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®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.

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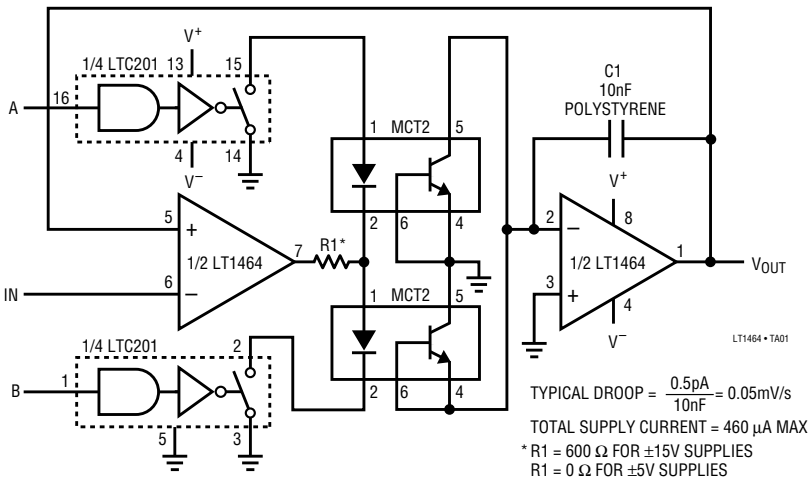
C-Load is a trademark of Linear Technology Corporation.

TYPICAL APPLICATION

Micropower Low Droop Track-and-Hold/Peak Detector



$$\text{TYPICAL DROOP} = \frac{0.5\text{pA}}{10\text{nF}} = 0.05\text{mV/s}$$

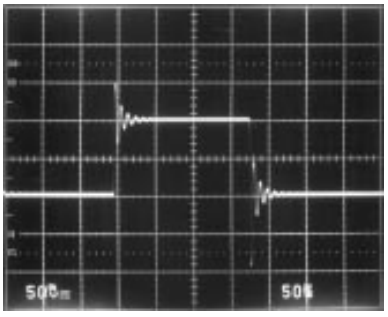
TOTAL SUPPLY CURRENT = 460 μA MAX

* R1 = 600 Ω FOR ±15V SUPPLIES
R1 = 0 Ω FOR ±5V SUPPLIES

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".

Small-Signal Response, C_{LOAD} = 10nF

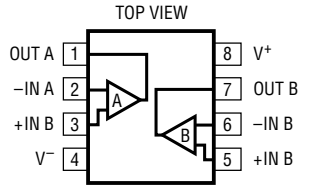


A_V = 1
V_S = ±5V, ±15V
C_L = 10nF

ABSOLUTE MAXIMUM RATINGS

Supply Voltage ..... ±20V
Differential Input Voltage ..... ±40V
Input Current 20mA
Output Short-Circuit Duration ..... Indefinite
Operating Temperature Range ..... –40°C to 85°C
Specified Temperature Range ..... –40°C to 85°C
Maximum Junction Temperature ..... 150°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

PACKAGE/ORDER INFORMATION



N8 PACKAGE 8-LEAD PDIP
S8 PACKAGE 8-LEAD PLASTIC SO

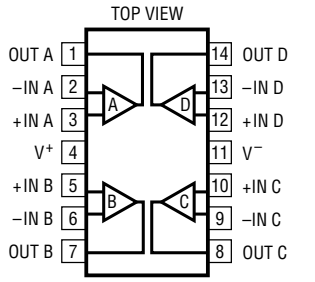
T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S)

ORDER PART NUMBER

LT1464ACN8
LT1464ACS8
LT1464CN8
LT1464CS8

S8 PART MARKING

1464A
1464



N PACKAGE 14-LEAD PDIP
S PACKAGE 14-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 110°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 150°C/W (S)

ORDER PART NUMBER

LT1465CN
LT1465CS

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

V_S = ±15V, V_{CM} = 0V, T_A = 25°C, unless otherwise noted.

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

ELECTRICAL CHARACTERISTICS

$V_S = \pm 15V$, $V_{CM} = 0V$, $T_A = 25°C$, unless otherwise noted.

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

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

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1464AC MIN	LT1464AC TYP	LT1464AC MAX	LT1464C/LT1465C MIN	LT1464C/LT1465C TYP	LT1464C/LT1465C MAX	UNITS
V_{OS}	Input Offset Voltage	$V_S = \pm 5V$	●		0.5	1.4		0.5	1.4	mV
		$V_S = \pm 15V$	●		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	µV/°C
I_{OS}	Input Offset Current		●		10	50		25	450	pA
I_B	Input Bias Current		●		60	150		150	750	pA
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	$V_O = \pm 10V$, $R_L = 10k$	●	200	600		200	600		V/mV
		$V_O = \pm 10V$, $R_L = 2k$	●	100	350		100	350		V/mV
		$V_S = \pm 5V$, $V_O = \pm 2V$, $R_L = 10k$	●	80	200		80	200		V/mV
		$V_S = \pm 5V$, $V_O = \pm 1V$, $R_L = 2k$	●	45	150		45	150		V/mV
V_{OUT}	Output Voltage Swing	$R_L = 10k$	●	±13.4	±13.6		±13.4	±13.6		V
		$R_L = 2k$	●	±13.2	±13.4		±13.2	±13.4		V
		$V_S = \pm 5V$, $R_L = 2k$	●	±3.4	±3.6		±3.4	±3.6		V
SR	Slew Rate	$R_L = 10k$ (Note 4)	●	0.4	0.8		0.4	0.8		V/µs
GBW	Gain Bandwidth Product	f = 10kHz	●	540	870		540	870		kHz
I_S	Supply Current per Amplifier		●		160	220		160	220	µA
		$V_S = \pm 5V$	●		150	220		150	220	µA
V_{OS}	Offset Voltage Match (Note 7)	$V_S = \pm 5V$	●		0.7	2.0		0.7	2.0	mV
		$V_S = \pm 15V$	●		0.9	3.5		0.9	3.5	mV
ΔI_B^+	Noninverting Bias Current Match (Note 7)		●		5	40		35	500	pA

