



PRELIMINARY

## LH7001 Positive/Negative Adjustable Regulator

### General Description

The LH7001 combines a positive and a negative adjustable regulator in one package. Both can supply 100 mA over a 1.2V to 37V output range. It is exceptionally easy to use and requires only two external resistors on each side to set the output voltage.

In addition to high performance both sides of the LH7001 offer full overload protection. Included are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

The LH7001 is intended for voltage and current regulation in systems where both polarities are required. This is, e.g., the case with supplies for op-amps and buffers, where the LH7001 can also be used to protect from overloads.

Normally, for stable operation, no external capacitor is needed on the positive side. The negative side requires only a single 1  $\mu$ F solid tantalum capacitor. On both sides, larger output capacitors can be added to improve transient response. In case the device is further than 6 inches from the input filter capacitors, input bypass capacitors are needed. The adjustment terminals can be bypassed to achieve very high ripple rejection.

The positive and the negative regulator are electrically separated and can therefore be used independent from each other. Since each regulator is "floating" and sees only the

input to output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input-to-output differential is not exceeded.

The LH7001 is available in a standard molded 8 pin DIP as LH7001CN with a temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ , and in an 8 pin TO-5 package as LH7001H with a temperature range from  $-55^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ .

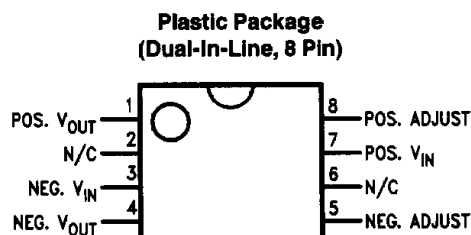
### Features

- Dual output down to  $\pm 1.2\text{V}$
- Guaranteed  $\pm 100\text{ mA}$  output current
- Line regulation typically 0.01%/V
- Load regulation typically 0.5%
- Current limit constant with temperature
- Standard 8 pin DIP and 8 pin TO-5 packages
- 80 dB ripple rejection
- Output is short circuit protected

### Applications

- Dual precision voltage regulator
- Dual precision current limiter
- Voltage and current protection for op-amps
- Dual tracking regulator

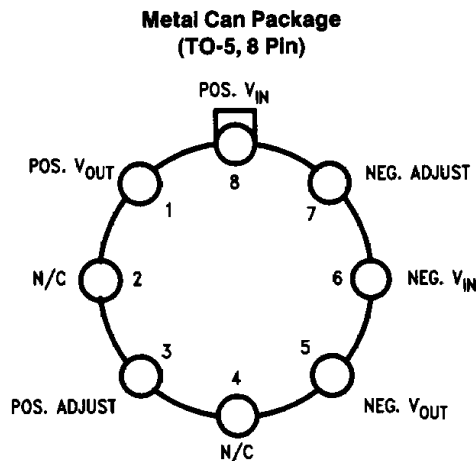
### Connection Diagrams



Top View

Order Number LH7001CN  
See NS Package Number N08E

TL/K/10127-1



Top View

Order Number LH7001H  
See NS Package Number H08D

TL/K/10127-2

## Absolute Maximum Ratings

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

Power Dissipation	Internally Limited
Input-Output Voltage Differential	40V
Operating Junction Temperature	
LH7001CN	−40°C to +125°C
LH7001H	−55°C to +150°C

Storage Temperature	−55°C to +150°C
Lead Temperature (Soldering)	
LH7001CN	4 sec. to 260°C
LH7001H	10 sec. to 300°C
ESD Rating	TBD

## Electrical Characteristics

(Note 1) (unless otherwise noted, these specifications apply:

−55°C <  $T_j$  < +150°C for the LH7001 and −40°C ≤  $T_j$  < +125°C for the LH7001C,  $|V_{IN} - V_{OUT}| = 5V$  and  $I_{OUT} = 40mA$ . Although power dissipation is internally limited, these specifications are applicable for power dissipations up to 600 mW for LH7001H and up to 900 mW for LH7001CN,  $I_{MAX}$  is 100 mA. Specifications apply for both positive and negative current limiter.

Parameter	Conditions	Typ	Tested Limit (Note 2)	Design Limit (Note 3)	Units (Max. Unless Otherwise Noted)
Line Regulation	$3V <  V_{IN} - V_{OUT}  < 40V$ (Note 4) $T_j = 25^\circ C$	0.01 <b>0.02</b>	0.04 <b>0.07</b>		%/V
Load Regulation	$5mA < I_{OUT} < I_{MAX}$ (Note 4), $P \leq 625mW$ $T_j = 25^\circ C$	0.5	0.8 <b>1.5</b>		%
Adjustment Pin Current		<b>50</b>	<b>100</b>		$\mu A$
Adjustment Pin Current Change	$5mA < I_L < 100mA$ $3V <  V_{IN} - V_{OUT}  < 40V$ , $P \leq 625mW$	<b>4</b>	<b>10</b>		$\mu A$
Reference Voltage	$3V <  V_{IN} - V_{OUT}  < 40V$ , (Note 4) $5mA < I_{OUT} < 100mA$	<b>1.25</b>	<b>1.3</b> <b>1.2</b>		V(Min)
Current Limit	$3V <  V_{IN} - V_{OUT}  < 13V$	<b>200</b>	<b>300</b> <b>100</b>		mA mA (Min)
	$ V_{IN} - V_{OUT}  < 40V$	<b>50</b>	<b>120</b> <b>25</b>		mA mA (Min)
Thermal Regulation	$T_j = 25^\circ C$ , 10 ms Pulse	0.04	0.2		%/W
Minimum Load Current	$ V_{IN} - V_{OUT}  < 40V$ $3 <  V_{IN} - V_{OUT}  < 15V$	<b>3.5</b>	<b>5</b>		mA
		<b>1.5</b>	<b>3.5</b>		mA
RMS Output Noise, % of $V_{OUT}$	$T_j = 25^\circ C$ , 10 Hz < $f$ < 10 kHz	0.003			%
Ripple Rejection Ratio	$V_{OUT} = 10V$ , $f = 120Hz$ $C_{ADJ} = 0\mu F$ $C_{ADJ} = 10\mu F$	65 80			dB
Long Term Stability	$T_j = 125^\circ C$ , 1000 Hrs.	0.3			%
Thermal Resistance Junction to Ambient (No Heat Sink)	H Package (TO-5)	<b>180</b>			$^\circ C/W$
	N Package (DIP)	<b>110</b>			$^\circ C/W$
Thermal Resistance Junction to Case	H Package (TO-5)	75			$^\circ C/W$

