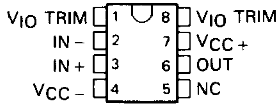
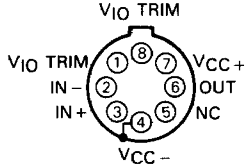
- **Low Input Offset Voltage:**
  LT1001AM . . . 15 µV Max
  LT1001AC . . . 25 µV Max
  LT1001M, LT1001C . . . 60 µV Max
- **Low Offset Voltage Temperature Coefficient:**
  LT1001AM, LT1001AC . . . 0.6 µV/°C Max
  LT1001M, LT1001C . . . 1 µV/°C Max
- **Low Input Bias Current:**
  LT1001AM, LT1001AC . . . ±2 nA Max
  LT1001M, LT1001C . . . ±4 nA Max
- **Low Common-Mode Rejection Ratio:**
  LT1001AM, LT1001AC . . . 114 dB Min
  LT1001M, LT1001C . . . 110 dB Min
- **Low Supply Voltage Rejection Ratio:**
  LT1001AM, LT1001AC . . . 110 dB Min
  LT1001M, LT1001C . . . 106 dB Min
- **Low Power Dissipation:**
  LT1001AM, LT1001AC . . . 75 mW Max
  LT1001M, LT1001C . . . 80 mW Max
- **Low Peak-to-Peak Equivalent Input Noise Voltage . . . 0.3 µV Typ**

D, JG, OR P PACKAGE
(TOP VIEW)



L PACKAGE
(TOP VIEW)



NC—No internal connection
Pin 4 (L package) is in electrical contact with the case.

description

The LT1001 is a precision operational amplifier suited for applications such as thermocouple amplifiers, strain gauge amplifiers, low-level signal processing, and high-accuracy data acquisition. In the design, processing, and testing of the device, particular attention has been paid to optimizing the entire distribution of several key parameters. The input offset voltage of all units is less than 60 µV, and the LT1001AM is specified at 15 µV maximum. Power dissipation is nearly halved compared to the most popular precision operational amplifiers without adversely affecting noise or speed performance. The output drive capability of the LT1001 is enhanced with voltage gain at a load current of 10 mA.

The specifications of the low-cost commercial-temperature device, the LT1001C, have been significantly improved when compared to equivalent grades of similar precision amplifiers. The input bias current, input offset current, and common-mode and supply voltage rejection ratios of the LT1001C offer performance previously attainable only with high-cost, selected grades of other devices.

The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C. The C-suffix devices are characterized for operation from 0°C to 70°C.

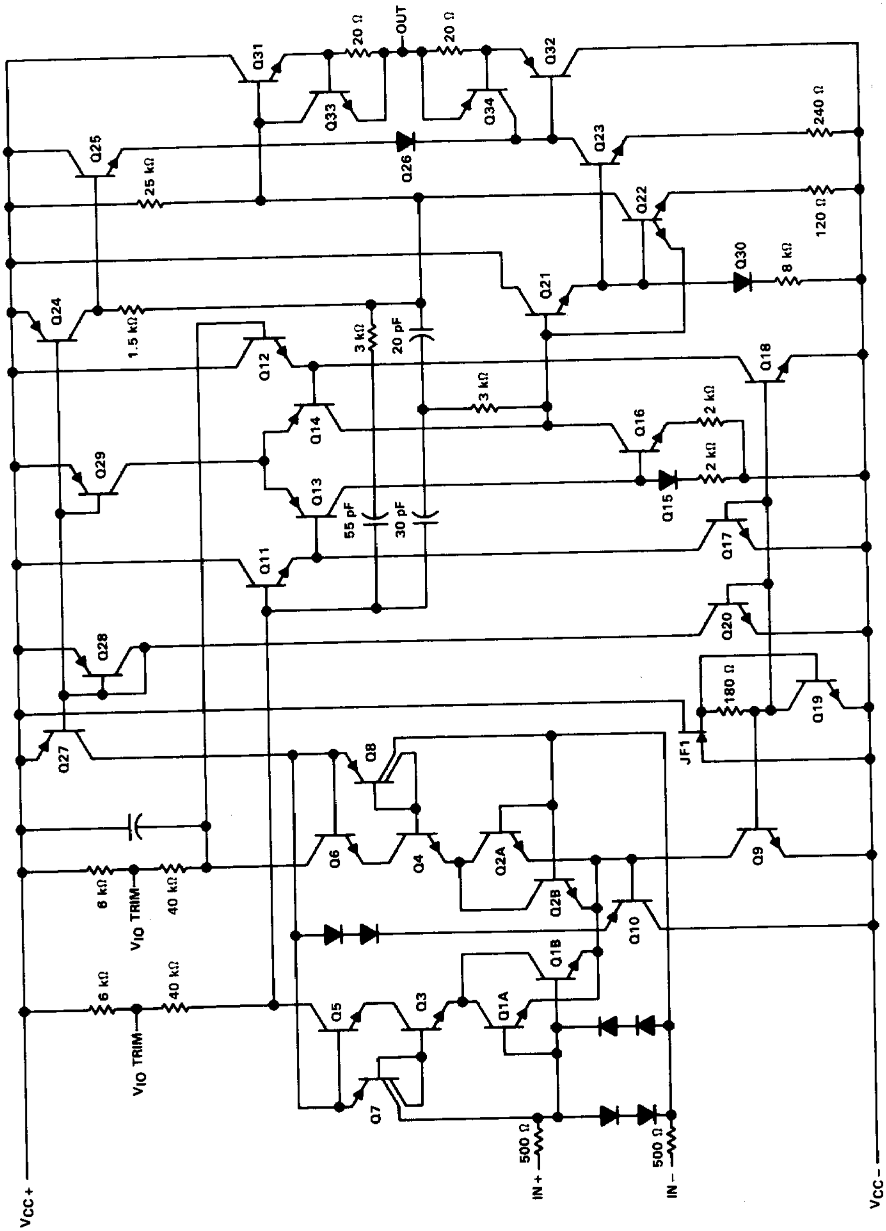
AVAILABLE OPTIONS

T_A	V_{IO} MAX	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C	60 µV	LT1001CD	LT1001CJG	LT1001CL	LT1001CP
to 70°C	25 µV		LT1001ACJG	LT1001ACL	LT1001ACP
−55°C	60 µV		LT1001MJG	LT1001ML	
to 125°C	15 µV		LT1001AMJG	LT1001AML	

The D package is available in tape and reel. Add the suffix R to the device type (e.g., LT1001CDR).

