

# LM101A/LM201A/LM301A Operational Amplifiers

## General Description

The LM101A series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. Advanced processing techniques make possible an order of magnitude reduction in input currents, and a redesign of the biasing circuitry reduces the temperature drift of input current. Improved specifications include:

- Offset voltage 3 mV maximum over temperature (LM101A/LM201A)
- Input current 100 nA maximum over temperature (LM101A/LM201A)
- Offset current 20 nA maximum over temperature (LM101A/LM201A)
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew rate of 10V/μs as a summing amplifier

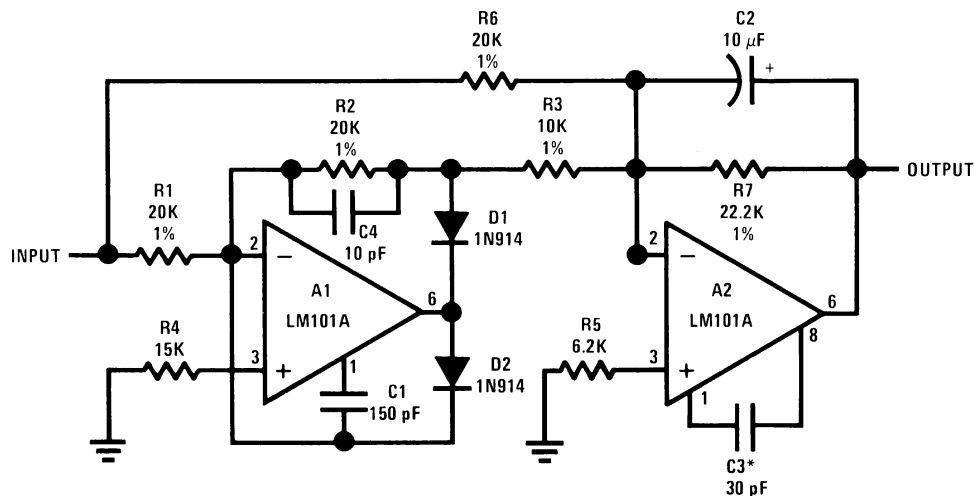
This amplifier offers many features which make its application nearly foolproof: overload protection on the input

and output, no latch-up when the common mode range is exceeded, and freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated amplifiers in that the frequency compensation can be tailored to the particular application. For example, in low frequency circuits it can be overcompensated for increased stability margin. Or the compensation can be optimized to give more than a factor of ten improvement in high frequency performance for most applications.

In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and a drift at a lower cost.

The LM101A is guaranteed over a temperature range of -55°C to +125°C, the LM201A from -25°C to +85°C, and the LM301A from 0°C to +70°C.

## Fast AC/DC Converter



**Note 1:** Feedforward compensation can be used to make a fast full wave rectifier without a filter.

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**Absolute Maximum Ratings** (Note 2)

If Military/Aerospace specified devices are required,  
please contact the National Semiconductor Sales Office/

Distributors for availability and specifications.

	LM101A/LM201A	LM301A
Supply Voltage	±22V	±18V
Differential Input Voltage	±30V	±30V
Input Voltage (Note 3)	±15V	±15V
Output Short Circuit Duration (Note 4)	Continuous	Continuous
Operating Ambient Temp. Range	-55°C to +125°C (LM101A) -25°C to +85°C (LM201A)	0°C to +70°C
<b>T<sub>J</sub> Max</b>		
H-Package	150°C	100°C
N-Package	150°C	100°C
J-Package	150°C	100°C
Power Dissipation at T <sub>A</sub> = 25°C		
H-Package (Still Air)	500 mW	300 mW
(400 LF/Min Air Flow)	1200 mW	700 mW
N-Package	900 mW	500 mW
J-Package	1000 mW	650 mW
Thermal Resistance (Typical) $\theta_{JA}$		
H-Package (Still Air)	165°C/W	165°C/W
(400 LF/Min Air Flow)	67°C/W	67°C/W
N Package	135°C/W	135°C/W
J-Package	110°C/W	110°C/W
(Typical) $\theta_{JC}$		
H-Package	25°C/W	25°C/W
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C
Lead Temperature (Soldering, 10 sec.)		
Metal Can or Ceramic	300°C	300°C
Plastic	260°C	260°C
ESD Tolerance (Note 7)	2000V	2000V

**Electrical Characteristics** (Note 5)

T<sub>A</sub> = T<sub>J</sub>

Parameter	Conditions	LM101A/LM201A			LM301A			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	T <sub>A</sub> = 25°C, R <sub>S</sub> ≤ 50 kΩ		0.7	2.0		2.0	7.5	mV
Input Offset Current	T <sub>A</sub> = 25°C		1.5	10		3.0	50	nA
Input Bias Current	T <sub>A</sub> = 25°C		30	75		70	250	nA
Input Resistance	T <sub>A</sub> = 25°C	1.5	4.0		0.5	2.0		MΩ
Supply Current	T <sub>A</sub> = 25°C		V <sub>S</sub> = ±20V	1.8	3.0			mA
			V <sub>S</sub> = ±15V				1.8	3.0
Large Signal Voltage Gain	T <sub>A</sub> = 25°C, V <sub>S</sub> = ±15V V <sub>OUT</sub> = ±10V, R <sub>L</sub> ≥ 2 kΩ	50	160		25	160		V/mV
Input Offset Voltage	R <sub>S</sub> ≤ 50 kΩ			3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage	R <sub>S</sub> ≤ 50 kΩ		3.0	15		6.0	30	μV/°C
Input Offset Current				20			70	nA
Average Temperature Coefficient of Input Offset Current	25°C ≤ T <sub>A</sub> ≤ T <sub>MAX</sub>		0.01	0.1		0.01	0.3	nA/°C
	T <sub>MIN</sub> ≤ T <sub>A</sub> ≤ 25°C		0.02	0.2		0.02	0.6	nA/°C
Input Bias Current				0.1			0.3	μA

## Electrical Characteristics (Note 5) (Continued)

$$T_A = T_J$$

Parameter	Conditions	LM101A/LM201A			LM301A			Units
		Min	Typ	Max	Min	Typ	Max	
Supply Current	$T_A = T_{MAX}$ , $V_S = \pm 20V$		1.2	2.5				mA
Large Signal Voltage Gain	$V_S = \pm 15V$ , $V_{OUT} = \pm 10V$ $R_L \geq 2k$	25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$	$R_L = 10 k\Omega$	$\pm 12$	$\pm 14$		$\pm 12$	$\pm 14$	V
		$R_L = 2 k\Omega$	$\pm 10$	$\pm 13$		$\pm 10$	$\pm 13$	V
Input Voltage Range	$V_S = \pm 20V$	$\pm 15$						V
	$V_S = \pm 15V$		+15, -13		$\pm 12$	+15, -13		V
Common-Mode Rejection Ratio	$R_S \leq 50 k\Omega$	80	96		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50 k\Omega$	80	96		70	96		dB

**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating ratings indicate for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 3:** For supply voltages less than  $\pm 15V$ , the absolute maximum input voltage is equal to the supply voltage.

**Note 4:** Continuous short circuit is allowed for case temperatures to  $125^\circ C$  and ambient temperatures to  $75^\circ C$  for LM101A/LM201A, and  $70^\circ C$  and  $55^\circ C$  respectively for LM301A.

**Note 5:** Unless otherwise specified, these specifications apply for  $C_1 = 30 pF$ ,  $\pm 5V \leq V_S \leq \pm 20V$  and  $-55^\circ C \leq T_A \leq +125^\circ C$  (LM101A),  $\pm 5V \leq V_S \leq \pm 20V$  and  $-25^\circ C \leq T_A \leq +85^\circ C$  (LM201A),  $\pm 5V \leq V_S \leq \pm 15V$  and  $0^\circ C \leq T_A \leq +70^\circ C$  (LM301A).