**Note 1:** Boldface limits are guaranteed over full temperature range. Operating junction temperature range of LH7001CN is −25°C to +125°C, and LH7001H is −55°C to +150°C.

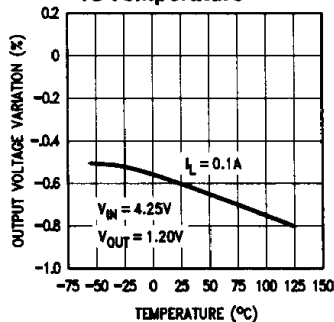
**Note 2:** Tested limits are guaranteed and 100% production tested.

**Note 3:** Design limits are guaranteed (but not production tested) over the indicated temperature or temperature range. These limits are not used to calculate outgoing quality level.

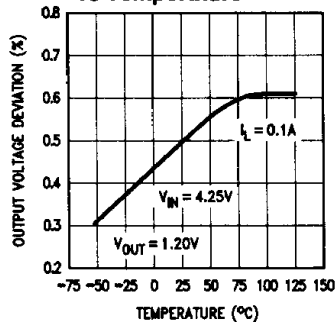
**Note 4:** This parameter is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

# Typical Performance Characteristics

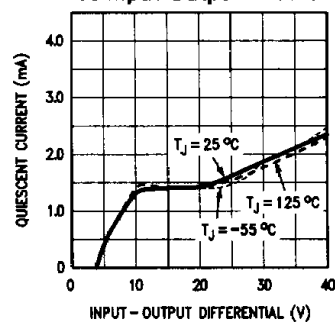
**Positive Regulator Load Regulation vs Temperature**



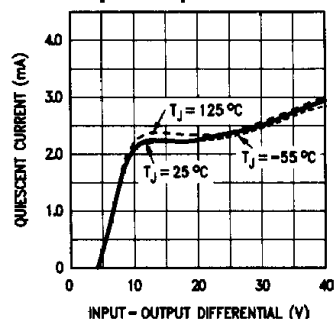
**Negative Regulator Load Regulation vs Temperature**



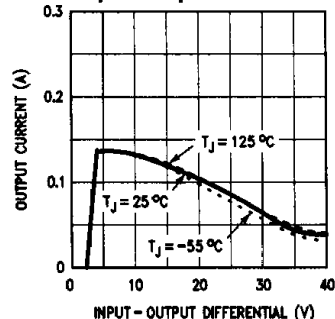
**Positive Regulator Min. Operating Current vs Input-Output Differential**



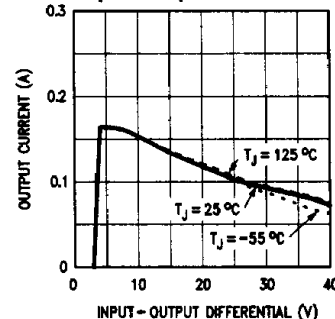
**Neg. Regulator Min. Operating Current vs Input-Output Differential**



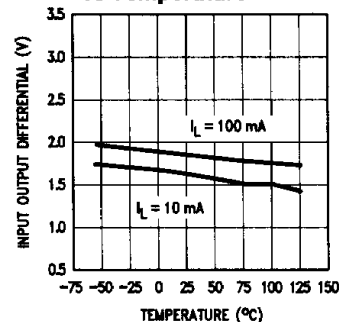
**Pos. Regulator Output Current Limit vs Input-Output Differential**



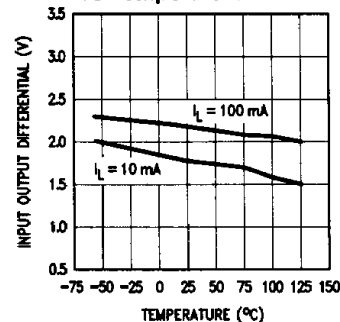
**Neg. Regulator Output Current Limit vs Input-Output Differential**



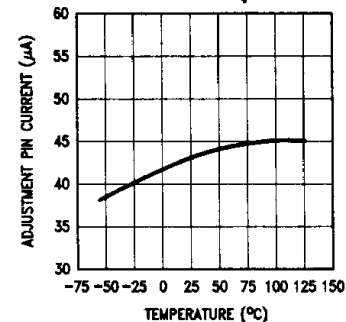
**Pos. Regulator Dropout Voltage vs Temperature**



