LH0101,LH0101A,LH0101AC,LH0101C

LH0101 LH0101A LH0101AC LH0101C Power Operational Amplifier

Literature Number: SNOSBF9A

National Semiconductor

February 1995

LH0101 Power Operational Amplifier

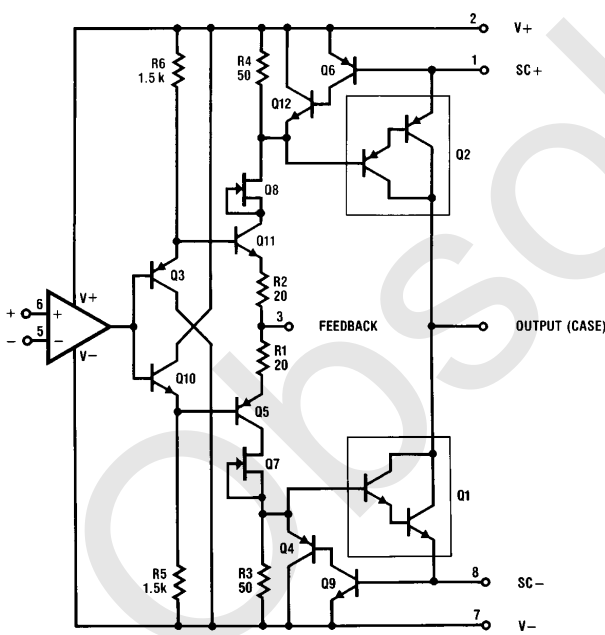
General Description

The LH0101 is a wideband power operational amplifier featuring FET inputs, internal compensation, virtually no crossover distortion, and rapid settling time. These features make the LH0101 an ideal choice for DC or AC servo amplifiers, deflection yoke drives, programmable power supplies, and disk head positioner amplifiers. The LH0101 is packaged in an 8 pin TO-3 hermetic package, rated at 60 watts with a suitable heat sink.

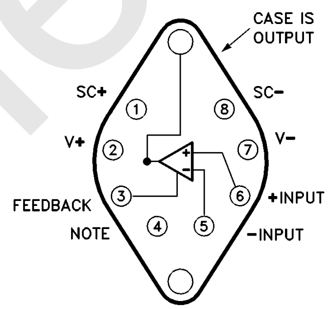
Features

- 5 Amp peak, 2 Amp continuous output current
- 300 kHz power bandwidth
- 850 mW standby power (±15V supplies)
- 300 pA input bias current
- 10 V/μs slew rate
- Virtually no crossover distortion
- 2 μs settling time to 0.01%
- 5 MHz gain bandwidth

Schematic and Connection Diagrams



TL/K/5558–1



TL/K/5558–2

Top View

Order Numbers LH0101K, LH0101K-MIL, LH0101CK, LH0101AK, LH0101AK-MIL or LH0101ACK
See NS Package Number K08A

Note: Electrically connected internally, no connection should be made to pin.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications. (Note 5)

Supply Voltage, V_S	±22V
Power Dissipation at T_A = 25°C, P_D Derate linearly at 25°C/W to zero at 150°C,	5W
Power Dissipation at T_C = 25°C Derate linearly at 2°C/W to zero at 150°C	62W
Differential Input Voltage, V_{IN}	±40V but < ±V_S
Input Voltage Range, V_{CM}	±20V but < ±V_S
Thermal Resistance— See Typical Performance Characteristics	
Peak Output Current (50 ms pulse), $I_{O(PK)}$	5A
Output Short Circuit Duration (within rated power dissipation, R_{SC} = 0.35Ω, T_A = 25°C)	Continuous
Operating Temperature Range, T_A	
LH0101AC, LH0101C	−25°C to +85°C
LH0101A, LH0101	−55°C to +125°C
Storage Temperature Range, T_{STG}	−65°C to +150°C
Maximum Junction Temperature, T_J	150°C
Lead Temperature (Soldering <10 sec.)	260°C
ESD rating to be determined.	

