

## Zero-Drift Operational Amplifiers in SOT-23

### FEATURES

- **Maximum Offset Voltage of 3 $\mu$ V**
- **Maximum Offset Voltage Drift of 30nV/°C**
- Noise: 1.5 $\mu$ V<sub>P-P</sub> (0.01Hz to 10Hz Typ)
- Voltage Gain: 140dB (Typ)
- PSRR: 130dB (Typ)
- CMRR: 130dB (Typ)
- Supply Current: 0.8mA (Typ)
- Supply Operation
  - LTC2050: 2.7V to 6V
  - LTC2050HV: 2.7V to  $\pm$ 5.5V
  - LTC2050HVMP: 4.5V to  $\pm$ 5.5V
- Extended Common Mode Input Range
- Output Swings Rail-to-Rail
- Input Overload Recovery Time: 2ms (Typ)
- Operating Temperature Range
  - LTC2050: -40°C to 125°C
  - LTC2050HVMP: -55°C to 150°C
- Low Profile (1mm) SOT-23 (ThinSOT™) Package
- AEC-Q100 Qualified for Automotive Applications

### APPLICATIONS

- Thermocouple Amplifiers
- Electronic Scales
- Medical Instrumentation
- Strain Gauge Amplifiers
- High Resolution Data Acquisition
- DC Accurate RC Active Filters
- Low Side Current Sense

### DESCRIPTION

The **LTC®2050** and **LTC2050HV** are zero-drift operational amplifiers available in the 5- or 6-lead SOT-23 and SO-8 packages. The LTC2050 operates from a single 2.7V to 6V supply. The LTC2050HV operates on supplies from 2.7V to  $\pm$ 5.5V. The current consumption is 800 $\mu$ A and the versions in the 6-lead SOT-23 and SO-8 packages offer power shutdown (active low). The LTC2050HVMP offer operating range from 4.5V to  $\pm$ 5.5V and operating temperature range of -55°C to 150°C.

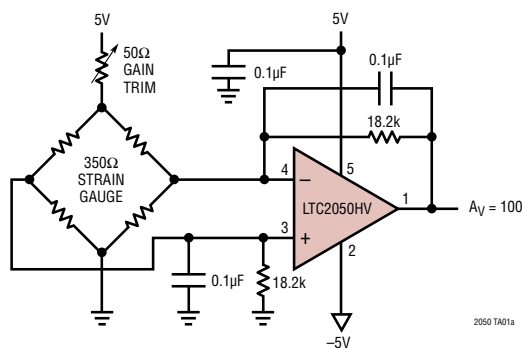
The LTC2050, despite its miniature size, features uncompromising DC performance. The typical input offset voltage and offset drift are 0.5 $\mu$ V and 10nV/°C. The almost zero DC offset and drift are supported with a power supply rejection ratio (PSRR) and common mode rejection ratio (CMRR) of more than 130dB.

The input common mode voltage ranges from the negative supply up to typically 1V from the positive supply. The LTC2050 also has an enhanced output stage capable of driving loads as low as 2k $\Omega$  to both supply rails. The open-loop gain is typically 140dB. The LTC2050 also features a 1.5 $\mu$ V<sub>P-P</sub> DC to 10Hz noise and a 3MHz gain bandwidth product.

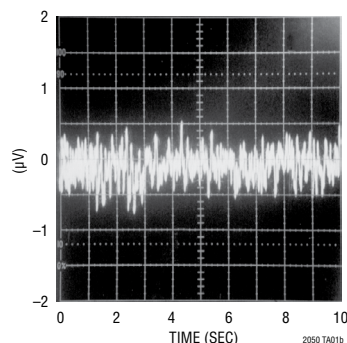
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### TYPICAL APPLICATION

**Differential Bridge Amplifier**



**Input Referred Noise 0.1Hz to 10Hz**



# LTC2050/LTC2050HV

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

Total Supply Voltage ( $V^+$  to  $V^-$ )

LTC2050 ..... 7V

LTC2050HV ..... 12V

Input Voltage ..... ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )

Output Short-Circuit Duration ..... Indefinite

Operating Temperature Range

LTC2050 .....  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$

LTC2050HVMP .....  $-55^{\circ}\text{C}$  to  $150^{\circ}\text{C}$

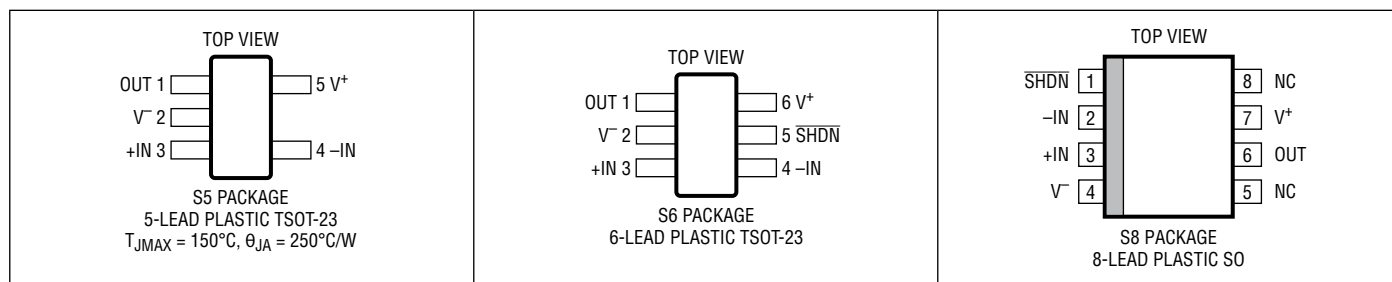
Specified Temperature Range

(Note 3) .....  $-55^{\circ}\text{C}$  to  $150^{\circ}\text{C}$

Storage Temperature Range .....  $-65^{\circ}\text{C}$  to  $150^{\circ}\text{C}$

Lead Temperature (Soldering, 10 sec) .....  $300^{\circ}\text{C}$

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL      | PART MARKING* | PACKAGE DESCRIPTION    | SPECIFIED TEMPERATURE RANGE                    |
|------------------|--------------------|---------------|------------------------|------------------------------------------------|
| LTC2050CS5#PBF   | LTC2050CS5#TRPBF   | LTAEG         | 5-Lead Plastic TSOT-23 | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |
| LTC2050IS5#PBF   | LTC2050IS5#TRPBF   | LTAEG         | 5-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| LTC2050HS5#PBF   | LTC2050HS5#TRPBF   | LTAEG         | 5-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTC2050HVC5#PBF  | LTC2050HVC5#TRPBF  | LTAEH         | 5-Lead Plastic TSOT-23 | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |
| LTC2050HVIS5#PBF | LTC2050HVIS5#TRPBF | LTAEH         | 5-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| LTC2050HVHS5#PBF | LTC2050HVHS5#TRPBF | LTAEH         | 5-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTC2050CS6#PBF   | LTC2050CS6#TRPBF   | LTA EJ        | 6-Lead Plastic TSOT-23 | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |
| LTC2050IS6#PBF   | LTC2050IS6#TRPBF   | LTA EJ        | 6-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| LTC2050HS6#PBF   | LTC2050HS6#TRPBF   | LTA EJ        | 6-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTC2050HVMS6#PBF | LTC2050HVMS6#TRPBF | LTHGP         | 6-Lead Plastic TSOT-23 | $-55^{\circ}\text{C}$ to $150^{\circ}\text{C}$ |
| LTC2050HVC6#PBF  | LTC2050HVC6#TRPBF  | LTA EK        | 6-Lead Plastic TSOT-23 | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |
| LTC2050HVIS6#PBF | LTC2050HVIS6#TRPBF | LTA EK        | 6-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| LTC2050HVHS6#PBF | LTC2050HVHS6#TRPBF | LTA EK        | 6-Lead Plastic TSOT-23 | $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTC2050CS8#PBF   | LTC2050CS8#TRPBF   | 2050          | 8-Lead Plastic SO      | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |
| LTC2050IS8#PBF   | LTC2050IS8#TRPBF   | 2050I         | 8-Lead Plastic SO      | $-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$  |
| LTC2050HVC8#PBF  | LTC2050HVC8#TRPBF  | 2050HV        | 8-Lead Plastic SO      | $0^{\circ}\text{C}$ to $70^{\circ}\text{C}$    |