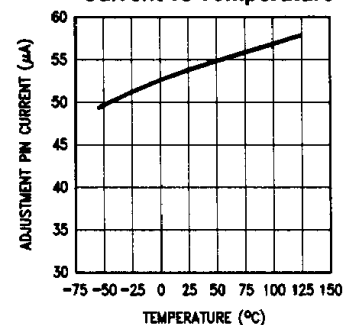
**Negative Regulator Dropout Voltage vs Temperature**



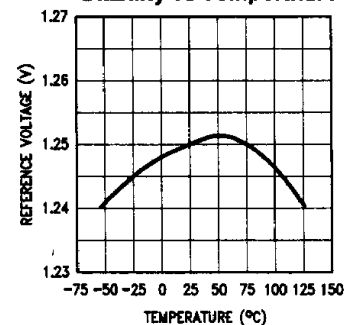
**Positive Regulator Adjustment Pin Current vs Temperature**



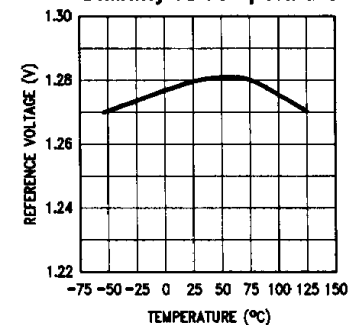
**Negative Regulator Adjustment Pin Current vs Temperature**



**Positive Regulator Reference Voltage Stability vs Temperature**

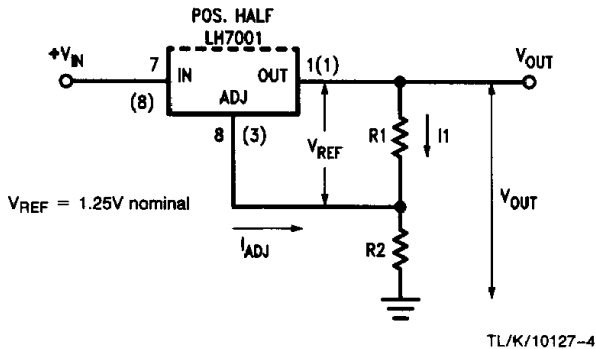


**Negative Regulator Reference Voltage Stability vs Temperature**



## Application Hints

In operation, the positive regulator develops a nominal 1.25V reference voltage,  $V_{REF}$ , between the output and the adjust terminal (Figure 1). The negative regulator develops  $-1.25V$ . The reference voltage is impressed across program resistor  $R1$  and, since the voltage is constant, a constant current  $I_1$  then flows through the output set resistor  $R2$ , giving an output voltage of  $V_{OUT} = V_{REF} (1 + R2/R1) + I_{ADJ} (R2)$



Pinout shown for DIP (TO-5 in parenthesis)

**FIGURE 1. Positive Voltage Regulator**

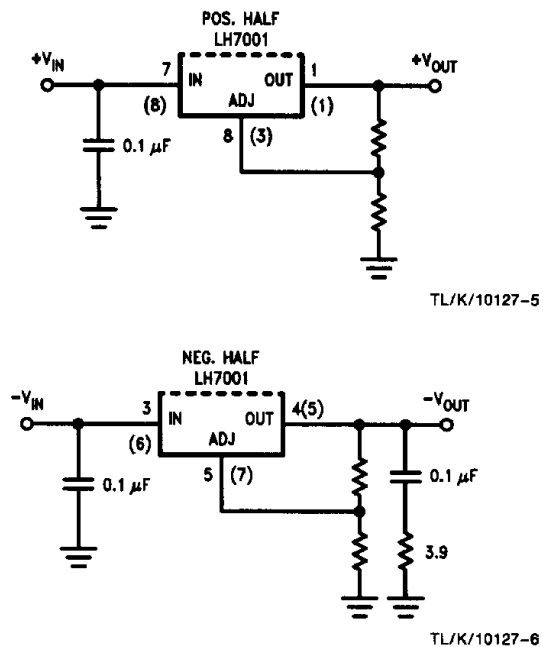
Since the current from the adjustment terminal represents an error term, the LH7001 was designed to minimize  $I_{ADJ}$  and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output voltage will rise.  $I_{ADJ}$  is typically 50  $\mu A$  (see graph in Typical Performance Characteristics).

## Stability

An input bypass capacitor is recommended for both the positive and the negative regulator in case the regulator is more than 6 inches away from the usual large filter capacitor. A 0.1  $\mu F$  disk or 1  $\mu F$  tantalum on the inputs is suitable bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used, but the above values will eliminate the possibility of problems.

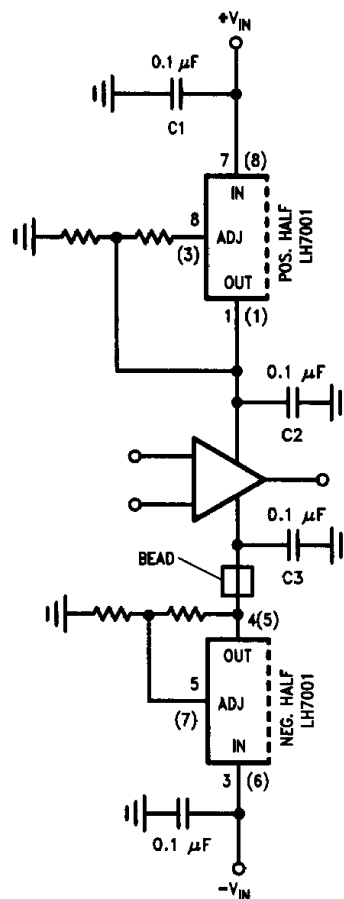
The positive regulator is stable with no output capacitors. However, like any feedback circuit, certain values of external capacitance can cause excessive ringing. For the positive regulator these values are between 500 pF and 5000 pF. Additional capacitance on the output will correct the problem.

