

# 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 $\mu$ V<sub>P-P</sub> (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 $\mu$ A for the LTC2054 and 130 $\mu$ A/amp for the LTC2055.

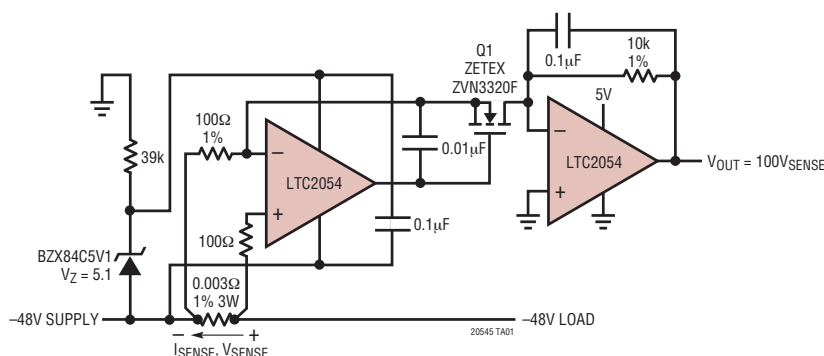
The LTC2054/LTC2055, despite their miniature size, feature uncompromising DC performance. The maximum input offset voltage and offset drift are 3.0 $\mu$ V and 30nV/ $^{\circ}\text{C}$  over the  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  industrial temperature range. The almost zero DC offset 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 $\mu$ V<sub>P-P</sub> DC to 10Hz noise and a 500kHz gain-bandwidth product.

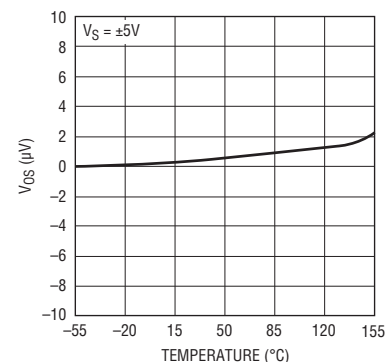
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## TYPICAL APPLICATION

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



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



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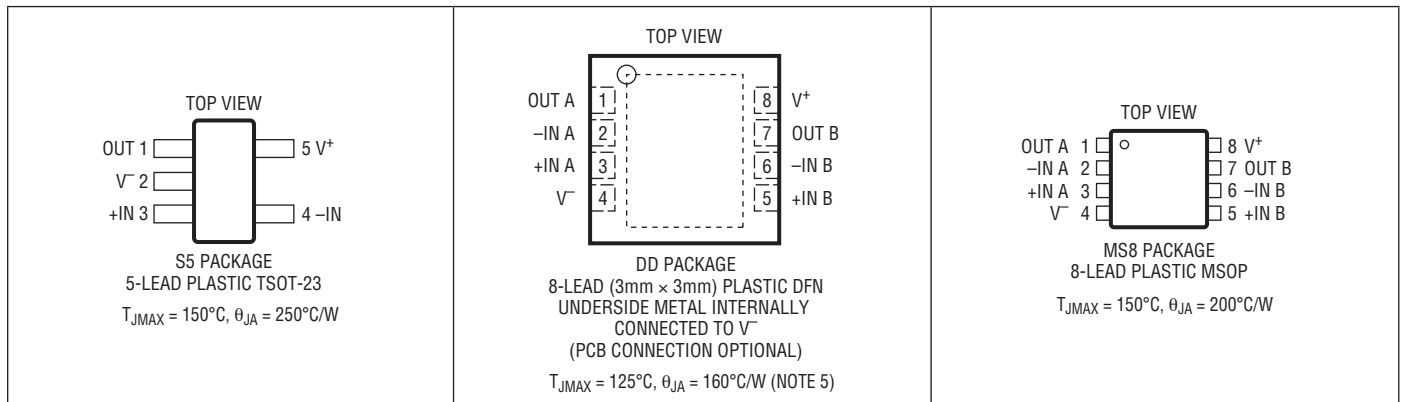
# LTC2054/LTC2055

