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National Semiconductor

December 1994

LH0033/LH0063
Fast and Ultra Fast Buffers

General Description

The LH0033 and LH0063 are high speed, FET input, voltage follower/buffers designed to provide high current drive at frequencies from DC to over 100 MHz. The LH0033 will provide ±10 mA into 1 kΩ loads (±100 mA peak) at slew rates of 1500V/μs. The LH0063 will provide ±250 mA into 50Ω loads (±500 mA peak) at slew rates up to 6000V/μs. In addition, both exhibit excellent phase linearity up to 20 MHz.

Both are intended to fulfill a wide range of buffer applications such as high speed line drivers, video impedance transformation, nuclear instrumentation amplifiers, op amp isolation buffers for driving reactive loads and high impedance input buffers for high speed A to Ds and comparators. In addition, the LH0063 can continuously drive 50Ω coaxial cables or be used as a yoke driver for high resolution CRT displays. For additional applications information, see AN-48.

These devices are constructed using specially selected junction FETs and active laser trimming to achieve guaranteed performance specifications. The LH0033 is specified for operation from −55°C to +125°C; the LH0033C and the LH0063C are specified from −25°C to +85°C. The LH0033 is available in either a 1.5W metal TO-8 package or an 8-pin ceramic dual-in-line package. The LH0063 is available in a 5W 8-pin TO-3 package.

Features

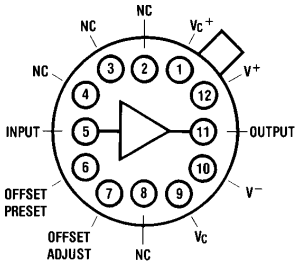
- Ultra fast (LH0063): 6000 V/μs
- Wide range single or dual supply operation
- Wide power bandwidth: DC to 100 MHz
- High output drive: ±10V with 50Ω load
- Low phase non-linearity: 2 degrees
- Fast rise times: 2 ns
- High input resistance: $10^{10}\Omega$

Advantages

- Only 10V supply needed for 5 Vp-p video out
- Speed does not degrade system performance
- Wide data rate range for phase encoded systems

Connection Diagrams

LH0033G
Metal Can Package



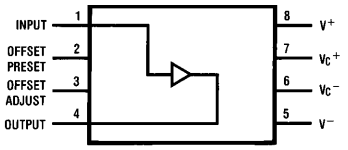
TOP VIEW

TL/K/5507–1

Case is electrically isolated

Order Number LH0033G, LH0033G-MIL
or LH0033CG
See NS Package Number G12B

LH0033J
Dual-In-Line Package

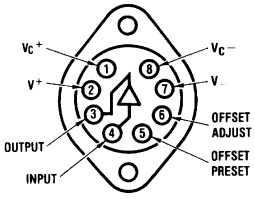


TOP VIEW

TL/K/5507–2

Order Number LH0033J or LH0033CJ
See NS Package Number HY08A

LH0063K
Metal Can Package



TL/K/5507–3

Top View

Case is electrically isolated

Order Number LH0063CK
See NS Package Number K08A

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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
Power Dissipation (See Curves)	
LH0063C	5W
LH0033/LH0033C	2.2W
Junction Temperature	175°C
Input Voltage	$\pm V_S$
Continuous Output Current	
LH0063C	±250 mA
LH0033/LH0033C	±100 mA
Peak Output Current	
LH0063C	±500 mA
LH0033/LH0033C	±250 mA
Lead Temp. (Soldering, 10 seconds)	300°C

Operating Temperature Range

LH0033	−55°C to +125°C
LH0033C and LH0063C	−25°C to +85°C
Storage Temperature Range	−65° to +150°C

ESD rating to be determined.

