September 1999

National Semiconductor

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

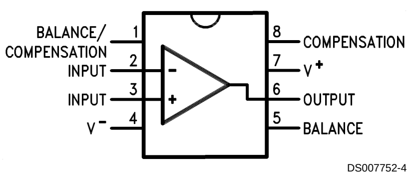
This amplifier offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, and freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated 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.

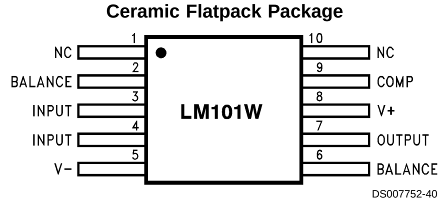
Connection Diagrams (Top View)

Dual-In-Line Package



Order Number LM101AJ, LM101J/883 (Note 1)**,**
LM201AN or LM301AN
See NS Package Number J08A or N08E

Ceramic Flatpack Package

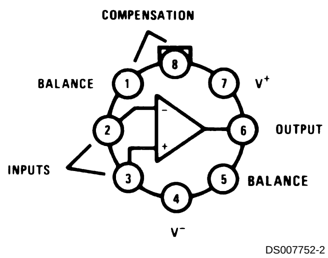


Order Number LM101AW/883 or LM101W/883
See NS Package Number W10A

LM101A/LM201A/LM301A Operational Amplifiers

Connection Diagrams (Top View) (Continued)

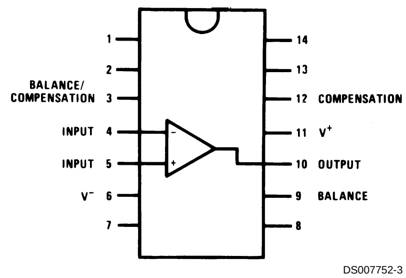
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM101AH, LM101AH/883 (Note 1)**,**
LM201AH or LM301AH
See NS Package Number H08C

Dual-In-Line Package



Order Number LM101AJ-14/883 (Note 1)
See NS Package Number J14A

Note 1: Available per JM38510/10103.

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)	0˚C to +70˚C
	−25˚C to +85˚C (LM201A)	
T_J Max		
H-Package	150˚C	100˚C
N-Package	150˚C	100˚C
J-Package	150˚C	100˚C
Power Dissipation at T_A = 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) θ_{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˚CmW
(Typical) θ_{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)

$T_A = T_J$

Parameter	Conditions		LM101A/LM201A			LM301A			Units
			Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	T_A = 25˚C, R_S ≤ 50 kΩ			0.7	2.0		2.0	7.5	mV
Input Offset Current	T_A = 25˚C			1.5	10		3.0	50	nA
Input Bias Current	T_A = 25˚C			30	75		70	250	nA
Input Resistance	T_A = 25˚C		1.5	4.0		0.5	2.0		MΩ
Supply Current	T_A = 25˚C	V_S = ±20V		1.8	3.0				mA
		V_S = ±15V					1.8	3.0	mA
Large Signal Voltage Gain	T_A = 25˚C, V_S = ±15V V_{OUT} = ±10V, R_L ≥ 2 kΩ		50	160		25	160		V/mV
Input Offset Voltage	R_S ≤ 50 kΩ				3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage	R_S ≤ 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_A ≤ T_{MAX}			0.01	0.1		0.01	0.3	nA/˚C
	T_{MIN} ≤ T_A ≤ 25˚C			0.02	0.2		0.02	0.6	nA/˚C
Input Bias Current					0.1			0.3	µA
Supply Current	T_A = T_{MAX}, V_S = ±20V			1.2	2.5				mA

Electrical Characteristics (Note 5) (Continued)

$T_A = T_J$

Parameter	Conditions		LM101A/LM201A			LM301A			Units
			Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	V_S = ±15V, V_{OUT} = ±10V R_L ≥ 2k		25			15			V/mV
Output Voltage Swing	V_S = ±15V	R_L = 10 kΩ	±12	±14		±12	±14		V
		R_L = 2 kΩ	±10	±13		±10	±13		V
Input Voltage Range	V_S = ±20V		±15						V
	V_S = ±15V			+15, −13		±12	+15, −13		V
Common-Mode Rejection Ratio	R_S ≤ 50 kΩ		80	96		70	90		dB
Supply Voltage Rejection Ratio	R_S ≤ 50 kΩ		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 no 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 ±15V, the absolute maximum input voltage is equal to the supply voltage.

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

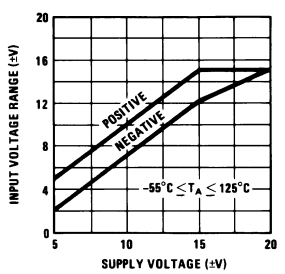
Note 5: Unless otherwise specified, these specifications apply for C1 = 30 pF, ±5V ≤ V_S ≤ ±20V and −55˚C ≤ T_A ≤ +125˚C (LM101A), ±5V ≤ V_S ≤ ±20V and −25˚C ≤ T_A ≤ +85˚C (LM201A), ±5V ≤ V_S ≤ ±15V and 0˚C ≤ T_A ≤ +70˚C (LM301A).

