



# LTC2050/LTC2050HV

## Zero-Drift Operational Amplifiers in SOT-23

### FEATURES

- Maximum Offset Voltage of 3 $\mu$ V
- Maximum Offset Voltage Drift of 30nV/ $^{\circ}$ 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: 2.7V to 6V (LTC2050)  
2.7V to  $\pm$ 5.5V (LTC2050HV)
- Extended Common Mode Input Range
- Output Swings Rail-to-Rail
- Input Overload Recovery Time: 2ms (Typ)
- Operating Temperature Range: -40 $^{\circ}$ C to 125 $^{\circ}$ C
- SOT-23 Package

### 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<sup>®</sup>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).

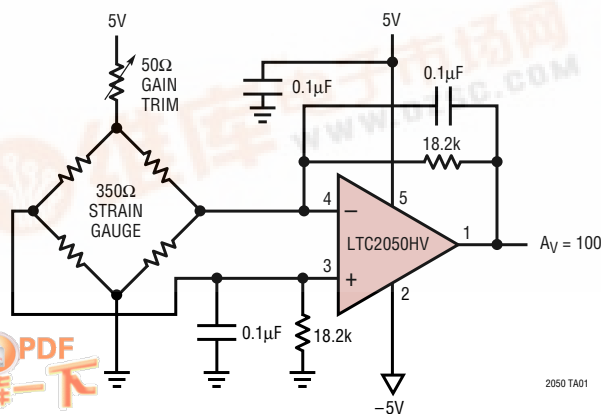
The LTC2050, despite its miniature size, features uncompromising DC performance. The typical input offset voltage and offset drift are 0.5 $\mu$ V and 10nV/ $^{\circ}$ C. The almost zero DC offset and drift are supported with a power supply rejection ratio (PSRR) and common mode rejection ratio (CMRR)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

The input common mode voltage ranges from the negative supply up to typically 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.

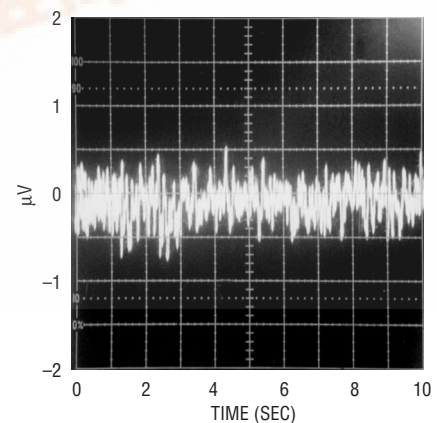
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### TYPICAL APPLICATION

Differential Bridge Amplifier



Input Referred Noise 0.1Hz to 10Hz



# LTC2050/LTC2050HV

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage ( $V^+$ to $V^-$ )	Operating Temperature Range	-40°C to 125°C
LTC2050	Specified Temperature Range	(Note 3)
LTC2050HV	Storage Temperature Range	-40°C to 125°C
Input Voltage ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )	Lead Temperature (Soldering, 10 sec)	-65°C to 150°C
Output Short-Circuit Duration		300°C

## PACKAGE/ORDER INFORMATION

ORDER PART NUMBER	S5 PART MARKING	ORDER PART NUMBER	S6 PART MARKING	ORDER PART NUMBER	S8 PART MARKING
LTC2050CS5	LTAEG	LTC2050CS6	LTA EJ	LTC2050CS8	2050
LTC2050IS5	LTAEG	LTC2050IS6	LTA EJ	LTC2050IS8	2050I
LTC2050HS5	LTAEG	LTC2050HS6	LTA EJ	LTC2050HVCS8	2050HV
LTC2050HVCS5	LTAEH	LTC2050HVCS6	LTA EK	LTC2050HVIS8	050HVI
LTC2050HVIS5	LTAEH	LTC2050HVIS6	LTA EK		
LTC2050HVHS5	LTAEH	LTC2050HVHS6	LTA EK		

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

## ELECTRICAL CHARACTERISTICS (LTC2050, LTC2050HV) 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 3)

PARAMETER	CONDITIONS	LTC2050C/LTC2050I			LTC2050H			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		±20	±75	pA
	LTC2050HV	●		±300	●		±4000	pA
Input Offset Current	LTC2050		±1	±50		±1	±50	pA
	LTC2050HV	●		±100	●		±4000	pA
Input Noise Voltage	LTC2050			±150			±150	pA
	LTC2050HV	●		±200	●		±1000	pA
Input Noise Voltage	LTC2050			±100			±100	pA
	LTC2050HV	●		±150	●		±1000	pA
Input Noise Voltage	$R_S = 100\Omega$ , 0.01Hz to 10Hz		1.5			1.5		μV <sub>P-P</sub>
Common Mode Rejection Ratio	$V_{CM} = \text{GND to } (V^+ - 1.3)$		115	130		115	130	dB
	$V_{CM} = \text{GND to } (V^+ - 1.3)$	●	110	130	●	110	130	dB