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

schematic



Component values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC+} (see Note 1) .... 22 V
Supply voltage, V_{CC-} .... −22 V
Differential input voltage (see Note 2) .... ±30 V
Input voltage range, V_I .... ±22 V
Duration of short-circuit current at (or below) 25°C .... unlimited
Continuous power dissipation .... See Dissipation Rating Table
Operating free-air temperature range: M-suffix .... −55°C to 125°C
C-suffix .... 0°C to 70°C
Storage temperature range .... −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package .... 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package .... 260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	145 mW
JG (M-suffix)	1050 mW	8.4 mW/°C	672 mW	210 mW
JG (C-suffix)	825 mW	6.6 mW/°C	528 mW	N/A
L (M-suffix)	825 mW	6.6 mW/°C	528 mW	165 mW
L (C-suffix)	650 mW	5.2 mW/°C	416 mW	N/A
P	1000 mW	8.0 mW/°C	640 mW	200 mW

recommended operating conditions

		M-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC+}		4	15	22	4	15	22	V
Supply voltage, V_{CC-}		−4	−15	−22	−4	−15	−22	V
Common-mode input voltage, V_{IC}	$V_{CC\pm} = \pm15$ V			±13			±13	V
Operating free-air temperature, T_A		−55		125	0		70	°C

electrical characteristics, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A	LT1001M			LT1001AM			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	See Note 3	25°C		18	60		7	15	µV
			−55°C to 125°C			160			60	
α_{VIO}	Average temperature coefficient of input offset voltage		−55°C to 125°C		0.3	1		0.2	0.6	µV/°C
	Long-term drift of input offset voltage	See Note 4			0.3	1.5		0.2	1	µV/mo
I_{IO}	Input offset current	V_O = 0, V_{IC} = 0	25°C		0.4	3.8		0.3	2	nA
			−55°C to 125°C			7.6			4	
I_{IB}	Input bias current	V_O = 0, V_{IC} = 0	25°C		±0.7	±4		±0.5	±2	nA
			−55°C to 125°C			±8			±4	
V_{OH}	Maxiumum peak output voltage swing	R_L ≥ 2 kΩ	25°C	±13	±14		±13	±14		V
		R_L ≥ 1 kΩ	25°C	±12	±13.5		±12	±13.5		
		R_L ≥ 2 kΩ	−55°C to 125°C	±12			±12.5			
A_{VD}	Large-signal differential voltage amplification	R_L ≥ 2 kΩ, V_O = ±12 V	25°C	400	800		450	800		V/mV
		R_L ≥ 1 kΩ, V_O = ±10 V	25°C	250	500		300	500		
		R_L ≥ 2 kΩ, V_O = ±10 V	−55°C to 125°C	200			300			
r_{id}	Differential input resistance		25°C	15	80		30	100		MΩ
CMRR	Common-mode rejection ratio	V_{IC} = ±13 V	25°C	110	126		114	126		dB
			−55°C to 125°C	106			110			
k_{SVR}	Supply voltage rejection ratio	$V_{CC\pm}$ = ±3 V to ±18 V	25°C	106	123		110	123		dB
			−55°C to 125°C	100			104			
P_D	Total power dissipation	No load	25°C		48	80		46	75	mW
		No load, $V_{CC\pm}$ = ± 3 V	25°C		4	8		4	6	
		No load	−55°C to 125°C			100			90	

NOTES: 3. The input offset voltage for all devices is measured with high-speed test equipment approximately 1 second after power is applied. The LT1001AM receives a 168-hour burn-in at 125°C or equivalent.

4. Long-term drift of input offset voltage refers to the average trend line of offset voltage versus time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, the change in V_{IO} during the first 30 days is typically 2.5 µV.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		LT1001M			LT1001AM			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L ≥ 2 kΩ		0.1	0.25		0.1	0.25		V/µs
ϕ_m	Phase margin at unity gain	A_V = 40 dB,	T_A = 25°C		60°			63°		
		R_S = 100 Ω,	T_A = MIN		63°			63°		
		C_L = 10 pF	T_A = MAX		57°			57°		
V_{NPP}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz			0.3	0.6		0.3	0.6	µV
V_n	Equivalent input noise voltage	f = 10 Hz			10.5	18		10.3	18	nV/√Hz
		f = 1 MHz			9.8	11		9.6	11	
GBW	Gain bandwidth product			0.4	0.8		0.4	0.8		MHz

TEXAS INSTRUMENTS
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electrical characteristics, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A	LT1001C			LT1001AC			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	See Note 5	25°C		18	60		10	25	µV
			0°C to 70°C			110			60	
α_{VIO}	Average temperature coefficient of input offset voltage		0°C to 70°C		0.3	1		0.2	0.6	µV/°C
	Long-term drift of input offset voltage	See Note 4			0.3	1.5		0.2	1	µV/mo
I_{IO}	Input offset current	V_O = 0, V_{IC} = 0	25°C		0.4	3.8		0.3	2	nA
			0°C to 70°C			5.3			3.5	
I_{IB}	Input bias current	V_O = 0, V_{IC} = 0	25°C		±0.7	±4		±0.5	±2	nA
			0°C to 70°C			±5.5			±3.5	
V_{OH}	Maximum peak output voltage swing	R_L ≥ 2 kΩ	25°C	±13	±14		±13	±14		V
		R_L ≥ 1 kΩ	25°C	±12	±13.5		±12	±13.5		
		R_L ≥ 2 kΩ	0°C to 70°C	±12.5			±12.5			
A_{VD}	Large-signal differential voltage amplification	R_L ≥ 2 kΩ, V_O = ±12 V	25°C	400	800		450	800		V/mV
		R_L ≥ 1 kΩ, V_O = ±10 V	25°C	250	500		300	500		
		R_L ≥ 2 kΩ, V_O = ±10 V	0°C to 70°C	250			350			
r_{id}	Differential input resistance		25°C	15	80		30	100		MΩ
CMRR	Common-mode rejection ratio	V_{IC} = ±13 V	25°C	110	126		114	126		dB
			0°C to 70°C	106			110			
k_{SVR}	Supply voltage rejection ratio	$V_{CC\pm}$ = ±3 V to ±18 V	25°C	106	123		110	123		dB
			0°C to 70°C	103			106			
P_D	Total power dissipation	No load	25°C		48	80		46	75	mW
		No load, $V_{CC\pm}$ = ± 3 V	25°C		4	8		4	6	
		No load	0°C to 70°C			90			85	

Notes: 4. Long-term drift of input offset voltage refers to the average trend line of offset voltage versus time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, the change in V_{IO} during the first 30 days is typically 2.5 µV.
5. The input offset voltage for all devices is measured with high-speed test equipment approximately 1 second after power is applied.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		LT1001C			LT1001AC			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L ≥ 2 kΩ		0.1	0.25		0.1	0.25		V/µs
ϕ_m	Phase margin at unity gain	A_V = 40 dB,	T_A = 25°C		60°			63°		
		R_S = 100 Ω,	T_A = MIN		63°			63°		
		C_L = 10 pF	T_A = MAX		57°			57°		
V_{NPP}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz			0.3	0.6		0.3	0.6	µV
V_n	Equivalent input noise voltage	f = 10 Hz			10.5	18		10.3	18	nV/√Hz
		f = 1 MHz			9.8	11		9.6	11	
GBW	Gain bandwidth product			0.4	0.8		0.4	0.8		MHz

