

## FEATURES

- Supply Current 175 $\mu$ A (Max), Guaranteed Over Temperature
- Offset Voltage 3 $\mu$ V (Max)
- Offset Voltage Drift 30nV/ $^{\circ}$ C (Max)
- Noise: 1.6 $\mu$ V<sub>P-P</sub> (0.01Hz to 10Hz Typ)
- Voltage Gain: 140dB (Typ)
- PSRR: 130dB (Typ)
- CMRR: 130dB (Typ)
- Input Bias Current <1pA (Typ)
- Supply Operation: 2.7V to 6V (LTC2054)  
2.7V to  $\pm$ 5.5V (LTC2054HV)
- Common Mode Input Range from  $V^-$  to  $V^+$  -0.5V
- Output Swings Rail-to-Rail
- Low Profile (1mm) SOT-23 (ThinSOT™) Package

## 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

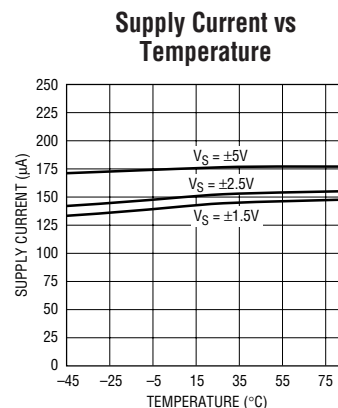
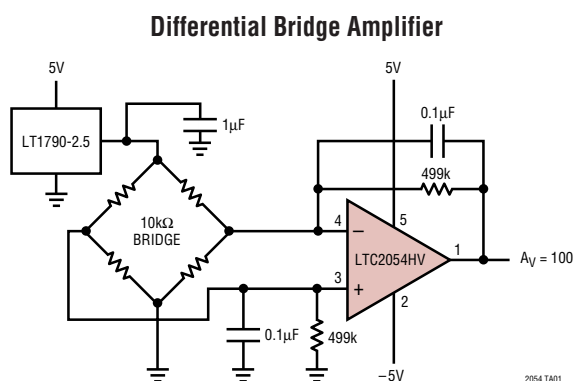
The LTC<sup>®</sup>2054 and LTC2054HV are low power, low noise zero-drift operational amplifiers available in the 5-lead SOT-23 package. The LTC2054 operates from a single 2.7V to 6V supply. The LTC2054HV operates on supplies from 2.7V to  $\pm$ 5.5V. The current consumption is 150 $\mu$ A (typical), 175 $\mu$ A maximum over temperature.

The LTC2054, despite its miniature size, features uncompromising DC performance. The typical input offset voltage and offset drift are 0.5 $\mu$ V and 25nV/ $^{\circ}$ 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 0.5V from the positive supply. The open-loop gain is typically 140dB. The LTC2054 also features a 1.6 $\mu$ V<sub>P-P</sub> DC to 10Hz noise and a 500kHz gain bandwidth product.

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## TYPICAL APPLICATION



# LTC2054/LTC2054HV

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

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

LTC2054 ..... 7V

LTC2054HV ..... 12V

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

Output Short-Circuit Duration ..... Indefinite

Operating Temperature Range .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$

Specified Temperature Range

(Note 4) .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$

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

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

## PACKAGE/ORDER INFORMATION

<p>S5 PACKAGE 5-LEAD PLASTIC TSOT-23 <math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 250^\circ\text{C/W}</math></p>	
ORDER PART NUMBER	S5 PART MARKING
LTC2054CS5 LTC2054HVCS5 LTC2054IS5 LTC2054HVIS5	LTAGB LTAGD LTAGB LTAGD

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

## ELECTRICAL CHARACTERISTICS

(LTC2054, LTC2054HV) The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = 3V$  unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$I_S$	Supply Current	No Load	●	140	175	$\mu\text{A}$
$V_{OS}$	Input Offset Voltage	(Note 2)		$\pm 0.5$	$\pm 3$	$\mu\text{V}$
$\Delta V_{OS}/\Delta T$	Average Input Offset Drift	(Note 2)	●		$\pm 0.03$	$\mu\text{V}/^\circ\text{C}$
	Long-Term Offset Drift			50		$\text{nV}/\sqrt{\text{mo}}$
$I_B$	Input Bias Current	(Note 3)	●	$\pm 600$	$\pm 150$	fA pA
$I_{OS}$	Input Offset Current	(Note 3)	●	$\pm 1.2$	$\pm 300$	pA pA
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , 0.01Hz to 10Hz		1.6		$\mu\text{V}_{P-P}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = \text{GND to } (V^+ - 0.7V)$	●	115 110	130	dB dB
PSRR	Power Supply Rejection Ratio	$V_S = 2.7V$ to $6V$	●	120 115	130	dB dB