## ABSOLUTE MAXIMUM RATINGS (Note 1)

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

Specified Temperature Range (Note 2)	
LTC2054C/LTC2055C	0°C to 70°C
LTC2054I/LTC2055I	-40°C to 85°C
LTC2054H/LTC2055H	-40°C to 125°C
LTC2054MP	-55°C to 150°C
Storage Temperature Range	-65°C to 150°C
DD Package	-65°C to 125°C
Lead Temperature (Soldering, 10 sec)	
TSOT23 and MS8 Packages	300°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°C to 70°C
LTC2054HVC55#PBF	LTC2054HVC55#TRPBF	LTAGD	5-Lead Plastic TSOT-23	0°C to 70°C
LTC2054IS5#PBF	LTC2054IS5#TRPBF	LTAGB	5-Lead Plastic TSOT-23	-40°C to 85°C
LTC2054HVIS5#PBF	LTC2054HVIS5#TRPBF	LTAGD	5-Lead Plastic TSOT-23	-40°C to 85°C
LTC2054HS5#PBF	LTC2054HS5#TRPBF	LTAGB	5-Lead Plastic TSOT-23	-40°C to 125°C
LTC2054HVHS5#PBF	LTC2054HVHS5#TRPBF	LTAGD	5-Lead Plastic TSOT-23	-40°C to 125°C
LTC2055CDD#PBF	LTC2055CDD#TRPBF	LBCW	8-Lead (3mm x 3mm) Plastic DFN	0°C to 70°C
LTC2055HCDD#PBF	LTC2055HCDD#TRPBF	LBCX	8-Lead (3mm x 3mm) Plastic DFN	0°C to 70°C
LTC2055IDD#PBF	LTC2055IDD#TRPBF	LBCW	8-Lead (3mm x 3mm) Plastic DFN	-40°C to 85°C
LTC2055HVIDD#PBF	LTC2055HVIDD#TRPBF	LBCX	8-Lead (3mm x 3mm) Plastic DFN	-40°C to 85°C
LTC2055HDD#PBF	LTC2055HDD#TRPBF	LBCW	8-Lead (3mm x 3mm) Plastic DFN	-40°C to 125°C
LTC2055HVHDD#PBF	LTC2055HVHDD#TRPBF	LBCX	8-Lead (3mm x 3mm) Plastic DFN	-40°C to 125°C
LTC2055CMS8#PBF	LTC2054CMS8#TRPBF	LTBCR	8-Lead Plastic MSOP	0°C to 70°C
LTC2055HVCMS8#PBF	LTC2055HVCMS8#TRPBF	LTBCT	8-Lead Plastic MSOP	0°C to 70°C
LTC2055IM8#PBF	LTC2055IM8#TRPBF	LTBCR	8-Lead Plastic MSOP	-40°C to 85°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
LTC2054HVMP5#PBF	LTC2054HVMP5#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 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)	●		$\pm 1$	$\pm 150$	$\pm 1$	$\pm 3000$	$\text{pA}$ $\text{pA}$	
$I_{OS}$	Input Offset Current	(Note 4)	●		$\pm 2$	$\pm 300$	$\pm 2$	$\pm 700$	$\text{pA}$ $\text{pA}$	
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , DC to 1Hz $R_S = 100\Omega$ , DC to 10Hz			0.6 1.6		0.6 1.6		$\mu\text{V}_{\text{P-P}}$ $\mu\text{V}_{\text{P-P}}$	
CMRR	Common Mode Rejection Ratio	$V_{\text{CM}} = \text{GND to } V^+ - 0.7\text{V}$ $V_S = 3\text{V}$	●		115 110	130	115 110	130	$\text{dB}$ $\text{dB}$	
		$V_{\text{CM}} = \text{GND to } V^+ - 0.7\text{V}$ $V_S = 5\text{V}$	●		120 115	130	120 115	130	$\text{dB}$ $\text{dB}$	
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V to } 6\text{V}$	●		120 115	130	120 115	130	$\text{dB}$ $\text{dB}$	
$A_{\text{VOL}}$	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_S = 3\text{V}$ , $V_{\text{OUT}} = V_S/2$	●		120 115	135	120 115	135	$\text{dB}$ $\text{dB}$	
		$R_L = 100\text{k}$ , $V_S = 5\text{V}$ , $V_{\text{OUT}} = V_S/2$	●		125 120	140	125 120	140	$\text{dB}$ $\text{dB}$	
$V_{\text{OUT}}$	Output Voltage Swing High	$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$	●		2.87 2.85	2.89	2.87 2.84	2.89	$\text{V}$ $\text{V}$	
		$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$	●		4.80 4.75	4.83	4.80 4.70	4.83	$\text{V}$ $\text{V}$	
		$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$	●		2.98 2.975	2.99	2.98 2.97	2.99	$\text{V}$ $\text{V}$	
		$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$	●		4.985 4.980	4.99	4.985 4.970	4.99	$\text{V}$ $\text{V}$	

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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 LTC2054I/LTC2055I			LTC2054H/LTC2055H			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OUT}$	Output Voltage Swing Low	$R_L = 5\text{k to GND}, V_S = 3\text{V}$ $R_L = 5\text{k to GND}, V_S = 3\text{V}$	●	2	8	10	3	8	10	mV mV
			●	2	8	10	3	8	10	mV mV
		$R_L = 100\text{k to GND}, V_S = 3\text{V}$ $R_L = 100\text{k to GND}, V_S = 3\text{V}$	●	2	8	10	3	8	10	mV mV
			●	2	8	10	3	8	10	mV 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 LTC2054HVI/LTC2055HVI			LTC2054HVH/LTC2055HVH			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			$\text{nV}/\sqrt{\text{mo}}$
$I_B$	Input Bias Current	(Note 4)	●	$\pm 3$		$\pm 150$	$\pm 3$		$\pm 3000$	$\mu\text{A}$ $\text{pA}$
			●	$\pm 6$		$\pm 300$	$\pm 6$		$\pm 700$	$\text{pA}$ $\text{pA}$
$e_n$	Input Noise Voltage	$R_S = 100\Omega, \text{DC to } 1\text{Hz}$ $R_S = 100\Omega, \text{DC to } 10\text{Hz}$		0.6	1.6		0.6	1.6		$\mu\text{V}_{P-P}$ $\mu\text{V}_{P-P}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = \text{GND to } V^+ - 0.9$	●	120	130		120	130		$\text{dB}$ $\text{dB}$
			●	115			115			
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V to } 11\text{V}$	●	120	130		120	130		$\text{dB}$ $\text{dB}$
			●	115			115			
AVOL	Large-Signal Voltage Gain	$R_L = 100\text{k}, V_{OUT} = \text{GND}$	●	125	140		125	140		$\text{dB}$ $\text{dB}$
			●	120			120			
$V_{OUT}$	Maximum Output Voltage Swing	$R_L = 5\text{k to GND}$ $R_L = 5\text{k to GND}$	●	$\pm 4.78$	$\pm 4.82$		$\pm 4.78$	$\pm 4.82$		V V
			●	$\pm 4.75$			$\pm 4.70$			
		$R_L = 100\text{k to GND}$ $R_L = 100\text{k to GND}$	●	$\pm 4.98$	$\pm 4.99$		$\pm 4.98$	$\pm 4.99$		V V
			●	$\pm 4.975$			$\pm 4.97$			
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) (Note 3) $-55^\circ\text{C}$ to $135^\circ\text{C}$	●			$\pm 10$ $\pm 8$	$\mu\text{V}$ $\mu\text{V}$
$\Delta V_{OS}/\Delta T$	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)	●		$\pm 1$	$\pm 12$	$\text{pA}$ $\text{nA}$
$I_{OS}$	Input Offset Current	(Note 4)	●		$\pm 2$	$\pm 5$	$\text{pA}$ $\text{nA}$
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , DC to 1Hz $R_S = 100\Omega$ , DC to 10Hz			0.6 1.6		$\mu\text{V}_{\text{P-P}}$ $\mu\text{V}_{\text{P-P}}$
CMRR	Common Mode Rejection Ratio	$V_{\text{CM}} = \text{GND to } V^+ - 0.7\text{V}$ $V_S = 3\text{V}$	●	115 105	130		$\text{dB}$ $\text{dB}$
		$V_{\text{CM}} = \text{GND to } V^+ - 0.7\text{V}$ $V_S = 5\text{V}$	●	120 110	130		$\text{dB}$ $\text{dB}$
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V to } 6\text{V}$	●	120 110	130		$\text{dB}$ $\text{dB}$
$A_{\text{VOL}}$	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_S = 3\text{V}$ , $V_{\text{OUT}} = V_S/2$	●	120 110	135		$\text{dB}$ $\text{dB}$
		$R_L = 100\text{k}$ , $V_S = 5\text{V}$ , $V_{\text{OUT}} = V_S/2$	●	125 115	140		$\text{dB}$ $\text{dB}$
$V_{\text{OUT}}$	Output Voltage Swing High	$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$	●	2.87 2.84	2.89		$\text{V}$ $\text{V}$
		$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$	●	4.80 4.70	4.83		$\text{V}$ $\text{V}$
		$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$	●	2.98 2.97	2.99		$\text{V}$ $\text{V}$
		$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$	●	4.985 4.970	4.99		$\text{V}$ $\text{V}$
$V_{\text{OUT}}$	Output Voltage Swing Low	$R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 3\text{V}$	●		3	8 10	$\text{mV}$ $\text{mV}$
		$R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 5\text{k to GND}$ , $V_S = 5\text{V}$	●		3	8 10	$\text{mV}$ $\text{mV}$
		$R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 3\text{V}$	●		3	8 10	$\text{mV}$ $\text{mV}$
		$R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$ $R_L = 100\text{k to GND}$ , $V_S = 5\text{V}$	●		3	8 10	$\text{mV}$ $\text{mV}$
SR	Slew Rate			0.5		$\text{V}/\mu\text{s}$	
GBW	Gain Bandwidth Product			500		$\text{kHz}$	
$f_S$	Internal Sampling Frequency			1		$\text{kHz}$	