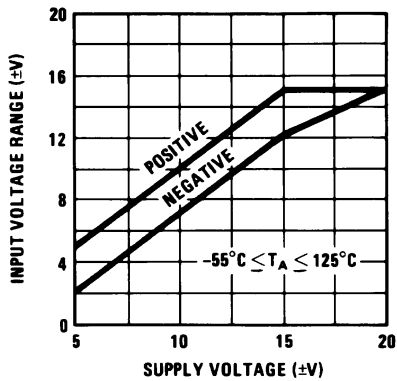
**Note 6:** Refer to RETS101AX for LM101A military specifications and RETS101X for LM101 military specifications.

**Note 7:** Human body model, 100 pF discharged through 1.5 k $\Omega$ .

## Typical Performance Characteristics

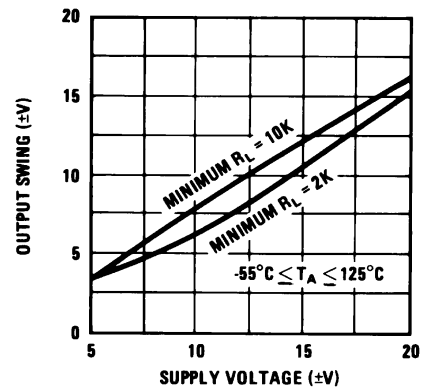
LM101A/LM201A

Input Voltage Range



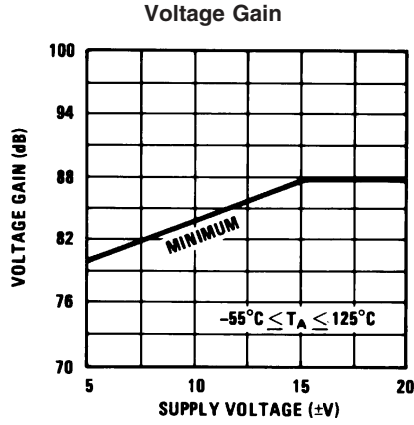
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Output Swing



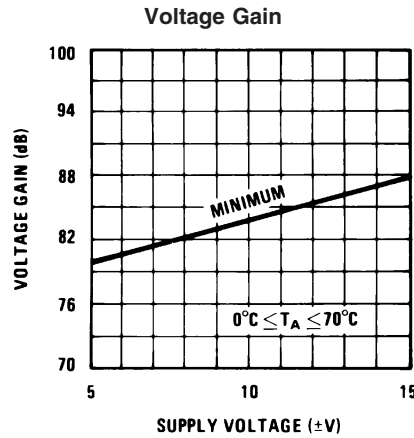
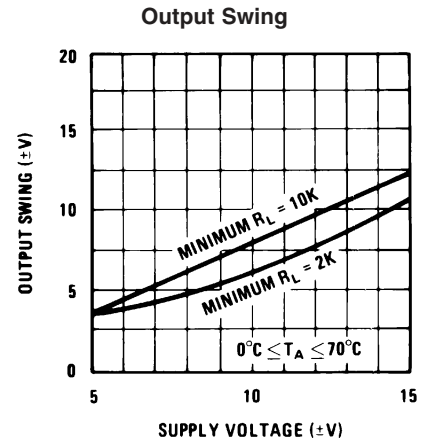
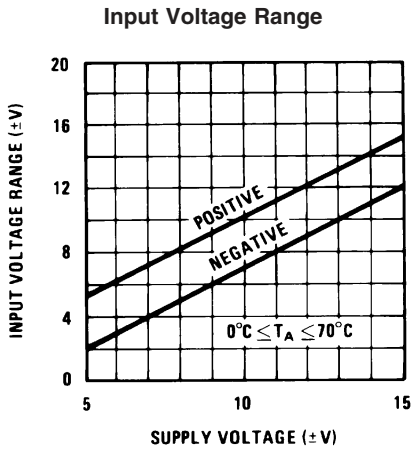
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## Typical Performance Characteristics LM101A/LM201A (Continued)



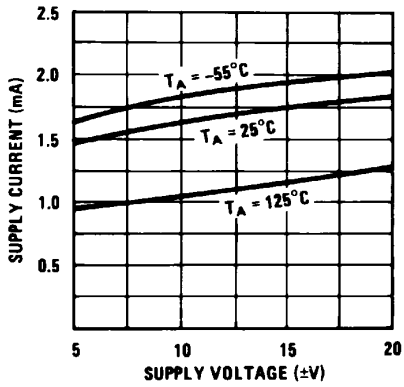
## Guaranteed Performance Characteristics

LM301A



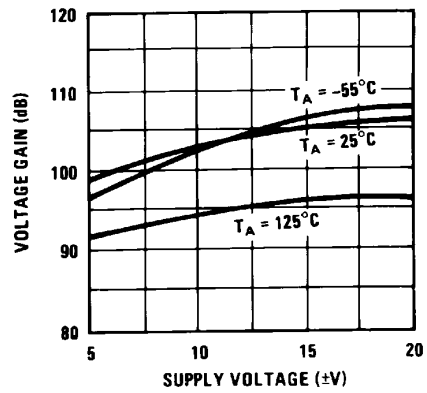
# Typical Performance Characteristics

Supply Current



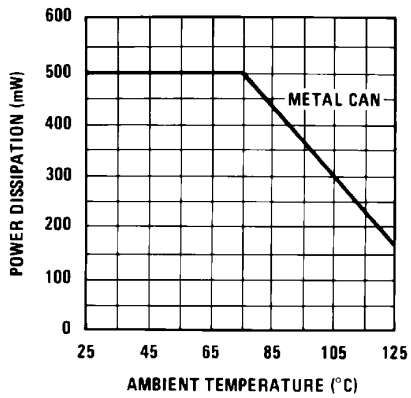
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Voltage Gain



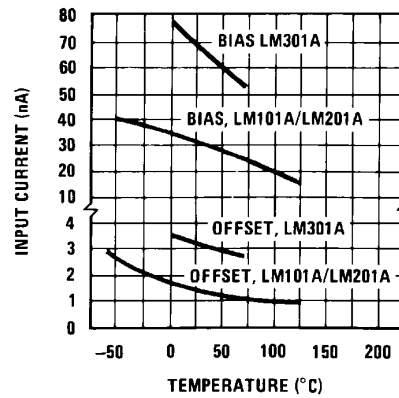
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Maximum Power Dissipation



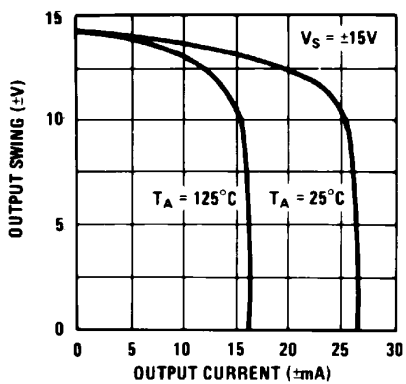
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Input Current, LM101A/LM201A/LM301A



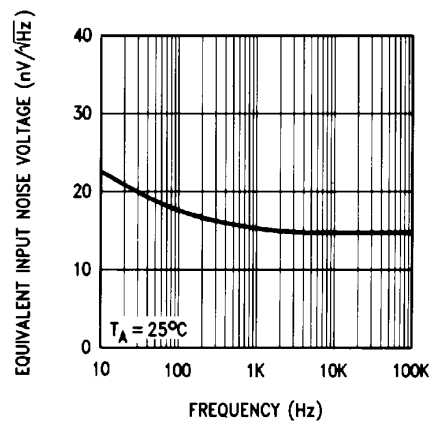
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Current Limiting



