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# Dual/Quad Micropower, 1MHz C-Load Picoampere Bias Current JFET Input Op Amps

## FEATURES

- **Input Bias Current:**  
**2pA Max (LT1464A)**  
**20pA Max (LT1464, LT1465)**
- **Supply Current per Amplifier: 200µA Max**
- Gain Bandwidth Product: 1MHz Typ
- Slew Rate: 0.9V/µs Typ
- Input Common Mode Range Includes Positive Rail
- Unity-Gain Stable for C-Load™ Up to 10nF
- Open-Loop Gain: 1 Million Typ
- Guaranteed Specs with ±5V, ±15V Supplies
- Guaranteed Matching Specifications
- Standard Pinout: SO-8, SO-14 Package

## APPLICATIONS

- Battery-Powered Systems
- Photocurrent Amplifiers
- Low Frequency, Micropower Active Filters
- Low Droop Track-and-Hold Circuits

## DESCRIPTION

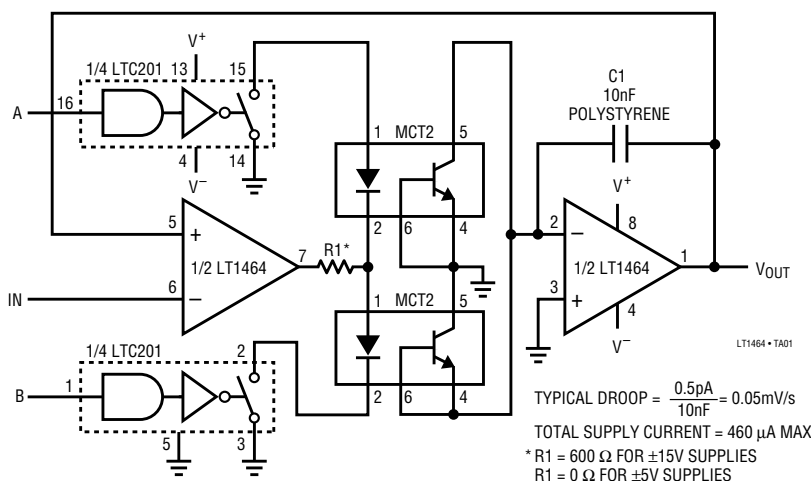
The LT<sup>®</sup>1464 (dual) and LT1465 (quad) are the first micropower op amps (200µA max per amp) to offer picoampere input bias currents (500fA typ) and unity-gain stability for capacitive loads up to 10nF. The output can swing a 10k load to within 1.5V of either supply, just like op amps that require an order of magnitude more supply current. This unique combination of performance makes the LT1464/LT1465 ideal over a wide range of input and output impedances.

In the design and testing of the LT1464/LT1465, particular emphasis has been placed on optimizing performance in the low cost SO-8 (dual) and 14-lead SO (quad) package for ±15V and ±5V supplies. The input common mode range includes the positive rail. Slew rate (0.5V/µs min) and gain bandwidth product (650kHz min) are 100% tested. A full set of matching specifications is also provided.

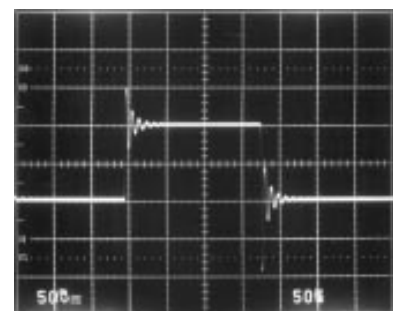
**LT**, LTC and LT are registered trademarks of Linear Technology Corporation.  
 C-Load is a trademark of Linear Technology Corporation.

## TYPICAL APPLICATION

### Micropower Low Droop Track-and-Hold/Peak Detector



### Small-Signal Response, C<sub>LOAD</sub> = 10nF



A<sub>V</sub> = 1  
 V<sub>S</sub> = ±5V, ±15V  
 C<sub>L</sub> = 10nF

1464 • TA02

FUNCTION	MODE	IN A	IN B	MODE	IN A	IN B
Track-and-Hold	Track	0	0	Hold	1	1
Positive Peak Detector	Reset	0	0	Store	0	1
Negative Peak Detector	Reset	0	0	Store	1	0

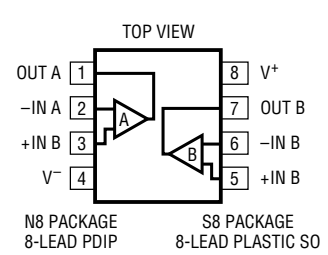
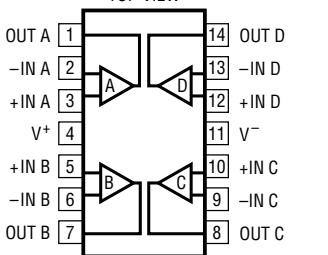
LTC201 switch is open for logic '1'.

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....  $\pm 20V$   
 Differential Input Voltage .....  $\pm 40V$   
 Input Current ..... 20mA  
 Output Short-Circuit Duration ..... Indefinite  
 Operating Temperature Range .....  $-40^{\circ}C$  to  $85^{\circ}C$

Specified Temperature Range .....  $-40^{\circ}C$  to  $85^{\circ}C$   
 Maximum Junction Temperature .....  $150^{\circ}C$   
 Storage Temperature Range .....  $-65^{\circ}C$  to  $150^{\circ}C$   
 Lead Temperature (Soldering, 10 sec) .....  $300^{\circ}C$

## PACKAGE/ORDER INFORMATION

 <p>N8 PACKAGE 8-LEAD PDIP</p> <p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 130^{\circ}C/W</math> (N)  <math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 190^{\circ}C/W</math> (S)</p>	ORDER PART NUMBER	 <p>N PACKAGE 14-LEAD PDIP</p> <p>S PACKAGE 14-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 110^{\circ}C/W</math> (N)  <math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 150^{\circ}C/W</math> (S)</p>	ORDER PART NUMBER
	LT1464ACN8 LT1464ACS8 LT1464CN8 LT1464CS8		LT1465CN LT1465CS
	S8 PART MARKING		
	1464A 1464		

Consult factory for Industrial and Military grade parts.