## 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)	●		$\pm 3$	$\pm 12$	$\mu\text{A}$ $\text{nA}$
$I_{OS}$	Input Offset Current	(Note 4)	●		$\pm 6$	$\pm 5$	$\mu\text{A}$ $\text{nA}$
$e_n$	Input Noise Voltage	$R_S = 100\Omega$ , DC to 1Hz $R_S = 100\Omega$ , DC to 10Hz			0.6 1.6		$\mu\text{V}_{P-P}$ $\mu\text{V}_{P-P}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = \text{GND to } V^+ - 0.9$	●	120 110	130		$\text{dB}$ $\text{dB}$
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{V to } 11\text{V}$	●	120 110	130		$\text{dB}$ $\text{dB}$
AVOL	Large-Signal Voltage Gain	$R_L = 100\text{k}$ , $V_{OUT} = \text{GND}$	●	125 115	140		$\text{dB}$ $\text{dB}$
$V_{OUT}$	Maximum Output Voltage Swing	$R_L = 5\text{k to GND}$ $R_L = 5\text{k to GND}$	●	$\pm 4.78$ $\pm 4.675$	$\pm 4.82$		$\text{V}$ $\text{V}$
		$R_L = 100\text{k to GND}$ $R_L = 100\text{k to GND}$	●	$\pm 4.98$ $\pm 4.965$	$\pm 4.99$		$\text{V}$ $\text{V}$
SR	Slew Rate			0.5			$\text{V}/\mu\text{s}$
GBW	Gain Bandwidth Product			500			$\text{kHz}$
$f_S$	Internal Sampling Frequency			1			$\text{kHz}$

**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  $150^\circ\text{C}$ .

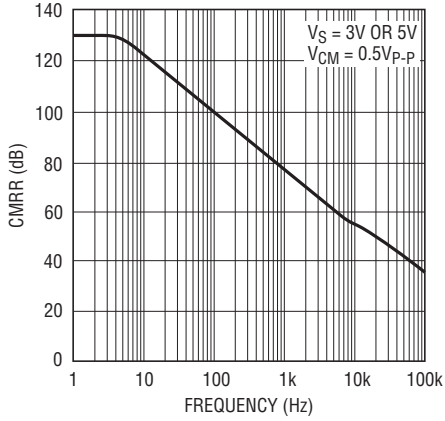
**Note 3:** These parameters are guaranteed by design. Thermocouple effects preclude measurements of these voltage levels during automated testing.