## ELECTRICAL CHARACTERISTICS

(LTC2054, LTC2054HV) The ● denotes 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 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$A_{VOL}$	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_{OUT} = V_S/2$	● 120	135		dB
			115			dB
$V_{OUT}$	Output Voltage Swing High	$R_L = 5\text{k}$ to GND $R_L = 100\text{k}$ to GND	● 2.85			V
			● 2.98			V
$V_{OUT}$	Output Voltage Swing Low	$R_L = 5\text{k}$ to GND $R_L = 100\text{k}$ to GND	●		10	mV
			●		10	mV
SR	Slew Rate			0.5		V/ $\mu\text{s}$
GBW	Gain Bandwidth Product			500		kHz
$f_s$	Internal Sampling Frequency			1.0		kHz

### (LTC2054, LTC2054HV) $V_S = 5\text{V}$ unless otherwise noted. (Note 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$I_S$	Supply Current	No Load	●	150	175	$\mu\text{A}$
$V_{OS}$	Input Offset Voltage	(Note 2)			$\pm 3$	$\mu\text{V}$
$\Delta V_{OS}/\Delta T$	Average Input Offset Drift	(Note 2)	●		$\pm 0.03$	$\mu\text{V}/^\circ\text{C}$
	Long-Term Offset Drift			50		$\text{nV}/\sqrt{\text{mo}}$
$I_B$	Input Bias Current	(Note 3)	●	$\pm 800$	$\pm 150$	fA pA
$I_{OS}$	Input Offset Current	(Note 3)	●	$\pm 1.6$	$\pm 300$	pA pA
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , 0.01Hz to 10Hz		1.6		$\mu\text{V}_{P-P}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = \text{GND}$ to $(V^+ - 0.7\text{V})$	● 120	130		dB
			115			dB
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V}$ to 6V	● 120	130		dB
			115			dB
$A_{VOL}$	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_{OUT} = V_S/2$	● 125	140		dB
			120			dB
$V_{OUT}$	Output Voltage Swing High	$R_L = 5\text{k}$ to GND $R_L = 100\text{k}$ to GND	● 4.75			V
			● 4.98			V
$V_{OUT}$	Output Voltage Swing Low	$R_L = 5\text{k}$ to GND $R_L = 100\text{k}$ to GND	●		10	mV
			●		10	mV
SR	Slew Rate			0.5		V/ $\mu\text{s}$
GBW	Gain Bandwidth Product			500		kHz
$f_s$	Internal Sampling Frequency			1.0		kHz

# LTC2054/LTC2054HV

## ELECTRICAL CHARACTERISTICS (LTC2054HV) The ● denotes 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 4)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$I_S$	Supply Current	No Load ●		175	210	$\mu\text{A}$
$V_{OS}$	Input Offset Voltage	(Note 2)		$\pm 0.5$	$\pm 5$	$\mu\text{V}$
$\Delta V_{OS}/\Delta T$	Average Input Offset Drift	(Note 2) ●			$\pm 0.03$	$\mu\text{V}/^\circ\text{C}$
	Long-Term Offset Drift			50		$\text{nV}/\sqrt{\text{mo}}$
$I_B$	Input Bias Current	(Note 3) ●		$\pm 1$	$\pm 150$	$\text{pA}$ $\text{pA}$
$I_{OS}$	Input Offset Current	(Note 3) ●		$\pm 2$	$\pm 300$	$\text{pA}$ $\text{pA}$
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , 0.01Hz to 10Hz		1.6		$\mu\text{V}_{\text{P-P}}$
CMRR	Common Mode Rejection Ratio	$V_{\text{CM}} = V^-$ to $(V^+ - 0.9\text{V})$ ●	120	130		$\text{dB}$ $\text{dB}$
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V}$ to $11\text{V}$ ●	120	130		$\text{dB}$ $\text{dB}$
$A_{\text{VOL}}$	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_{\text{OUT}} = \text{GND}$ ●	125	140		$\text{dB}$ $\text{dB}$
$V_{\text{OUT}}$	Maximum Output Voltage Swing	$R_L = 5\text{k}$ to GND ● $R_L = 100\text{k}$ to GND ●	$\pm 4.75$			$\text{V}$ $\text{V}$
SR	Slew Rate			0.5		$\text{V}/\mu\text{s}$
GBW	Gain Bandwidth Product			500		$\text{kHz}$
$f_S$	Internal Sampling Frequency			1.0		$\text{kHz}$

