

## FEATURES

- Offset Voltage 50 $\mu$ V Max
- Offset Voltage Drift 1 $\mu$ V/ $^{\circ}$ C Max
- Bias Current 250pA Max
- Offset Current 250pA Max
- Bias and Offset Current Drift 4pA/ $^{\circ}$ C Max
- Supply Current 560 $\mu$ A Max
- 0.1Hz to 10Hz Noise 0.5 $\mu$ Vp-p, 2.2pAp-p
- CMRR 115dB Min
- Voltage Gain 117dB Min
- PSRR 114dB Min
- Guaranteed Operation on Two NiCad Batteries

## APPLICATIONS

- Replaces OP-07/OP-77/OP-97/OP-177/AD707/LT1001 with Improved Price/Performance
- High Impedance Difference Amplifiers
- Logarithmic Amplifiers (Wide Dynamic Range)
- Thermocouple Amplifiers
- Precision Instrumentation
- Active Filters (with Small Capacitors)

## DESCRIPTION

LT<sup>®</sup>1097 achieves a new standard in combining low price and outstanding precision performance.

On all operational amplifier data sheets, the specifications listed on the front page are for highly selected, expensive grades, while the specs for the low cost grades are buried deep in the data sheet.

The LT1097 does not have any selected grades, the outstanding specifications shown in the Features section are for its only grade.

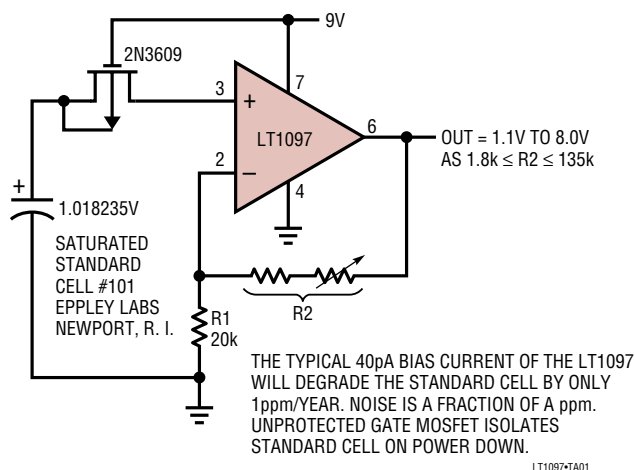
The design effort of the LT1097 concentrated on optimizing the performance of all precision specs—at only 350 $\mu$ A of supply current. Typical values are 10 $\mu$ V offset voltage, 40pA bias and offset currents, 0.2 $\mu$ V/ $^{\circ}$ C and 0.4pA/ $^{\circ}$ C drift. Common mode and power supply rejections, voltage gain are typically in excess of 128dB.

All parameters that are important for precision, low power op amps have been optimized. Consequently, using the LT1097 error budget calculations in most applications is unnecessary.

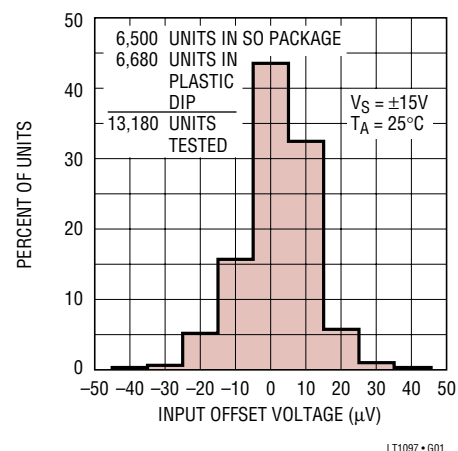
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## TYPICAL APPLICATION

**Saturated Standard Cell Amplifier**



**Input Offset Voltage Distribution**



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....  $\pm 20\text{V}$   
 Differential Input Current (Note 1) .....  $\pm 10\text{mA}$   
 Input Voltage .....  $\pm 20\text{V}$   
 Output Short Circuit Duration ..... Indefinite