**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.

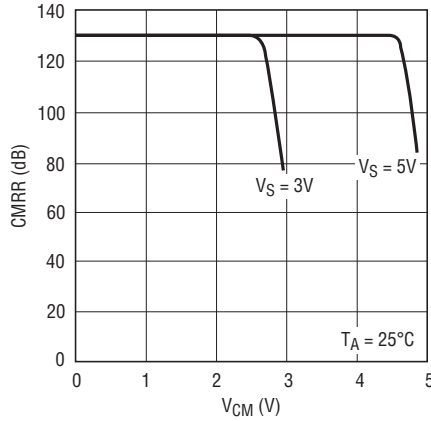
# TYPICAL PERFORMANCE CHARACTERISTICS

**Common Mode Rejection Ratio vs Frequency**



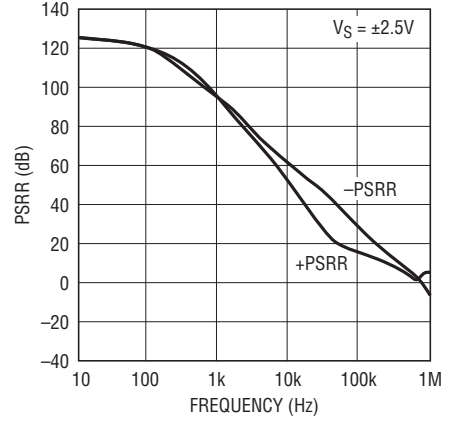
20545 G01

**DC CMRR vs Common Mode Input Range**



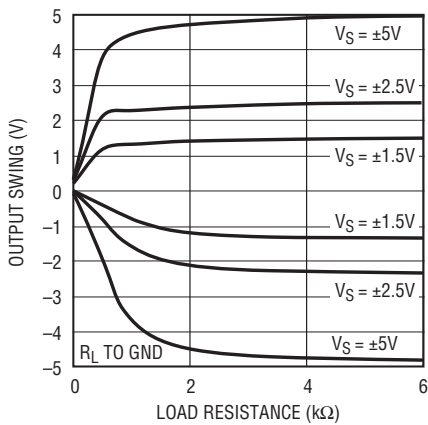
20545 G02

**PSRR vs Frequency**



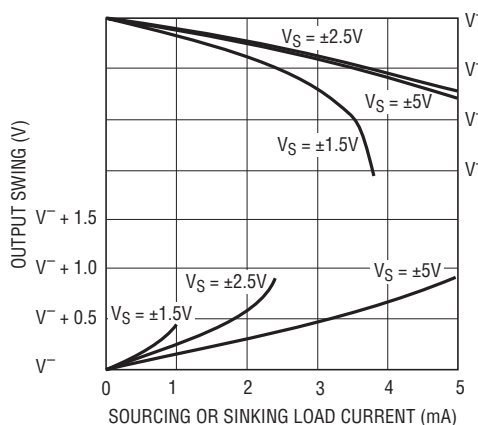
20545 G03

**Output Voltage Swing vs Load Resistance**



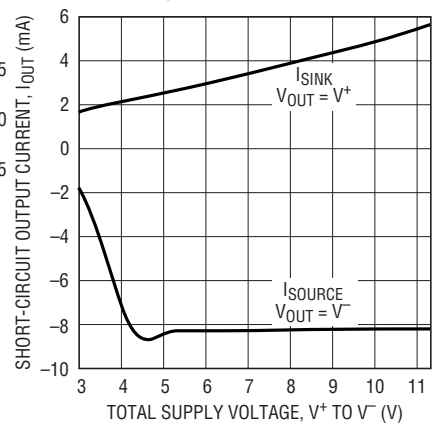
20545 G04

**Output Swing vs Load Current**



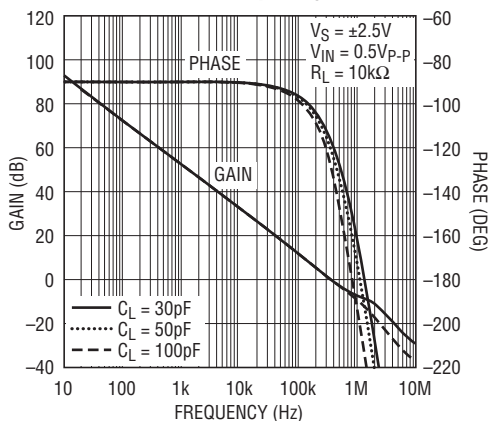
20545 G05

**Short-Circuit Output Current vs Supply Voltage**



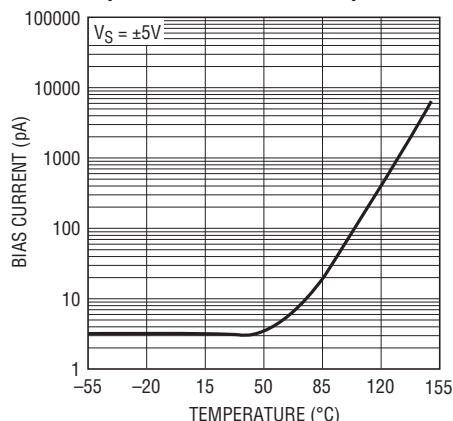
20545 G06

**Gain/Phase vs Frequency**



20545 G07

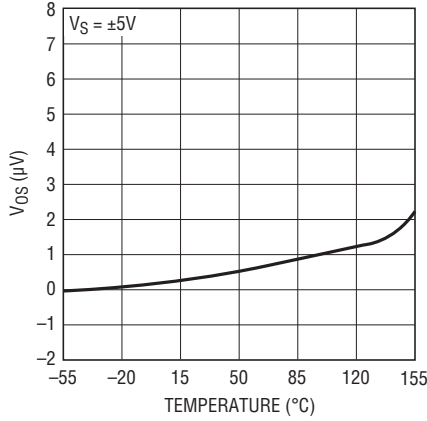
**Input Bias Current vs Temperature**



20545 G08

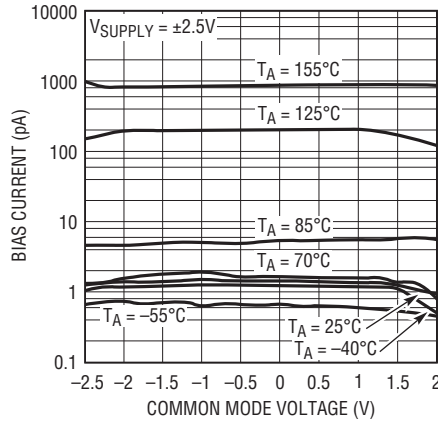
## TYPICAL PERFORMANCE CHARACTERISTICS

### $V_{OS}$ vs Temperature



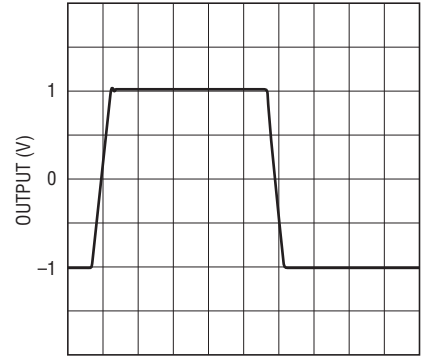
20545 G09

### Input Bias Current vs Input Common Mode Voltage



20545 G10

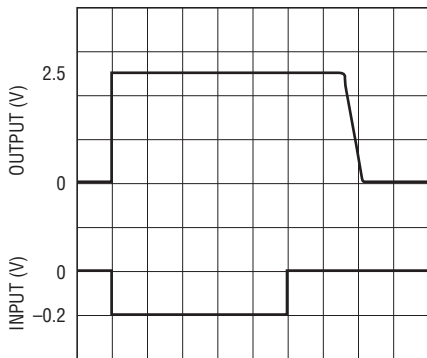
### Transient Response



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