# LTC2050/LTC2050HV

## ELECTRICAL CHARACTERISTICS (LTC2050, LTC2050HV) 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 3)

PARAMETER	CONDITIONS		LTC2050C/LTC2050I			LTC2050H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
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 $R_L = 10\text{k}$ to GND	●	2.85	2.94		2.85	2.94		V
			2.95	2.98		2.95	2.98		V
Output Voltage Swing Low	$R_L = 2\text{k}$ to GND $R_L = 10\text{k}$ to GND	●		1	10		1	10	mV
				1	10		1	10	mV
Slew Rate				2			2	$\text{V}/\mu\text{s}$	
Gain Bandwidth Product				3			3	MHz	
Supply Current	$V_{\text{SHDN}} = V_{\text{IH}}$ , No Load $V_{\text{SHDN}} = V_{\text{IL}}$	●		0.75	1.1		0.75	1.2	mA
					10			10	$\mu\text{A}$
Shutdown Pin Input Low Voltage ( $V_{\text{IL}}$ )		●			$V^- + 0.5$			$V^- + 0.5$	V
Shutdown Pin Input High Voltage ( $V_{\text{IH}}$ )		●	$V^+ - 0.5$			$V^+ - 0.5$			V
Shutdown Pin Input Current	$V_{\text{SHDN}} = \text{GND}$	●		-0.5	-3		-0.5	-3	$\mu\text{A}$
Internal Sampling Frequency				7.5			7.5		kHz

The ● denotes 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		LTC2050C/LTC2050I			LTC2050H			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)	●			$\pm 0.03$			$\pm 0.05$	$\mu\text{V}/^\circ\text{C}$
Long-Term Offset Drift				50			50		$\text{nV}/\sqrt{\text{mo}}$
Input Bias Current	LTC2050	●		$\pm 75$	$\pm 150$ $\pm 300$		$\pm 75$	$\pm 150$ $\pm 4000$	pA pA
	LTC2050HV		●		$\pm 7$	$\pm 50$ $\pm 150$		$\pm 7$	$\pm 50$ $\pm 4000$
Input Offset Current	LTC2050	●			$\pm 300$ $\pm 400$			$\pm 300$ $\pm 1000$	pA pA
	LTC2050HV		●			$\pm 100$ $\pm 200$			$\pm 100$ $\pm 1000$
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	$V_{\text{CM}} = \text{GND}$ to $(V^+ - 1.3)$ $V_{\text{CM}} = \text{GND}$ to $(V^+ - 1.3)$	●	120	130		120	130		dB
			115	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	$R_L = 10\text{k}$	●	125	140		125	140		dB
			120	140		115	140		dB
Output Voltage Swing High	$R_L = 2\text{k}$ to GND $R_L = 10\text{k}$ to GND	●	4.85	4.94		4.85	4.94		V
			4.95	4.98		4.95	4.98		V
Output Voltage Swing Low	$R_L = 2\text{k}$ to GND $R_L = 10\text{k}$ to GND	●		1	10		1	10	mV
				1	10		1	10	mV
Slew Rate				2			2	$\text{V}/\mu\text{s}$	
Gain Bandwidth Product				3			3	MHz	
Supply Current	$V_{\text{SHDN}} = V_{\text{IH}}$ , No Load $V_{\text{SHDN}} = V_{\text{IL}}$	●		0.8	1.2		0.8	1.3	mA
					15			15	$\mu\text{A}$

# LTC2050/LTC2050HV

## ELECTRICAL CHARACTERISTICS

The ● denotes 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		LTC2050C/LTC2050I			LTC2050H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
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	-7		-0.5	-7		$\mu\text{A}$
Internal Sampling Frequency			7.5			7.5			kHz