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

## PACKAGE/ORDER INFORMATION

<p>TOP VIEW</p> <p>N8 PACKAGE 8-LEAD PLASTIC DIP</p>	<p>ORDER PART NUMBER</p> <p>LT1097CN8</p>	<p>TOP VIEW</p> <p>S8 PACKAGE 8-LEAD PLASTIC SO</p>	<p>ORDER PART NUMBER</p> <p>LT1097S8</p>
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## ELECTRICAL CHARACTERISTICS $V_S = \pm 15\text{V}$ , $V_{CM} = 0\text{V}$ , $T_A = 25^{\circ}\text{C}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1097CN8			LT1097S8			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage			10	50		10	60	$\mu\text{V}$
$\frac{\Delta V_{OS}}{\Delta \text{TIME}}$	Long Term Input Offset Voltage Stability			0.3			0.3		$\mu\text{V}/\text{Mo}$
$I_{OS}$	Input Offset Current			40	250		60	350	$\text{pA}$
$I_B$	Input Bias Current			$\pm 40$	$\pm 250$		$\pm 50$	$\pm 350$	$\text{pA}$
$e_n$	Input Noise Voltage	0.1Hz to 10Hz		0.5			0.5		$\mu\text{Vp-p}$
	Input Noise Voltage Density	$f_0 = 10\text{Hz}$ $f_0 = 1000\text{Hz}$		16 14			16 14		$\text{nV}/\sqrt{\text{Hz}}$ $\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Input Noise Current	0.1Hz to 10Hz		2.2			2.4		$\text{pAp-p}$
	Input Noise Current Density	$f_0 = 10\text{Hz}$ $f_0 = 1000\text{Hz}$		0.03 0.008			0.035 0.008		$\text{pA}/\sqrt{\text{Hz}}$ $\text{pA}/\sqrt{\text{Hz}}$
	Input Resistance Differential Mode Common Mode	(Note 2)	30	80 $10^{12}$		25	70 $8 \cdot 10^{11}$		$\text{M}\Omega$ $\Omega$
	Input Voltage Range		$\pm 13.5$	$\pm 14.3$		$\pm 13.5$	$\pm 14.3$		$\text{V}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5\text{V}$	115	130		115	130		$\text{dB}$
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.2\text{V}$ to $\pm 20\text{V}$	114	130		114	130		$\text{dB}$
$A_{VOL}$	Large Signal Voltage Gain	$V_O = \pm 12\text{V}$ , $R_L = 10\text{k}$ $V_O = \pm 10\text{V}$ , $R_L = 2\text{k}$	700 250	2500 1000		700 250	2500 1000		$\text{V}/\text{mV}$ $\text{V}/\text{mV}$
$V_{OUT}$	Output Voltage Swing	$R_L = 10\text{k}$ $R_L = 2\text{k}$	$\pm 13$ $\pm 11.5$	$\pm 13.8$ $\pm 13$		$\pm 13$ $\pm 11.5$	$\pm 13.8$ $\pm 13$		$\text{V}$ $\text{V}$
SR	Slew Rate		0.1	0.2		0.1	0.2		$\text{V}/\mu\text{s}$
GBW	Gain Bandwidth Product			700			700		$\text{kHz}$
$I_S$	Supply Current			350	560		350	560	$\mu\text{A}$
	Offset Adjustment Range	$R_{POT} = 10\text{k}$ , Wiper to $V^+$		$\pm 600$			$\pm 600$		$\mu\text{V}$
	Minimum Supply Voltage	(Note 3)	$\pm 1.2$	—		$\pm 1.2$	—		$\text{V}$

# 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		LT1097CN8			LT1097S8			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		●		20	100		20	130	$\mu V$
	Average Temperature Coefficient of Input Offset Voltage	(Note 4)	●		0.2	1		0.2	1.4	$\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●		60	430		75	570	pA
	Average Temperature Coefficient of Input Offset Current	(Note 4)	●		0.4	4		0.5	5	$pA/^\circ C$
$I_B$	Input Bias Current		●		$\pm 60$	$\pm 430$		$\pm 75$	$\pm 570$	pA
	Average Temperature Coefficient of Input Bias Current	(Note 4)	●		0.4	4		0.5	5	$pA/^\circ C$
$A_{VOL}$	Large Signal Voltage Gain	$V_{OUT} = \pm 12V$ , $R_L \geq 10k$	●	450	2000		450	2000		V/mV
		$V_{OUT} = \pm 10V$ , $R_L \geq 2k$	●	180	800		180	800		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	●	112	128		112	128		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.3V$ to $\pm 20V$	●	111	128		111	128		dB
	Input Voltage Range		●	$\pm 13.5$	$\pm 14.2$		$\pm 13.5$	$\pm 14.2$		V
$V_{OUT}$	Output Voltage Swing	$R_L = 10k$	●	$\pm 13$	$\pm 13.7$		$\pm 13$	$\pm 13.7$		V
$I_S$	Supply Current		●		380	700		380	700	$\mu A$

# ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$ , $V_{CM} = 0V$ , $-40^\circ C \leq T_A \leq 85^\circ C$ , unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		LT1097CN8			LT1097S8			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage		●		25	130		30	170	$\mu V$
	Average Temperature Coefficient of Input Offset Voltage		●		0.3	1.2		0.3	1.6	$\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●		70	600		85	750	pA
	Average Temperature Coefficient of Input Offset Current		●		0.5	5		0.6	6	$pA/^\circ C$
$I_B$	Input Bias Current		●		$\pm 70$	$\pm 600$		$\pm 85$	$\pm 750$	pA
	Average Temperature Coefficient of Input Bias Current		●		0.5	5		0.6	6	$pA/^\circ C$
$A_{VOL}$	Large Signal Voltage Gain	$V_{OUT} = \pm 12V$ , $R_L \geq 10k$	●	300	1700		300	1700		V/mV
		$V_{OUT} = \pm 10V$ , $R_L \geq 2k$	●		700			700		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm 13.5V$	●	108	127		108	127		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 1.5V$ to $\pm 20V$	●	108	127		108	127		dB
	Input Voltage Range		●	$\pm 13.5$	$\pm 14$		$\pm 13.5$	$\pm 14$		V
$V_{OUT}$	Output Voltage Swing	$R_L = 10k$	●	$\pm 13$	$\pm 13.6$		$\pm 13$	$\pm 13.6$		V
$I_S$	Supply Current		●		400	800		400	800	$\mu A$

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

**Note 1:** Differential input voltages greater than 1V will cause excessive current to flow through the input protection diodes unless limiting resistance is used.