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 kΩ.

Guaranteed Performance Characteristics LM101A/LM201A

Input Voltage Range



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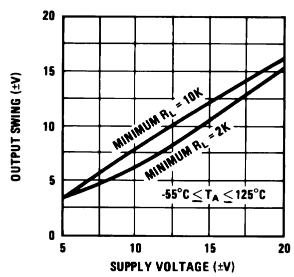
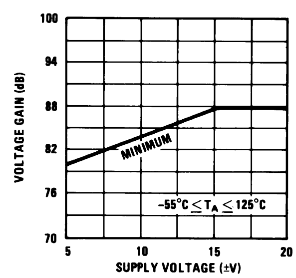
Output Swing



DS007752-42

Voltage Gain



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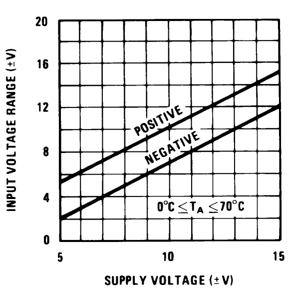
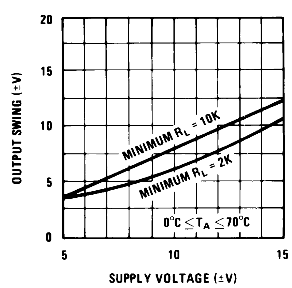
Guaranteed Performance Characteristics LM301A

Input Voltage Range



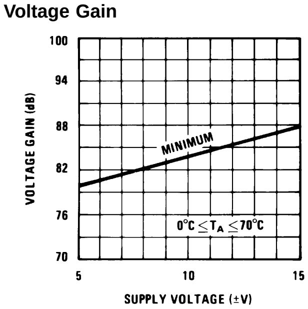
DS007752-44

Output Swing



DS007752-45

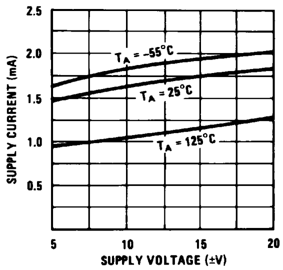
Voltage Gain



DS007752-46

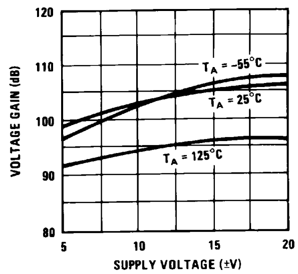
Typical Performance Characteristics

Supply Current



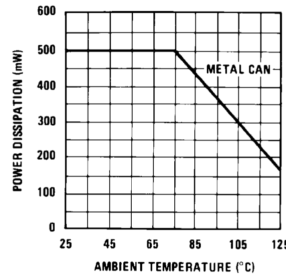
DS007752-47

Voltage Gain



DS007752-48

Maximum Power Dissipation



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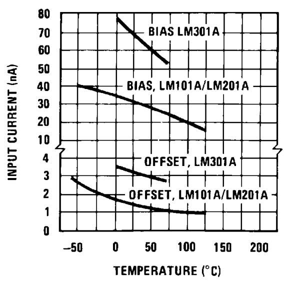
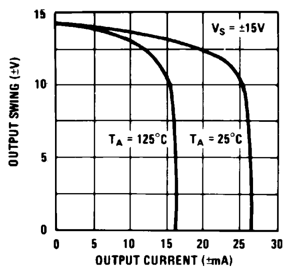
Input Current, LM101A/LM201A/LM301A