## (LTC2050HV) 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 3)

PARAMETER	CONDITIONS		LTC2050C/LTC2050I			LTC2050H			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)	●			$\pm 0.03$			$\pm 0.05$	$\mu\text{V}/^\circ\text{C}$
Long-Term Offset Drift				50			50		$\text{nV}/\sqrt{\text{mo}}$
Input Bias Current (Note 4)		●		$\pm 25$	$\pm 125$		$\pm 25$	$\pm 125$	$\text{pA}$
Input Offset Current (Note 4)		●			$\pm 300$			$\pm 4000$	$\text{pA}$
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	$V_{\text{CM}} = V^-$ to $(V^+ - 1.3)$	●	120	130		120	130		dB
	$V_{\text{CM}} = V^-$ to $(V^+ - 1.3)$	●	115	130		115	130		dB
Power Supply Rejection Ratio	$V_S = 2.7\text{V}$ to $11\text{V}$	●	120	130		120	130		dB
		●	115	130		115	130		dB
Large-Signal Voltage Gain	$R_L = 10\text{k}$	●	125	140		125	140		dB
		●	120	140		120	140		dB
Maximum Output Voltage Swing	$R_L = 2\text{k}$ to $\text{GND}$	●	$\pm 4.75$	$\pm 4.94$		$\pm 4.50$	$\pm 4.94$		V
	$R_L = 10\text{k}$ to $\text{GND}$	●	$\pm 4.90$	$\pm 4.98$		$\pm 4.85$	$\pm 4.98$		V
Slew Rate				2			2		$\text{V}/\mu\text{s}$
Gain Bandwidth Product				3			3		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 ( $V_{IL}$ )		●			$V^- + 0.5$			$V^- + 0.5$	V
Shutdown Pin Input High Voltage ( $V_{IH}$ )		●	$V^+ - 0.5$			$V^+ - 0.5$			V
Shutdown Pin Input Current	$V_{\text{SHDN}} = V^-$	●	-3	-20		-3	-20		$\mu\text{A}$
Internal Sampling Frequency			7.5			7.5			kHz

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

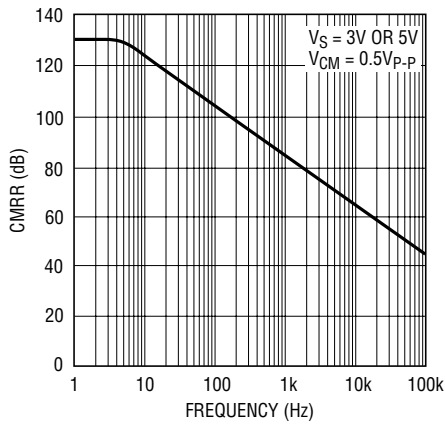
**Note 2:** These parameters are guaranteed by design. Thermocouple effects preclude measurements of these voltage levels during automated testing.