DC Electrical Characteristics (Note 1) V_S = ±15V, T_A = 25°C unless otherwise noted

Symbol	Parameter	Conditions		LH0101AC LH0101A			LH0101C LH0101			Units
				Min	Typ	Max	Min	Typ	Max	
V_{OS}	Input Offset Voltage				1	3		5	10	mV
		$T_{MIN} \le T_A \le T_{MAX}$				7			15	
$\Delta V_{OS}/\Delta P_D$	Change in Input Offset Voltage with Dissipated Power	(Note 2)			150			300		μV/W
$\Delta V_{OS}/\Delta T$	Change in Input Offset Voltage with Temperature	V_{CM} = 0			10			10		μV/°C
I_B	Input Bias Current					300			1000	pA
		$T_A \le T_{MAX}$	LH0101C/AC			60			60	nA
			LH0101/A			300			1000	
I_{OS}	Input Offset Current					75			250	pA
		$T_A \le T_{MAX}$	LH0101C/AC			15			15	nA
			LH0101/A			75			250	
A_{VOL}	Large Signal Voltage Gain	V_O = ±10V R_L = 10Ω		50	200		50	200		V/mV
V_O	Output Voltage Swing	R_{SC} = 0	R_L = 100Ω	±12	±12.5		±12	±12.5		V
		A_V = +1	R_L = 10Ω	±11.25	±11.6		±11.25	±11.6		
		Note 3	R_L = 5Ω	±10.5	±11		±10.5	±11		
CMRR	Common Mode Rejection Ratio	ΔV_{IN} = ±10V		85	100		85	100		dB
PSRR	Power Supply Rejection Ratio	ΔV_S = ±5V to ±15V		85	100		85	100		
I_S	Quiescent Supply Current				28	35		28	35	mA

AC Electrical Characteristics (Note 1), $V_S = \pm 15V$, $T_A = 25°C$

Symbol	Parameter	Conditions	LH0101 LH0101A Min	LH0101 LH0101A Typ	LH0101 LH0101A Max	LH0101C LH0101AC Min	LH0101C LH0101AC Typ	LH0101C LH0101AC Max	Units
e_n	Equivalent Input Noise Voltage	f = 1 kHz		25			25		$nV/\sqrt{Hz}$
C_{IN}	Input Capacitance	f = 1 MHz		3.0			3.0		pF
	Power Bandwidth, −3 dB	$R_L = 10\Omega$, $A_V = +1$		300			300		kHz
SR	Slew Rate	$R_L = 10\Omega$, $A_V = +1$	7.5 (Note 4)	10			10		V/µs
t_r, t_f	Small Signal Rise or Fall Time	$R_L = 10\Omega$, $A_V = +1$		200			200		ns
	Small Signal Overshoot	$R_L = 10\Omega$, $A_V = +1$		10			10		%
GBW	Gain-Bandwidth Product	$R_L = \infty$, $A_V = +1$	4.0 (Note 4)	5.0			5.0		MHz
t_s	Large Signal Settling Time to 0.01%	$R_L = \infty$, $A_V = +1$		2.0			2.0		µs
THD	Total Harmonic Distortion	$P_o = 10W$, f = 1 kHz, $R_L = 10\Omega$		0.008			0.008		%

Note 1: Specification is at $T_A = 25°C$. Actual values at operating temperature may differ from the $T_A = 25°C$ value. When supply voltages are ±15V, quiescent operating junction temperature will rise approximately 20°C without heat sinking. Accordingly, V_{OS} may change 0.5 mV and I_B and I_{OS} will change significantly during warm-ups. Refer to the I_B vs. temperature and power dissipation graphs for expected values. Power supply voltage is ±15V. Temperature tests are made only at extremes.

Note 2: Change in offset voltage with dissipated power is due entirely to average device temperature rise and not to differential thermal feedback effects. Test is performed without any heat sink.

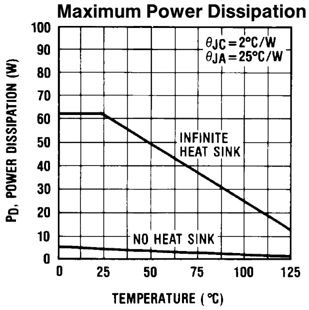
Note 3: At light loads, the output swing may be limited by the second stage rather than the output stage. See the application section under ''Output swing enhancement'' for hints on how to obtain extended operation.

Note 4: These parameters are sample tested to 10% LTPD.

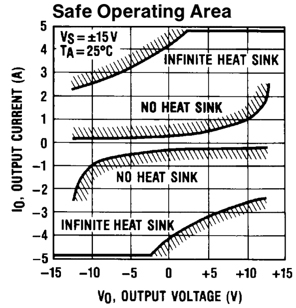
Note 5: Refer to RETS0101AK for the LH0101AK military specifications and RETS0101K for the LH0101K military specifications.