## ELECTRICAL CHARACTERISTICS $V_S = \pm 15V, V_{CM} = 0V, T_A = 25^{\circ}C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)	LT1464AC			LT1464C/LT1465C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	$V_S = \pm 5V$		0.4	0.8		0.4	0.8	mV
		$V_S = \pm 15V$		0.6	2.0		0.6	2.0	mV
$I_{OS}$	Input Offset Current	$V_S = \pm 5V$		0.2	1.2				pA
		$V_S = \pm 15V$		0.5	2.0		0.5	15	pA
$I_B$	Input Bias Current	$V_S = \pm 5V$		$\pm 0.4$	$\pm 2.0$				pA
		$V_S = \pm 15V$		$\pm 0.5$	$\pm 3.0$		$\pm 0.5$	$\pm 20$	pA
$e_n$	Input Noise Voltage	0.1Hz to 10Hz		2			2		$\mu V_{P-P}$
		Input Noise Voltage Density	$f_0 = 10Hz$		33		33		$nV/\sqrt{Hz}$
			$f_0 = 1000Hz$		24		24		$nV/\sqrt{Hz}$
	Input Noise Current Density	$f_0 = 10Hz, 1kHz$ (Note 3)		0.4		0.4		$fA/\sqrt{Hz}$	
CMRR	Common Mode Rejection Ratio	$V_{CM} = -12.5V$ to $15V$	76	85		74	85		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2.5V$ to $\pm 20V$	81	90		78	90		dB
$R_{IN}$	Input Resistance—Differential Common Mode Common Mode	$V_{CM} = -12.5V$ to $8V$		$10^{12}$			$10^{12}$		$\Omega$
		$V_{CM} = 8V$ to $15V$		$10^{12}$			$10^{12}$		$\Omega$
				$0^{11}$			$10^{11}$		$\Omega$
$C_{IN}$	Input Capacitance			3		3		pF	
$A_{VOL}$	Large-Signal Voltage Gain	$V_0 = \pm 10V, R_L = 10k$	350	1000		300	900		V/mV
		$V_0 = \pm 10V, R_L = 2k$	150	450		150	450		V/mV
		$V_S = \pm 5V, V_0 = \pm 2V, R_L = 10k$	100	250		100	250		V/mV
		$V_S = \pm 5V, V_0 = \pm 1V, R_L = 2k$	50	170		50	170		V/mV

**ELECTRICAL CHARACTERISTICS**  $V_S = \pm 15V$ ,  $V_{CM} = 0V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)	LT1464AC			LT1464C/LT1465C			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{OUT}$	Output Voltage Swing	$R_L = 10k$	$\pm 13.5$	$\pm 13.7$		$\pm 13.5$	$\pm 13.7$		V	
		$R_L = 2k$	$\pm 13.3$	$\pm 13.5$		$\pm 13.3$	$\pm 13.5$		V	
		$V_S = \pm 5V$ , $R_L = 2k$	$\pm 3.5$	$\pm 3.7$		$\pm 3.5$	$\pm 3.7$		V	
SR	Slew Rate	$R_L = 10k$ (Note 4)	0.5	0.9		0.5	0.9		V/ $\mu s$	
GBW	Gain Bandwidth Product	$f = 10kHz$	650	1000		650	1000		kHz	
$I_S$	Supply Current per Amplifier	$V_S = \pm 5V$		145	200		145	200		$\mu A$
					135	200		135	200	
	Channel Separation	$f = 10Hz$ , $V_0 = \pm 10V$ , $R_L = 10k$		132			132		dB	
$V_{OS}$	Offset Voltage Match (Note 7)	$V_S = \pm 5V$ $V_S = \pm 15V$		0.5	1.3		0.5	1.3		mV
					0.8	3.3		0.8	3.3	
$\Delta I_B^+$	Noninverting Bias Current Match (Note 7)	$V_S = \pm 5V$ $V_S = \pm 15V$		0.4	3.0					$\mu A$
					0.5	4.0		0.5	30	
$\Delta CMRR$	Common Mode Rejection Match	(Notes 5, 7)	74	85		71	85		dB	
$\Delta PSRR$	Power Supply Rejection Match	(Notes 5, 7)	78	88		74	88		dB	

$V_S = \pm 15V$ ,  $V_{CM} = 0V$ ,  $0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)	LT1464AC			LT1464C/LT1465C			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{OS}$	Input Offset Voltage	$V_S = \pm 5V$ $V_S = \pm 15V$	●	0.5	1.4		0.5	1.4		mV
			●	0.9	2.8		0.9	2.8		mV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Input Offset Voltage Drift	(Note 6)	●	7	20		7	20		$\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●	10	50		25	450		$\mu A$
$I_B$	Input Bias Current		●	60	150		150	750		$\mu A$
CMRR	Common Mode Rejection Ratio	$V_{CM} = -12V$ to $15V$	●	75	85		73	85		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 20V$	●	80	89		77	89		dB
$A_{VOL}$	Large-Signal Voltage Gain	$V_0 = \pm 10V$ , $R_L = 10k$ $V_0 = \pm 10V$ , $R_L = 2k$	●	200	600		200	600		V/mV
			●	100	350		100	350		V/mV
		$V_S = \pm 5V$ , $V_0 = \pm 2V$ , $R_L = 10k$ $V_S = \pm 5V$ , $V_0 = \pm 1V$ , $R_L = 2k$	●	80	200		80	200		V/mV
			●	45	150		45	150		V/mV
$V_{OUT}$	Output Voltage Swing	$R_L = 10k$ $R_L = 2k$ $V_S = \pm 5V$ , $R_L = 2k$	●	$\pm 13.4$	$\pm 13.6$		$\pm 13.4$	$\pm 13.6$		V
			●	$\pm 13.2$	$\pm 13.4$		$\pm 13.2$	$\pm 13.4$		V
			●	$\pm 3.4$	$\pm 3.6$		$\pm 3.4$	$\pm 3.6$		V
SR	Slew Rate	$R_L = 10k$ (Note 4)	●	0.4	0.8		0.4	0.8		V/ $\mu s$
GBW	Gain Bandwidth Product	$f = 10kHz$	●	540	870		540	870		kHz
$I_S$	Supply Current per Amplifier	$V_S = \pm 5V$	●	160	220		160	220		$\mu A$
			●	150	220		150	220		$\mu A$
$V_{OS}$	Offset Voltage Match (Note 7)	$V_S = \pm 5V$ $V_S = \pm 15V$	●	0.7	2.0		0.7	2.0		mV
			●	0.9	3.5		0.9	3.5		mV
$\Delta I_B^+$	Noninverting Bias Current Match (Note 7)		●	5	40		35	500		$\mu A$

## ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$ , $V_{CM} = 0V$ , $0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1464AC			LT1464C/LT1465C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$\Delta CMRR$	Common Mode Rejection Match	(Notes 5, 7)	●	73	84		70	84	dB	
$\Delta PSRR$	Power Supply Rejection Match	(Notes 5, 7)	●	77	85		73	85	dB	

$V_S = \pm 15V$ ,  $V_{CM} = 0V$ ,  $-40^\circ C \leq T_A \leq 85^\circ C$  (Note 2), unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1464AC			LT1464C/LT1465C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	$V_S = \pm 5V$ $V_S = \pm 15V$	●	0.6	1.5		0.6	1.5	mV	
			●	1.0	3.0		1.0	3.0	mV	
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Input Offset Voltage Drift	(Note 6)	●	7	20		7	20	$\mu V/^\circ C$	
$I_{OS}$	Input Offset Current		●	40	150		60	700	pA	
$I_B$	Input Bias Current		●	200	500		300	2500	pA	
CMRR	Common Mode Rejection Ratio	$V_{CM} = -12V$ to $15V$	●	74	84		72	84	dB	
PSRR	Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 20V$	●	79	88		76	88	dB	
$A_{VOL}$	Large-Signal Voltage Gain	$V_O = \pm 10V$ , $R_L = 10k$ $V_O = \pm 10V$ , $R_L = 2k$	●	175	400		175	400	V/mV	
			●	80	250		80	250	V/mV	
			●	70	180		70	180	V/mV	
			●	45	140		45	140	V/mV	
$V_{OUT}$	Output Voltage Swing	$R_L = 10k$ $R_L = 2k$ $V_S = \pm 5V$ , $R_L = 2k$	●	$\pm 13.2$	$\pm 13.4$		$\pm 13.2$	$\pm 13.4$	V	
			●	$\pm 13.0$	$\pm 13.2$		$\pm 13.0$	$\pm 13.2$	V	
			●	$\pm 3.2$	$\pm 3.4$		$\pm 3.2$	$\pm 3.4$	V	
SR	Slew Rate	$R_L = 10k$ (Note 4)	●	0.35	0.7		0.35	0.7	V/ $\mu s$	
GBW	Gain Bandwidth Product	$f = 10kHz$	●	510	850		510	850	kHz	
$I_S$	Supply Current per Amplifier	$V_S = \pm 5V$	●	165	230		165	230	$\mu A$	
			●	160	230		160	230	$\mu A$	
$V_{OS}$	Offset Voltage Match (Note 7)	$V_S = \pm 5V$ $V_S = \pm 15V$	●	0.8	2.5		0.8	2.5	mV	
			●	1.0	4.0		1.0	4.0	mV	
$\Delta I_B^+$	Noninverting Bias Current Match (Note 7)		●	20	100		70	800	pA	
$\Delta CMRR$	Common Mode Rejection Match	(Notes 5, 7)	●	72	83		69	83	dB	
$\Delta PSRR$	Power Supply Rejection Match	(Notes 5, 7)	●	76	81		73	81	dB	

The ● denotes specifications which apply over the full operating temperature range.

**Note 1:** Typical parameters are defined as 60% yield of parameter distributions of individual amplifiers, i.e., out of 100 LT1465s (or 100 LT1464s) typically 240 op amps (or 120) will be better than the indicated specification.

**Note 2:** The LT1464 and LT1465 are designed, characterized and expected to meet these extended temperature limits, but are not tested at  $-40^\circ C$  and  $85^\circ C$ . Guaranteed I grade parts are available, consult factory.

**Note 3:** Current noise is calculated from the formula:  $i_n = (2q_i_b)^{1/2}$  where  $q = (1.6)(10)^{-19}$  coulomb. The noise of source resistors up to  $1G\Omega$  swamps the contribution of current noise.

**Note 4:** Slew rate is measured in  $A_V = -1$ ; input signal is  $\pm 7.5V$ , output is measured at  $\pm 2.5V$ .

**Note 5:**  $\Delta CMRR$  and  $\Delta PSRR$  are defined as follows:

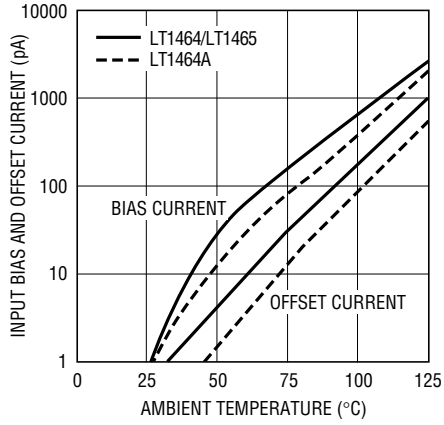
1. CMRR and PSRR are measured in  $\mu V/V$  on the individual amplifiers.
2. The difference is calculated between the matching sides in  $\mu V/V$ .
3. The result is converted to dB.

**Note 6:** This parameter is not 100% tested.

**Note 7:** Matching parameters are the difference between amplifiers A and D and between B and C on the LT1465; between the two amplifiers on the LT1464.

