Single/Dual Micropower Zero-Drift Operational Amplifiers

FEATURES

- **Supply Current 150μA (Max per Amplifier) Guaranteed Over Temperature**
- **Offset Voltage 3μV (Max)**
- **Offset Voltage Drift 30nV/°C (Max)**
- Common Mode Input Range from V^- to V^+ –0.5V
- Output Swings Rail-to-Rail
- Voltage Gain: 140dB (Typ)
- PSRR and CMRR: 130dB (Typ)
- Input Bias Current: 1pA (Typ, 25°C)
- Noise: 1.6μV_{P-P} (0.01Hz to 10Hz Typ)
- Supply Operation:
  2.7V to 6V (LTC2054/LTC2055)
  2.7V to ±5.5V (LTC2054HV/LTC2055HV)
- Low Profile (1mm) SOT-23, MS8 and 3mm × 3mm × 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®2054/LTC2055 are low power, low noise single/dual zero-drift operational amplifiers available in the SOT-23 (ThinSOT™) and MS8 packages. For space limited applications, the LTC2055 is also available in a 3mm × 3mm × 0.8mm dual fine pitch leadless package (DFN). They operate from a single 2.7V minimum supply and support ±5V applications. The current consumption is typically 150μA for the LTC2054 and 130μA/amp for the LTC2055.

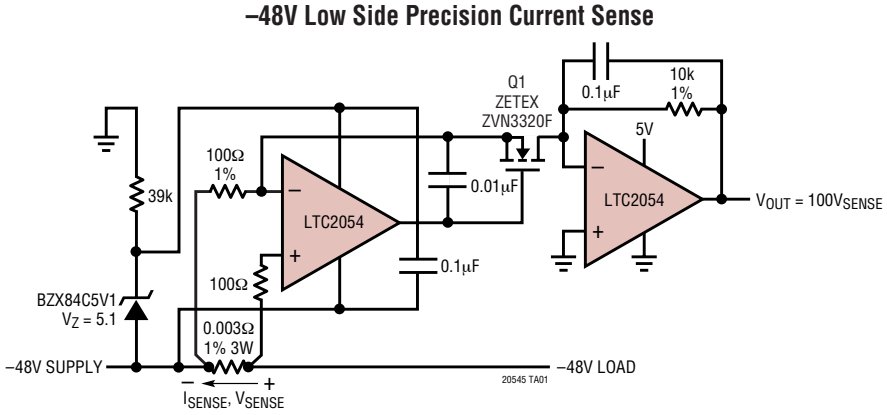
The LTC2054/LTC2055, despite their miniature size, feature uncompromising DC performance. The typical input offset voltage and offset drift are 0.5μV and 25nV/°C. The almost zero DC offset and drift are supported with a power supply rejection ratio (PSRR) and common mode rejection ratio (CMRR) of more 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/LTC2055 also feature a 1.6μV_{P-P} DC to 10Hz noise and a 500kHz gain-bandwidth product.

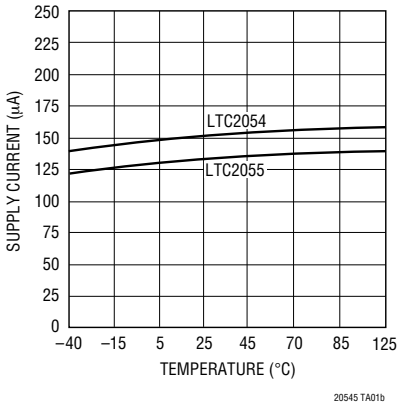
LT, LTC and LT are registered trademarks of Linear Technology Corporation.
ThinSOT is a trademark of Linear Technology Corporation

TYPICAL APPLICATION

–48V Low Side Precision Current Sense



Supply Current (per Amplifier)



ABSOLUTE MAXIMUM RATINGS (Note 1)

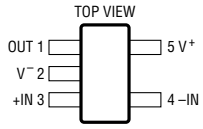
Total Supply Voltage (V^+ to V^-)
- LTC2054/LTC2055 ..... 7V
- LTC2054HV/LTC2055HV 12V

Input Voltage ..... (V^+ + 0.3V) to (V^- – 0.3V)
Input Current ..... ±10mA
Output Short-Circuit Duration ..... Indefinite

Operating Temperature Range ..... –40°C to 125°C
Specified Temperature Range (Note 3) –40°C to 125°C
Storage Temperature Range ..... –65°C to 150°C
- DD Package ..... –65°C to 125°C

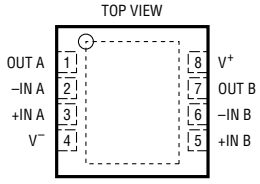
Lead Temperature (Soldering, 10 sec) ..... 300°C

PACKAGE/ORDER INFORMATION



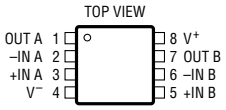
S5 PACKAGE
5-LEAD PLASTIC SOT-23

T_{JMAX} = 150°C, θ_{JA} = 250°C/W



DD PACKAGE
8-LEAD (3mm × 3mm) PLASTIC DFN
UNDERSIDE METAL INTERNALLY
CONNECTED TO V^-
(PCB CONNECTION OPTIONAL)