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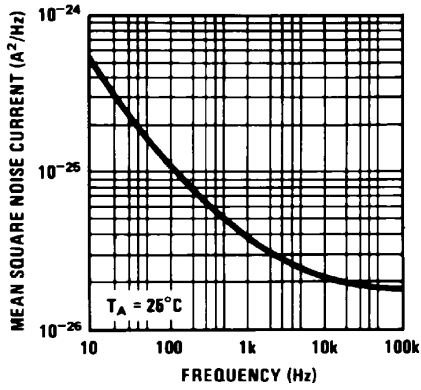
Input Noise Voltage



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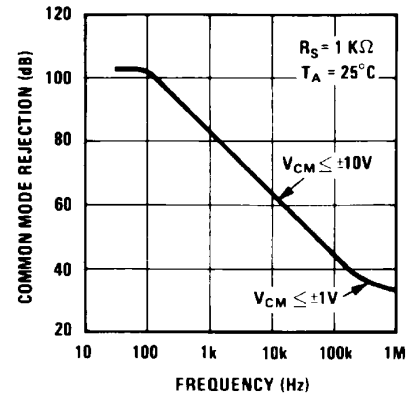
Typical Performance Characteristics (Continued)

Input Noise Current



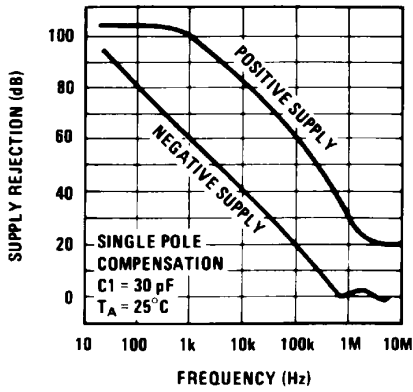
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Common Mode Rejection



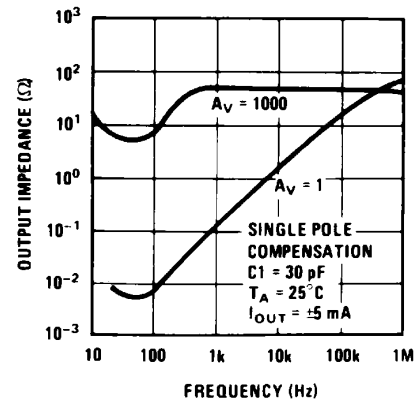
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Power Supply Rejection



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Closed Loop Output Impedance

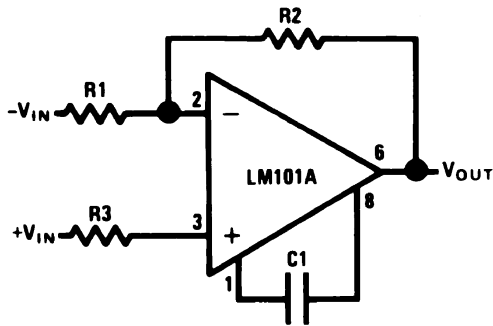


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# Typical Performance Characteristics for Various Compensation Circuits

(Note 9)

Single Pole Compensation

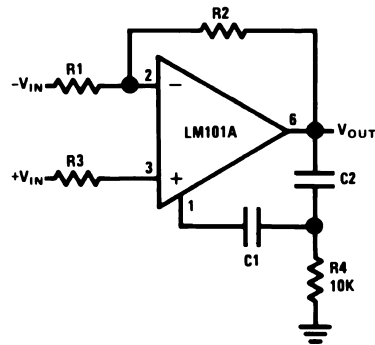


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$$C1 \geq \frac{R1 C_S}{R1 + R2}$$

C<sub>S</sub> = 30 pF

Two Pole Compensation

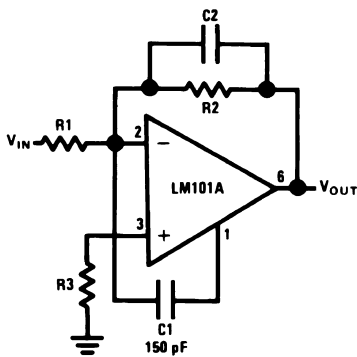


00775212

$$C1 \geq \frac{R1 C_S}{R1 + R2}$$

C<sub>S</sub> = 30 pF  
C<sub>2</sub> = 10 C<sub>1</sub>

Feedforward Compensation

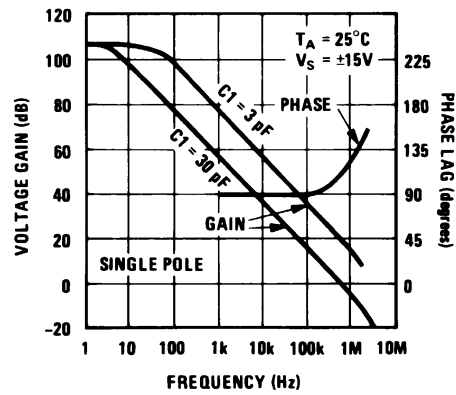


00775216

$$C2 = \frac{1}{2\pi f_0 R2}$$

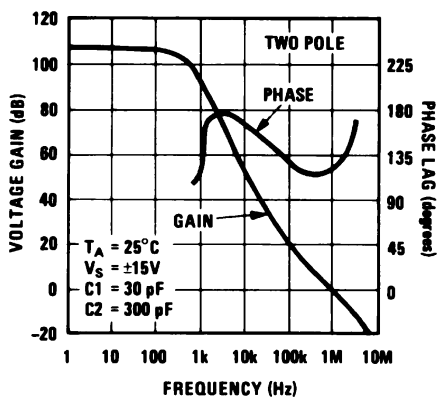
f<sub>0</sub> = 3 MHz

Open Loop Frequency Response



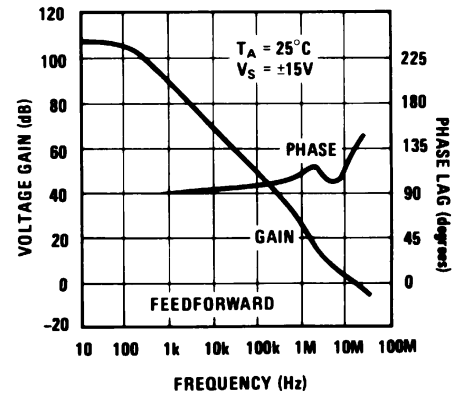
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Open Loop Frequency Response



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Open Loop Frequency Response

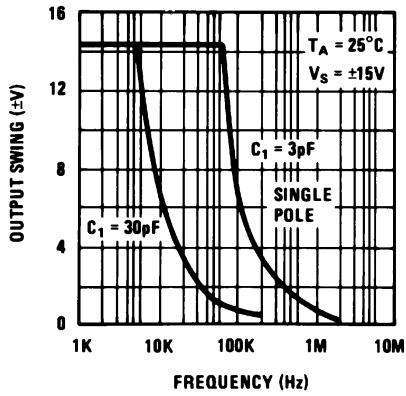


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# Typical Performance Characteristics for Various Compensation Circuits

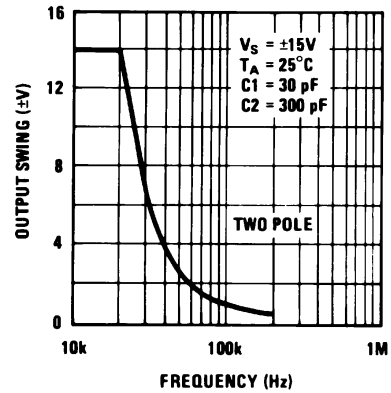
(Note 9) (Continued)