DC Electrical Characteristics

$V_S = \pm 15V$, $T_{MIN} \leq T_A \leq T_{MAX}$, unless otherwise specified, (Note 1)

Parameter	Conditions	LH0033			LH0033C			Units
		Min	Typ	Max	Min	Typ	Max	
Output Offset Voltage	$R_S = 100\Omega$, $T_J = 25°C$, $V_{IN} = 0V$ (Note 2) $R_S = 100\Omega$		5.0	10 15		12	20 25	mV mV
Average Temperature Coefficient of Offset Voltage	$R_S = 100\Omega$, $V_{IN} = 0V$ (Note 3)		50	100		50	100	μV/°C
Input Bias Current	$V_{IN} = 0V$ $T_J = 25°C$ (Note 2) $T_A = 25°C$ (Note 4) $T_J = T_A = T_{MAX}$			250 2.5 10			500 5.0 20	pA nA nA
Voltage Gain	$V_O = \pm 10V$, $R_S = 100\Omega$, $R_L = 1.0k\Omega$	0.97	0.98	1.00	0.96	0.98	1.00	V/V
Input Impedance	$R_L = 1\ k\Omega$	10^{10}	10^{11}		10^{10}	10^{11}		Ω
Output Impedance	$V_{IN} = \pm 1.0V$, $R_L = 1.0k$		6.0	10		6.0	10	Ω
Output Voltage Swing	$V_I = \pm 14V$, $R_L = 1.0k$ $V_I = \pm 10.5V$, $R_L = 100\Omega$, $T_A = 25°C$	±12 ±9.0			±12 ±9.0			V V
Supply Current	$V_{IN} = 0V$ (Note 5)		20	22		21	24	mA
Power Consumption	$V_{IN} = 0V$		600	660		630	720	mW

AC Electrical Characteristics

$T_J = 25°C$, $V_S = \pm 15V$, $R_S = 50\Omega$, $R_L = 1.0\ K\Omega$ (Note 6)

Parameter	Conditions	LH0033			LH0033C			Units
		Min	Typ	Max	Min	Typ	Max	
Slew Rate	$V_{IN} = \pm 10V$	1000	1500		1000	1400		V/μs
Bandwidth	$V_{IN} = 1.0$ Vrms		100			100		MHz
Phase Non-Linearity	BW = 1.0Hz to 20 MHz		2.0			2.0		degrees
Rise Time	$\Delta V_{IN} = 0.5V$		2.9			3.2		ns
Propagation Delay	$\Delta V_{IN} = 0.5V$		1.2			1.5		ns
Harmonic Distortion	f > 1 kHz		< 0.1			< 0.1		%

Note 1: LH0033 is 100% production tested as specified at 25° C, 125°C, and −55°C. LH0033AC/C are 100% production tested at 25°C only. Specifications at temperature extremes are verified by sample testing, but these limited are not used to calculate outgoing quality level.

Note 2: Specification is at 25°C junction temperature due to requirements of high speed automatic testing. Actual values at operating temperature will exceed the value at $T_J = 25°C$. When supply voltages are ±15V, no-load operating junction temperature may rise 40-60°C above ambient, and more under load conditions. Accordingly, V_{OS} may change one to several mV, and I_B will change significantly during warm-up. Refer to I_B vs temperature graph for expected values.

Note 3: LH0033 is 100% production tested for this parameter. LH0033C is sample tested only. Limits are not used to calculate outgoing quality levels. $\Delta V_{OS}/\Delta T$ is the average value calculated from measurements at 25°C and T_{MAX}.

Note 4: Measured in still air 7 minutes after application of power. Guaranteed through correlated automatic pulse testing.

Note 5: Guaranteed through correlated automatic pulse testing at $T_J = 25°C$.

Note 6: Not 100% production tested; verified by sample testing only. Limits are not used to calculate outgoing quality level.

Note 7: Refer to RETS0033 for the LH0033G military specifications.

