



## LH4010/LH4010C Fast FET Buffer

### General Description

The LH4010/LH4010C is a high speed, FET input, voltage follower/buffer designed to provide high current drive at frequencies from DC to over 100 MHz. LH4010 will provide  $\pm 100$  mA into  $50\Omega$  loads ( $\pm 250$  mA peak) at slew rates of  $2500$  V/ $\mu$ s. In addition, both exhibit excellent phase linearity up to 20 MHz.

The LH4010 is intended to fulfill a wide range of buffer applications such as high speed line drivers, video impedance transformation, nuclear instrumentation amplifiers, op amp isolation buffer for driving reactive loads and high impedance input buffers for high speed ADCs and comparators.

These devices are constructed using specially selected junction FETs and active laser trimming to achieve guaranteed performance specifications. The LH4010 is specified for operation from  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ ; whereas, the LH4010C is specified from  $-25^\circ\text{C}$  to  $+85^\circ\text{C}$ . The LH4010/LH4010C is available in a 1.5W metal TO-8 package or a 16 lead dual-in-line package, N16A.

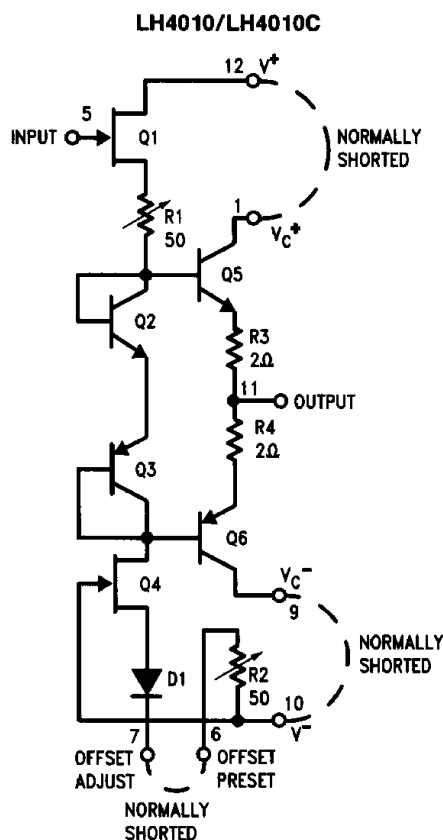
### Features

- Slew rate  $2500$  V/ $\mu$ s
- Wide range single or dual supply operation
- Power bandwidth DC to 20 MHz
- High output drive  $\pm 10$ V with  $100\Omega$  load
- Low phase non-linearity  $2^\circ$
- Fast rise times  $2$  ns
- High current gain  $120$  dB
- High input resistance  $10^{10}\Omega$
- Pin compatible with LH0033

### Applications

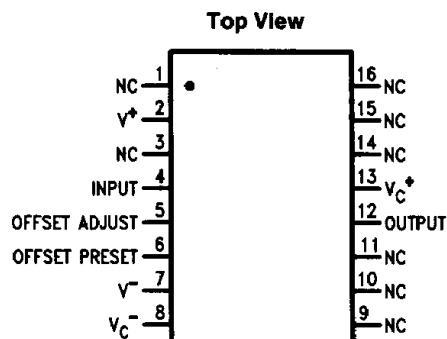
- High speed cable driver
- Isolation buffer
- ADC input buffer
- Op amp current booster

### Schematic and Connection Diagram



Pin numbers shown for TO-8 ("G") package.

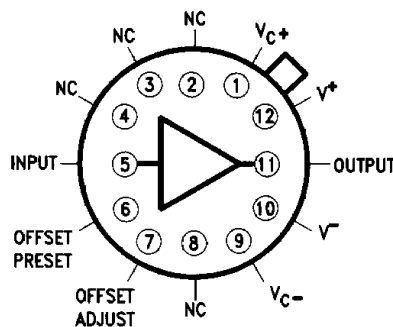
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TL/K/9349-24

**Order Number LH4010CN**  
**See NS Package Number N16A**

**Metal Can Package (TO-8)**



TL/K/9349-1

**Top View**

Case is Electrically Isolated.