Large Signal Frequency Response



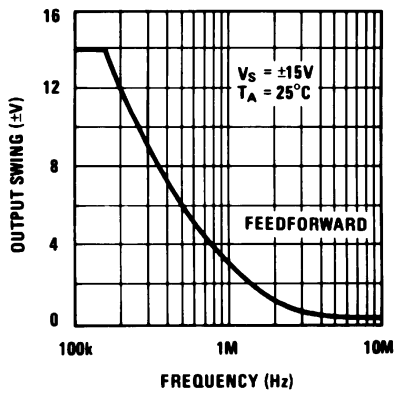
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Large Signal Frequency Response



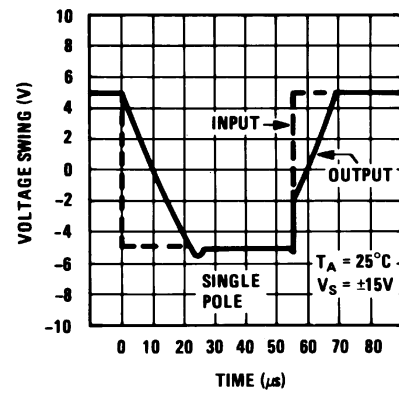
00775214

Large Signal Frequency Response



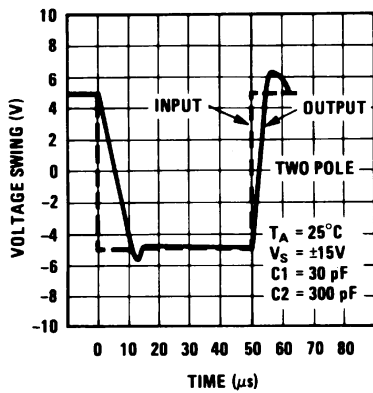
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Voltage Follower Pulse Response



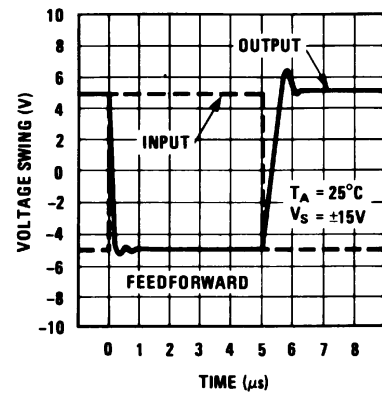
00775211

Voltage Follower Pulse Response



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Inverter Pulse Response

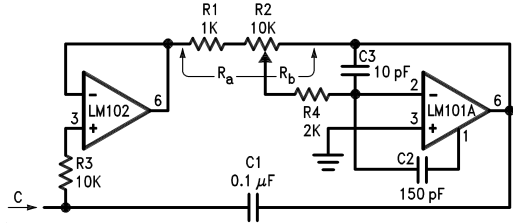


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# Typical Applications (Note 9)

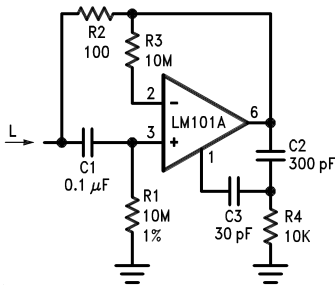
## Variable Capacitance Multiplier



00775220

$$C = 1 + \frac{R_b}{R_a} C_1$$

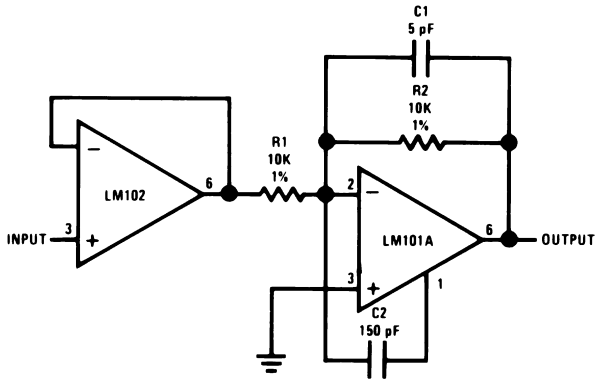
## Simulated Inductor



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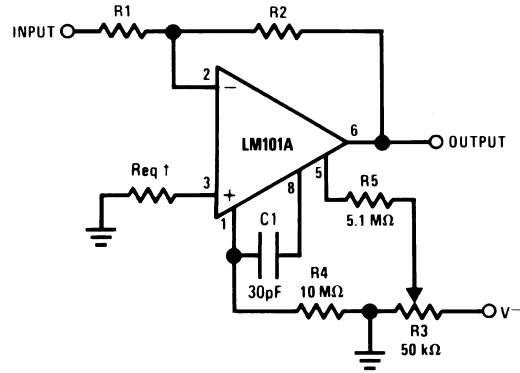
$L = R_1 R_2 C_1$   
 $R_S = R_2$   
 $R_P = R_1$

## Fast Inverting Amplifier with High Input Impedance



00775222

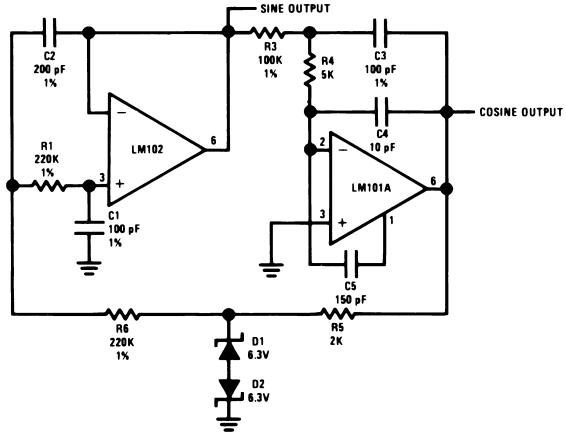
## Inverting Amplifier with Balancing Circuit



00775223

\*May be zero or equal to parallel combination of R1 and R2 for minimum offset.

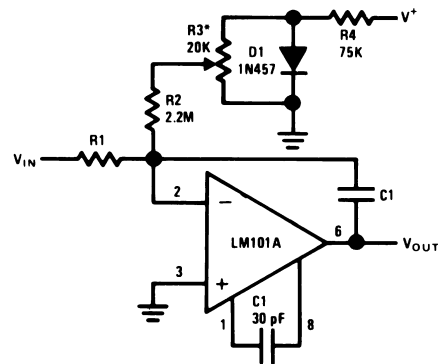
## Sine Wave Oscillator



00775224

$f_o = 10 \text{ kHz}$

## Integrator with Bias Current Compensation

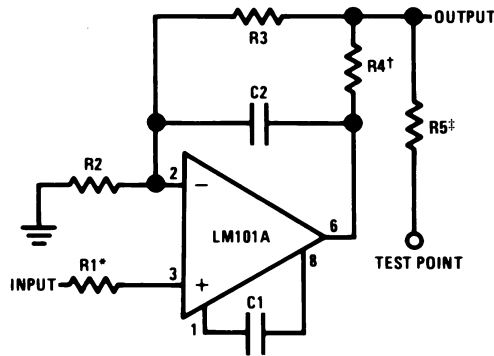


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\*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over -55°C to +125°C temperature range.

## Application Hints (Note 9)

### Protecting Against Gross Fault Conditions



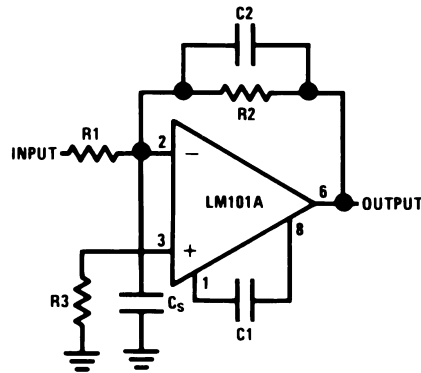
00775226

\*Protects input

†Protects output

‡Protects output — not needed when R4 is used.