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

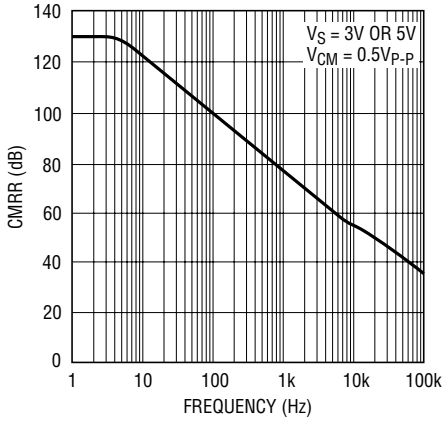
**Note 2:** These parameters are guaranteed by design. Thermocouple effects preclude measurements of these voltage levels during automated testing.

**Note 3:** Limit is determined by high speed automated test capability. See characteristic curves for actual typical performance. For tighter specifications, please consult Linear Technology Marketing.

**Note 4:** The LTC2054C, LTC2054HVC are guaranteed to meet specified performance from  $0^\circ\text{C}$  to  $70^\circ\text{C}$  and are designed, characterized and expected to meet these extended temperature limits, but are not tested at  $-40^\circ\text{C}$  and  $85^\circ\text{C}$ . The LTC2054I, LTC2054HVI are guaranteed to meet the specified performance from  $-40^\circ\text{C}$  and  $85^\circ\text{C}$ .