Rev. F

## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL      | PART MARKING* | PACKAGE DESCRIPTION | SPECIFIED TEMPERATURE RANGE |
|------------------|--------------------|---------------|---------------------|-----------------------------|
| LTC2050HVIS8#PBF | LTC2050HVIS8#TRPBF | 050HVI        | 8-Lead Plastic SO   | –40°C to 85°C               |

## AUTOMOTIVE PRODUCTS\*\*

|                   |                     |       |                        |                |
|-------------------|---------------------|-------|------------------------|----------------|
| LTC2050HVMP6#WPBF | LTC2050HVMP6#WTRPBF | LTHGP | 6-Lead Plastic TSOT-23 | –55°C to 150°C |
|-------------------|---------------------|-------|------------------------|----------------|

Contact the factory for parts specified with wider operating temperature ranges. \*The temperature grade is identified by a label on the shipping container.

[Tape and reel specifications](#). Some packages are available in 500 unit reels through designated sales channels with #TRMPBF suffix.

\*\*Versions of this part are available with controlled manufacturing to support the quality and reliability requirements of automotive applications. These models are designated with a #W suffix. Only the automotive grade products shown are available for use in automotive applications. Contact your local Analog Devices account representative for specific product ordering information and to obtain the specific Automotive Reliability reports for these models.

## ELECTRICAL CHARACTERISTICS (LTC2050/LTC2050HV) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ . $V_S = 3\text{V}$ unless otherwise noted. (Note 3)

| PARAMETER                                    | CONDITIONS                                                                                          |   | C, I SUFFIXES |      |              | H SUFFIX    |      |               | UNITS             |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------|---|---------------|------|--------------|-------------|------|---------------|-------------------|
|                                              |                                                                                                     |   | MIN           | TYP  | MAX          | MIN         | TYP  | MAX           |                   |
| Input Offset Voltage                         | (Note 2)                                                                                            |   |               | ±0.5 | ±3           |             | ±0.5 | ±3            | μV                |
| Average Input Offset Drift                   | (Note 2)                                                                                            | ● |               |      | ±0.03        |             |      | ±0.05         | μV/°C             |
| Long-Term Offset Drift                       |                                                                                                     |   |               | 50   |              |             | 50   |               | nV/√mo            |
| Input Bias Current                           | LTC2050                                                                                             | ● |               | ±20  | ±75<br>±300  |             | ±20  | ±75<br>±4000  | pA<br>pA          |
|                                              | LTC2050HV                                                                                           | ● |               | ±1   | ±50<br>±100  |             | ±1   | ±50<br>±4000  | pA<br>pA          |
| Input Offset Current                         | LTC2050                                                                                             | ● |               |      | ±150<br>±200 |             |      | ±150<br>±1000 | pA<br>pA          |
|                                              | LTC2050HV                                                                                           | ● |               |      | ±100<br>±150 |             |      | ±100<br>±1000 | pA<br>pA          |
| Input Noise Voltage                          | $R_S = 100\Omega$ , 0.01Hz to 10Hz                                                                  |   |               | 1.5  |              |             | 1.5  |               | μV <sub>P-P</sub> |
| Input Capacitance                            |                                                                                                     |   |               | 1.7  |              |             | 1.7  |               | pF                |
| Common Mode Rejection Ratio                  | LTC2050/LTC2050HV<br>$V_{CM} = \text{GND to } (V^+ - 1.3)$<br>$V_{CM} = \text{GND to } (V^+ - 1.3)$ | ● | 115           | 130  |              | 115         | 130  |               | dB                |
|                                              |                                                                                                     |   | 110           | 130  |              | 110         | 130  |               | dB                |
| Power Supply Rejection Ratio                 | $V_S = 2.7\text{V to } 6\text{V}$                                                                   | ● | 120           | 130  |              | 120         | 130  |               | dB                |
|                                              |                                                                                                     |   | 115           | 130  |              | 115         | 130  |               | dB                |
| Large-Signal Voltage Gain                    | $R_L = 10\text{k}$                                                                                  | ● | 120           | 140  |              | 120         | 140  |               | dB                |
|                                              |                                                                                                     |   | 115           | 140  |              | 115         | 140  |               | dB                |
| Output Voltage Swing High                    | $R_L = 2\text{k to GND}$                                                                            | ● | 2.85          | 2.94 |              | 2.85        | 2.94 |               | V                 |
|                                              | $R_L = 10\text{k to GND}$                                                                           | ● | 2.95          | 2.98 |              | 2.95        | 2.98 |               | V                 |
| Output Voltage Swing Low                     | $R_L = 2\text{k to GND}$                                                                            | ● |               | 1    | 10           |             | 1    | 10            | mV                |
|                                              | $R_L = 10\text{k to GND}$                                                                           | ● |               | 1    | 10           |             | 1    | 10            | mV                |
| Slew Rate                                    |                                                                                                     |   |               | 2    |              |             | 2    |               | V/μs              |
| Gain Bandwidth Product                       |                                                                                                     |   |               | 3    |              |             | 3    |               | MHz               |
| Supply Current                               | $V_{SHDN} = V_{IH}$ , No Load                                                                       | ● |               | 0.75 | 1.1          |             | 0.75 | 1.2           | mA                |
|                                              | $V_{SHDN} = V_{IL}$                                                                                 | ● |               |      | 10           |             |      | 10            | μA                |
| Shutdown Pin Input Low Voltage ( $V_{IL}$ )  |                                                                                                     | ● |               |      | $V^- + 0.5$  |             |      | $V^- + 0.5$   | V                 |
| Shutdown Pin Input High Voltage ( $V_{IH}$ ) |                                                                                                     | ● | $V^+ - 0.5$   |      |              | $V^+ - 0.5$ |      |               | V                 |
| Shutdown Pin Input Current                   | $V_{SHDN} = \text{GND}$                                                                             | ● |               | –0.5 | –3           |             | –0.5 | –3            | μA                |
| Internal Sampling Frequency                  |                                                                                                     |   |               | 7.5  |              |             | 7.5  |               | kHz               |

