

# Single/Dual Micropower Zero-Drift Operational Amplifiers

## FEATURES

- **Supply Current 150 $\mu$ A (Max per Amplifier)**  
Guaranteed from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$
- **Offset Voltage 3 $\mu$ V (Max,  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ )**
- **Offset Voltage Drift 30nV/ $^{\circ}\text{C}$  (Max,  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ )**
- **Guaranteed Specifications from  $-55^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  (LTC2054MP)**
- Common Mode Input Range from  $V^{-}$  to  $V^{+} - 0.5\text{V}$
- Output Swings Rail-to-Rail
- Voltage Gain: 140dB (Typ)
- PSRR and CMRR: 130dB (Typ)
- Input Bias Current: 1pA (Typ,  $25^{\circ}\text{C}$ )
- Noise: 1.6 $\mu\text{V}_{\text{P-P}}$  (0.01Hz to 10Hz Typ)
- Supply Operation:  
2.7V to 6V (LTC2054/LTC2055)  
2.7V to  $\pm 5.5\text{V}$  (LTC2054HV/LTC2055HV)
- Low Profile (1mm) TSOT-23, MS8 and  
3mm  $\times$  3mm  $\times$  0.8mm DFN Packages

## APPLICATIONS

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

## DESCRIPTION

The LTC<sup>®</sup>2054/LTC2055 are low power, low noise, single/dual, zero-drift operational amplifiers with an extended temperature version (LTC2054MP) that has guaranteed specifications from  $-55^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ . They are available in TSOT-23 (ThinSOT<sup>™</sup>) and MS8 packages. For space limited applications, the LTC2055 is also available in a 3mm  $\times$  3mm  $\times$  0.8mm dual fine pitch leadless package (DFN). They operate from a single 2.7V minimum supply and support  $\pm 5\text{V}$  applications. The current consumption is typically 150 $\mu\text{A}$  for the LTC2054 and 130 $\mu\text{A}/\text{amp}$  for the LTC2055.

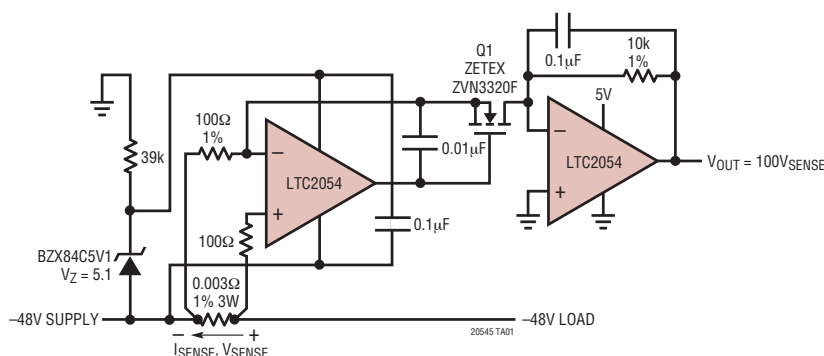
The LTC2054/LTC2055, despite their miniature size, feature uncompromising DC performance. The maximum input offset voltage and offset drift are 3.0 $\mu\text{V}$  and 30nV/ $^{\circ}\text{C}$  over the  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  industrial temperature range. The almost zero DC offset and drift are supported with a power supply rejection ratio (PSRR) and common mode rejection ratio (CMRR) of 130dB (typ).

The input common mode voltage ranges from the negative supply up to typically 0.5V below the positive supply. The open-loop gain is typically 140dB. The LTC2054/LTC2055 also feature a 1.6 $\mu\text{V}_{\text{P-P}}$  DC to 10Hz noise and a 500kHz gain-bandwidth product.

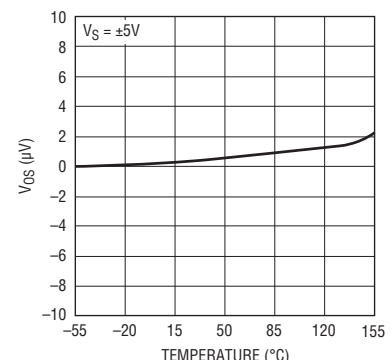
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## TYPICAL APPLICATION

**-48V Low Side Precision Current Sense**



**V<sub>OS</sub> vs Temperature**



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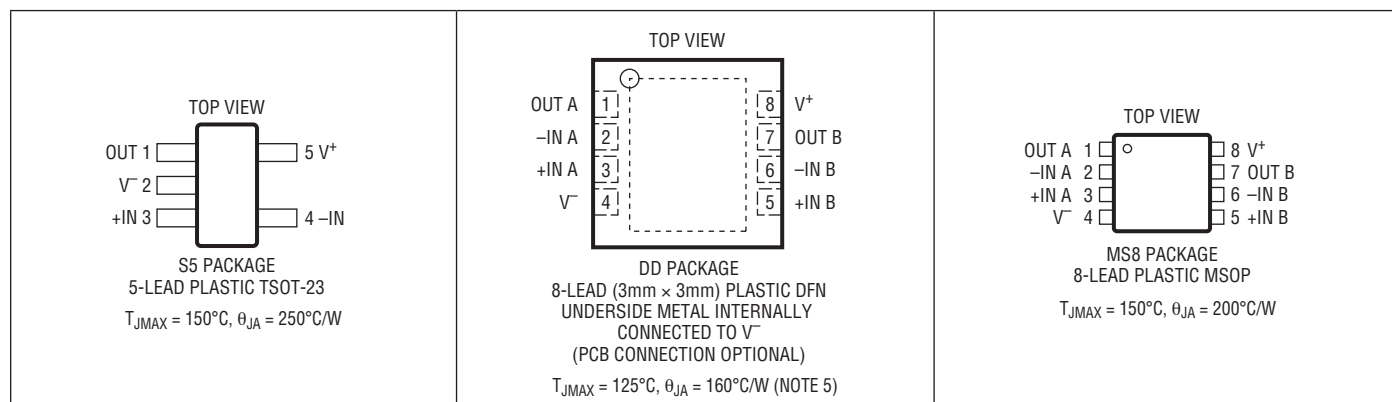
# LTC2054/LTC2055

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage ( $V^+$  to  $V^-$ )  
 LTC2054/LTC2055 ..... 7V  
 LTC2054HV/LTC2055HV ..... 12V  
 Input Voltage ..... ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )  
 Input Current .....  $\pm 10mA$   
 Output Short-Circuit Duration ..... Indefinite

Specified Temperature Range (Note 2)  
 LTC2054C/LTC2055C .....  $0^{\circ}C$  to  $70^{\circ}C$   
 LTC2054I/LTC2055I .....  $-40^{\circ}C$  to  $85^{\circ}C$   
 LTC2054H/LTC2055H .....  $-40^{\circ}C$  to  $125^{\circ}C$   
 LTC2054MP .....  $-55^{\circ}C$  to  $150^{\circ}C$   
 Storage Temperature Range .....  $-65^{\circ}C$  to  $150^{\circ}C$   
 DD Package .....  $-65^{\circ}C$  to  $125^{\circ}C$   
 Lead Temperature (Soldering, 10 sec)  
 TSOT23 and MS8 Packages .....  $300^{\circ}C$