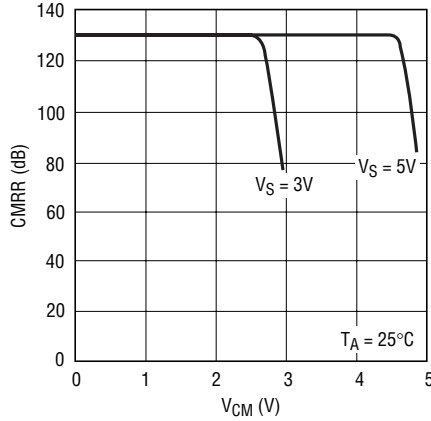
# TYPICAL PERFORMANCE CHARACTERISTICS

**Common Mode Rejection Ratio vs Frequency**



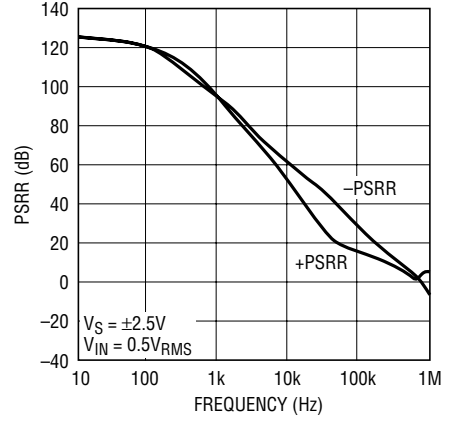
2054 G01

**DC CMRR vs Common Mode Input Voltage**



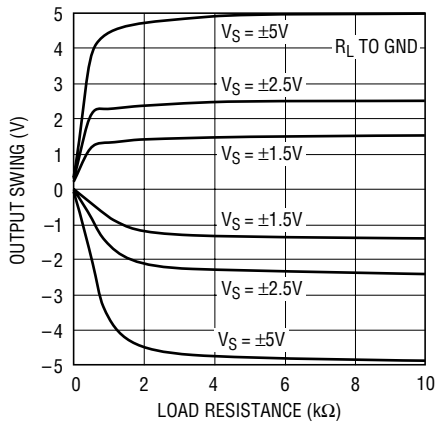
2054 G02

**PSRR vs Frequency**



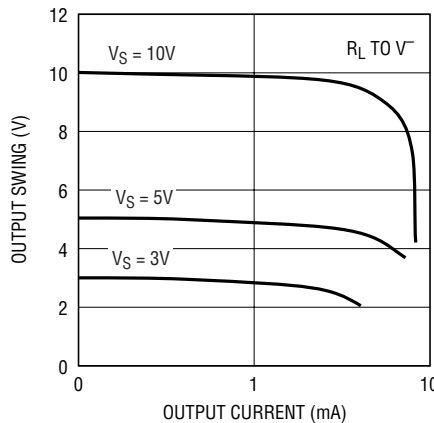
LTC2054 • G14

**Output Voltage Swing vs Load Resistance**



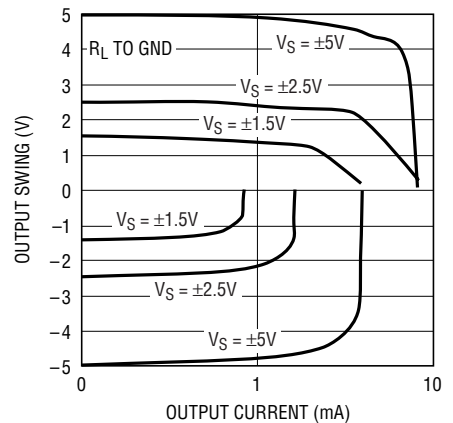
2054 G03

**Single Supply Output Swing vs Output Current**



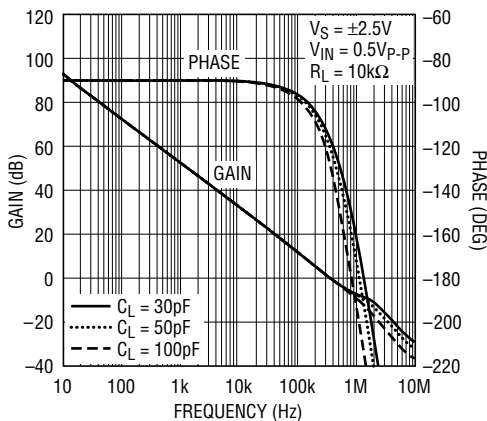
2054 G04

**Dual Supply Output Swing vs Output Current**



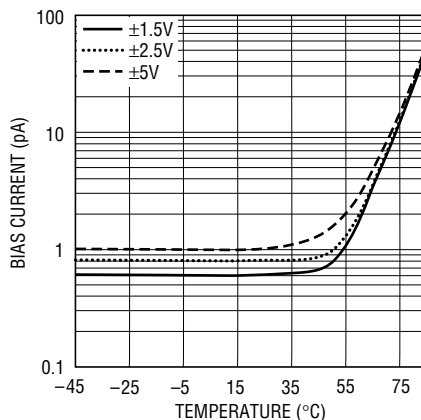
2054 G20

**Gain/Phase vs Frequency**



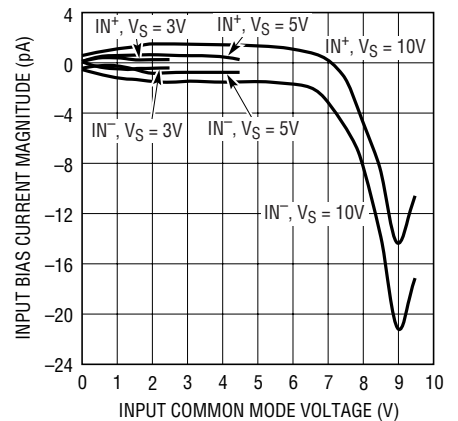
2054 G05

**Bias Current vs Temperature**



2054 G06

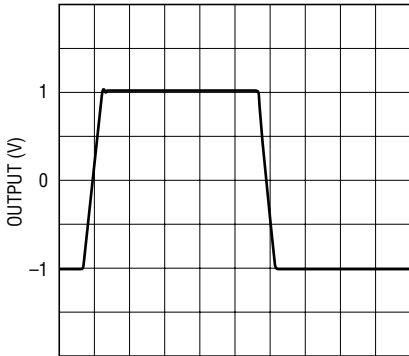
**Input Bias Current vs Input Common Mode Voltage**



2054 G13

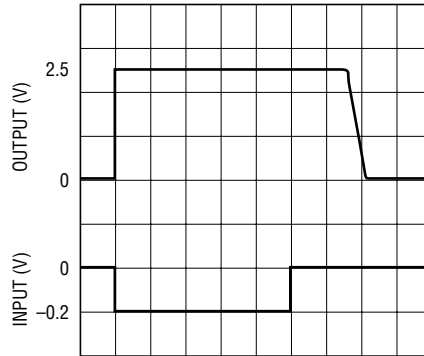
## TYPICAL PERFORMANCE CHARACTERISTICS

### Transient Response



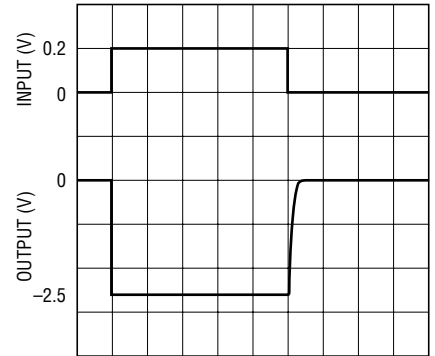
$A_V = 1$   
 $R_L = 100k$   
 $C_L = 50pF$   
 $V_S = \pm 2.5V$   
 $V_{IN} = 10kHz\ 2V_{p-p}$ 
2054 G07