ELECTRICAL CHARACTERISTICS

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

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

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

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1464AC MIN	LT1464AC TYP	LT1464AC MAX	LT1464C/LT1465C MIN	LT1464C/LT1465C TYP	LT1464C/LT1465C MAX	UNITS
V_{OS}	Input Offset Voltage	$V_S = \pm 5V$ $V_S = \pm 15V$	● ●		0.6 1.0	1.5 3.0		0.6 1.0	1.5 3.0	mV mV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Input Offset Voltage Drift	(Note 6)	●		7	20		7	20	μV/°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 80	400 250		175 80	400 250		V/mV V/mV
		$V_S = \pm 5V$, $V_O = \pm 2V$, $R_L = 10k$ $V_S = \pm 5V$, $V_O = \pm 1V$, $R_L = 2k$	● ●	70 45	180 140		70 45	180 140		V/mV V/mV
V_{OUT}	Output Voltage Swing	$R_L = 10k$ $R_L = 2k$ $V_S = \pm 5V$, $R_L = 2k$	● ● ●	±13.2 ±13.0 ±3.2	±13.4 ±13.2 ±3.4		±13.2 ±13.0 ±3.2	±13.4 ±13.2 ±3.4		V V V
SR	Slew Rate	$R_L = 10k$ (Note 4)	●	0.35	0.7		0.35	0.7		V/μs
GBW	Gain Bandwidth Product	f = 10kHz	●	510	850		510	850		kHz
I_S	Supply Current per Amplifier	 $V_S = \pm 5V$	● ●		165 160	230 230		165 160	230 230	μA μA
V_{OS}	Offset Voltage Match (Note 7)	$V_S = \pm 5V$ $V_S = \pm 15V$	● ●		0.8 1.0	2.5 4.0		0.8 1.0	2.5 4.0	mV mV
ΔI_B^+	Noninverting Bias Current Match (Note 7)		●		20	100		70	800	pA
ΔCMRR	Common Mode Rejection Match	(Notes 5, 7)	●	72	83		69	83		dB
ΔPSRR	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°C and 85°C. Guaranteed I grade parts are available, consult factory.

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

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

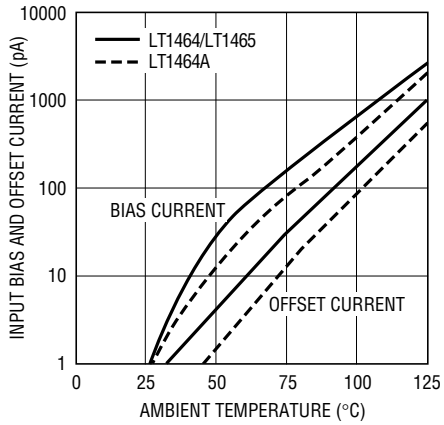
Note 5: ΔCMRR and ΔPSRR are defined as follows:
1. CMRR and PSRR are measured in μV/V on the individual amplifiers.
2. The difference is calculated between the matching sides in μV/V.
3. The result is converted to dB.

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.