T_{JMAX} = 125°C, θ_{JA} = 160°C/W, NOTE 5



MS8 PACKAGE
8-LEAD PLASTIC MSOP

T_{JMAX} = 150°C, θ_{JA} = 200°C/W

ORDER PART NUMBER*	S5 PART MARKING	ORDER PART NUMBER*	DD PART MARKING	ORDER PART NUMBER*	MS8 PART MARKING
LTC2054CS5	LTAGB	LTC2055CDD	LBCW	LTC2055CMS8	LTBCR
LTC2054HVCS5	LTAGD	LTC2055HVCDD	LBCX	LTC2055HVCMS8	LTBCT
LTC2054IS5	LTAGB	LTC2055IDD	LBCW	LTC2055IMS8	LTBCR
LTC2054HVIS5	LTAGD	LTC2055HVIDD	LBCX	LTC2055HVIMS8	LTBCT
LTC2054HS5	LTAGB	LTC2055HDD	LBCW	LTC2055HMS8	LTBCR
LTC2054HVHS5	LTAGD	LTC2055HVHDD	LBCX	LTC2055HVHMS8	LTBCT

*The temperature grade (C, I or H) is indicated on the shipping container. Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

(LTC2054/LTC2055, LTC2054HV/LTC2055HV) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 3V, 5V unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		LTC2054C/LTC2055C LTC2054I/LTC2055I MIN	TYP	MAX	LTC2054H/LTC2055H MIN	TYP	MAX	UNITS
I_S	Supply Current (LTC2054)	No Load, V_S = 3V	●		140	175		140	180	µA
		No Load, V_S = 5V	●		150	175		150	180	µA
I_S	Supply Current Per Amplifier	No Load, V_S = 3V	●		130	150		130	155	µA
	(LTC2055)	No Load, V_S = 5V	●		135	150		135	155	µA
V_{OS}	Input Offset Voltage	(Note 2)			±0.5	±3		±0.5	±3	µV
$\Delta V_{OS}/\Delta T$	Average Input Offset Drift	(Note 2)	●		0.02	±0.03		0.02	±0.05	µV/°C
	Long-Term Offset Drift				50			50		nV/√mo
I_B	Input Bias Current (Note 4)	V_S = 3V			±1			±1		pA
		V_S = 3V	●			±150			±3000	pA
		V_S = 5V			±1			±1		pA
		V_S = 5V	●			±150			±3000	pA

ELECTRICAL CHARACTERISTICS

(LTC2054/LTC2055, LTC2054HV/LTC2055HV) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 3V, 5V unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		LTC2054C/LTC2055C LTC2054I/LTC2055I MIN	TYP	MAX	LTC2054H/LTC2055H MIN	TYP	MAX	UNITS
I_{OS}	Input Offset Current (Note 4)	V_S = 3V			±2			±2		pA
		V_S = 3V	●			±300			±700	pA
		V_S = 5V			±2			±2		pA
		V_S = 5V	●			±300			±700	pA
e_n	Input Noise Voltage	R_S = 100Ω, DC to 1Hz			0.6			0.6		μV_{P-P}
		R_S = 100Ω, DC to 10Hz			1.6			1.6		μV_{P-P}
CMRR	Common Mode Rejection Ratio	V_{CM} = GND to V^+ – 0.7V		115	130		115	130		dB
		V_S = 3V	●	110			110			dB
		V_{CM} = GND to V^+ – 0.7V		120	130		120	130		dB
		V_S = 5V	●	115			115			dB
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 6V		120	130		120	130		dB
			●	115			115			dB
A_{VOL}	Large-Signal Voltage Gain	R_L = 100k, V_S = 3V, V_{OUT} = V_S/2		120	135		120	135		dB
			●	115			115			dB
		R_L = 100k, V_S = 5V, V_{OUT} = V_S/2		125	140		125	140		dB
			●	120			120			dB
V_{OUT}	Output Voltage Swing High	R_L = 5k to GND, V_S = 3V		2.87	2.89		2.87	2.89		V
		R_L = 5k to GND, V_S = 3V	●	2.85			2.84			V
		R_L = 5k to GND, V_S = 5V		4.80	4.83		4.80	4.83		V
		R_L = 5k to GND, V_S = 5V	●	4.75			4.70			V
		R_L = 100k to GND, V_S = 3V		2.98	2.99		2.98	2.99		V
		R_L = 100k to GND, V_S = 3V	●	2.975			2.97			V
		R_L = 100k to GND, V_S = 5V		4.985	4.99		4.985	4.99		V
		R_L = 100k to GND, V_S = 5V	●	4.980			4.970			V
V_{OUT}	Output Voltage Swing Low	R_L = 5k to GND, V_S = 3V			2	8		3	8	mV
		R_L = 5k to GND, V_S = 3V	●			10			10	mV
		R_L = 5k to GND, V_S = 5V			2	8		3	8	mV
		R_L = 5k to GND, V_S = 5V	●			10			10	mV
		R_L = 100k to GND, V_S = 3V			2	8		3	8	mV
		R_L = 100k to GND, V_S = 3V	●			10			10	mV
		R_L = 100k to GND, V_S = 5V			2	8		3	8	mV
		R_L = 100k to GND, V_S = 5V	●			10			10	mV
SR	Slew Rate				0.5			0.5		V/µs
GBW	Gain Bandwidth Product				500			500		kHz
f_S	Internal Sampling Frequency				1			1		kHz