20545 G11

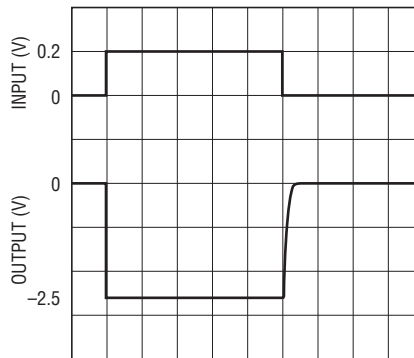
### Output Overload Recovery



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

20545 G12

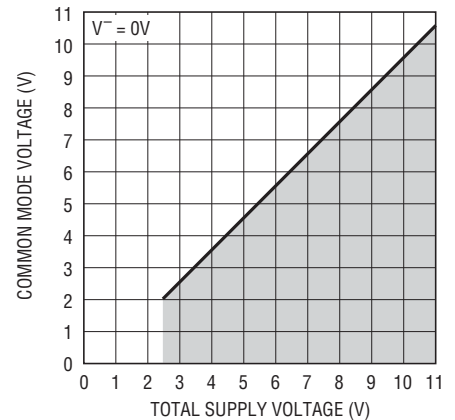
### Output Overload Recovery



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

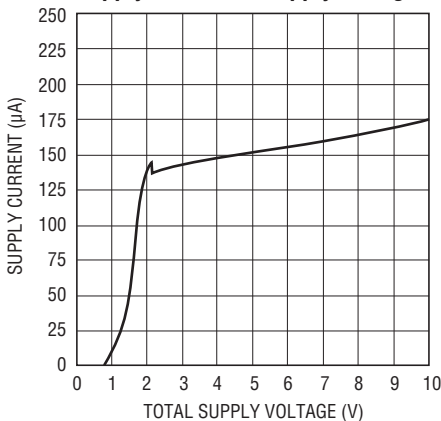
20545 G13

### Common Mode Input Range



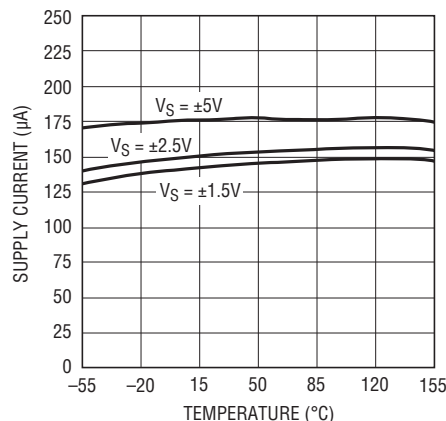
20545 G14

### Supply Current vs Supply Voltage



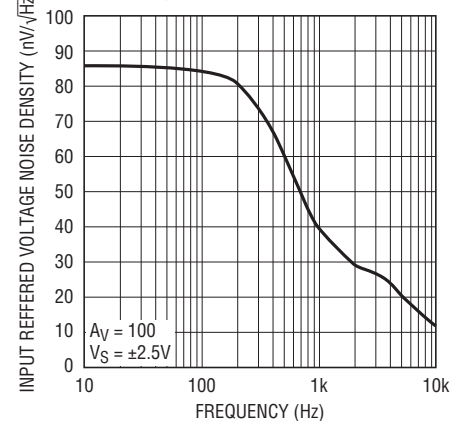
20545 G15

### Supply Current vs Temperature



20545 G16

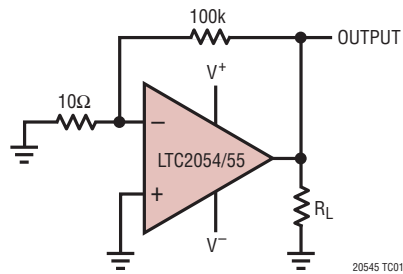
### Noise Spectrum



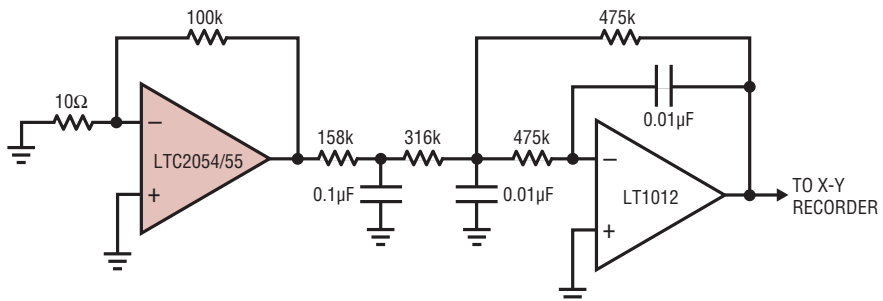
20545 G17



## 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

### 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.

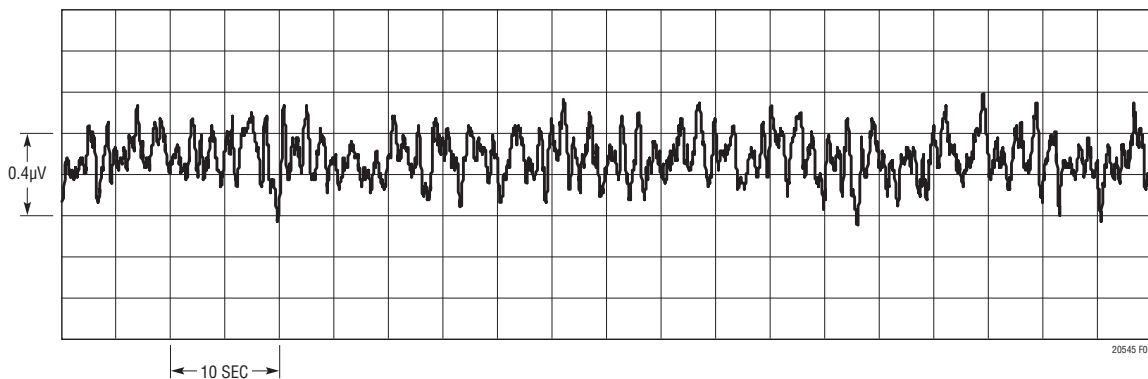
The first form of clock feedthrough is caused by the settling of the internal sampling capacitor and is input referred; that is, it is multiplied by the closed loop gain of the op amp. This form of clock feedthrough is independent of the magnitude of the input source resistance or the magnitude of the 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.