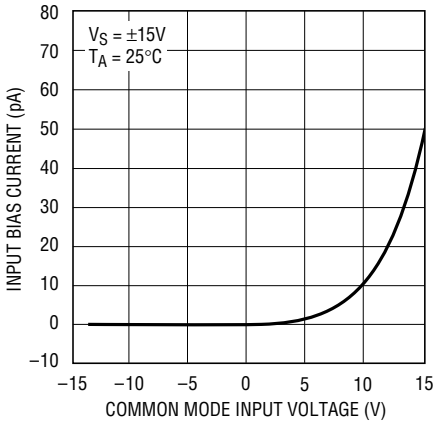
TYPICAL PERFORMANCE CHARACTERISTICS

Input Bias and Offset Current vs Temperature



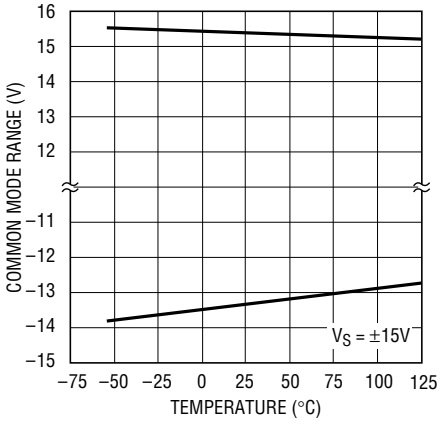
LT1464 • TPC01

Input Bias Current Over the Common Mode Range



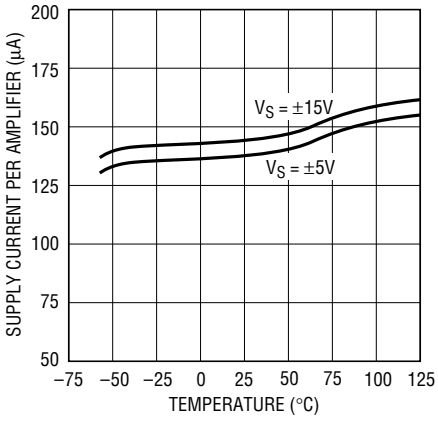
LT1464 • TPC02

Common Mode Range vs Temperature



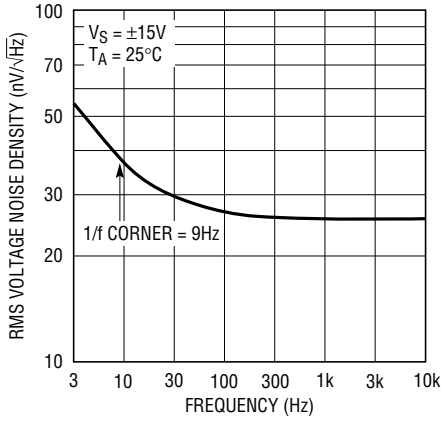
LT1464 • TPC03

Supply Current vs Temperature



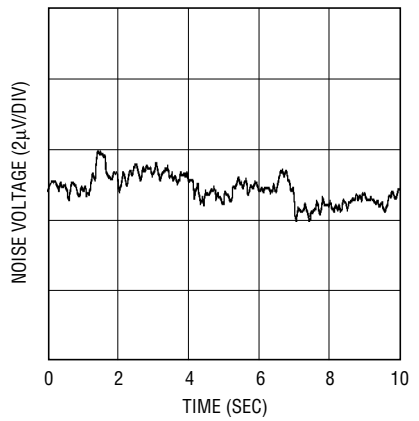
LT1464 • TPC04

Voltage Noise vs Frequency



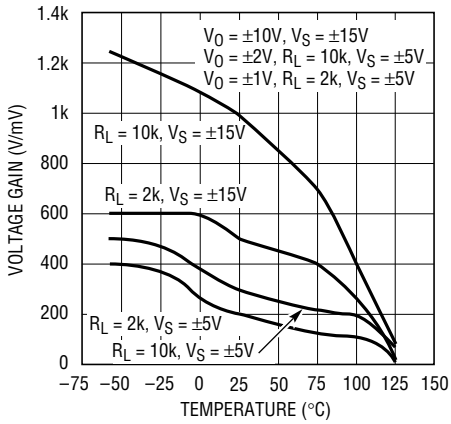
LT1464 • TPC05

0.1Hz to 10Hz Noise



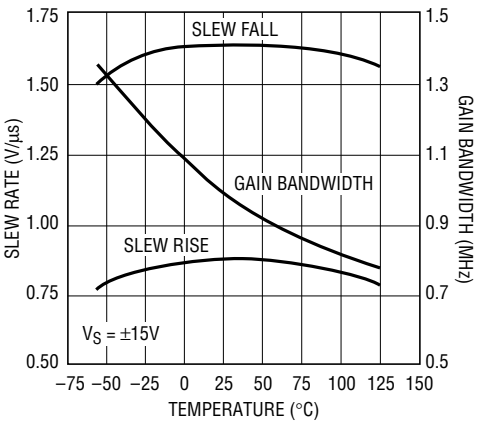
LT1464 • TPC06

Voltage Gain vs Temperature



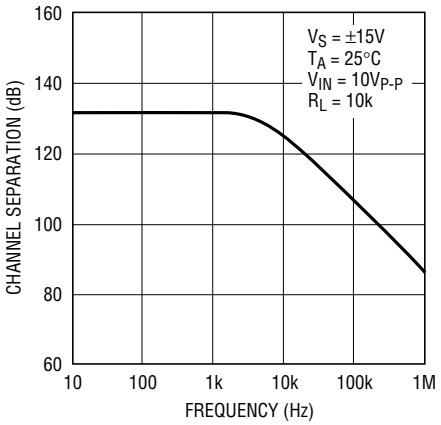
LT1464 • TPC07

Slew Rate, Gain Bandwidth Product vs Temperature



LT1464 • TPC08

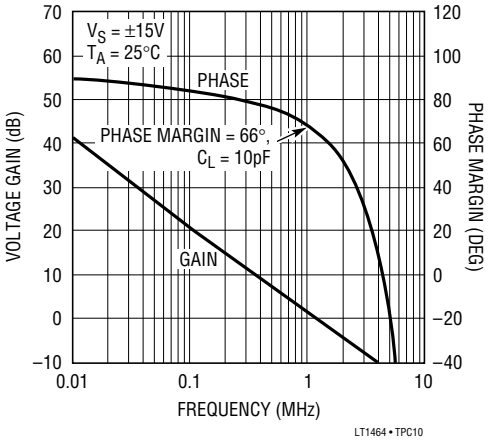
Channel Separation vs Frequency



LT1464 • TPC09

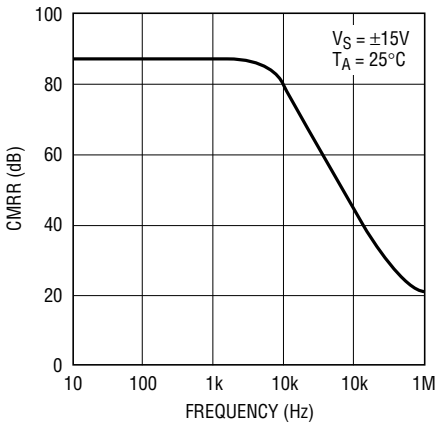
TYPICAL PERFORMANCE CHARACTERISTICS

Gain and Phase vs Frequency



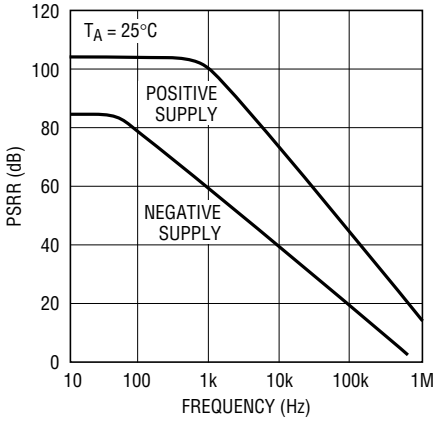
LT1464 • TPC10

Common Mode Rejection Ratio vs Frequency



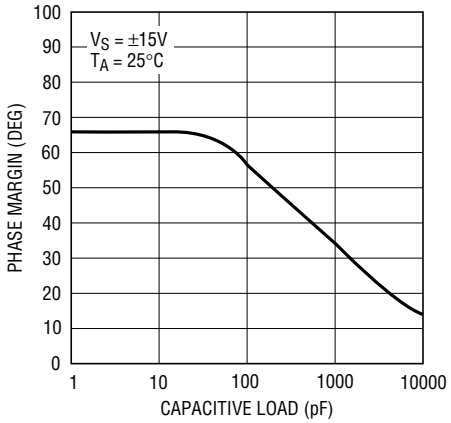
LT1464 • TPC11

Power Supply Rejection Ratio vs Frequency