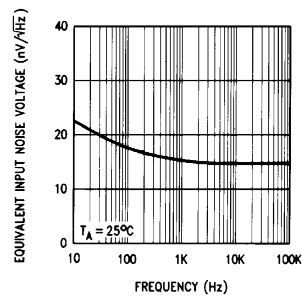
DS007752-50

Current Limiting



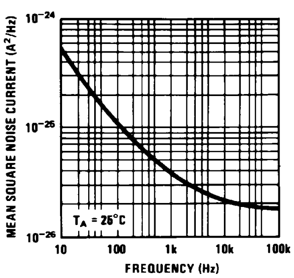
DS007752-51

Input Noise Voltage



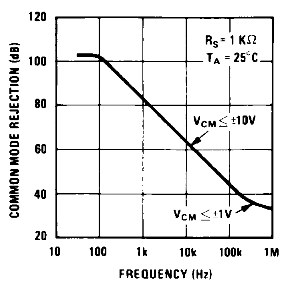
DS007752-52

Input Noise Current



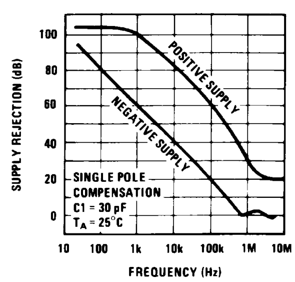
DS007752-53

Common Mode Rejection



DS007752-54

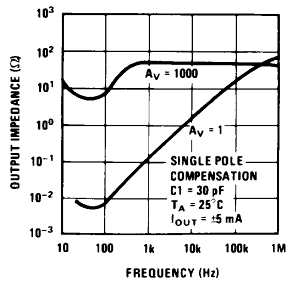
Power Supply Rejection



DS007752-55

Typical Performance Characteristics (Continued)

Closed Loop Output Impedance

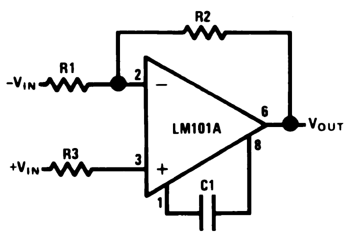


DS007752-56

Typical Performance Characteristics for Various Compensation Circuits

(Note 9)

Single Pole Compensation

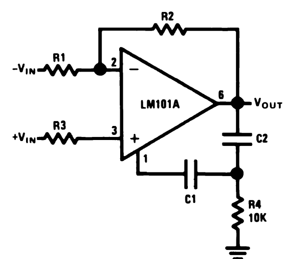


DS007752-8

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

C_S= 30 pF

Two Pole Compensation



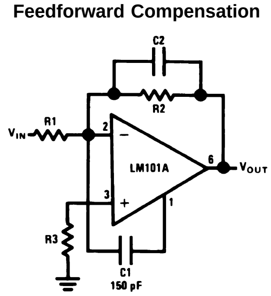
DS007752-12

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

C_S= 30 pF

C2 = 10 C1

Feedforward Compensation



DS007752-16

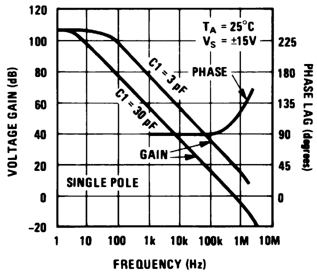
$$C2 = \frac{1}{2\pi\ f_o\ R2}$$

f_o= 3 MHz

Typical Performance Characteristics for Various Compensation Circuits

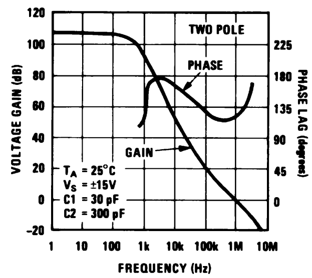
(Note 9) (Continued)