# LTC2050/LTC2050HV

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . (LTC2050/LTC2050HV)  $V_S = 5\text{V}$  unless otherwise noted. (Note 3)

| PARAMETER                                           | CONDITIONS                                                                                                        |        | C, I SUFFIXES |            |                        | H, MP SUFFIX |            |                          | UNITS                                                        |
|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|--------|---------------|------------|------------------------|--------------|------------|--------------------------|--------------------------------------------------------------|
|                                                     |                                                                                                                   |        | MIN           | TYP        | MAX                    | MIN          | TYP        | MAX                      |                                                              |
| Input Offset Voltage                                | (Note 2)                                                                                                          |        |               | $\pm 0.5$  | $\pm 3$                |              | $\pm 0.5$  | $\pm 3$                  | $\mu\text{V}$                                                |
| Average Input Offset Drift                          | (Note 2)<br>LTC2050HVMP                                                                                           | ●<br>● |               |            | $\pm 0.03$             |              |            | $\pm 0.05$<br>$\pm 0.10$ | $\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$ |
| Long-Term Offset Drift                              |                                                                                                                   |        |               | 50         |                        |              | 50         |                          | $\text{nV}/\sqrt{\text{mo}}$                                 |
| Input Bias Current                                  | LTC2050                                                                                                           | ●      |               | $\pm 75$   | $\pm 150$<br>$\pm 300$ |              | $\pm 75$   | $\pm 150$<br>$\pm 4000$  | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HV                                                                                                         | ●      |               | $\pm 7$    | $\pm 50$<br>$\pm 150$  |              | $\pm 7$    | $\pm 50$<br>$\pm 4000$   | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HVMP                                                                                                       | ●      |               |            |                        |              | $\pm 7$    | $\pm 50$<br>$\pm 8000$   | $\text{pA}$<br>$\text{pA}$                                   |
| Input Offset Current                                | LTC2050                                                                                                           | ●      |               |            | $\pm 300$<br>$\pm 400$ |              |            | $\pm 300$<br>$\pm 1000$  | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HV                                                                                                         | ●      |               |            | $\pm 100$<br>$\pm 200$ |              |            | $\pm 100$<br>$\pm 1000$  | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HVMP                                                                                                       | ●      |               |            |                        |              |            | $\pm 2000$               | $\text{pA}$                                                  |
| Input Noise Voltage                                 | $R_S = 100\Omega$ , 0.01Hz to 10Hz                                                                                |        |               | 1.5        |                        |              | 1.5        |                          | $\mu\text{V}_{\text{P-P}}$                                   |
| Common Mode Rejection Ratio                         | LTC2050/LTC2050HV<br>$V_{\text{CM}} = \text{GND to } (V^+ - 1.3)$<br>$V_{\text{CM}} = \text{GND to } (V^+ - 1.3)$ | ●<br>● | 120<br>115    | 130<br>130 |                        | 120<br>110   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     | LTC2050HVMP<br>$V_{\text{CM}} = \text{GND to } (V^+ - 1.3)$                                                       | ●      |               |            |                        | 107          | 130        |                          | $\text{dB}$                                                  |
|                                                     |                                                                                                                   |        |               |            |                        |              |            |                          |                                                              |
| Power Supply Rejection Ratio                        | $V_S = 2.7\text{V to } 6\text{V}$                                                                                 | ●      | 120<br>115    | 130<br>130 |                        | 120<br>115   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     | LTC2050HVMP<br>$V_S = 4.5\text{V to } 11\text{V}$                                                                 | ●      |               |            |                        | 117<br>112   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     |                                                                                                                   |        |               |            |                        |              |            |                          |                                                              |
| Large-Signal Voltage Gain                           | $R_L = 10\text{k}$                                                                                                | ●      | 125<br>120    | 140<br>140 |                        | 125<br>115   | 140<br>140 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     |                                                                                                                   |        |               |            |                        |              |            |                          |                                                              |
| Output Voltage Swing High                           | $R_L = 2\text{k to GND}$                                                                                          | ●      | 4.85          | 4.94       |                        | 4.85         | 4.94       |                          | $\text{V}$                                                   |
|                                                     | $R_L = 10\text{k to GND}$                                                                                         | ●      | 4.95          | 4.98       |                        | 4.95         | 4.98       |                          | $\text{V}$                                                   |
| Output Voltage Swing Low                            | $R_L = 2\text{k to GND}$                                                                                          | ●      |               | 1          | 10                     |              | 1          | 10                       | $\text{mV}$                                                  |
|                                                     | $R_L = 10\text{k to GND}$                                                                                         | ●      |               | 1          | 10                     |              | 1          | 10                       | $\text{mV}$                                                  |
| Slew Rate                                           |                                                                                                                   |        |               | 2          |                        |              | 2          |                          | $\text{V}/\mu\text{s}$                                       |
| Gain Bandwidth Product                              |                                                                                                                   |        |               | 3          |                        |              | 3          |                          | $\text{MHz}$                                                 |
| Supply Current                                      | $V_{\text{SHDN}} = V_{\text{IH}}$ , No Load                                                                       | ●      |               | 0.8        | 1.2                    |              | 0.8        | 1.3                      | $\text{mA}$                                                  |
|                                                     | $V_{\text{SHDN}} = V_{\text{IL}}$                                                                                 | ●      |               |            | 15                     |              |            | 15                       | $\mu\text{A}$                                                |
| Shutdown Pin Input Low Voltage ( $V_{\text{IL}}$ )  |                                                                                                                   | ●      |               |            | $V^- + 0.5$            |              |            | $V^- + 0.5$              | $\text{V}$                                                   |
| Shutdown Pin Input High Voltage ( $V_{\text{IH}}$ ) |                                                                                                                   | ●      | $V^+ - 0.5$   |            |                        | $V^+ - 0.5$  |            |                          | $\text{V}$                                                   |
| Shutdown Pin Input Current                          | $V_{\text{SHDN}} = \text{GND}$                                                                                    | ●      |               | -0.5       | -7                     |              | -0.5       | -7                       | $\mu\text{A}$                                                |
| Internal Sampling Frequency                         |                                                                                                                   |        |               | 7.5        |                        |              | 7.5        |                          | $\text{kHz}$                                                 |

# ELECTRICAL CHARACTERISTICS (LTC2050HV) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ . $V_S = \pm 5\text{V}$ unless otherwise noted. (Note 3)