ELECTRICAL CHARACTERISTICS

(LTC2054HV/LTC2055HV) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±5V unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		LTC2054HVC/LTC2055HVC LTC2054HVI/LTC2055HVI MIN	TYP	MAX	LTC2054HVH/LTC2055HVH MIN	TYP	MAX	UNITS
I_S	Supply Current	No Load (LTC2054)	●		175	210		175	215	µA
I_S	Supply Current (Per Amplifier)	No Load (LTC2055)	●		150	180		150	185	µA
V_{OS}	Input Offset Voltage	(Note 2)			±0.5	±5		±0.5	±5	µV
$\Delta V_{OS}/\Delta T$	Average Input Offset Drift	(Note 2)	●		0.025	±0.03		0.025	±0.05	µV/°C
	Long-Term Offset Drift				50			50		nV/√mo
I_B	Input Bias Current (Note 4)		 ●		±3	 ±150		±3	 ±3000	pA pA
I_{OS}	Input Offset Current (Note 4)		 ●		±6	 ±300		±6	 ±700	pA pA
e_n	Input Noise Voltage	R_S = 100Ω, DC to 1Hz R_S = 100Ω, DC to 10Hz			0.6 1.6			0.6 1.6		μV_{P-P} μV_{P-P}
CMRR	Common Mode Rejection Ratio	V_{CM} = GND to V^+ – 0.9	 ●	120 115	130		120 115	130		dB dB
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 11V	 ●	120 115	130		120 115	130		dB dB
AVOL	Large-Signal Voltage Gain	R_L = 100k, V_{OUT} = GND	 ●	125 120	140		125 120	140		dB dB
V_{OUT}	Maximum Output Voltage Swing	R_L = 5k to GND R_L = 5k to GND	 ●	±4.78 ±4.75	±4.82		±4.78 ±4.70	±4.82		V V
		R_L = 100k to GND R_L = 100k to GND	 ●	±4.98 ±4.975	±4.99		±4.98 ±4.97	±4.99		V V
SR	Slew Rate				0.5			0.5		V/µs
GBW	Gain Bandwidth Product				500			500		kHz
f_S	Internal Sampling Frequency				1			1		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.

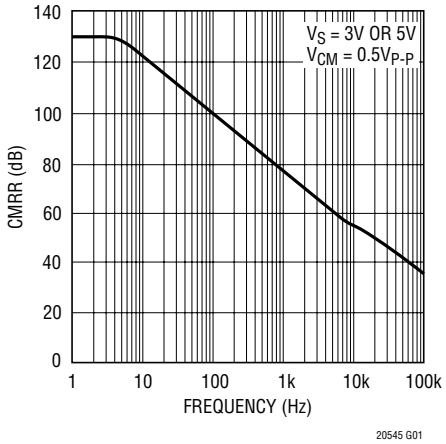
Note 3: All versions of the LTC2054/LTC2055 are designed, characterized and expected to meet the extended temperature limits of –40°C and 125°C. The LTC2054C/LTC2055C/LTC2054HVC/LTC2055HVC are guaranteed to meet the temperature limits of 0°C and 70°C. The LTC2054I/LTC2055I/LTC2054HVI/LTC2055HVI are guaranteed to meet temperature limits of –40°C and 85°C. The LTC2054H/LTC2055H and LTC2054HVH/LTC2055HVH are guaranteed to meet the temperature limits of –40°C and 125°C.

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

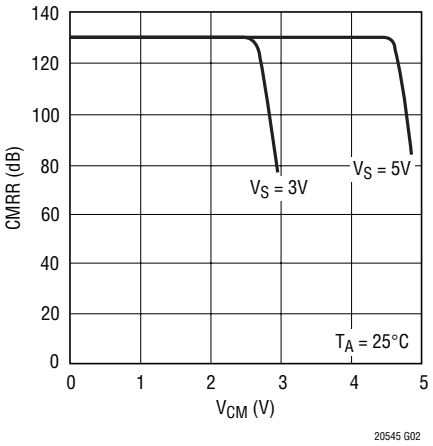
Note 5: The θ_{JA} specified for the DD package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

TYPICAL PERFORMANCE CHARACTERISTICS

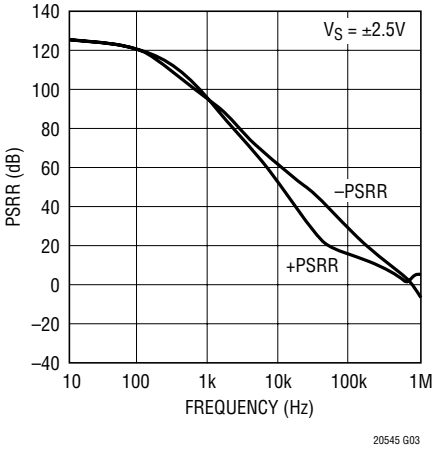
Common Mode Rejection Ratio vs Frequency