Open Loop Frequency Response



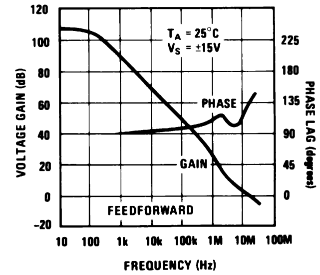
DS007752-9

Open Loop Frequency Response



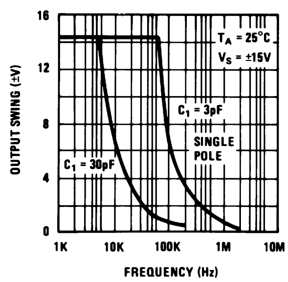
DS007752-13

Open Loop Frequency Response



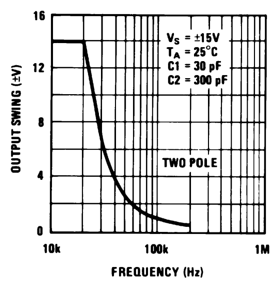
DS007752-17

Large Signal Frequency Response



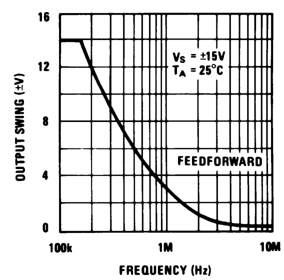
DS007752-10

Large Signal Frequency Response



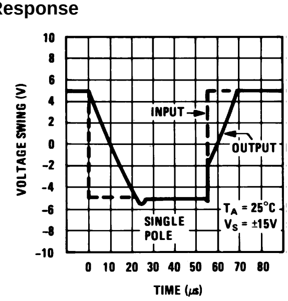
DS007752-14

Large Signal Frequency Response



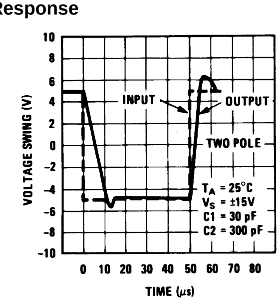
DS007752-18

Voltage Follower Pulse Response



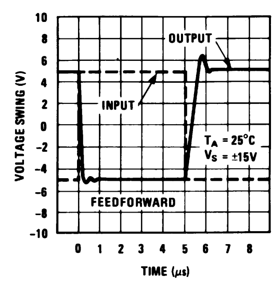
DS007752-11

Voltage Follower Pulse Response



DS007752-15

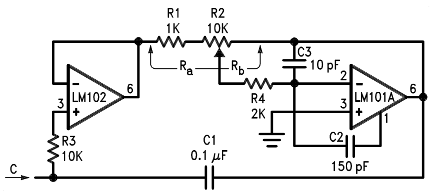
Inverter Pulse Response



DS007752-19

Typical Applications (Note 9)

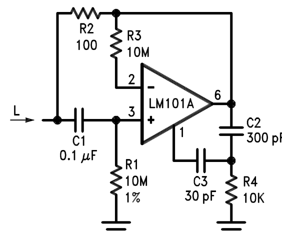
Variable Capacitance Multiplier



DS007752-20

$C = 1 + \frac{R_b}{R_a} C1$

Simulated Inductor



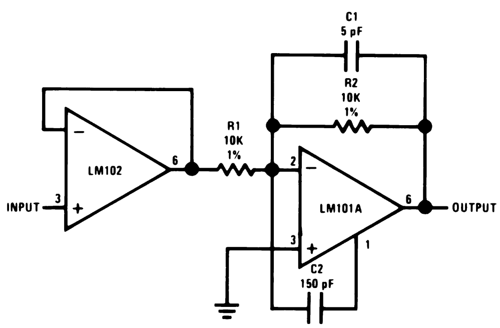
DS007752-21

L ≅ R1 R2 C1

R_S = R2

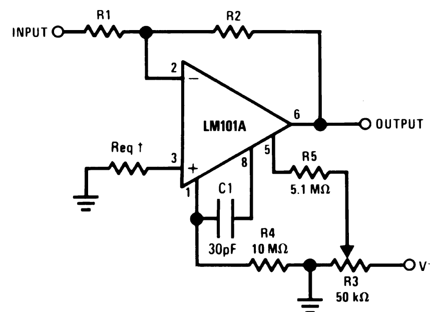
R_P = R1

Fast Inverting Amplifier with High Input Impedance



DS007752-22

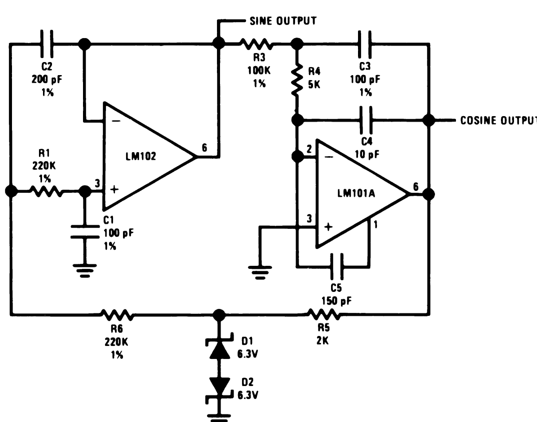
Inverting Amplifier with Balancing Circuit



DS007752-23

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

Sine Wave Oscillator

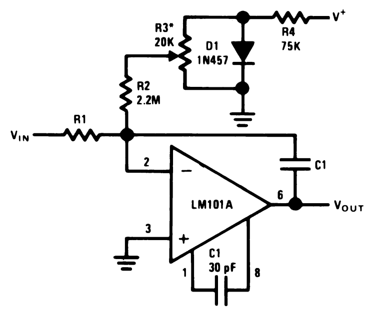


DS007752-24

f_o = 10 kHz

Typical Applications (Note 9) (Continued)

Integrator with Bias Current Compensation

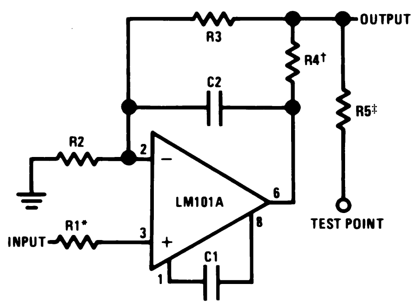


DS007752-25

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

Application Hints (Note 9)

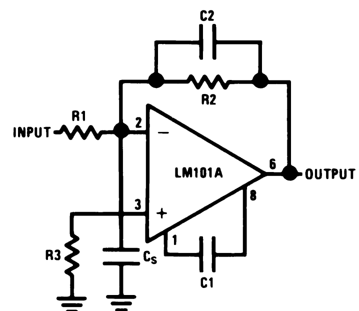
Protecting Against Gross Fault Conditions



DS007752-26

*Protects input
†Protects output
‡Protects output — not needed when R4 is used.