### Input Overload Recovery



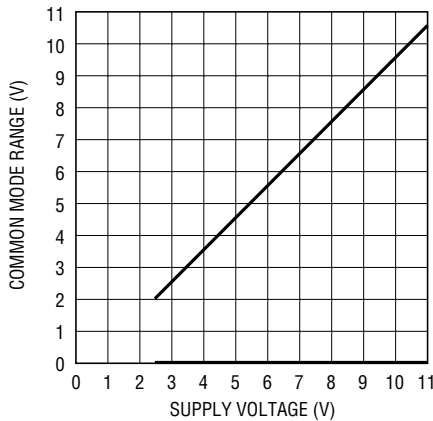
$A_V = -100$   
 $R_L = 100k$   
 $V_S = \pm 2.5V$   
 $V_{IN} = 50Hz\ 200mV_{p-p}$   
 OFFSET = -100mV
 2054 G08

### Input Overload Recovery



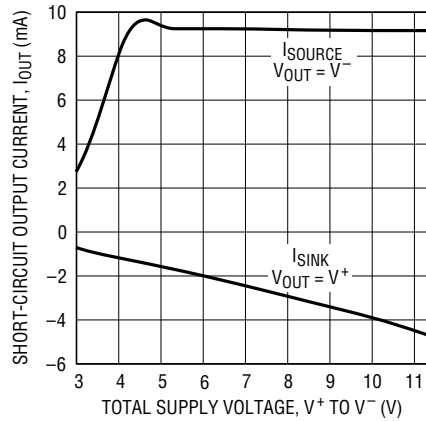
$A_V = -100$   
 $R_L = 100k$   
 $V_S = \pm 2.5V$   
 $V_{IN} = 50Hz\ 200mV_{p-p}$   
 OFFSET = 100mV
 2054 G18