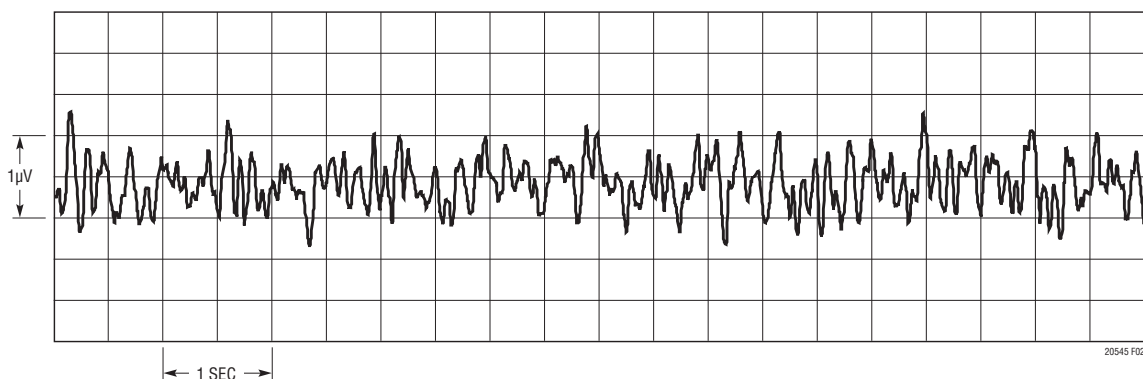
Placing a capacitor across the feedback resistor reduces either form of clock feedthrough by limiting the bandwidth of the closed loop gain.

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

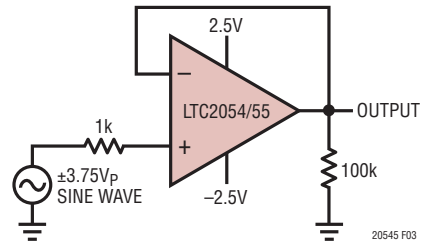
cause the second form of clock feedthrough described above, when averaged, dominate the DC input bias current of the op amp below 70°C.

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).