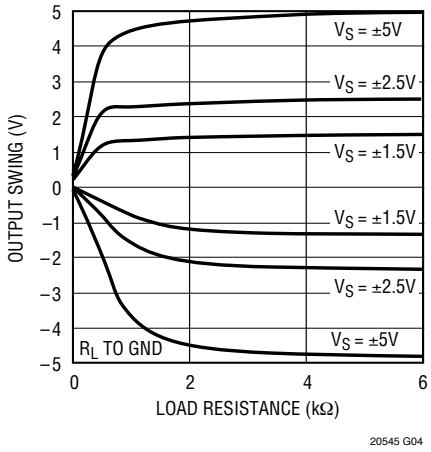
DC CMRR vs Common Mode Input Range



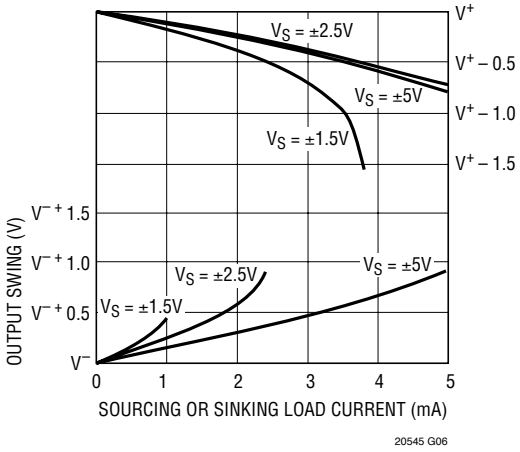
PSRR vs Frequency



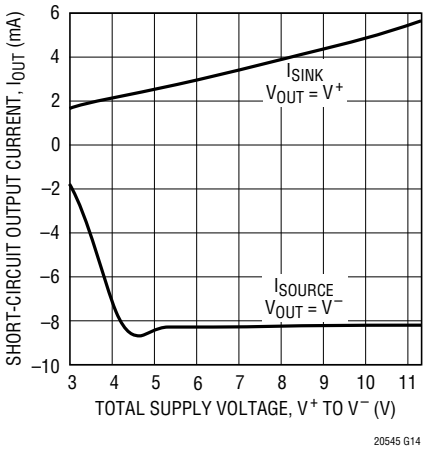
Output Voltage Swing vs Load Resistance



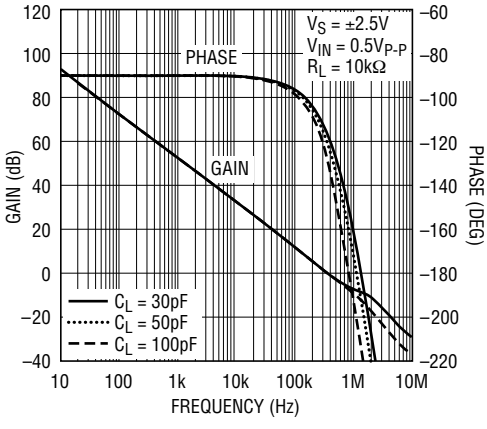
Output Swing vs Load Current



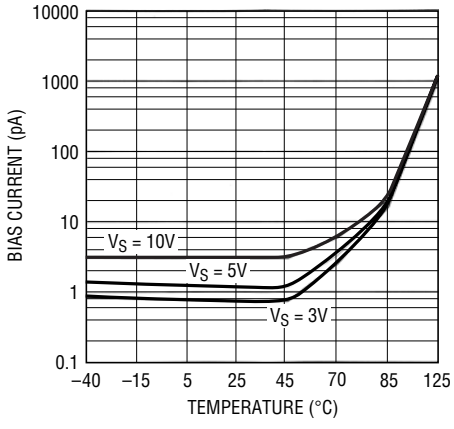
Short-Circuit Output Current vs Supply Voltage