**Order Number LH4010G or LH4010CG**  
**See NS Package Number H12B**

## Absolute Maximum Ratings

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

Supply Voltage ( $V^+ - V^-$ )	40V
Maximum Power Dissipation (See Curves)	1.5W
Maximum Junction Temperature	175°C
Input Voltage	Equal to Supplies

Output Current, Continuous	$\pm 100$ mA
Pulsed	$\pm 250$ mA
Operating Temperature Range	
LH4010C	$-25^\circ\text{C}$ to $+85^\circ\text{C}$
LH4010	$-55^\circ\text{C}$ to $+125^\circ\text{C}$
Storage Temperature Range	$-65^\circ\text{C}$ to $+150^\circ\text{C}$
Lead Temperature (Soldering, 10 seconds)	300°C

## DC Electrical Characteristics

$V_S = \pm 15\text{V}$ ,  $V_{IN} = 0\text{V}$ ,  $R_L = 1\text{k}$ ,  $T_A = 25^\circ\text{C}$  unless otherwise noted (Note 1)

Symbol	Parameter	Conditions	LH4010C			Units (Max Unless Otherwise Noted)
			Typical	Tested Limit (Note 2)	Design Limit (Note 3)	
$V_{OS}$	Output Offset Voltage	$V_{IN} = 0\text{V}$ , $T_A = T_J = 25^\circ\text{C}$ (Note 4)	5	10	<b>20</b>	mV
$I_B$	Input Bias Current	$T_J = 25^\circ\text{C}$ (Note 1)	0.5	1	<b>50</b>	nA
$V_O$	Output Voltage Swing	$V_{IN} = \pm 14\text{V}$ (Note 1)		$\pm 12$	$\pm \mathbf{12}$	V (Min)
		$V_{IN} = \pm 10.5$ , $R_L = 100\Omega$		$\pm 9$		V (Min)
$R_{IN}$	Input Impedance	$T_J = 25^\circ\text{C}$ , $V_{IN} = \pm 1\text{V}$	$10^{10}$			$\Omega$
$I_S$	Supply Current		22	26		mA
$R_{OUT}$	Output Impedance	$V_{IN} = \pm V_{DC}$ , $\Delta R_L = 100\Omega$ to $\infty$		10		$\Omega$
$A_V$	Voltage Gain	$V_{IN} = \pm 10\text{V}$		0.96	<b>0.96</b>	V/V (Min)
		$V_{IN} = \pm 10\text{V}$ , $R_L = 100\Omega$		0.90	<b>0.90</b>	V/V (Min)

**DC Electrical Characteristics**  $V_S = \pm 15V$ ,  $V_{IN} = 0V$ ,  $R_L = 1k$ ,  $T_A = 25^\circ C$  otherwise noted (Note 1)

Symbol	Parameter	Conditions	LH4010			Units (Max Unless Otherwise Noted)
			Typical	Tested Limit (Note 2)	Design Limit (Note 3)	
$V_{OS}$	Input Offset	$V_{IN} = 0V$ , $T_A = T_J = 25^\circ C$ (Notes 1, 4)	5	10		mV
				<b>25</b>		
$I_B$	Input Bias Current	$T_J = 25^\circ C$ (Notes 1, 4)	200	500		pA
				<b>10</b>		nA
$V_O$	Output Voltage Swing	$V_{IN} = \pm 14V$		$\pm 12$		V (Min)
		$V_{IN} = \pm 10.5$ , $R_L = 100\Omega$ , $T_A = 25^\circ C$		$\pm 9$		V (Min)
$R_{IN}$	Input Impedance	$T_J = 25^\circ C$ , $V_{IN} = \pm 1V$	1010			$\Omega$
$I_S$	Supply Current		22	<b>26</b>		mA
$R_{OUT}$	Output Impedance	$V_{IN} = \pm V_{DC}$ (Note 4) $\Delta R_L = 100\Omega$ to $\infty$		<b>8</b>		$\Omega$
$A_V$	Voltage Gain	$V_{IN} = \pm 10V$		<b>0.97</b>		V/V (Min)
		$V_{IN} = \pm 10V$ , $R_L = 100\Omega$		<b>0.92</b>		V/V (Min)

**AC Electrical Characteristics**  $V_S = \pm 15V$ ,  $R_L = 1k\Omega$ ,  $R_S = 50\Omega$ ,  $T_A = 25^\circ C$  unless otherwise noted