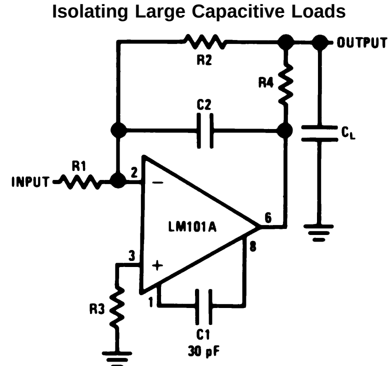
Compensating for Stray Input Capacitances or Large Feedback Resistor



DS007752-27

$$C2 = \frac{R1\,C_S}{R2}$$

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.

Application Hints (Note 9) (Continued)

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 µF) 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 amplifer drives a load external to the equipment, it is also advisable to use some sort of limiting resistance to preclude mishaps.

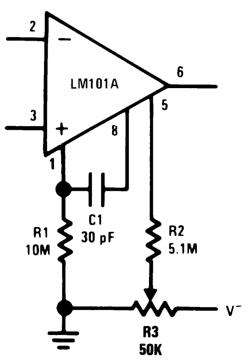
Precautions should be taken to insure that the power supplies for the integrated circuit never become reversed — even under transient conditions. With reverse voltages greater than 1V, the IC will conduct excessive current, fusing internal aluminum interconnects. If there is a possibility of this happening, 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 kΩ, 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.

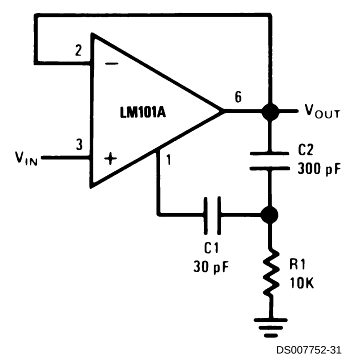
Although the LM101A is relatively unaffected by supply bypassing, this cannot be ignored altogether. Generally it is necessary to bypass the supplies to ground at least once on every circuit card, and more bypass points may be required if more than five amplifiers are used. When feed-forward compensation 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



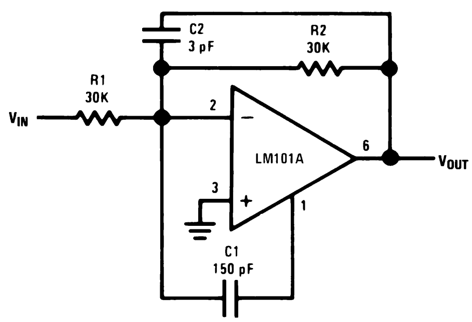
Fast Voltage Follower



Power Bandwidth: 15 kHz
Slew Rate: 1V/µs

Typical Applications (Note 9) (Continued)

Fast Summing Amplifier



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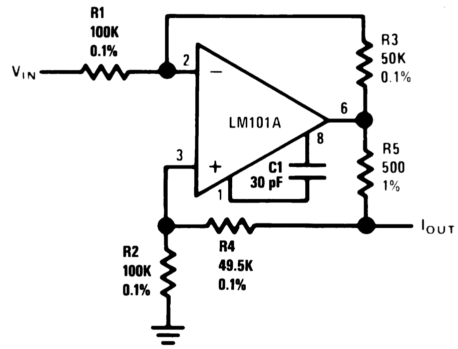
Power Bandwidth: 250 kHz
Small Signal Bandwiidth: 3.5 MHz
Slew Rate: 10V/µs

Bilateral Current Source

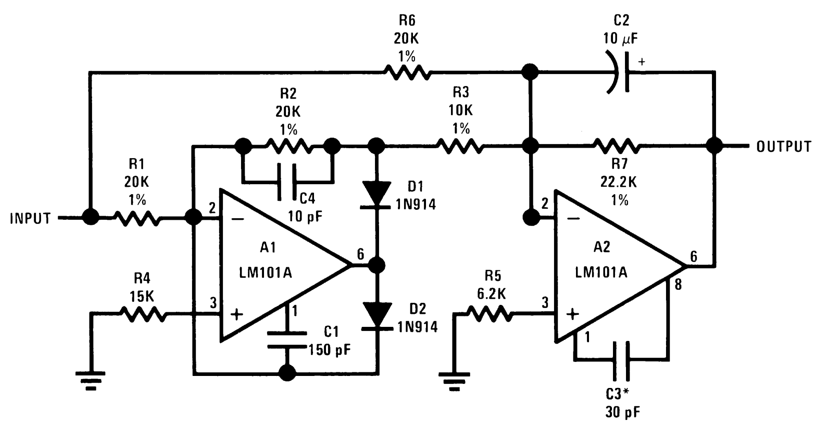


DS007752-32

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

R3 = R4 + R5
R1 = R2

Fast AC/DC Converter (Note 8)