### Common Mode Input Range vs Supply Voltage



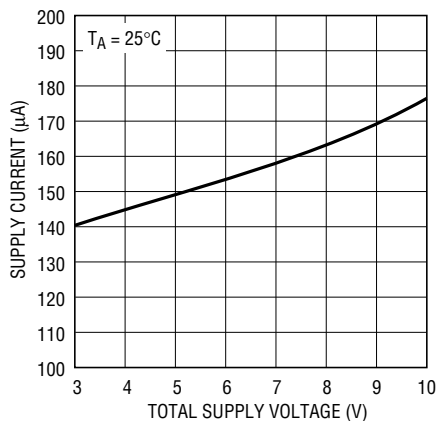
2054 G09

### Short-Circuit Output Current vs Supply Voltage



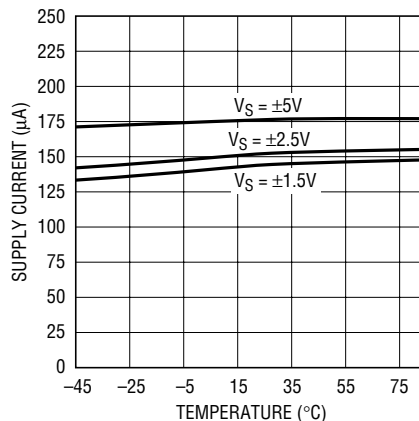
2054 G10

### Supply Current vs Supply Voltage



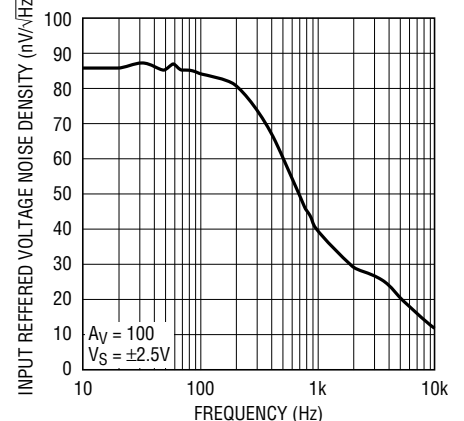
2054 G11

### Supply Current vs Temperature



2054 G12

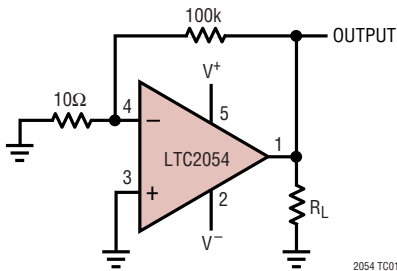
### Noise Spectrum



2054 G15

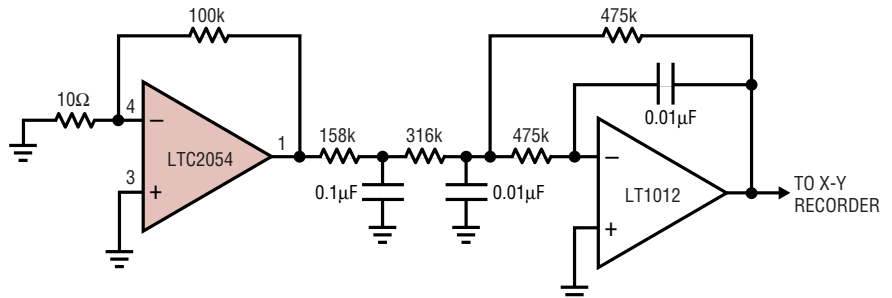
## TEST CIRCUITS

Electrical Characteristics  
Test Circuit



2054 TC01

DC-10Hz Noise Test Circuit



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

2054 TC02

## APPLICATIONS INFORMATION

### Clock Feedthrough, Input Bias Current

The LTC2054 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 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.

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 has a residue clock feedthrough of less than  $0.2\mu\text{V}_{\text{RMS}}$  input referred 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, 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 the amount of residue clock feedthrough from the first form described above.

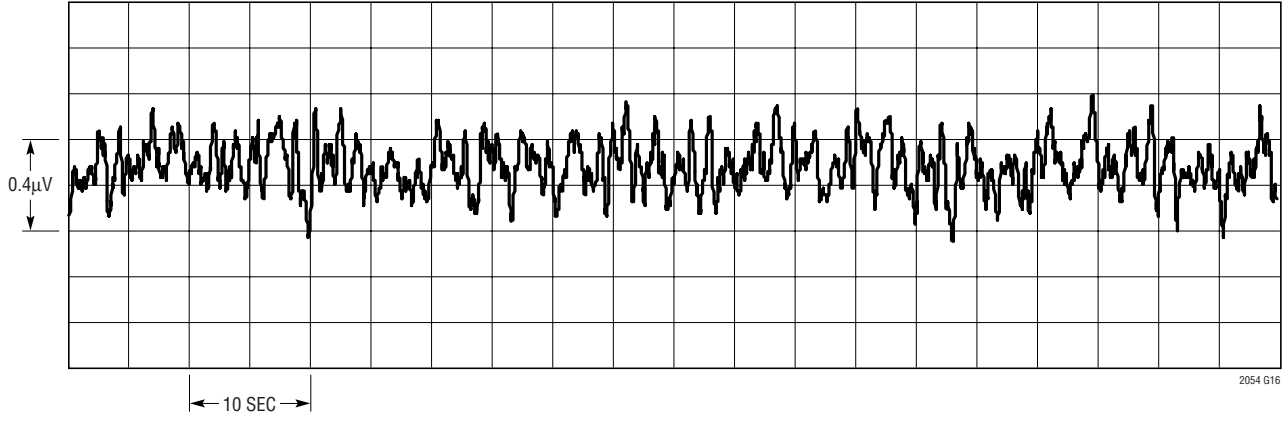
Placing a capacitor across the feedback resistor reduces either form of clock feedthrough by limiting the bandwidth of the closed loop gain.

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.