**Note 3:** 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  $125^\circ\text{C}$ .

**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.

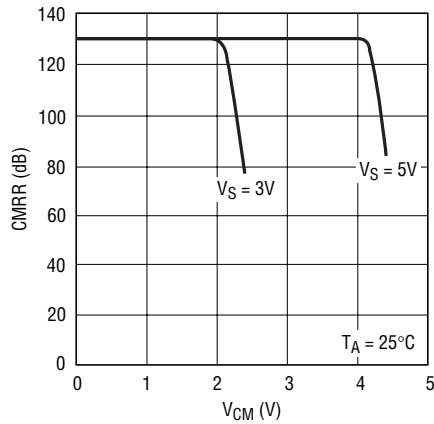
## TYPICAL PERFORMANCE CHARACTERISTICS

**Common Mode Rejection Ratio vs Frequency**



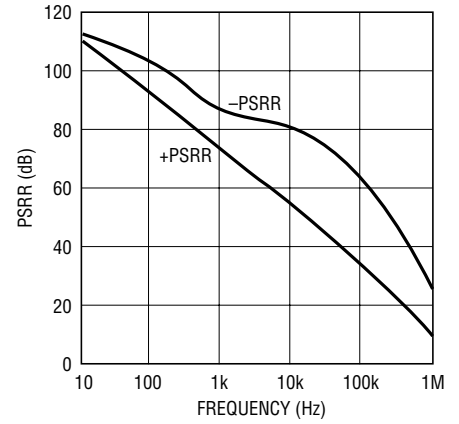
2050 G01

**DC CMRR vs Common Mode Input Voltage**



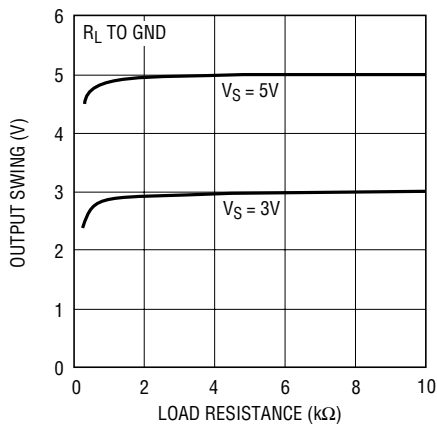
2050 G02

**PSRR vs Frequency**



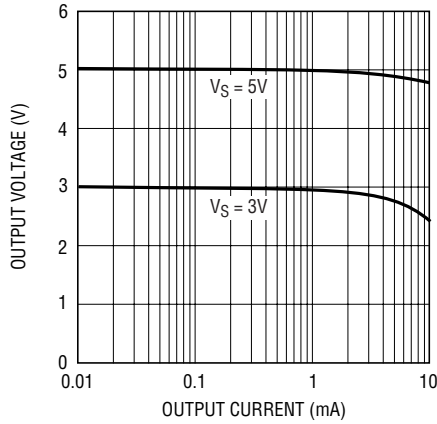
LTC2050 • G14

**Output Voltage Swing vs Load Resistance**



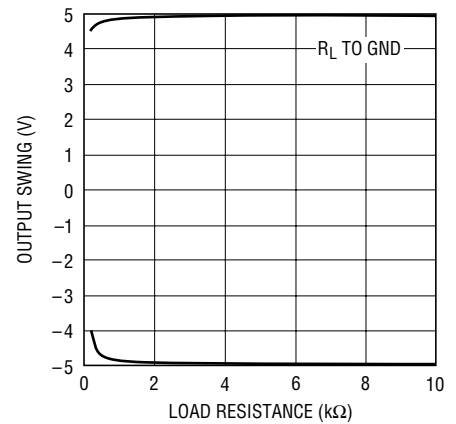
2050 G03

**Output Swing vs Output Current**



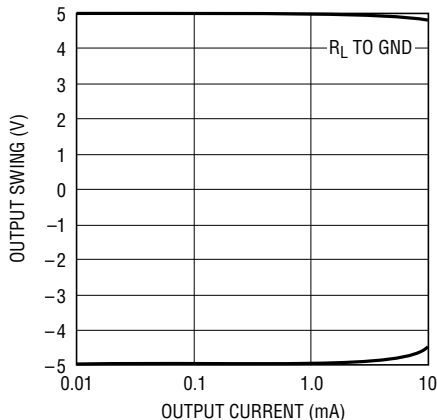
2050 G04

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



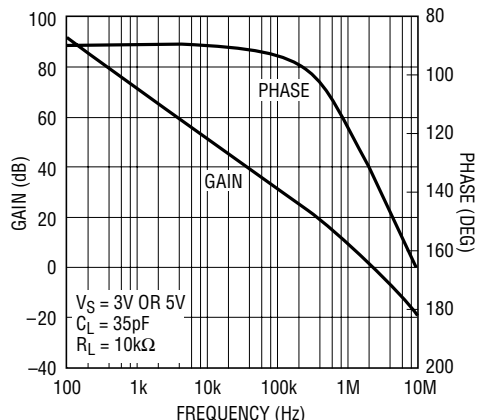
2050 G16

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



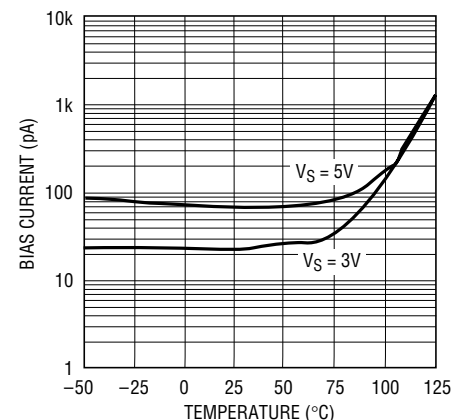
2050 G17

**Gain/Phase vs Frequency**



2050 G05