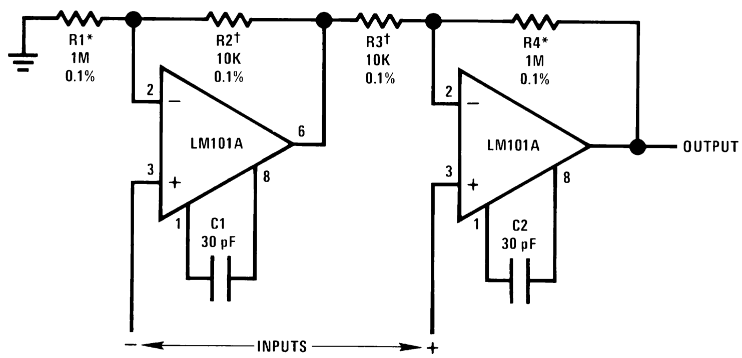


DS007752-33

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

Typical Applications (Note 9) (Continued)

Instrumentation Amplifier



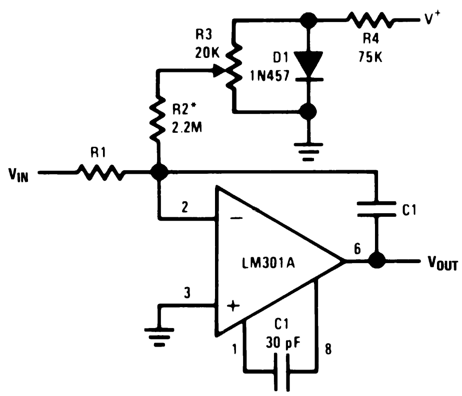
DS007752-34

R1 = R4; R2 = R3

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

*,† Matching determines CMRR.

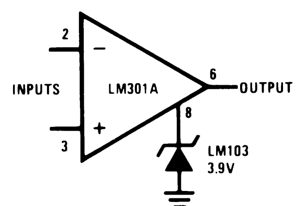
Integrator with Bias Current Compensation



DS007752-35

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

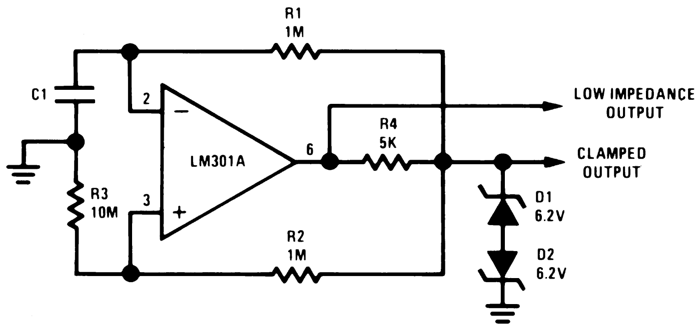
Voltage Comparator for Driving RTL Logic or High Current Driver



DS007752-37

Typical Applications (Note 9) (Continued)

Low Frequency Square Wave Generator



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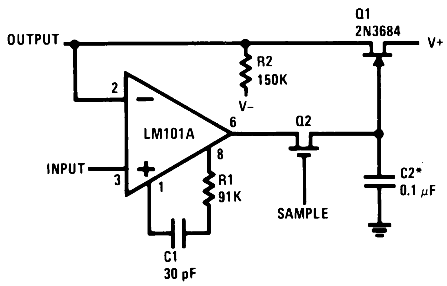
Low Drift Sample and Hold



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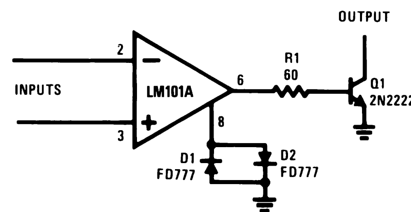
Voltage Comparator for Driving DTL or TTL Integrated Circuits



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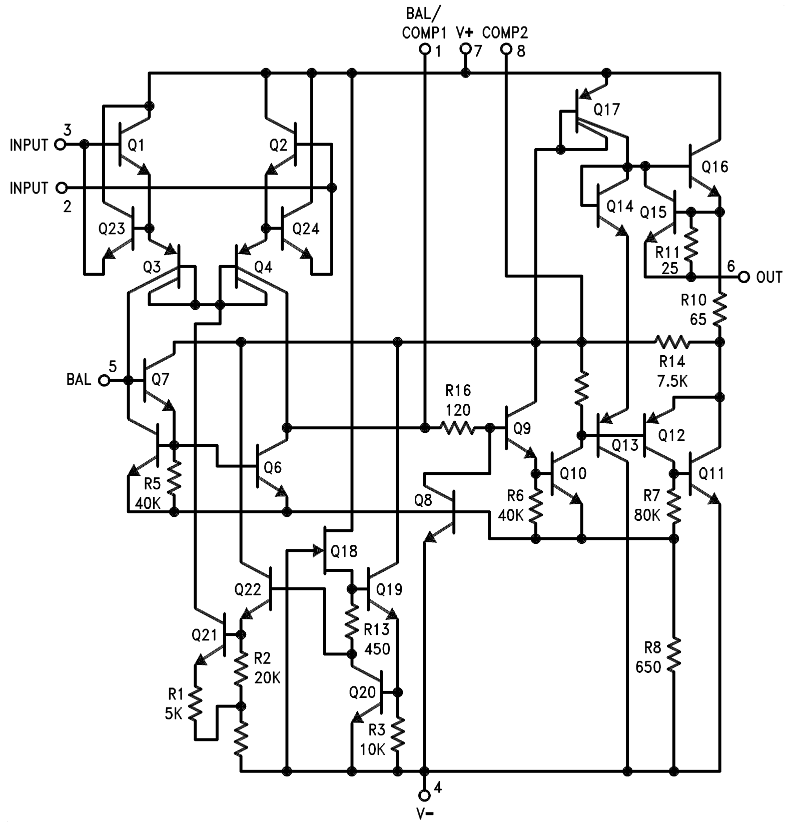
*Polycarbonate-dielectric capacitor