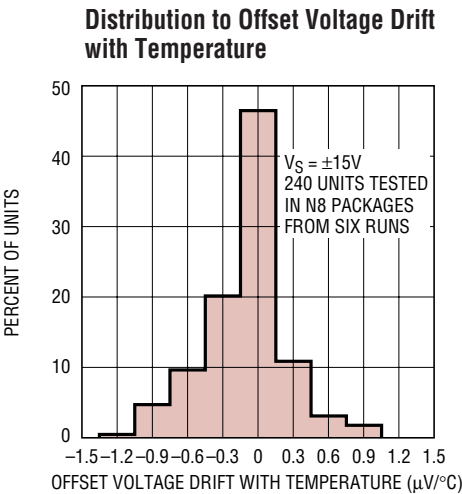
**Note 2:** This parameter is guaranteed by design and is not tested.

**Note 3:** Power supply rejection ratio is measured at the minimum supply voltage.

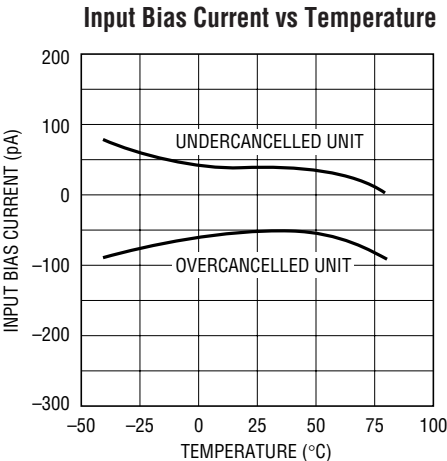
**Note 4:** This parameter is not 100% tested.

**Note 5:** The LT1097 is designed, characterized and expected to meet these extended temperature limits, but is not tested at  $-40^\circ C$  and  $85^\circ C$ . Guaranteed I grade parts are available; consult factory.