DC Electrical Characteristics $V_S = \pm 15V$, $T_{MIN} \leq T_A \leq T_{MAX}$ unless otherwise specified (Note 1)

Parameter	Conditions	LH0063C			Units
		Min	Typ	Max	
Output Offset Voltage	$R_S \leq 100k\Omega$, $T_J = 25°C$, $R_L = 100\Omega$ (Note 2)		10	50	mV
				100	mV
Average Temperature Coefficient of Output Offset Voltage	$R_S \leq 100\ k\Omega$		300		$\mu V/°C$
Input Bias Current	$T_J = 25°C$ (Note 2)		10	30	nA
				100	nA
Voltage Gain	$V_{IN} = \pm 10V$, $R_S \leq 100\ k\Omega$, $R_L = 1\ k\Omega$	0.94	0.96	1.0	V/V
Voltage Gain	$V_{IN} = \pm 10V$, $R_S \leq 100\ k\Omega$, $R_L = 50\Omega$ $T_J = 25°C$	0.91	0.93	0.98	V/V
Input Capacitance	Case Shorted to Output		8.0		pF
Output Impedance	$V_{OUT} = \pm 10V$, $R_S \leq 100\ k\Omega$, $R_L = 50\Omega$		1.0	4.0	Ω
Output Current Swing	$V_{IN} = \pm 10V$, $R_S \leq 100\ k\Omega$	0.2	0.25		A
Output Voltage Swing	$R_L = 50\Omega$	± 10	± 13		V
Output Voltage Swing	$V_S = \pm 5.0V$, $R_L = 50\Omega$, $T_J = 25°C$	5.09	7.0		Vp-p
Supply Current	$T_J = 25°C$, $R_L = \infty$, $V_S = \pm\ 15V$		50	65	mA
Supply Current	$V_S = \pm 5.0V$		40		mA
Power Consumption	$T_J = 25°C$, $R_L = \infty$, $V_S = \pm 15V$		1.5	1.95	W
Power Consumption	$V_S = \pm 5.0V$		400		mW

AC Electrical Characteristics $T_J = 25°C$, $V_S = \pm 15V$, $R_S = 50\Omega$, $R_L = 50\Omega$ (Note 3)

Parameter	Conditions	LH0063C			Units
		Min	Typ	Max	
Slew Rate	$R_L = 1.0\ k\Omega$, $V_{IN} = \pm 10V$		6000		$V/\mu s$
Slew Rate	$R_L = 50\Omega$, $V_{IN} = \pm 10V$, $T_J = 25°C$	2000	2400		$V/\mu s$
Bandwidth	$V_{IN} = 1.0$ Vrms		200		MHz
Phase Non-Linearity	BW = 1.0 Hz to 20 MHz		2.0		degrees
Rise Time	$\Delta V_{IN} = 0.5V$		1.9		ns
Propagation Delay	$\Delta V_{IN} = 0.5V$		2.1		ns
Harmonic Distortion			<0.1		%

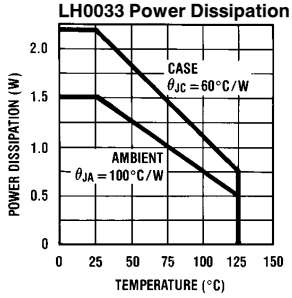
Note 1: LH0063C is 100% production tested at 25°C only. Specifications at temperature extremes are verified by sample testing, but these limits are not used to calculate outgoing quality level.

Note 2: Specification is at 25°C junction temperature due to requirements of high speed automatic testing. Actual values at operating temperature will exceed the value at $T_J = 25°C$. When supply voltages are $\pm 15V$, no-load operating junction temperature may rise 40-60°C above ambient, and more under load conditions. Accordingly, V_{OS} may change one to several mV, and I_B will change significantly during warm-up. Refer to I_B vs temperature graph for expected values.

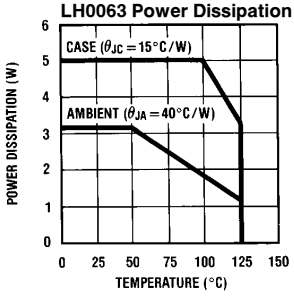
Note 3: Not 100% production tested; verified by sample testing only. Limits are not used to calculate outgoing quality level.