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH  | TAPE AND REEL       | PART MARKING* | PACKAGE DESCRIPTION            | SPECIFIED TEMPERATURE RANGE      |
|-------------------|---------------------|---------------|--------------------------------|----------------------------------|
| LTC2054CS5#PBF    | LTC2054CS5#TRPBF    | LTAGB         | 5-Lead Plastic TSOT-23         | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2054HVC5#PBF   | LTC2054HVC5#TRPBF   | LTAGD         | 5-Lead Plastic TSOT-23         | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2054IS5#PBF    | LTC2054IS5#TRPBF    | LTAGB         | 5-Lead Plastic TSOT-23         | $-40^{\circ}C$ to $85^{\circ}C$  |
| LTC2054HVIS5#PBF  | LTC2054HVIS5#TRPBF  | LTAGD         | 5-Lead Plastic TSOT-23         | $-40^{\circ}C$ to $85^{\circ}C$  |
| LTC2054HS5#PBF    | LTC2054HS5#TRPBF    | LTAGB         | 5-Lead Plastic TSOT-23         | $-40^{\circ}C$ to $125^{\circ}C$ |
| LTC2054HVHS5#PBF  | LTC2054HVHS5#TRPBF  | LTAGD         | 5-Lead Plastic TSOT-23         | $-40^{\circ}C$ to $125^{\circ}C$ |
| LTC2055CDD#PBF    | LTC2055CDD#TRPBF    | LBCW          | 8-Lead (3mm x 3mm) Plastic DFN | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2055HVCDD#PBF  | LTC2055HVCDD#TRPBF  | LBCX          | 8-Lead (3mm x 3mm) Plastic DFN | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2055IDD#PBF    | LTC2055IDD#TRPBF    | LBCW          | 8-Lead (3mm x 3mm) Plastic DFN | $-40^{\circ}C$ to $85^{\circ}C$  |
| LTC2055HVIDD#PBF  | LTC2055HVIDD#TRPBF  | LBCX          | 8-Lead (3mm x 3mm) Plastic DFN | $-40^{\circ}C$ to $85^{\circ}C$  |
| LTC2055HDD#PBF    | LTC2055HDD#TRPBF    | LBCW          | 8-Lead (3mm x 3mm) Plastic DFN | $-40^{\circ}C$ to $125^{\circ}C$ |
| LTC2055HVHDD#PBF  | LTC2055HVHDD#TRPBF  | LBCX          | 8-Lead (3mm x 3mm) Plastic DFN | $-40^{\circ}C$ to $125^{\circ}C$ |
| LTC2055CMS8#PBF   | LTC2054CMS8#TRPBF   | LTBCR         | 8-Lead Plastic MSOP            | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2055HVCMS8#PBF | LTC2055HVCMS8#TRPBF | LTBCT         | 8-Lead Plastic MSOP            | $0^{\circ}C$ to $70^{\circ}C$    |
| LTC2055IMS8#PBF   | LTC2055IMS8#TRPBF   | LTBCR         | 8-Lead Plastic MSOP            | $-40^{\circ}C$ to $85^{\circ}C$  |

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## ORDER INFORMATION

| LEAD FREE FINISH  | TAPE AND REEL       | PART MARKING* | PACKAGE DESCRIPTION    | SPECIFIED TEMPERATURE RANGE |
|-------------------|---------------------|---------------|------------------------|-----------------------------|
| LTC2055HVIMS8#PBF | LTC2055HVIMS8#TRPBF | LTBCT         | 8-Lead Plastic MSOP    | –40°C to 85°C               |
| LTC2055HMS8#PBF   | LTC2055HMS8#TRPBF   | LTBCR         | 8-Lead Plastic MSOP    | –40°C to 125°C              |
| LTC2055HVHMS8#PBF | LTC2055HVHMS8#TRPBF | LTBCT         | 8-Lead Plastic MSOP    | –40°C to 125°C              |
| LTC2054MPS5#PBF   | LTC2054MPS5#TRPBF   | LTFFF         | 5-Lead Plastic TSOT-23 | –55°C to 150°C              |
| LTC2054HVMP55#PBF | LTC2054HVMP55#TRPBF | LTFFG         | 5-Lead Plastic TSOT-23 | –55°C to 150°C              |

Consult LTC Marketing for parts specified with wider operating temperature ranges. \*The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

## ELECTRICAL CHARACTERISTICS (LTC2054/LTC2055) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ . $V_S = 3\text{V}$ , $5\text{V}$ unless otherwise noted. (Note 2)

| SYMBOL                   | PARAMETER                              | CONDITIONS                                                                                       |   | LTC2054C/LTC2055C<br>LTC2054I/LTC2055I |            |            | LTC2054H/LTC2055H |            |            | UNITS                                      |
|--------------------------|----------------------------------------|--------------------------------------------------------------------------------------------------|---|----------------------------------------|------------|------------|-------------------|------------|------------|--------------------------------------------|
|                          |                                        |                                                                                                  |   | MIN                                    | TYP        | MAX        | MIN               | TYP        | MAX        |                                            |
| $I_S$                    | Supply Current (LTC2054)               | No Load                                                                                          | ● |                                        | 140        | 175        |                   | 140        | 180        | $\mu\text{A}$                              |
| $I_S$                    | Supply Current Per Amplifier (LTC2055) | No Load                                                                                          | ● |                                        | 130        | 150        |                   | 130        | 155        | $\mu\text{A}$                              |
| $V_{OS}$                 | Input Offset Voltage                   | (Note 3)                                                                                         |   |                                        | $\pm 0.5$  | $\pm 3$    |                   | $\pm 0.5$  | $\pm 3$    | $\mu\text{V}$                              |
| $\Delta V_{OS}/\Delta T$ | Average Input Offset Drift             | (Note 3)                                                                                         | ● |                                        | 0.02       | $\pm 0.03$ |                   | 0.02       | $\pm 0.05$ | $\mu\text{V}/^\circ\text{C}$               |
|                          | Long-Term Offset Drift                 |                                                                                                  |   |                                        | 50         |            |                   | 50         |            | $\text{nV}/\sqrt{\text{mo}}$               |
| $I_B$                    | Input Bias Current                     | (Note 4)                                                                                         | ● |                                        | $\pm 1$    | $\pm 150$  |                   | $\pm 1$    | $\pm 3000$ | $\text{pA}$<br>$\text{pA}$                 |
| $I_{OS}$                 | Input Offset Current                   | (Note 4)                                                                                         | ● |                                        | $\pm 2$    | $\pm 300$  |                   | $\pm 2$    | $\pm 700$  | $\text{pA}$<br>$\text{pA}$                 |
| $e_n$                    | Input Noise Voltage                    | $R_S = 100\Omega$ , DC to 1Hz<br>$R_S = 100\Omega$ , DC to 10Hz                                  |   |                                        | 0.6<br>1.6 |            |                   | 0.6<br>1.6 |            | $\mu\text{V}_{P-P}$<br>$\mu\text{V}_{P-P}$ |
| CMRR                     | Common Mode Rejection Ratio            | $V_{CM} = \text{GND to } V^+ - 0.7\text{V}$<br>$V_S = 3\text{V}$                                 | ● | 115<br>110                             | 130        |            | 115<br>110        | 130        |            | $\text{dB}$<br>$\text{dB}$                 |
|                          |                                        | $V_{CM} = \text{GND to } V^+ - 0.7\text{V}$<br>$V_S = 5\text{V}$                                 | ● | 120<br>115                             | 130        |            | 120<br>115        | 130        |            | $\text{dB}$<br>$\text{dB}$                 |
| PSRR                     | Power Supply Rejection Ratio           | $V_S = 2.7\text{V to } 6\text{V}$                                                                | ● | 120<br>115                             | 130        |            | 120<br>115        | 130        |            | $\text{dB}$<br>$\text{dB}$                 |
| $A_{VOL}$                | Large-Signal Voltage Gain              | $R_L = 100\text{k}$ , $V_S = 3\text{V}$ , $V_{OUT} = V_S/2$                                      | ● | 120<br>115                             | 135        |            | 120<br>115        | 135        |            | $\text{dB}$<br>$\text{dB}$                 |
|                          |                                        | $R_L = 100\text{k}$ , $V_S = 5\text{V}$ , $V_{OUT} = V_S/2$                                      | ● | 125<br>120                             | 140        |            | 125<br>120        | 140        |            | $\text{dB}$<br>$\text{dB}$                 |
| $V_{OUT}$                | Output Voltage Swing High              | $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$     | ● | 2.87<br>2.85                           | 2.89       |            | 2.87<br>2.84      | 2.89       |            | $\text{V}$<br>$\text{V}$                   |
|                          |                                        | $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$     | ● | 4.80<br>4.75                           | 4.83       |            | 4.80<br>4.70      | 4.83       |            | $\text{V}$<br>$\text{V}$                   |
|                          |                                        | $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ | ● | 2.98<br>2.975                          | 2.99       |            | 2.98<br>2.97      | 2.99       |            | $\text{V}$<br>$\text{V}$                   |
|                          |                                        | $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ | ● | 4.985<br>4.980                         | 4.99       |            | 4.985<br>4.970    | 4.99       |            | $\text{V}$<br>$\text{V}$                   |

