTC6079DHC                                                                       | ●             | $\pm 0.3$ | $\pm 1.8$ |          |           |           | $\mu\text{V}/^\circ\text{C}$ |
| $I_{\text{B}}$                  | Input Bias Current (Note 6)                                 | $V_{\text{CM}} = V^+/2$                                                          |               | 0.2       | 1         |          | 0.2       | 1         | pA                           |
|                                 |                                                             | $V_{\text{CM}} = V^+/2$                                                          | ●             | 10        | 50        |          | 150       | 350       | pA                           |
| $I_{\text{OS}}$                 | Input Offset Current (Note 6)                               | $V_{\text{CM}} = V^+/2$                                                          |               | 0.1       |           |          | 0.1       |           | pA                           |
|                                 |                                                             | $V_{\text{CM}} = V^+/2$                                                          | ●             | 0.5       | 25        |          | 10        | 100       | pA                           |
| $e_{\text{n}}$                  | Input Noise Voltage                                         | 0.1Hz to 10Hz                                                                    |               | 1         |           |          | 1         |           | $\mu\text{V}_{\text{P-P}}$   |
|                                 |                                                             |                                                                                  |               |           |           |          |           |           |                              |
|                                 | Input Noise Voltage Density                                 | $f = 1\text{kHz}$                                                                |               | 18        |           |          | 18        |           | $\text{nV}/\sqrt{\text{Hz}}$ |
|                                 |                                                             | $f = 10\text{kHz}$                                                               |               | 16        |           |          | 16        |           | $\text{nV}/\sqrt{\text{Hz}}$ |
| $i_{\text{n}}$                  | Input Noise Current Density (Note 8)                        |                                                                                  |               | 0.56      |           |          | 0.56      |           | $\text{fA}/\sqrt{\text{Hz}}$ |
|                                 |                                                             |                                                                                  |               |           |           |          |           |           |                              |
|                                 | Input Common Mode Range                                     |                                                                                  | ●             | $V^-$     | $V^+$     | $V^-$    | $V^+$     |           | V                            |
| $C_{\text{DIFF}}$               | Differential Input Capacitance                              |                                                                                  |               | 10        |           |          | 10        |           | pF                           |
| $C_{\text{CM}}$                 | Common Mode Input Capacitance                               |                                                                                  |               | 18        |           |          | 18        |           | pF                           |
| CMRR                            | Common Mode Rejection Ratio                                 | All Packages                                                                     |               | 95        | 110       |          | 95        | 110       | dB                           |
|                                 |                                                             | LTC6078AMS8                                                                      | ●             | 87        | 105       |          | 87        | 103       | dB                           |
|                                 |                                                             | LTC6078AMS8                                                                      | ●             | 91        | 103       |          | 91        | 103       | dB                           |
|                                 |                                                             | LTC6078MS8                                                                       | ●             | 85        | 102       |          | 85        | 100       | dB                           |
|                                 |                                                             | LTC6078MS8                                                                       | ●             | 89        | 102       |          | 89        | 102       | dB                           |
|                                 |                                                             | LTC6079GN                                                                        | ●             | 84        | 102       |          | 84        | 100       | dB                           |
|                                 |                                                             | LTC6079GN                                                                        | ●             | 88        | 102       |          | 88        | 102       | dB                           |
|                                 |                                                             | LTC6078DD, LTC6079DHC                                                            | ●             | 83        | 100       |          |           |           | dB                           |
|                                 |                                                             | LTC6078DD, LTC6079DHC                                                            | ●             | 87        | 102       |          |           |           | dB                           |
| PSRR                            | Power Supply Rejection Ratio                                | $V_{\text{S}} = 2.7\text{V to } 5.5\text{V}$                                     |               | 100       | 120       |          | 100       | 120       | dB                           |
|                                 |                                                             |                                                                                  | ●             | 97        |           |          | 97        |           | dB                           |
| $V_{\text{OUT}}$                | Output Voltage, High (Referred to $V^+$ )                   | No Load                                                                          |               |           | 1         |          |           | 1         | mV                           |
|                                 |                                                             | $I_{\text{SOURCE}} = 0.2\text{mA}$                                               | ●             | 35        | 15        |          | 40        | 15        | mV                           |
|                                 |                                                             | $I_{\text{SOURCE}} = 2\text{mA}$                                                 | ●             | 350       | 150       |          | 400       | 150       | mV                           |
|                                 | Output Voltage, Low (Referred to $V^-$ )                    | No Load                                                                          |               |           | 1         |          |           | 1         | mV                           |
|                                 |                                                             | $I_{\text{SINK}} = 0.2\text{mA}$                                                 | ●             |           | 10        | 30       |           | 10        | 35                           |
|                                 |                                                             | $I_{\text{SINK}} = 2\text{mA}$                                                   | ●             |           | 100       | 300      |           | 100       | 350                          |
| $A_{\text{VOL}}$                | Large-Signal Voltage Gain                                   | $R_{\text{LOAD}} = 10\text{k}, 0.5\text{V} \leq V_{\text{OUT}} \leq 2.5\text{V}$ | ●             | 115       | 130       |          | 110       | 125       | dB                           |
| $I_{\text{SC}}$                 | Output Short-Circuit Current                                | Source                                                                           | ●             | 5         | 10        |          | 4         | 10        | mA                           |
|                                 |                                                             | Sink                                                                             | ●             | 7         | 14        |          | 6         | 14        | mA                           |
| SR                              | Slew Rate                                                   | $A_{\text{V}} = 1$                                                               |               |           | 0.05      |          |           | 0.05      | V/ $\mu\text{s}$             |
| GBW                             | Gain-Bandwidth Product ( $f_{\text{TEST}} = 10\text{kHz}$ ) | $R_{\text{L}} = 100\text{k}$                                                     |               | 420       | 750       |          | 420       | 750       | kHz                          |
|                                 |                                                             |                                                                                  | ●             | 360       |           |          | 320       |           | kHz                          |
| $\Phi_0$                        | Phase Margin                                                | $R_{\text{L}} = 10\text{k}, C_{\text{L}} = 200\text{pF}$                         |               |           | 66        |          |           | 66        | Deg                          |
| $t_{\text{S}}$                  | Settling Time 0.1%                                          | $A_{\text{V}} = 1, 1\text{V Step}$                                               |               |           | 24        |          |           | 24        | $\mu\text{s}$                |

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# LTC6078/LTC6079

**ELECTRICAL CHARACTERISTICS** The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . Test conditions are  $V^+ = 3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{CM} = 0.5\text{V}$  unless otherwise noted.