Symbol	Parameter	Conditions	LH4010/LH4010C			Units (Max Unless Otherwise Noted)
			Typical	Tested Limit (Note 2)	Design Limit (Note 3)	
$t_r$	Small Signal Rise Time (Note 5)	$\Delta V_{IN} = 0.5V$	1.5			ns
		$R_L = 50\Omega$ , $V_{IN} = 0.5V$		2.5		
$t_p$	Propagation Delay (Note 5)	$\Delta V_{IN} = 0.5V$	2.0			ns
BW	Small Signal Bandwidth (Note 7)		200			MHz (Min)
		$R_L = 50\Omega$			140	
SR	Slew Rate (Note 6)	$V_{IN} = \pm 5V$	2500	2000		V/ $\mu s$ (Min)

**Note 1:** Boldface limits are guaranteed over full temperature range. Operating ambient temperature range of LH4010C is  $-25^\circ C$  to  $+85^\circ C$ , and LH4010 is  $-55^\circ C$  to  $+125^\circ C$ .

**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:** Specifications are at  $25^\circ C$  junction temperature due to requirements of high speed automatic testing. Actual values at operating temperature will exceed value at  $T_J = 25^\circ C$ .

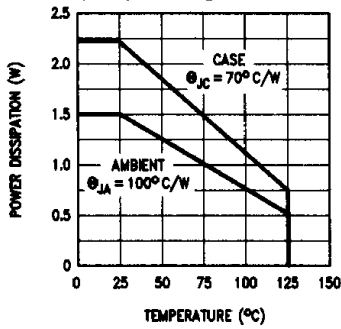
**Note 5:** See AC Test Circuit.

**Note 6:** Slew rate is measured between  $+2.5V$  and  $-2.5V$ . See AC Test Circuit.

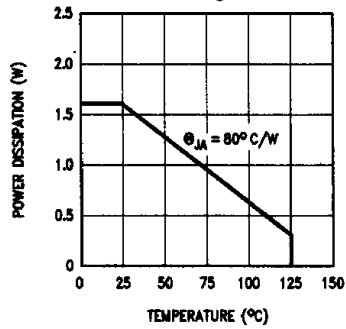
**Note 7:** Bandwidth is calculated from rise time with  $f = t_r/\pi$ .

# Typical Characteristics

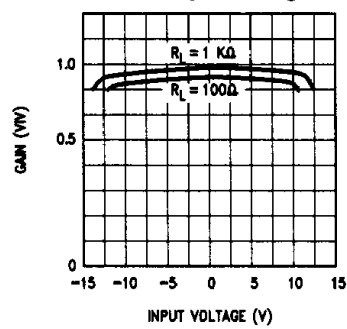
Maximum Power Dissipation for TO-8 ("G") Package



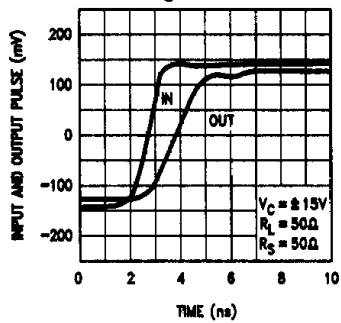
Maximum Power Dissipation for N16A Package