| PARAMETER                                           | CONDITIONS                                                                                    |        | C, I SUFFIXES |            |                        | H, MP SUFFIX |            |                          | UNITS                                                        |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------|--------|---------------|------------|------------------------|--------------|------------|--------------------------|--------------------------------------------------------------|
|                                                     |                                                                                               |        | MIN           | TYP        | MAX                    | MIN          | TYP        | MAX                      |                                                              |
| Input Offset Voltage                                | (Note 2)                                                                                      |        |               | $\pm 0.5$  | $\pm 3$                |              | $\pm 0.5$  | $\pm 3$                  | $\mu\text{V}$                                                |
| Average Input Offset Drift                          | (Note 2)<br>LTC2050HVMP                                                                       | ●<br>● |               |            | $\pm 0.03$             |              |            | $\pm 0.05$<br>$\pm 0.10$ | $\mu\text{V}/^\circ\text{C}$<br>$\mu\text{V}/^\circ\text{C}$ |
| Long-Term Offset Drift                              |                                                                                               |        |               | 50         |                        |              | 50         |                          | $\text{nV}/\sqrt{\text{mo}}$                                 |
| Input Bias Current (Note 4)                         | LTC2050HV                                                                                     | ●      |               | $\pm 25$   | $\pm 125$<br>$\pm 300$ |              | $\pm 25$   | $\pm 125$<br>$\pm 4000$  | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HVMP                                                                                   | ●      |               |            |                        |              | $\pm 25$   | $\pm 125$<br>$\pm 8000$  | $\text{pA}$<br>$\text{pA}$                                   |
| Input Offset Current (Note 4)                       | LTC2050HV                                                                                     | ●      |               |            | $\pm 250$<br>$\pm 500$ |              |            | $\pm 250$<br>$\pm 1000$  | $\text{pA}$<br>$\text{pA}$                                   |
|                                                     | LTC2050HVMP                                                                                   | ●      |               |            |                        |              |            | $\pm 2000$               | $\text{pA}$                                                  |
| Input Noise Voltage                                 | $R_S = 100\Omega$ , 0.01Hz to 10Hz                                                            |        |               | 1.5        |                        |              | 1.5        |                          | $\mu\text{V}_{\text{p-p}}$                                   |
| Common Mode Rejection Ratio                         | LTC2050HV<br>$V_{\text{CM}} = V^-$ to $(V^+ - 1.3)$<br>$V_{\text{CM}} = V^-$ to $(V^+ - 1.3)$ | ●      | 120<br>115    | 130<br>130 |                        | 120<br>115   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     | LTC2050HVMP<br>$V_{\text{CM}} = V^-$ to $(V^+ - 1.3)$                                         | ●      |               |            |                        | 112          | 130        |                          | $\text{dB}$                                                  |
|                                                     |                                                                                               |        |               |            |                        |              |            |                          |                                                              |
| Power Supply Rejection Ratio                        | $V_S = 2.7\text{V}$ to $11\text{V}$                                                           | ●      | 120<br>115    | 130<br>130 |                        | 120<br>115   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     | LTC2050HVMP<br>$V_S = 4.5$ to $11\text{V}$                                                    | ●      |               |            |                        | 117<br>112   | 130<br>130 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     |                                                                                               |        |               |            |                        |              |            |                          |                                                              |
| Large-Signal Voltage Gain                           | $R_L = 10\text{k}$                                                                            | ●      | 125<br>120    | 140<br>140 |                        | 125<br>120   | 140<br>140 |                          | $\text{dB}$<br>$\text{dB}$                                   |
|                                                     |                                                                                               |        |               |            |                        |              |            |                          |                                                              |
| Maximum Output Voltage Swing                        | $R_L = 2\text{k}$ to GND                                                                      | ●      | $\pm 4.75$    | $\pm 4.94$ |                        | $\pm 4.50$   | $\pm 4.94$ |                          | $\text{V}$                                                   |
|                                                     | $R_L = 10\text{k}$ to GND                                                                     | ●      | $\pm 4.90$    | $\pm 4.98$ |                        | $\pm 4.85$   | $\pm 4.98$ |                          | $\text{V}$                                                   |
| Slew Rate                                           |                                                                                               |        |               | 2          |                        |              | 2          |                          | $\text{V}/\mu\text{s}$                                       |
| Gain Bandwidth Product                              |                                                                                               |        |               | 3          |                        |              | 3          |                          | $\text{MHz}$                                                 |
| Supply Current                                      | $V_{\text{SHDN}} = V_{\text{IH}}$ , No Load                                                   | ●      |               | 1          | 1.5                    |              | 1          | 1.6                      | $\text{mA}$                                                  |
|                                                     | $V_{\text{SHDN}} = V_{\text{IL}}$                                                             | ●      |               |            | 25                     |              |            | 25                       | $\mu\text{A}$                                                |
| Shutdown Pin Input Low Voltage ( $V_{\text{IL}}$ )  |                                                                                               | ●      |               |            | $V^- + 0.5$            |              |            | $V^- + 0.5$              | $\text{V}$                                                   |
| Shutdown Pin Input High Voltage ( $V_{\text{IH}}$ ) |                                                                                               | ●      | $V^+ - 0.5$   |            |                        | $V^+ - 0.5$  |            |                          | $\text{V}$                                                   |
| Shutdown Pin Input Current                          | $V_{\text{SHDN}} = V^-$                                                                       | ●      |               | -3         | -20                    |              | -3         | -20                      | $\mu\text{A}$                                                |
| Internal Sampling Frequency                         |                                                                                               |        |               | 7.5        |                        |              | 7.5        |                          | $\text{kHz}$                                                 |

**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:** These parameters are guaranteed by design. Thermocouple effects preclude measurements of these voltage levels during automated testing.

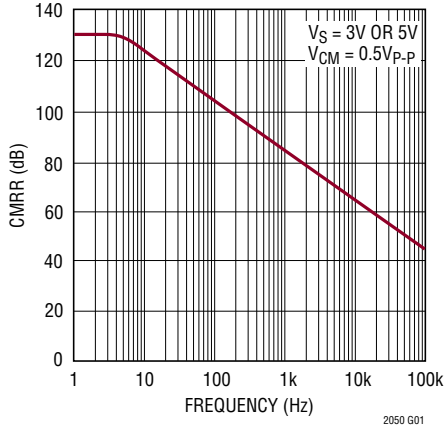
**Note 3:** All versions of the LTC2050 are designed, characterized and expected to meet the extended temperature limits of  $-40^\circ\text{C}$  and  $125^\circ\text{C}$ .

The LTC2050C/LTC2050HVC are guaranteed to meet the temperature limits of  $0^\circ\text{C}$  and  $70^\circ\text{C}$ . The LTC2050I/LTC2050HVI are guaranteed to meet the temperature limits of  $-40^\circ\text{C}$  and  $85^\circ\text{C}$ . The LTC2050H/LTC2050HVH are guaranteed to meet the temperature limits of  $-40^\circ\text{C}$  and  $125^\circ\text{C}$ . The LTC2050HVMP is guaranteed to meet the temperature limits of  $-55^\circ\text{C}$  and  $150^\circ\text{C}$ .

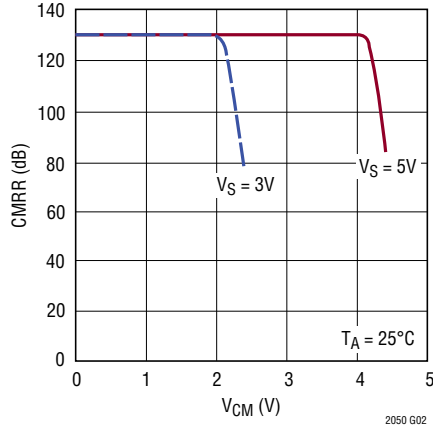
**Note 4:** The bias current measurement accuracy depends on the proximity of the supply bypass capacitor to the device under test, especially at  $\pm 5\text{V}$  supplies. Because of testing limitations on the placement of this bypass capacitor, the bias current at  $\pm 5\text{V}$  supplies is guaranteed by design to meet the data sheet limits, but tested to relaxed limits.

## TYPICAL PERFORMANCE CHARACTERISTICS

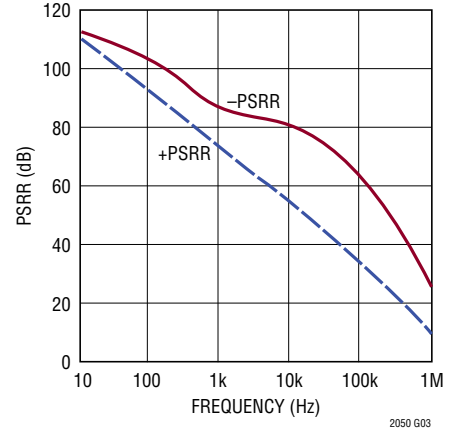
**Common Mode Rejection Ratio vs Frequency**



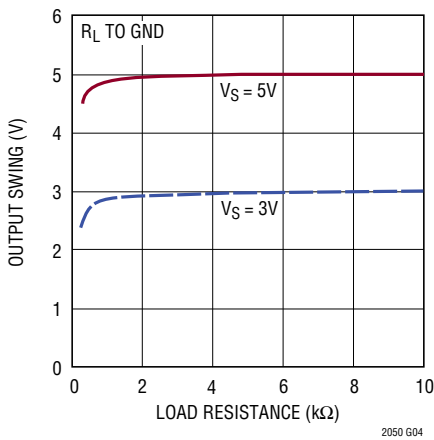
**DC CMRR vs Common Mode Input Voltage**