TYPICAL CHARACTERISTICS†

INPUT OFFSET VOLTAGE
OF REPRESENTATIVE UNITS
vs
FREE-AIR TEMPERATURE

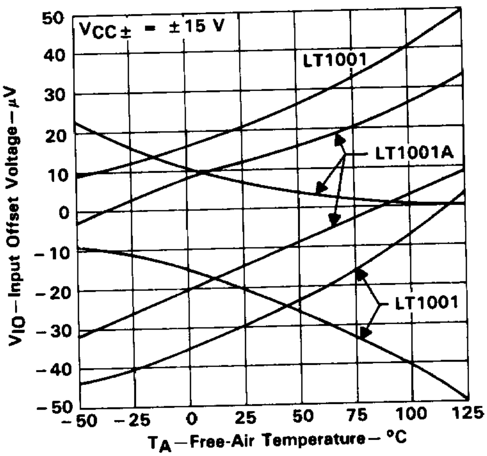

FIGURE 1

WARM-UP CHANGE
IN INPUT OFFSET VOLTAGE
vs
ELAPSED TIME

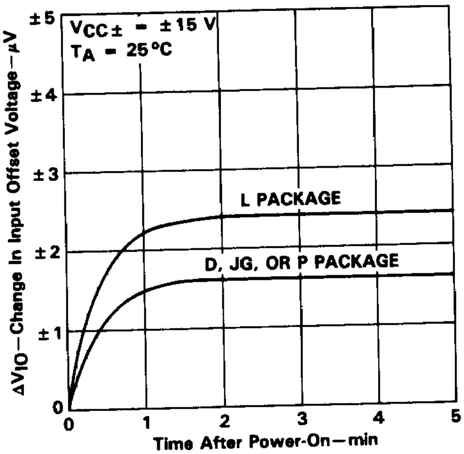

FIGURE 2

LONG-TERM DRIFT OF
INPUT OFFSET VOLTAGE
OF REPRESENTATIVE UNITS

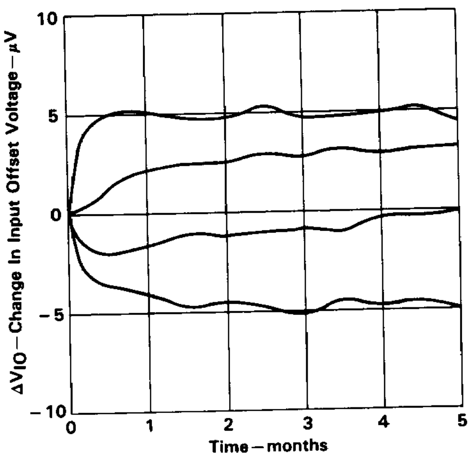

FIGURE 3

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS†

INPUT OFFSET CURRENT
and INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

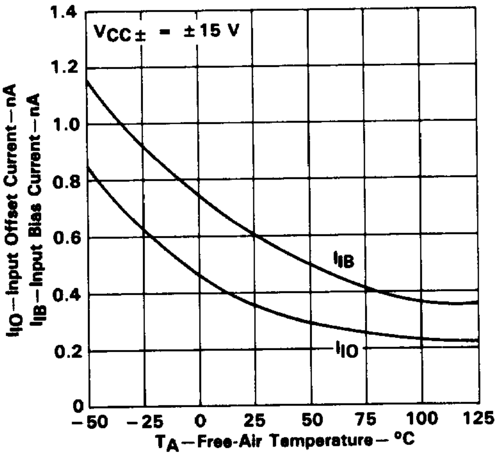

FIGURE 4

INPUT BIAS CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

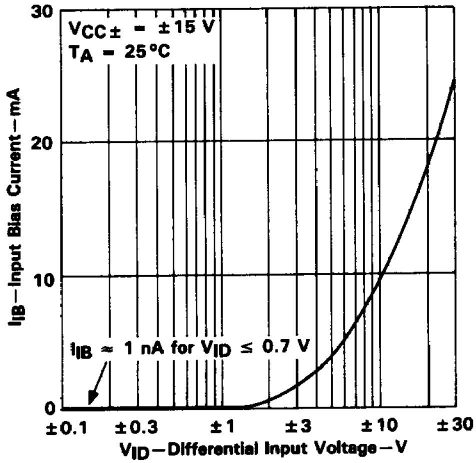

FIGURE 5

2
Operational Amplifiers

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

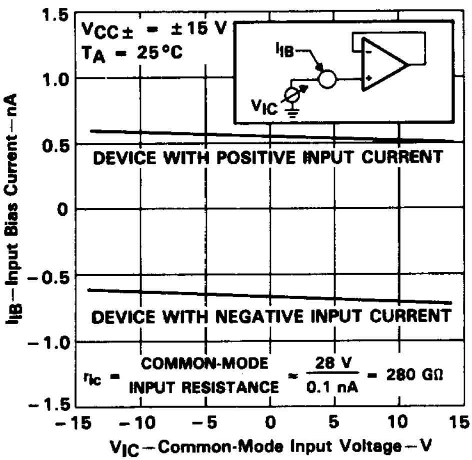

FIGURE 6

COMMON-MODE INPUT VOLTAGE RANGE LIMITS
vs
FREE-AIR TEMPERATURE

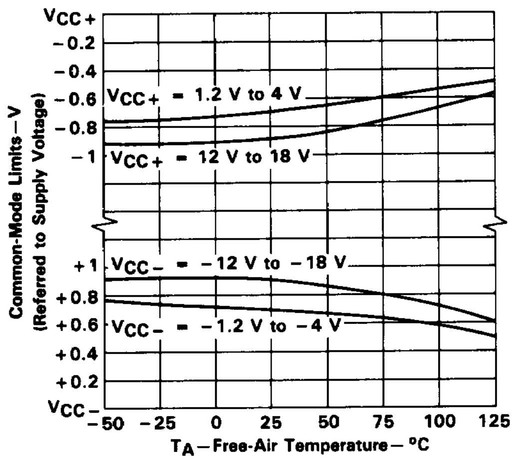

FIGURE 7