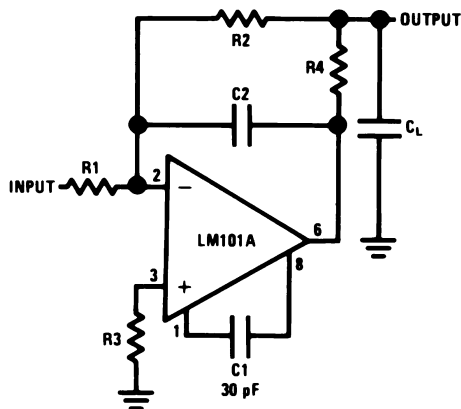
### Compensating for Stray Input Capacitances or Large Feedback Resistor



00775227

$$C2 = \frac{R1 C_s}{R2}$$

### Isolating Large Capacitive Loads



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Although the LM101A is designed for trouble free operation, experience has indicated that it is wise to observe certain

precautions given below to protect the devices from abnormal operating conditions. It might be pointed out that the

advice given here is applicable to practically any IC op amp, although the exact reason why may differ with different devices.

When driving either input from a low-impedance source, a limiting resistor should be placed in series with the input lead to limit the peak instantaneous output current of the source to something less than 100 mA. This is especially important when the inputs go outside a piece of equipment where they could accidentally be connected to high voltage sources. Large capacitors on the input (greater than 0.1  $\mu\text{F}$ ) should be treated as a low source impedance and isolated with a resistor. Low impedance sources do not cause a problem unless their output voltage exceeds the supply voltage. However, the supplies go to zero when they are turned off, so the isolation is usually needed.

The output circuitry is protected against damage from shorts to ground. However, when the amplifier output is connected to a test point, it should be isolated by a limiting resistor, as test points frequently get shorted to bad places. Further, when the amplifier drives a load external to the equipment, it is also advisable to use some sort of limiting resistance to preclude mishaps.

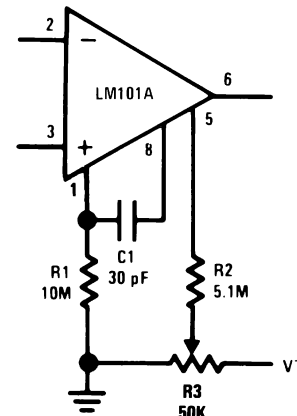
Precautions should be taken to insure that the power supplies for the integrated circuit never become reversed—even under transient conditions. With reverse voltages greater than 1V, the IC will conduct excessive current, fusing internal aluminum interconnects. If there is a possibility of this happening, clamp diodes with a high peak current rating should be installed on the supply lines. Reversal of the voltage between  $V^+$  and  $V^-$  will always cause a problem, although reversals with respect to ground may also give difficulties in many circuits.

The minimum values given for the frequency compensation capacitor are stable only for source resistances less than 10 k $\Omega$ , stray capacitances on the summing junction less than 5 pF and capacitive loads smaller than 100 pF. If any of these conditions are not met, it becomes necessary to overcompensate the amplifier with a larger compensation capacitor. Alternately, lead capacitors can be used in the feedback network to negate the effect of stray capacitance and large feedback resistors or an RC network can be added to isolate capacitive loads.

Although the LM101A is relatively unaffected by supply bypassing, this cannot be ignored altogether. Generally it is necessary to bypass the supplies to ground at least once on every circuit card, and more bypass points may be required if more than five amplifiers are used. When feed-forward compensation is employed, however, it is advisable to bypass the supply leads of each amplifier with low inductance capacitors because of the higher frequencies involved.

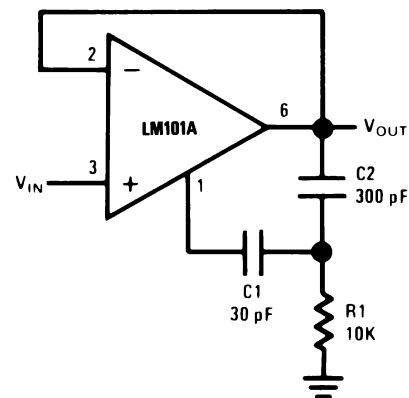
## Typical Applications (Note 9)

### Standard Compensation and Offset Balancing Circuit



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### Fast Voltage Follower

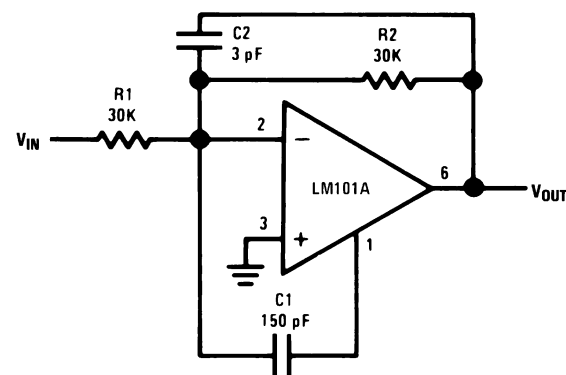


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Power Bandwidth: 15 kHz

Slew Rate: 1V/ $\mu\text{s}$ 

### Fast Summing Amplifier



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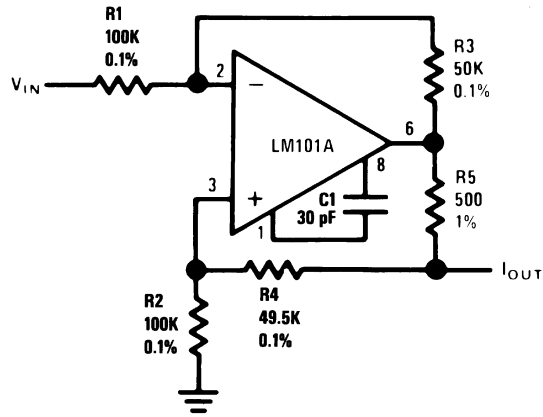
Power Bandwidth: 250 kHz

Small Signal Bandwidth: 3.5 MHz

Slew Rate: 10V/ $\mu\text{s}$

Typical Applications (Note 9) (Continued)

Bilateral Current Source



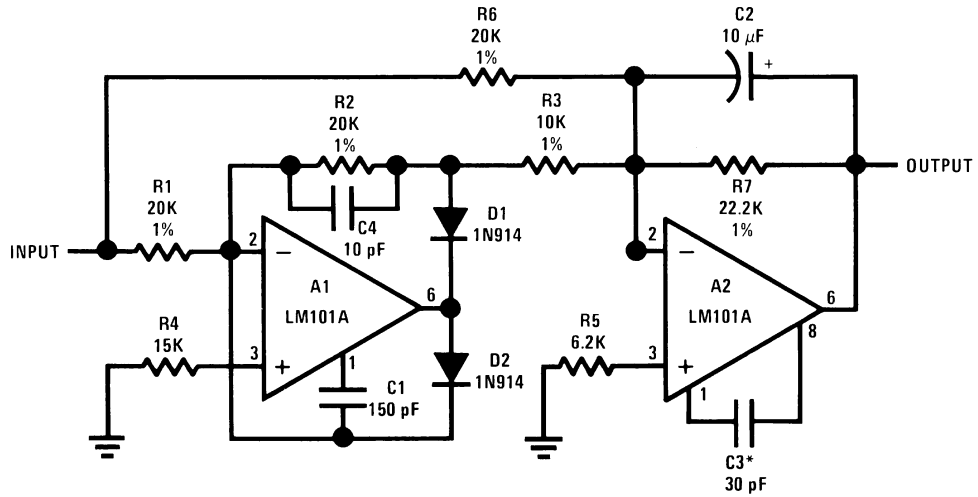
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$$I_{OUT} = \frac{R3 V_{IN}}{R1 R5}$$