| SYMBOL    | PARAMETER                               | CONDITIONS                                                                          |        | C, I SUFFIXES |      |          | H SUFFIX |      |          | UNITS                          |
|-----------|-----------------------------------------|-------------------------------------------------------------------------------------|--------|---------------|------|----------|----------|------|----------|--------------------------------|
|           |                                         |                                                                                     |        | MIN           | TYP  | MAX      | MIN      | TYP  | MAX      |                                |
| $I_S$     | Supply Current (per Amplifier)          | No Load                                                                             | ●      |               | 54   | 72<br>78 |          | 54   | 72<br>80 | $\mu\text{A}$<br>$\mu\text{A}$ |
|           | Shutdown Current (per Amplifier)        | Shutdown, $V_{SHDN} \leq 0.8\text{V}$ , LTC6078DD                                   | ●      |               | 0.3  | 1        |          |      |          | $\mu\text{A}$                  |
| $V_S$     | Supply Voltage Range                    | Guaranteed by the PSRR Test                                                         | ●      | 2.7           |      | 5.5      | 2.7      |      | 5.5      | V                              |
|           | Channel Separation                      | $f_s = 10\text{kHz}$ , $R_L = 10\text{k}$                                           |        |               | -110 |          |          | -110 |          | dB                             |
|           | Shutdown Logic                          | $\overline{\text{SHDN}}$ High, LTC6078DD<br>$\overline{\text{SHDN}}$ Low, LTC6078DD | ●<br>● | 2             |      | 0.8      | 2        |      | 0.8      | V<br>V                         |
| $t_{ON}$  | Turn on Time                            | $V_{SHDN} = 0.8\text{V}$ to $2\text{V}$ , LTC6078DD                                 |        |               | 50   |          |          | 50   |          | $\mu\text{s}$                  |
| $t_{OFF}$ | Turn off Time                           | $V_{SHDN} = 2\text{V}$ to $0.8\text{V}$ , LTC6078DD                                 |        |               | 2    |          |          | 2    |          | $\mu\text{s}$                  |
|           | Leakage of $\overline{\text{SHDN}}$ Pin | $V_{SHDN} = 0\text{V}$ , LTC6078DD                                                  |        |               | 0.6  |          |          |      |          | $\mu\text{A}$                  |

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . Test conditions are  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{CM} = 0.5\text{V}$  unless otherwise noted.

| SYMBOL                   | PARAMETER                            | CONDITIONS                                                                                                                                                                                                                                                                                                             |                                                | C, I SUFFIXES |                                                                                              |                                                                                      | H SUFFIX |                                                          |                                                 | UNITS                                                                                                                                |
|--------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|---------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------|----------------------------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
|                          |                                      |                                                                                                                                                                                                                                                                                                                        |                                                | MIN           | TYP                                                                                          | MAX                                                                                  | MIN      | TYP                                                      | MAX                                             |                                                                                                                                      |
| $V_{OS}$                 | Offset Voltage                       | LTC6078MS8, LTC6078AMS8, LTC6079GN<br>$V_{CM} = 0.5\text{V}$<br>LTC6078DD, LTC6079DHC<br>$V_{CM} = 0.5\text{V}$<br>LTC6078AMS8<br>$V_{CM} = 0.5\text{V}$<br>LTC6078MS8<br>$V_{CM} = 0.5\text{V}$<br>LTC6079GN<br>$V_{CM} = 0.5\text{V}$<br>LTC6078DD<br>$V_{CM} = 0.5\text{V}$<br>LTC6079DHC<br>$V_{CM} = 0.5\text{V}$ | ●<br>●<br>●<br>●<br>●<br>●<br>●<br>●<br>●<br>● |               | $\pm 10$<br>$\pm 10$<br>$\pm 20$<br>$\pm 25$<br>$\pm 30$<br>$\pm 30$<br>$\pm 30$<br>$\pm 35$ | $\pm 30$<br>$\pm 35$<br>$\pm 75$<br>$\pm 102$<br>$\pm 120$<br>$\pm 125$<br>$\pm 155$ |          | $\pm 10$<br>$\pm 10$<br>$\pm 25$<br>$\pm 30$<br>$\pm 35$ | $\pm 30$<br>$\pm 100$<br>$\pm 140$<br>$\pm 170$ | $\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$<br>$\mu\text{V}$ |
| $\Delta V_{OS}/\Delta T$ | Input Offset Voltage Drift (Note 7)  | LTC6078AMS8<br>LTC6078MS8<br>LTC6078DD, LTC6079GN<br>LTC6079DHC                                                                                                                                                                                                                                                        | ●<br>●<br>●<br>●                               |               | $\pm 0.2$<br>$\pm 0.3$<br>$\pm 0.3$                                                          | $\pm 0.7$<br>$\pm 1.1$<br>$\pm 1.4$<br>$\pm 1.8$                                     |          | $\pm 0.2$<br>$\pm 0.3$                                   | $\pm 0.7$<br>$\pm 1.1$<br>$\pm 1.4$             | $\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$         |
| $I_B$                    | Input Bias Current                   | $V_{CM} = V^+/2$<br>$V_{CM} = V^+/2$                                                                                                                                                                                                                                                                                   | ●                                              |               | 0.2<br>10                                                                                    | 1<br>50                                                                              |          | 0.2<br>150                                               | 1<br>350                                        | pA<br>pA                                                                                                                             |
| $I_{OS}$                 | Input Offset Current                 | $V_{CM} = V^+/2$<br>$V_{CM} = V^+/2$                                                                                                                                                                                                                                                                                   | ●                                              |               | 0.1<br>0.5                                                                                   | 25                                                                                   |          | 0.1<br>10                                                | 100                                             | pA<br>pA                                                                                                                             |
| $e_n$                    | Input Noise Voltage                  | 0.1Hz to 10Hz                                                                                                                                                                                                                                                                                                          |                                                |               | 1                                                                                            |                                                                                      |          | 1                                                        |                                                 | $\mu\text{V}_{P-P}$                                                                                                                  |
|                          | Input Noise Voltage Density          | $f = 1\text{kHz}$<br>$f = 10\text{kHz}$                                                                                                                                                                                                                                                                                |                                                |               | 18<br>16                                                                                     |                                                                                      |          | 18<br>16                                                 |                                                 | $\text{nV}/\sqrt{\text{Hz}}$<br>$\text{nV}/\sqrt{\text{Hz}}$                                                                         |
| $i_n$                    | Input Noise Current Density (Note 8) |                                                                                                                                                                                                                                                                                                                        |                                                |               | 0.56                                                                                         |                                                                                      |          | 0.56                                                     |                                                 | $\text{fA}/\sqrt{\text{Hz}}$                                                                                                         |
|                          | Input Common Mode Range              |                                                                                                                                                                                                                                                                                                                        | ●                                              | $V^-$         |                                                                                              | $V^+$                                                                                | $V^-$    |                                                          | $V^+$                                           | V                                                                                                                                    |
| $C_{DIFF}$               | Differential Input Capacitance       |                                                                                                                                                                                                                                                                                                                        |                                                |               | 10                                                                                           |                                                                                      |          | 10                                                       |                                                 | pF                                                                                                                                   |
| $C_{CM}$                 | Common Mode Input Capacitance        |                                                                                                                                                                                                                                                                                                                        |                                                |               | 18                                                                                           |                                                                                      |          | 18                                                       |                                                 | pF                                                                                                                                   |

# ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . Test conditions are  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = 0.5\text{V}$  unless otherwise noted.

