LINEAR TECHNOLOGY

Precision Operational Amplifier

FEATURES

- *Guaranteed* Low Offset Voltage
  - LT1001AM 15µV max
  - LT1001C 60µV max
- *Guaranteed* Low Drift
  - LT1001AM 0.6µV/°C max
  - LT1001C 1.0µV/°C max
- *Guaranteed* Low Bias Current
  - LT1001AM 2nA max
  - LT1001C 4nA max
- *Guaranteed* CMRR
  - LT1001AM 114dB min
  - LT1001C 110dB min
- *Guaranteed* PSRR
  - LT1001AM 110dB min
  - LT1001C 106dB min
- Low Power Dissipation
  - LT1001AM 75mW max
  - LT1001C 80mW max
- Low Noise 0.3µV$_{P-P}$

APPLICATIONS

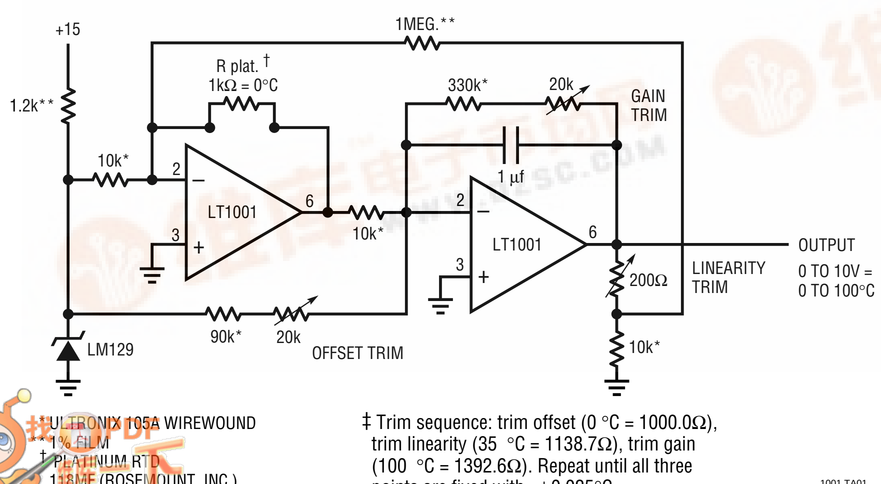
- Thermocouple amplifiers
- Strain gauge amplifiers
- Low level signal processing
- High accuracy data acquisition

DESCRIPTION

The LT®1001 significantly advances the state-of-the-art of precision operational amplifiers. In the design, processing, and testing of the device, particular attention has been paid to the optimization of the entire distribution of several key parameters. Consequently, the specifications of the lowest cost, commercial temperature device, the LT1001C, have been dramatically improved when compared to equivalent grades of competing precision amplifiers.

Essentially, the input offset voltage of all units is less than 50µV (see distribution plot below). This allows the LT1001AM/883 to be specified at 15µV. Input bias and offset currents, common-mode and power supply rejection of the LT1001C offer guaranteed performance which were previously attainable only with expensive, selected grades of other devices. Power dissipation is nearly halved compared to the most popular precision op amps, without adversely affecting noise or speed performance. A beneficial by-product of lower dissipation is decreased warm-up drift. Output drive capability of the LT1001 is also enhanced with voltage gain guaranteed at 10 mA of load current. For similar performance in a dual precision op amp, with guaranteed matching specifications, see the LT1002. Shown below is a platinum resistance thermometer application.

Linearized Platinum Resistance Thermometer with ±0.025°C Accuracy Over 0 to 100°C

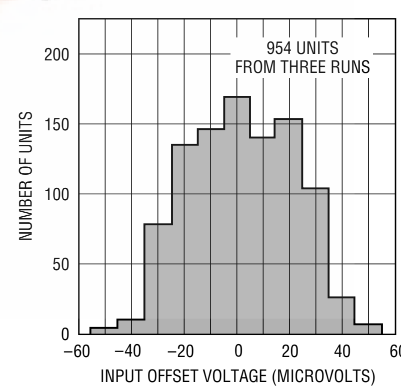


** ULTRONIX 105A WIREWOUND
* 1% FILM
† PLATINUM RTD 118MF (ROSEMOUNT, INC.)

‡ Trim sequence: trim offset (0 °C = 1000.0Ω), trim linearity (35 °C = 1138.7Ω), trim gain (100 °C = 1392.6Ω). Repeat until all three points are fixed with ±0.025°C.

1001 TA01

Typical Distribution of Offset Voltage $V_S = \pm15V$, $T_A = 25°C$

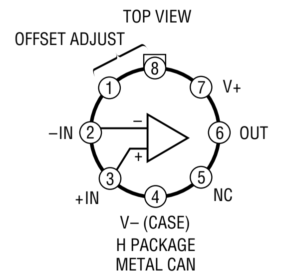


1001 TA02

ABSOLUTE MAXIMUM RATINGS

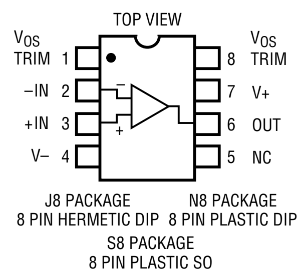
Supply Voltage .... ±22V
Differential Input Voltage .... ±30V
Input Voltage .... ±22V
Output Short Circuit Duration .... Indefinite
Operating Temperature Range
  LT1001AM/LT1001M .... −55°C to 150°C
  LT1001AC/LT1001C .... 0°C to 125°C
  Storage: All Devices......................... −65°C to 150°C
Lead Temperature (Soldering, 10 sec.)................. 300°C

PACKAGE/ORDER INFORMATION



ORDER PART NUMBER

LT1001AMH/883
LT1001MH
LT1001ACH
LT1001CH



LT1001AMJ8/883
LT1001MJ8
LT1001ACJ8
LT1001CJ8
LT1001ACN8
LT1001CN8
LT1001CS8

S8 PART MARKING
1001

ELECTRICAL CHARACTERISTICS

V_S = ±15V, T_A = 25°C, unless otherwise noted

SYMBOL	PARAMETER	CONDITIONS	LT1001AM/883 LT1001AC MIN	TYP	MAX	LT1001M/LT1001C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	Note 1 LT1001AM/883		7	15		18	60	µV
		Note 1 LT1001AC		10	25				
$\frac{\Delta V_{OS}}{\Delta Time}$	Long Term Input Offset Voltage Stability	Notes 2 and 3		0.2	1.0		0.3	1.5	µV/month
I_{OS}	Input Offset Current			0.3	2.0		0.4	3.8	nA
I_b	Input Bias Current			±0.5	±2.0		±0.7	±4.0	nA
e_n	Input Noise Voltage	0.1Hz to 10Hz (Note 2)		0.3	0.6		0.3	0.6	μV_{p-p}
e_n	Input Noise Voltage Density	f_O = 10Hz (Note 5) f_O = 1000Hz (Note 2)		10.3 9.6	18.0 11.0		10.5 9.8	18.0 11.0	$nV\sqrt{Hz}$
A_{VOL}	Large Signal Voltage Gain	$R_L \geq 2k\Omega$, V_O = ±12V $R_L \geq 1k\Omega$ V_O = ±10V	450 300	800 500		400 250	800 500		V/mV
CMRR	Common Mode Rejection Ratio	V_{CM} = ±13V	114	126		110	126		dB
PSRR	Power Supply Rejection Ratio	V_S = ±3V to ±18V	110	123		106	123		dB
R_{in}	Input Resistance Differential Mode		30	100		15	80		MΩ
	Input Voltage Range		±13	±14		±13	±14		V
V_{OUT}	Maximum Output Voltage Swing	$R_L \geq 2k\Omega$ $R_L \geq 1k\Omega$	±13 ±12	±14 ±13.5		±13 ±12	±14 ±13.5		V V
S_R	Slew Rate	$R_L \geq 2k\Omega$ (Note 4)	0.1	0.25		0.1	0.25		V/µs
GBW	Gain-Bandwidth Product	(Note 4)	0.4	0.8		0.4	0.8		MHz
P_d	Power Dissipation	No load No load, V_S = ±3V		46 4	75 6		48 4	80 8	mW

See Notes on page 3.