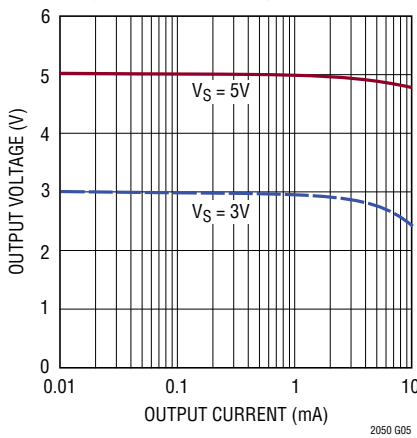
**PSRR vs Frequency**



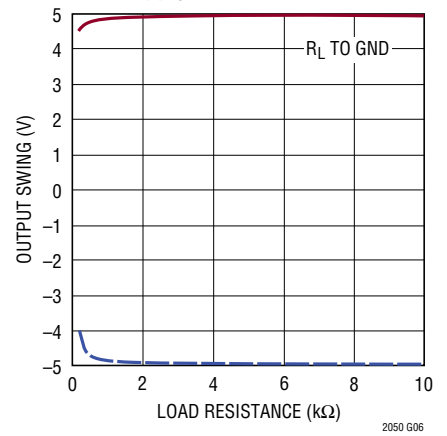
**Output Voltage Swing vs Load Resistance**



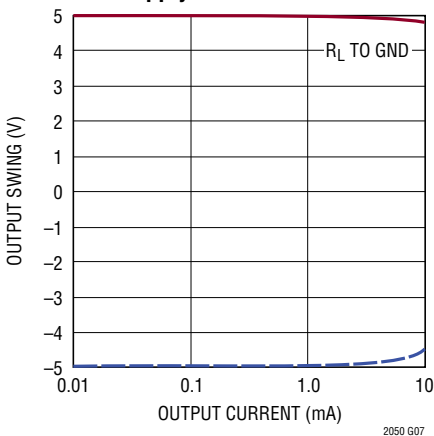
**Output Swing vs Output Current**



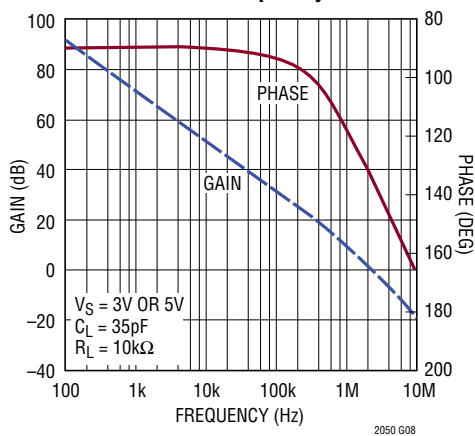
**Output Swing vs Load Resistance  $\pm 5V$  Supply**



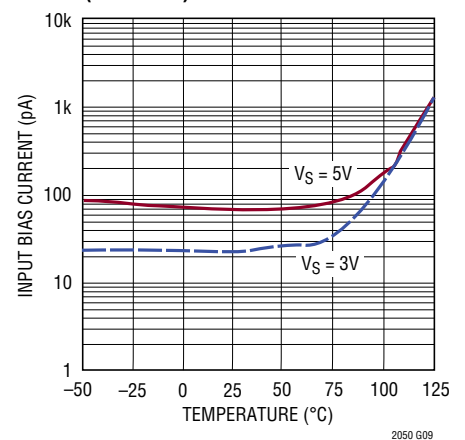
**Output Swing vs Output Current  $\pm 5V$  Supply**



**Gain/Phase vs Frequency**

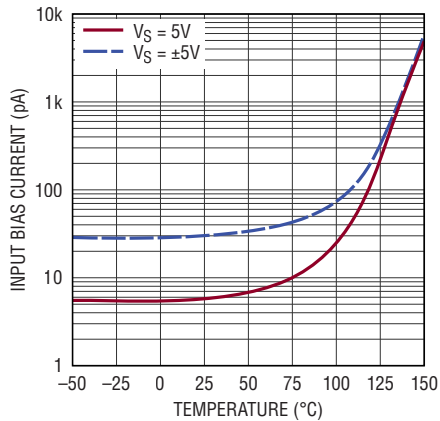


**Input Bias Current vs Temperature (LTC2050)**

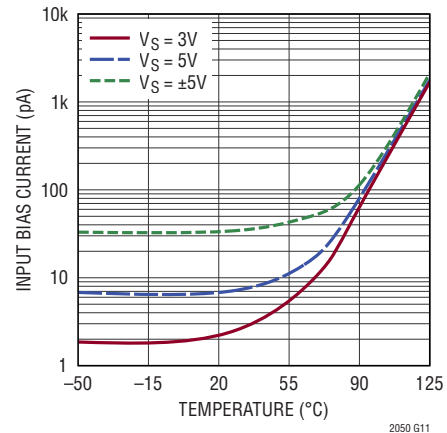


## TYPICAL PERFORMANCE CHARACTERISTICS

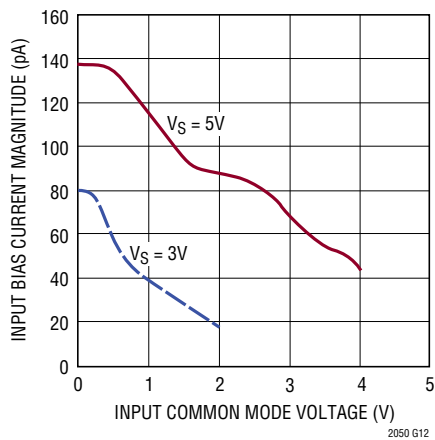
Input Bias Current vs Temperature  
(LTC2050HVMP)



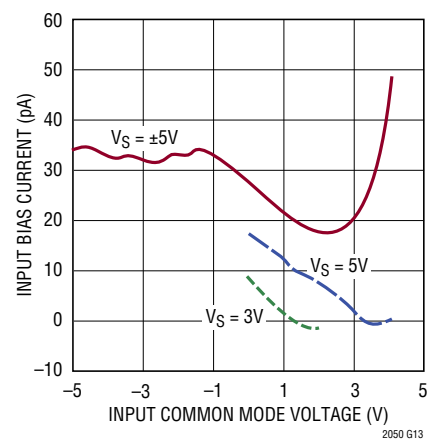
Input Bias Current vs Temperature  
(LTC2050HV)



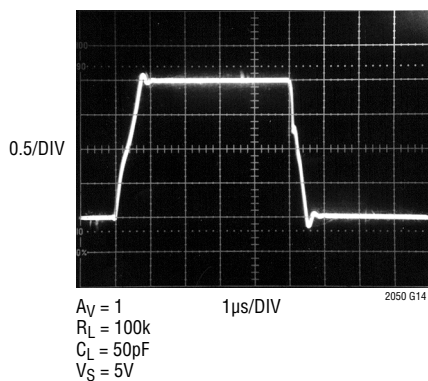
Input Bias Current vs Input  
Common Mode Voltage



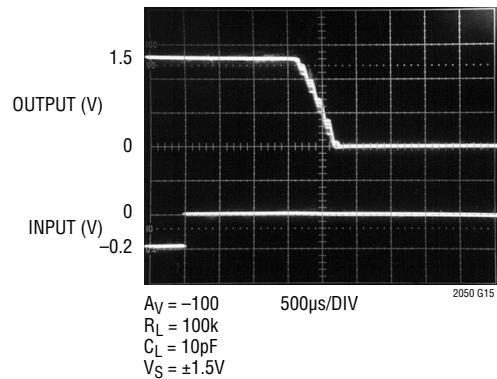
Input Bias Current vs Input  
Common Mode Voltage  
(LTC2050HV)