Typical Performance Characteristics

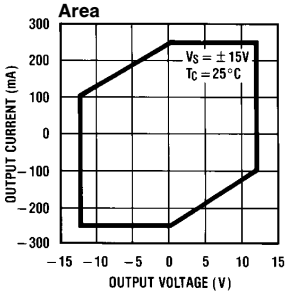
LH0033 Power Dissipation



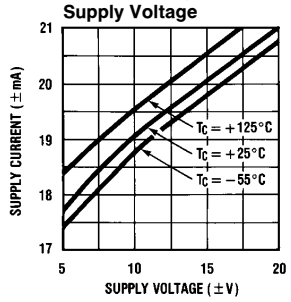
LH0063 Power Dissipation



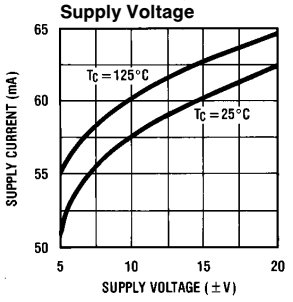
LH0063 DC Safe Operating Area



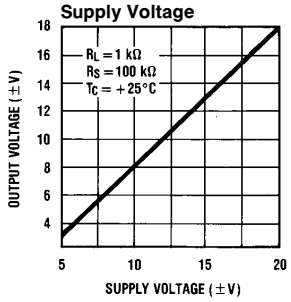
LH0033 Supply Current vs Supply Voltage



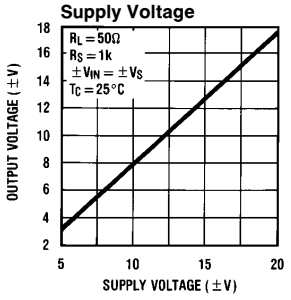
LH0063 Supply Current vs Supply Voltage



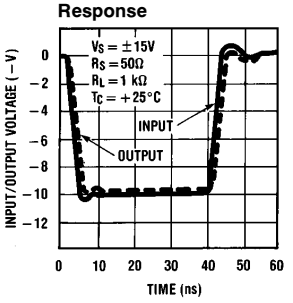
LH0033 Output Voltage vs Supply Voltage



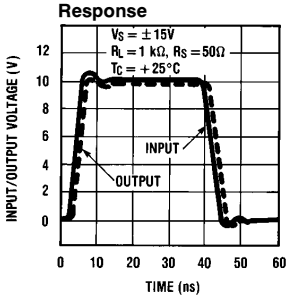
LH0063 Output Voltage vs Supply Voltage



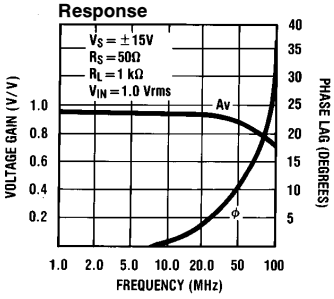
LH0033 Negative Pulse Response



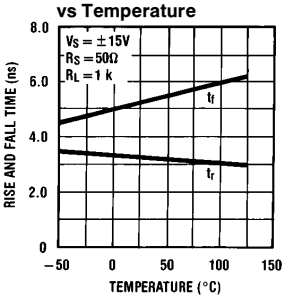
LH0033 Positive Pulse Response



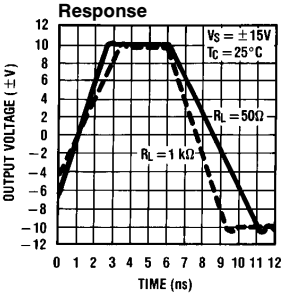
LH0033 Frequency Response



LH0033 Rise and Fall Time vs Temperature



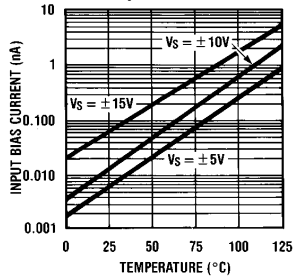
LH0063 Large Signal Pulse Response



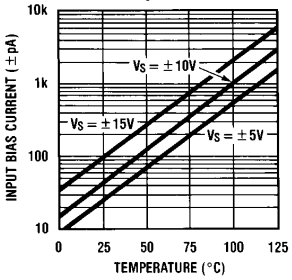
TL/K/5507–4

Typical Performance Characteristics (Continued)