ELECTRICAL CHARACTERISTICS $V_S = \pm15V$, $-55°C \le T_A \le 125°C$, unless otherwise noted

SYMBOL	PARAMETER	CONDITIONS		LT1001AM/883 MIN	LT1001AM/883 TYP	LT1001AM/883 MAX	LT1001M MIN	LT1001M TYP	LT1001M MAX	UNITS
V_{OS}	Input Offset Voltage		●		30	60		45	160	µV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Offset Voltage Drift		●		0.2	0.6		0.3	1.0	µV/°C
I_{OS}	Input Offset Current		●		0.8	4.0		1.2	7.6	nA
I_B	Input Bias Current		●		±1.0	±4.0		±1.5	±8.0	nA
A_{VOL}	Large Signal Voltage Gain	$R_L \ge 2k\Omega$, $V_O = \pm10V$	●	300	700		200	700		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13V$	●	110	122		106	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm3$ to $\pm18V$	●	104	117		100	117		dB
	Input Voltage Range		●	±13	±14		±13	±14		V
V_{OUT}	Output Voltage Swing	$R_L \ge 2k\Omega$	●	±12.5	±13.5		±12.0	±13.5		V
P_d	Power Dissipation	No load	●		55	90		60	100	mW

$V_S = \pm15V$, $0°C \le T_A \le 70°C$, unless otherwise noted

SYMBOL	PARAMETER	CONDITIONS		LT1001AC MIN	LT1001AC TYP	LT1001AC MAX	LT1001C MIN	LT1001C TYP	LT1001C MAX	UNITS
V_{OS}	Input Offset Voltage		●		20	60		30	110	µV
$\frac{\Delta V_{OS}}{\Delta Temp}$	Average Offset Voltage Drift		●		0.2	0.6		0.3	1.0	µV/°C
I_{OS}	Input Offset Current		●		0.5	3.5		0.6	5.3	nA
I_B	Input Bias Current		●		±0.7	±3.5		±1.0	±5.5	nA
A_{VOL}	Large Signal Voltage Gain	$R_L \ge 2k\Omega$, $V_O = \pm10V$	●	350	750		250	750		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm13V$	●	110	124		106	123		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm3V$ to $\pm18V$	●	106	120		103	120		dB
	Input Voltage Range		●	±13	±14		±13	±14		V
V_{OUT}	Output Voltage Swing	$R_L \ge 2k\Omega$	●	±12.5	±13.8		±12.5	±13.8		V
P_d	Power Dissipation	No load	●		50	85		55	90	mW

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

Note 1: Offset voltage for the LT1001AM/883 and LT1001AC are measured after power is applied and the device is fully warmed up. All other grades are measured with high speed test equipment, approximately 1 second after power is applied. The LT1001AM/883 receives 168 hr. burn-in at 125°C. or equivalent.

Note 2: This parameter is tested on a sample basis only.

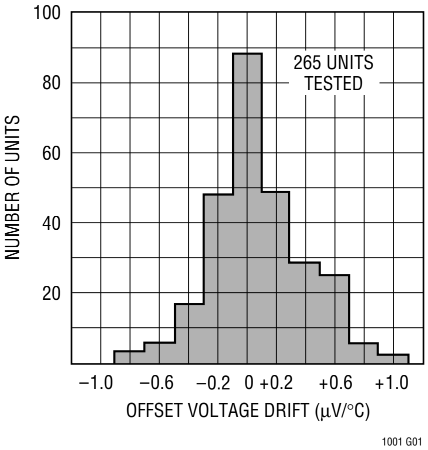
Note 3: Long Term Input Offset Voltage Stability refers to the averaged trend line of V_{OS} versus Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 days are typically 2.5µV.

Note 4: Parameter is guaranteed by design.

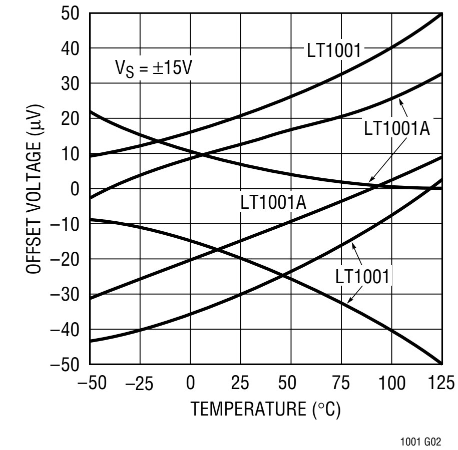
Note 5: 10Hz noise voltage density is sample tested on every lot. Devices 100% tested at 10Hz are available on request.

TYPICAL PERFORMANCE CHARACTERISTICS

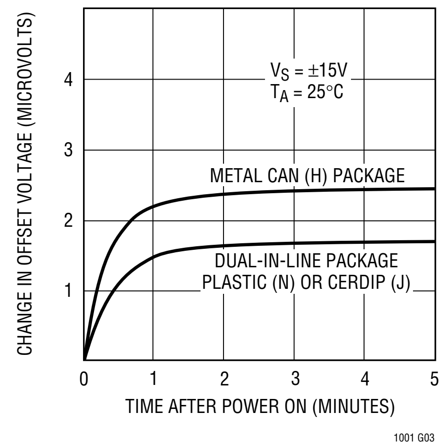
Typical Distribution of Offset Voltage Drift with Temperature



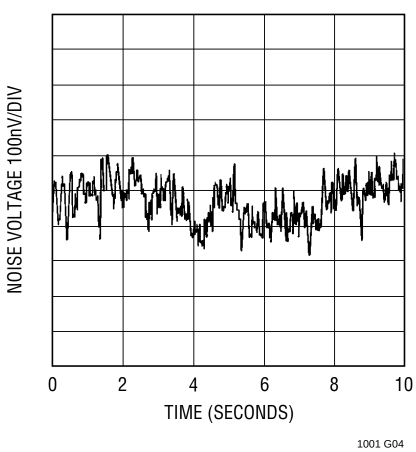
Offset Voltage Drift withTemperature of Representative Units