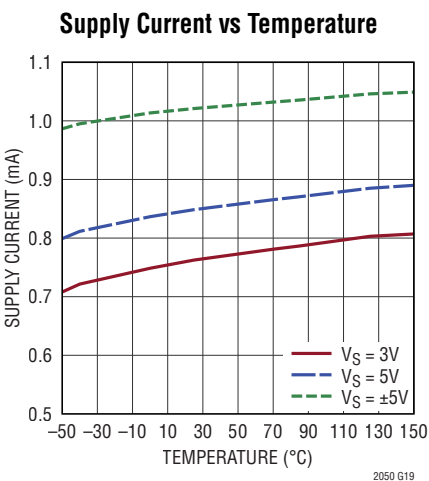
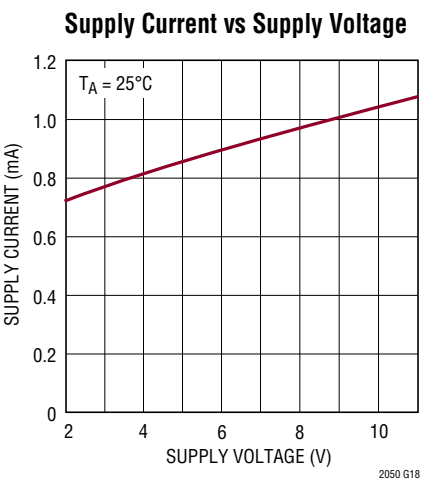
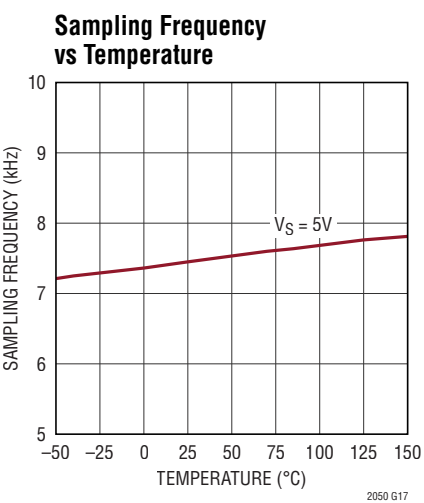
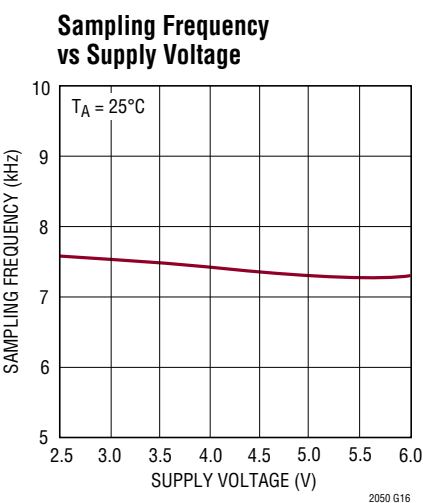
Transient Response



Input Overload Recovery

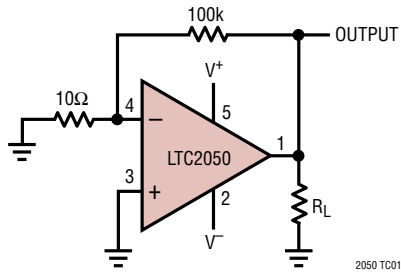


TYPICAL PERFORMANCE CHARACTERISTICS

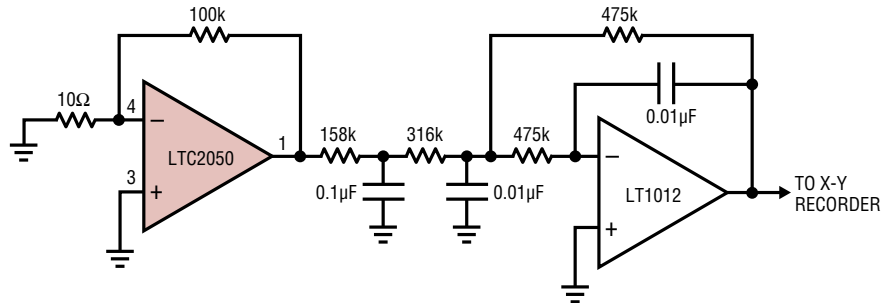


## TEST CIRCUITS

Electrical Characteristics Test Circuit



DC-10Hz Noise Test Circuit



## APPLICATIONS INFORMATION

### Shutdown

The LTC2050 includes a shutdown pin in the 6-lead SOT-23 and the SO-8 version. When this active low pin is high or allowed to float, the device operates normally. When the shutdown pin is pulled low, the device enters shutdown mode; supply current drops to 3 $\mu$ A, all clocking stops, and both inputs and output assume a high impedance state.

### Clock Feedthrough, Input Bias Current

The LTC2050 uses auto-zeroing circuitry to achieve an almost zero DC offset over temperature, common mode voltage, and power supply voltage. The frequency of the clock used for auto-zeroing is typically 7.5kHz. The term clock feedthrough is broadly used to indicate visibility of this clock frequency in the op amp output spectrum. There are typically two types of clock feedthrough in auto zeroed op amps like the LTC2050.

The first form of clock feedthrough is caused by the settling of the internal sampling capacitor and is input referred; that is, it is multiplied by the closed loop gain of the op amp. This form of clock feedthrough is independent of the magnitude of the input source resistance or the magnitude of the gain setting resistors. The LTC2050 has a residue clock feedthrough of less than 1 $\mu$ V<sub>RMS</sub> input referred at 7.5kHz.

The second form of clock feedthrough is caused by the small amount of charge injection occurring during the sampling and holding of the op amp's input offset voltage. The current spikes are multiplied by the impedance seen at the input terminals of the op amp, appearing at the

output multiplied by the closed loop gain of the op amp. To reduce this form of clock feedthrough, use smaller valued gain setting resistors and minimize the source resistance at the input. If the resistance seen at the inputs is less than 10k, this form of clock feedthrough is less than 1 $\mu$ V<sub>RMS</sub> input referred at 7.5kHz, or less than the amount of residue clock feedthrough from the first form described above.

Placing a capacitor across the feedback resistor reduces either form of clock feedthrough by limiting the bandwidth of the closed loop gain.

Input bias current is defined as the DC current into the input pins of the op amp. The same current spikes that cause the second form of clock feedthrough described above, when averaged, dominate the DC input bias current of the op amp below 70°C.

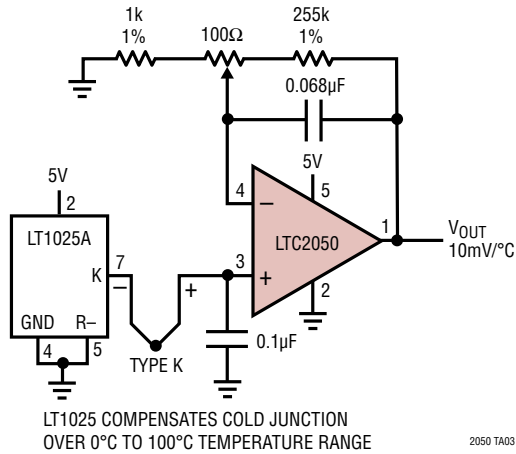
At temperatures above 70°C, the leakage of the ESD protection diodes on the inputs increases the input bias currents of both inputs in the positive direction, while the current caused by the charge injection stays relatively constant. At elevated temperatures (above 85°C) the leakage current begins to dominate and both the negative and positive pin's input bias currents are in the positive direction (into the pins).

### Input Pins, ESD Sensitivity

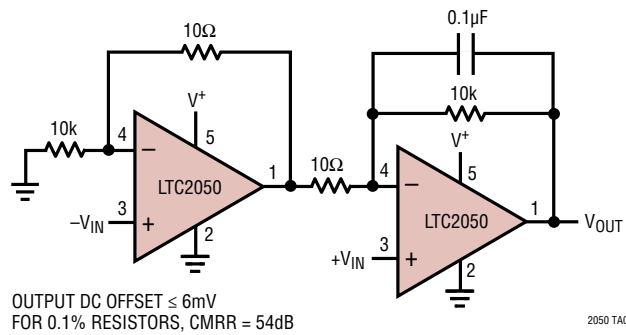
ESD voltages above 700V on the input pins of the op amp will cause the input bias currents to increase (more DC current into the pins). At these voltages, it is possible to damage the device to a point where the input bias current exceeds the maximums specified in this data sheet.