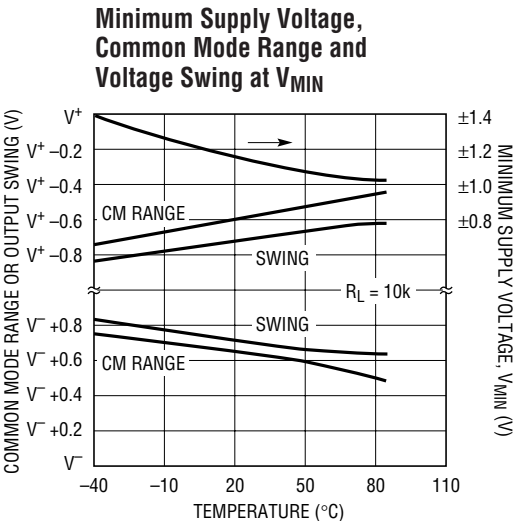
TYPICAL PERFORMANCE CHARACTERISTICS



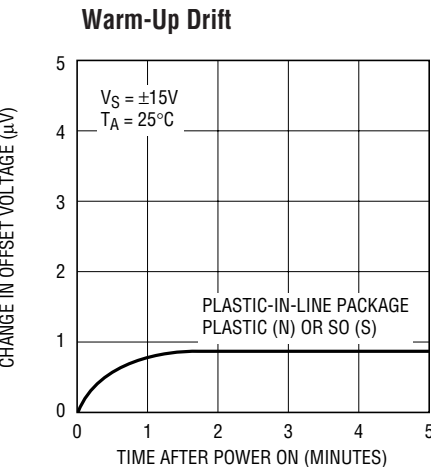
LT1097 • G02



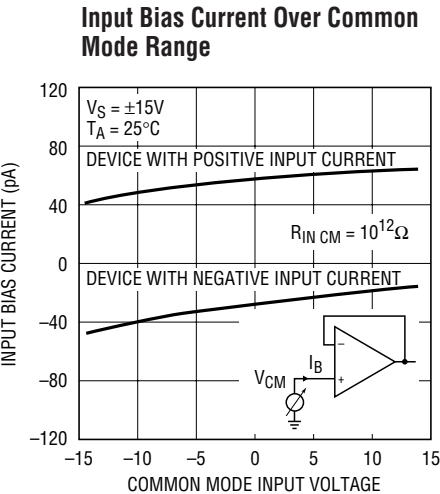
1097 • G03



1097 • G04



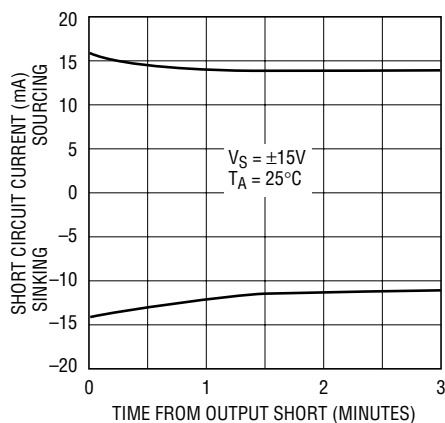
1097 • G05



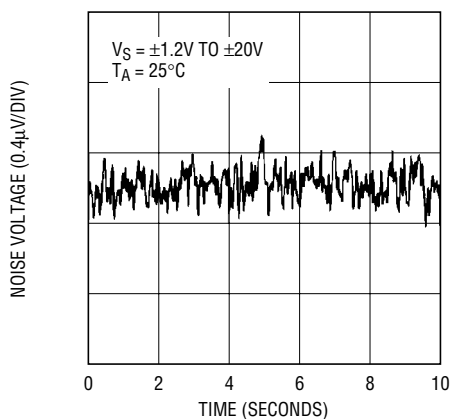
1097 • G06

# TYPICAL PERFORMANCE CHARACTERISTICS

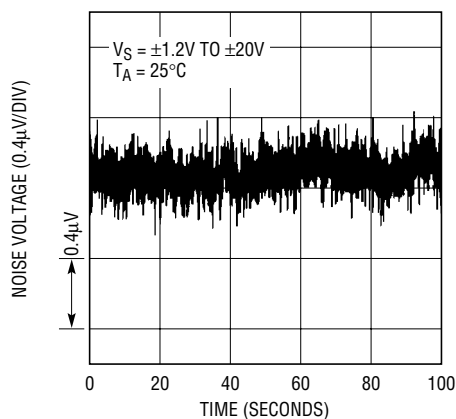
## Output Short Circuit Current vs Time



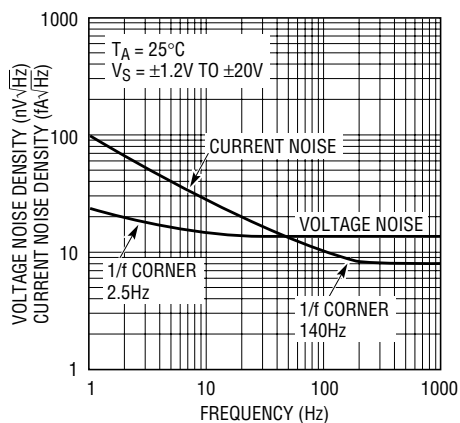
## 0.1Hz to 10Hz Noise



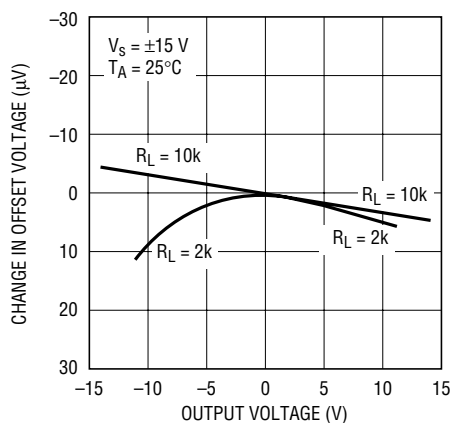
## 0.01Hz to 10Hz Noise



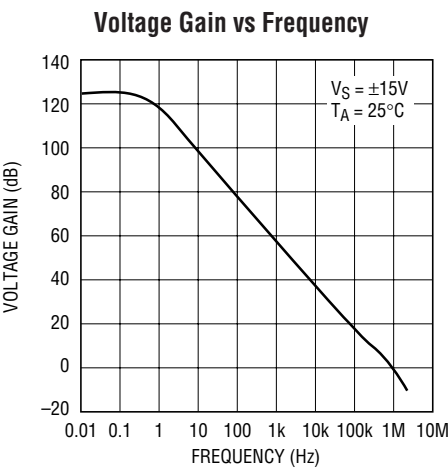
## Noise Spectrum



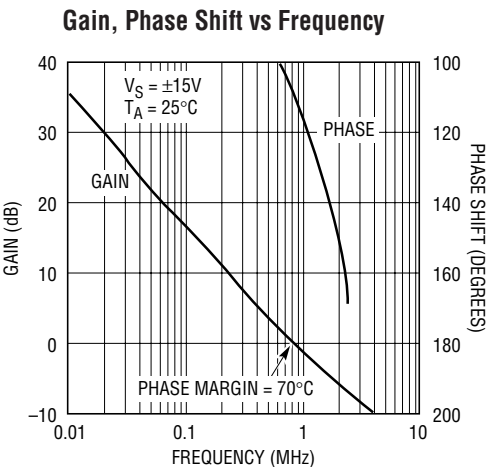
## Voltage Gain



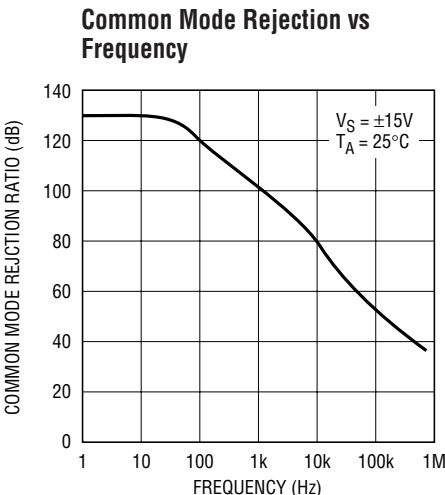
TYPICAL PERFORMANCE CHARACTERISTICS



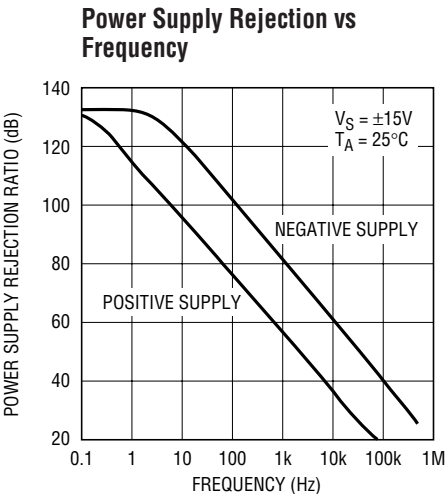
1097 • G12



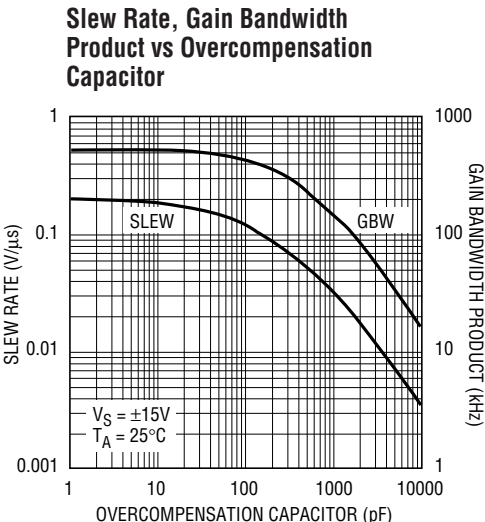
1097 • G13



1097 • G14



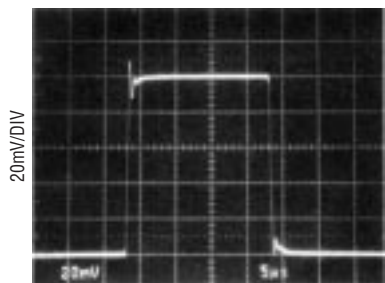