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# LTC2054/LTC2055

## ELECTRICAL CHARACTERISTICS (LTC2054/LTC2055) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ . $V_S = 3\text{V}$ , $5\text{V}$ unless otherwise noted. (Note 2)

| SYMBOL    | PARAMETER                   | CONDITIONS                                     |   | LTC2054C/LTC2055C<br>LTC2054I/LTC2055I |     |     | LTC2054H/LTC2055H |     |     | UNITS            |
|-----------|-----------------------------|------------------------------------------------|---|----------------------------------------|-----|-----|-------------------|-----|-----|------------------|
|           |                             |                                                |   | MIN                                    | TYP | MAX | MIN               | TYP | MAX |                  |
| $V_{OUT}$ | Output Voltage Swing Low    | $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$   | ● |                                        | 2   | 8   |                   | 3   | 8   | mV               |
|           |                             | $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$   |   |                                        |     | 10  |                   |     | 10  | mV               |
|           |                             | $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$   | ● |                                        | 2   | 8   |                   | 3   | 8   | mV               |
|           |                             | $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$   |   |                                        |     | 10  |                   |     | 10  | mV               |
|           |                             | $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ | ● |                                        | 2   | 8   |                   | 3   | 8   | mV               |
|           |                             | $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ |   |                                        |     | 10  |                   |     | 10  | mV               |
|           |                             | $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ | ● |                                        | 2   | 8   |                   | 3   | 8   | mV               |
|           |                             | $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ |   |                                        |     | 10  |                   |     | 10  | mV               |
| SR        | Slew Rate                   |                                                |   |                                        | 0.5 |     |                   | 0.5 |     | V/ $\mu\text{s}$ |
| GBW       | Gain Bandwidth Product      |                                                |   |                                        | 500 |     |                   | 500 |     | kHz              |
| $f_S$     | Internal Sampling Frequency |                                                |   |                                        | 1   |     |                   | 1   |     | kHz              |

## (LTC2054HV/LTC2055HV) 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 2)

| SYMBOL                   | PARAMETER                      | CONDITIONS                                                      |   | LTC2054HVC/LTC2055HVC<br>LTC2054HVI/LTC2055HVI |            |            | LTC2054HVV/LTC2055HVV |            |            | UNITS                        |
|--------------------------|--------------------------------|-----------------------------------------------------------------|---|------------------------------------------------|------------|------------|-----------------------|------------|------------|------------------------------|
|                          |                                |                                                                 |   | MIN                                            | TYP        | MAX        | MIN                   | TYP        | MAX        |                              |
| $I_S$                    | Supply Current                 | No Load (LTC2054)                                               | ● |                                                | 175        | 210        |                       | 175        | 215        | $\mu\text{A}$                |
| $I_S$                    | Supply Current (Per Amplifier) | No Load (LTC2055)                                               | ● |                                                | 150        | 180        |                       | 150        | 185        | $\mu\text{A}$                |
| $V_{OS}$                 | Input Offset Voltage           | (Note 3)                                                        |   |                                                | $\pm 0.5$  | $\pm 5$    |                       | $\pm 0.5$  | $\pm 5$    | $\mu\text{V}$                |
| $\Delta V_{OS}/\Delta T$ | Average Input Offset Drift     | (Note 3)                                                        | ● |                                                | 0.025      | $\pm 0.03$ |                       | 0.025      | $\pm 0.05$ | $\mu\text{V}/^\circ\text{C}$ |
|                          | Long-Term Offset Drift         |                                                                 |   |                                                | 50         |            |                       | 50         |            | nV/ $\sqrt{\text{mo}}$       |
| $I_B$                    | Input Bias Current             | (Note 4)                                                        | ● |                                                | $\pm 3$    | $\pm 150$  |                       | $\pm 3$    | $\pm 3000$ | pA                           |
|                          |                                |                                                                 |   |                                                |            |            |                       |            |            | pA                           |
| $I_{OS}$                 | Input Offset Current           | (Note 4)                                                        | ● |                                                | $\pm 6$    | $\pm 300$  |                       | $\pm 6$    | $\pm 700$  | pA                           |
|                          |                                |                                                                 |   |                                                |            |            |                       |            |            | pA                           |
| $e_n$                    | Input Noise Voltage            | $R_S = 100\Omega$ , DC to 1Hz<br>$R_S = 100\Omega$ , DC to 10Hz |   |                                                | 0.6        |            |                       | 0.6        |            | $\mu\text{V}_{P-P}$          |
|                          |                                |                                                                 |   |                                                | 1.6        |            |                       | 1.6        |            | $\mu\text{V}_{P-P}$          |
| CMRR                     | Common Mode Rejection Ratio    | $V_{CM} = \text{GND to } V^+ - 0.9$                             | ● | 120                                            | 130        |            | 120                   | 130        |            | dB                           |
|                          |                                |                                                                 |   | 115                                            |            |            | 115                   |            |            | dB                           |
| PSRR                     | Power Supply Rejection Ratio   | $V_S = 2.7\text{V to } 11\text{V}$                              | ● | 120                                            | 130        |            | 120                   | 130        |            | dB                           |
|                          |                                |                                                                 |   | 115                                            |            |            | 115                   |            |            | dB                           |
| AVOL                     | Large-Signal Voltage Gain      | $R_L = 100\text{k}$ , $V_{OUT} = \text{GND}$                    | ● | 125                                            | 140        |            | 125                   | 140        |            | dB                           |
|                          |                                |                                                                 |   | 120                                            |            |            | 120                   |            |            | dB                           |
| $V_{OUT}$                | Maximum Output Voltage Swing   | $R_L = 5\text{k to GND}$                                        | ● | $\pm 4.78$                                     | $\pm 4.82$ |            | $\pm 4.78$            | $\pm 4.82$ |            | V                            |
|                          |                                | $R_L = 5\text{k to GND}$                                        |   | $\pm 4.75$                                     |            |            | $\pm 4.70$            |            |            | V                            |
|                          |                                | $R_L = 100\text{k to GND}$                                      | ● | $\pm 4.98$                                     | $\pm 4.99$ |            | $\pm 4.98$            | $\pm 4.99$ |            | V                            |
|                          |                                | $R_L = 100\text{k to GND}$                                      |   | $\pm 4.975$                                    |            |            | $\pm 4.97$            |            |            | V                            |
| SR                       | Slew Rate                      |                                                                 |   |                                                | 0.5        |            |                       | 0.5        |            | V/ $\mu\text{s}$             |
| GBW                      | Gain Bandwidth Product         |                                                                 |   |                                                | 500        |            |                       | 500        |            | kHz                          |
| $f_S$                    | Internal Sampling Frequency    |                                                                 |   |                                                | 1          |            |                       | 1          |            | kHz                          |

# ELECTRICAL CHARACTERISTICS (LTC2054MP) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$ . $V_S = 3\text{V}$ , $5\text{V}$ unless otherwise noted. (Note 2)