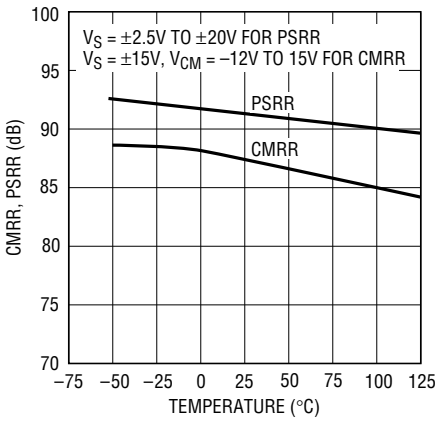
LT1464 • TPC12

Phase Margin vs C_{LOAD}



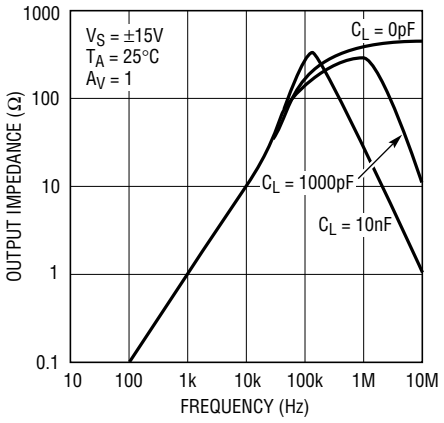
LT1464 • TPC13

Common Mode and Power Supply Rejections vs Temperature



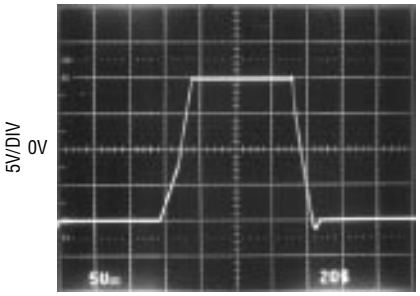
LT1464 • TPC14

Closed-Loop Output Impedance



LT1464 • TPC15

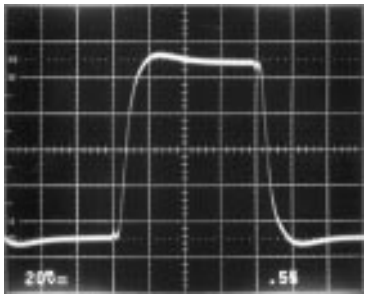
Large-Signal Response, V_S = ±15V



A_V = 1 20µs/DIV
C_L = 10pF

LT1464 • TPC16

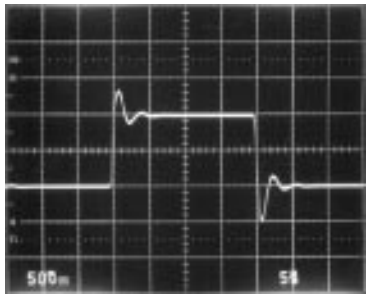
Small-Signal Response, V_S = ±5V, ±15V



A_V = 1 0.5µs/DIV
C_L = 10pF

LT1464 • TPC17

Small-Signal Response, V_S = ±5V, ±15V, C_{LOAD} = 1000pF



A_V = 1 5µs/DIV
C_L = 1000pF

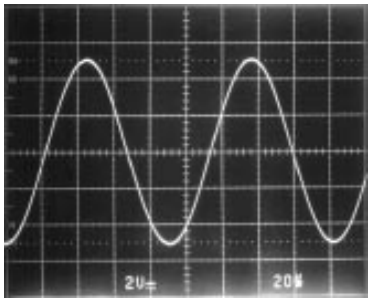
LT1464 • TPC18

APPLICATIONS INFORMATION

Phase Reversal Protection

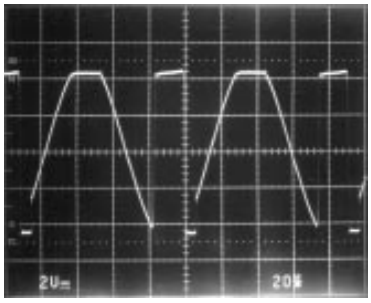
Most industry standard JFET input single, dual and quad op amps exhibit phase reversal at the output when the negative common mode limit at the input is exceeded. Common mode range is at a premium at ±5V supplies. The Figures show a ±5.2V sine wave input (Figure 1a), the response of a competing JFET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