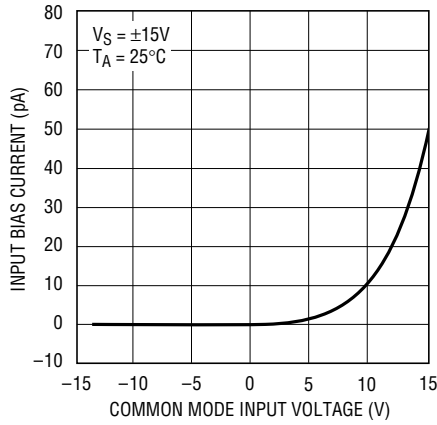
# TYPICAL PERFORMANCE CHARACTERISTICS

**Input Bias and Offset Current vs Temperature**



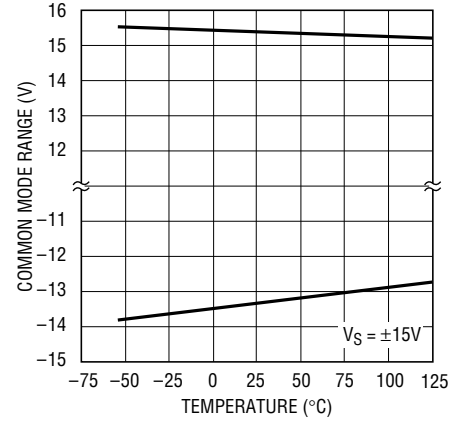
LT1464 • TPC01

**Input Bias Current Over the Common Mode Range**



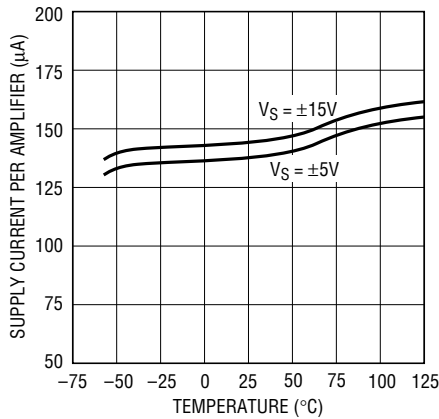
LT1464 • TPC02

**Common Mode Range vs Temperature**



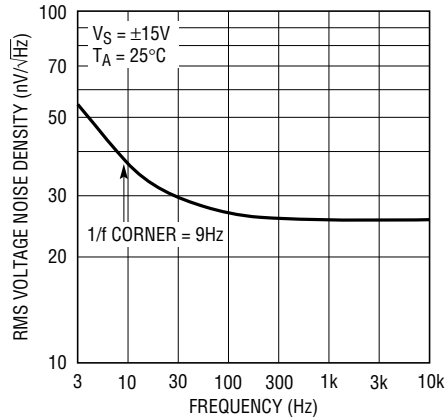
LT1464 • TPC03

**Supply Current vs Temperature**



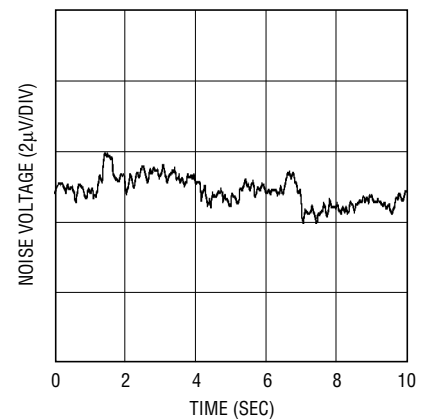
LT1464 • TPC04

**Voltage Noise vs Frequency**



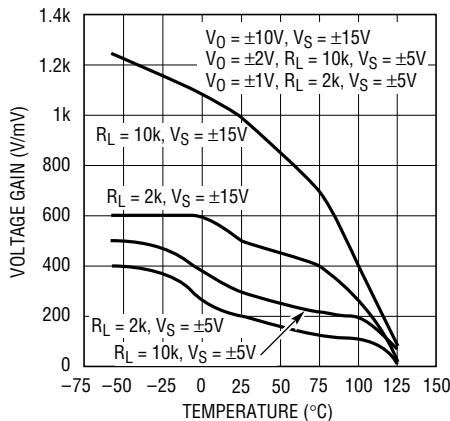
LT1464 • TPC05

**0.1Hz to 10Hz Noise**



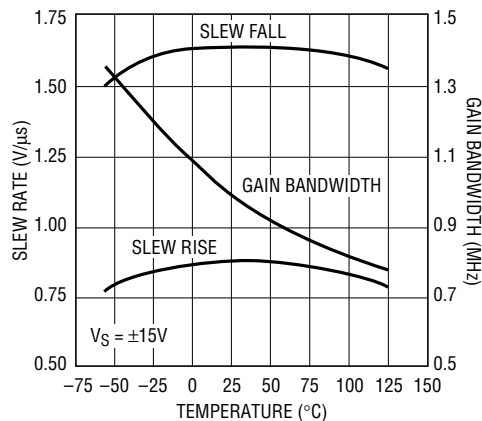
LT1464 • TPC06

**Voltage Gain vs Temperature**



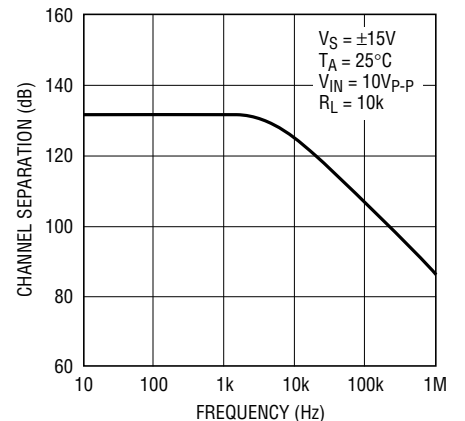
LT1464 • TPC07

**Slew Rate, Gain Bandwidth Product vs Temperature**



LT1464 • TPC08

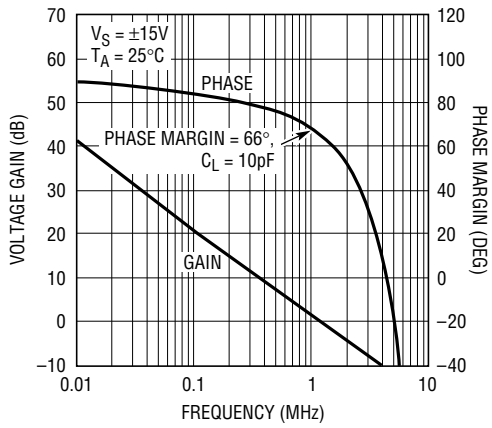
**Channel Separation vs Frequency**



LT1464 • TPC09

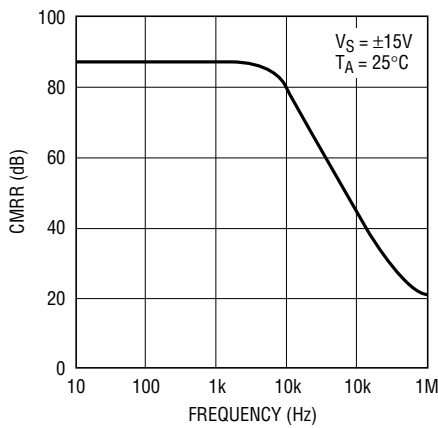
# TYPICAL PERFORMANCE CHARACTERISTICS

**Gain and Phase vs Frequency**



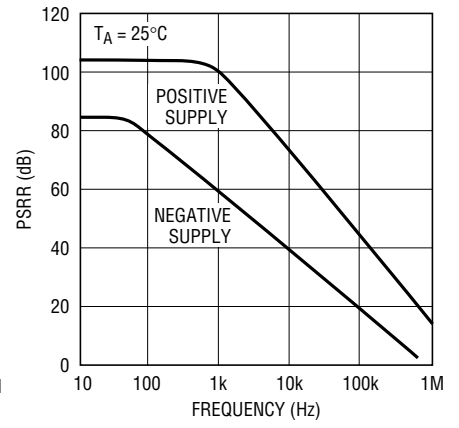
LT1464 • TPC10

**Common Mode Rejection Ratio vs Frequency**



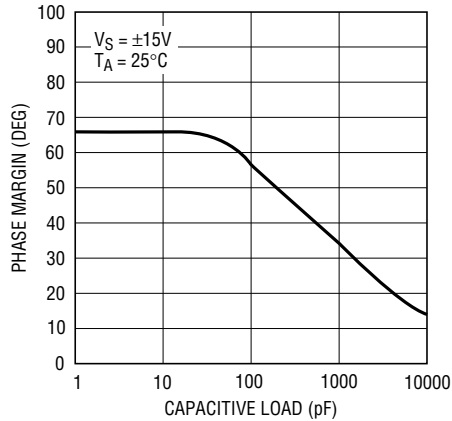
LT1464 • TPC11

**Power Supply Rejection Ratio vs Frequency**



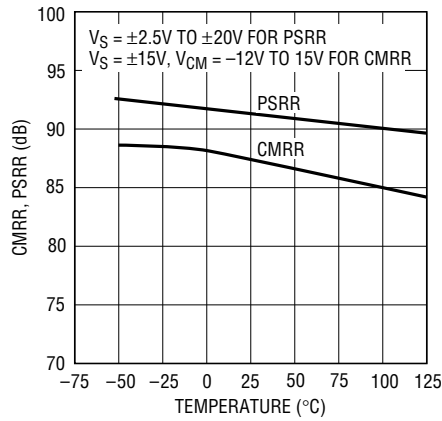
LT1464 • TPC12

**Phase Margin vs  $C_{LOAD}$**



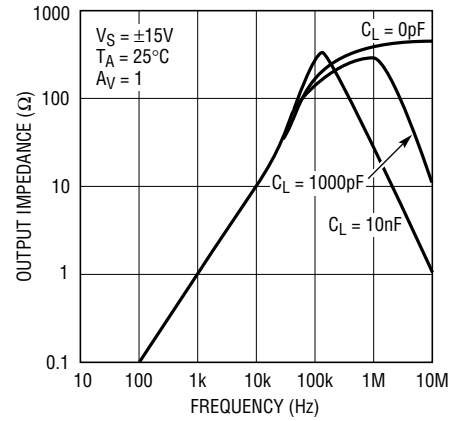