| SYMBOL           | PARAMETER                                                   | CONDITIONS                                                                          | C, I SUFFIXES |     |      | H SUFFIX |      |     | UNITS            |
|------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------|-----|------|----------|------|-----|------------------|
|                  |                                                             |                                                                                     | MIN           | TYP | MAX  | MIN      | TYP  | MAX |                  |
| CMRR             | Common Mode Rejection Ratio                                 | All Packages $V_{\text{CM}} = 0\text{V to } 5\text{V}$                              | ●             | 91  | 105  | 91       | 105  |     | dB               |
|                  |                                                             | LTC6078AMS8 $V_{\text{CM}} = 0\text{V to } 5\text{V}$                               | ●             | 90  | 105  | 90       | 105  |     | dB               |
|                  |                                                             | LTC6078AMS8 $V_{\text{CM}} = 0\text{V to } 3.7\text{V}$                             | ●             | 94  | 105  | 94       | 105  |     | dB               |
|                  |                                                             | LTC6078MS8 $V_{\text{CM}} = 0\text{V to } 5\text{V}$                                | ●             | 88  | 100  | 88       | 100  |     | dB               |
|                  |                                                             | LTC6078MS8 $V_{\text{CM}} = 0\text{V to } 3.7\text{V}$                              | ●             | 90  | 105  | 90       | 105  |     | dB               |
|                  |                                                             | LTC6079GN $V_{\text{CM}} = 0\text{V to } 5\text{V}$                                 | ●             | 86  | 100  | 86       | 100  |     | dB               |
|                  |                                                             | LTC6079GN $V_{\text{CM}} = 0\text{V to } 3.7\text{V}$                               | ●             | 90  | 105  | 90       | 105  |     | dB               |
|                  |                                                             | LTC6078DD, LTC6079DHC $V_{\text{CM}} = 0\text{V to } 5\text{V}$                     | ●             | 86  | 100  |          |      |     | dB               |
|                  |                                                             | LTC6078DD, LTC6079DHC $V_{\text{CM}} = 0\text{V to } 3.7\text{V}$                   | ●             | 90  | 105  |          |      |     | dB               |
| PSRR             | Power Supply Rejection Ratio                                | $V_S = 2.7\text{V to } 5.5\text{V}$                                                 | ●             | 100 | 120  |          |      |     | dB               |
|                  |                                                             |                                                                                     |               | 97  |      | 97       | 120  |     | dB               |
| $V_{\text{OUT}}$ | Output Voltage, High (Referred to $V^+$ )                   | No Load                                                                             | ●             |     | 2    |          | 2    |     | mV               |
|                  |                                                             | $I_{\text{SOURCE}} = 0.5\text{mA}$                                                  | ●             | 50  | 20   | 55       | 20   |     | mV               |
|                  |                                                             | $I_{\text{SOURCE}} = 5\text{mA}$                                                    | ●             | 500 | 200  | 550      | 200  |     | mV               |
|                  | Output Voltage, Low (Referred to $V^-$ )                    | No Load                                                                             | ●             |     | 1    |          | 1    |     | mV               |
|                  |                                                             | $I_{\text{SINK}} = 0.5\text{mA}$                                                    | ●             |     | 15   | 40       | 15   | 45  | mV               |
|                  |                                                             | $I_{\text{SINK}} = 5\text{mA}$                                                      | ●             |     | 150  | 400      | 150  | 450 | mV               |
| $A_{\text{VOL}}$ | Large-Signal Voltage Gain                                   | $R_{\text{LOAD}} = 10\text{k}$ , $0.5\text{V} \leq V_{\text{OUT}} \leq 4.5\text{V}$ | ●             | 115 | 130  | 110      | 125  |     | dB               |
| $I_{\text{SC}}$  | Output Short-Circuit Current                                | Source                                                                              | ●             | 14  | 25   | 12       | 25   |     | mA               |
|                  |                                                             | Sink                                                                                | ●             | 14  | 25   | 12       | 25   |     | mA               |
| SR               | Slew Rate                                                   | $A_V = 1$                                                                           |               |     | 0.05 |          | 0.05 |     | V/ $\mu\text{s}$ |
| GBW              | Gain-Bandwidth Product ( $f_{\text{TEST}} = 10\text{kHz}$ ) | $R_L = 100\text{k}$                                                                 | ●             | 420 | 750  | 420      | 750  |     | kHz              |
|                  |                                                             |                                                                                     |               | 360 |      | 320      |      |     | kHz              |
| $\Phi_0$         | Phase Margin                                                | $R_L = 10\text{k}$ , $C_L = 200\text{pF}$                                           |               |     | 66   |          | 66   |     | Deg              |
| $t_S$            | Settling Time 0.1%                                          | $A_V = 1$ , 1V Step                                                                 |               |     | 24   |          | 24   |     | $\mu\text{s}$    |
| $I_S$            | Supply Current (per Amplifier)                              | No Load                                                                             | ●             |     | 55   | 74       | 55   | 74  | $\mu\text{A}$    |
|                  |                                                             |                                                                                     |               |     |      | 82       |      | 84  | $\mu\text{A}$    |
|                  | Shutdown Current (per Amplifier)                            | Shutdown, $V_{\text{SHDN}} \leq 1.2\text{V}$ , LTC6078DD                            | ●             |     | 1.5  | 5        | 1.5  | 5   | $\mu\text{A}$    |
| $V_S$            | Supply Voltage Range                                        | Guaranteed by the PSRR Test                                                         | ●             | 2.7 | 5.5  | 2.7      | 5.5  |     | V                |
|                  | Channel Separation                                          | $f_S = 10\text{kHz}$ , $R_L = 10\text{k}$                                           |               |     | -110 |          | -110 |     | dB               |
|                  | Shutdown Logic                                              | $\text{SHDN High}$ , LTC6078DD<br>$\text{SHDN Low}$ , LTC6078DD                     | ●<br>●        | 3.5 | 1.2  | 3.5      | 1.2  |     | V<br>V           |
| $t_{\text{ON}}$  | Turn on Time                                                | $V_{\text{SHDN}} = 1.2\text{V to } 3.5\text{V}$ , LTC6078DD                         |               |     | 50   |          | 50   |     | $\mu\text{s}$    |
| $t_{\text{OFF}}$ | Turn off Time                                               | $V_{\text{SHDN}} = 1.2\text{V to } 3.5\text{V}$ , LTC6078DD                         |               |     | 2    |          | 2    |     | $\mu\text{s}$    |
|                  | Leakage of SHDN Pin                                         | $V_{\text{SHDN}} = 0\text{V}$ , LTC6078DD                                           |               |     | 0.6  |          |      |     | $\mu\text{A}$    |

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted.

**Note 3:** The LTC6078C/LTC6079C and LTC6078I/LTC6079I are guaranteed functional over the operating temperature range of  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ . The LTC6078H/LTC6079H are guaranteed functional over the operating temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**Note 4:** The LTC6078C/LTC6079C are guaranteed to meet specified

performance from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ . The LTC6078C/LTC6079C are designed, characterized and expected to meet specified performance from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  but are not tested or QA sampled at these temperatures. The LTC6078I/LTC6079I are guaranteed to meet specified performance from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ . The LTC6078H/LTC6079H are guaranteed to meet specified performance from  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