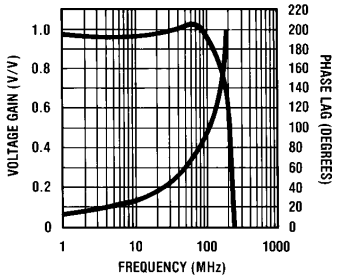
LH0033 Input Bias Current vs Temperature



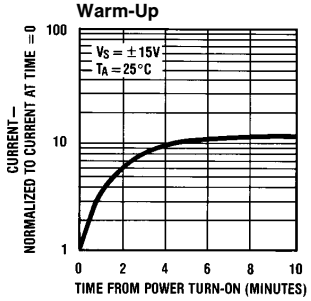
LH0063 Input Current



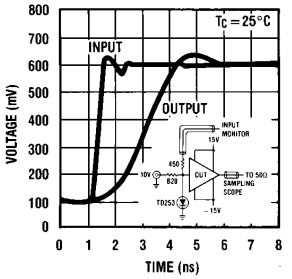
LH0063 Frequency Response



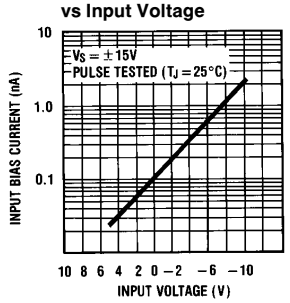
LH0033 Normalized Input Bias Current During Warm-Up



LH0063 Small Signal Rise Time



LH0033 Input Bias Current vs Input Voltage



TL/K/5507–5

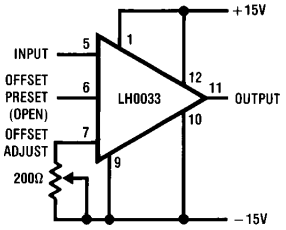
Application Hints

RECOMMENDED LAYOUT PRECAUTIONS

RF/video printed circuit board layout rules should be followed when using the LH0033 and LH0063 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.

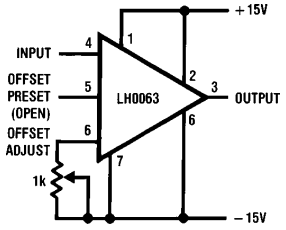
OFFSET VOLTAGE ADJUSTMENT

Both the LH0033's and LH0063's 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 for the LH0033 or 1 kΩ for the LH0063 between the offset adjust pin and V^-, as illustrated in *Figures 1* and *2*.



TL/K/5507–6

FIGURE 1. Offset Zero Adjust for LH0033 (Pin numbers shown for TO-8)



TL/K/5507–7

FIGURE 2. Offset Zero Adjust for LH0063

Application Hints (Continued)

OPERATION FROM SINGLE OR ASYMMETRICAL POWER SUPPLIES

Both device types may be readily used in applications 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:

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

where:

A_V = No load voltage gain, typically 0.99

V^+ = Positive supply voltage

V^- = Negative supply voltage

For the above example, ΔV_O would be $-35mV$. This may be adjusted to zero as described in *Figure 2*. 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