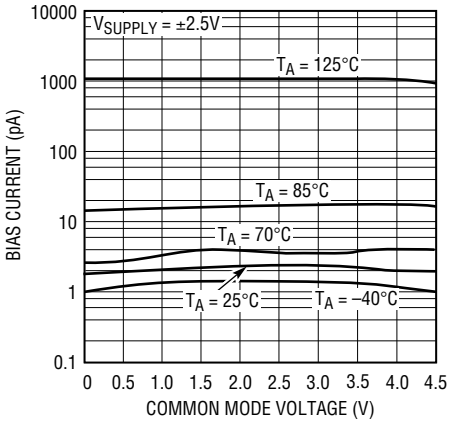
Gain/Phase vs Frequency



Input Bias Current vs Temperature

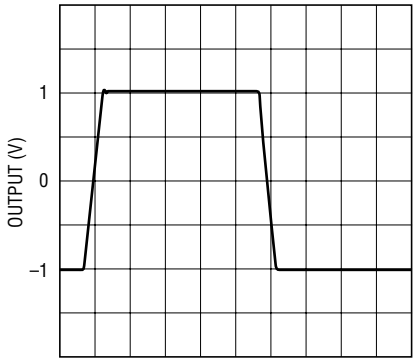


Input Bias Current vs Input Common Mode Voltage



TYPICAL PERFORMANCE CHARACTERISTICS

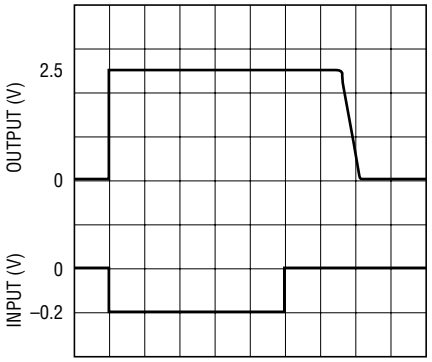
Transient Response



A_V = 1 10µs/DIV
R_L = 100k
C_L = 50pF
V_S = ±2.5V
V_{IN} = 10kHz $2V_{P-P}$

20545 G10

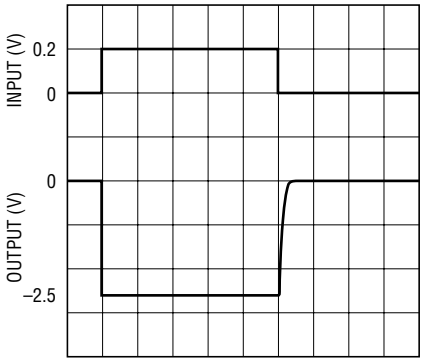
Output Overload Recovery



A_V = –100 2ms/DIV
R_L = 100k
V_S = ±2.5V

20545 G11

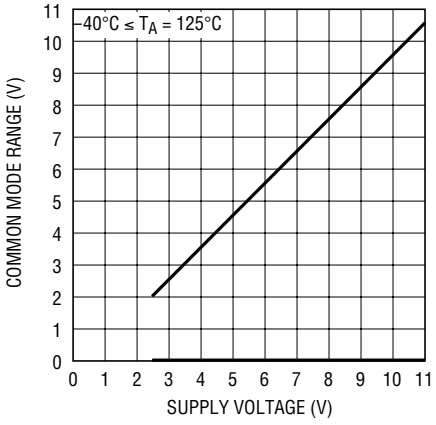
Output Overload Recovery



A_V = –100 2ms/DIV
R_L = 100k
V_S = ±2.5V

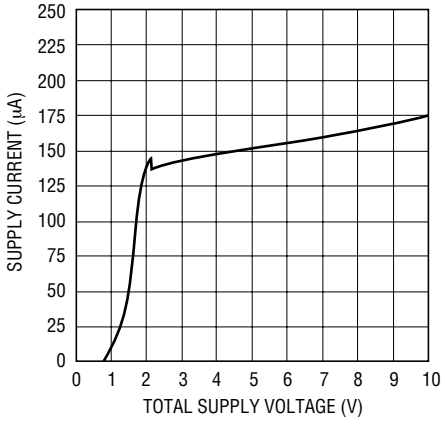
20545 G12

Common Mode Input Range vs Supply Voltage



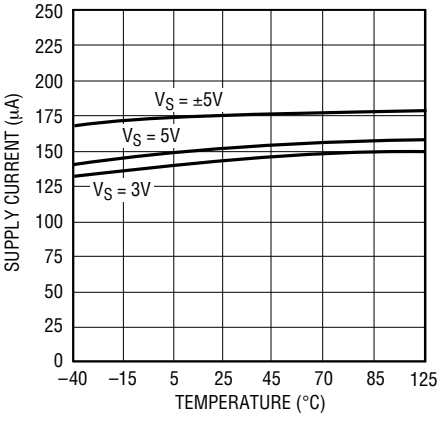
20545 G13

LTC2054 Supply Current vs Supply Voltage



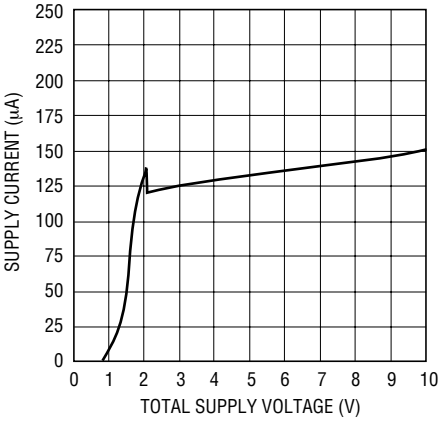
20545 G15

LTC2054 Supply Current vs Temperature



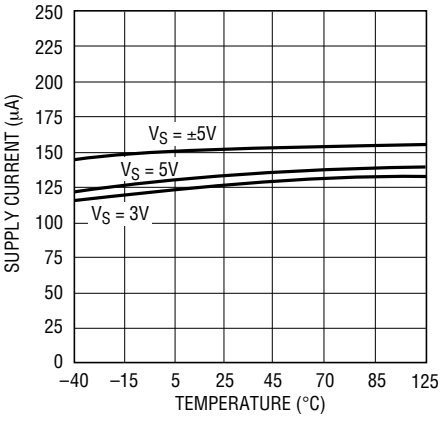
20545 G16

LTC2055 Supply Current (Per Amplifier) vs Supply Voltage



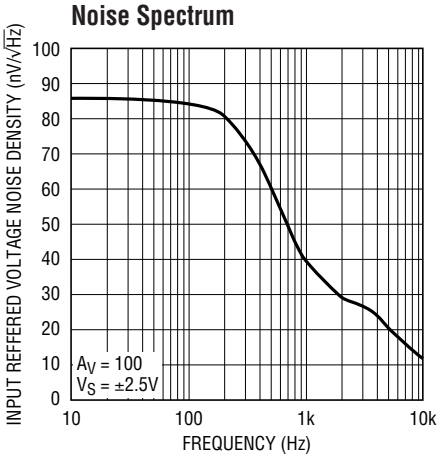
20545 G17

LTC2055 Supply Current (Per Amplifier) vs Temperature



20545 G18

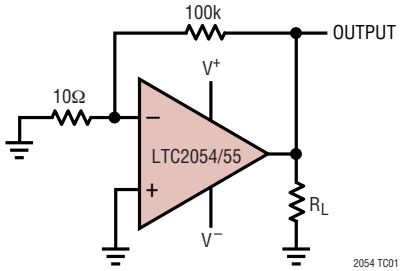
Noise Spectrum



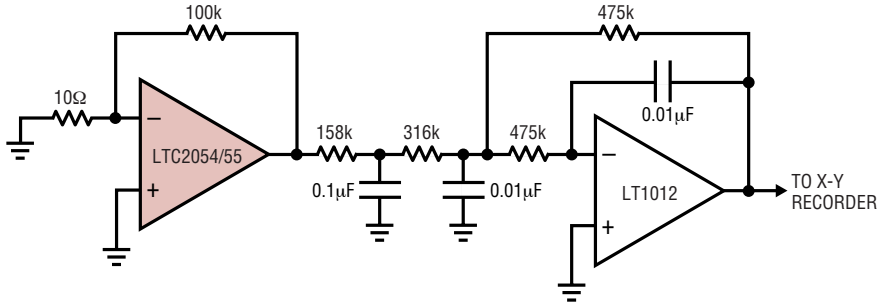
20545 G19

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.