Typical Performance Characteristics

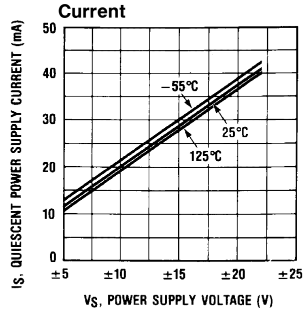
Maximum Power Dissipation



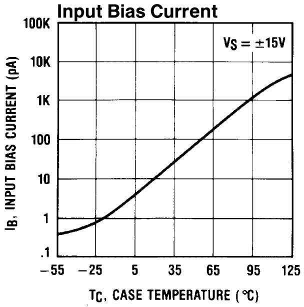
Safe Operating Area



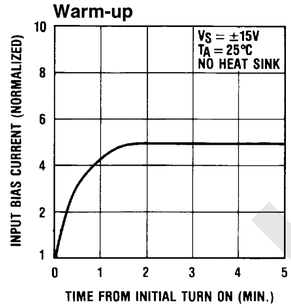
Quiescent Power Supply Current



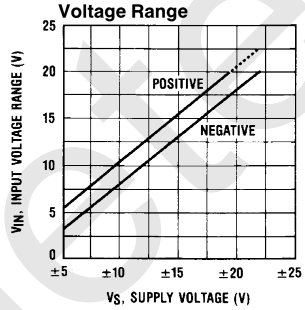
Input Bias Current



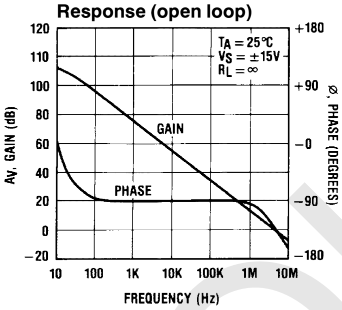
Input Bias Current after Warm-up



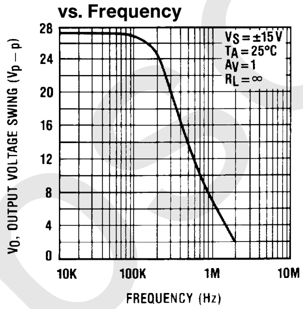
Input Common-Mode Voltage Range



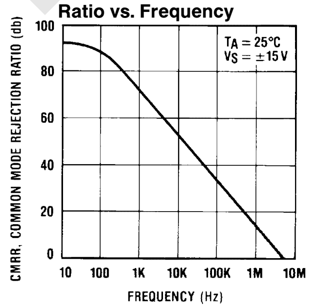
Small Signal Frequency Response (open loop)



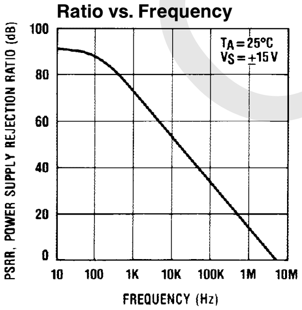
Output Voltage Swing vs. Frequency



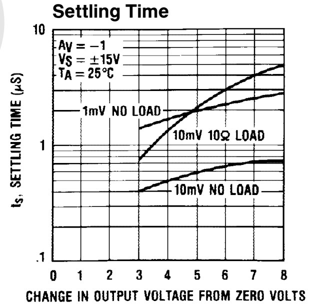
Common-Mode Rejection Ratio vs. Frequency



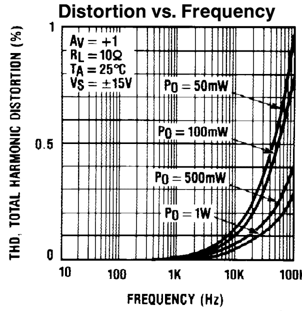
Power Supply Rejection Ratio vs. Frequency



Settling Time



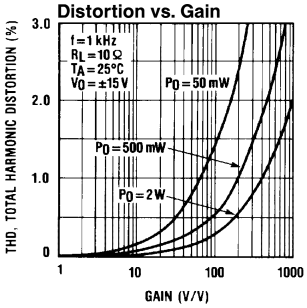
Total Harmonic Distortion vs. Frequency



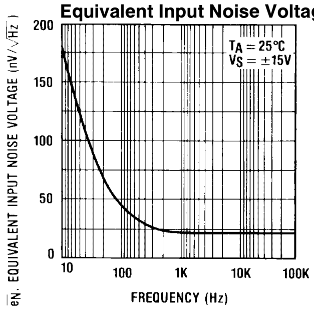
TL/K/5558–3

Typical Performance Characteristics (Continued)