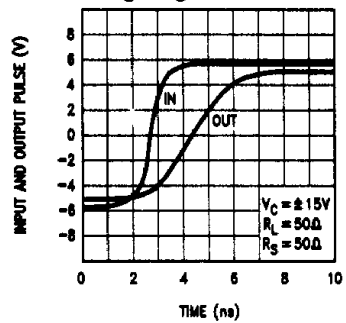
Gain vs Input Voltage



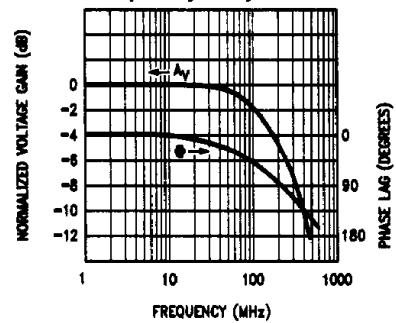
Small Signal Pulse



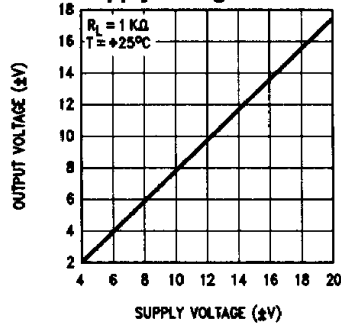
Large Signal Pulse



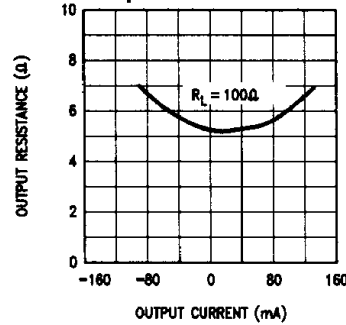
Frequency Response



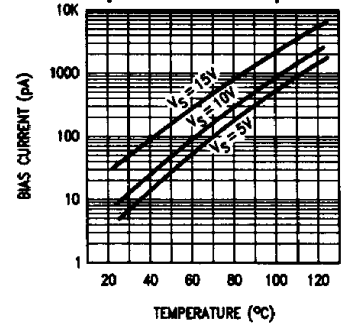
Output Voltage vs Supply Voltage



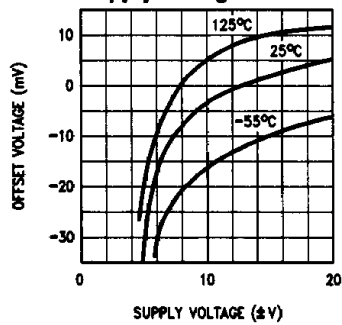
Output Resistance vs Output Current



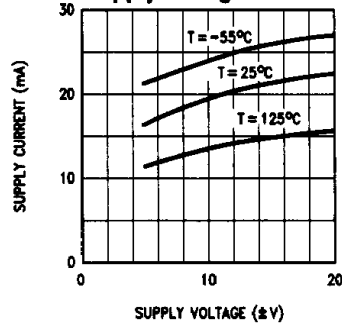
Input Bias vs Temperature



Offset Voltage vs Supply Voltage

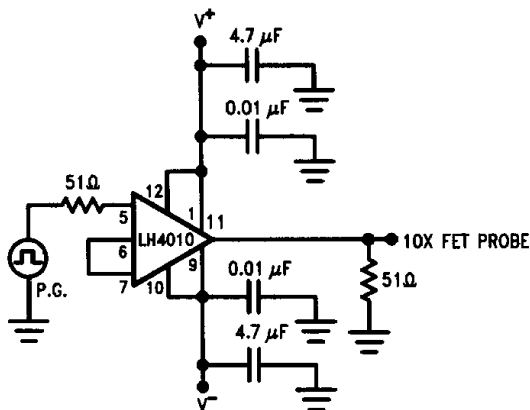


Supply Current vs Supply Voltage



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## AC Test Circuit



TL/K/9349-2

## Application Hints

**Recommended Layout Precautions:** RF/video printed circuit board layout rules should be followed when using the LH4010 and LH4010C since they will provide power gain to frequencies over 100 MHz. Ground planes are recommended and power supplies should be decoupled at each device with low inductance capacitors. In addition, ground plane shielding may be extended to the metal case of the device since it is electrically isolated from internal circuitry. Alternatively the case should be connected to the output to minimize input capacitance.

**Offset Voltage Adjustment:** Both the LH4010 and LH4010C offset voltages have been actively trimmed by laser to meet guaranteed specifications when the offset preset pin is shorted to the offset adjust pin. This pre-calibration allows the devices to be used in most DC or AC applications without individually offset nulling each device. If offset null is desirable, it is simply obtained by leaving the offset preset pin open and connecting a trim pot of 100Ω between the offset adjust pin and  $V^-$  as illustrated in Figure 1.