| SYMBOL                   | PARAMETER                    | CONDITIONS                                                                                       |   | MIN            | TYP        | MAX                 | UNITS                                      |
|--------------------------|------------------------------|--------------------------------------------------------------------------------------------------|---|----------------|------------|---------------------|--------------------------------------------|
| $I_S$                    | Supply Current               | No Load                                                                                          | ● |                | 145        | 190                 | $\mu\text{A}$                              |
| $V_{OS}$                 | Input Offset Voltage         | (Note 3)<br>(Note 3) $-55^\circ\text{C}$ to $135^\circ\text{C}$                                  | ● |                |            | $\pm 10$<br>$\pm 8$ | $\mu\text{V}$<br>$\mu\text{V}$             |
| $\Delta V_{OS}/\Delta T$ | Average Input Offset Drift   | (Note 3)                                                                                         | ● |                | 0.04       | $\pm 0.1$           | $\mu\text{V}/^\circ\text{C}$               |
|                          | Long-Term Offset Drift       |                                                                                                  |   |                | 50         |                     | $\text{nV}/\sqrt{\text{mo}}$               |
| $I_B$                    | Input Bias Current           | (Note 4)                                                                                         | ● |                | $\pm 1$    | $\pm 12$            | $\text{pA}$<br>$\text{nA}$                 |
| $I_{OS}$                 | Input Offset Current         | (Note 4)                                                                                         | ● |                | $\pm 2$    | $\pm 5$             | $\text{pA}$<br>$\text{nA}$                 |
| $e_n$                    | Input Noise Voltage          | $R_S = 100\Omega$ , DC to 1Hz<br>$R_S = 100\Omega$ , DC to 10Hz                                  |   |                | 0.6<br>1.6 |                     | $\mu\text{V}_{P-P}$<br>$\mu\text{V}_{P-P}$ |
| CMRR                     | Common Mode Rejection Ratio  | $V_{CM} = \text{GND to } V^+ - 0.7\text{V}$<br>$V_S = 3\text{V}$                                 | ● | 115<br>105     | 130        |                     | $\text{dB}$<br>$\text{dB}$                 |
|                          |                              | $V_{CM} = \text{GND to } V^+ - 0.7\text{V}$<br>$V_S = 5\text{V}$                                 | ● | 120<br>110     | 130        |                     | $\text{dB}$<br>$\text{dB}$                 |
| PSRR                     | Power Supply Rejection Ratio | $V_S = 2.7\text{V to } 6\text{V}$                                                                | ● | 120<br>110     | 130        |                     | $\text{dB}$<br>$\text{dB}$                 |
| $A_{VOL}$                | Large-Signal Voltage Gain    | $R_L = 100\text{k}$ , $V_S = 3\text{V}$ , $V_{OUT} = V_S/2$                                      | ● | 120<br>110     | 135        |                     | $\text{dB}$<br>$\text{dB}$                 |
|                          |                              | $R_L = 100\text{k}$ , $V_S = 5\text{V}$ , $V_{OUT} = V_S/2$                                      | ● | 125<br>115     | 140        |                     | $\text{dB}$<br>$\text{dB}$                 |
| $V_{OUT}$                | Output Voltage Swing High    | $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$     | ● | 2.87<br>2.84   | 2.89       |                     | $\text{V}$<br>$\text{V}$                   |
|                          |                              | $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$     | ● | 4.80<br>4.70   | 4.83       |                     | $\text{V}$<br>$\text{V}$                   |
|                          |                              | $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ | ● | 2.98<br>2.97   | 2.99       |                     | $\text{V}$<br>$\text{V}$                   |
|                          |                              | $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ | ● | 4.985<br>4.970 | 4.99       |                     | $\text{V}$<br>$\text{V}$                   |
|                          |                              |                                                                                                  |   |                |            |                     |                                            |
| $V_{OUT}$                | Output Voltage Swing Low     | $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$     | ● |                | 3          | 8<br>10             | $\text{mV}$<br>$\text{mV}$                 |
|                          |                              | $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$     | ● |                | 3          | 8<br>10             | $\text{mV}$<br>$\text{mV}$                 |
|                          |                              | $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ | ● |                | 3          | 8<br>10             | $\text{mV}$<br>$\text{mV}$                 |
|                          |                              | $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$<br>$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ | ● |                | 3          | 8<br>10             | $\text{mV}$<br>$\text{mV}$                 |
|                          |                              |                                                                                                  |   |                |            |                     |                                            |
| SR                       | Slew Rate                    |                                                                                                  |   |                | 0.5        |                     | $\text{V}/\mu\text{s}$                     |
| GBW                      | Gain Bandwidth Product       |                                                                                                  |   |                | 500        |                     | $\text{kHz}$                               |
| $f_S$                    | Internal Sampling Frequency  |                                                                                                  |   |                | 1          |                     | $\text{kHz}$                               |

# LTC2054/LTC2055

## ELECTRICAL CHARACTERISTICS (LTC2054HVMP) 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 2)

| SYMBOL                   | PARAMETER                    | CONDITIONS                                                      |   | MIN                       | TYP        | MAX       | UNITS                                      |
|--------------------------|------------------------------|-----------------------------------------------------------------|---|---------------------------|------------|-----------|--------------------------------------------|
| $I_S$                    | Supply Current               | No Load                                                         | ● |                           | 175        | 220       | $\mu\text{A}$                              |
| $V_{OS}$                 | Input Offset Voltage         | (Note 3)                                                        | ● |                           |            | $\pm 10$  | $\mu\text{V}$                              |
| $\Delta V_{OS}/\Delta T$ | Average Input Offset Drift   | (Note 3)                                                        | ● |                           | 0.05       | $\pm 0.1$ | $\mu\text{V}/^\circ\text{C}$               |
|                          | Long-Term Offset Drift       |                                                                 |   |                           | 50         |           | $\text{nV}/\sqrt{\text{mo}}$               |
| $I_B$                    | Input Bias Current           | (Note 4)                                                        | ● |                           | $\pm 3$    | $\pm 12$  | $\text{pA}$<br>$\text{nA}$                 |
| $I_{OS}$                 | Input Offset Current         | (Note 4)                                                        | ● |                           | $\pm 6$    | $\pm 5$   | $\text{pA}$<br>$\text{nA}$                 |
| $e_n$                    | Input Noise Voltage          | $R_S = 100\Omega$ , DC to 1Hz<br>$R_S = 100\Omega$ , DC to 10Hz |   |                           | 0.6<br>1.6 |           | $\mu\text{V}_{P-P}$<br>$\mu\text{V}_{P-P}$ |
| CMRR                     | Common Mode Rejection Ratio  | $V_{CM} = \text{GND to } V^+ - 0.9$                             | ● | 120<br>110                | 130        |           | $\text{dB}$<br>$\text{dB}$                 |
| PSRR                     | Power Supply Rejection Ratio | $V_S = 2.7\text{V to } 11\text{V}$                              | ● | 120<br>110                | 130        |           | $\text{dB}$<br>$\text{dB}$                 |
| AVOL                     | Large-Signal Voltage Gain    | $R_L = 100\text{k}$ , $V_{OUT} = \text{GND}$                    | ● | 125<br>115                | 140        |           | $\text{dB}$<br>$\text{dB}$                 |
| $V_{OUT}$                | Maximum Output Voltage Swing | $R_L = 5\text{k to GND}$<br>$R_L = 5\text{k to GND}$            | ● | $\pm 4.78$<br>$\pm 4.675$ | $\pm 4.82$ |           | $\text{V}$<br>$\text{V}$                   |
|                          |                              | $R_L = 100\text{k to GND}$<br>$R_L = 100\text{k to GND}$        | ● | $\pm 4.98$<br>$\pm 4.965$ | $\pm 4.99$ |           | $\text{V}$<br>$\text{V}$                   |
|                          |                              |                                                                 |   |                           |            |           |                                            |
| SR                       | Slew Rate                    |                                                                 |   |                           | 0.5        |           | $\text{V}/\mu\text{s}$                     |
| GBW                      | Gain Bandwidth Product       |                                                                 |   |                           | 500        |           | $\text{kHz}$                               |
| $f_S$                    | Internal Sampling Frequency  |                                                                 |   |                           | 1          |           | $\text{kHz}$                               |

**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.

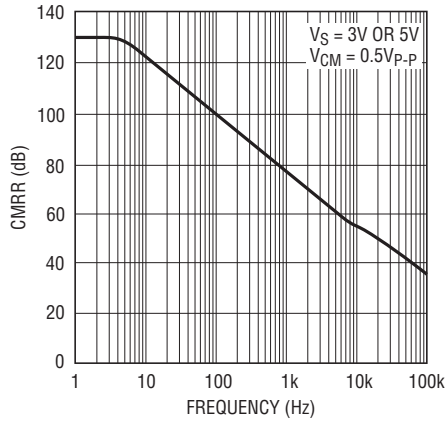
**Note 2:** The LTC2054/LTC2055 are designed, characterized and expected to meet the extended temperature limits of  $-40^\circ\text{C}$  and  $125^\circ\text{C}$ . The LTC2054C/LTC2055C/LTC2054HVC/LTC2055HVC are guaranteed to meet the temperature limits of  $0^\circ\text{C}$  and  $70^\circ\text{C}$ . The LTC2054I/LTC2055I/LTC2054HVI/LTC2055HVI are guaranteed to meet temperature limits of  $-40^\circ\text{C}$  and  $85^\circ\text{C}$ . The LTC2054H/LTC2055H and LTC2054HVH/LTC2055HVH are guaranteed to meet the temperature limits of  $-40^\circ\text{C}$  and  $125^\circ\text{C}$ . The LTC2054MP/LTC2054HVMP are guaranteed to meet the temperature limits of  $-55^\circ\text{C}$  and  $150^\circ\text{C}$ .

**Note 3:** These parameters are guaranteed by design. Thermocouple effects preclude measurements of these voltage levels during automated testing.