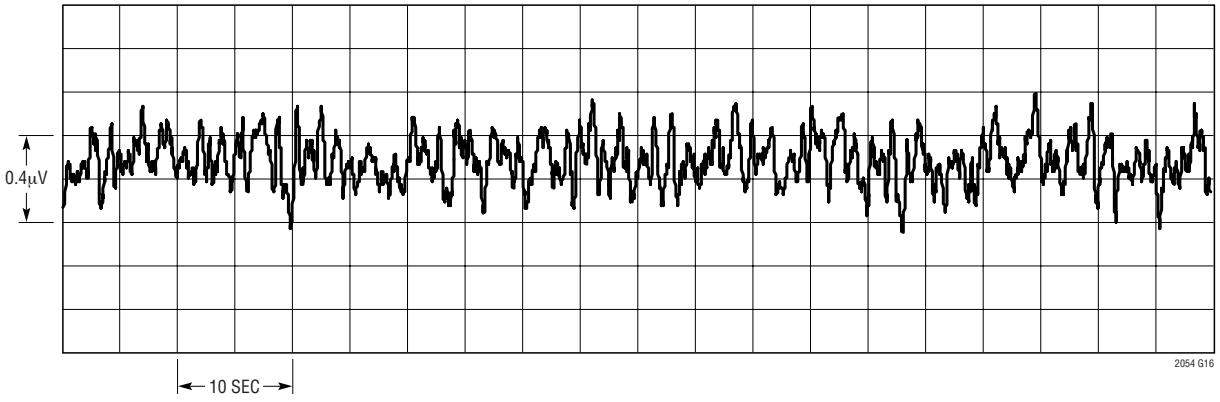
The first form of clock feedthrough is caused by the settling of the internal sampling capacitor and is input referred; that is, it is multiplied by the closed loop gain of the op amp. This form of clock feedthrough is independent of the magnitude of the input source resistance or the magnitude of the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

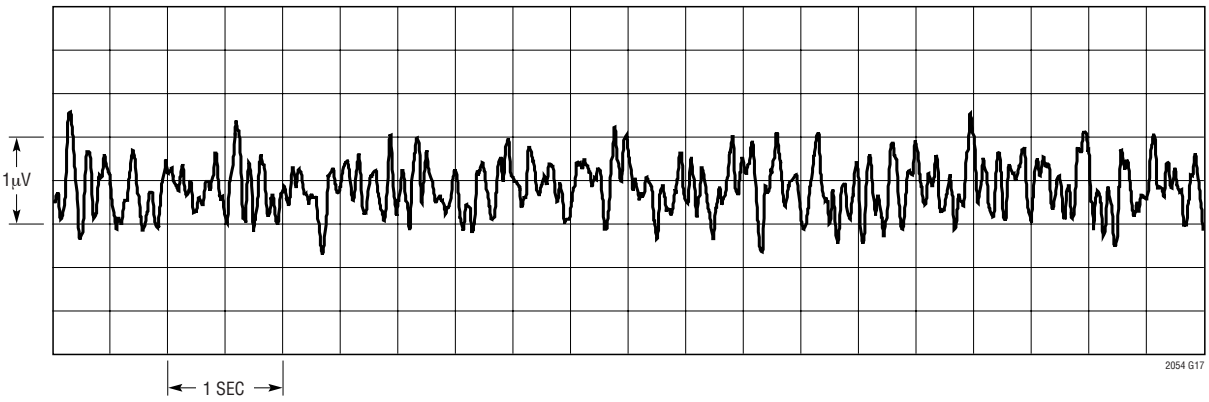
Placing a capacitor across the feedback resistor reduces either form of clock feedthrough by limiting the bandwidth of the closed loop gain.

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

LTC2054/LTC2055 DC to 1Hz Noise



LTC2054/LTC2055 DC to 10Hz Noise



APPLICATIONS INFORMATION

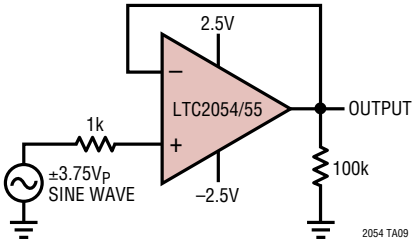
cause the second form of clock feedthrough described above, when averaged, dominate the DC input bias current of the op amp below 70°C.

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).