**Bias Current vs Temperature**

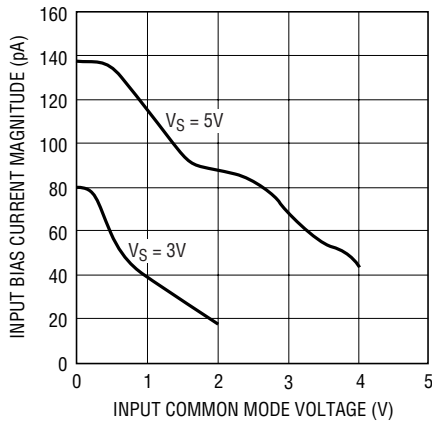


2050 G06

# LTC2050/LTC2050HV

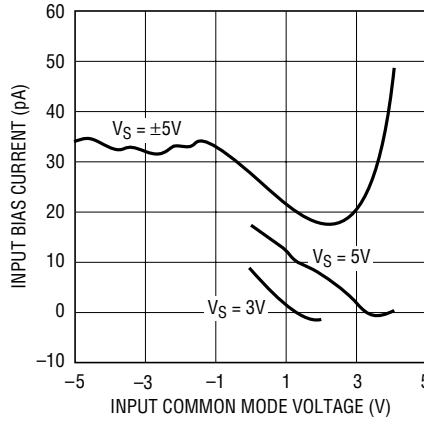
## TYPICAL PERFORMANCE CHARACTERISTICS

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



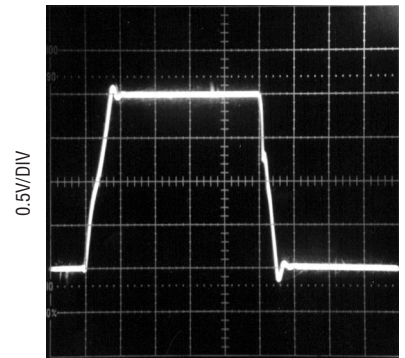
2050 G13

**Input Bias Current vs Input Common Mode Voltage (LTC2050HV)**



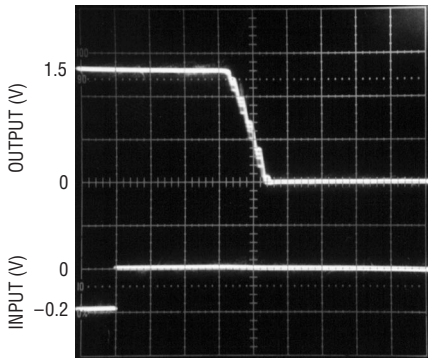
2050 G15

**Transient Response**



$A_V = 1$   
 $R_L = 100k$   
 $C_L = 50pF$   
 $V_S = 5V$

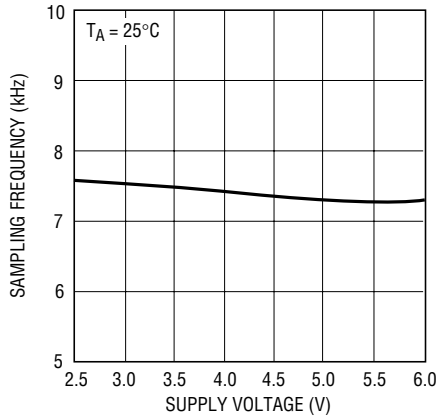
**Input Overload Recovery**



$A_V = -100$   
 $R_L = 100k$   
 $C_L = 10pF$   
 $V_S = \pm 1.5V$

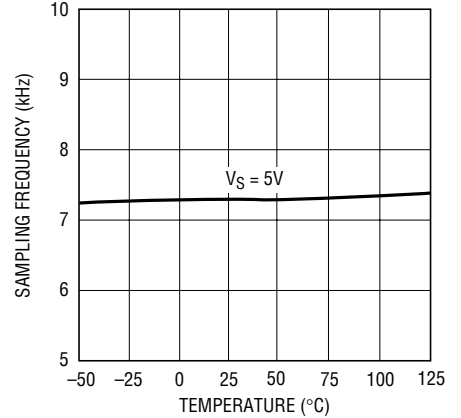
2050 G08

**Sampling Frequency vs Supply Voltage**



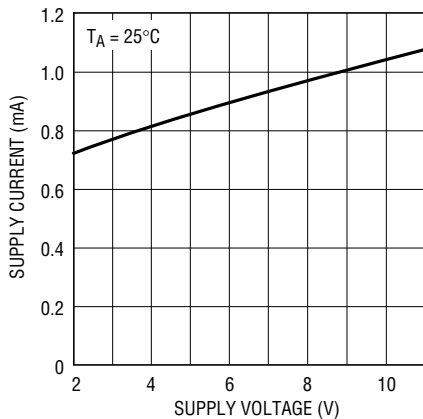
2050 G09

**Sampling Frequency vs Temperature**



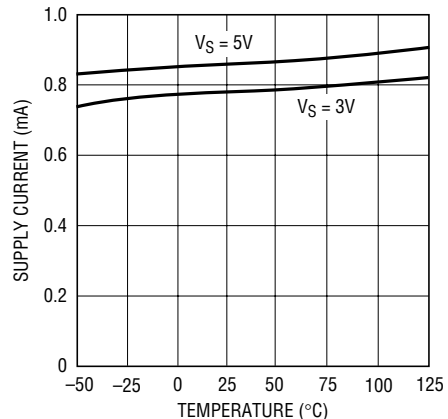
2050 G10

**Supply Current vs Supply Voltage**



2050 G11

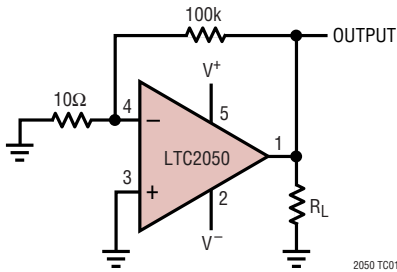