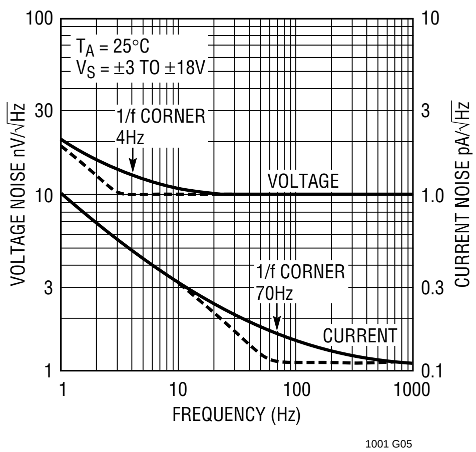
Warm-Up Drift



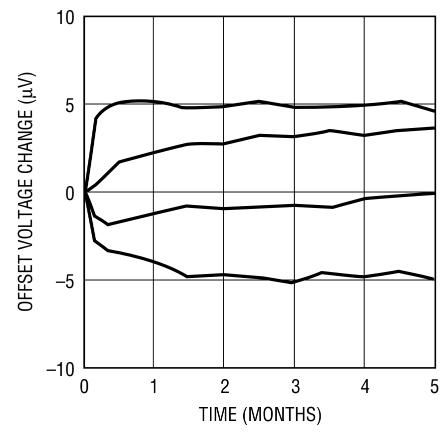
0.1Hz to 10Hz Noise



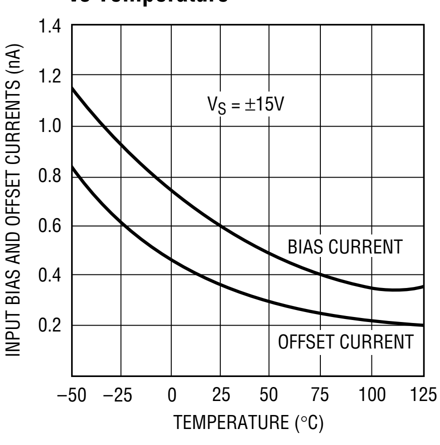
Noise Spectrum



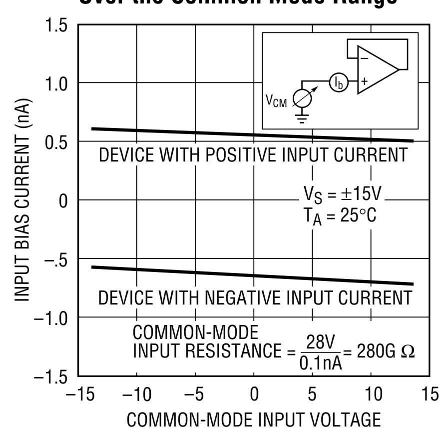
Long Term Stability of Four Representative Units



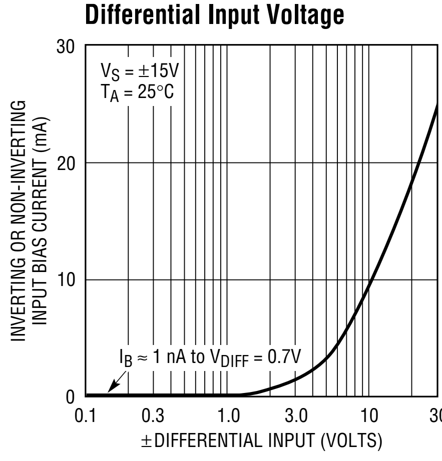
Input Bias and Offset Current vs Temperature



Input Bias Current Over the Common Mode Range

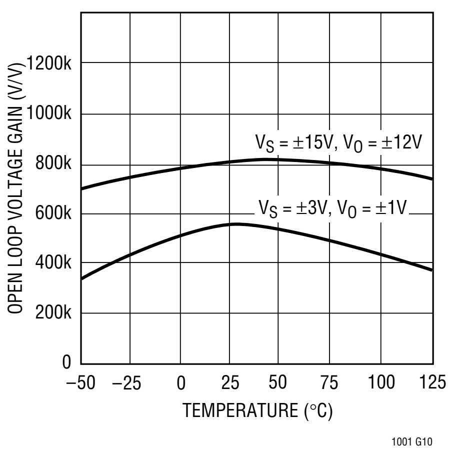


Input Bias Current vs Differential Input Voltage

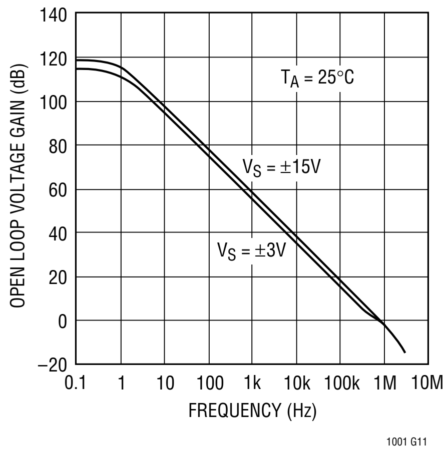


TYPICAL PERFORMANCE CHARACTERISTICS

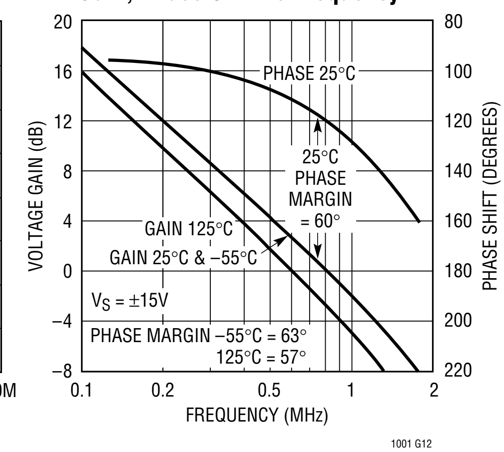
Open Loop Voltage Gain vs Temperature



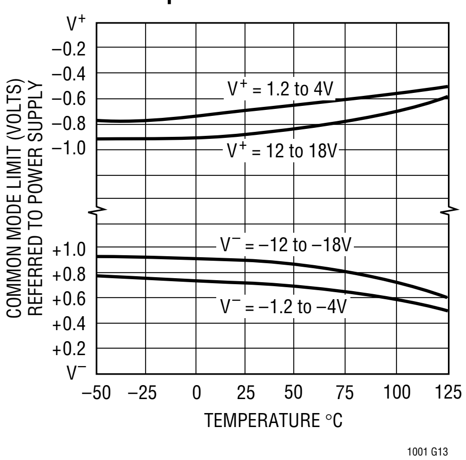
Open Loop Voltage Gain Frequency Response



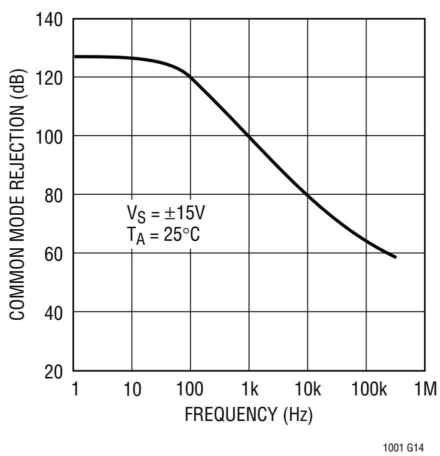
Gain, Phase Shift vs Frequency



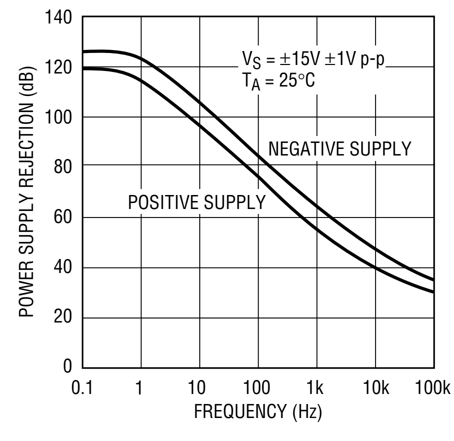
Common Mode Limit vs Temperature



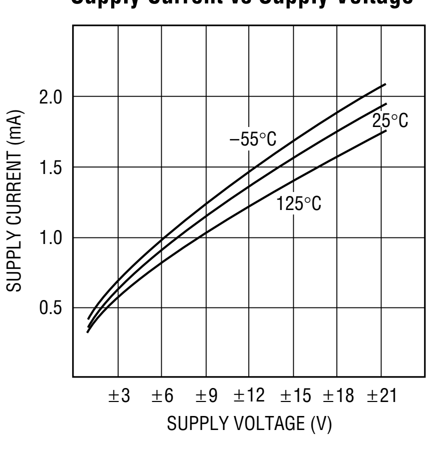
Common Mode Rejection Ratio vs Frequency