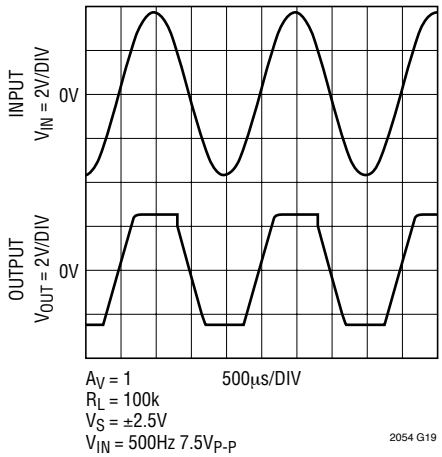
Extended Common Mode Range

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

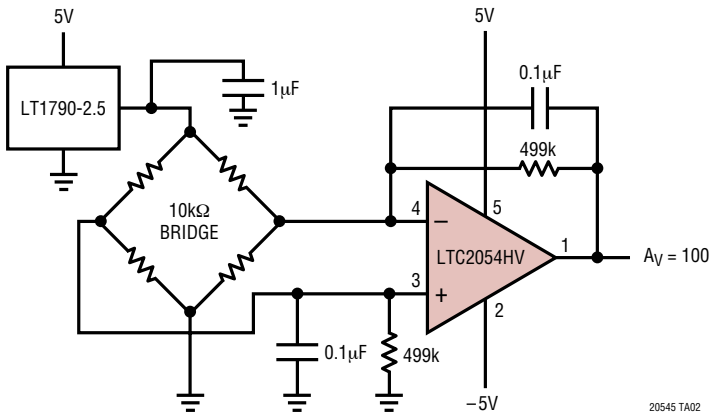


LTC2054/LTC2055 Extended Common Mode Range



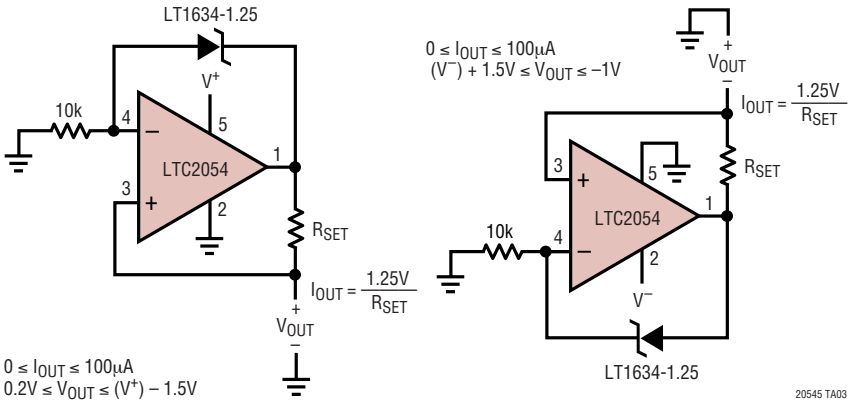
TYPICAL APPLICATIONS

Simple Differential Bridge Amplifier

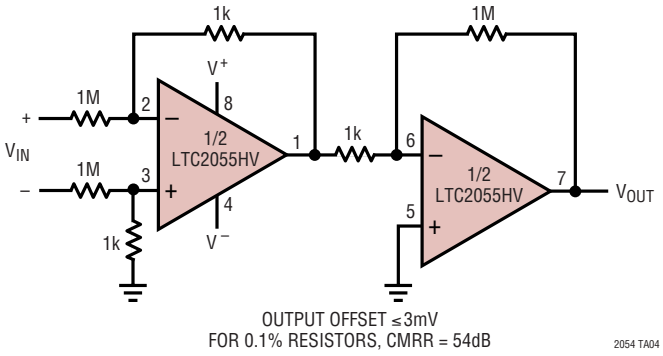


TYPICAL APPLICATIONS

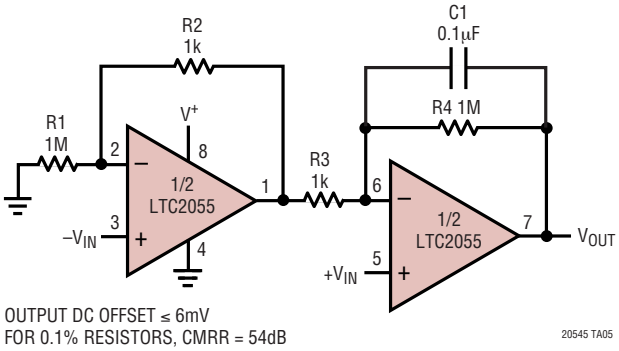
Ground Referred Precision Current Sources



Instrumentation Amplifier with 100V Common Mode Input Voltage

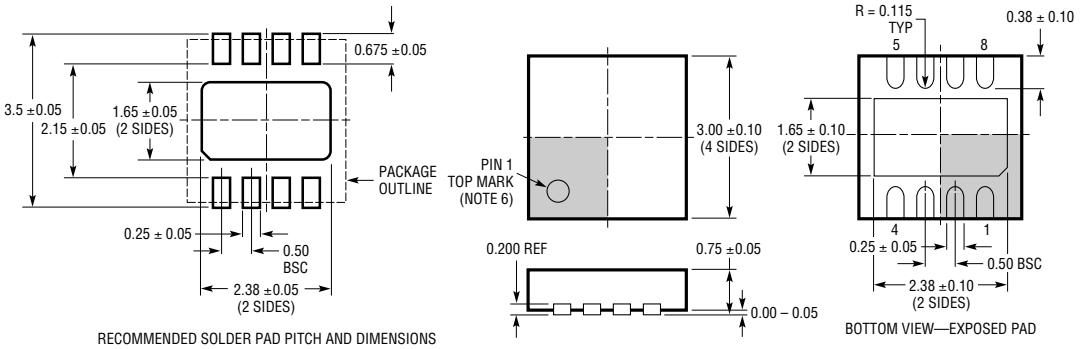


Gain of 1001 Single Supply Instrumentation Amplifier



PACKAGE DESCRIPTION

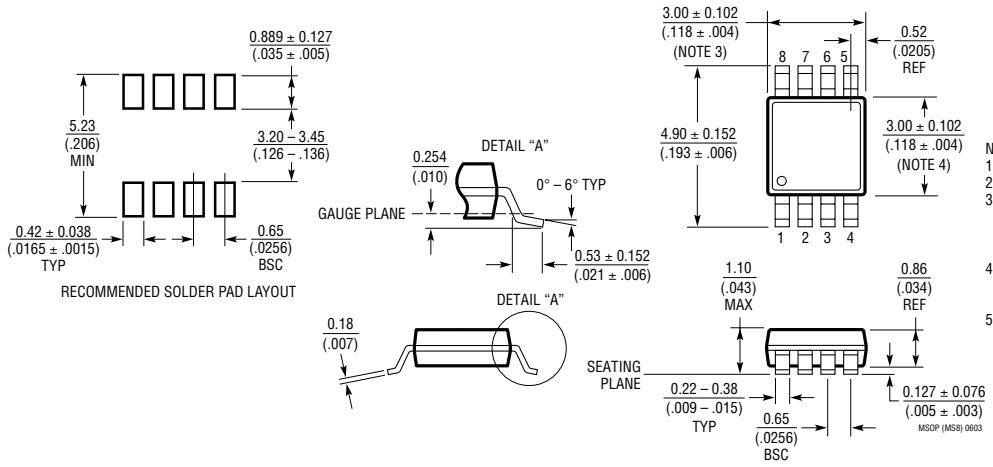
DD Package
8-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698)