R3 = R4 + R5

R1 = R2

Fast AC/DC Converter (Note 8)

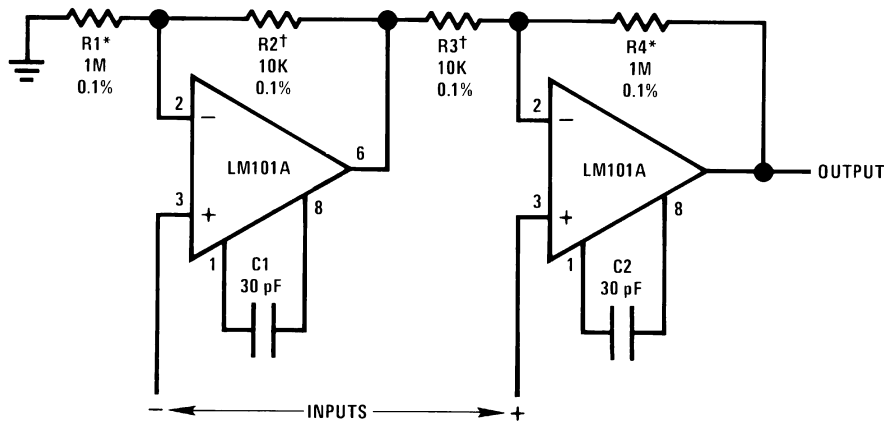


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Note 8: Feedforward compensation can be used to make a fast full wave rectifier without a filter.

Typical Applications (Note 9) (Continued)

Instrumentation Amplifier



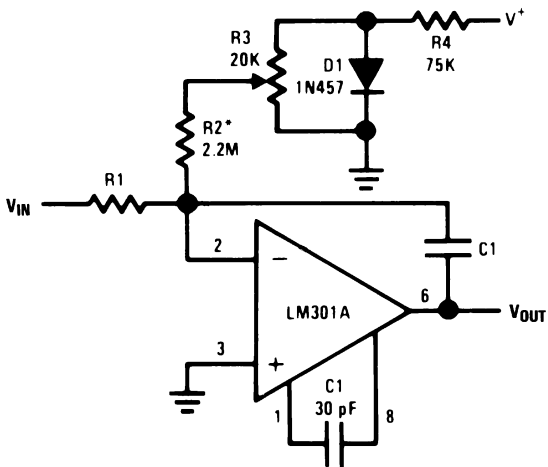
00775234

R1 = R4; R2 = R3

$$A_v = 1 + \frac{R1}{R2}$$

\*;† Matching determines CMRR.

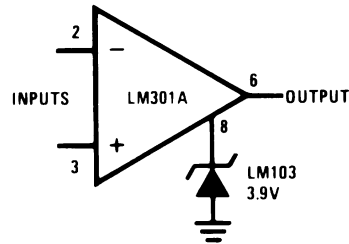
Integrator with Bias Current Compensation



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\*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over 0°C to +70°C temperature range.

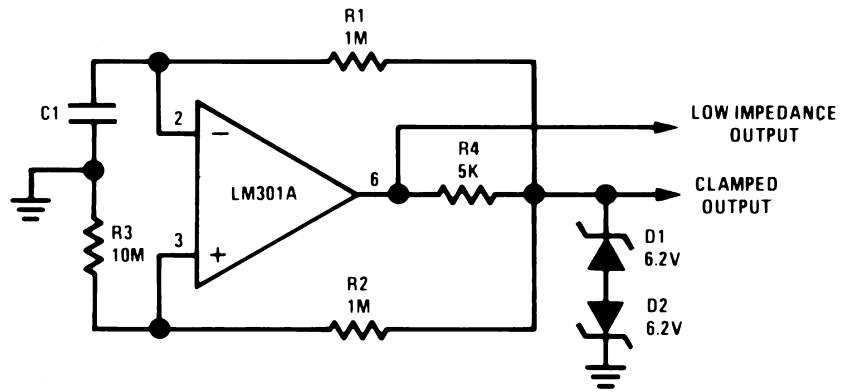
Voltage Comparator for Driving RTL Logic or High Current Driver



00775237

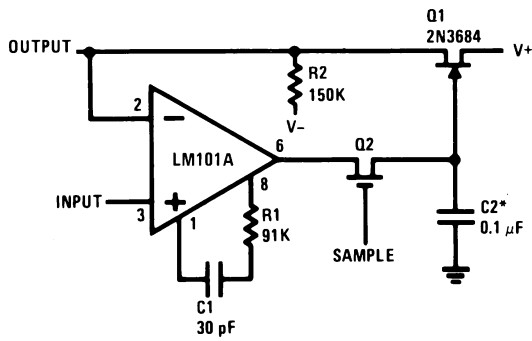
# Typical Applications (Note 9) (Continued)