To stabilize the negative side, a lossy capacitor of more than 0.1  $\mu F$  is needed from the negative output to ground. A 1  $\mu F$  tantalum or 3.9  $\Omega$  in series with a 0.1  $\mu F$  ceramic will meet the requirement (Figure 2). However, in some applications, like on the supply voltage for an op-amp, a high grade bypass capacitor is needed. In this case a lossy ceramic bead in series with the negative output, followed by 0.1  $\mu F$  to ground, is recommended (Figure 3). The bead needs to be optimized for frequencies around 1 MHz, a Fair-Rite 2673000101 works well.



Pinout shown for DIP (TO-5 in parenthesis)

**FIGURE 2. Choice of Capacitors for Stable Operation**



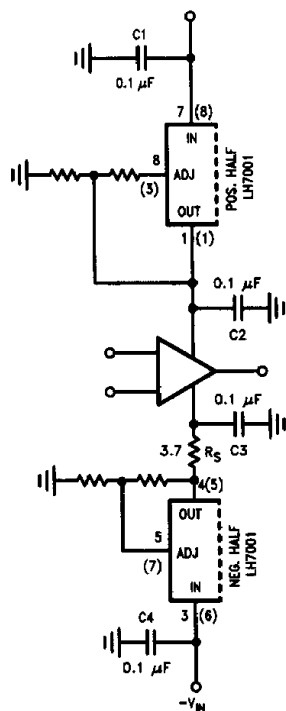
The negative regulator is stabilized with ferrite bead and C3.

Pinout shown for DIP (TO-5 in parenthesis)

**FIGURE 3. LH7001 Supplying an Op-Amp**

## Stability (Continued)

A resistor value of  $3.9\Omega$  in series with the output followed by a  $0.1\mu\text{F}$  to ground is another way to suppress oscillations of the negative regulator, but this is only acceptable where the load regulation is not critical (Figure 4).

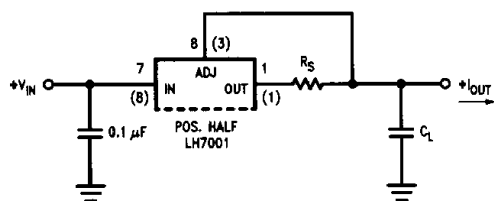


TL/K/10127-8

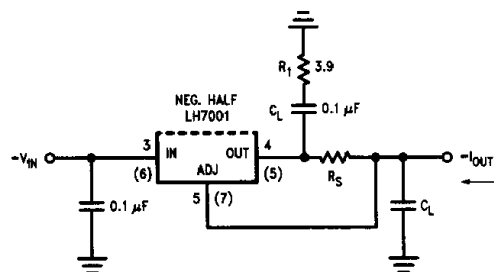
The negative regulator is stabilized by  $R_S$ ,  $C_3$ .

**FIGURE 4. LH7001 Supplying an Op-Amp\***

In the current limit mode the negative regulator has a series sense resistor which separates the device from the load and its bypass capacitor. A  $0.1\mu\text{F}$  ceramic capacitor in series with  $3.9\Omega$  from the output to ground will suppress oscillations (Figure 5).



TL/K/10127-9



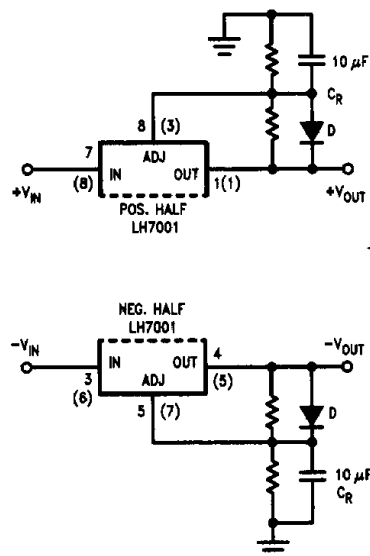
TL/K/10127-10

$R_1$ ,  $C_1$  Stabilize the negative side.  $I_{OUT} = \pm 1.25 \text{ V}/R_S$ .

**FIGURE 5. LH7001 as Dual Current Limiter\***

## Improved Ripple Rejection

The adjustment terminals on both the positive and the negative regulator can be bypassed to ground to improve ripple rejection and noise. These bypass capacitors prevent ripple and noise from being amplified. With  $10\mu\text{F}$  bypass capacitors 80 dB ripple rejection is obtainable at any output level. Increases over  $10\mu\text{F}$  do not appreciable increase the ripple rejection at frequencies above 120 Hz. If bypass capacitors are used, it is sometimes necessary to include protection diodes (see next section) to prevent the capacitors from discharging through internal low current paths and damaging the device (Figure 6).