1097 • G15



1097 • G16

## TYPICAL PERFORMANCE CHARACTERISTICS

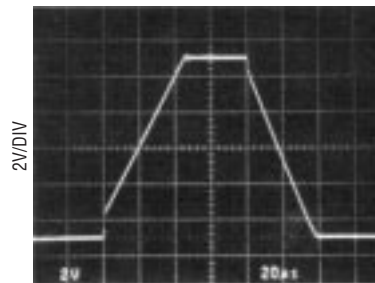
### Small Signal Transient Response



$A_V = 1$ ,  $C_{LOAD} = 100\text{pF}$ ,  $5\mu\text{s}/\text{DIV}$

1097 G17

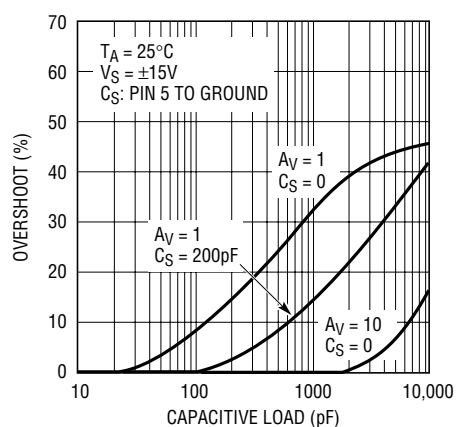
### Large Signal Transient Response



$A_V = 1$ ,  $20\mu\text{s}/\text{DIV}$

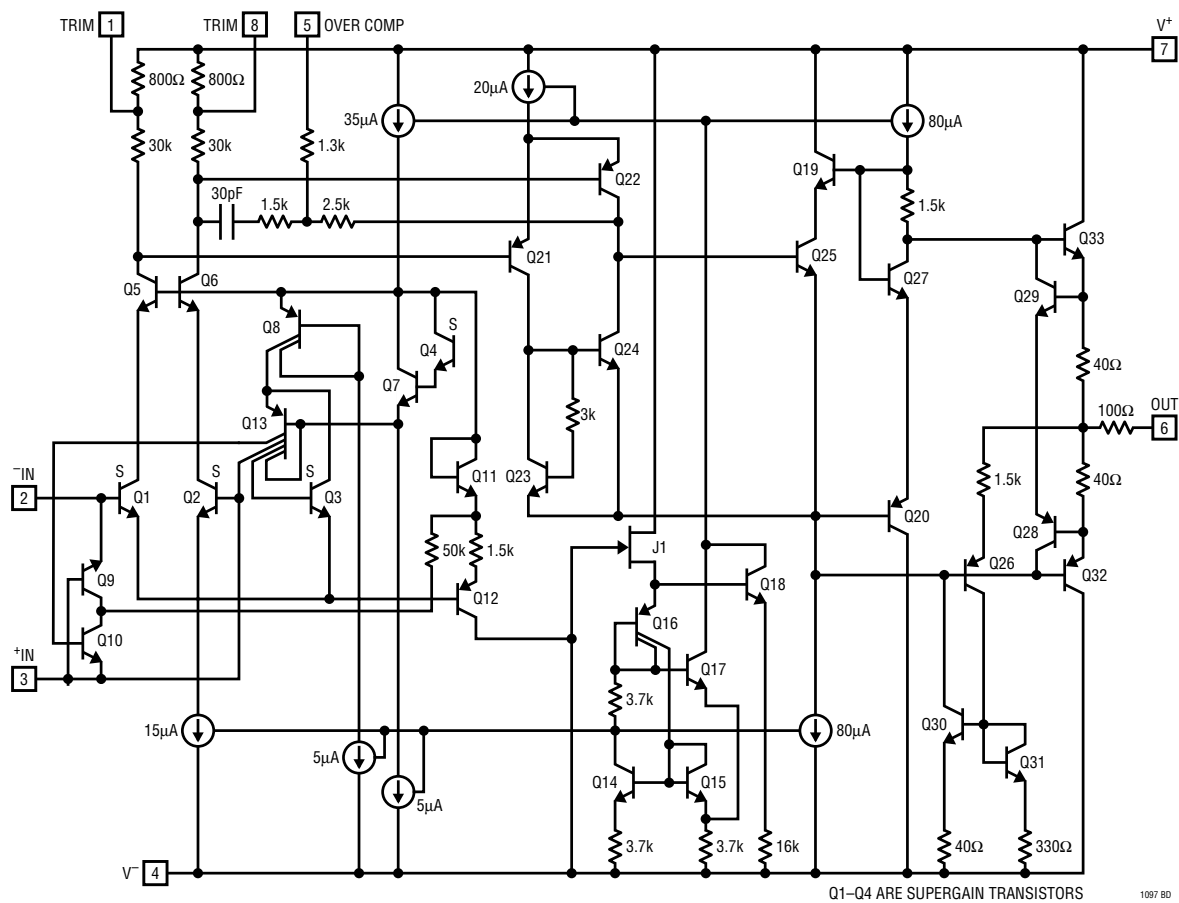
1097 G18

### Capacitive Load Handling



1097 G19

## SCHEMATIC DIAGRAM



1097 BD



## APPLICATIONS INFORMATION

The LT1097 is pin compatible to and directly replaces such precision op amps as the OP-07, OP-77, AD707, OP-97, OP-177, LM607 and LT1001 with improved price/performance. Compatibility includes externally nulling the offset voltage, as all of the above devices are trimmed with a potentiometer between Pin 1 and Pin 8 and the wiper tied to  $V^+$ .

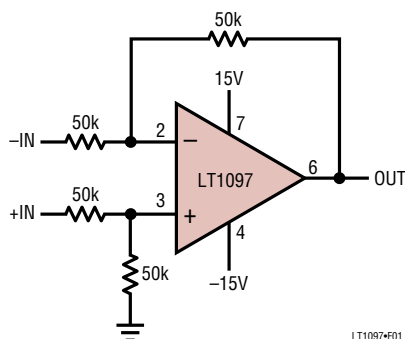
The simple difference amplifier can be used to illustrate the all-around excellence of the LT1097. The 50k input resistance is selected to be large enough compared to input signal source resistance. Simultaneously, the 50k resistors should not dominate the precision and noise error budget. Assuming perfect matching between the four resistors, the following table summarizes the input

referred performance obtained using the LT1097 and other popular, low cost precision op amps.

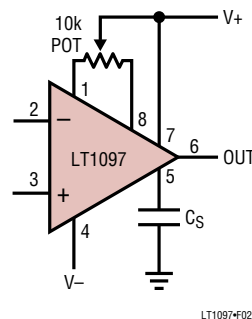
Input offset voltage can be adjusted over a  $\pm 600\mu\text{V}$  range with a 10k potentiometer.

The LT1097 is internally compensated for unity gain stability. As shown on the Capacitive Load Handling plot, the LT1097 is stable with any capacitive load. However, the overcompensation capacitor,  $C_S$ , can be used to reduce overshoot with heavy capacitive loads, to narrow noise bandwidth or to stabilize circuits with gain in the feedback loop.