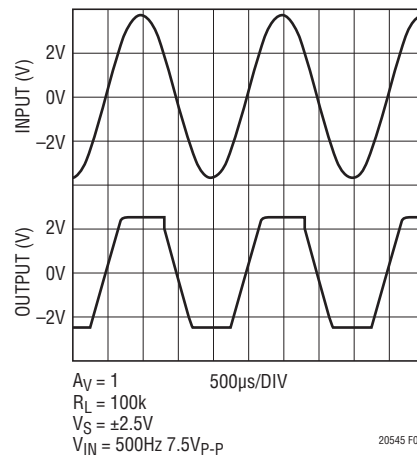
### Extended Common Mode Range

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

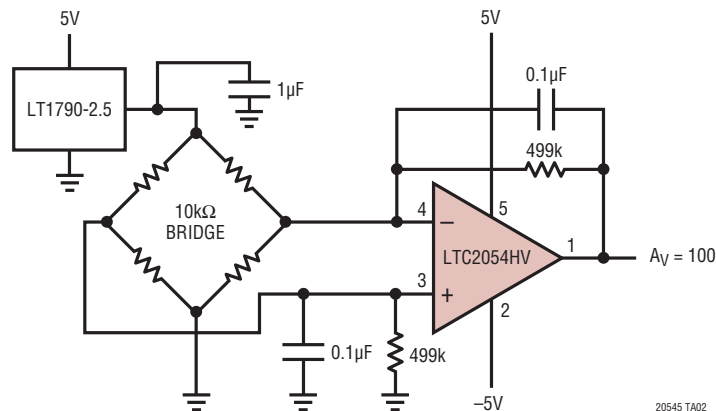


Extended Common Mode Range



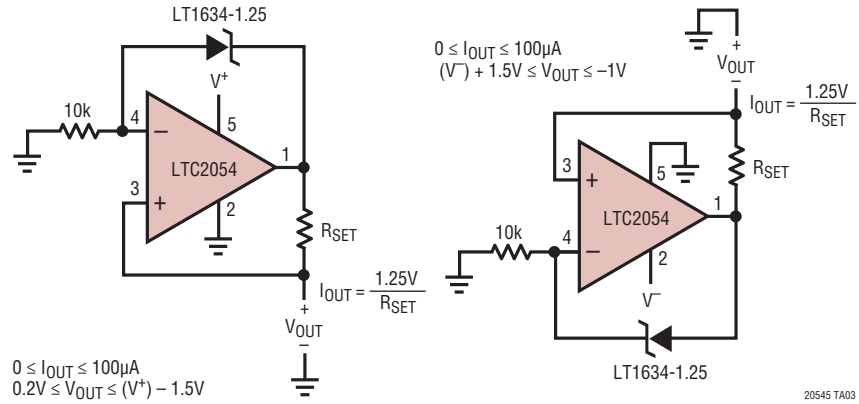
## TYPICAL APPLICATIONS

Simple Differential Bridge Amplifier

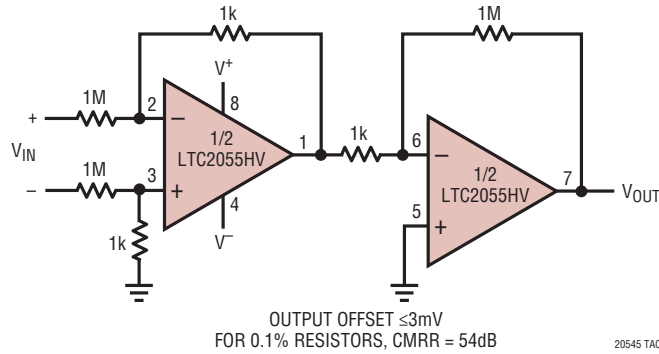


## TYPICAL APPLICATIONS

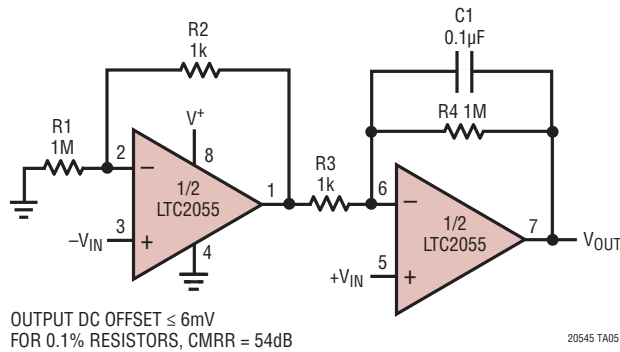
### Ground Referred Precision Current Sources



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

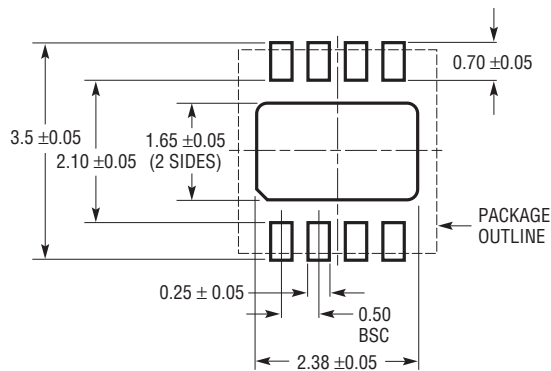


### Gain of 1001 Single Supply Instrumentation Amplifier

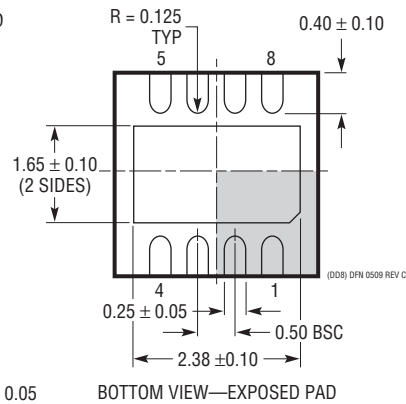
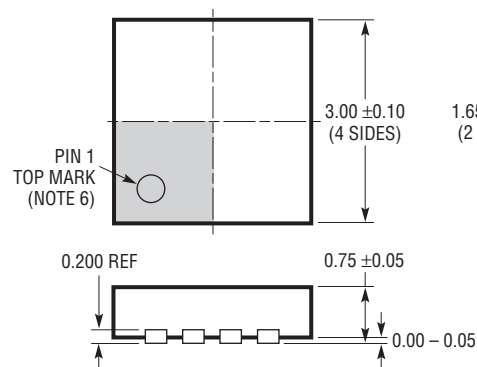


## PACKAGE DESCRIPTION

**DD Package**  
**8-Lead Plastic DFN (3mm × 3mm)**  
 (Reference LTC DWG # 05-08-1698 Rev C)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS  
 APPLY SOLDER MASK TO AREAS THAT ARE NOT SOLDERED

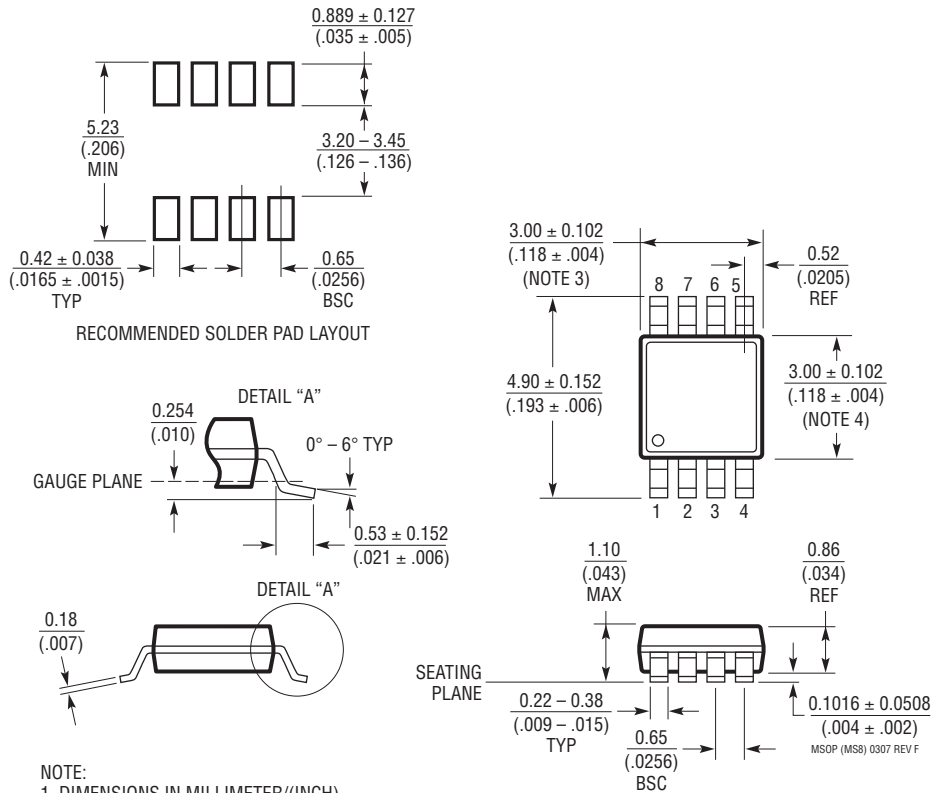


**NOTE:**

1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON TOP AND BOTTOM OF PACKAGE