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

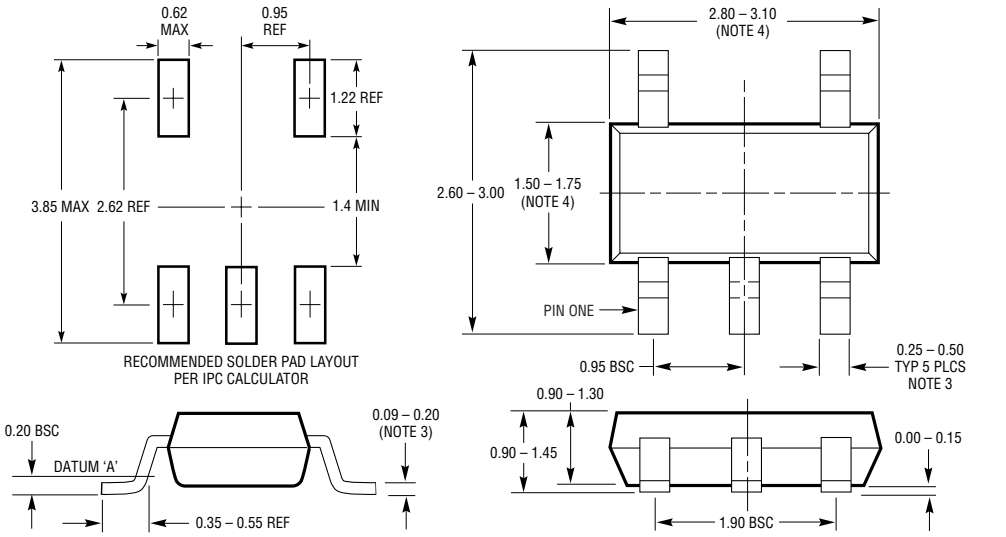
(DD8) DFN 1203

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



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

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. PACKAGE EIAJ REFERENCE IS SC-74A (EIAJ)

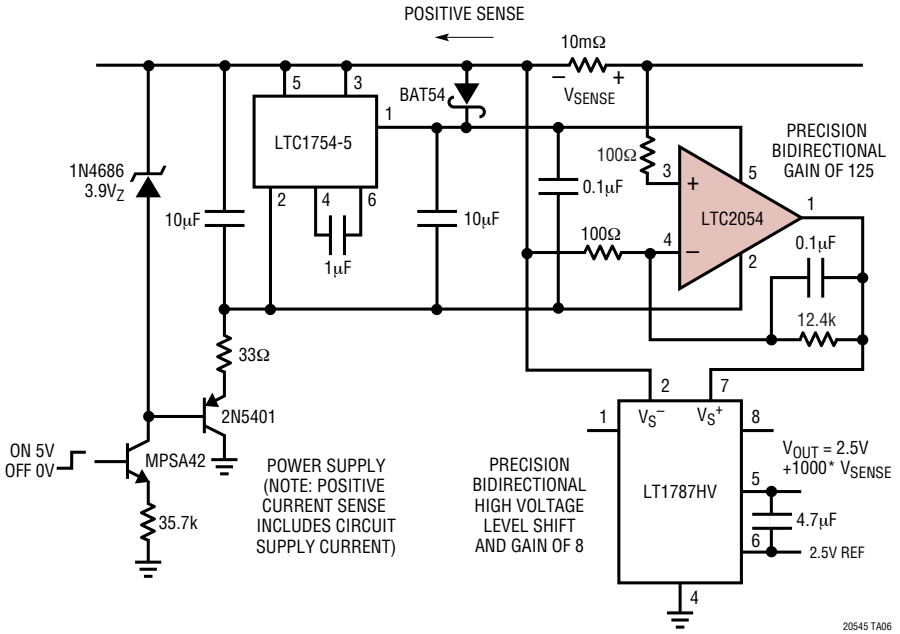
ATTENTION: ORIGINAL SOT23-5L PACKAGE.
MOST SOT23-5L PRODUCTS CONVERTED TO THIN SOT23 PACKAGE, DRAWING # 05-08-1635 AFTER APPROXIMATELY APRIL 2001 SHIP DATE

S5 SOT-23 0502

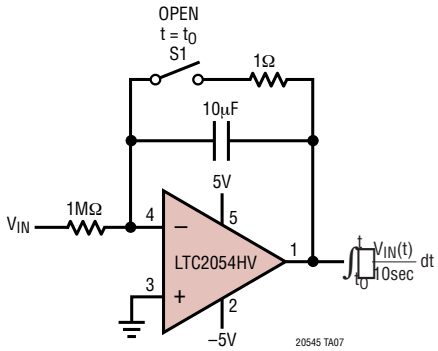
Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATIONS

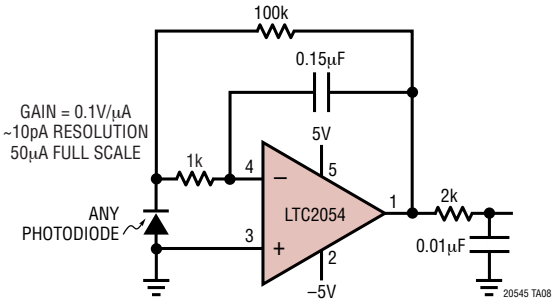
Low Power, Bidirectional 60V Precision Hi Side Current Sense



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 Ouptput Precision Op Amp	V_{OS} = 90µV, V_S = 2.7V to 44V
LT1884/LT1885	Rail-to-Rail Output Precision Op Amp	V_{OS} = 50µV, 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

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

LT/TP 0404 1K REV A • PRINTED IN USA

© LINEAR TECHNOLOGY CORPORATION 2004