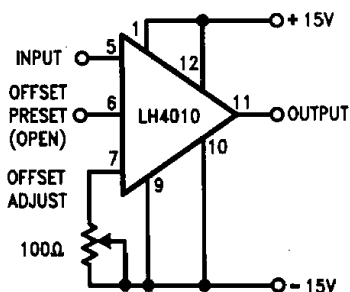


FIGURE 1. Offset Zero Adjust for LH4010

**Operation from Single or Asymmetrical Power Supplies:** Both device types may be readily used in application where symmetrical supplies are unavailable or not desirable. A typical application might be an interface to a MOS shift register where  $V^+ = +5V$  and  $V^- = -12V$ . In this case, an apparent output offset occurs due to the device's voltage gain of less than unity. This additional output offset error may be predicted by:

$$\Delta V_O \approx (1 - A_V) \frac{(V^+ - V^-)}{2} = 0.005 (V^+ - V^-)$$

where:

$A_V$  = No load voltage gain, typically 0.99

$V^+$  = Positive supply voltage

$V^-$  = Negative supply voltage

For the above example,  $\Delta V_O$  would be  $-35$  mV. This may be adjusted to zero as discussed above. For AC coupled applications, no additional offset occurs if the DC input is properly biased as illustrated in the "typical applications" section.

**Short Circuit Protection:** In order to optimize transient response and output swing, output current limit has been omitted from the LH4010 and LH4010C. Short circuit protection may be added by inserting appropriate value resistors between  $V^+$  and  $V_C^+$  pins and  $V^-$  and  $V_C^-$  pins as illustrated in Figure 2. Resistor values may be predicted by:

$$R_{LIM} \approx \frac{V^+}{I_{SC}} = \frac{-V^-}{I_{SC}}$$

where:

$$I_{SC} \leq 100 \text{ mA}$$

The inclusion of limiting resistors in the collectors of the output transistors reduces output voltage swing. Decoupling  $V_C^+$  and  $V_C^-$  pins with capacitors to ground will retain full output swing for transient pulses. An alternate active current limit technique that retains full DC output swing is shown in Figure 3.

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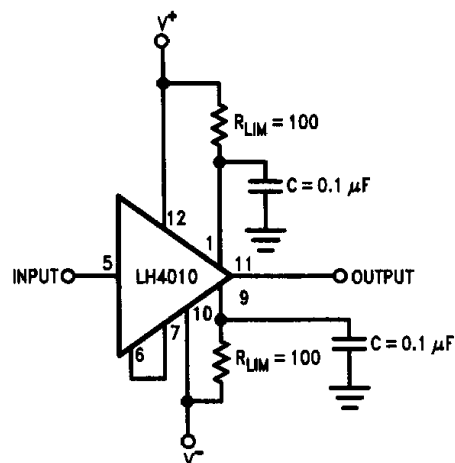


FIGURE 2

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## Applications Hints (Continued)

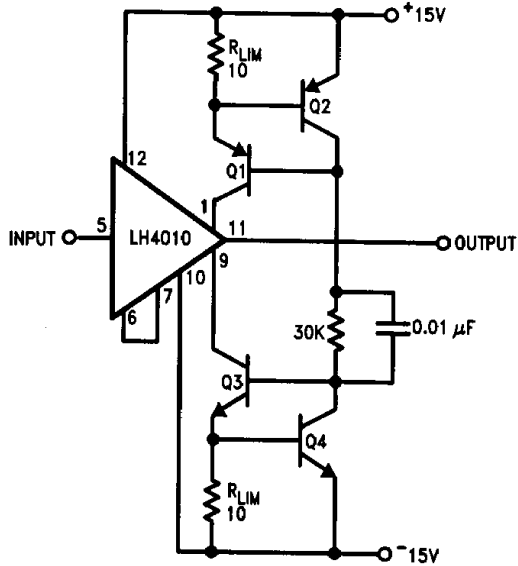


FIGURE 3. LH4010 Current Limiting Using Current Sources

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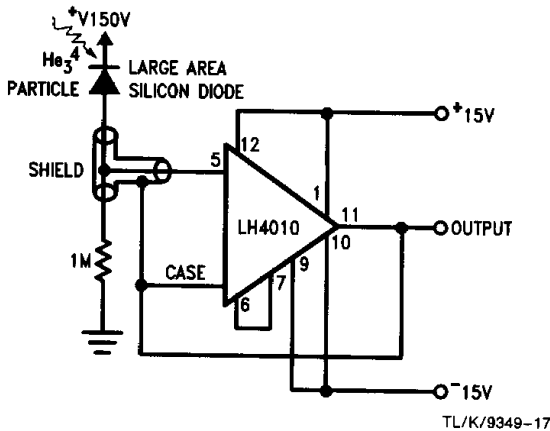
**Capacitive Loading:** The LH4010 is designed to drive capacitive loads such as coaxial cables in excess of several thousand picofarads without being susceptible to oscillation. However, peak current resulting from  $(C \times dV/dt)$  should be limited below absolute maximum peak current ratings for the devices.