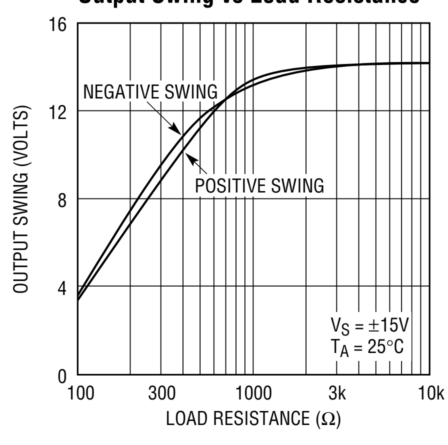
Power Supply Rejection Ratio vs Frequency



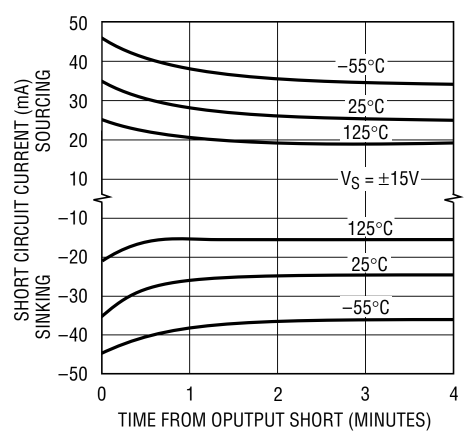
Supply Current vs Supply Voltage



Output Swing vs Load Resistance

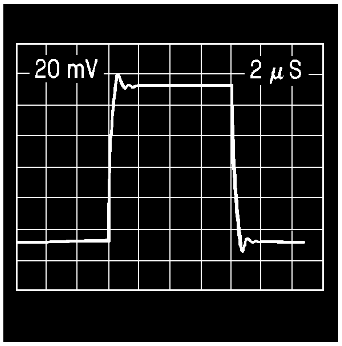


Output Short-Circuit Current vs Time



TYPICAL PERFORMANCE CHARACTERISTICS

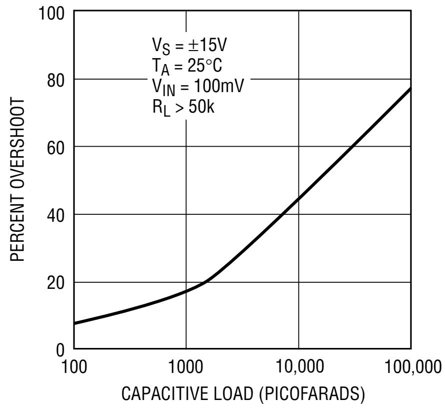
Small Signal Transient Response



$A_V = +1$, $C_L = 50pF$

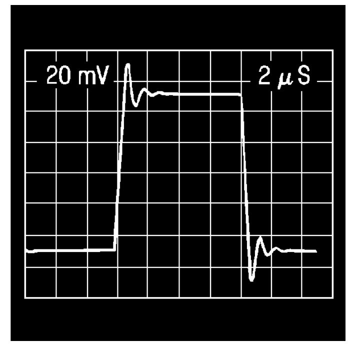
1001 G19

Voltage Follower Overshoot vs Capacitive Load



1001 G20

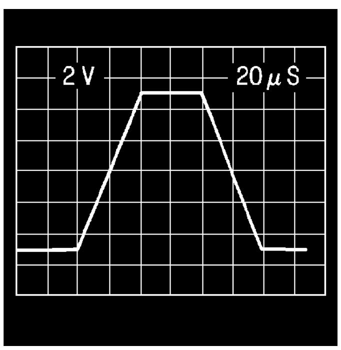
Small Signal Transient Response



$A_V = +1$, $C_L = 1000pF$

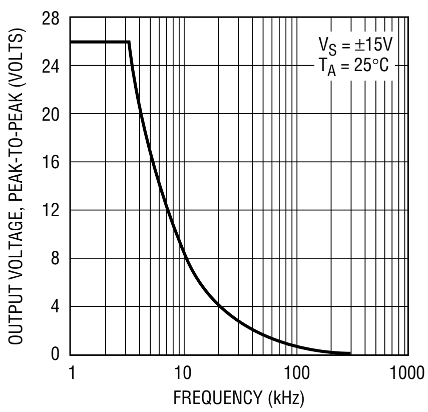
1001 G21

Large Signal Transient Response



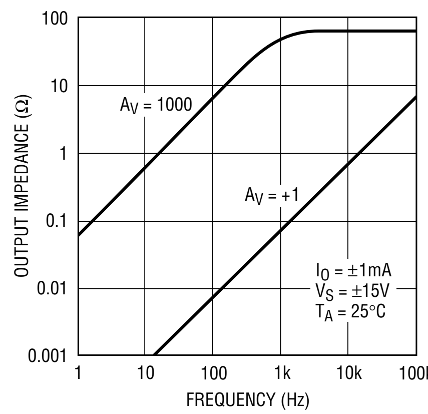
1001 G22

Maximum Undistorted Output vs. Frequency



1001 G23

Closed Loop Output Impedance



1001 G24

APPLICATIONS INFORMATION

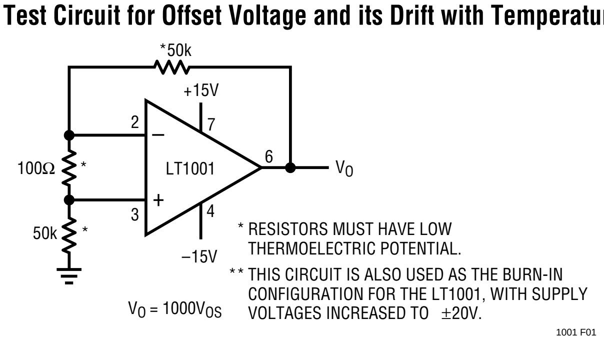
Application Notes and Test Circuits

The LT1001 series units may be inserted directly into OP-07, OP-05, 725, 108A or 101A sockets with or without removal of external frequency compensation or nulling components. The LT1001 can also be used in 741, LF156 or OP-15 applications provided that the nulling circuitry is removed.

The LT1001 is specified over a wide range of power supply voltages from ±3V to ±18V. Operation with lower supplies is possible down to ±1.2V (two Ni-Cad batteries). However, with ±1.2V supplies, the device is stable only in closed loop gains of +2 or higher (or inverting gain of one or higher).

Unless proper care is exercised, thermocouple effects caused by temperature gradients across dissimilar metals at the contacts to the input terminals, can exceed the inherent drift of the amplifier. Air currents over device leads should be minimized, package leads should be short, and the two input leads should be as close together as possible and maintained at the same temperature.

Test Circuit for Offset Voltage and its Drift with Temperature

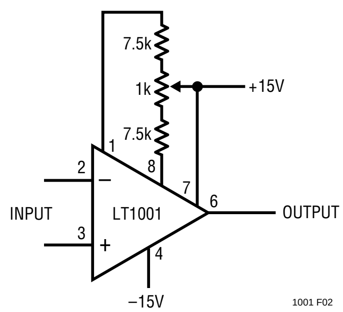


1001 F01

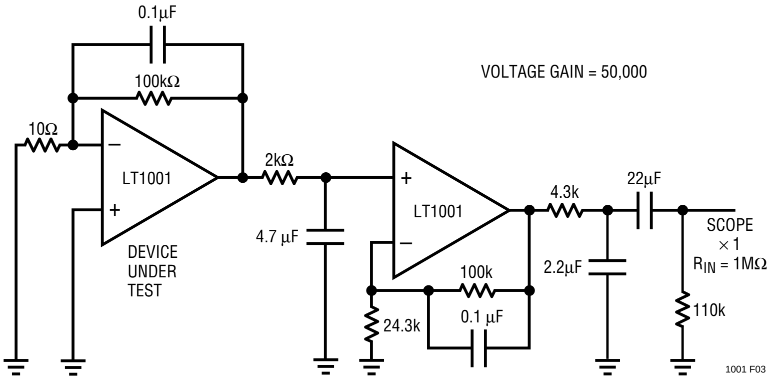
Offset Voltage Adjustment

The input offset voltage of the LT1001, and its drift with temperature, are permanently trimmed at wafer test to a low level. However, if further adjustment of Vos is necessary, nulling with a 10k or 20k potentiometer will not degrade drift with temperature. Trimming to a value other than zero creates a drift of (Vos/300)µV/°C, e.g., if Vos is adjusted to 300 µV, the change in drift will be 1 µV/°C. The adjustment range with a 10k or 20k pot is approximately ±2.5mV. If less adjustment range is needed, the sensitivity and resolution of the nulling can be improved by using a smaller pot in conjunction with fixed resistors. The example below has an approximate null range of ±100 µV.