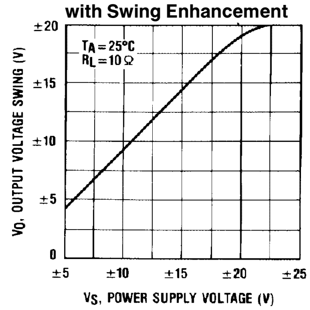
Total Harmonic Distortion vs. Gain



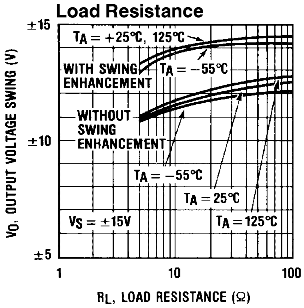
Equivalent Input Noise Voltage



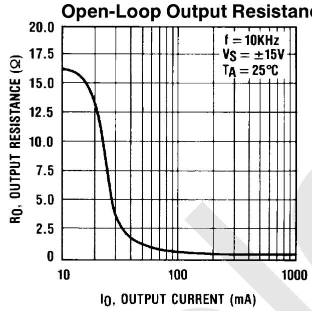
Output Voltage Swing with Swing Enhancement



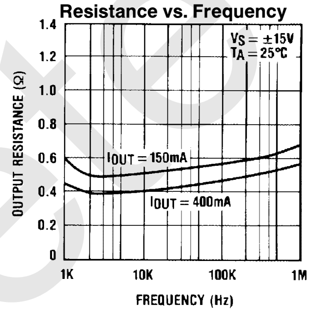
Output Voltage Swing vs. Load Resistance



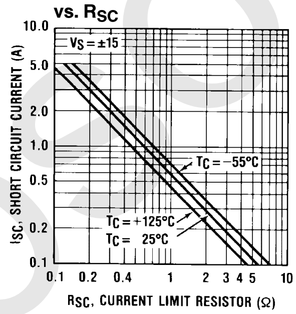
Open-Loop Output Resistance



Open-Loop Output Resistance vs. Frequency

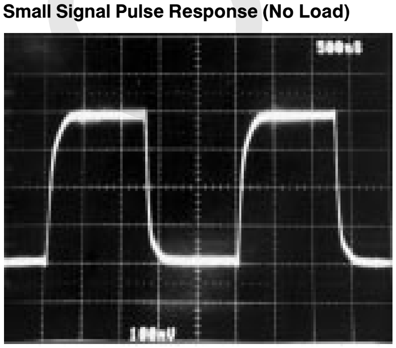


Short Circuit Current vs. R_{SC}



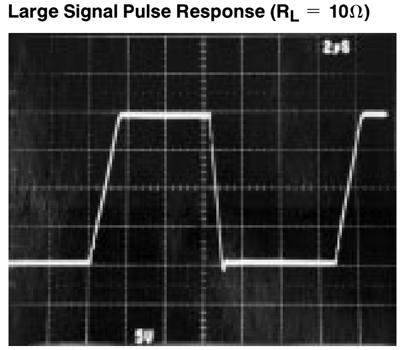
TL/K/5558–4

Small Signal Pulse Response (No Load)



TL/K/5558–5

Large Signal Pulse Response (R_L = 10Ω)



TL/K/5558–6

Application Hints

Input Voltages

The LH0101 operational amplifier contains JFET input devices which exhibit high reverse breakdown voltages from gate to source or drain. This eliminates the need for input clamp diodes, so that high differential input voltages may be applied without a large increase in input current. However, neither input voltage should be allowed to exceed the negative supply as the resultant high current flow may destroy the unit.

Exceeding the negative common-mode limit on either input will cause a reversal of the phase to the output and force the amplifier output to the corresponding high or low state. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

These amplifiers will operate with the common-mode input voltage equal to the positive supply. In fact, the common-mode voltage may exceed the positive supply by approximately 100 mV, independent of supply voltage and over the full operating temperature range. The positive supply may therefore be used as a reference on an input as, for example, in a supply current monitor and/or limiter.

With the LH0101 there is a temptation to remove the bias current compensation resistor normally used on the non-inverting input of a summing amplifier. Direct connection of the inputs to ground or a low-impedance voltage source is not recommended with supply voltages greater than 3V. The potential problem involves loss of one supply which can cause excessive current in the second supply. Destruction of the IC could result if the current to the inputs of the device is not limited to less than 100 mA or if there is much more than 1 μF bypass on the supply buss.