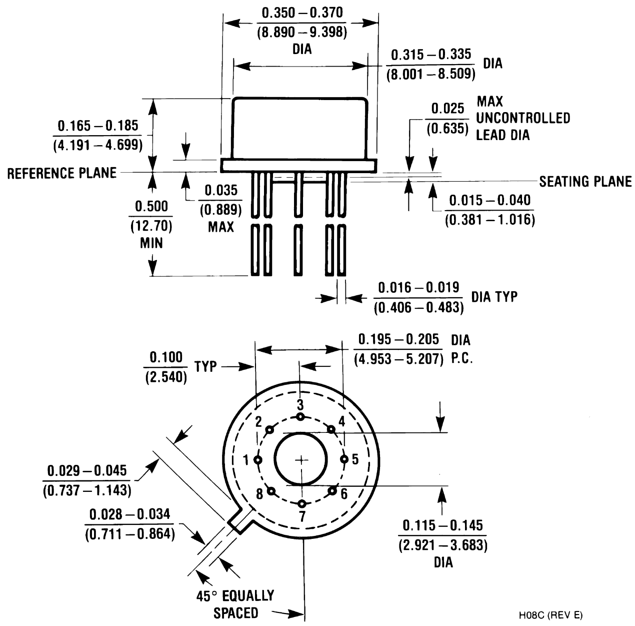
Schematic (Note 9)