Improved Sensitivity Adjustment



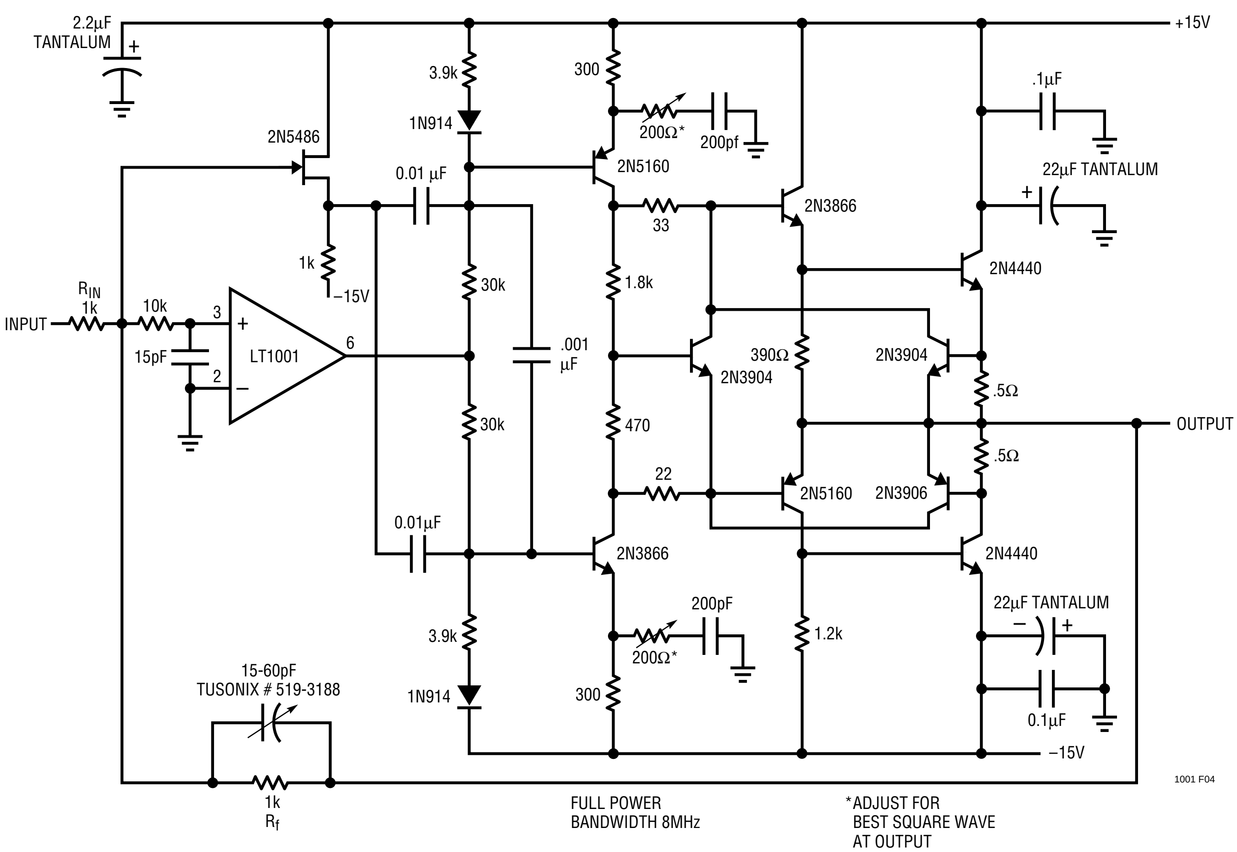
0.1Hz to 10Hz Noise Test Circuit



(Peak-to-Peak noise measured in 10 sec interval)

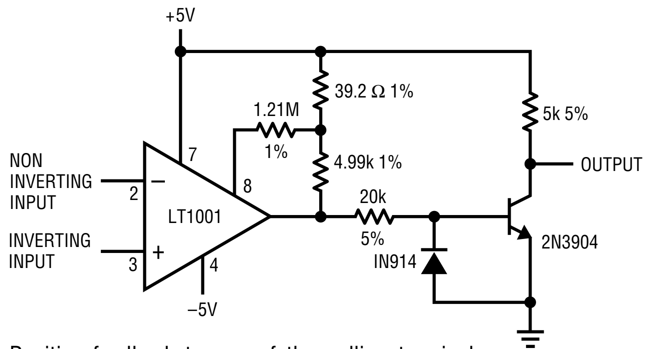
The device under test should be warmed up for three minutes and shielded from air currents.

DC Stabilized
1000v/µsec Op Amp



TYPICAL APPLICATIONS

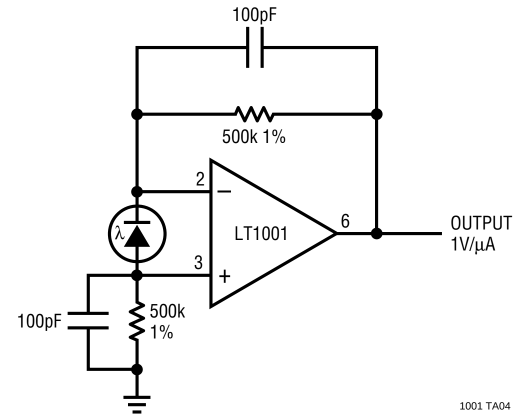
Microvolt Comparator with TTL Output



Positive feedback to one of the nulling terminals creates 5 μ to 20 μV of hysteresis. Input offset voltage is typically changed by less than 5 μV due to the feedback.