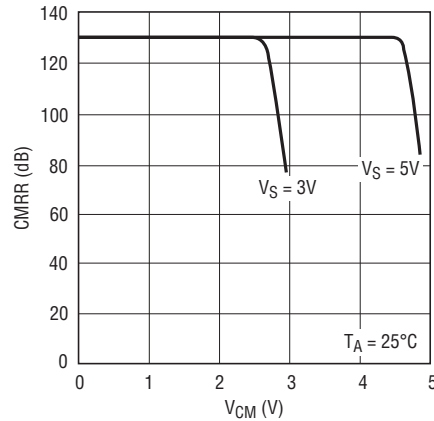
**Note 4:** Limit is determined by high speed automated test capability. See Typical Characteristic curves for actual typical performance. For tighter specifications, please consult Linear Technology Marketing.

**Note 5:** The  $\theta_{JA}$  specified for the DD package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

## TYPICAL PERFORMANCE CHARACTERISTICS

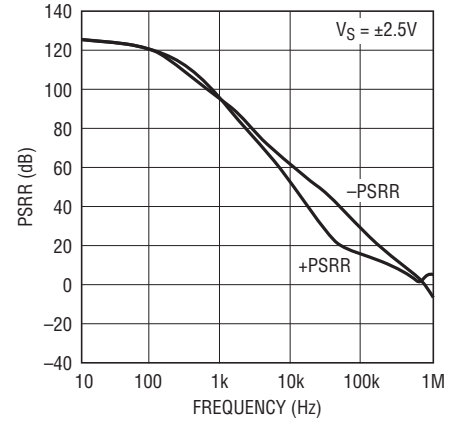
Common Mode Rejection Ratio  
vs Frequency

20545 G01

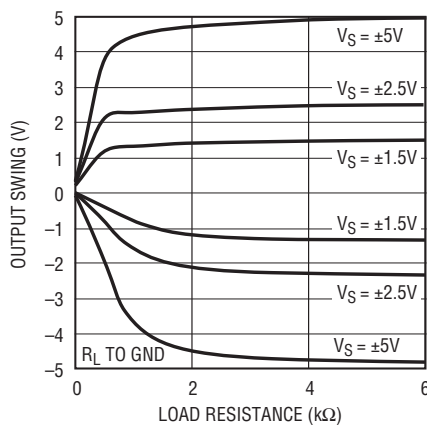
DC CMRR  
vs Common Mode Input Range

20545 G02

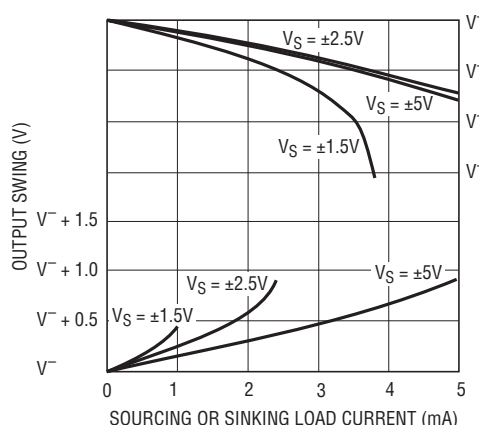
PSRR vs Frequency



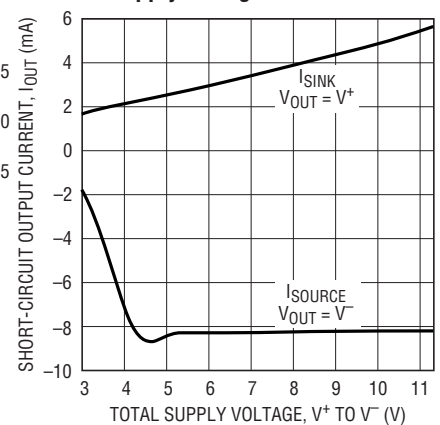
20545 G03

Output Voltage Swing  
vs Load Resistance

20545 G04

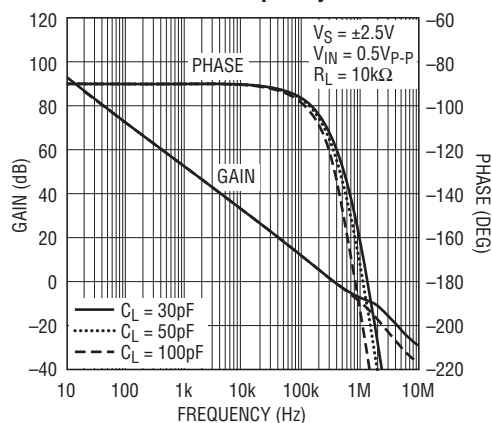
Output Swing  
vs Load Current

20545 G05

Short-Circuit Output Current  
vs Supply Voltage

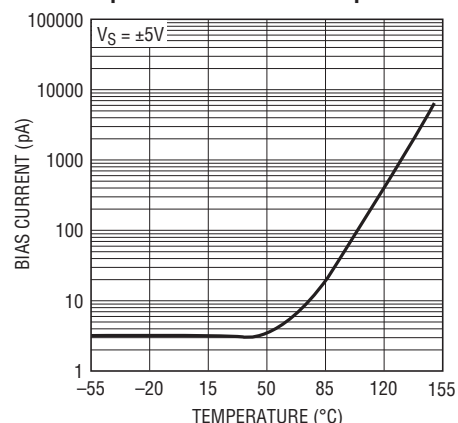
20545 G06

Gain/Phase vs Frequency



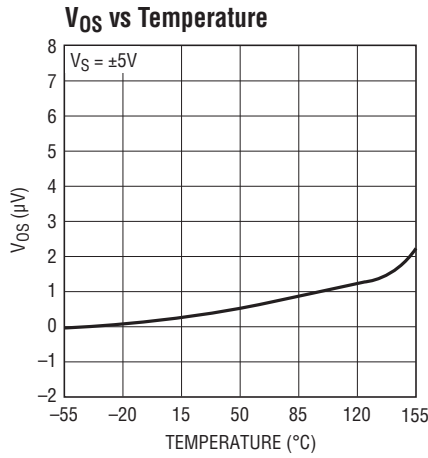
20545 G07

Input Bias Current vs Temperature

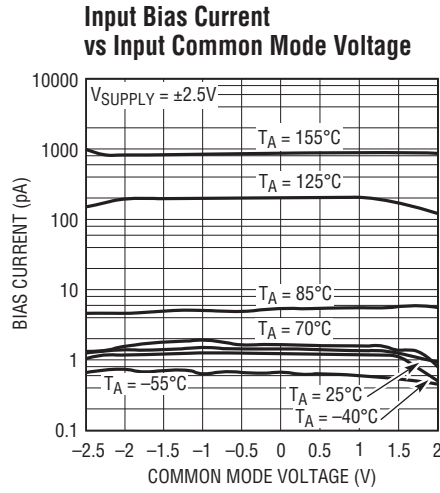


20545 G08

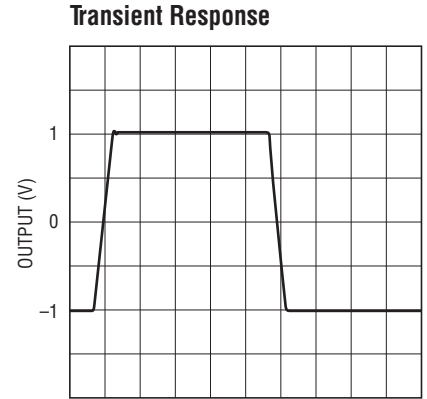
## TYPICAL PERFORMANCE CHARACTERISTICS



20545 G09

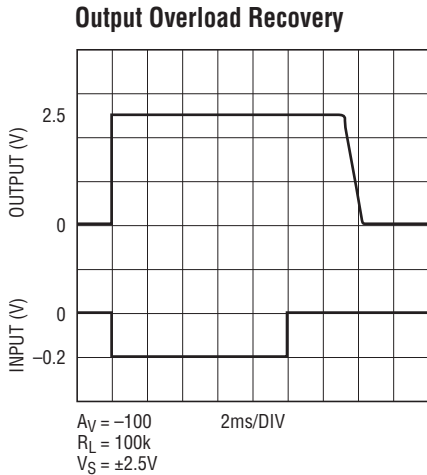


20545 G10



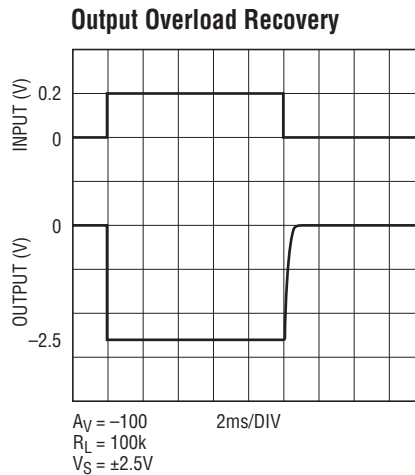
$A_V = 1$   
 $R_L = 100k$   
 $C_L = 50pF$   
 $V_S = \pm 2.5V$   
 $V_{IN} = 10kHz\ 2V_{P-P}$