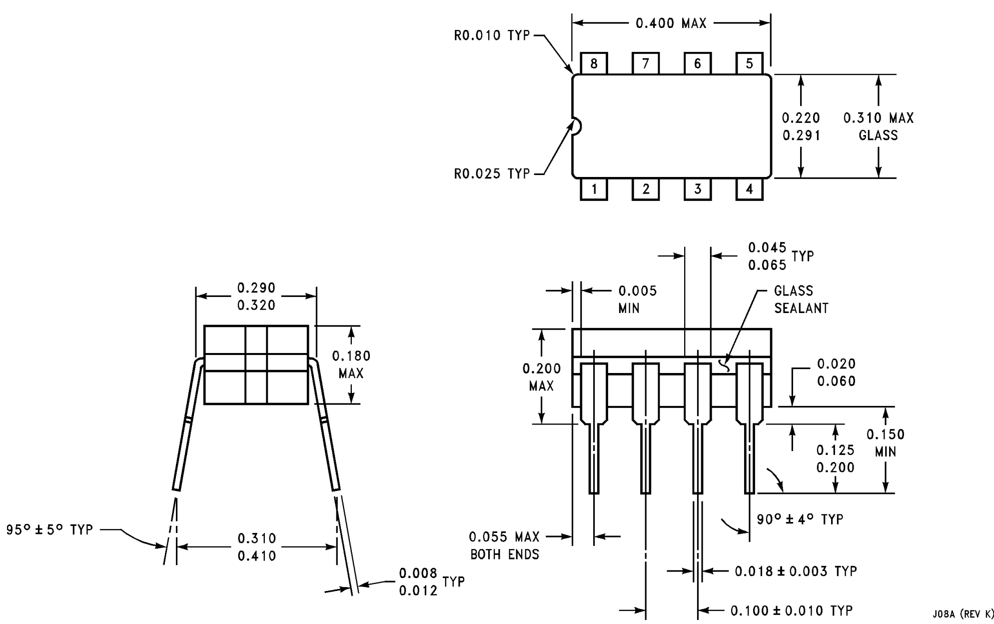
DS007752-1

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

Physical Dimensions inches (millimeters) unless otherwise noted

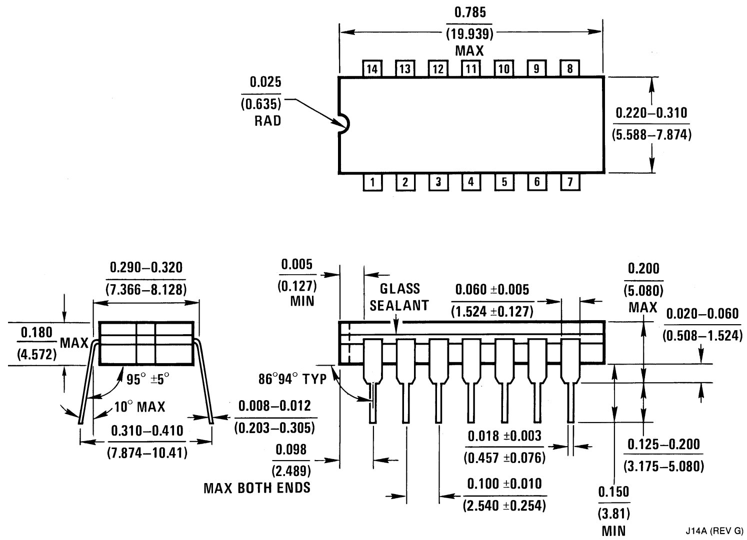


Metal Can Package (H)
Order Number LM101AH, LM101AH/883
LM201AH or LM301AH
NS Package Number H08C

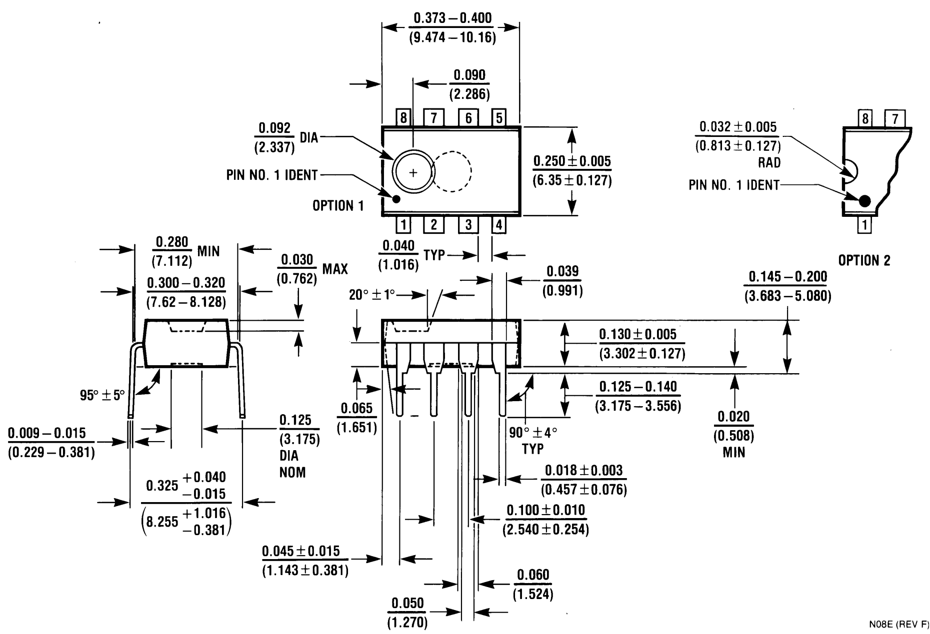


Ceramic Dual-In-Line Package (J)
Order Number LM101J/883 or LM101AJ
NS Package Number J08A

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

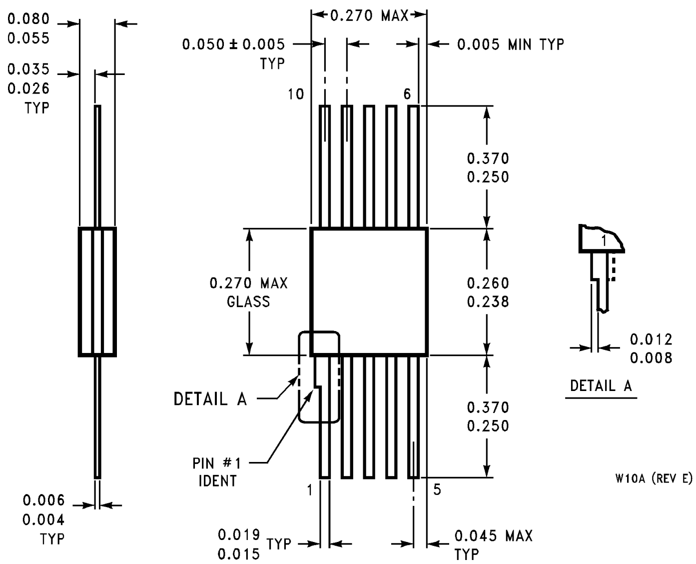


Ceramic Dual-In-Line Package (J)
Order Number LM101AJ-14/883
NS Package Number J14A



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

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



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

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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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