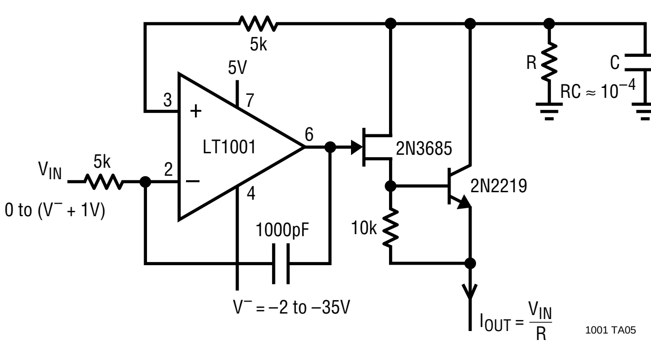
1001 TA03

Photodiode Amplifier



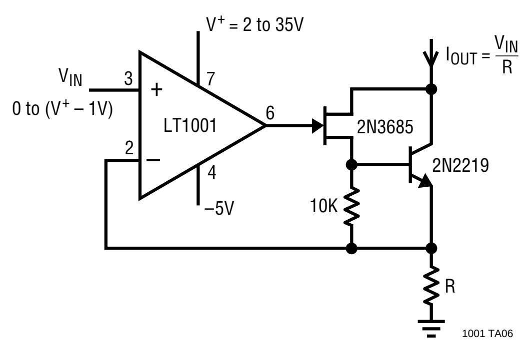
1001 TA04

Precision Current Source



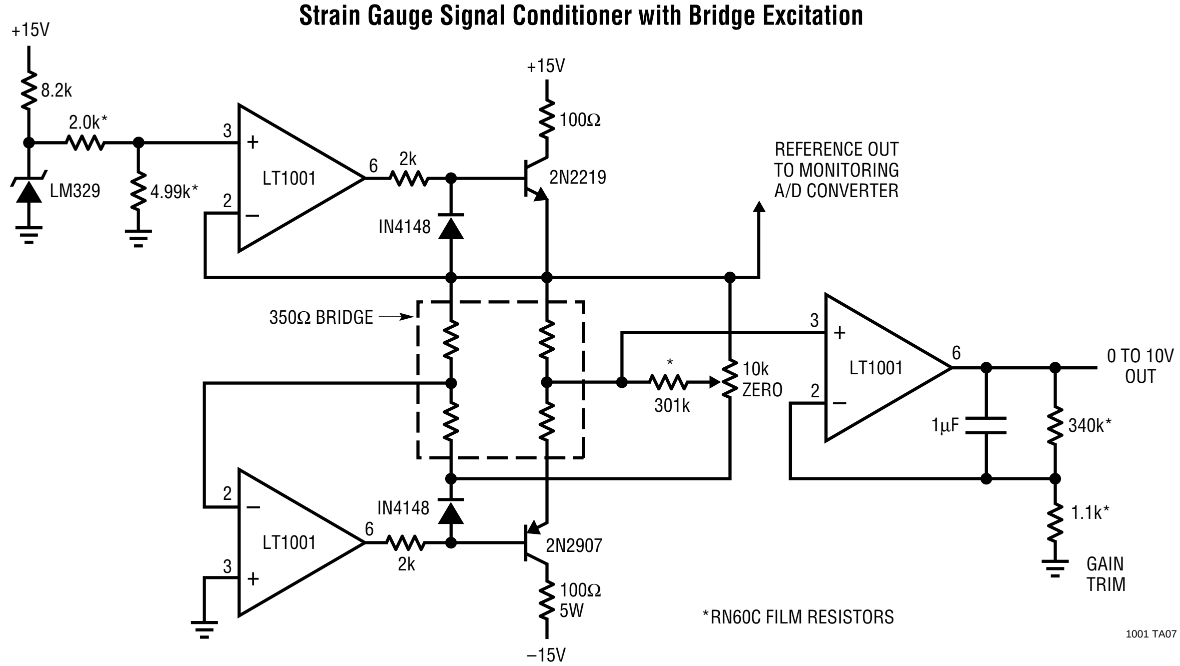
1001 TA05

Precision Current Sink



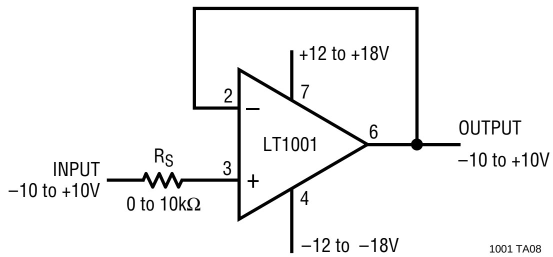
1001 TA06

Strain Gauge Signal Conditioner with Bridge Excitation



1001 TA07

Large Signal Voltage Follower With 0.001% Worst-Case Accuracy

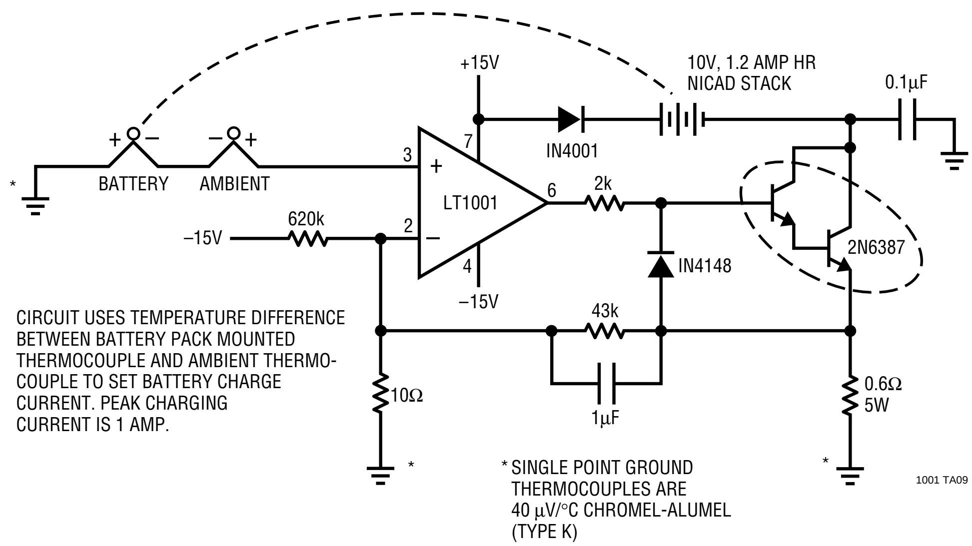


The voltage follower is an ideal example illustrating the overall excellence of the LT1001. The contributing error terms are due to offset voltage, input bias current, voltage gain, common-mode and power-supply rejections. Worst-case summation of guaranteed specifications is tabulated below.

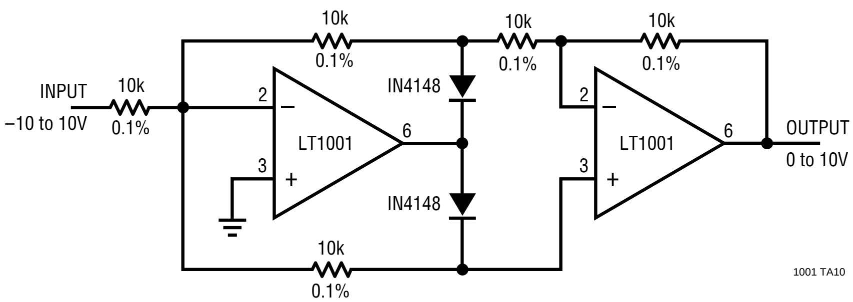
OUTPUT ACCURACY

Error	LT1001AM /883 25°C Max.	LT1001C 25°C Max.	LT1001AM /883 −55 to 125°C Max.	LT1001C 0 to 70°C Max.
Offset Voltage	15µV	60µV	60µV	110µV
Bias Current	20µV	40µV	40µV	55µV
Common-Mode Rejection	20µV	30µV	30µV	50µV
Power Supply Rejection	18µV	30µV	36µV	42µV
Voltage Gain	22µV	25µV	33µV	40µV
Worst-case Sum	95µV	185µV	199µV	297µV
Percent of Full Scale (=20V)	0.0005%	0.0009%	0.0010%	0.0015%