## TYPICAL APPLICATIONS

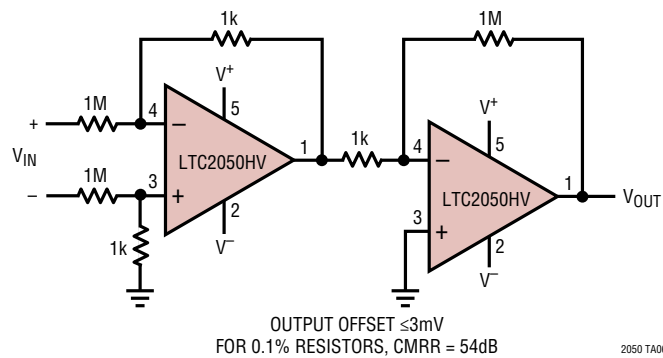
## Single Supply Thermocouple Amplifier



## Gain of 1001 Single Supply Instrumentation Amplifier

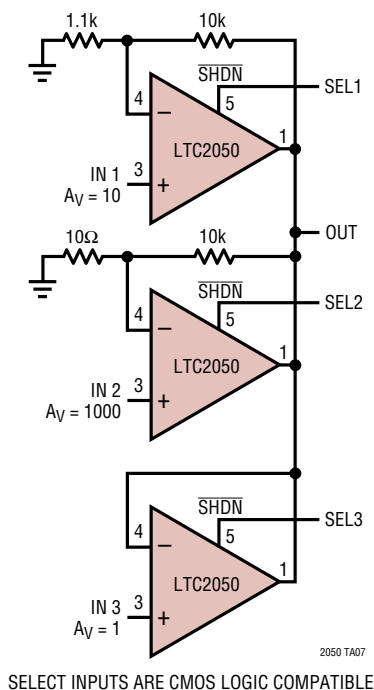


## Instrumentation Amplifier with 100V Common Mode Input Voltage

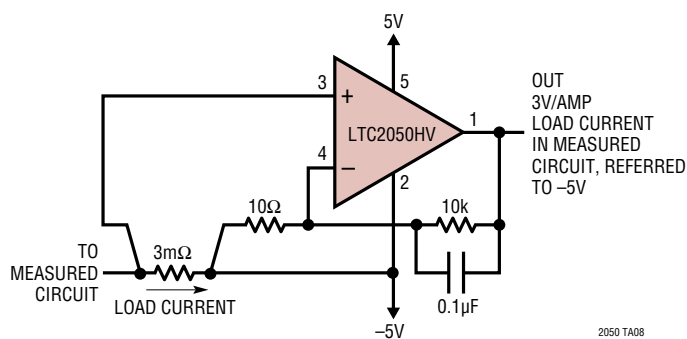


## TYPICAL APPLICATIONS

### High Precision 3-Input Mux

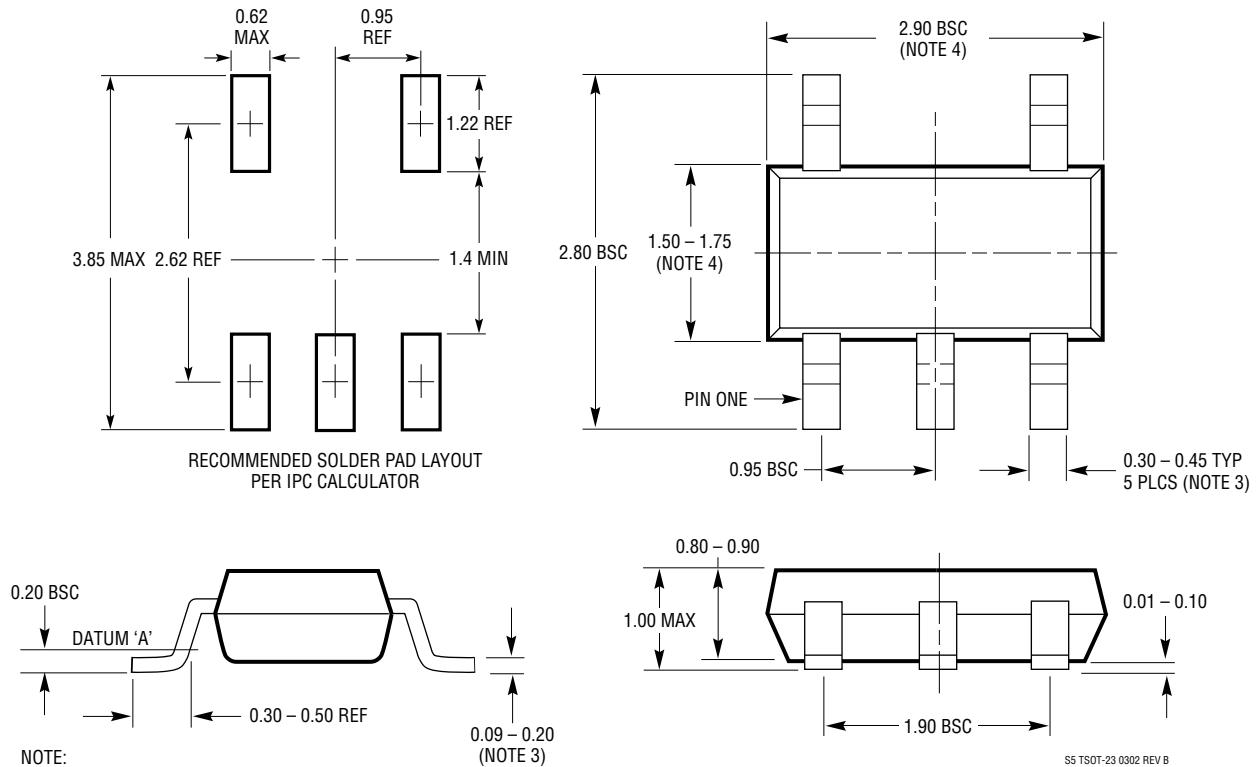


### Low Side Power Supply Current Sensing



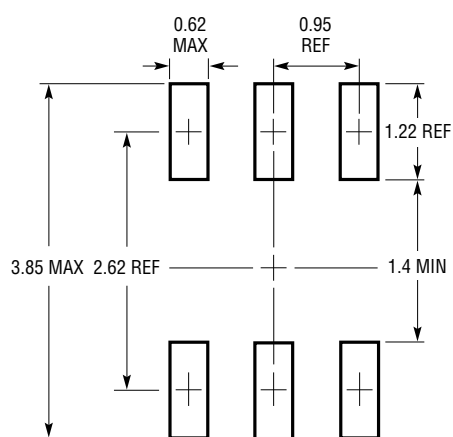
## PACKAGE DESCRIPTION

**S5 Package**  
**5-Lead Plastic TSOT-23**  
 (Reference LTC DWG # 05-08-1635 Rev B)

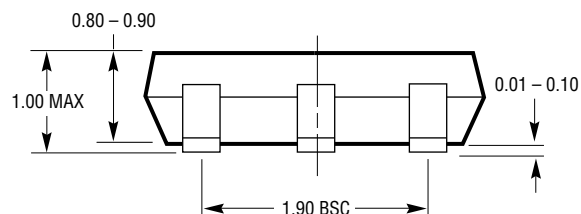
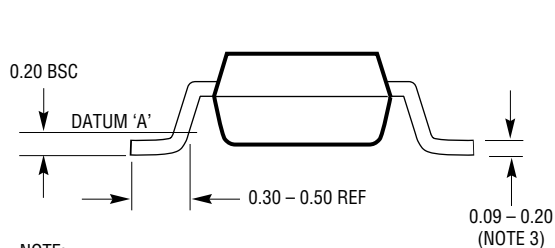
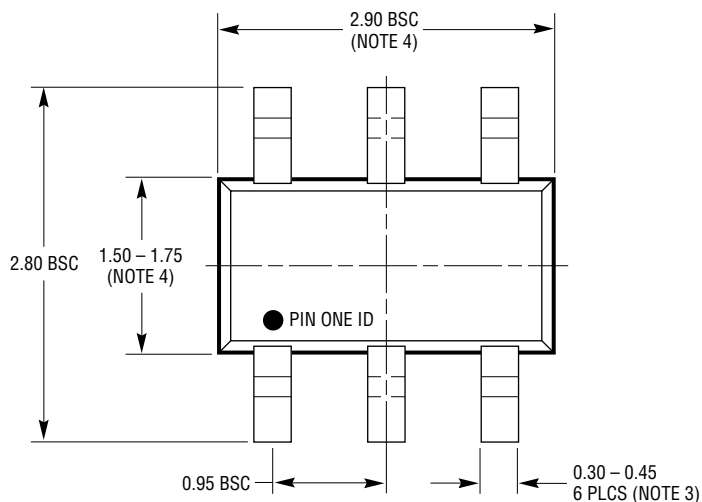


## PACKAGE DESCRIPTION

**S6 Package**  
**6-Lead Plastic TSOT-23**  
 (Reference LTC DWG # 05-08-1636)



RECOMMENDED SOLDER PAD LAYOUT  
 PER IPC CALCULATOR



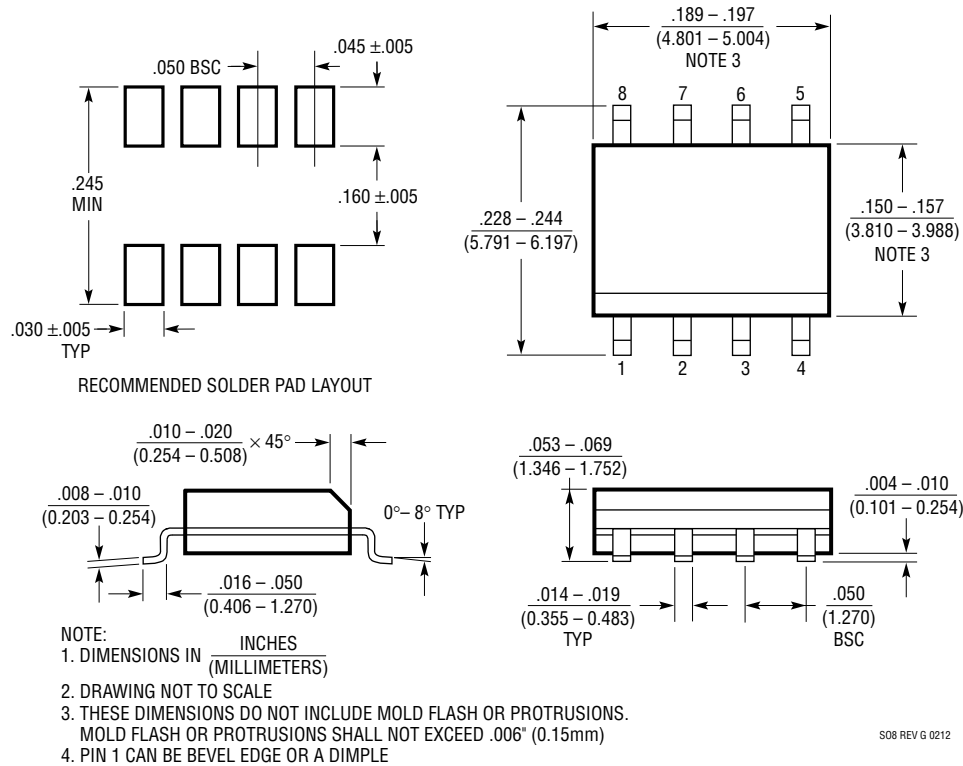
**NOTE:**

1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

S6 TSOT-23 0302

## PACKAGE DESCRIPTION

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

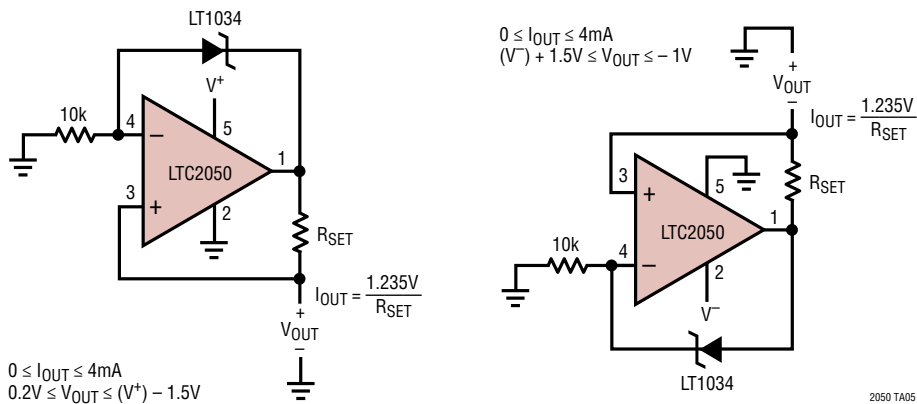


## REVISION HISTORY (Revision history begins at Rev D)

| REV | DATE  | DESCRIPTION                                  | PAGE NUMBER    |
|-----|-------|----------------------------------------------|----------------|
| D   | 08/17 | Updated T <sub>JMAX</sub>                    | 2              |
| E   | 11/18 | Added MP option (higher temperature version) | 1, 2, 4-6, 7-8 |
| F   | 10/19 | Added Automotive product option              | All            |

TYPICAL APPLICATION

Ground Referred Precision Current Sources



RELATED PARTS