**Supply Current vs Temperature**



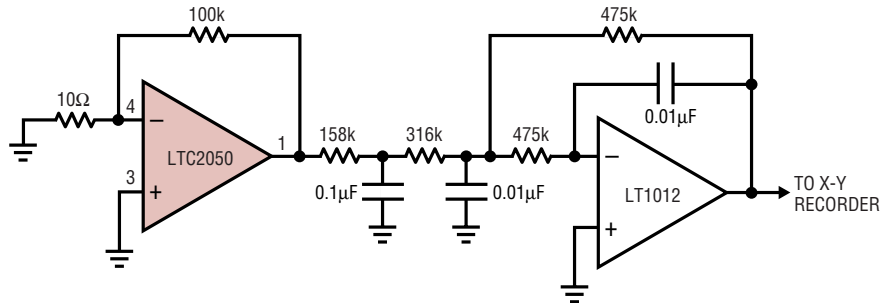
2050 G12

## TEST CIRCUITS

Electrical Characteristics  
Test Circuit



DC-10Hz Noise Test Circuit



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

## 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.

# LTC2050/LTC2050HV

## APPLICATIONS INFORMATION

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

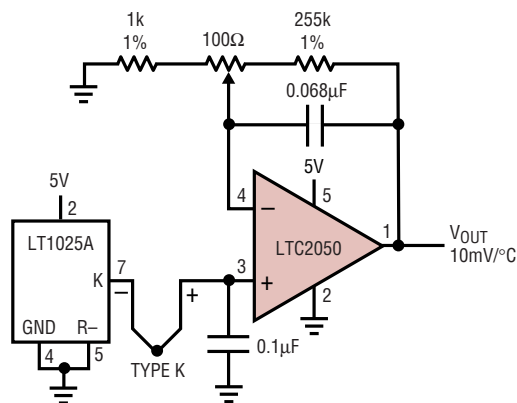
leakage current begins to dominate and both the negative and positive pin's input bias currents are in the positive direction (into the pins).

### 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

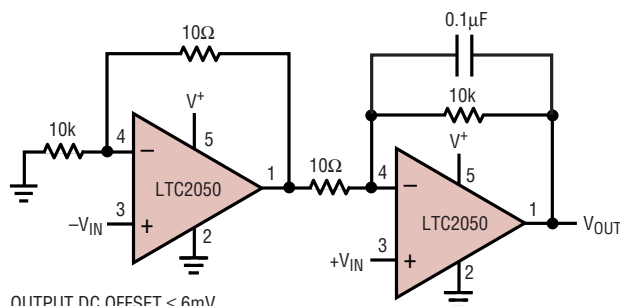
### Single Supply Thermocouple Amplifier



LT1025 COMPENSATES COLD JUNCTION  
OVER 0°C TO 100°C TEMPERATURE RANGE

2050 TA03

### Gain of 1001 Single Supply Instrumentation Amplifier



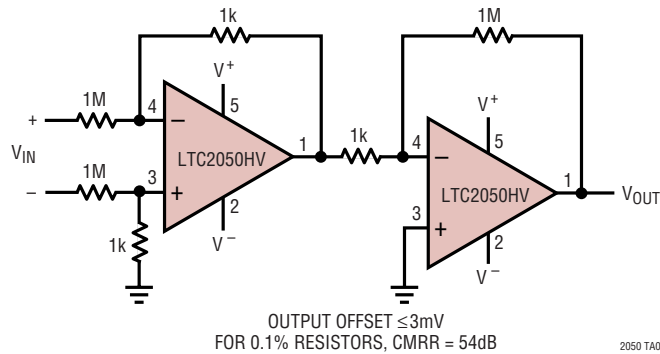
OUTPUT DC OFFSET  $\leq$  6mV  
FOR 0.1% RESISTORS, CMRR = 54dB