## PACKAGE DESCRIPTION

**MS8 Package**  
**8-Lead Plastic MSOP**  
 (Reference LTC DWG # 05-08-1660 Rev F)

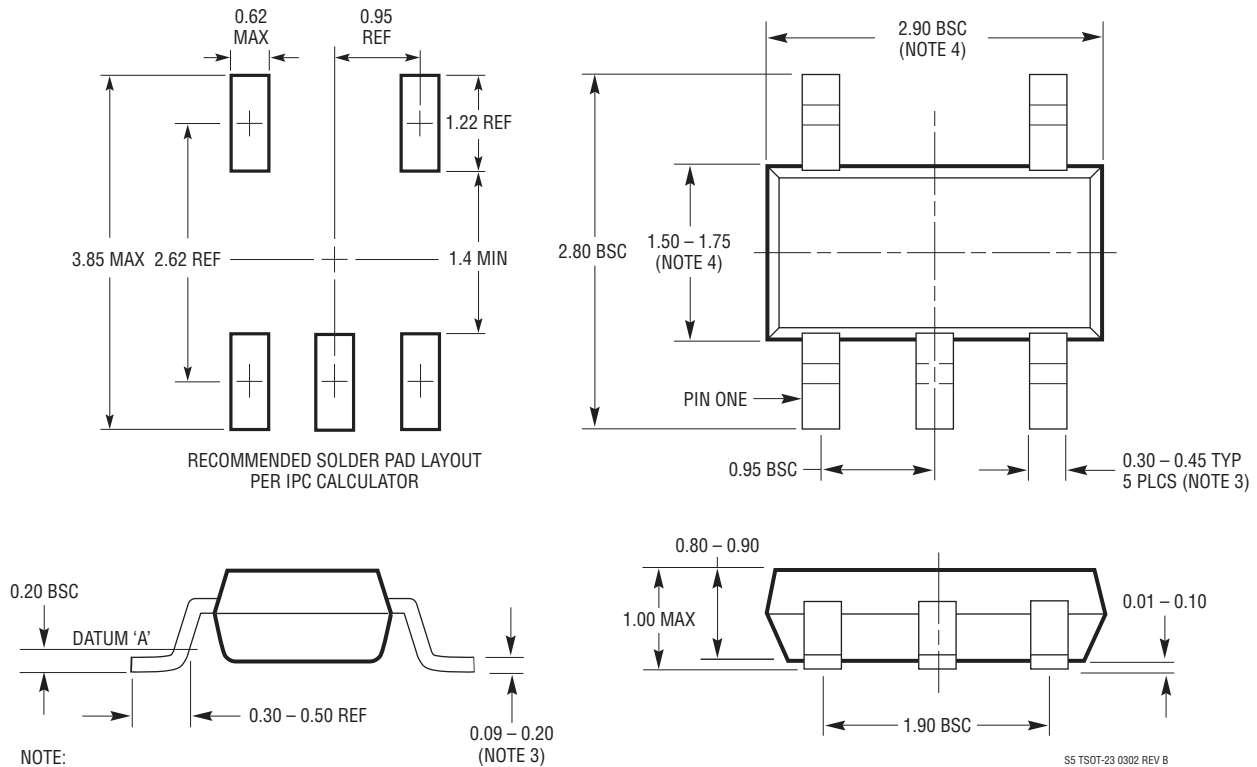


**NOTE:**

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

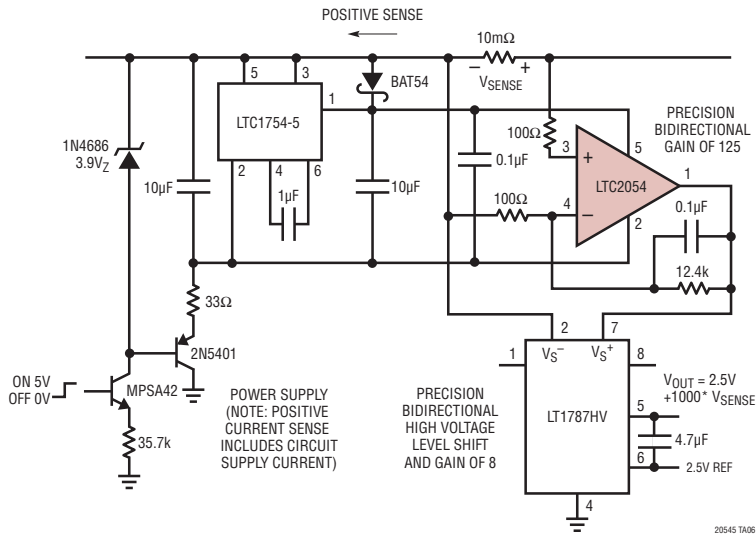
# PACKAGE DESCRIPTION

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

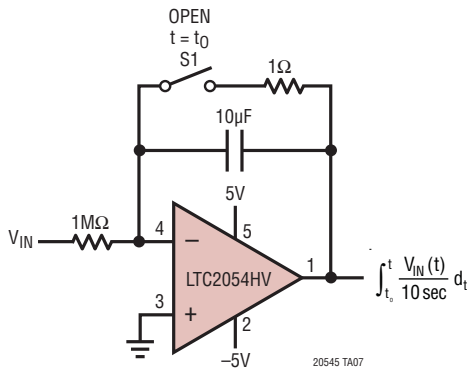


## TYPICAL APPLICATIONS

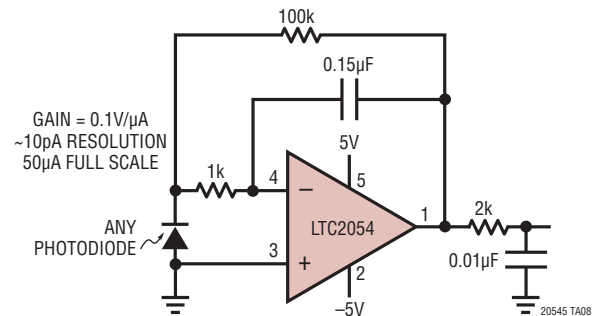
### Low Power, Bidirectional 60V Precision Hi Side Current Sense



### 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	$V_{OS} = 90\mu V$ , $V_S = 2.7V$ 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