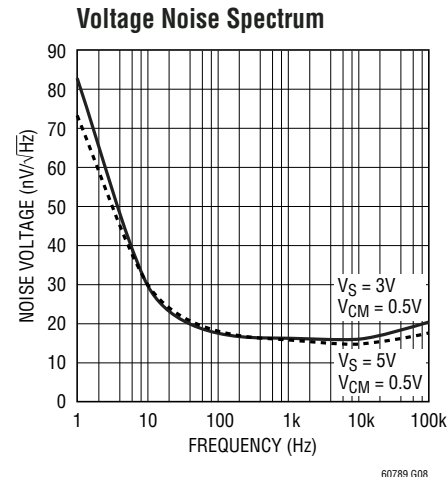
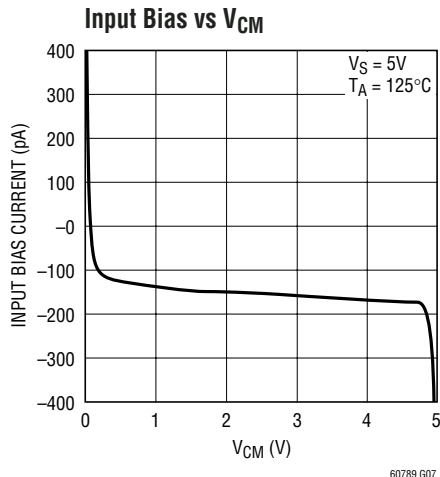
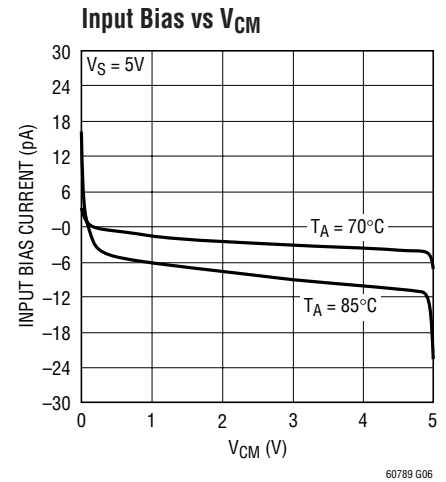
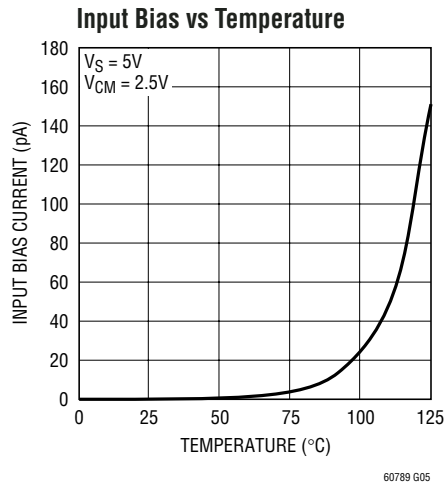
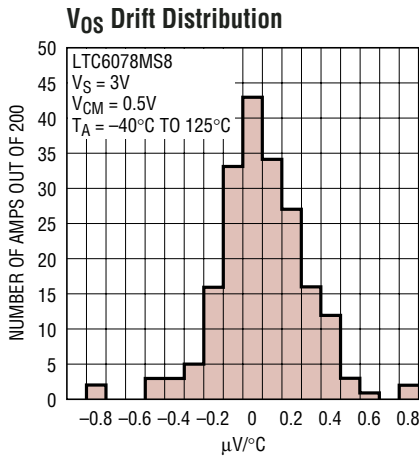
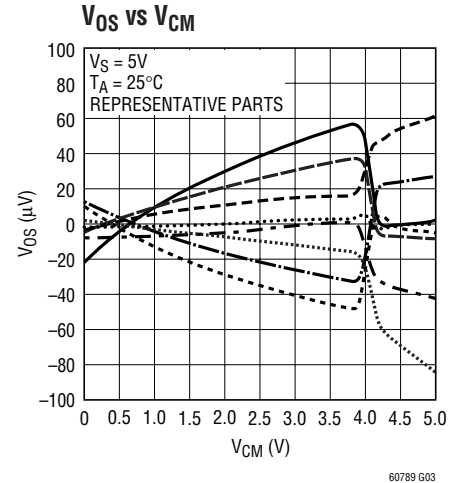
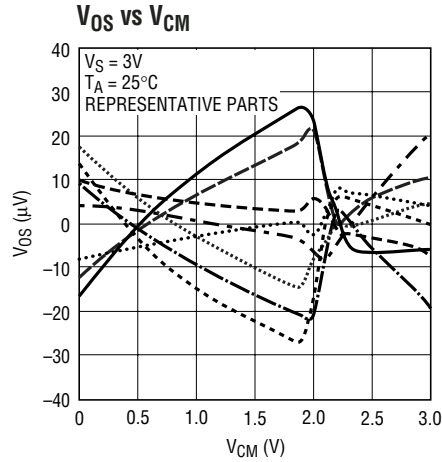
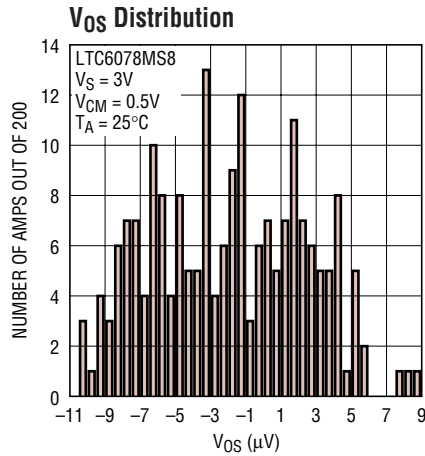
**Note 5:**  $V_{\text{OS}}$  and  $V_{\text{OS}}$  drift are 100% tested at  $25^\circ\text{C}$  and  $125^\circ\text{C}$ .

**Note 6:**  $I_B$  and  $I_{\text{OS}}$  are guaranteed by the  $V_S = 5\text{V}$  test.

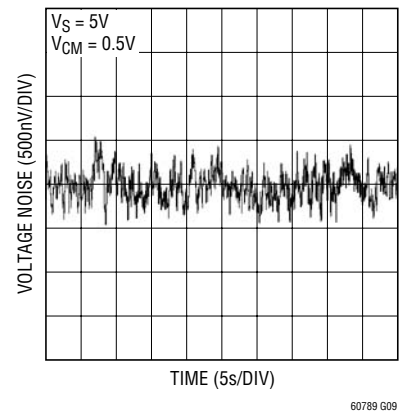
**Note 7:**  $V_{\text{OS}}$  drift is guaranteed by the  $V_S = 3\text{V}$  test.