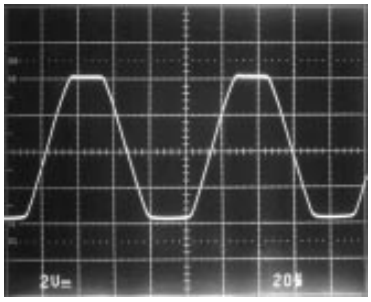
LT1464 • F01a

(1a) ±5.2V Sine Wave



LT1464 • F01b

(1b) Typical JFET Input Op Amp with ±5V Supplies



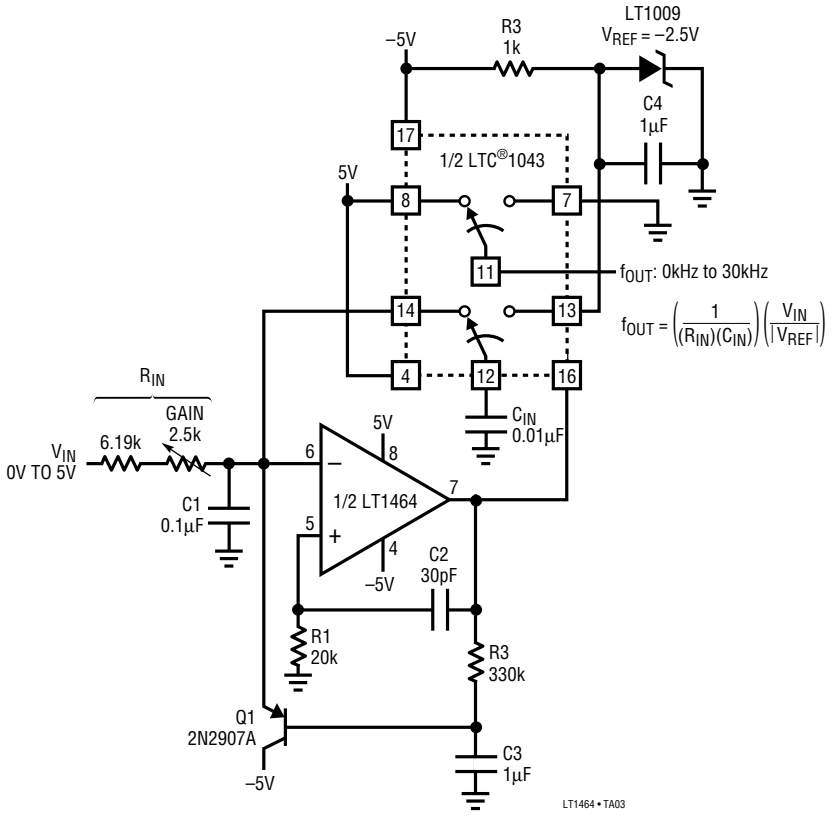
LT1464 • F01c

(1c) LT1464/LT1465 Output with ±5V Supplies

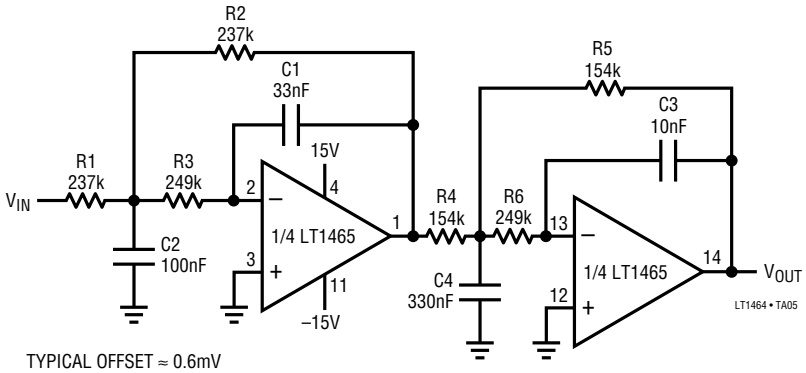