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

MAXIMUM PEAK
OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE

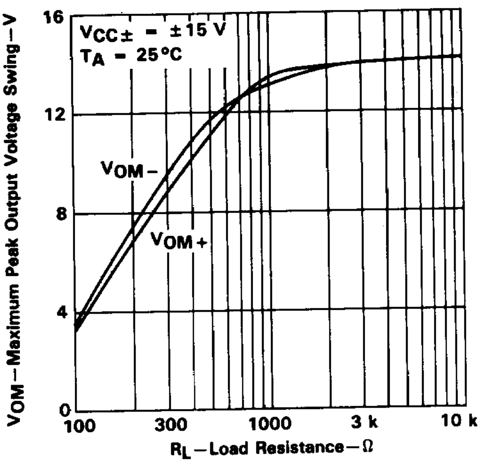

FIGURE 8

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE SWING
vs
FREQUENCY

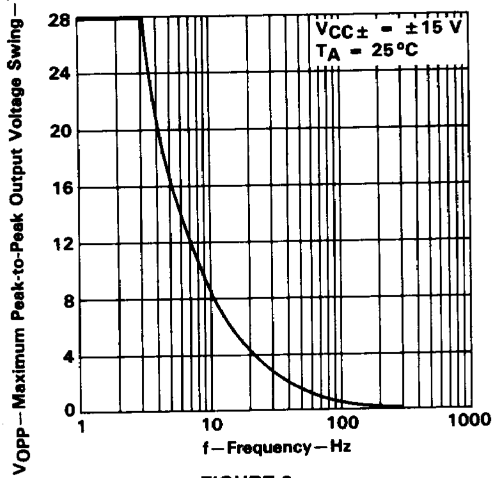

FIGURE 9

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
FREQUENCY

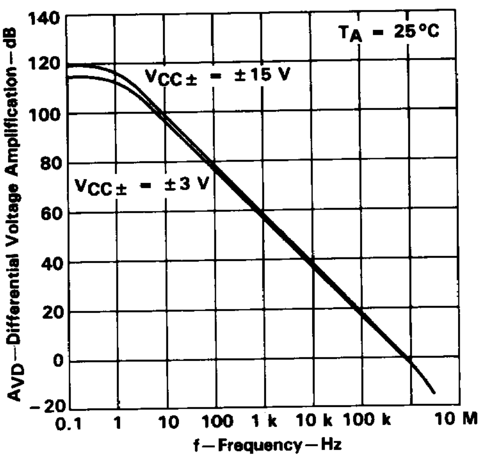

FIGURE 10

DIFFERENTIAL VOLTAGE AMPLIFICATION
and PHASE SHIFT
vs
FREQUENCY

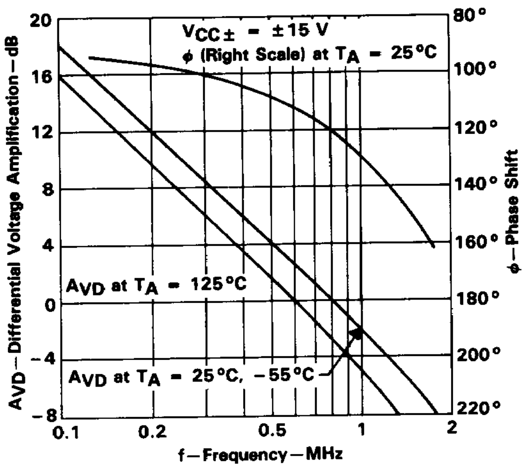

FIGURE 11

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS†

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

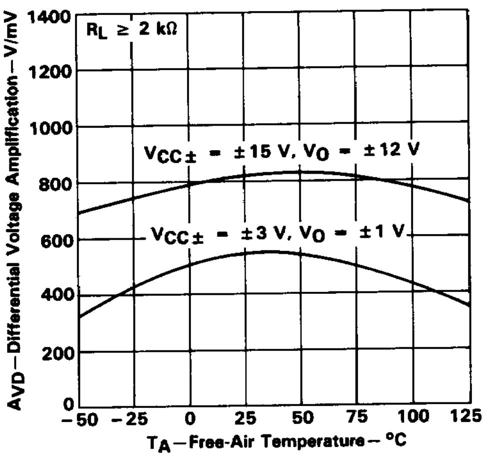


FIGURE 12

OUTPUT IMPEDANCE
vs
FREQUENCY

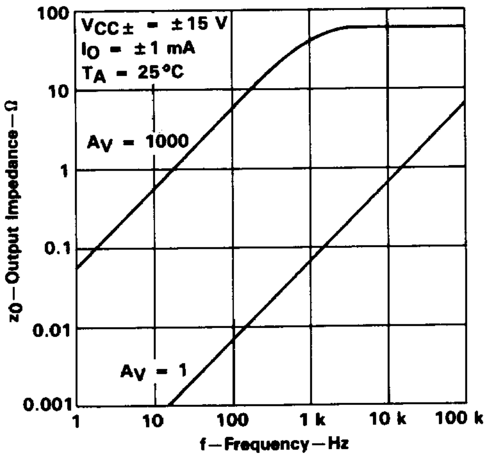


FIGURE 13

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

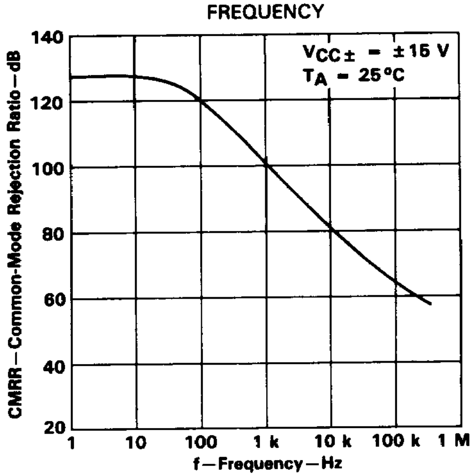


FIGURE 14

SUPPLY VOLTAGE REJECTION RATIO
vs
FREQUENCY

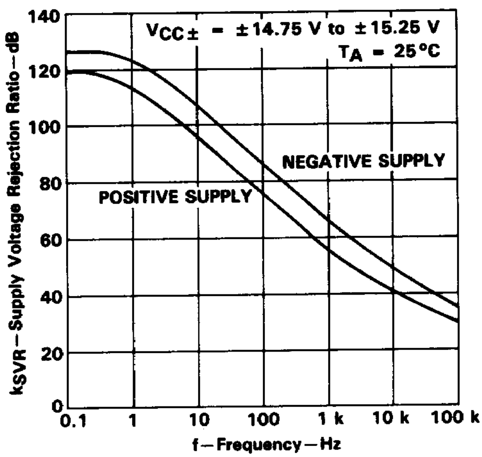