Although difficulties can be largely avoided by installing clamp diodes across the supply lines on every PC board, a conservative design would include enough resistance in the input lead to limit current to 10 mA if the input lead is pulled to either supply by internal currents. This precaution is by no means limited to the LH0101.

Layout Considerations

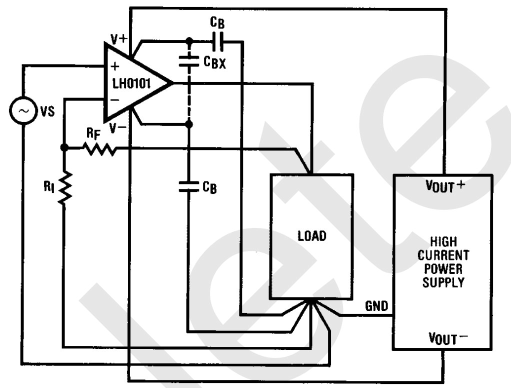
When working with circuitry capable of resolving pico-ampere level signals, leakage currents in circuitry external to the op amp can significantly degrade performance. High quality insulation is a must (Kel-F and Teflon rate high). Proper cleaning of all insulating surfaces to remove fluxes and other residues is also required. This includes the IC package as well as sockets and printed circuit boards. When operating in high humidity environments or near 0°C, some form of surface coating may be necessary to provide a moisture barrier.

The effects of board leakage can be minimized by encircling the input circuitry with a conductive guard ring operated at a potential close to that of the inputs. Electrostatic shielding of high impedance circuitry is advisable.

Error voltages can also be generated in the external circuitry. Thermocouples formed between dissimilar metals can cause hundreds of microvolts of error in the presence of temperature gradients.

Since the LH0101 can deliver large output currents, careful attention should be paid to power supply, power supply bypassing and load currents. Incorrect grounding of signal inputs and load can cause significant errors.

Every attempt should be made to achieve a single point ground system as shown in the figure below.



TL/K/5558–7

FIGURE 1. Single-Point Grounding

Bypass capacitor C_{BX} should be used if the lead lengths of bypass capacitors C_B are long. If a single point ground system is not possible, keep signal, load, and power supply from intermingling as much as possible. For further information on proper grounding techniques refer to "Grounding and Shielding Techniques in Instrumentation" by Morrison, and "Noise Reduction Techniques in Electronic Systems" by Ott (both published by John Wiley and Sons).

Leads or PC board traces to the supply pins, short-circuit current limit pins, and the output pin must be substantial enough to handle the high currents that the LH0101 is capable of producing.

Short Circuit Current Limiting

Should current limiting of the output not be necessary, SC+ should be shorted to V+ and SC− should be shorted to V−. Remember that the short circuit current limit is dependent upon the total resistance seen between the supply and current limit pins. This total resistance includes the desired resistor plus leads, PC Board traces, and solder joints.* Assuming a zero TCR current limit resistor, typical temperature coefficient of the short circuit current will be approximately .3%/°C.

*Short circuit current will be limited to approximately $\frac{0.6}{RSC}$.

Application Hints (Continued)

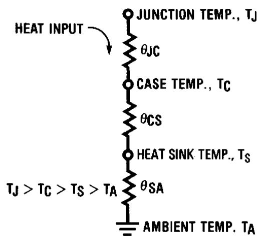
Thermal Resistance

The thermal resistance between two points of a conductive system is expressed as:

$$\theta_{12} = \frac{T_1 - T_2}{P_D} \,°C/W$$

where subscript order indicates the direction of heat flow. A simplified heat transfer circuit for a cased semiconductor and heat sink system is shown in the figure below.

The circuit is valid only if the system is in thermal equilibrium (constant heat flow) and there are, indeed, single specific temperatures T_J, T_C and T_S (no temperature distribution in junction, case, or heat sink). Nevertheless, this is a reasonable approximation of actual performance.



TL/K/5558–8

FIGURE 2. Semiconductor-Heat Sink Thermal Circuit

The junction-to-case thermal resistance θ_{JC} specified in the data sheet depends upon the material and size of the package, die size and thickness, and quality of the die bond to the case or lead frame. The case-to-heat sink thermal resistance θ_{CS} depends on the mounting of the device to the heat sink and upon the area and quality of the contact surface. Typical θ_{CS} for a TO-3 package is 0.5 to 0.7°C/W, and 0.3 to 0.5°C/W using silicone grease.