20545 G11



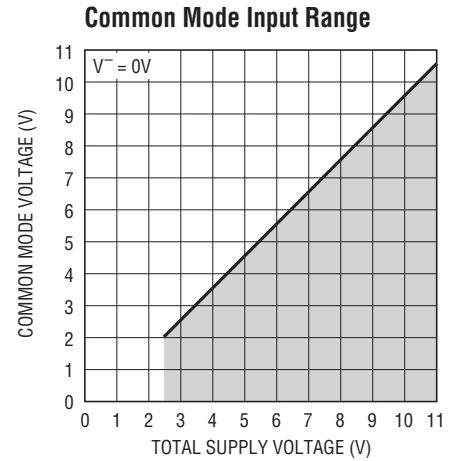
$A_V = -100$   
 $R_L = 100k$   
 $V_S = \pm 2.5V$

20545 G12

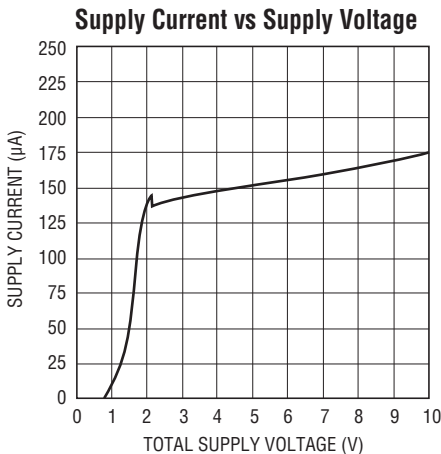


$A_V = -100$   
 $R_L = 100k$   
 $V_S = \pm 2.5V$

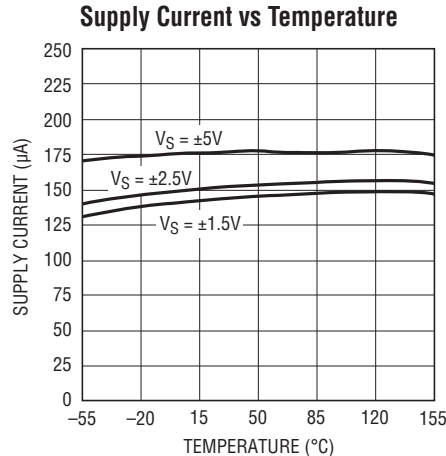
20545 G13



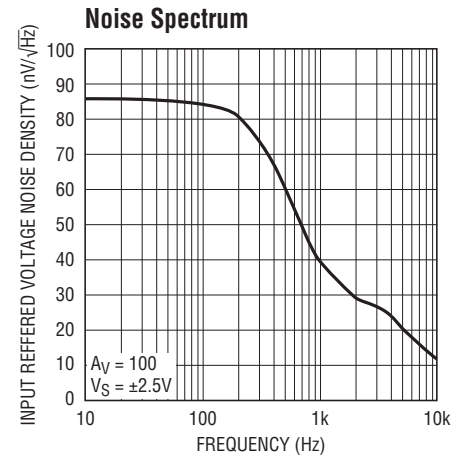
20545 G14



20545 G15



20545 G16

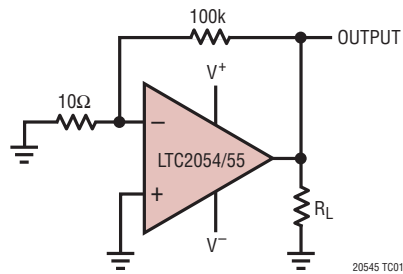


20545 G17

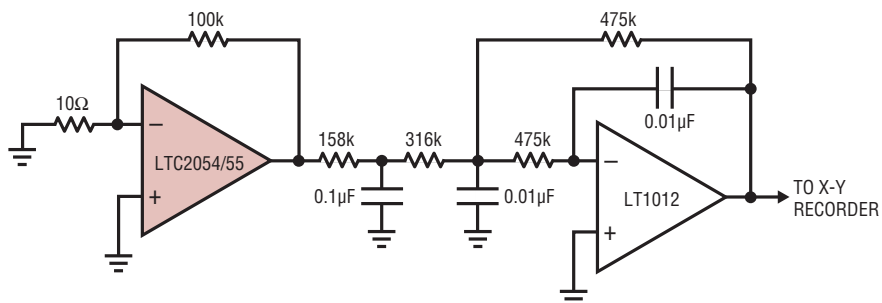
20545fc



## TEST CIRCUITS

Electrical Characteristics  
Test Circuit

DC-10Hz Noise Test Circuit



FOR 1Hz NOISE BW INCREASE ALL THE CAPACITORS BY A FACTOR OF 10.

20545 TC02

## APPLICATIONS INFORMATION

### Clock Feedthrough, Input Bias Current

The LTC2054 and LTC2055 use 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 1.0kHz. 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 LTC2054/LTC2055.

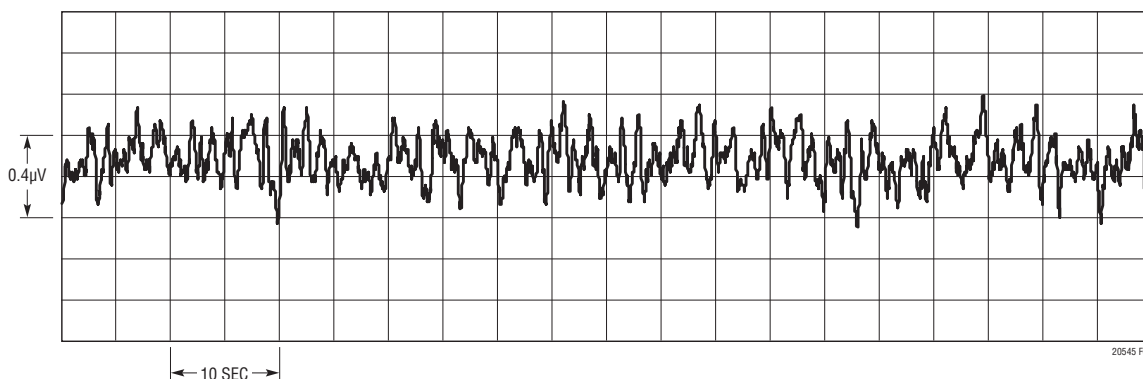
The first form of clock feedthrough is caused by the settling of the internal sampling capacitor and is input referred; that is, it is multiplied by the closed loop gain of the op amp. This form of clock feedthrough is independent of the magnitude of the input source resistance or the magnitude of the gain setting resistors. The LTC2054/LTC2055 have an input referred residue clock feedthrough of less than  $0.2\mu\text{V}_{\text{RMS}}$  at 1.0kHz.

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, and the resulting voltage spikes appear 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  $10\text{k}\Omega$ , this form of clock feedthrough is less than the amount of residue clock feedthrough from the first form described above.