FIGURE 15

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

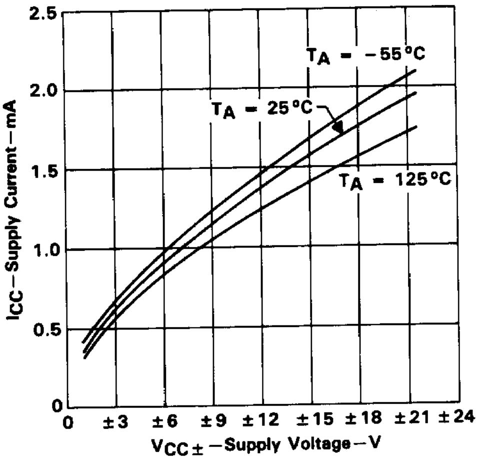


FIGURE 16

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

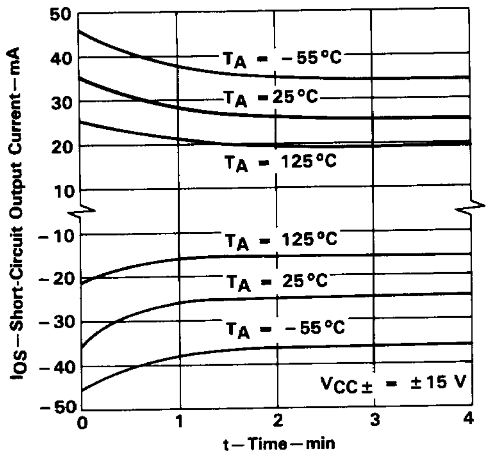


FIGURE 17

EQUIVALENT INPUT NOISE VOLTAGE
and EQUIVALENT INPUT NOISE CURRENT
vs
FREQUENCY

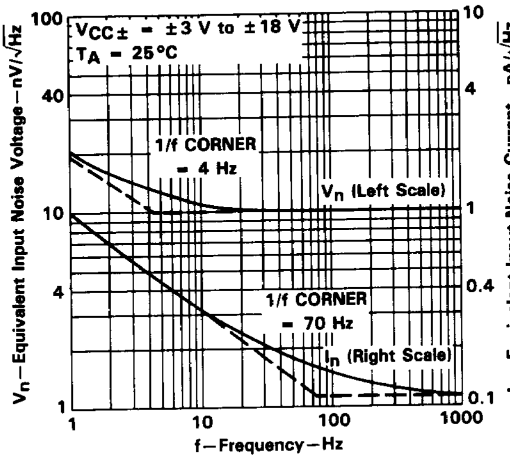


FIGURE 18

OUTPUT NOISE VOLTAGE
OVER A
10-SECOND PERIOD

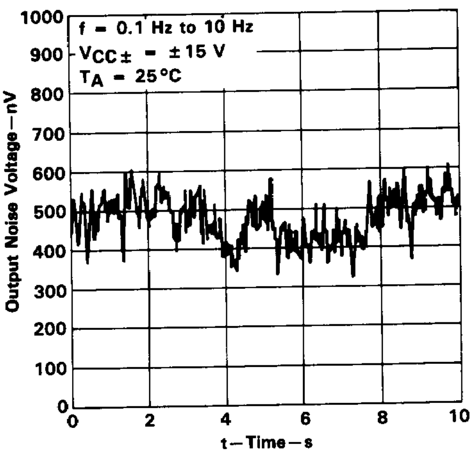


FIGURE 19

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

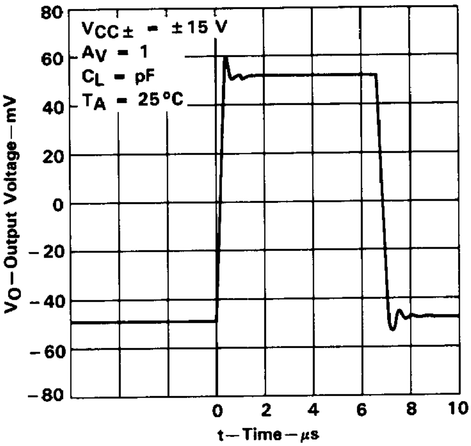


FIGURE 20

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

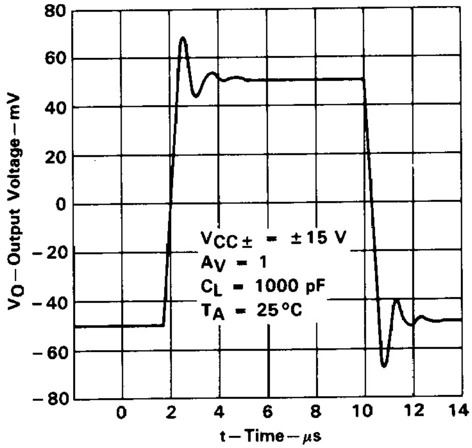


FIGURE 21

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE-RESPONSE

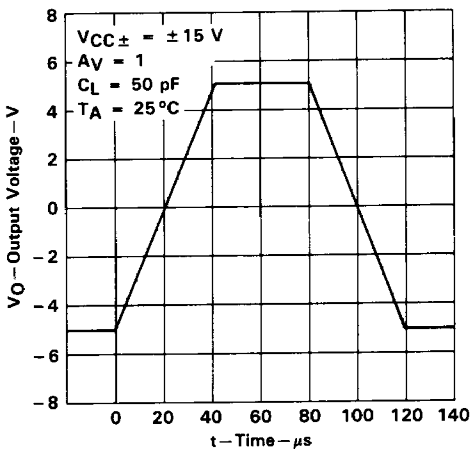


FIGURE 22

VOLTAGE-FOLLOWER OVERSHOOT
vs
LOAD CAPACITANCE

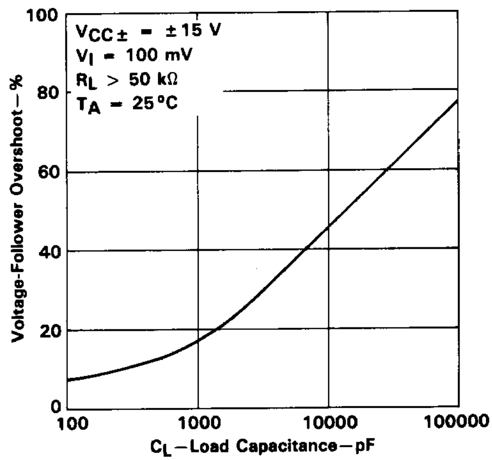
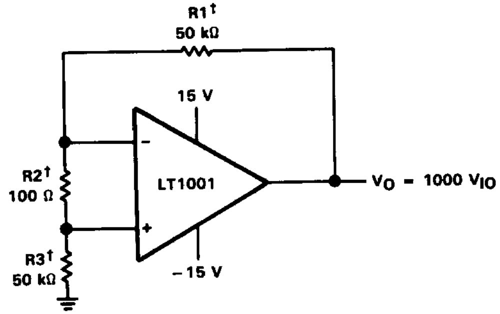