**Note 8:** Current noise is calculated from  $i_n = \sqrt{2qI_B}$ , where  $q = 1.6 \cdot 10^{-19}$  coulomb.

## TYPICAL PERFORMANCE CHARACTERISTICS



### 0.1Hz to 10Hz Output Voltage Noise



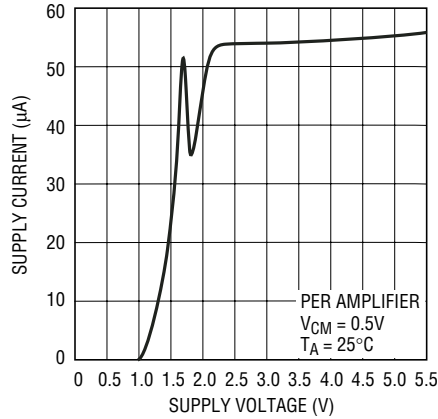
## TYPICAL PERFORMANCE CHARACTERISTICS

Output Voltage Swing vs Load Current



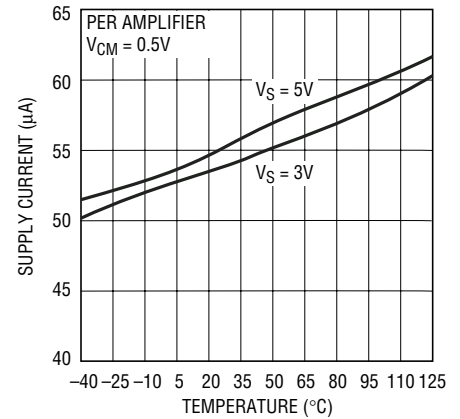
60789 G10

Supply Current vs Supply Voltage



60789 G11

Supply Current vs Temperature



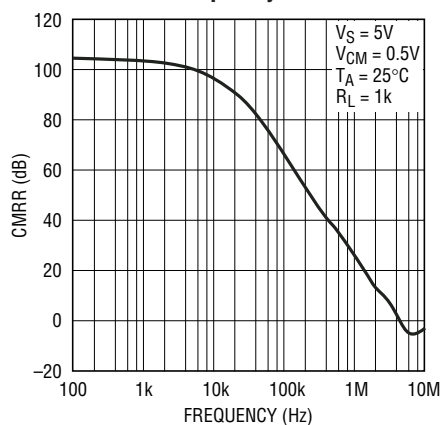
60789 G12

Open Loop Gain vs Frequency



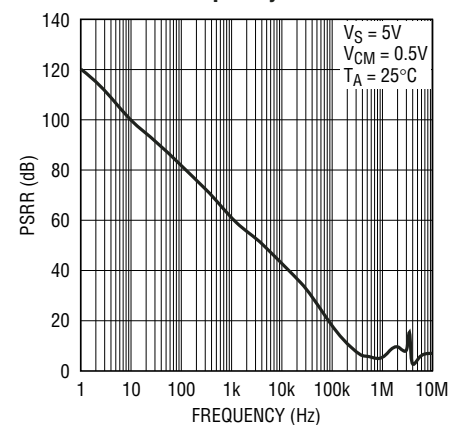
60789 G13

CMRR vs Frequency



60789 G14

PSRR vs Frequency



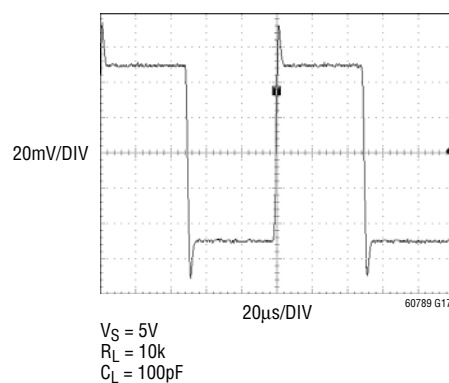
60789 G15

Output Impedance vs Frequency



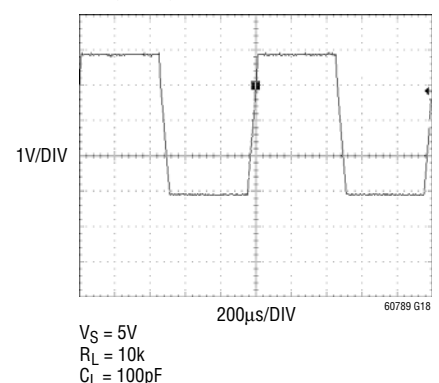
60789 G16

Small Signal Transient



60789 G17

Large Signal Transient



60789 G18

## TYPICAL PERFORMANCE CHARACTERISTICS

Disabled Output Impedance vs Frequency

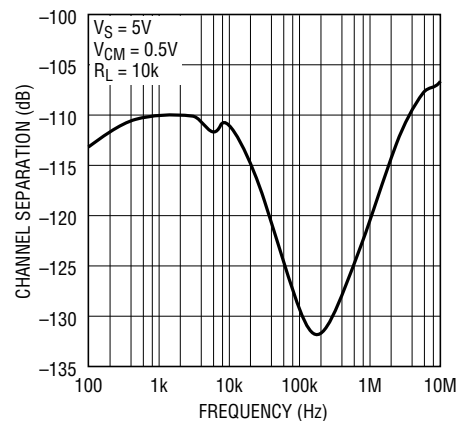


60789 G19

Overshoot vs  $C_L$ 

60789 G20

Channel Separation vs Frequency



60789 G21

## PIN FUNCTIONS

**OUT:** Amplifier Output**-IN:** Inverting Input**+IN:** Noninverting Input**V+:** Positive Supply**V-:** Negative Supply

**SHDN\_A:** Shutdown Pin of Amplifier A, active low and only valid for LTC6078DD. An internal current source pulls the pin to  $V^+$  when floating.

**SHDN\_B:** Shutdown Pin of Amplifier B, active low and only valid for LTC6078DD. An internal current source pulls the pin to  $V^+$  when floating.

**NC:** Not internally connected.

**Exposed Pad:** Connected to  $V^-$ .

## APPLICATIONS INFORMATION

### Preserving Input Precision

Preserving input accuracy of the LTC6078/LTC6079 requires that the application circuit and PC board layout do not introduce errors comparable or greater than the  $10\mu\text{V}$  typical offset of the amplifiers. Temperature differentials across the input connections can generate thermocouple voltages of 10's of microvolts so the connections to the input leads should be short, close together and away from heat dissipating components. Air current across the board can also generate temperature differentials.

The extremely low input bias currents ( $0.2\text{pA}$  typical) allow high accuracy to be maintained with high impedance sources and feedback resistors. Leakage currents on the PC board can be higher than the input bias current. For example,  $10\text{G}\Omega$  of leakage between a  $5\text{V}$  supply lead and an input lead will generate  $500\text{pA}$ ! Surround the input leads with a guard ring driven to the same potential as the input common mode to avoid excessive leakage in high impedance applications.

### Input Clamps

Large differential voltages across the inputs over very long time periods can impact the precisely trimmed input offset voltage of the LTC6078/LTC6079. As an example, a  $2\text{V}$  differential voltage between the inputs over a period of 100 hours can shift the input offset voltage by tens of microvolts. If the amplifier is to be subjected to large differential input voltages, adding back-to-back diodes between the two inputs will minimize this shift and retain the DC precision. If necessary, current-limiting series resistors can be added in front of the diodes, as shown in Figure 1. These diodes are not necessary for normal closed loop applications.

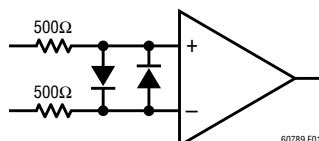


Figure 1. Op Amp with Input Voltage Clamp

### Capacitive Load

LTC6078/LTC6079 can drive capacitive load up to  $200\text{pF}$  in unity gain. The capacitive load driving capability increases as the amplifier is used in higher gain configurations. A small series resistance between the output and the load further increases the amount of capacitance the amplifier can drive.

### SHDN Pins

Pins 5 and 6 are used for power shutdown on the LTC6078 in the DD package. If they are floating, internal current sources pull Pins 5 and 6 to  $V+$  and the amplifiers operate normally. In shutdown, the amplifier output is high impedance, and each amplifier draws less than  $2\mu\text{A}$  current.

When the chip is turned on, the supply current per amplifier is about  $35\mu\text{A}$  larger than its normal values for  $50\mu\text{s}$ .

### Rail-to-Rail Input

The input stage of LTC6078/LTC6079 combines both PMOS and NMOS differential pairs, extending its input common mode voltage range to both positive and negative supply voltages. At high input common mode range, the NMOS pair is on. At low common mode range, the PMOS pair is on. The transition happens when the common voltage is between  $1.3\text{V}$  and  $0.9\text{V}$  below the positive supply.

### Thermal Hysteresis

Figure 2 shows the input offset hysteresis of LTC6078MS8 for 3 thermal cycles from  $-45^\circ\text{C}$  to  $90^\circ\text{C}$ . The typical offset shift after the 3 cycles is only  $1\mu\text{V}$ .

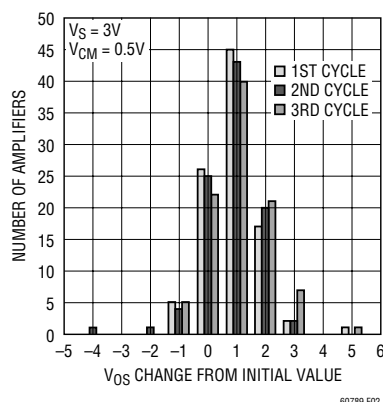


Figure 2.  $V_{OS}$  Thermal Hysteresis of LTC6078MS8

60789fa

## APPLICATIONS INFORMATION

### PC Board Layout

Mechanical stress on a PC board and soldering-induced stress can cause the  $V_{OS}$  and  $V_{OS}$  drift to shift. The DD and DHC packages are more sensitive to stress. A simple way to reduce the stress-related shifts is to mount the IC near the short edge of the PC board, or in a corner. The board edge acts as a stress boundary, or a region where the flexure of the board is minimum. The package should always be mounted so that the leads absorb the stress and not the package. The package is generally aligned with the leads parallel to the long side of the PC board.