Thus:

$$\left\{ \frac{\Delta V_{IN}}{\Delta t} \right\} \times C_L \leq I_{OUT} \leq \pm 250 \text{ mA}$$

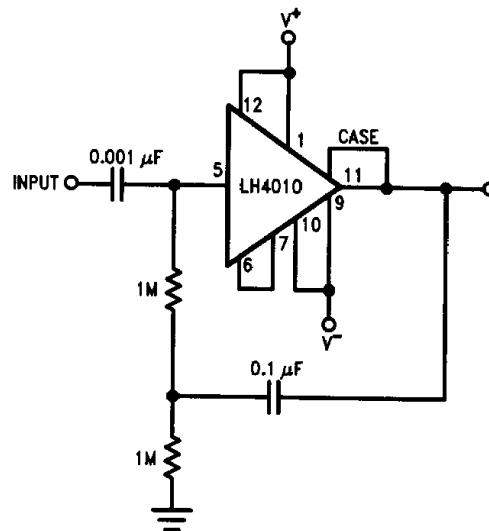
## Typical Applications

### Nuclear Particle Detector



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### High Input Impedance AC Coupled Amplifier



TL/K/9349-18

In addition, power dissipation resulting from driving capacitive loads plus standby power should be kept below total package power rating:

$$P_{diss \text{ pkg}} \geq P_{DC} + P_{AC}$$

$$P_{diss \text{ pkg}} \geq (V^+ - V^-) \times I_S + P_{AC}$$

$$P_{AC} \approx (V_{PP})^2 \times f \times C_L$$

where:  $V_{PP}$  = Peak-to-peak output voltage swing  
 $f$  = frequency  
 $C_L$  = Load Capacitance

**Operation Within an Op Amp Loop:** Both devices may be used as a current booster or isolation buffer within a closed loop with op amps such as LH0032, LM6361, or LM118. An isolation resistor of  $47\Omega$  should be used between the op amp output and the input of LH4010. The wide bandwidths and high slew rates of the LH4010 assure that loop has the characteristics of the op amp and that additional rolloff is not required.

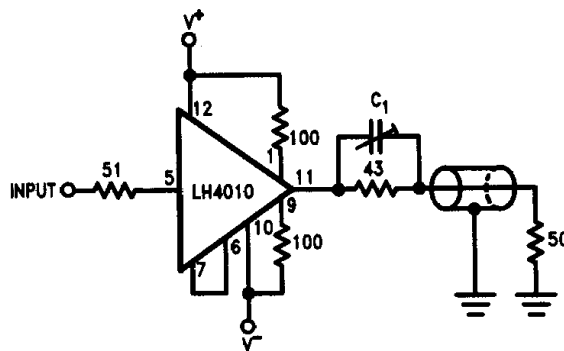
**Hardware:** In order to utilize the full drive capabilities of the device, it should be mounted with a heat sink particularly for extended temperature operation. The case is isolated from the circuit and may be connected to system chassis.

### ATTENTION!

Power supply bypassing is necessary to prevent oscillation in all circuits. Low inductance ceramic disc capacitors with the shortest practical lead lengths must be connected from each supply lead (within  $< 1/4"$  to  $1/2"$  of the device package) to a ground plane. Capacitors should be one or two  $0.1 \mu F$  in parallel; adding a  $4.7 \mu F$  solid tantalum capacitor will help in troublesome instances.