TL/K/10127-11

TL/K/10127-12

**FIGURE 6. LH7001 with Improved Ripple Rejection\***

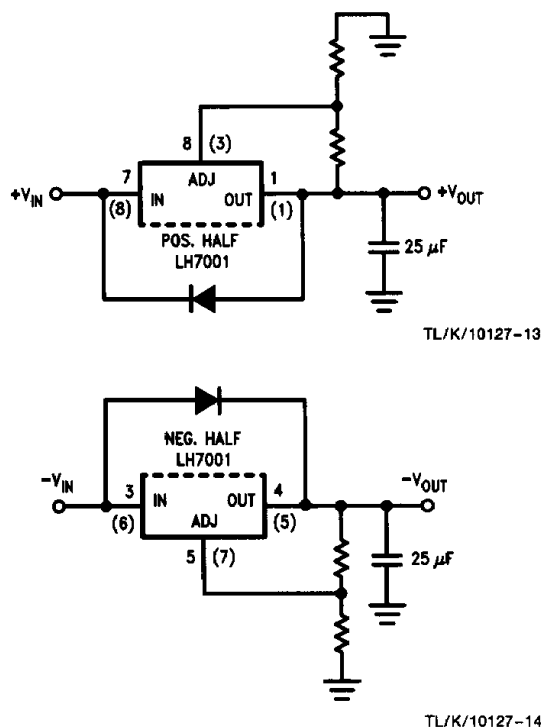
## Protection Diodes

When external capacitors are used with any IC regulator, it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most  $10\mu\text{F}$  capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage the device.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. Figure 7 shows how to protect the device with discharge diodes.

\*Pinout shown for DIP (TO-5 in parenthesis)

## Protection Diodes



**FIGURE 7. LH7001 with Large Capacitive Loads\***

The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of  $V_{IN}$ . In the LH7001 the discharge path is through a large junction that is able to sustain a 2A surge without being degraded. For output capacitors of 10  $\mu$ F or less, the LH7001's ballast resistors and output structure limit the peak current to a low enough level so that there is no need to use protection diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when either the input or output is shorted. When shorts might occur and the capacitance is in excess of 10  $\mu$ F discharge diodes are recommended (Figure 6).

## Capacitors

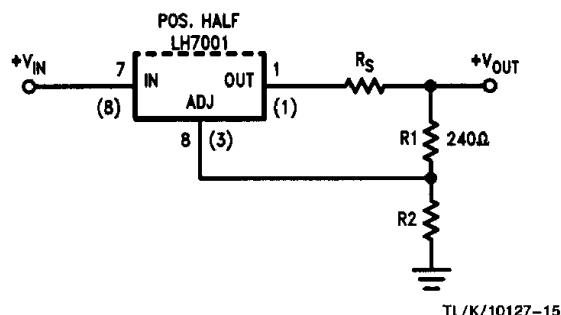
In general, the best type of capacitor to use are solid tantalum. These capacitors have low impedance even at high frequencies. Depending on capacitor construction, it takes about 25  $\mu$ F in aluminum electrolytic to equal 1  $\mu$ F solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies, but some types have a large decrease in capacitance at frequencies around 5 MHz. For this reason, a 0.01  $\mu$ F disk may work better than a 0.1  $\mu$ F disk as a bypass.

## Load Regulation

The LH7001 is capable of providing extremely good load regulation, but a few precautions are needed to obtain maxi-

mum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240 $\Omega$ ) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15V regulator with 50 m $\Omega$  resistance between the regulator and load will have a load regulation due to line resistance of 50 m $\Omega$   $\times$   $I_L$ . If the set resistor is connected near the load the effective line resistance will be 50 m $\Omega$  (1 +  $R_2/R_1$ ) or, in this case, 11.5 times worse.

Figure 8 shows the effect of resistance between the regulator and the connection of the set resistor.



**FIGURE 8. Positive Regulator with Line Resistance in Output Lead\***

It is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the output pin. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation. The setting resistor is normally chosen to be 240 $\Omega$ . The reference voltage of 1.25V causes a current of 5.2 mA to flow, which is much larger than the maximally 100  $\mu$ A flowing through the adjustment pin. This makes the regulation very stable. However, if a smaller set current is desired, the setting resistor can be increased at the expense of voltage accuracy, e.g. to 2 k $\Omega$ .

## Thermal Regulation

When power is dissipated in an IC, temperature gradient occurs across the chip affecting the individual IC circuit components. With an IC regulator, this gradient can be especially severe since power dissipation is large. Thermal regulation is the effect of these temperature gradients on output voltage (in percentage output change) per Watt of power change in a specified time. Thermal regulation error is independent of electrical regulation or temperature coefficient and occurs within 5 ms to 50 ms after a change in power dissipation. Thermal regulation depends on IC layout as well as electrical design. The thermal regulation of a voltage regulator is defined as the percentage change of  $V_{OUT}$ , per Watt, within the first 10 ms after a step of power is applied. The LH7002 specification is 0.2 %/W, maximum.

\*Pinout shown for DIP (TO-5 in parenthesis)

## Current Limiting and Thermal Protection

Both the positive and the negative regulator protect themselves as well as the loads. They do this by limiting the current and by a thermal shutdown feature that cuts in should the temperature in the regulator get too high.

The current limiting is relatively constant over temperature. The limit is constant up to about 15V input-to-output differential, then drops (see the graphs in the Typical Performance Characteristics).