The most effective technique to relieve the PC board stress is to cut slots in the board around the op amp. These slots can be cut on three sides of the IC and the leads can exit on

the fourth side. Figure 3 shows the layout of a LTC6078DD with slots at three sides.

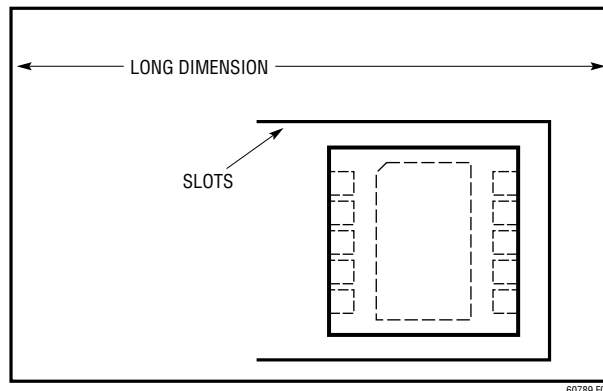
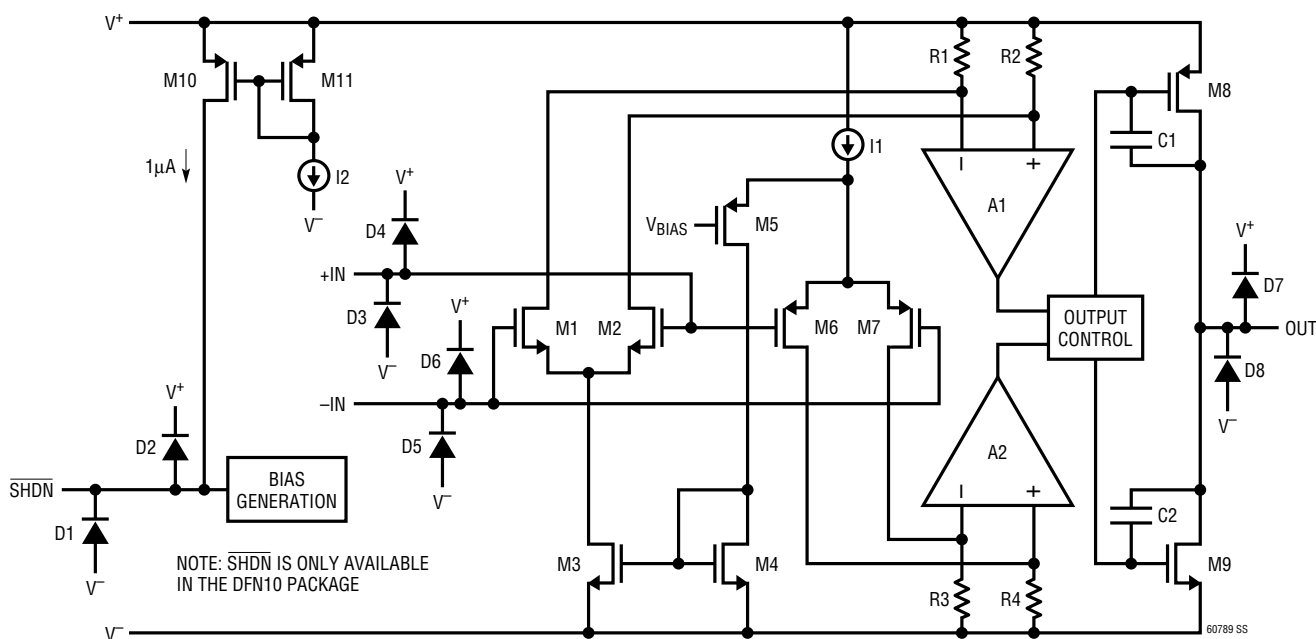


Figure 3. Vertical Orientation of LTC6078DD with Slots

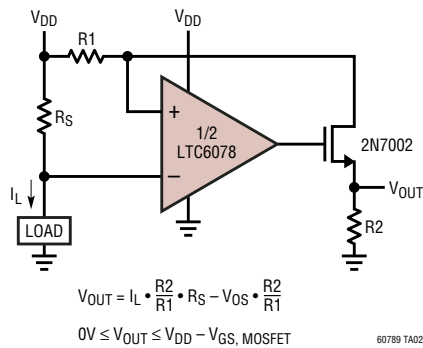
## SIMPLIFIED SCHEMATIC



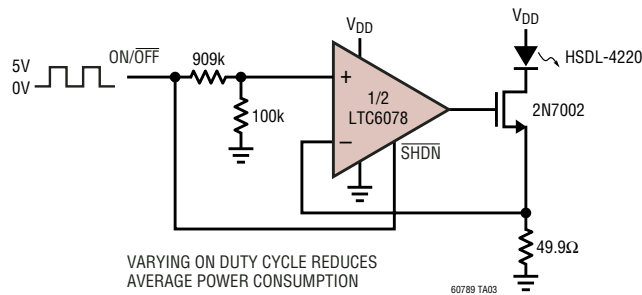
Simplified Schematic of the Amplifier

## TYPICAL APPLICATIONS

## 2.7V High Side Current Sense



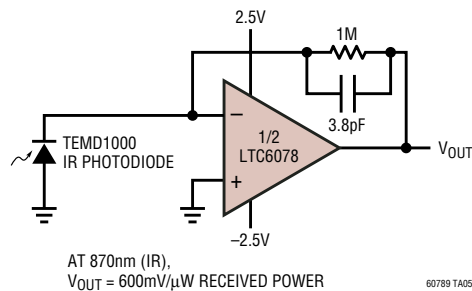
## Low Average Power IR LED Driver



## Accelerometer Signal Conditioner



## Photodiode Amplifier



The circuit diagram shows a precision current-to-voltage converter. An input current source  $I_{IN}$  is connected to the non-inverting input of op-amp A. The output of op-amp A is connected to the base of transistor Q1. The emitter of Q1 is connected to ground. The collector of Q1 is connected to the non-inverting input of op-amp D. The output of op-amp D is connected to the base of transistor Q2. The emitter of Q2 is connected to ground. The collector of Q2 is connected to a precision resistor PT146, which is connected to ground. The output voltage  $V_{OUT}$  is taken across the resistor. The circuit also includes a feedback network with a 100k resistor and a 1000pF capacitor. The LT6650 is powered by  $V_{CC}$  and ground, with a 1μF capacitor on the ground pin. The output of the LT6650 is connected to the non-inverting input of op-amp B. The output of op-amp B is connected to the non-inverting input of op-amp C. The output of op-amp C is connected to the non-inverting input of op-amp D. The output of op-amp D is connected to the base of transistor Q2. The output of the circuit is  $V_{OUT}$ .