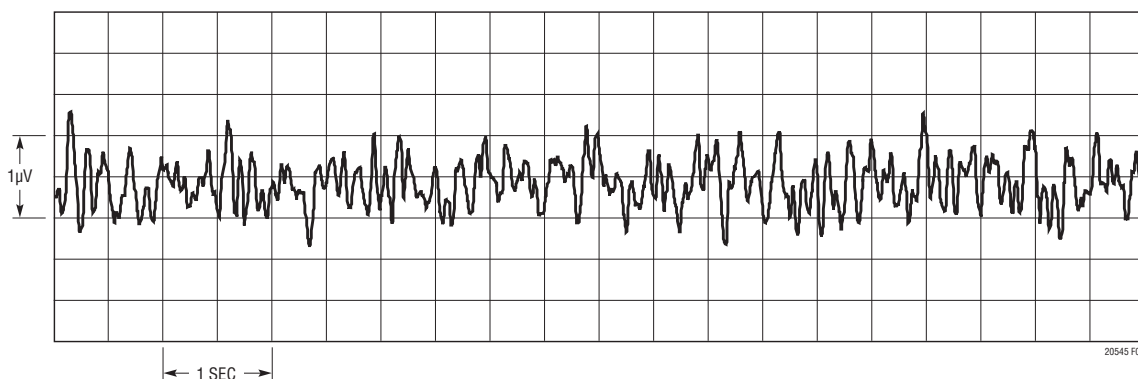
Placing a capacitor across the feedback resistor reduces either form of clock feedthrough by limiting the bandwidth of the closed loop gain.

Input bias current is defined as the DC current into the input pins of the op amp. The same current spikes that

DC to 1Hz Noise



DC to 10Hz Noise



## APPLICATIONS INFORMATION

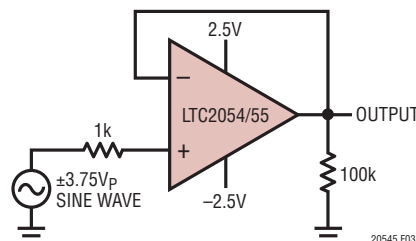
cause the second form of clock feedthrough described above, when averaged, dominate the DC input bias current of the op amp below 70°C.

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 70°C) the leakage current begins to dominate and both the negative and positive pins' input bias currents are in the positive direction (into the pins).

### Extended Common Mode Range

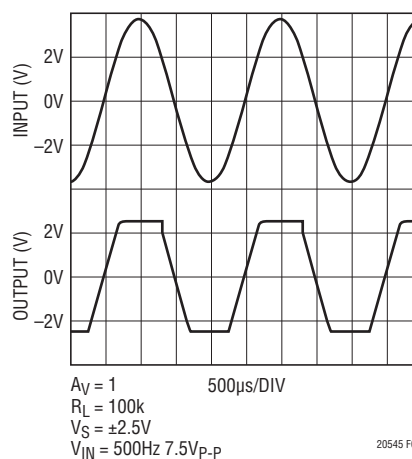
The LTC2054/LTC2055 input stage is designed to allow nearly rail-to-rail input common mode signals. In addition, signals that extend beyond the allowed input common mode range do not cause output phase inversion.

### Voltage Follower with Input Exceeding the Common Mode Range



20545 F03

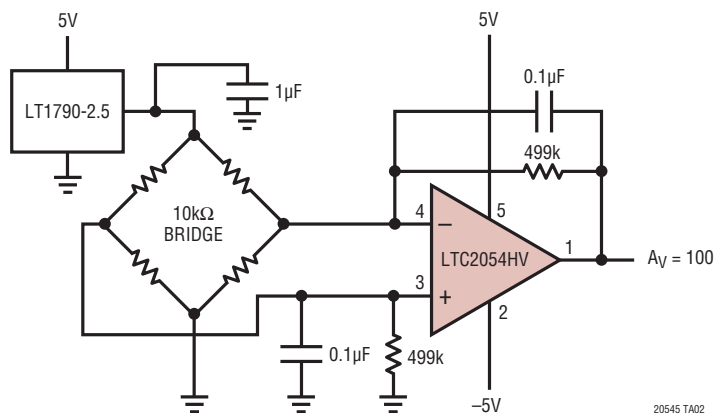
### Extended Common Mode Range



20545 F04

## TYPICAL APPLICATIONS

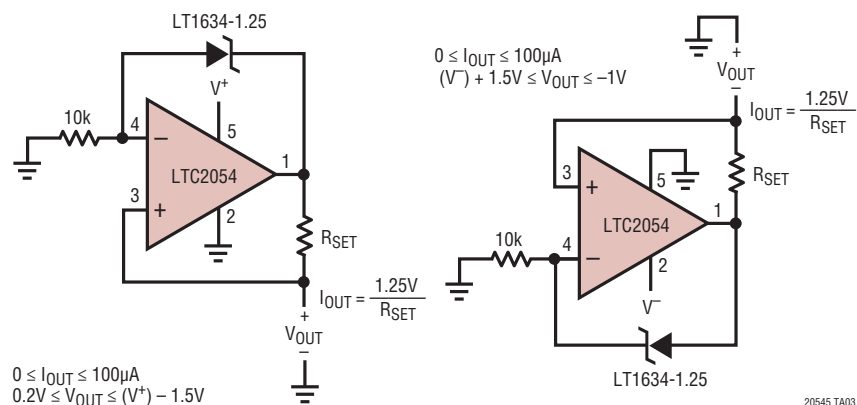
### Simple Differential Bridge Amplifier



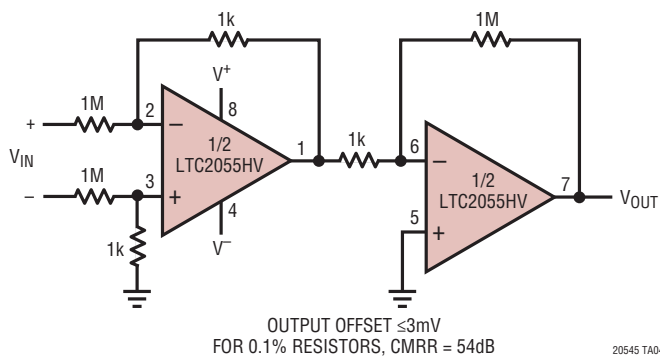
20545 TA02

## TYPICAL APPLICATIONS

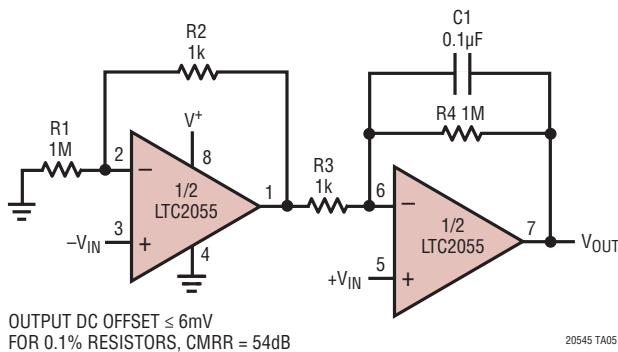
### Ground Referred Precision Current Sources