FIGURE 23

2

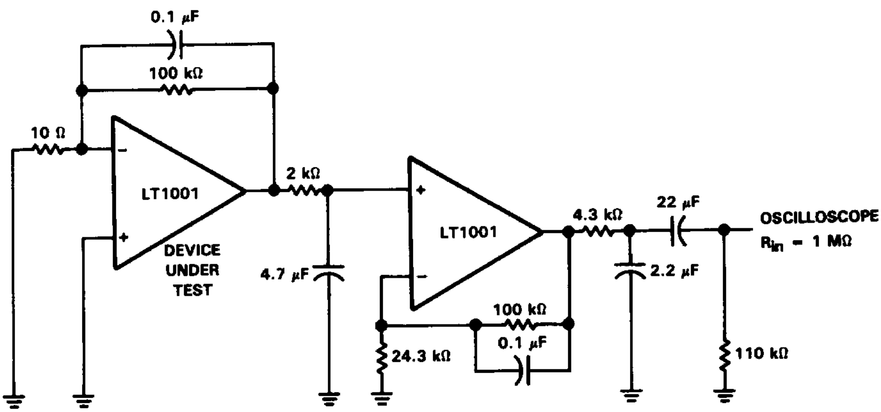
Operational Amplifiers

PARAMETER MEASUREMENT INFORMATION



†Resistors must have low thermoelectric potential.
NOTE: This circuit is also used as the burn-in configuration for the LT1001 with supply voltages increased to ±20 V, R1 = R3 = 10 kΩ, R2 = 200 Ω, and A_V = 100.

FIGURE 24. TEST CIRCUIT FOR INPUT OFFSET VOLTAGE AND ITS TEMPERATURE COEFFICIENT



NOTES: A. A_V = 50,000.
B. The device under test should be warmed up for three minutes and shielded from air currents.

FIGURE 25. TEST CIRCUIT FOR 0.1-Hz TO 10-Hz PEAK-TO-PEAK NOISE VOLTAGE (MEASURED OVER A 10-SECOND INTERVAL)

TYPICAL APPLICATION DATA

application notes

The LT1001 series units may be inserted directly into OP-07 or LM108A sockets with or without removing external frequency compensation or nulling components.

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

input offset voltage adjustment

The input offset voltage and temperature coefficient of the LT1001 are permanently trimmed to a low level at wafer test. However, if further adjustment of V_{IO} is necessary, nulling with a 10-kΩ or 20-kΩ potentiometer will not degrade the temperature coefficient. Trimming to a value other than zero creates a temperature coefficient change of (V_{IO}/300) µV/°C. For example, if V_{IO} is adjusted to 300 µV, the change in the temperature coefficient will be 1 µV/°C. The adjustment range with a 10-kΩ or 20-kΩ potentiometer is approximately ±2.5 mV. If less adjustment range is needed, the sensitivity and resolution of the nulling can be improved by using a smaller potentiometer in conjunction with fixed resistors. The example in Figure 26 has an approximate null range of ±100 µV.

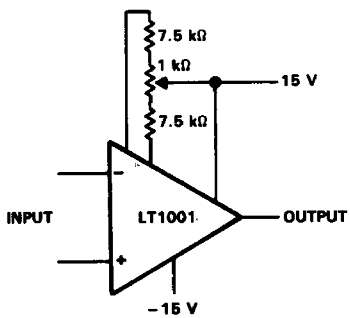
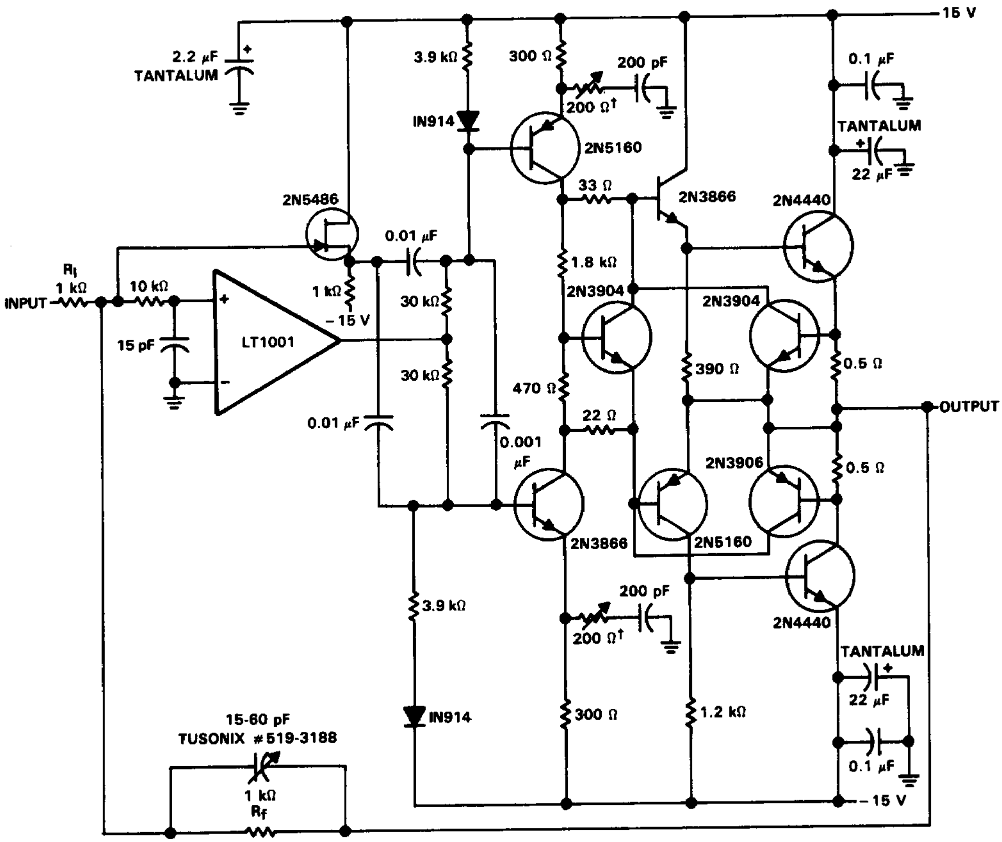


FIGURE 26. IMPROVED SENSITIVITY ADJUSTMENT

TYPICAL APPLICATION DATA



†Adjust for best square wave at output.
NOTE: Full-power bandwidth is 8 MHz.