The thermal shutdown will cut the current off as soon as the thermal sensor reaches typically 162°C. Thus the cut-off depends on the power dissipated in the LH7001 and the thermal resistance:

$$I_{MAX} = T_{MAX}/R_{TH} (V_{IN} - V_{OUT})$$

There are also two time constants involved. One is the time constant of the chip; it is typically 100 ms. The other one is the time constant of the package; it is typically 20 sec (the exact value depends on the type of cooling, heatsink, etc.). This means that for a short time the device can absorb more power than in a steady state condition.

The thermal protection on each side is independent of the other. When the protection cuts in, the output current becomes pulse width modulated. In this way the dissipation in the device is limited. The repetition time can range from several tens to several hundreds of milliseconds, with the faster times for the higher overstress. Normally, under symmetrical electric conditions, the positive side will go into thermal protection before the negative side.

Figure 9 shows the dissipation of the positive and the negative regulator for the DIP package. The conditions are symmetrical as shown in Figure 10. The current through the regulators is held at a constant  $\pm 100$  mA. With increasing voltage the dissipation in the device increases, and the positive regulator starts to turn off in a pulsed fashion. When the power is increased further, the positive regulator is OFF and the negative regulator goes into pulsed thermal shutdown. Figure 11 shows the same graph for the TO-5 package.

It needs to be mentioned that the LH7001CN in the DIP package will be protected from catastrophic failure, but if operated in thermal shutdown frequently or for long durations the thermal shutdown temperature of nominally 162°C, will reduce the lifetime of the plastic package.

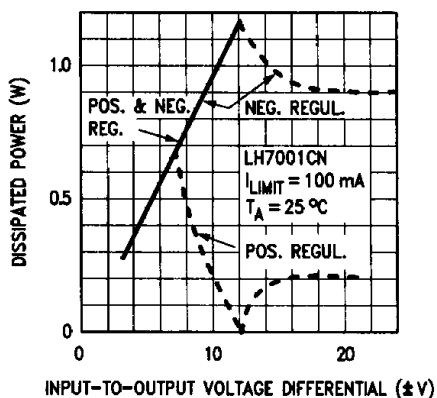
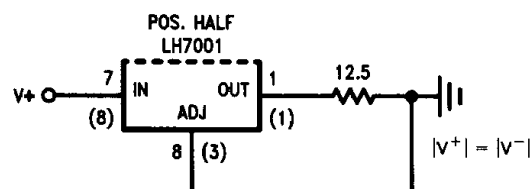
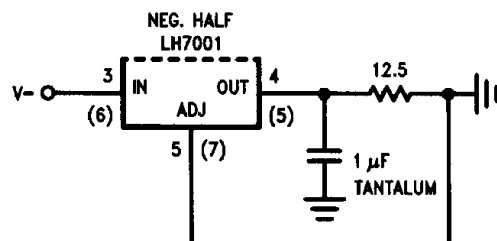


FIGURE 9. Dissipated Power of Positive and Negative Regulator vs In-to-Out Voltage Differential in a Typical LH7001CN (DIP Package)



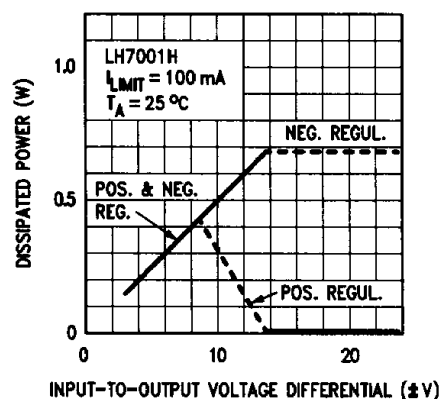
TL/K/10127-17



TL/K/10127-18

\*Pinout shown for DIP (TO-5 in parenthesis)

FIGURE 10. Circuit Used to Determine Dissipation Characteristics\*

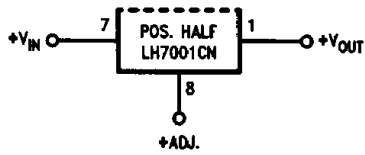


TL/K/10127-19

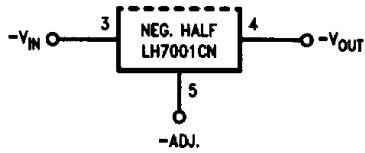
FIGURE 11. Dissipated Power of Positive and Negative Regulator vs In-to-Out Voltage Differential in a Typical LH7001H (TO-5 Package)

## Schematic Diagrams

LH7001CN (DIP)



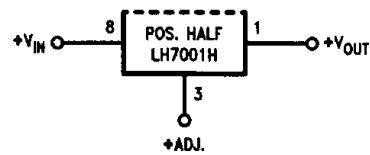
TL/K/10127-20



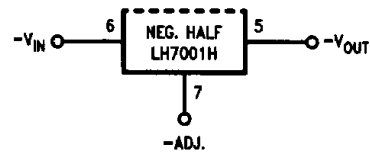
TL/K/10127-21

For detailed schematic diagrams see LM317L and LM337L datasheets.