### Instrumentation Amplifier with 100V Common Mode Input Voltage

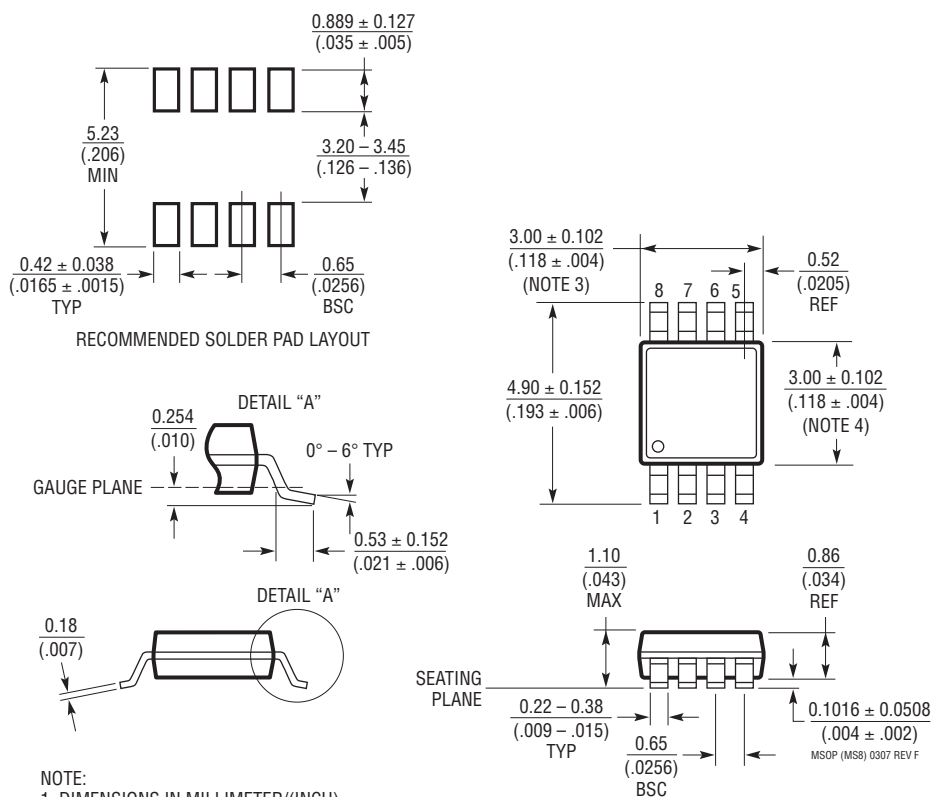


### Gain of 1001 Single Supply Instrumentation Amplifier





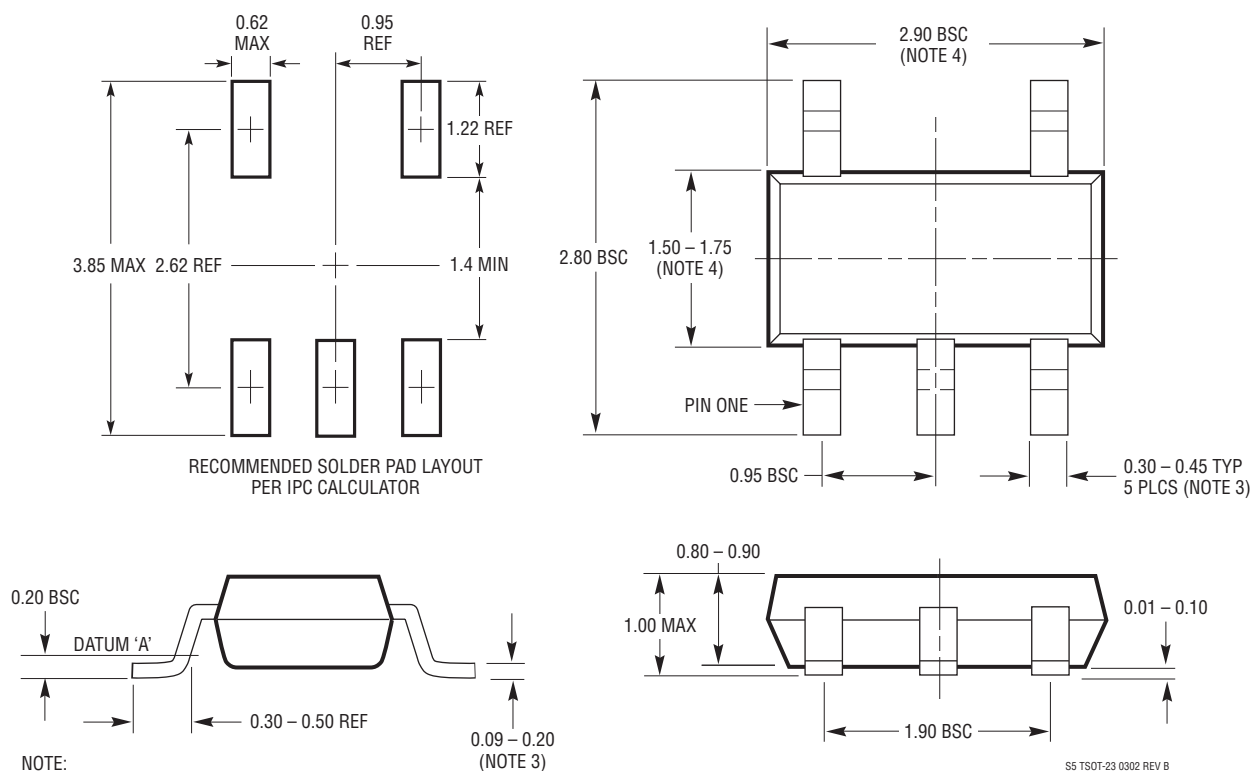
(Reference LTC DWG # 05-08-1660 Rev F)



- NOTE: (.0256)  
BSC
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

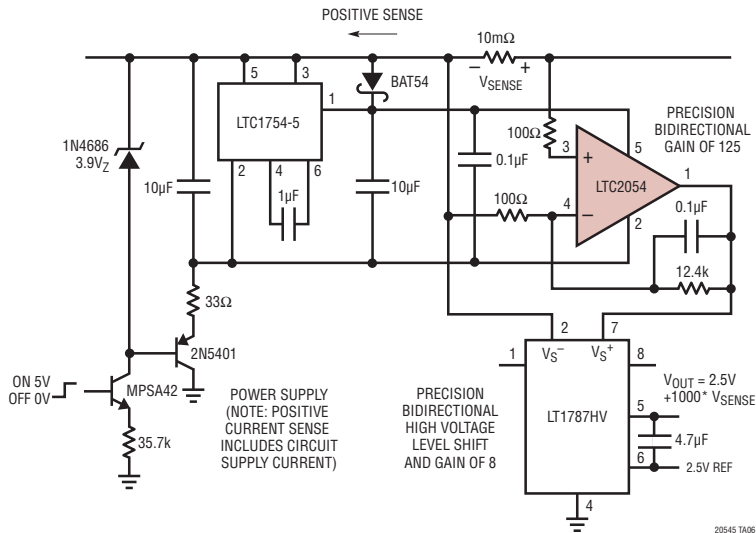
## PACKAGE DESCRIPTION

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

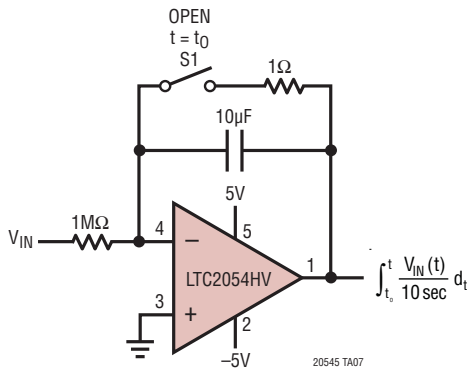


## TYPICAL APPLICATIONS

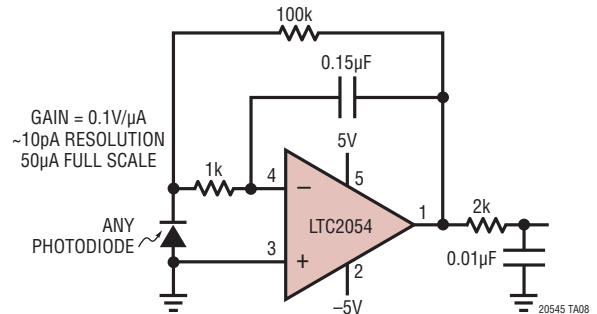
### Low Power, Bidirectional 60V Precision Hi Side Current Sense



### Precision Low Drift Integrator



### Ultra-Precision, Wide Dynamic Range 10Hz Bandwidth Photodiode Amplifier



## RELATED PARTS

| PART NUMBER     | DESCRIPTION                                              | COMMENTS                                                                     |
|-----------------|----------------------------------------------------------|------------------------------------------------------------------------------|
| LTC1049         | Low Power Zero-Drift Op Amp                              | Low Supply Current 200µA                                                     |
| LTC1050         | Precision Zero-Drift Op Amp                              | Single Supply Operation 4.75V to 16V, Noise Tested and Guaranteed            |
| LTC1051/LTC1053 | Precision Zero-Drift Op Amp                              | Dual/Quad Version of the LTC1050                                             |
| LTC1150         | ±15V Zero-Drift Op Amp                                   | High Voltage Operation ±18V                                                  |
| LTC1152         | Rail-to-Rail Input and Output Zero-Drift Op Amp          | Single Zero-Drift Op Amp with Rail-to-Rail Input and Output and Shutdown     |
| LT1677          | Low Noise Rail-to-Rail Input and Output Precision Op Amp | V <sub>OS</sub> = 90µV, V <sub>S</sub> = 2.7V to 44V                         |
| LT1884/LT1885   | 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 |
| LTC2050         | Zero-Drift Op Amp                                        | Enhanced Output Drive Capability                                             |
| LTC2051/LTC2052 | Dual/Quad Zero-Drift Op Amp                              | Dual/Quad Version of the LTC2050 in MS8/GN16 Package                         |
| LTC2053         | Zero-Drift Instrumentation Amp                           | Rail-to-Rail Input                                                           |