LT1464 • TPC13

**Common Mode and Power Supply Rejections vs Temperature**



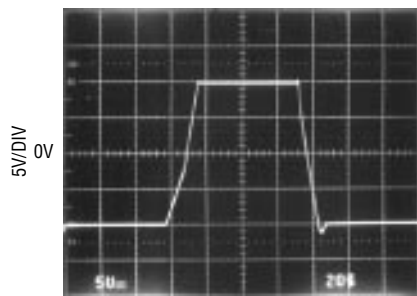
LT1464 • TPC14

**Closed-Loop Output Impedance**



LT1464 • TPC15

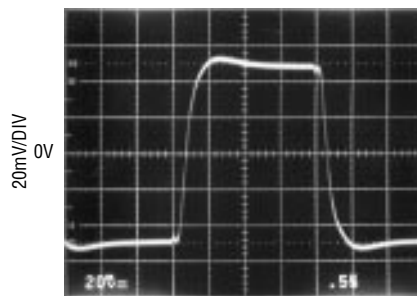
**Large-Signal Response,  $V_S = \pm 15V$**



$A_V = 1$  20μs/DIV  
 $C_L = 10pF$

LT1464 • TPC16

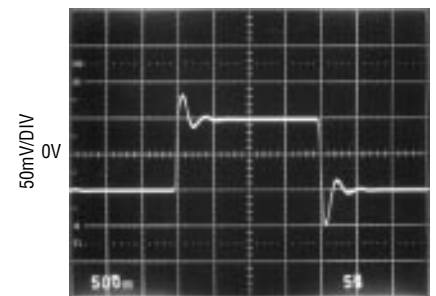
**Small-Signal Response,  $V_S = \pm 5V, \pm 15V$**



$A_V = 1$  0.5μs/DIV  
 $C_L = 10pF$

LT1464 • TPC17

**Small-Signal Response,  $V_S = \pm 5V, \pm 15V, C_{LOAD} = 1000pF$**



$A_V = 1$  5μs/DIV  
 $C_L = 1000pF$

LT1464 • TPC18

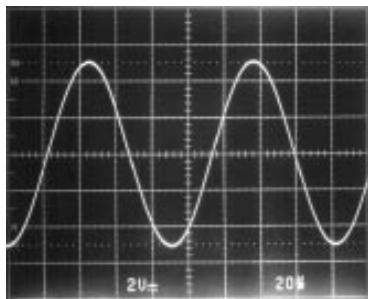
## APPLICATIONS INFORMATION

### Phase Reversal Protection

Most industry standard JFET input single, dual and quad op amps exhibit phase reversal at the output when the negative common mode limit at the input is exceeded. Common mode range is at a premium at  $\pm 5V$  supplies. The Figures show a  $\pm 5.2V$  sine wave input (Figure 1a), the response of a competing JFET input op amp in the unity-

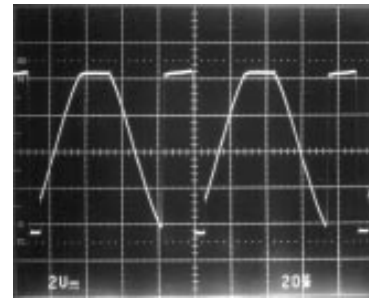
gain follower mode (Figure 1b) and the response of the LT1464/LT1465 (Figure 1c).

The phase reversal of Figure 1b can cause lock-up in servo systems. The LT1464/LT1465 does not phase-reverse when the common mode input is anywhere within the supplies.