10nA ≤  $I_{IN}$  ≤ 10mA  
Q1, Q2: DIODES INC. DMMT3906W  
A TO D: LTC6079  
 $V_{OUT} \approx 150\text{mV} \cdot \log(I_{IN}) + 1.23\text{V}$ ,  $I_{IN}$  IN AMPS

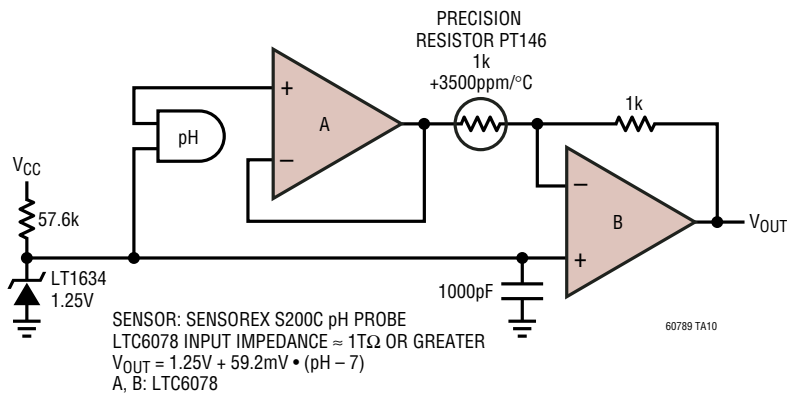
[illegible]

## TYPICAL APPLICATIONS

## LDO Load Balancing

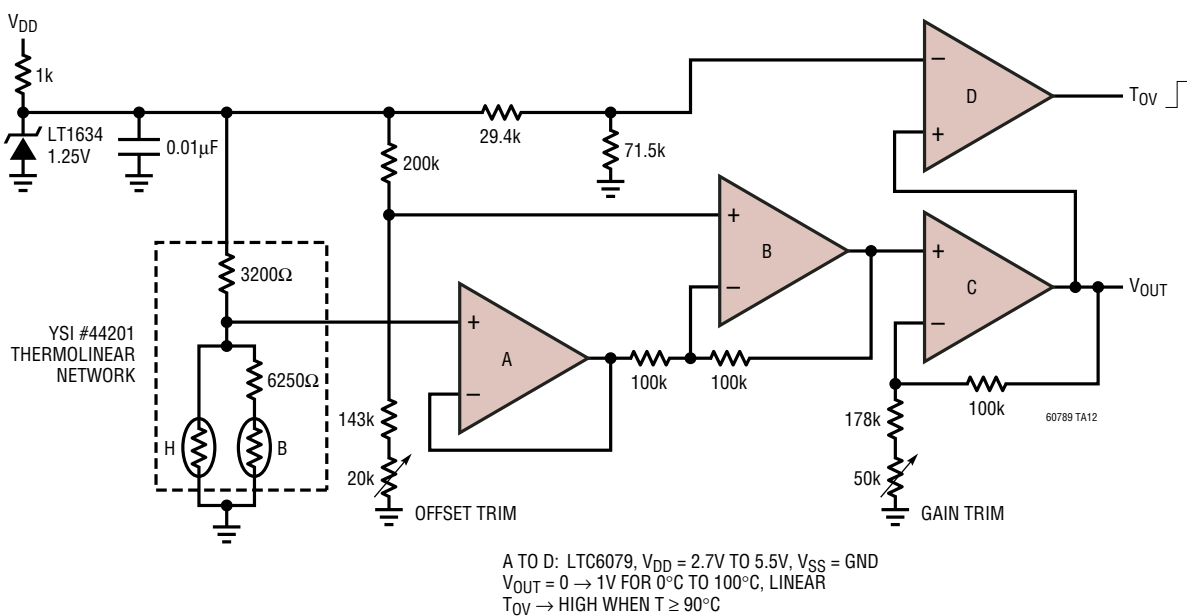


## pH Probe Amplifier

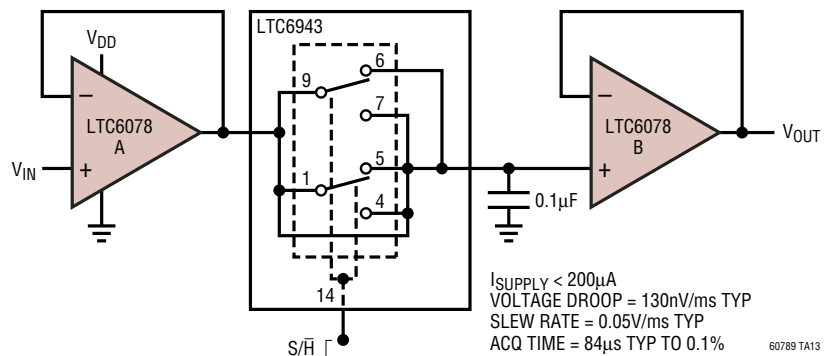


## TYPICAL APPLICATIONS

Thermistor Amplifier with Overtemperature Alarm

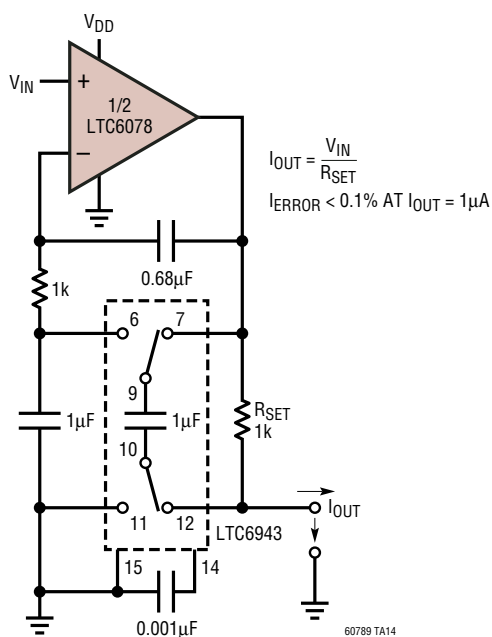


Precision Sample-and-Hold

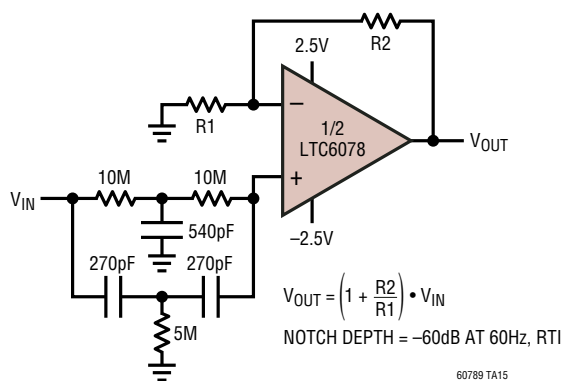


# TYPICAL APPLICATIONS

## Precision Voltage-Controlled Current Source



## 60Hz Notch



Top view of the package showing dimensions and tolerances:

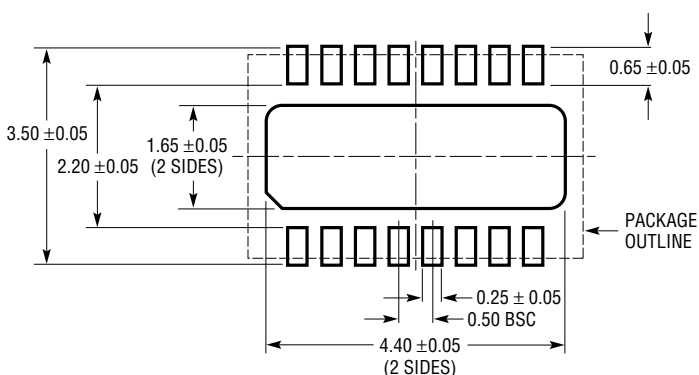
- Overall width:  $3.50 \pm 0.05$
- Distance from top edge to top of package body:  $2.15 \pm 0.05$
- Distance from top edge to top of lead frame:  $1.65 \pm 0.05$  (2 SIDES)
- Distance from top edge to top of lead frame:  $0.675 \pm 0.05$
- Distance from centerline to edge of lead frame:  $0.25 \pm 0.05$
- Distance from centerline to edge of lead frame:  $0.50$  BSC
- Distance from centerline to edge of lead frame:  $2.38 \pm 0.05$  (2 SIDES)
- PACKAGE OUTLINE