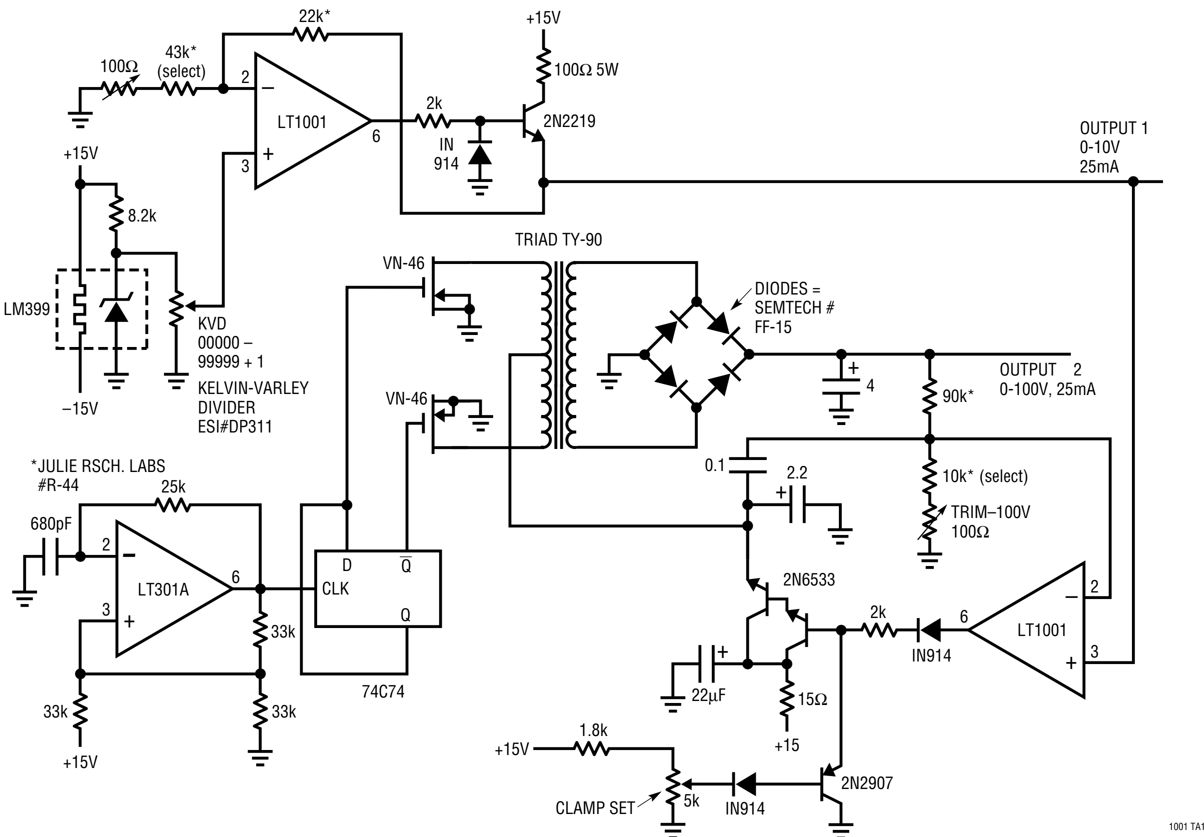
Thermally Controlled NiCad Charger



Precision Absolute Value Circuit

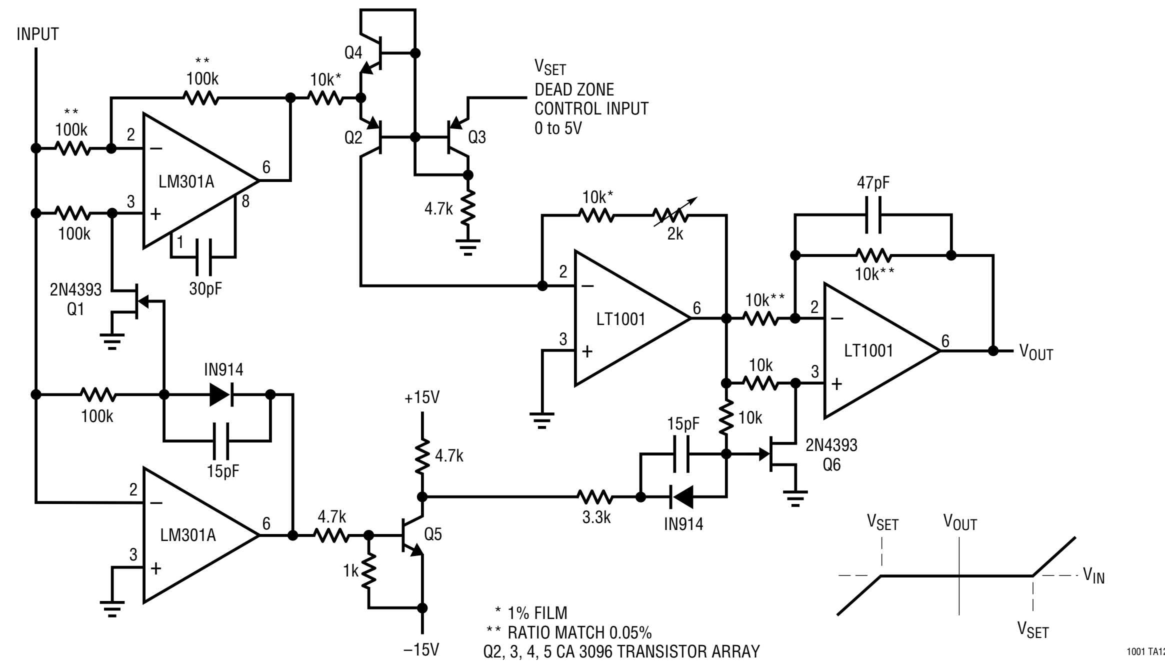


Precision Power Supply with Two Outputs (1) 0V to 10V in 100μV STEPS (2) 0V to 100V in 1mV STEPS