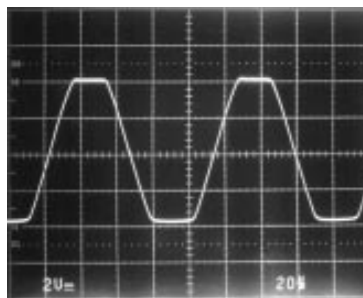
(1a)  $\pm 5.2V$  Sine Wave

LT1464 • F01a



(1b) Typical JFET Input Op Amp with  $\pm 5V$  Supplies

LT1464 • F01b



(1c) LT1464/LT1465 Output with  $\pm 5V$  Supplies

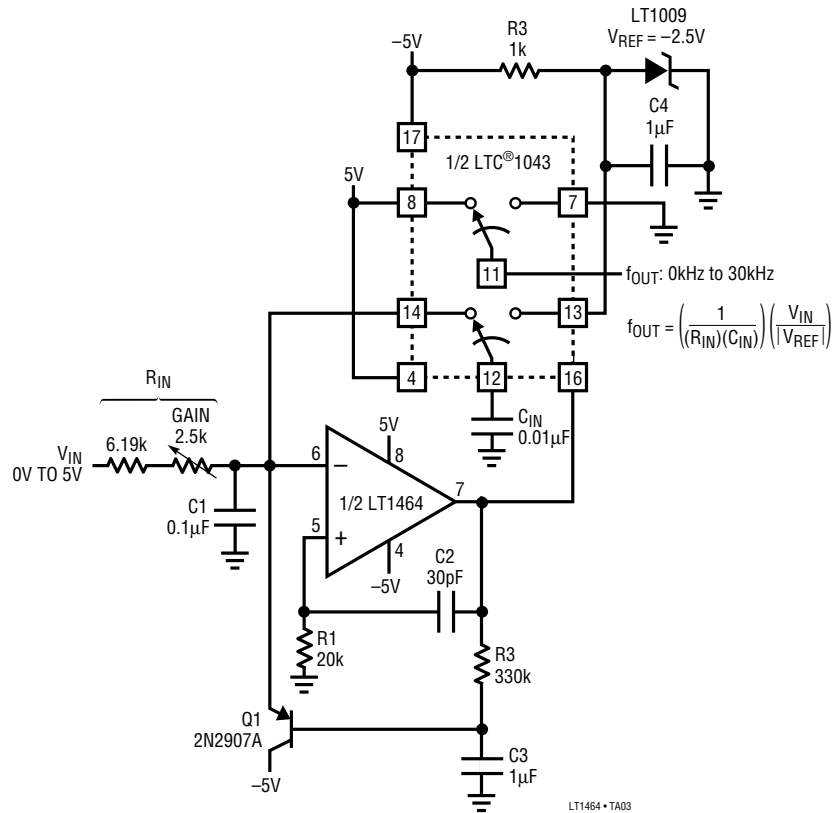
LT1464 • F01c

Figure 1. Voltage Follower with Input Exceeding the Common Mode Range ( $V_S = \pm 5V$ )