2050 TA04

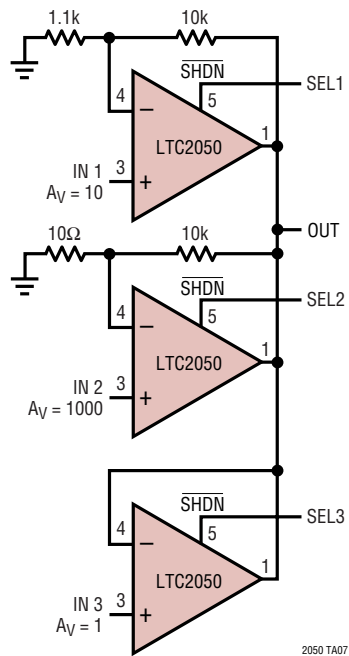


## TYPICAL APPLICATIONS

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

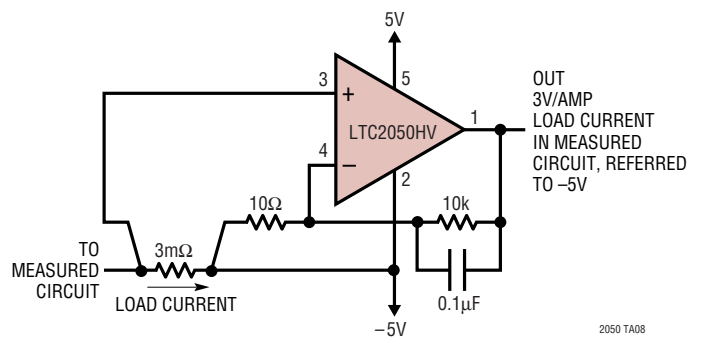


### High Precision Three-Input Mux



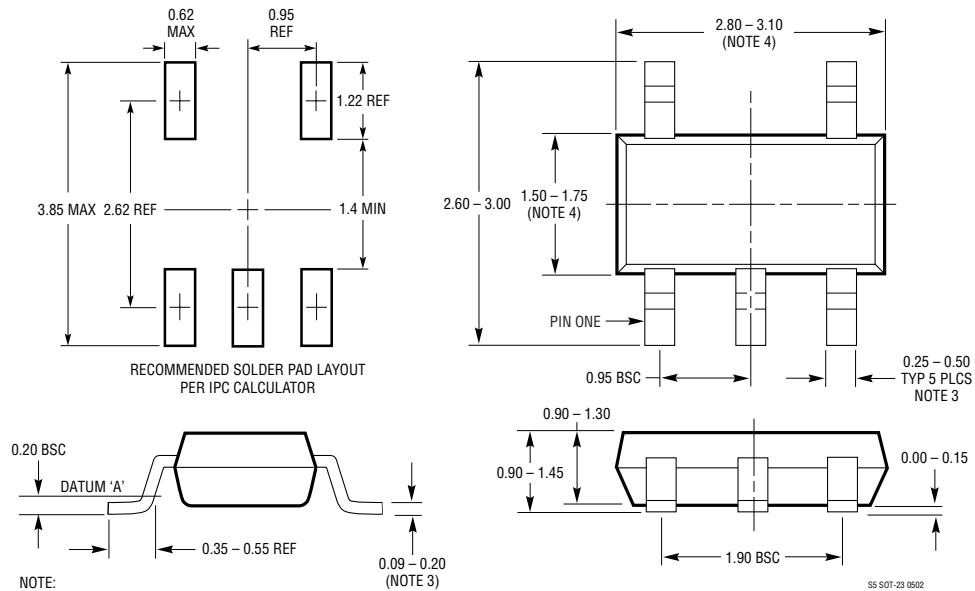
SELECT INPUTS ARE CMOS LOGIC COMPATIBLE

### Low-Side Power Supply Current Sensing



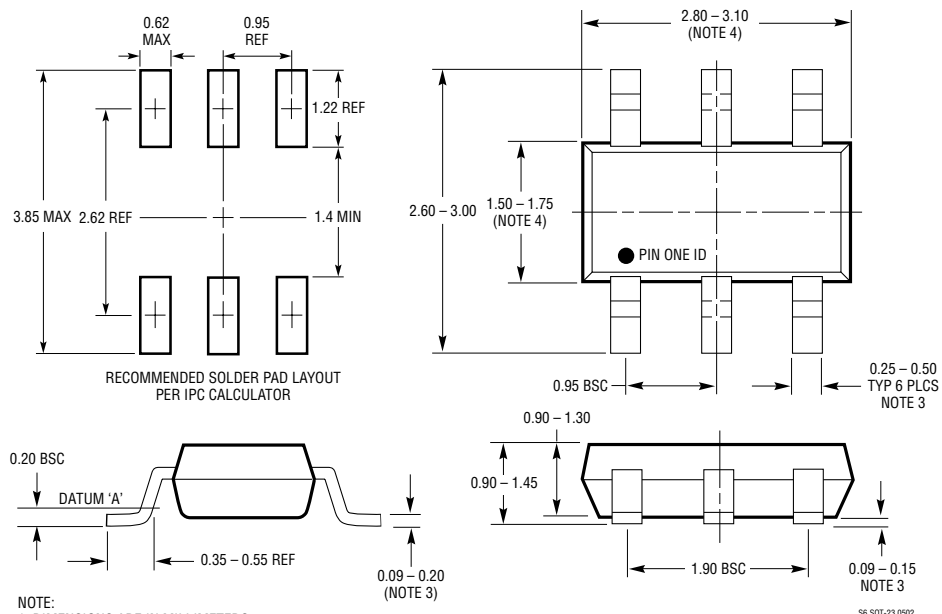
## PACKAGE DESCRIPTION

### S5 Package 5-Lead Plastic SOT-23 (Reference LTC DWG # 05-08-1633)



**ATTENTION: ORIGINAL SOT23-5L PACKAGE.**  
MOST SOT23-5L PRODUCTS CONVERTED TO THIN SOT23 PACKAGE, DRAWING # 05-08-1635 AFTER APPROXIMATELY APRIL 2001 SHIP DATE