**$\pm 27\text{V}$  Common Mode Range Difference Amplifier**



**Frequency Compensation and Optional Offset Nulling**



**Guaranteed Performance,  $V_S = \pm 15\text{V}$ ,  $T_A = 25^\circ\text{C}$**

PARAMETER	LT1097CN8	OP-77GP	AD707JN	OP-177GP	OP-97FP	UNITS
Error Terms						
$V_{OS}$ Max	50	100	90	60	75	$\mu\text{V}$
$I_{OS}$ Max•25k	6	70	50	70	4	$\mu\text{V}$
Gain Min, 10V Out	14	5	3	5	50	$\mu\text{V}$
CMRR, Min, $\pm 25\text{V}$ In	22	20	13	22	39	$\mu\text{V}$
PSRR, Min, $V_S = \pm 15\text{V} \pm 10\%$	6	9	9	9	9	$\mu\text{V}$
Sum of All Error Terms	98	204	165	166	177	$\mu\text{V}$
0.1Hz to 10Hz Noise						
Voltage Noise	0.5	0.38	0.23	0.38	0.5	$\mu\text{Vp-p Typ}$
Current Noise•50k	0.11	0.75	0.7	0.75	0.1	$\mu\text{Vp-p Typ}$
Resistor Noise	0.55	0.55	0.55	0.55	0.55	$\mu\text{Vp-p Typ}$
RMS sum	0.75	1	0.92	1	0.75	$\mu\text{Vp-p}$
Drift with Temp						
$TCV_{OS}$ Max	1	1.2	1	1.2	2	$\mu\text{V}/^\circ\text{C}$
$TCI_{OS}$ Max•25k	0.1	2.1	1	2.1	0.2	$\mu\text{V}/^\circ\text{C}$
Sum of Drift Terms	1.1	3.3	2	3.3	2.2	$\mu\text{V}/^\circ\text{C}$
Supply Current Max	0.56	2	3	2	0.6	mA

## APPLICATIONS INFORMATION

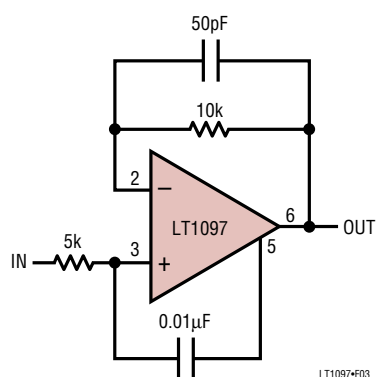
The availability of the compensation terminal permits the use of feedforward frequency compensation to enhance slew rate. The voltage follower feedforward scheme bypasses the amplifier's gain stages and slews at nearly  $10\text{V}/\mu\text{s}$ .

The inputs of the LT1097 are protected with back-to-back diodes. In the voltage follower configuration, when the input is driven by a fast, large signal pulse ( $>1\text{V}$ ), the input

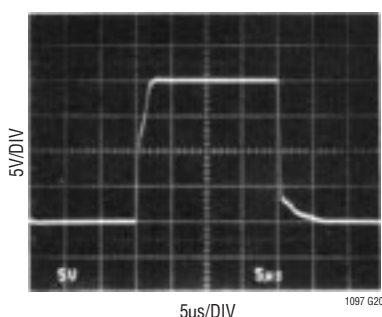
protection diodes effectively short the output to the input during slewing, and a current, limited only by the output short circuit protection will flow through the diodes.

The use of a feedback resistor, as shown in the voltage follower feedforward diagram, is recommended because this resistor keeps the current below the short circuit limit, resulting in faster recovery and settling of the output.