FIGURE 27. DC-STABILIZED 1000-V/µs OPERATIONAL AMPLIFIER

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TYPICAL APPLICATION DATA

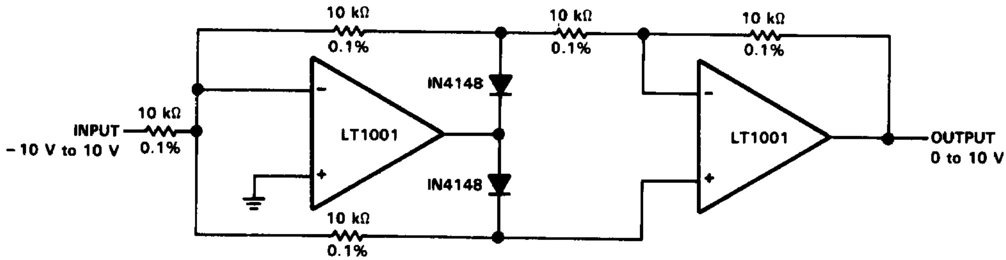


FIGURE 28. PRECISION ABSOLUTE VALUE CIRCUIT

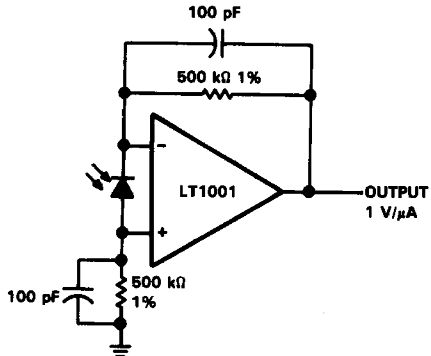


FIGURE 29. PHOTODIODE AMPLIFIER

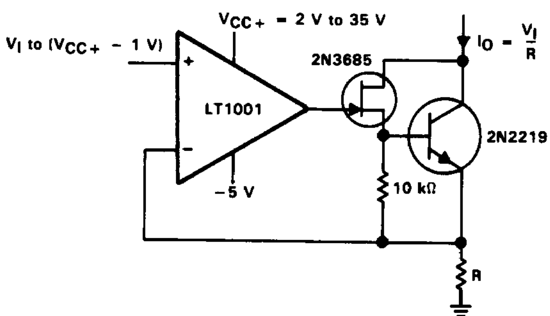
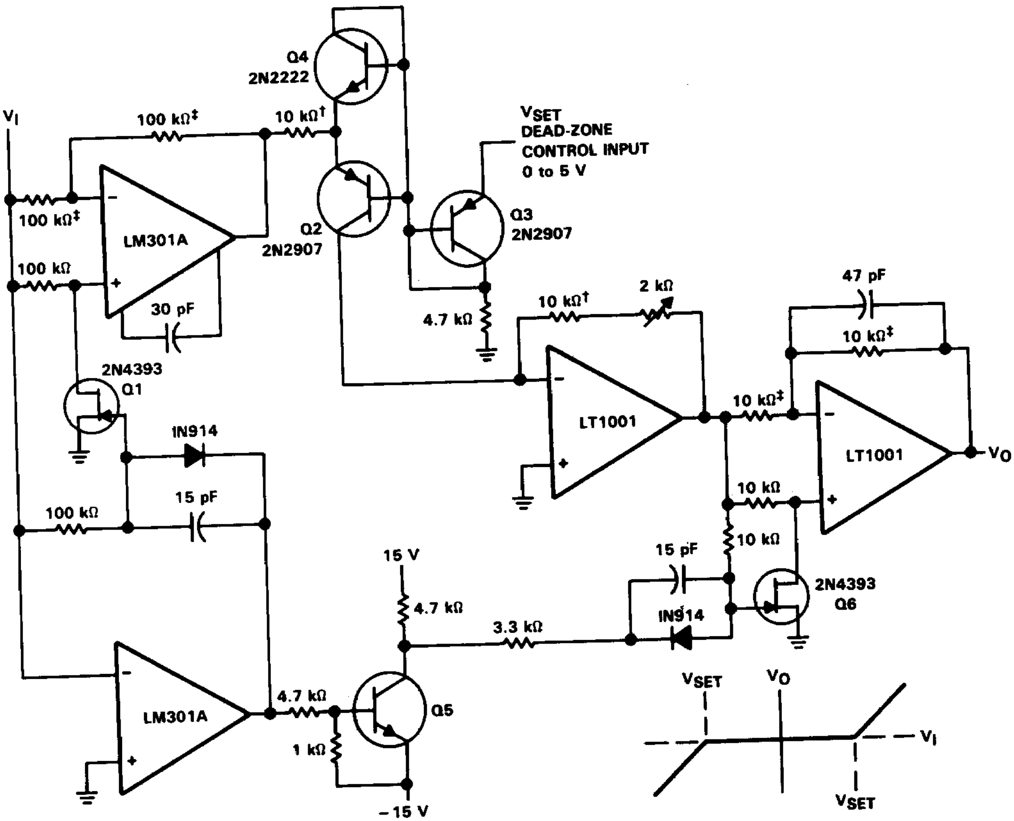


FIGURE 30. PRECISION CURRENT SINK

TYPICAL APPLICATION DATA



† 1% film
‡ Ratio match 0.05%

NOTES: A. The bipolar symmetry for this application is excellent because one device, Q2, sets both limits.
B. Q2-Q5 are a CA 3096 transistor array.

FIGURE 31. DEAD-ZONE GENERATOR

TYPICAL APPLICATION DATA

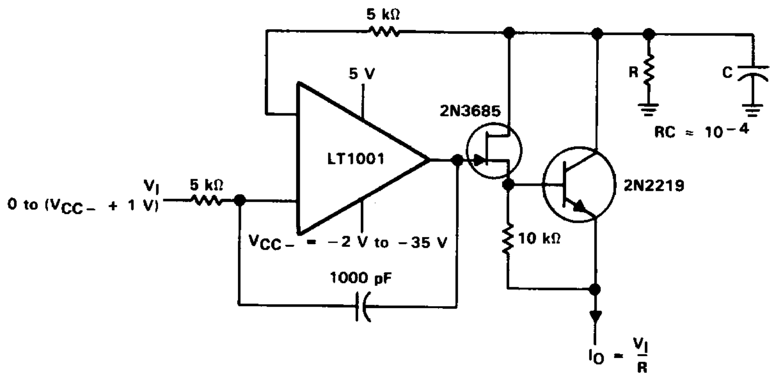
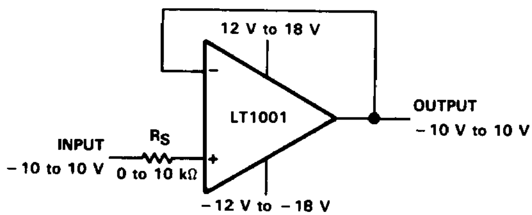


FIGURE 32. PRECISION CURRENT SOURCE



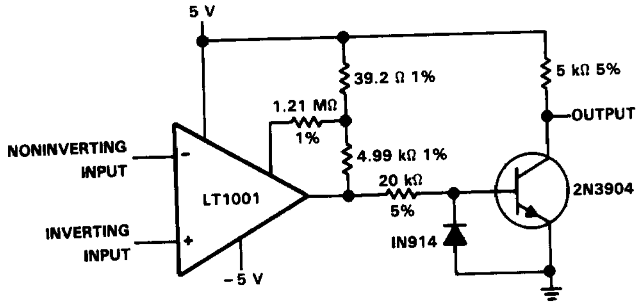
OUTPUT ACCURACY

ERROR	LT1001AM T_A = 25°C MAX	LT1001C T_A = 25°C MAX	LT1001AM T_A = −55°C to 125°C MAX	LT1001C T_A = 0°C to 70°C MAX
Input Offset Voltage	15 μV	60 μV	60 μV	110 μV
Input Bias Current	20 μV	40 μV	40 μV	55 μV
Common-Mode Rejection Ratio	20 μV	30 μV	30 μV	50 μV
Supply Voltage Rejection Ratio	18 μV	30 μV	36 μV	42 μV
Differential Voltage Amplification	22 μV	25 μV	33 μV	40 μV
Worst-case Sum	95 μV	185 μV	199 μV	297 μV
Percent of Full Scale (= 20 V)	0.0005%	0.0009%	0.0010%	0.0015%

NOTE: The contributing error terms are due to input offset voltage, input bias current, voltage gain, common-mode rejection ratio, and supply voltage rejection ratio. The worst-case specifications are given in the above table.