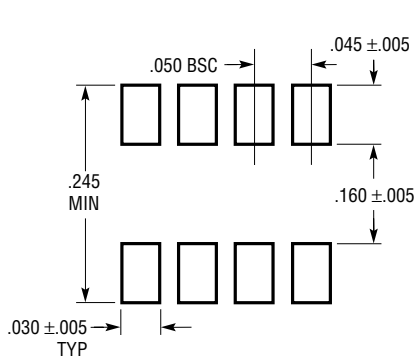
### S6 Package 6-Lead Plastic SOT-23 (Reference LTC DWG # 05-08-1634)



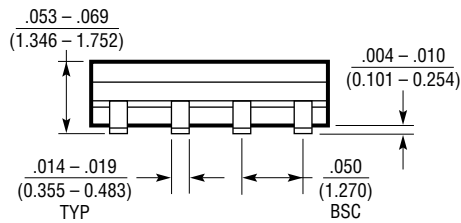
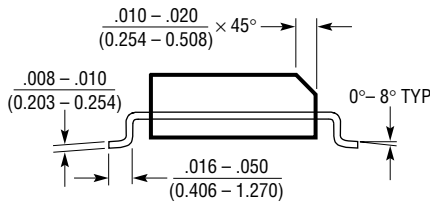
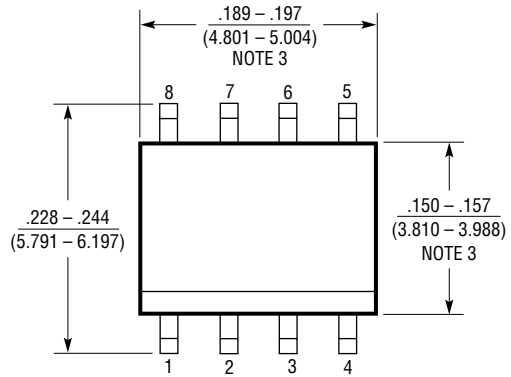
**ATTENTION: ORIGINAL SOT23-6L PACKAGE.**  
MOST SOT23-6L PRODUCTS CONVERTED TO THIN SOT23 PACKAGE, DRAWING # 05-08-1636 AFTER APPROXIMATELY APRIL 2001 SHIP DATE

# PACKAGE DESCRIPTION

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



RECOMMENDED SOLDER PAD LAYOUT



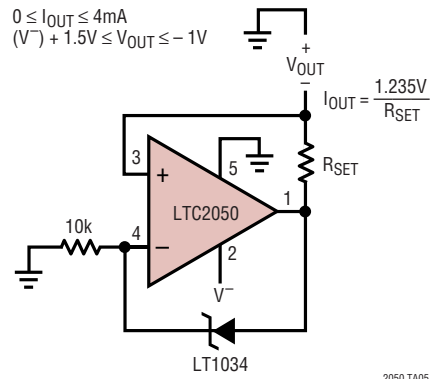
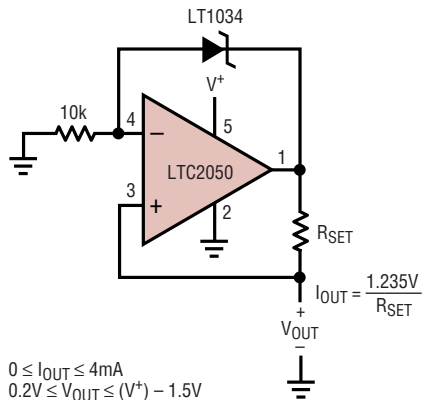
- NOTE:  
 1. DIMENSIONS IN  $\frac{\text{INCHES}}{\text{MILLIMETERS}}$   
 2. DRAWING NOT TO SCALE  
 3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

S08 0303

# LTC2050/LTC2050HV

## TYPICAL APPLICATIONS

### Ground Referred Precision Current Sources



2050 TA05

## 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
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	$V_{OS} = 90\mu\text{V}$ , $V_S = 2.7\text{V to } 44\text{V}$
LT1884/LT1885	Rail-to-Rail Output Precision Op Amp	$V_{OS} = 50\mu\text{V}$ , $I_B = 400\text{pA}$ , $V_S = 2.7\text{V to } 40\text{V}$
LTC2051	Dual Zero-Drift Op Amp	Dual Version of the LTC2050 in MS8 Package