Figure 1. Voltage Follower with Input Exceeding the Common Mode Range (V_S = ±5V)

TYPICAL APPLICATIONS

Low Voltage 0.016% Voltage to Frequency Converter

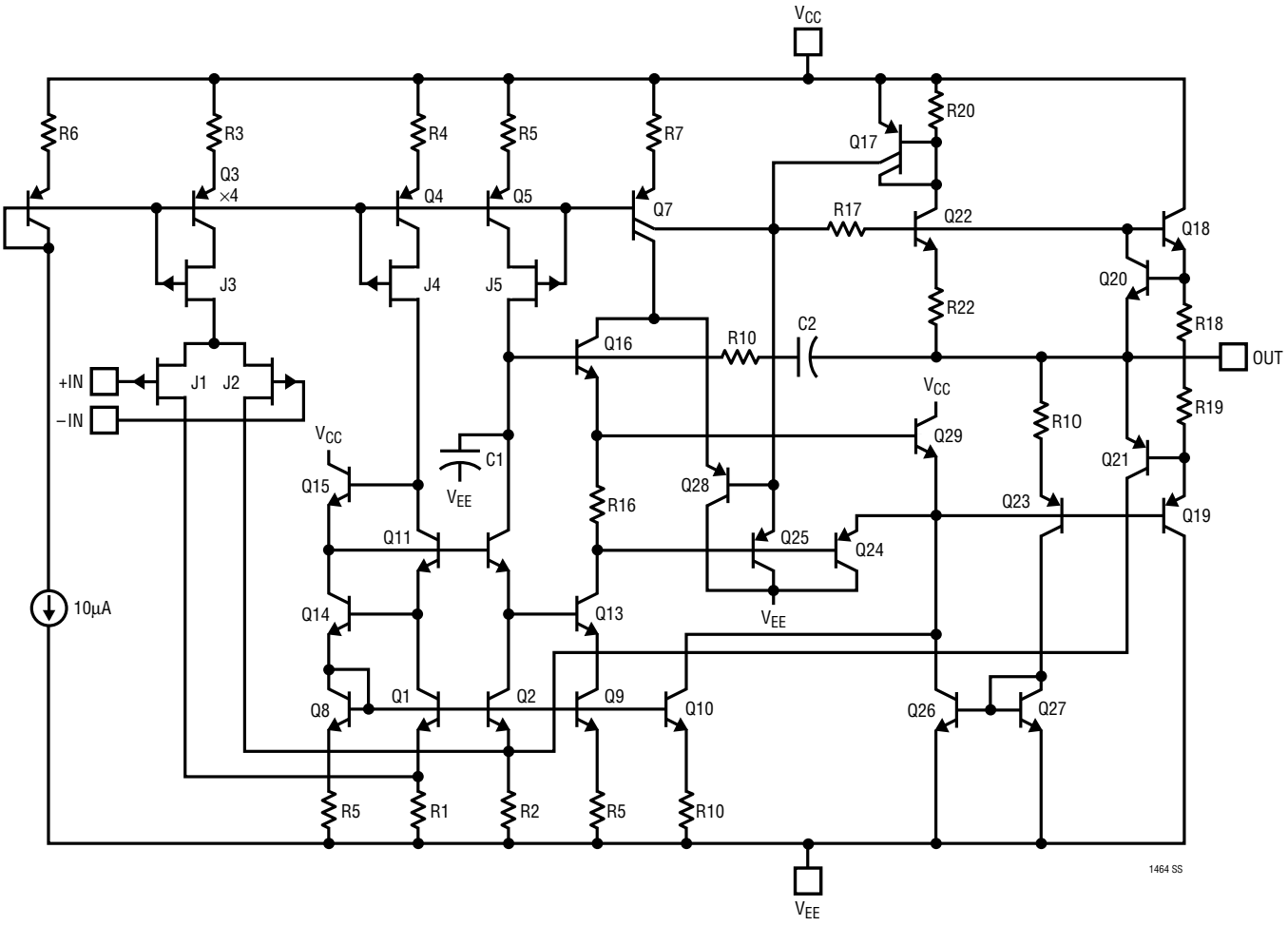


10Hz 4th Order Chebyshev Lowpass Filter (0.01dB Ripple)