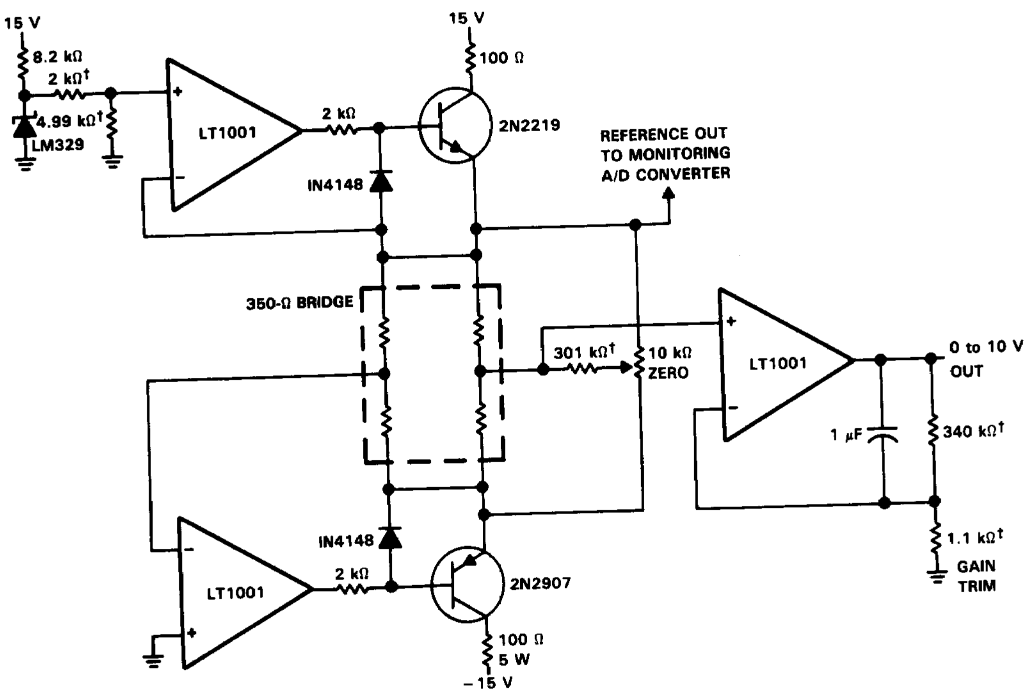
FIGURE 33. LARGE-SIGNAL VOLTAGE FOLLOWER WITH 0.001% WORST-CASE ACCURACY

TYPICAL APPLICATION DATA



NOTE: Positive feedback to one of the nulling terminals creates 5 μV to 20 μV of hysteresis. The input offset voltage is typically changed by less than 5 μV due to the feedback.

FIGURE 34. MICROVOLT COMPARATOR WITH TTL OUTPUT



†RN60C film resistors

FIGURE 35. STRAIN-GAUGE SIGNAL CONDITIONER WITH BRIDGE EXCITATION

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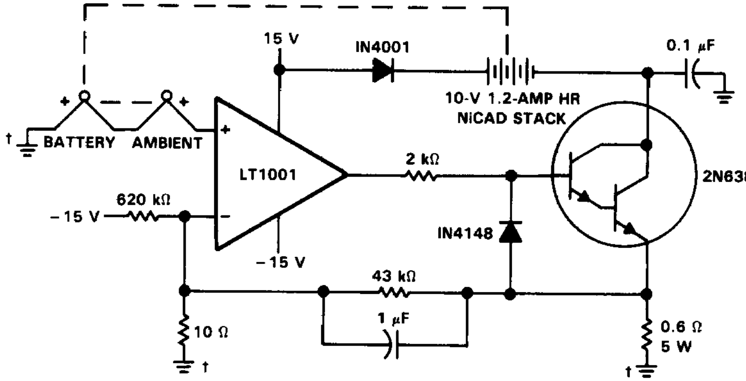
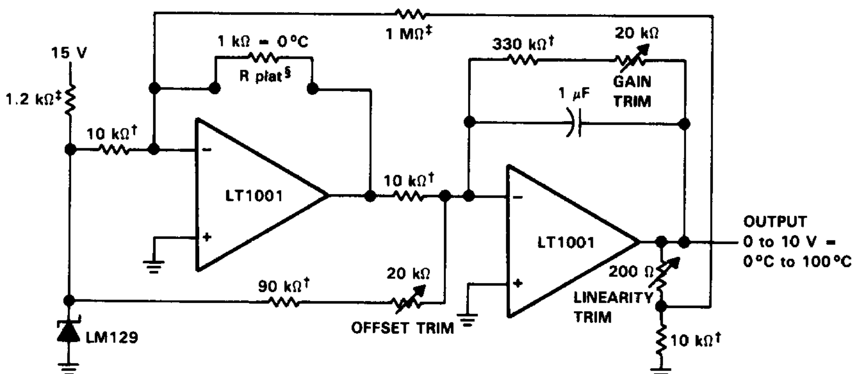
TYPICAL APPLICATION DATA



†Single point ground thermocouples are 40 μV/°C chromel-alumel (type K).
NOTE: This circuit uses the temperature difference between the battery pack mounted thermocouple and the ambient thermocouple to set the battery charge current. The peak charging current is 1 A.

FIGURE 36. THERMALLY CONTROLLED NICAD CHARGER



†ULTRONIX 105A wirewound
‡1% film
§Platinum RTD 118MF (Rosemount, Inc.)
NOTE: Trim sequence: trim offset (0°C = 1000 Ω), trim linearity (35°C = 1138.7 Ω), trim gain (100°C = 1392.6 Ω). Repeat until all three points are fixed with ±0.025°C.

FIGURE 37. LINEARIZED PLATINUM RESISTANCE THERMOMETER WITH ±0.025°C ACCURACY FOR T_A = 0°C TO 100°C

2
Operational Amplifiers