## Low Frequency Square Wave Generator



00775236

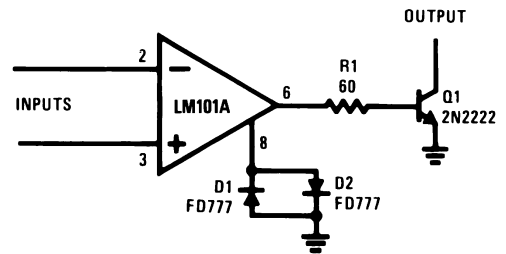
## Low Drift Sample and Hold



00775238

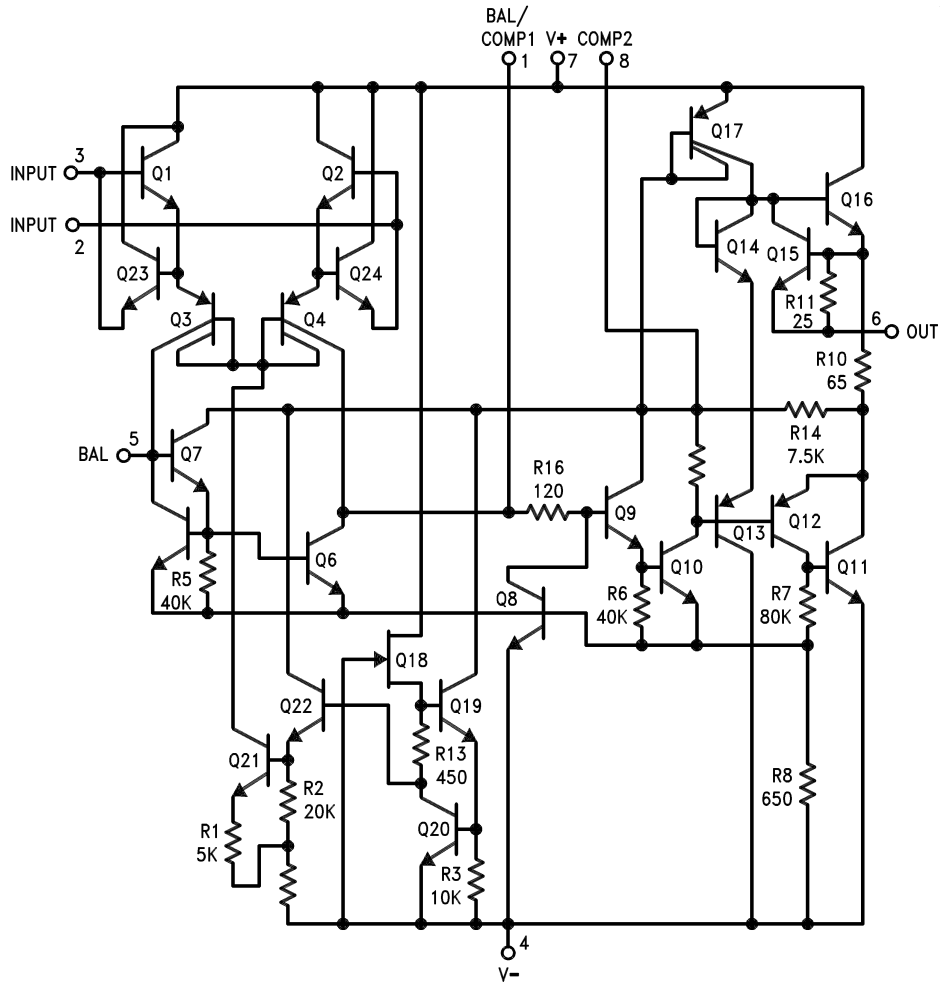
\*Polycarbonate-dielectric capacitor

## Voltage Comparator for Driving DTL or TTL Integrated Circuits



00775239

**Schematic** (Note 9)

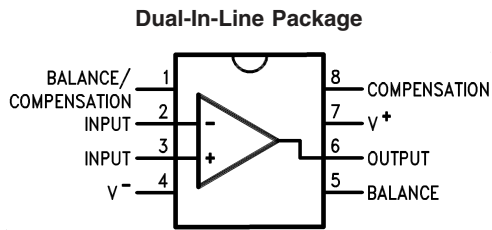


00775201

**Note 9:** Pin connections shown are for 8-pin packages.

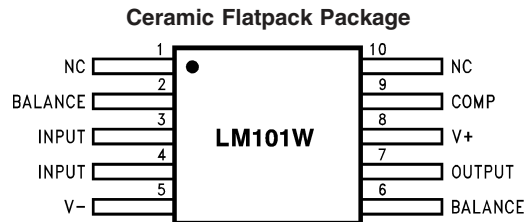
**Connection Diagrams**

(Top View)



00775204

Order Number LM101AJ, LM101J/883 (Note 10),  
LM201AN or LM301AN  
See NS Package Number J08A or N08E

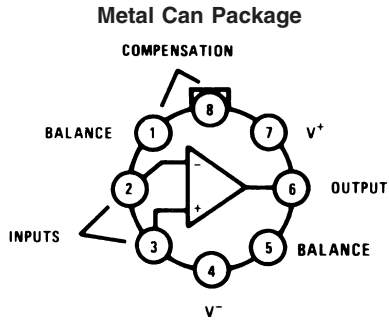


00775240

Order Number LM101AW/883 or LM101W/883  
See NS Package Number W10A

## Connection Diagrams (Top

View) (Continued)

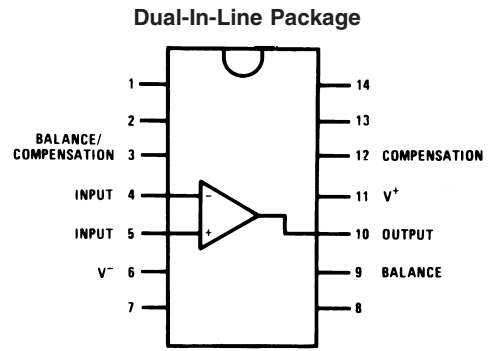


00775202

**Note:** Pin 4 connected to case.

**Order Number LM101AH, LM101AH/883 (Note 10),  
LM201AH or LM301AH  
See NS Package Number H08C**

**Note 10:** Available per JM38510/10103.



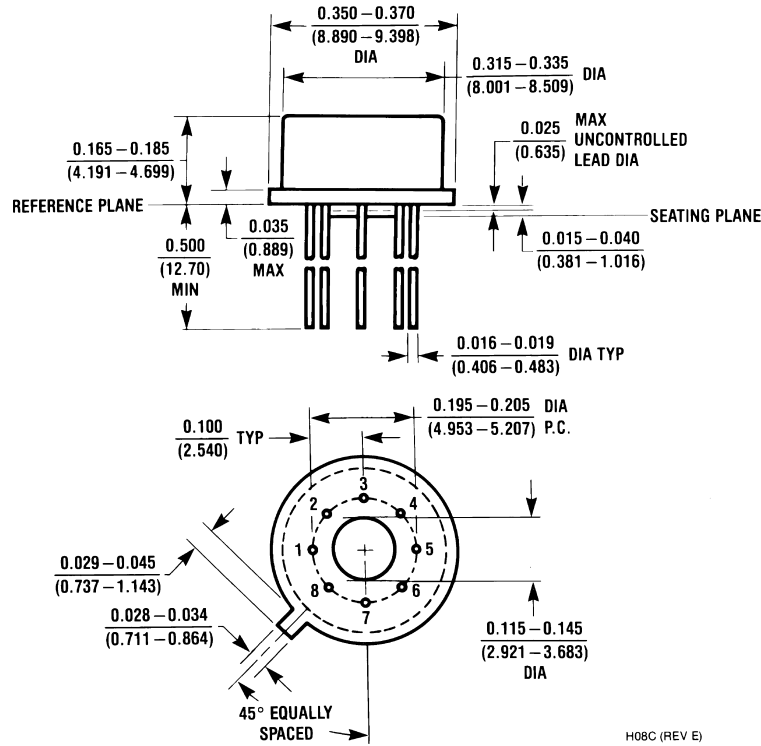
00775203

**Order Number LM101AJ-14/883 (Note 10)  
See NS Package Number J14A**



**Physical Dimensions** inches (millimeters)

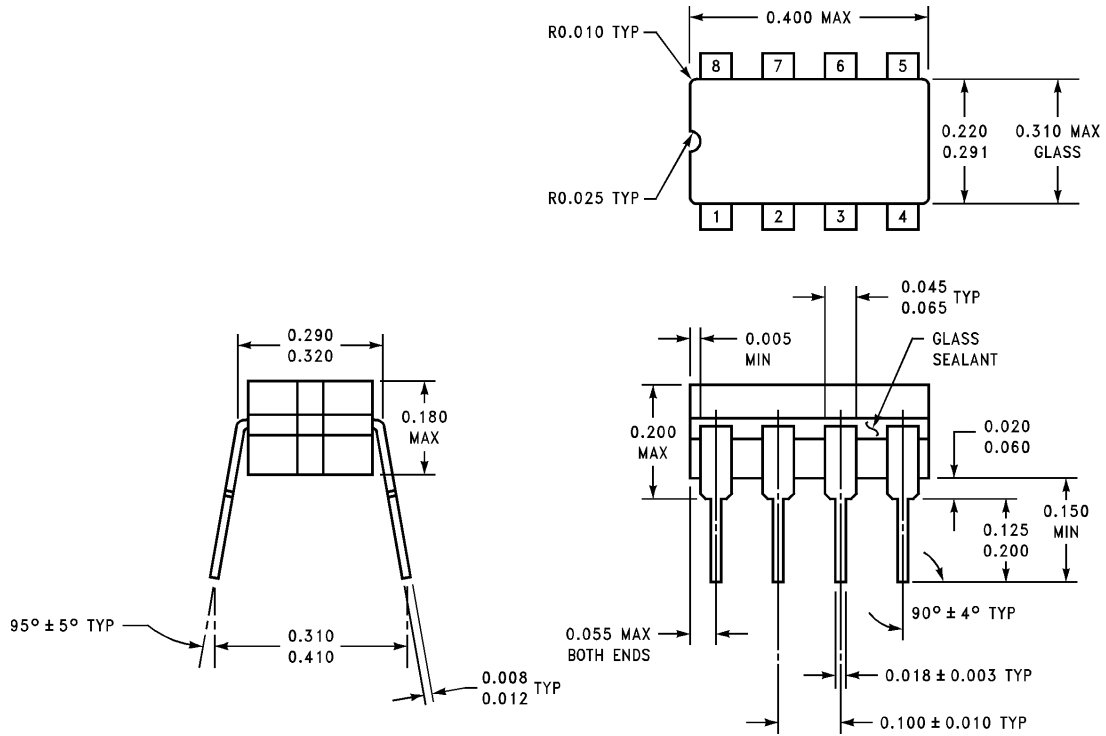
unless otherwise noted



H08C (REV E)