LH7001H (TO-5)



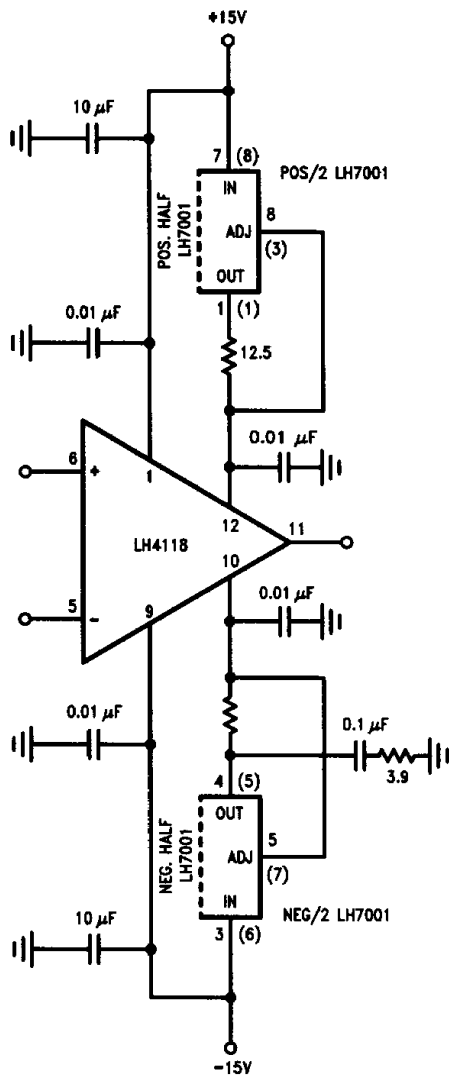
TL/K/10127-22



TL/K/10127-23

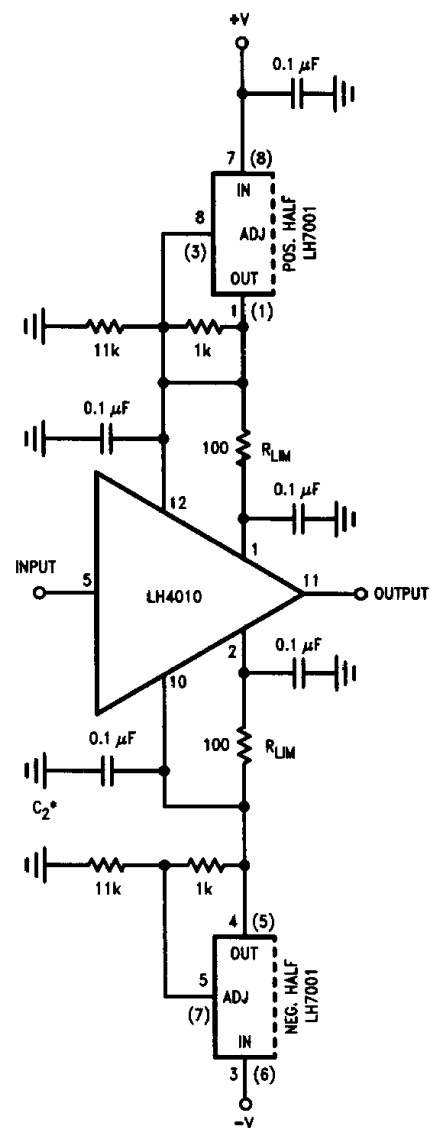
## Typical Applications

Dual Current Limiter\*



TL/K/10127-24

Dual Voltage Regulator\*



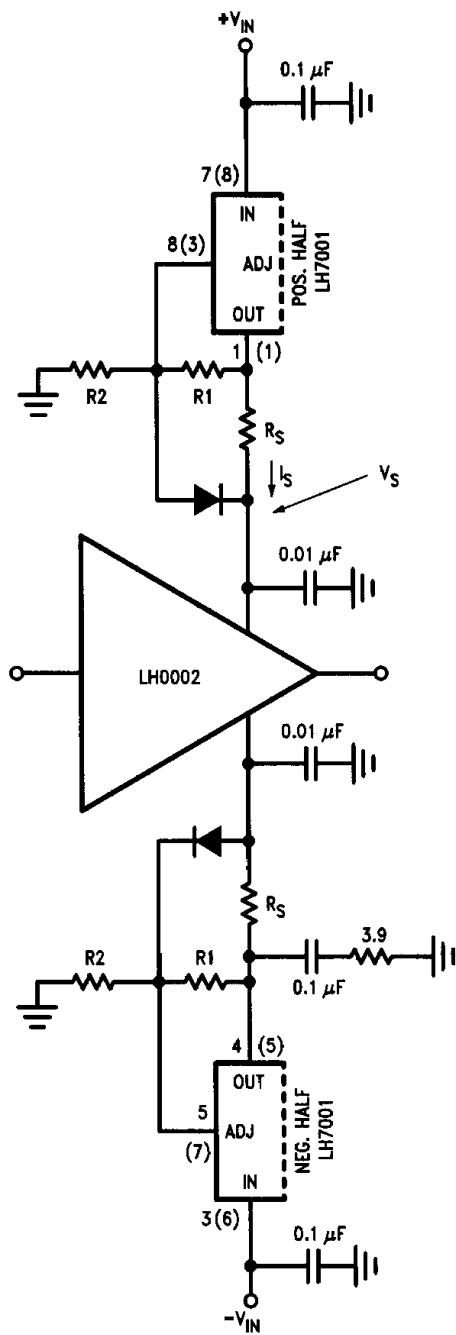
TL/K/10127-25

\*Pinout shown for DIP (TO-5 in parenthesis)