The heat sink to ambient thermal resistance θ_{SA} depends on the quality of the heat sink and the ambient conditions.

Cooling is normally required to maintain the worst case operating junction temperature T_J of the device below the specified maximum value $T_{J(MAX)}$. T_J can be calculated from known operating conditions. Rewriting the above equation, we find:

$$\theta_{JA} = \frac{T_J - T_A}{P_D} \,°C/W$$

$$T_J = T_A + P_D\theta_{JA} \,°C$$

Where: $P_D \ (V_S - V_{OUT})I_{OUT} + |V+ - (V-)|I_Q$ for a DC Signal

$$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA} \text{ and } V_S = \text{Supply Voltage}$$

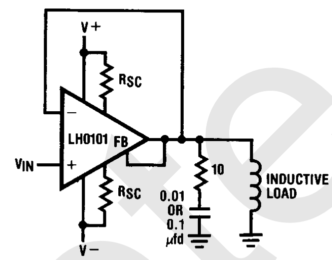
θ_{JC} for the LH0101 is about 2°C/W.

Stability and Compensation

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pickup" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input device (usually the inverting input) to ac ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time consistant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

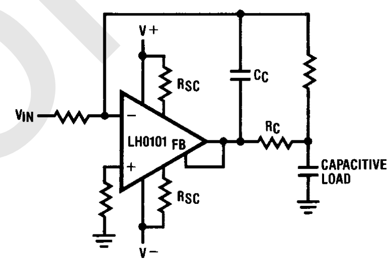
Some inductive loads may cause output stage oscillation. A .01 μF ceramic capacitor in series with a 10Ω resistor from the output to ground will usually remedy this situation.



TL/K/5558–9

FIGURE 3. Driving Inductive Loads

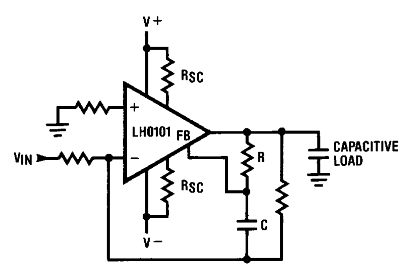
Capacitive loads may be compensated for by traditional techniques. (See "Operational Amplifiers: Theory and Practice" by Roberge, published by Wiley):



TL/K/5558–10

FIGURE 4. R_C and C_C Selected to Compensate for Capacitive Load

A similar but alternative technique may be used for the LH0101:



TL/K/5558–11

FIGURE 5. Alternate Compensation for Capacitive Load

Application Hints (Continued)

Output Swing Enhancement

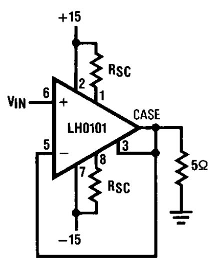
When the feedback pin is connected directly to the output, the output voltage swing is limited by the driver stage and not by output saturation. Output swing can be increased as shown by taking gain in the output stage as shown in High Power Voltage Follower with Swing Enhancement below. Whenever gain is taken in the output stage, as in swing enhancement, either the output stage, or the entire op amp must be appropriately compensated to account for the additional loop gain.

Output Resistance

The open loop output resistance of the LH0101 is a function of the load current. No load output resistance is approximately 10Ω. This decreases to under 1Ω for load currents exceeding 100 mA.

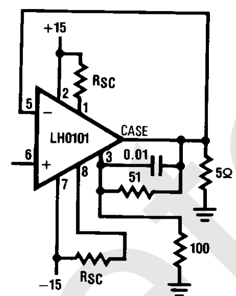
Typical Applications

See AN261 for more information.



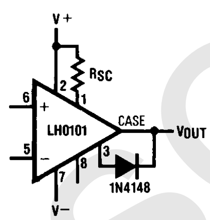
TL/K/5558–12

FIGURE 6. High Power Voltage Follower



TL/K/5558–13

FIGURE 7. High Power Voltage Follower with Swing Enhancement



TL/K/5558–14

FIGURE 8. Restricting Outputs to Positive Voltages Only

Following is a partial list of sockets and heat dissipators for use with the LH0101. National assumes no responsibility for their quality or availability.