[illegible]

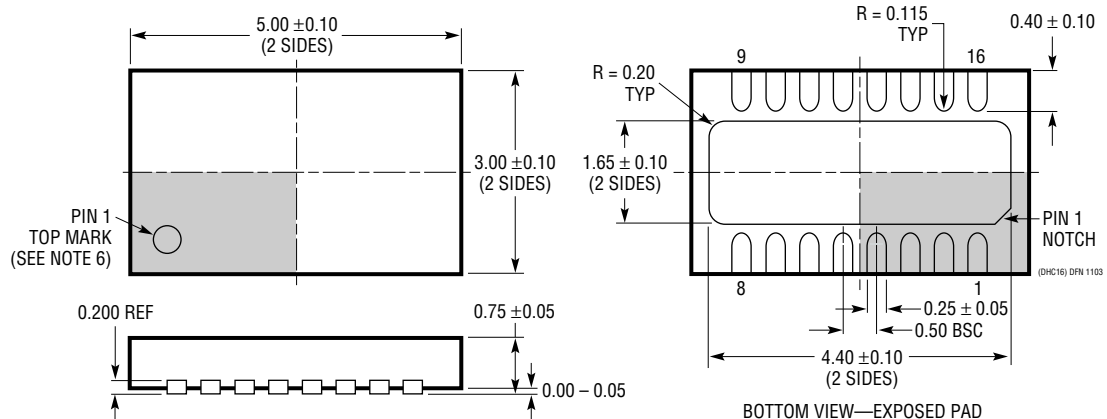
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE MO-229 VARIATION OF (WEED-2).  
CHECK THE LTC WEBSITE DATA SHEET FOR CURRENT STATUS OF VARIATION ASSIGNMENT
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE  
MOLD FLASH. MOLD FLASH,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

# PACKAGE DESCRIPTION

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



**RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS**



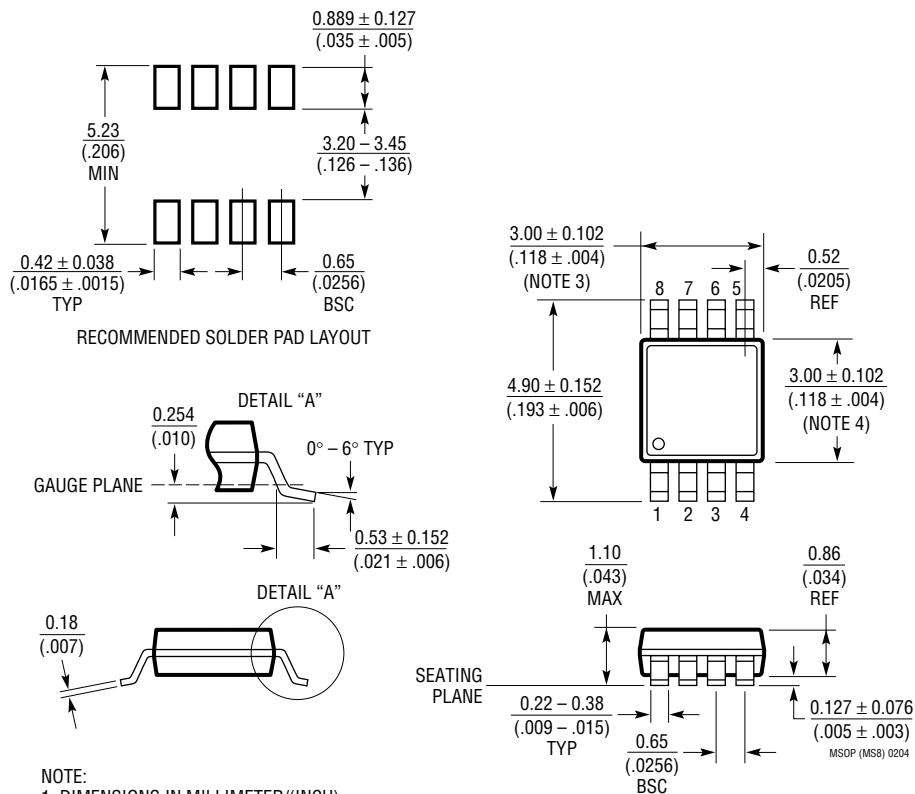
**NOTE:**

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

## PACKAGE DESCRIPTION

MS8 Package  
8-Lead Plastic MSOP

(Reference LTC DWG # 05-08-1660)

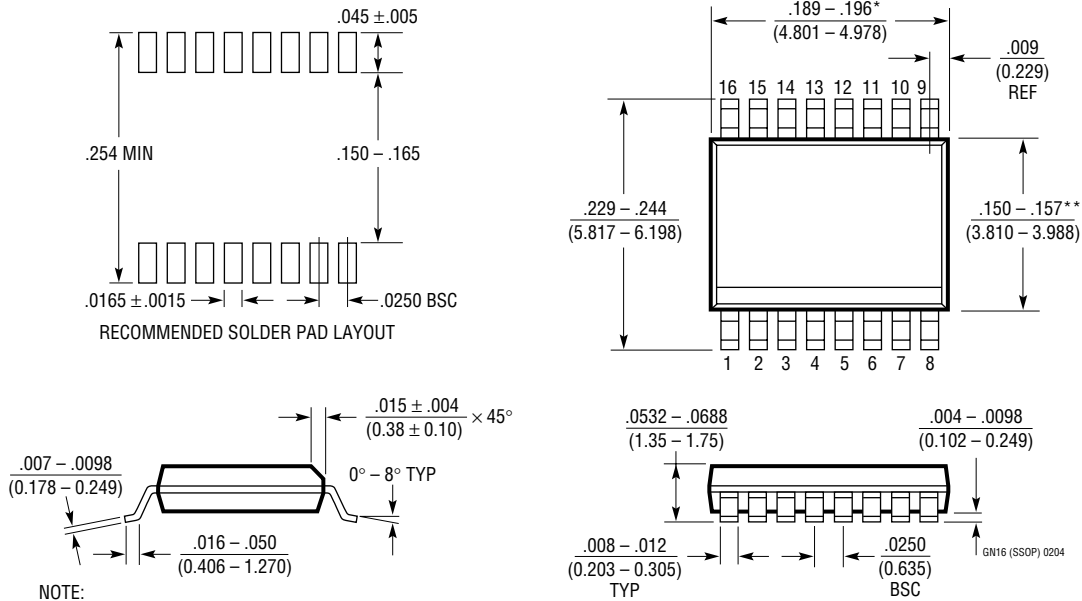


## NOTE:

1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.  
MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.  
INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

# PACKAGE DESCRIPTION

## GN Package 16-Lead Plastic SSOP (Narrow .150 Inch) (Reference LTC DWG # 05-08-1641)



### NOTE:

1. CONTROLLING DIMENSION: INCHES

2. DIMENSIONS ARE IN  $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$

3. DRAWING NOT TO SCALE

\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

\*\*DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

[illegible]

## RELATED PARTS

| PART NUMBER     | DESCRIPTION                  | COMMENTS                                                              |
|-----------------|------------------------------|-----------------------------------------------------------------------|
| LTC2051/LTC2052 | Dual/Quad Zero-Drift Op Amps | 3μV V <sub>OS</sub> , 30nV/°C V <sub>OS</sub> Drift                   |
| LT6011/LT6012   | Dual/Quad Precision Op Amps  | 60μV V <sub>OS</sub> , I <sub>B</sub> = 300pA, I <sub>S</sub> = 135μA |