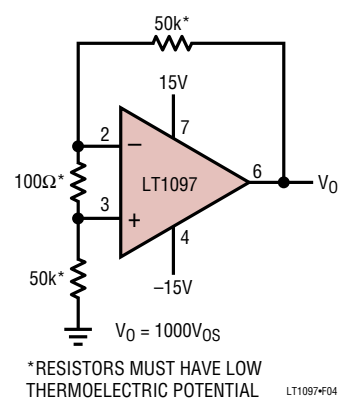
**Follower Feedforward Compensation**



**Pulse Response of Feedforward Compensation**

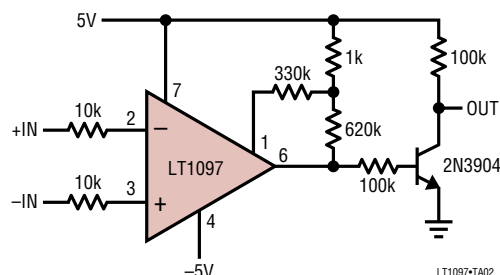


**Test Circuit for Offset Voltage and its Drift with Temperature**



## TYPICAL APPLICATION

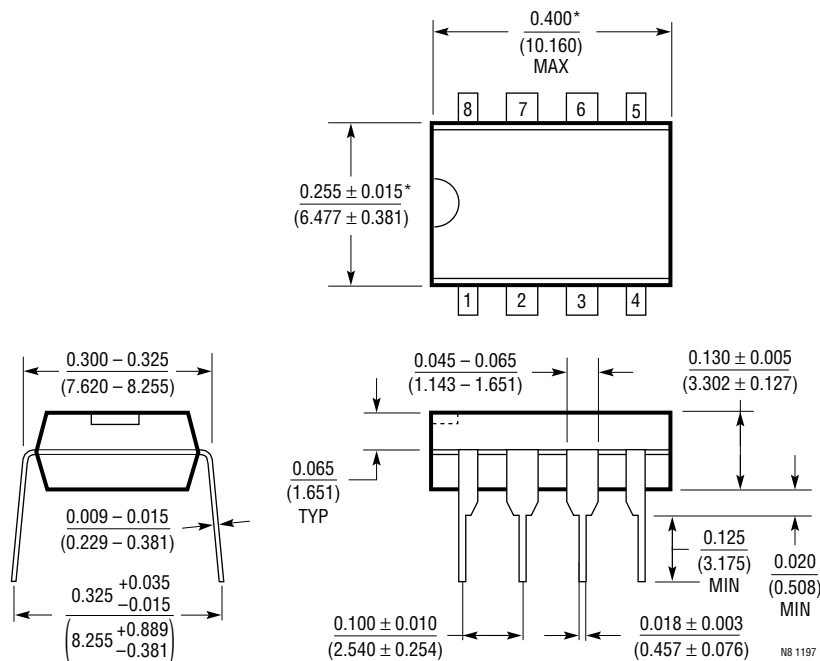
**Low Power Comparator with  $<10\mu\text{V}$  Hysteresis**



# PACKAGE DESCRIPTION

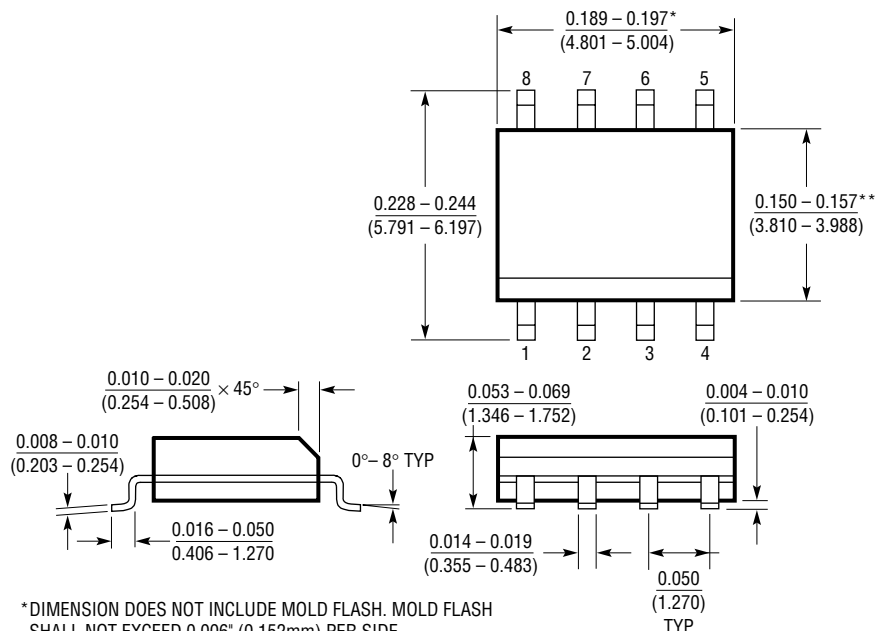
Dimensions in inches (millimeters) unless otherwise noted.

## 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)



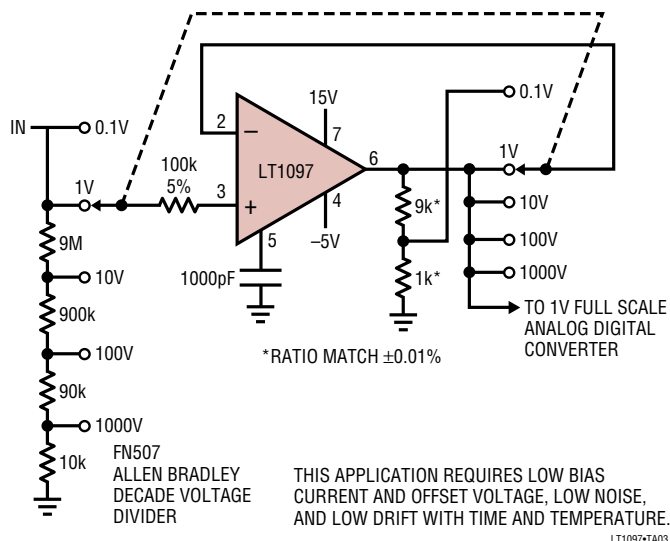
\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

S08 0996

## TYPICAL APPLICATION

### Input Amplifier for 4 1/2 Digit Voltmeter



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1490/LT1491	Dual/Quad General Purpose Micropower Rail-to-Rail Op Amps	Over-The-Top™ Inputs, 50µA Supply Current Per Amplifier, 2V to 44V Supply Range, 180kHz GBW
LT1492/LT1493	Dual/Quad 5MHz Low Power Single Supply Op Amps	180µV V <sub>OS</sub> Max, 3V/µs Slew Rate, 550µA Supply Per Amplifier
LT1077	Single Micropower Low V <sub>OS</sub> Op Amp	60µV V <sub>OS</sub> Max, 68µA Supply Current, 230kHz GBW, Optimized for 5V Supplies

Over-The-Top is a trademark of Linear Technology Corporation.

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