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

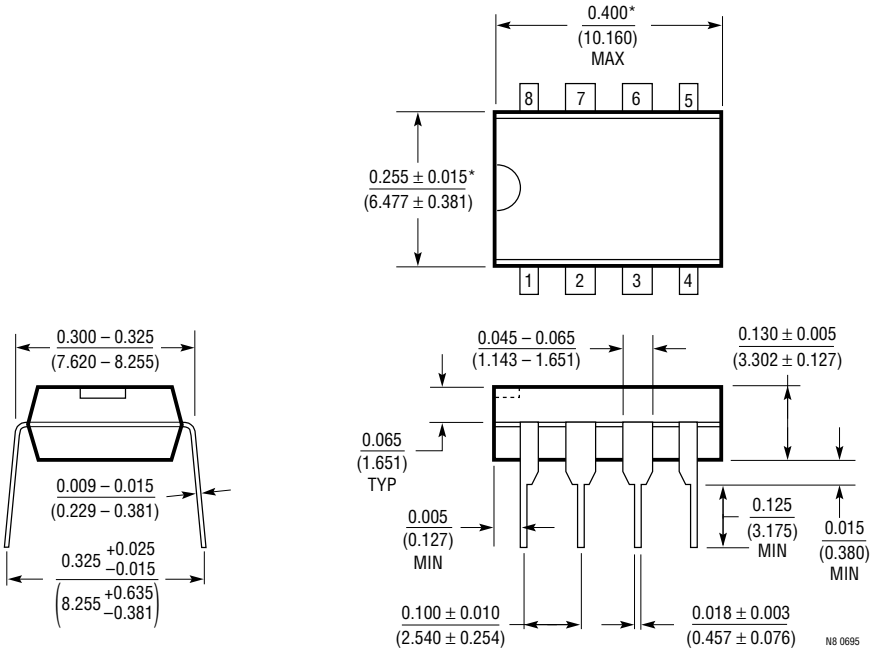
SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

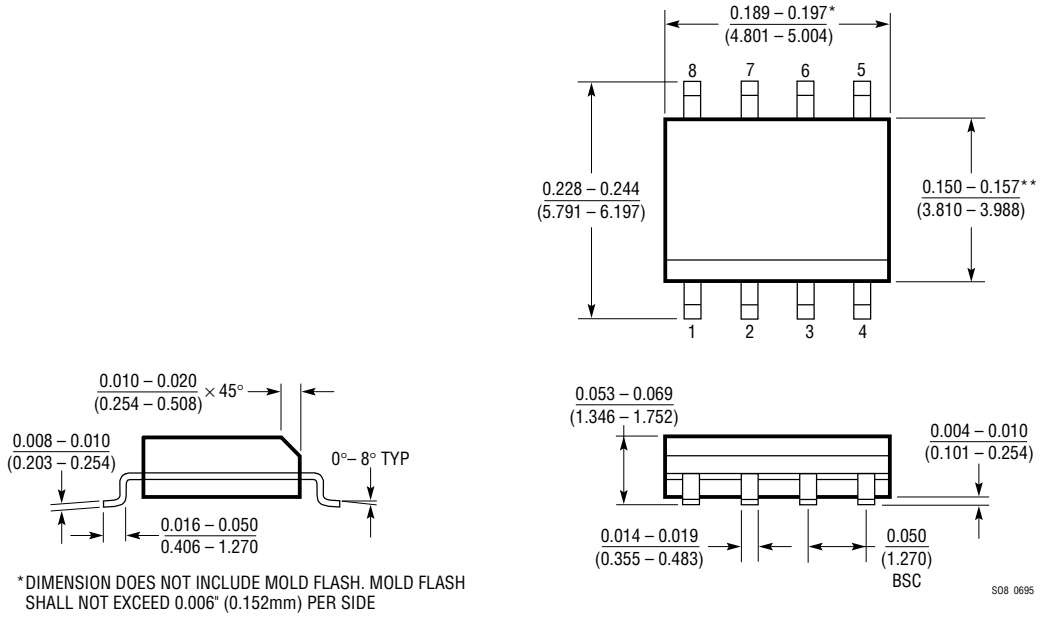
Dimensions in inches (millimeters) unless otherwise noted.

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)