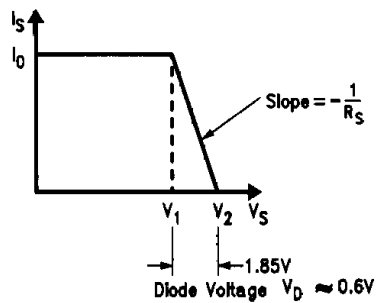


# Typical Applications (Continued)

## Dual Current and Voltage Protection\*



TL/K/10127-26



TL/K/10127-27

$$R_S = \frac{1.25V + V_D}{I_0}$$

$$R_1 = 1 \text{ k}\Omega \text{ (Chosen)}$$

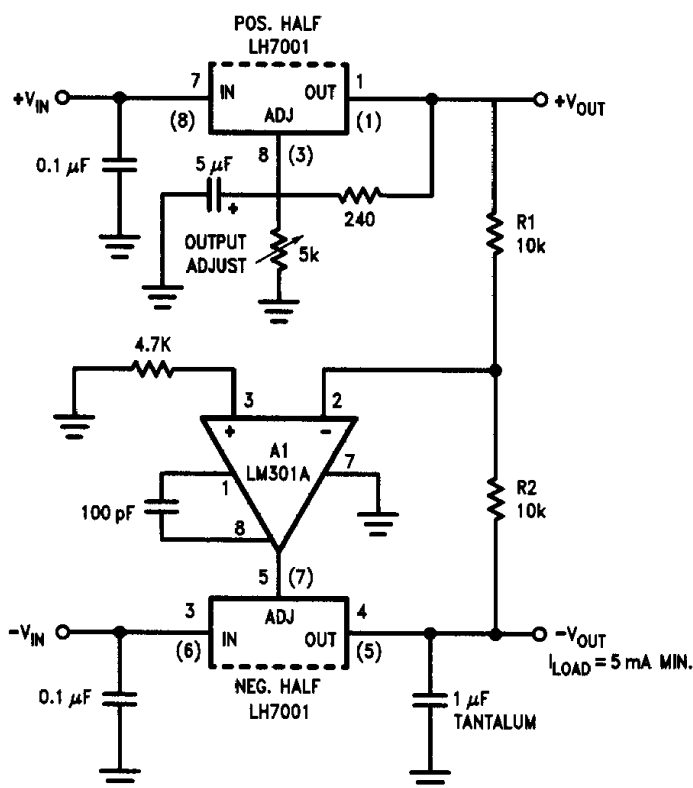
$$R_2 = R_1 \left( \frac{V_2}{1.25} - 1 \right)$$

$$V_1 = V_2 - I_0 R_S$$

\*Pinout shown for DIP (TO-5 in parenthesis)

## Typical Applications (Continued)

### Tracking Regulator\*



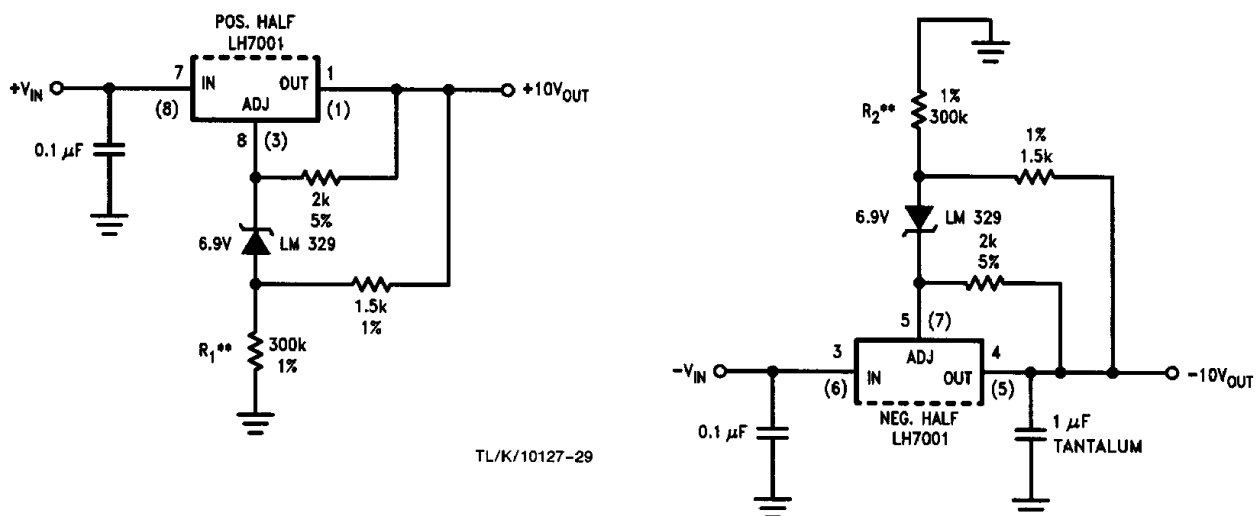
TL/K/10127-28

**A<sub>1</sub> = LM301A, LM307 or LF13741 Only**

$R_1, R_2$  = Matched resistors with good TC tracking

\*Pinout shown for DIP (TO-5 in parenthesis)

**± 10V High Stability Regulator\***



TL/K/10127-29

TL/K/10127-30

\*Pinout shown for DIP (TO-5 in parenthesis).

**\*\*To trim the output voltages  $R_1$  and  $R_2$  can be replaced by a series combination of  $240\Omega$  and a  $100\Omega$  potentiometer.**