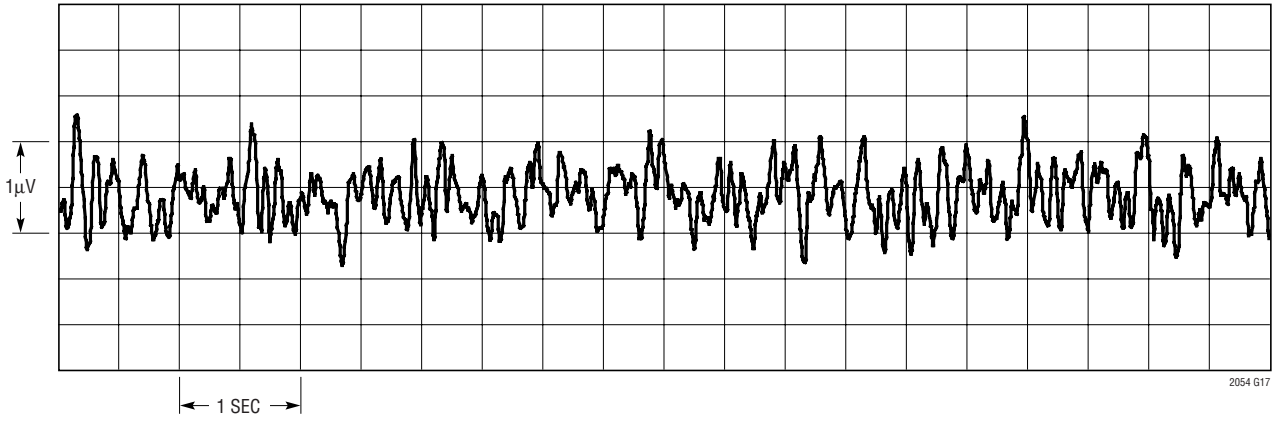
At temperatures above 70°C, the leakage of the ESD protection diodes on the inputs increases the input bias currents of both inputs in the positive direction, while the current caused by the charge injection stays relatively constant. At elevated temperatures (above 85°C) the leakage current begins to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

## APPLICATIONS INFORMATION

LTC2054 DC to 1Hz Noise



LTC2054 DC to 10Hz Noise

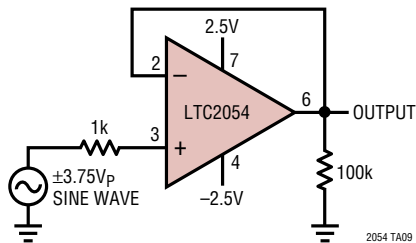


## APPLICATIONS INFORMATION

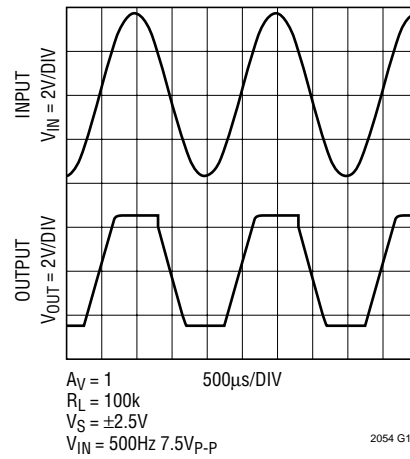
### Extended Common Mode Range

The LTC2054 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 inversion**.