8-Lead TO-3 Hardware

SOCKETS

Keystone 4626 or 4627
Robinson Nugent 0002011
Azimuth 6028 (test socket)

HEAT SINKS

Thermalloy 2266B (35°C/W)
IERC LAIC3B4CB
IERC HP1-TO3-33CB (7°C/W)
AAVID 5791B

MICA WASHERS

Keystone 4658

AAVID Engineering
30 Cook Court
Laconla, New Hampshire 03246

Azimuth Electronics
2377 S. El Camino Real
San Clemente, CA 92572

IERC
135 W. Magnolia Blvd.
Burbank, CA 91502

Keystone Electronics Corp.
49 Bleecker St.
New York, NY 10012

Robinson Nugent Inc.
800 E. 8th St.
New Albany, IN 47150

Thermalloy
P.O. Box 34829
Dallas, TX 75234

Typical Applications (Continued)

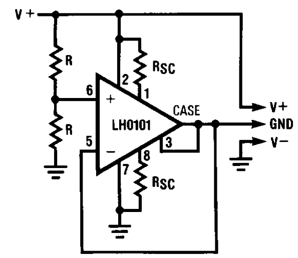


FIGURE 9. Generating a Split Supply from a Single Voltage Supply

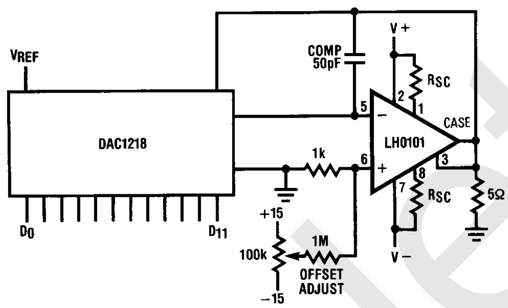


FIGURE 10. Power DAC

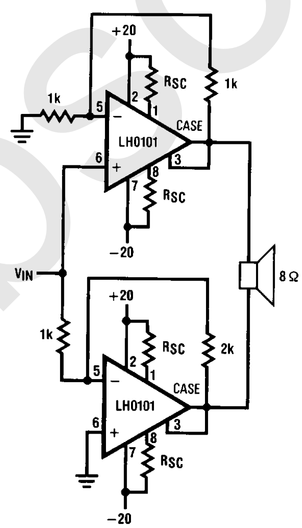
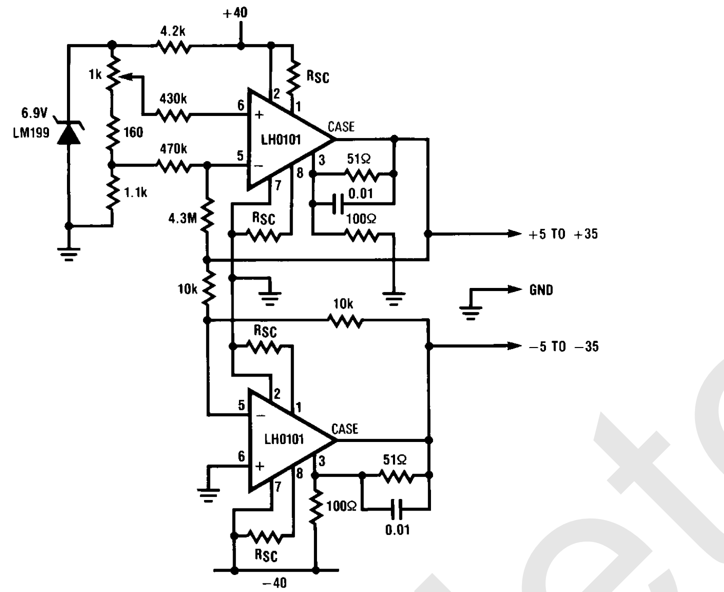


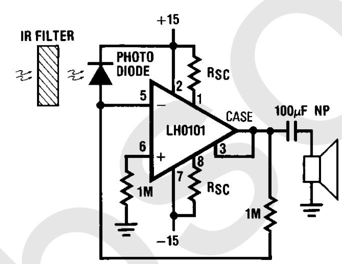
FIGURE 11. Bridge Audio Amplifier

Typical Applications (Continued)



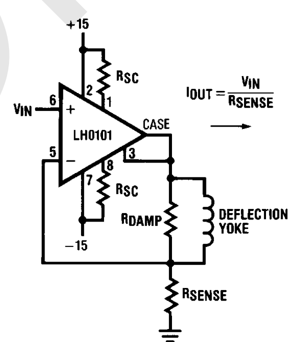
TL/K/5558–18

FIGURE 12. ±5 to ±35 Power Source or Sink



TL/K/5558–19

FIGURE 13. Remote Loudspeaker via Infrared Link



TL/K/5558–20

FIGURE 14. CRT Deflection Yoke Driver

Typical Applications (Continued)