| PART NUMBER                        | DESCRIPTION                                              | COMMENTS                                                                     |
|------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------|
| <a href="#">LTC1049</a>            | Low Power Zero-Drift Op Amp                              | Low Supply Current 200µA                                                     |
| <a href="#">LTC1050</a>            | Precision Zero-Drift Op Amp                              | Single Supply Operation 4.75V to 16V, Noise Tested and Guaranteed            |
| <a href="#">LTC1051/LTC1053</a>    | Precision Zero-Drift Op Amp                              | Dual/Quad                                                                    |
| <a href="#">LTC1150</a>            | ±15V Zero-Drift Op Amp                                   | High Voltage Operation ±18V                                                  |
| <a href="#">LTC1152</a>            | Rail-to-Rail Input and Output Zero-Drift Op Amp          | Single Zero-Drift Op Amp with Rail-to-Rail Input and Output and Shutdown     |
| <a href="#">LT<sup>®</sup>1677</a> | Low Noise Rail-to-Rail Input and Output Precision Op Amp | V <sub>OS</sub> = 90µV, V <sub>S</sub> = 2.7V to 44V                         |
| <a href="#">LT1884/LT1885</a>      | Rail-to-Rail Output Precision Op Amp                     | V <sub>OS</sub> = 50µV, I <sub>B</sub> = 400pA, V <sub>S</sub> = 2.7V to 40V |
| <a href="#">LTC2051</a>            | Dual Zero-Drift Op Amp                                   | Dual Version of the LTC2050 in MS8 Package                                   |

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### Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

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