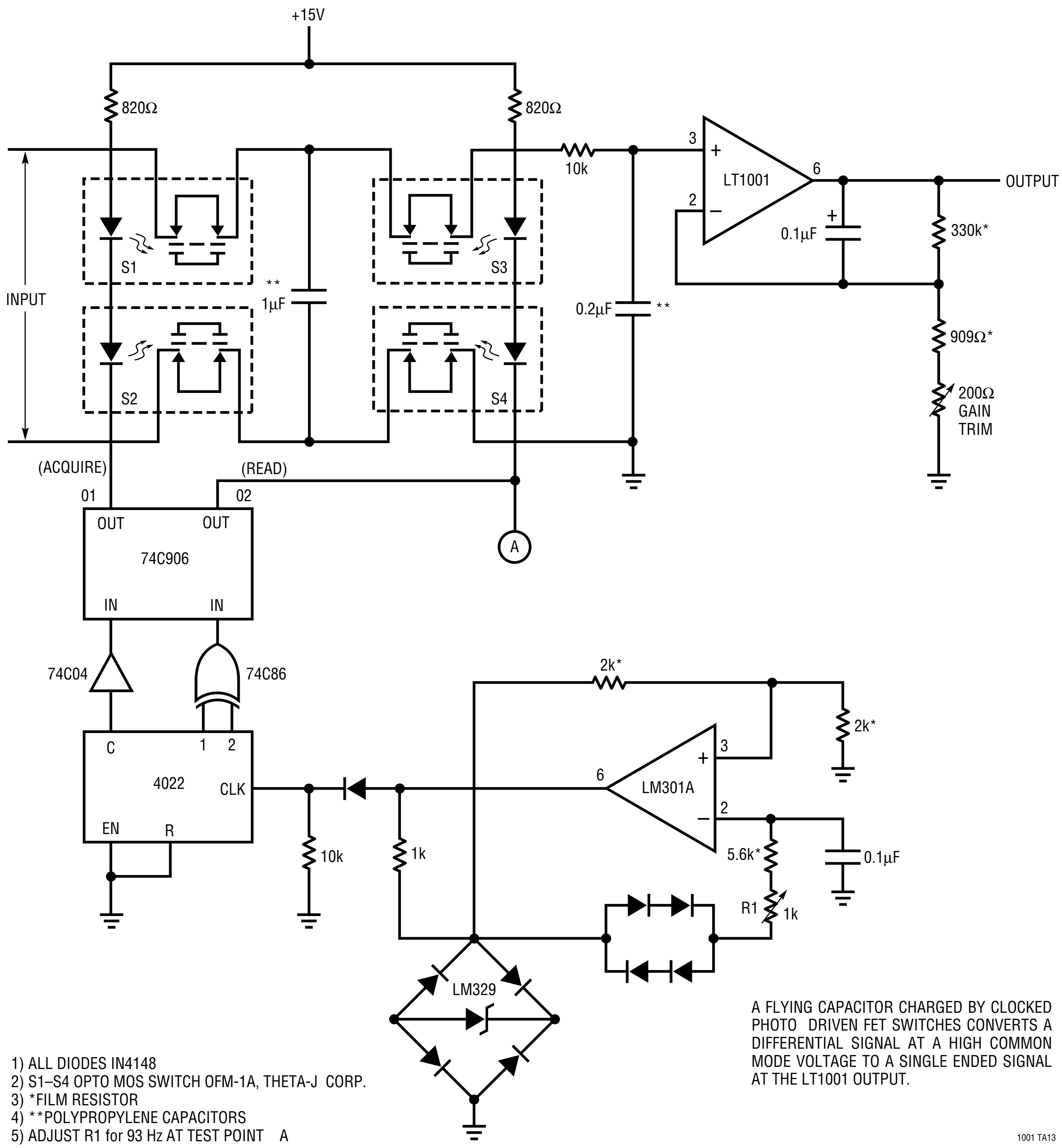


Dead Zone Generator

BIPOLAR SYMMETRY IS EXCELLENT BECAUSE ONE DEVICE, Q2, SETS BOTH LIMITS



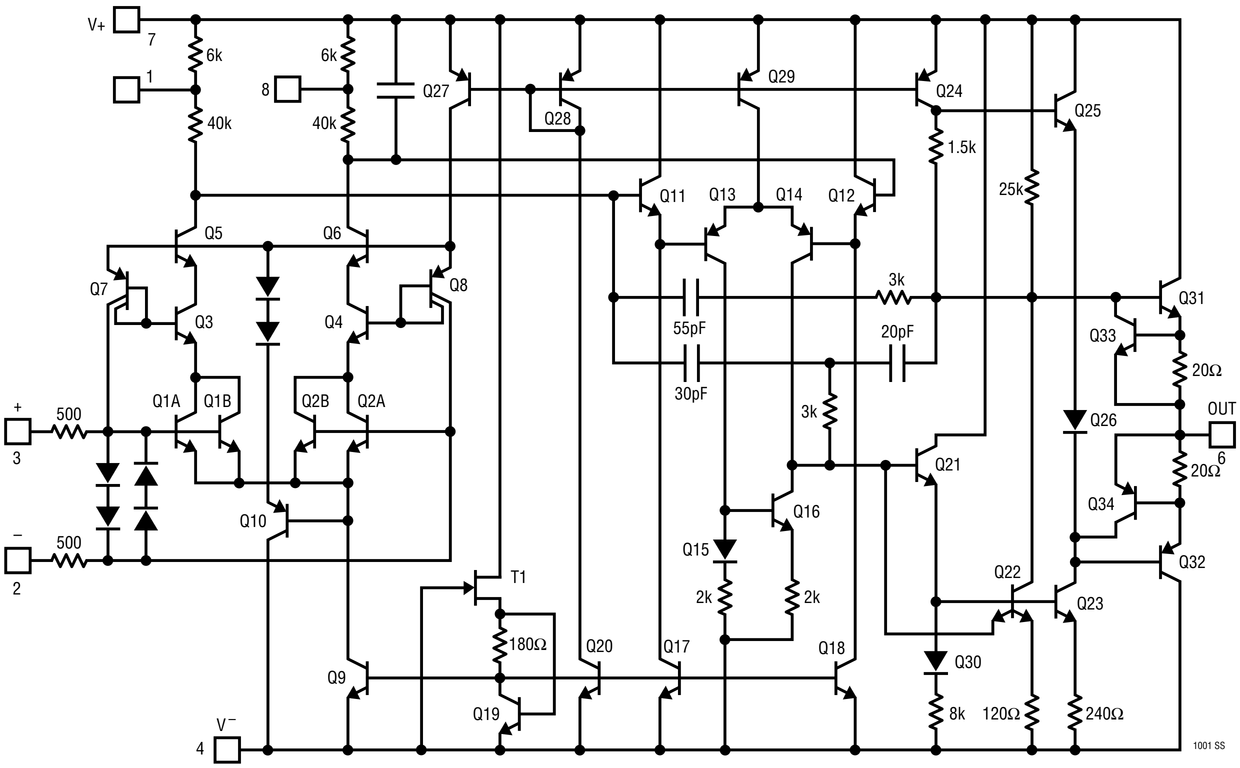
Instrumentation Amplifier with ±300V Common Mode Range and CMRR > 150dB



1) ALL DIODES IN4148
2) S1–S4 OPTO MOS SWITCH OFM-1A, THETA-J CORP.
3) *FILM RESISTOR
4) **POLYPROPYLENE CAPACITORS
5) ADJUST R1 for 93 Hz AT TEST POINT A

A FLYING CAPACITOR CHARGED BY CLOCKED PHOTO DRIVEN FET SWITCHES CONVERTS A DIFFERENTIAL SIGNAL AT A HIGH COMMON MODE VOLTAGE TO A SINGLE ENDED SIGNAL AT THE LT1001 OUTPUT.

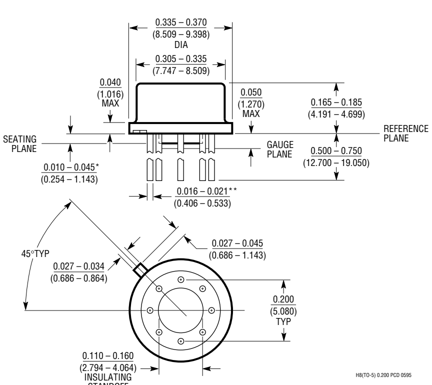
SCHEMATIC DIAGRAM



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

H Package
8-Lead TO-5 Metal Can (0.200 PCD)
(LTC DWG # 05-08-1320)

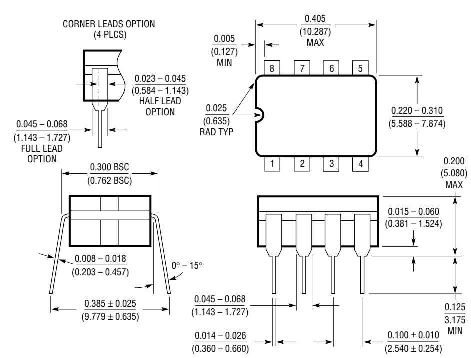


*LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND 0.045" BELOW THE REFERENCE PLANE

**FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS $\frac{0.016 - 0.024}{(0.406 - 0.610)}$

T_{jmax}	θ_{ja}	θ_{jc}
150°C	150°C/W	45°C/W

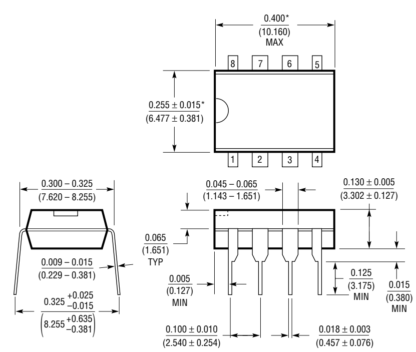
J8 Package
8-Lead CERDIP (Narrow 0.300, Hermetic)
(LTC DWG # 05-08-1110)



NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP/PLATE OR TIN PLATE LEADS.

T_{jmax}	θ_{ja}
150°C	100°C/W

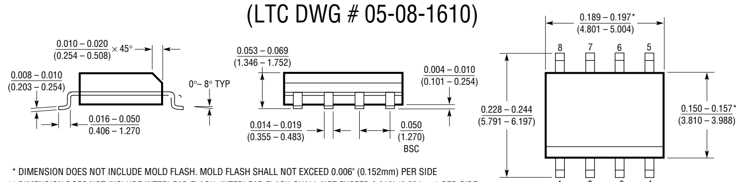
N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



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

T_{jmax}	θ_{ja}
150°C	130°C/W

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

T_{jmax}	θ_{ja}
150°C	150°C/W