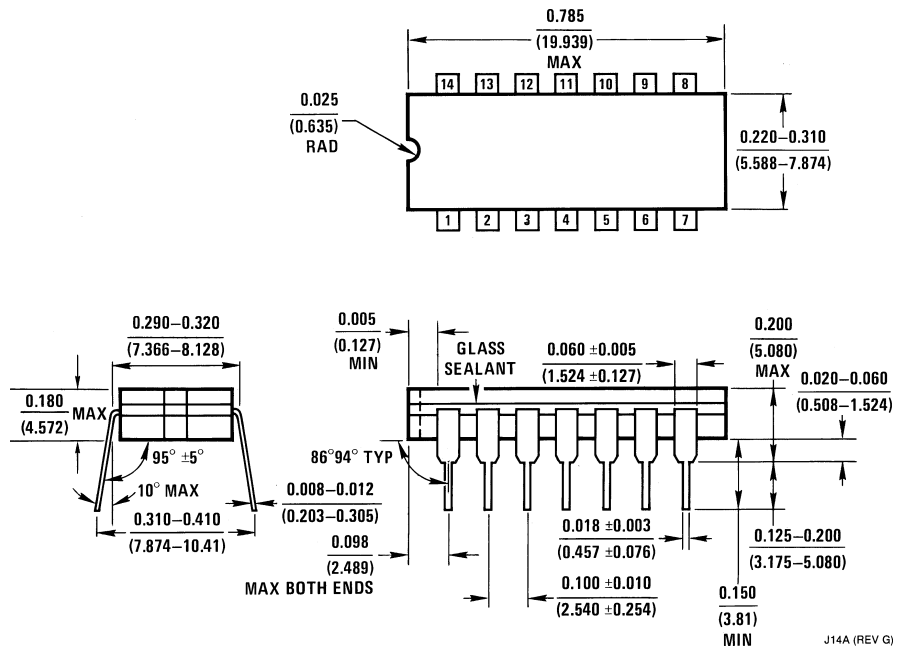
**Metal Can Package (H)**  
**Order Number LM101AH, LM101AH/883**  
**LM201AH or LM301AH**  
**NS Package Number H08C**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**Ceramic Dual-In-Line Package (J)**  
**Order Number LM101J/883 or LM101AJ**  
**NS Package Number J08A**

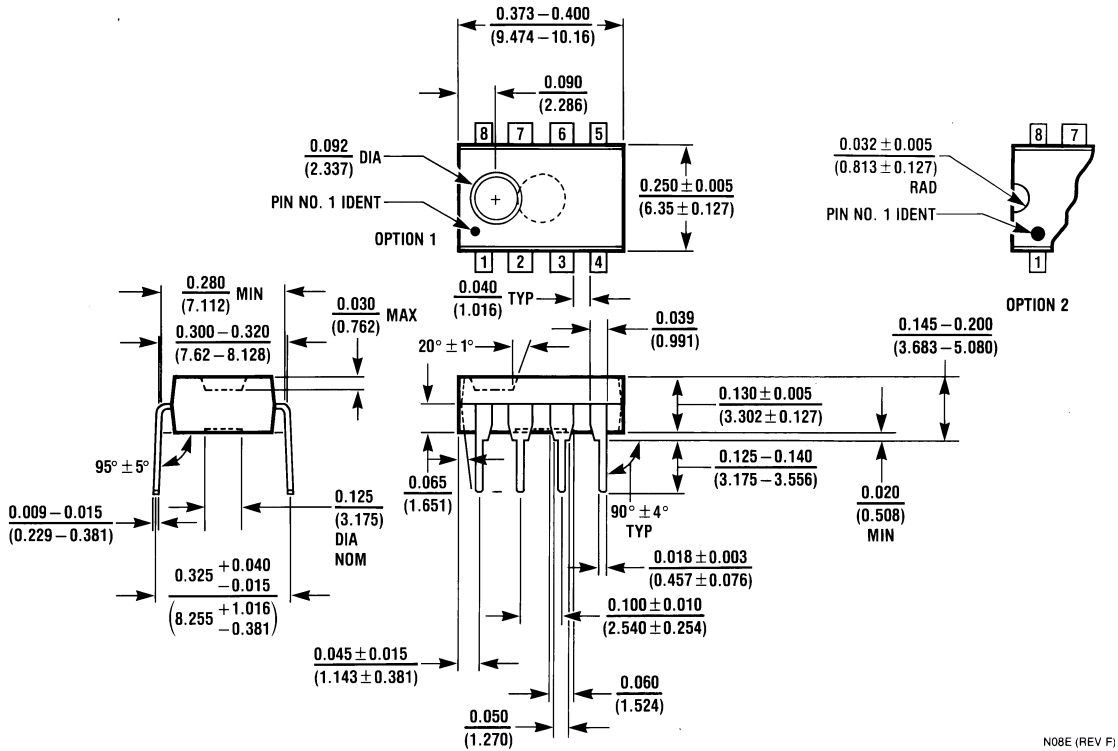
J08A (REV K)



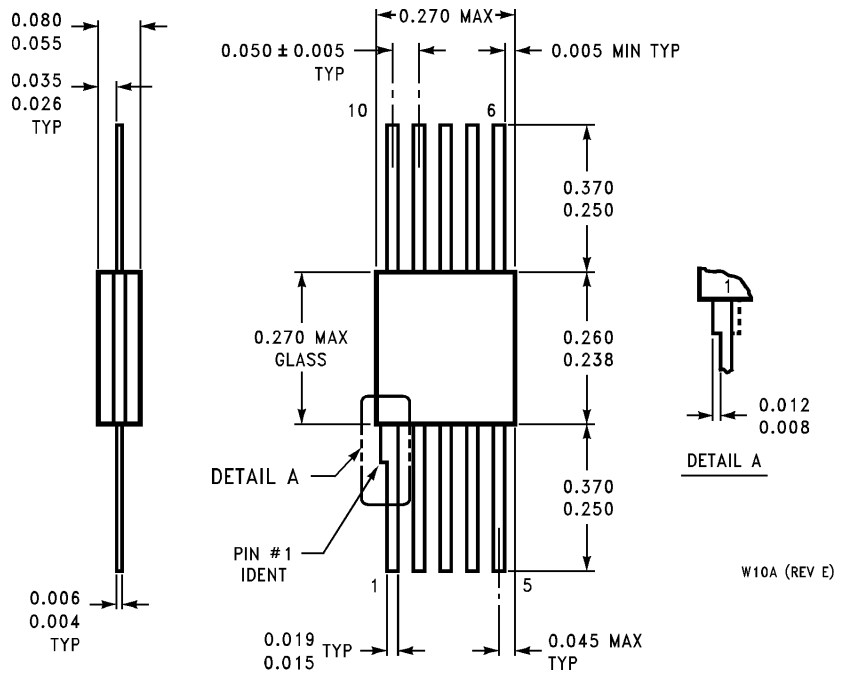
**Ceramic Dual-In-Line Package (J)**  
**Order Number LM101AJ-14/883**  
**NS Package Number J14A**

J14A (REV G)

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**Molded Dual-In-Line Package (N)**  
**Order Number LM201AN or LM301AN**  
**NS Package Number N08E**



**Ceramic Flatpack Package (W)**  
**Order Number LM101AW/883 or LM101W/883**  
**NS Package Number W10A**

## Notes

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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