## Typical Applications (Continued)

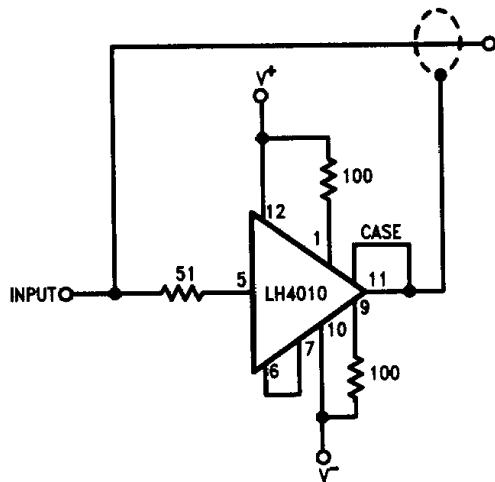
### Coaxial Cable Driver



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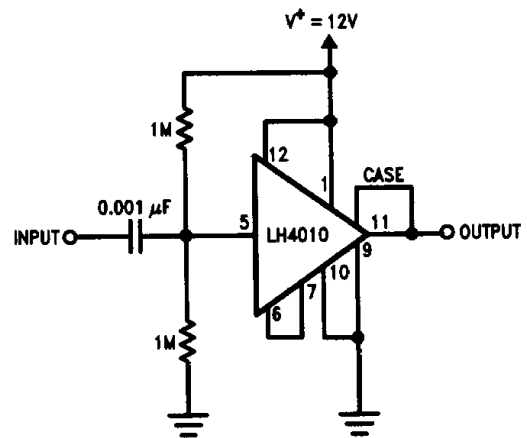
\*Select  $C_1$  for optimum pulse response.

### Instrumentation Shield/Line Driver



TL/K/9349-20

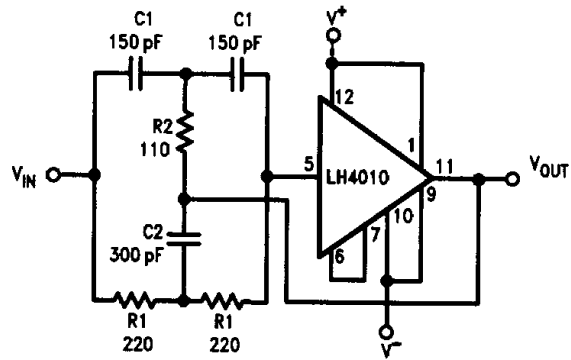
### Single Supply AC Amplifier



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# Typical Applications (Continued)

## 4.5 MHz Notch Filter



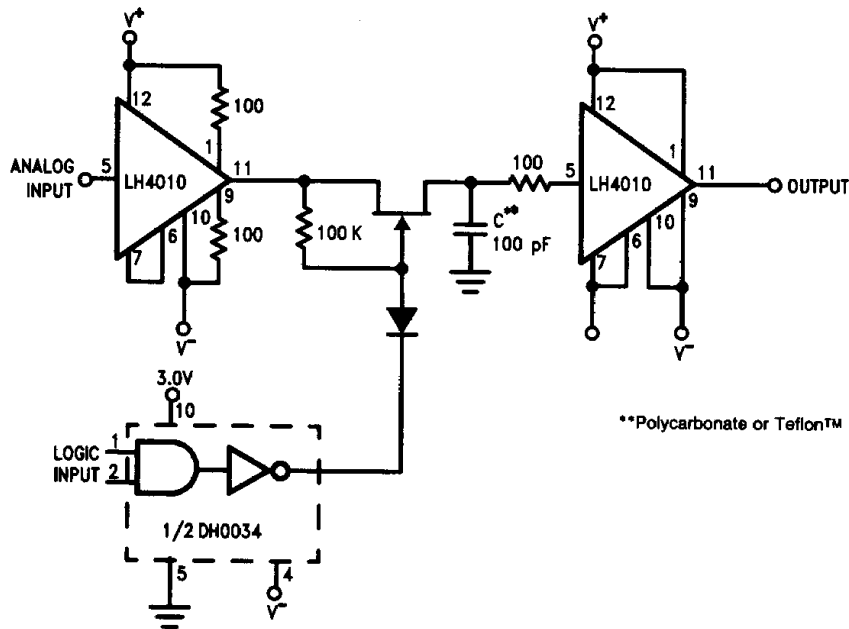
$$f_o = \frac{1}{2\pi R_1 C_1}$$

$$R_1 = 2 R_2$$

$$C_1 = \frac{C_2}{2}$$

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## High Speed Sample and Hold



\*\*Polycarbonate or Teflon™

\*Pin numbers shown for TO-8 ("G") package.

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