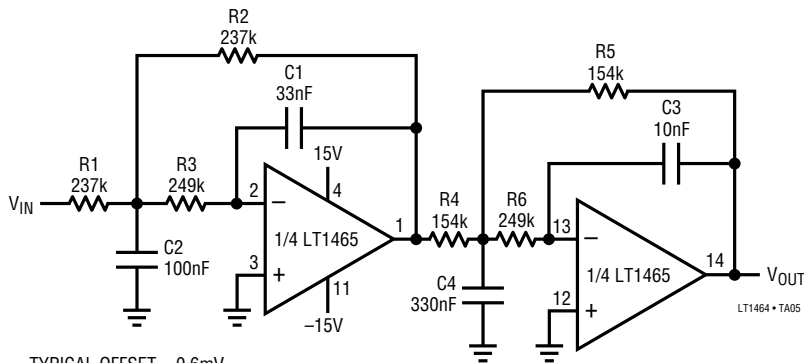


TYPICAL APPLICATIONS

Low Voltage 0.016% Voltage to Frequency Converter

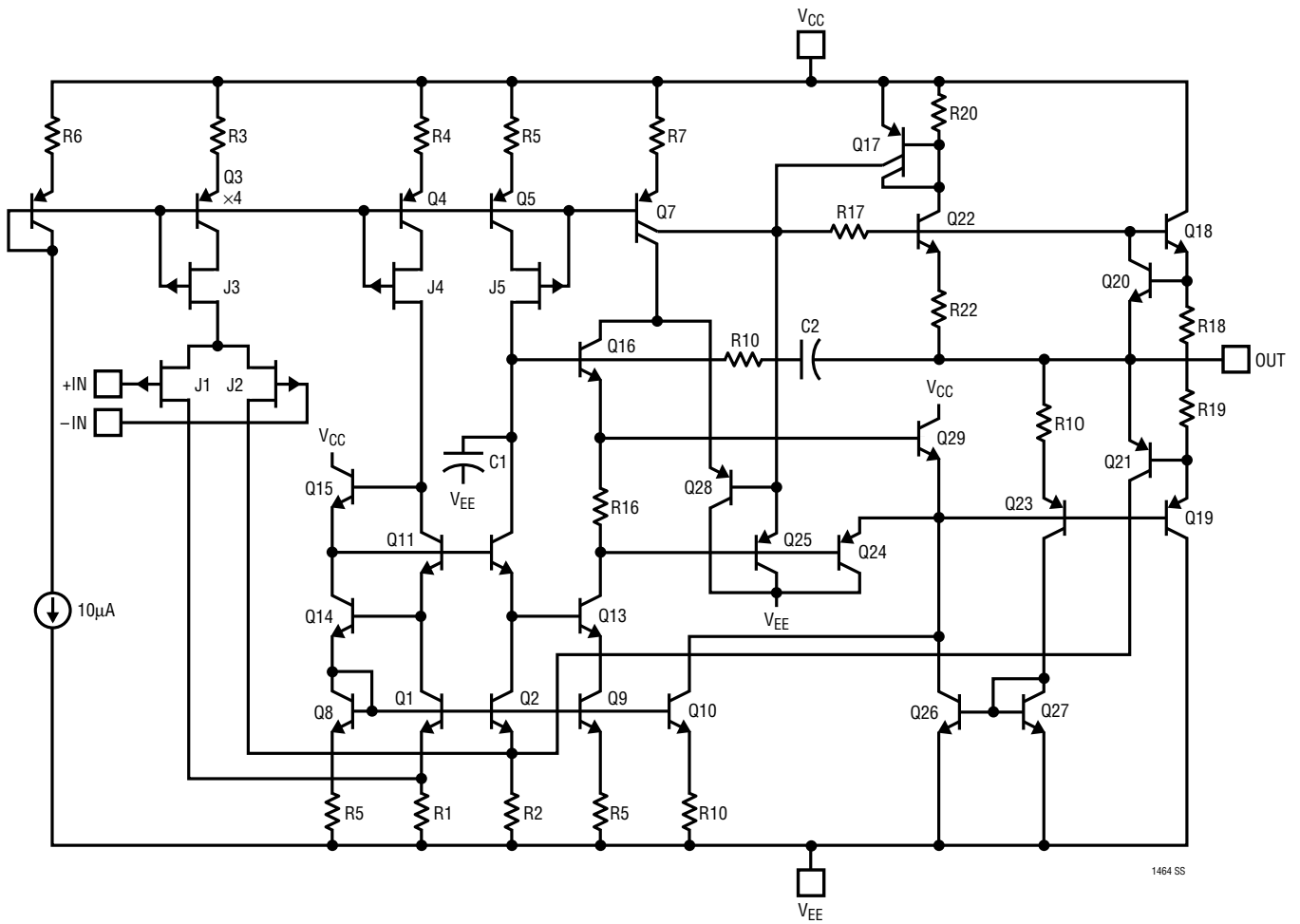


10Hz 4th Order Chebyshev Lowpass Filter (0.01dB Ripple)



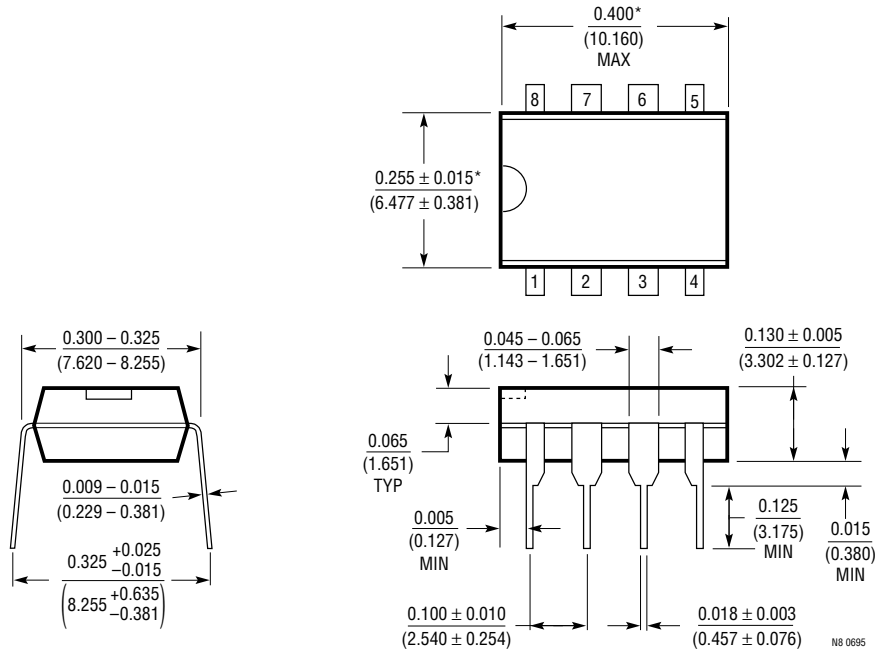
TYPICAL OFFSET = 0.6mV  
 1% TOLERANCES  
 FOR  $V_{IN} = 10V_{P-P}$ ,  $V_{OUT} = -110\text{dB}$  AT  $f > 300\text{Hz}$   
 $V_{OUT} = -6\text{dB}$  AT  $f = 16\text{Hz}$   
 THE LOW INPUT BIAS CURRENTS ALLOW THE USE OF HIGH RESISTOR VALUES

**SIMPLIFIED SCHEMATIC**



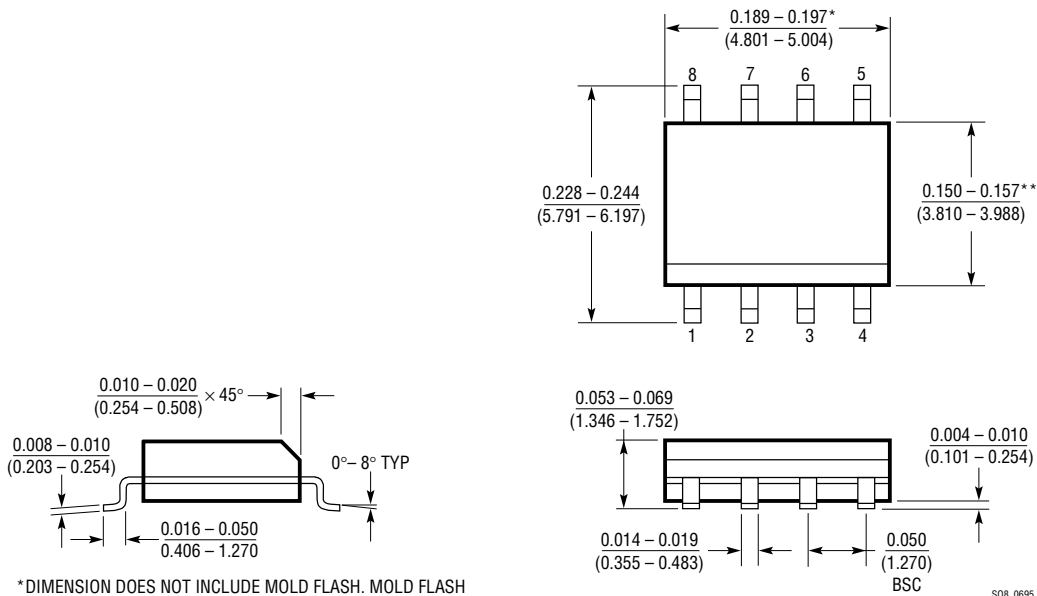
**PACKAGE DESCRIPTION** Dimensions in inches (millimeters) unless otherwise noted.