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

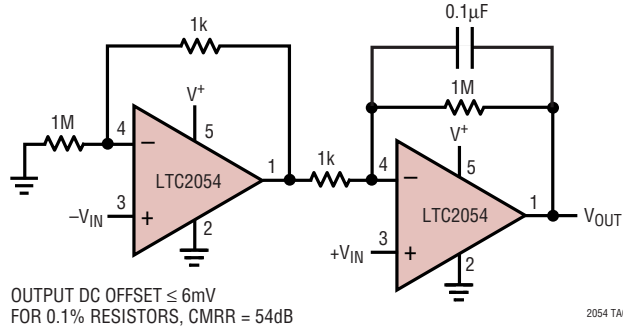


LTC2054 Extended  
Common Mode Range

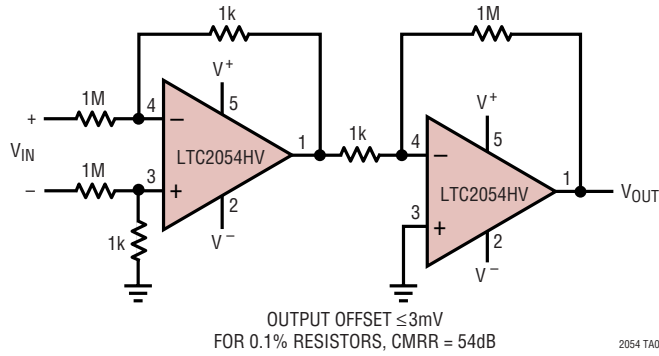


**TYPICAL APPLICATIONS**

**Gain of 1001 Single Supply Instrumentation Amplifier**

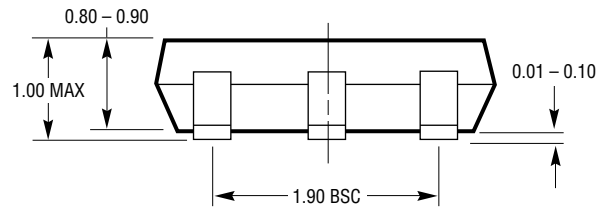
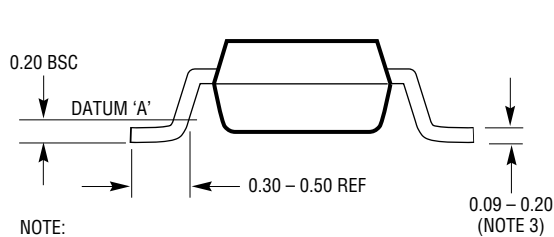
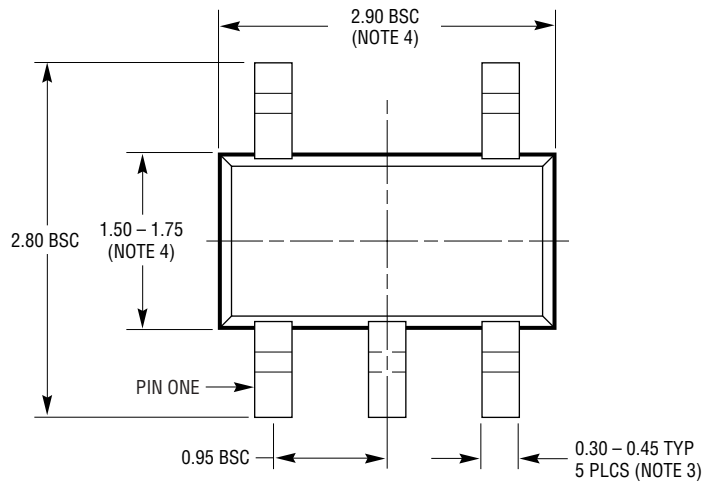
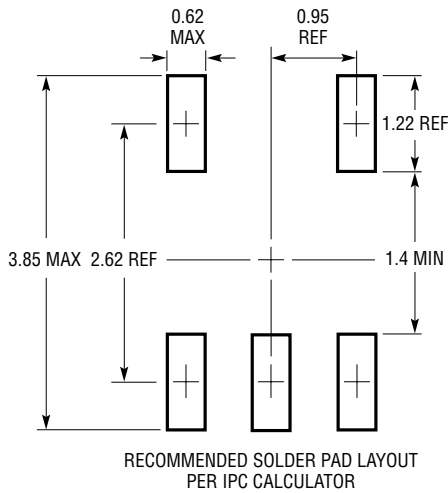


**Instrumentation Amplifier with 100V Common Mode Input Voltage**



# PACKAGE DESCRIPTION

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

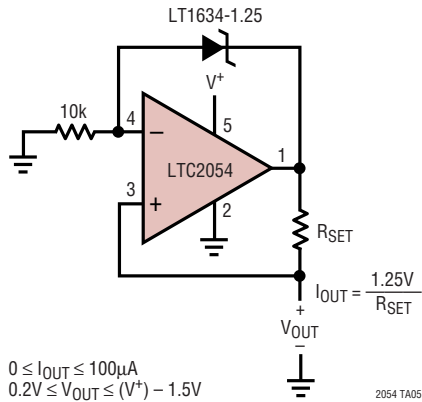


- NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
  2. DRAWING NOT TO SCALE
  3. DIMENSIONS ARE INCLUSIVE OF PLATING
  4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
  5. MOLD FLASH SHALL NOT EXCEED 0.254mm
  6. JEDEC PACKAGE REFERENCE IS MO-193

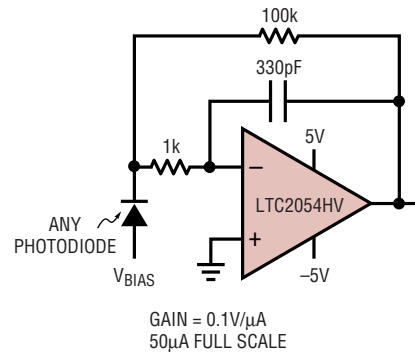
S5 TSOT-23 0302

## TYPICAL APPLICATIONS

### Ground Referred Precision Current Sources



### Ultra-Precision, Wide Dynamic Range 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	$V_{OS} = 90\mu V$ , $V_S = 2.7V$ to 44V
LT1884/LT1885	Rail-to-Rail Output Precision Op Amp	$V_{OS} = 50\mu V$ , $I_B = 400pA$ , $V_S = 2.7V$ 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