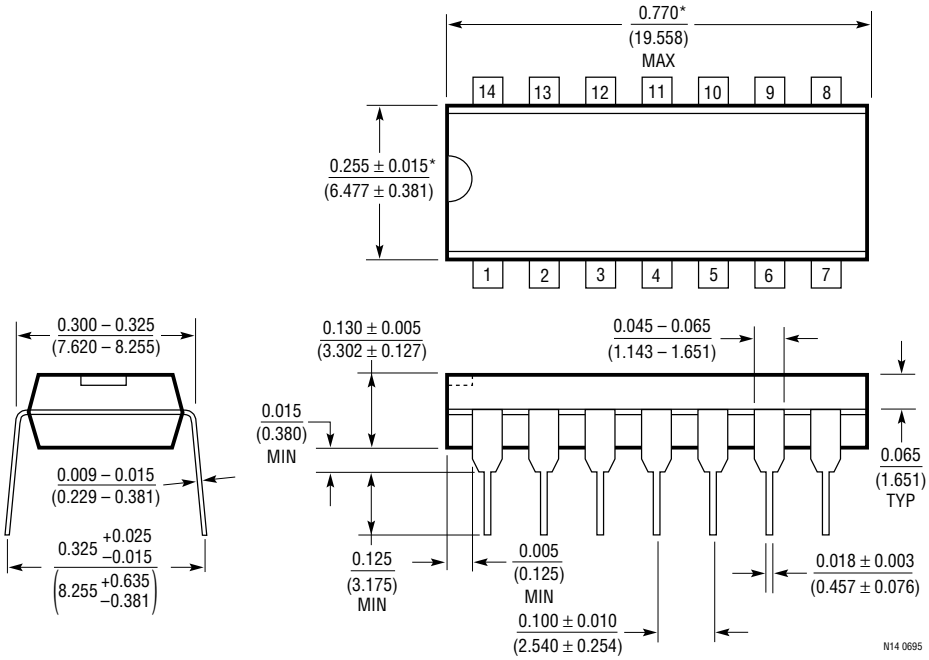


*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

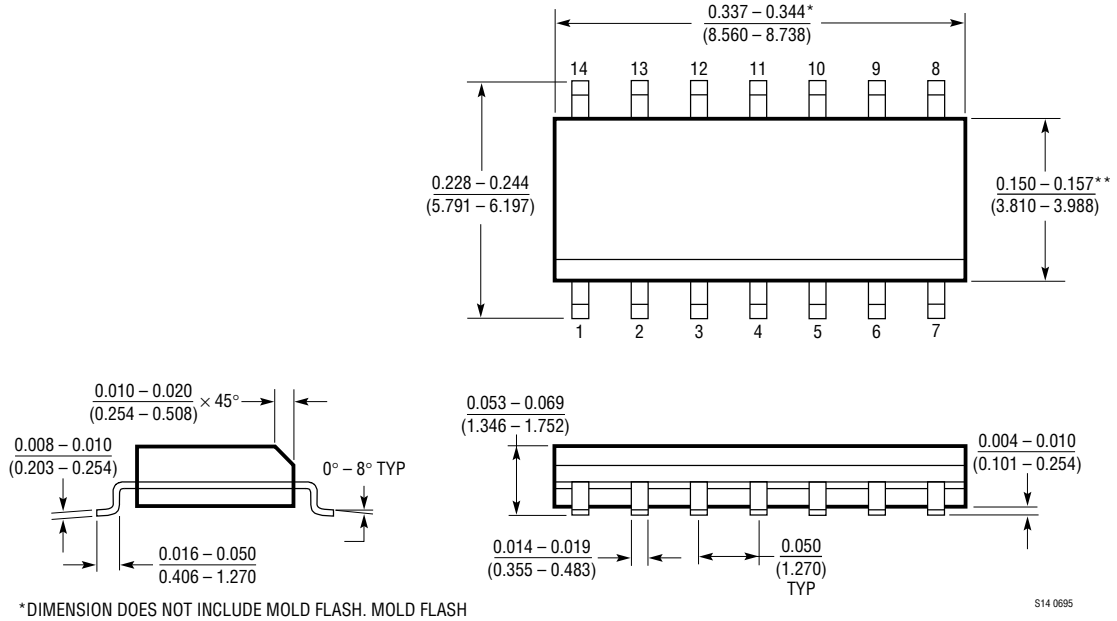
PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

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

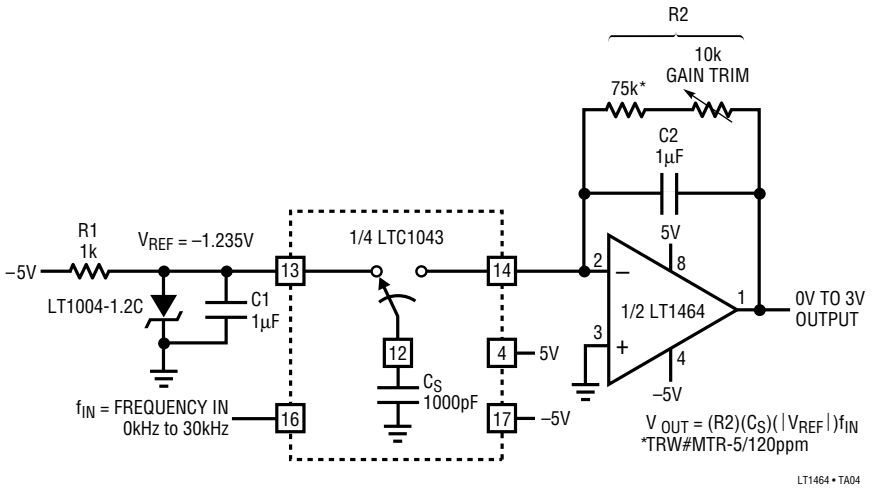
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

LINEAR TECHNOLOGY

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 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/$\sqrt{Hz}$ 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/$\sqrt{Hz}$ 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

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417• (408)432-1900
FAX: (408) 434-0507•TELEX: 499-3977 • www.linear-tech.com
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