**N8 Package**  
**8-Lead PDIP (Narrow 0.300)**  
 (LTC DWG # 05-08-1510)



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

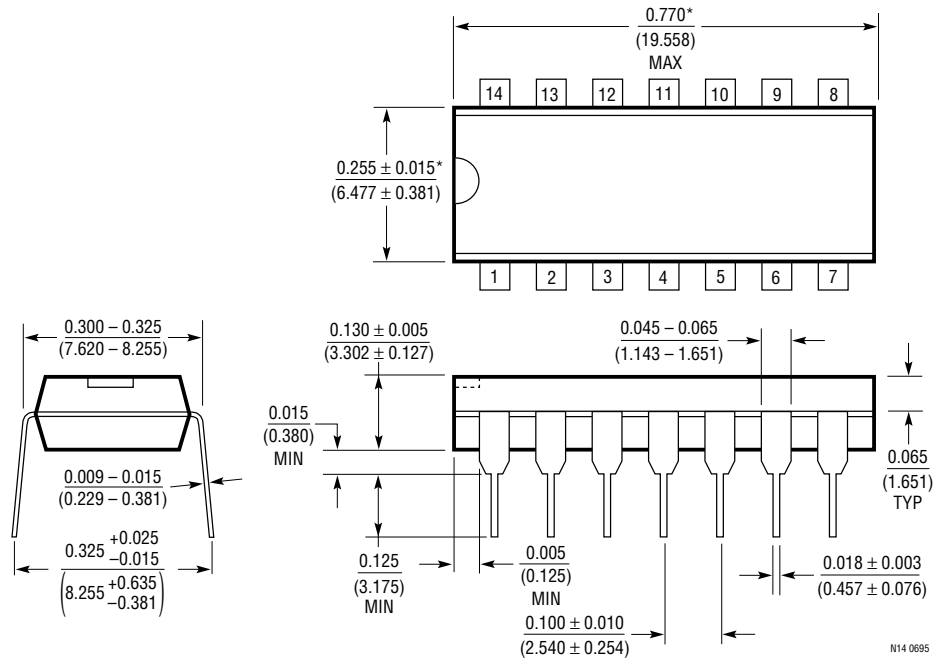
**S8 Package**  
**8-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)



\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE  
 \*\*DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

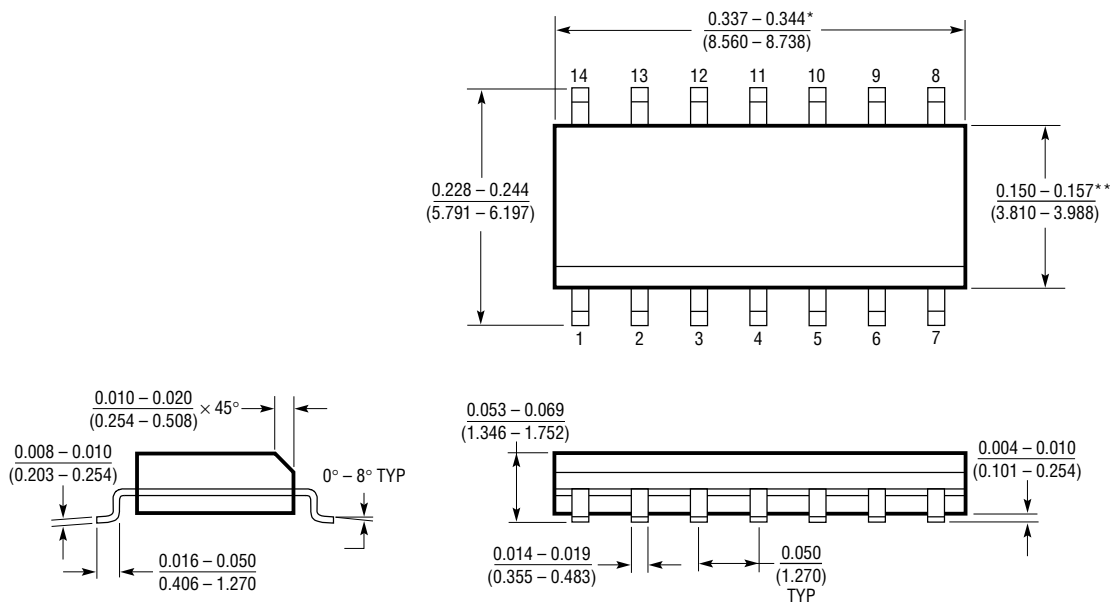
**PACKAGE DESCRIPTION** Dimensions in inches (millimeters) unless otherwise noted.

**N Package**  
**14-Lead PDIP (Narrow 0.300)**  
 (LTC DWG # 05-08-1510)



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

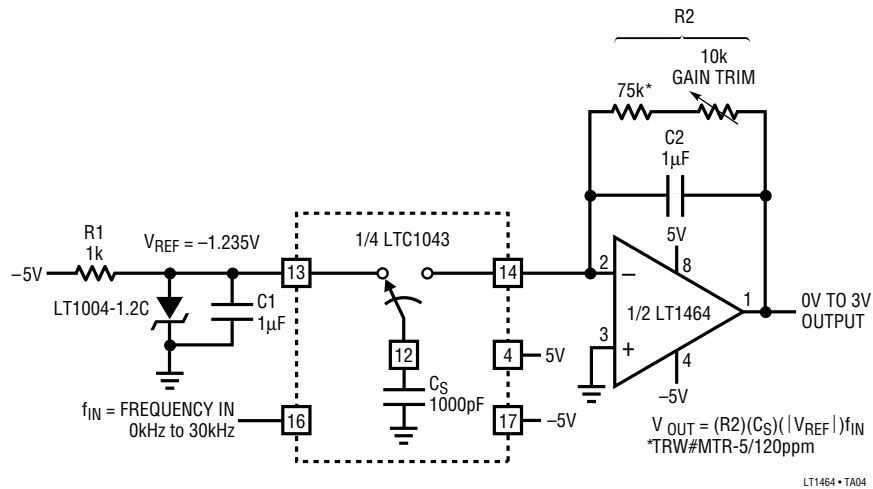
**S Package**  
**14-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)



\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE  
 \*\*DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

## TYPICAL APPLICATION

### Low Voltage 0.027% Frequency to Voltage Converter



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1057	Dual JFET Input Precision, High Speed Op Amp	Fast Settling Time, 14V/μs Slew Rate, 5MHz GBW, 450μV $V_{OS}$ (Max), 50pA $I_{OS}$ (Max)
LT1113	Dual Low Noise, Precision, JFET Input Op Amp	6nV/√Hz Input Noise Voltage Density, 480pA $I_B$ , 6.3MHz GBW
LT1169	Dual Low Noise, Picoampere Bias Current, JFET Input Op Amp	20pA $I_B$ , 8nV/√Hz $e_n$ , 5.3MHz GBW, 1.5pF Input Capacitance
LT1457	Dual Precision JFET Input Op Amp C-Load	Drives 10,000pF Capacitive Load, 450μV $V_{OS}$ (Max), 4μV/°C Drift
LT1462/LT1463	Dual/Quad Micropower, C-Load Picoampere Bias Current JFET Input Op Amps	28μA Supply Current Per Amplifiers Drives 10μF Capacitive Load, 175kHz GBW