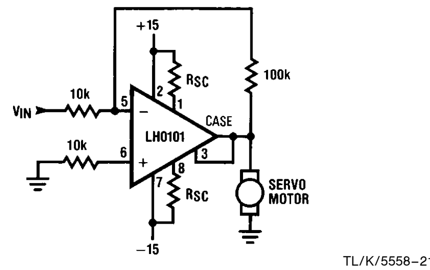


FIGURE 15. DC Servo Amplifier

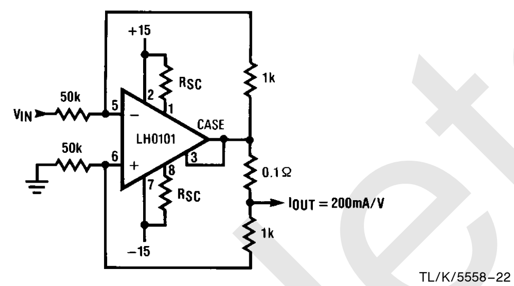
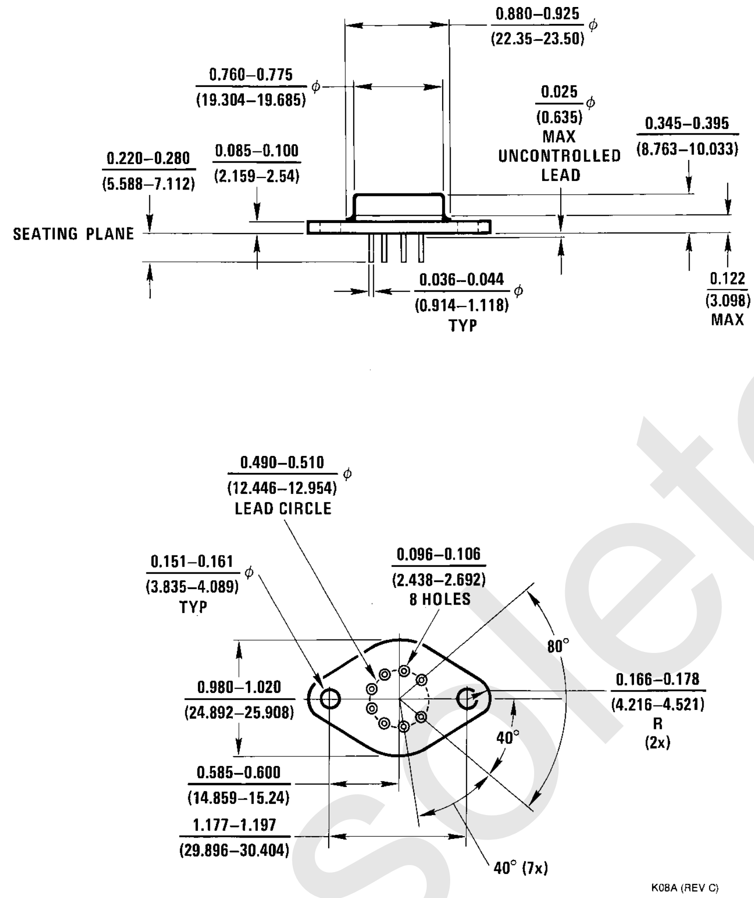


FIGURE 16. High Current Source/Sink

Physical Dimensions inches (millimeters)

Lit. # 106400



8 Lead TO-3 Metal Can (K)
Order Number LH0101K, LH0101K-MIL, LH0101CK, LH0101AK, LH0101AK-MIL or LH0101ACK
NS Package Number K08A

National Semiconductor Corporation
1111 West Bardin Road
Arlington, TX 76017
Tel: 1(800) 272-9959
Fax: 1(800) 737-7018

National Semiconductor Europe
Fax: (+49) 0-180-530 85 86
Email: cnjwge@tevm2.nsc.com
Deutsch Tel: (+49) 0-180-530 85 85
English Tel: (+49) 0-180-532 78 32
Français Tel: (+49) 0-180-532 93 58
Italiano Tel: (+49) 0-180-534 16 80

National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
Tel: 81-043-299-2309
Fax: 81-043-299-2408