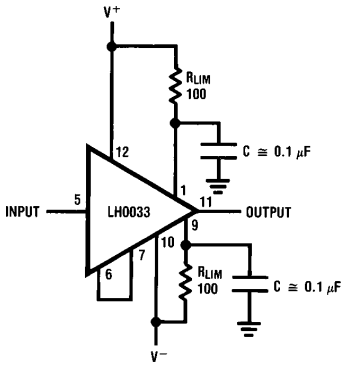
In order to optimize transient response and output swing, output current limit has been omitted from the LH0033 and LH0063. Short circuit protection may be added by inserting appropriate value resistors between V^+ and V_C^+ pins and V^- and V_C^- pins as illustrated in *Figures 3 and 4*. Resistor values may be predicted by:

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

where:

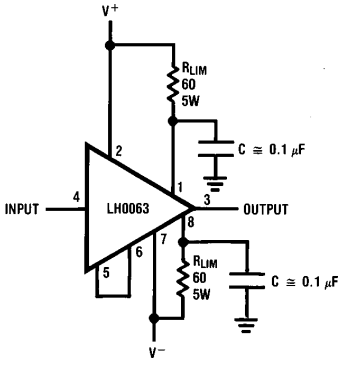
$I_{SC} \leq 100$ mA for LH0033

$I_{SC} \leq 250$ mA for LH0063



TL/K/5507–8

FIGURE 3. LH0033 Using Resistor Current Limiting



TL/K/5507–9

FIGURE 4. LH0063 Using Resistor Current Limiting

Application Hints (Continued)

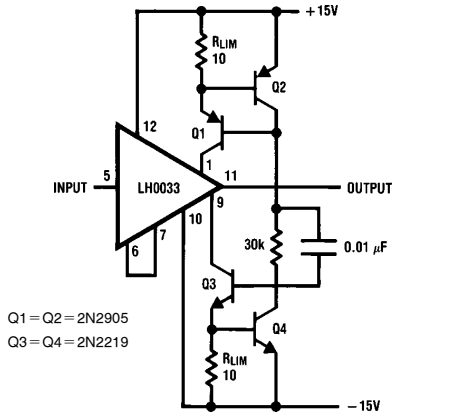
The inclusion of limiting resistors in the collectors of the output transistors reduces output voltage swing. Decoupling V_C^+ and V_C^- pins with capacitors to ground will retain full output swing for transient pulses. Alternate active current limit techniques that retain full DC output swing are shown in *Figures 5* and *6*. In *Figures 5* and *6,* the current sources are saturated during normal operation, thus apply full supply voltage to the V_C pins. Under fault conditions, the voltage decreases as required by the overload.

For *Figure 5:*

$$R_{LIM} = \frac{V_{BE}}{I_{SC}} = \frac{0.6V}{60\ mA} = 10\Omega$$

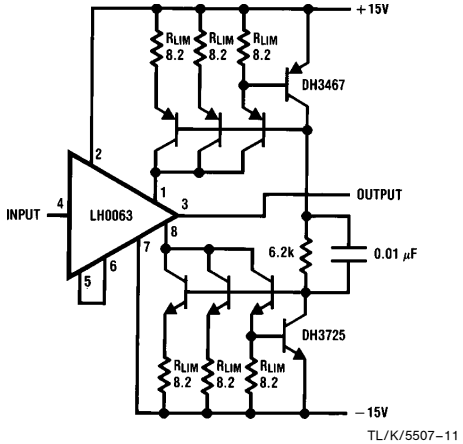
In *Figure 6,* quad transistor arrays are used to minimize can count and:

$$R_{LIM} = \frac{V_{BE}}{1/3(I_{SC})} = \frac{0.6V}{1/3(200\ mA)} = 8.2\Omega$$



TL/K/5507–10

FIGURE 5. LH0033 Current Limiting Using Current Sources



TL/K/5507–11

FIGURE 6. LH0063 Current Limiting Using Current Sources

CAPACITIVE LOADING

Both the LH0033 and LH0063 are designed to drive capacitive loads such as coaxial cables in excess of several thousand picofarads without susceptibility to oscillation. However, peak current resulting from $(C \times d_V/d_t)$ should be limited below absolute maximum peak current ratings for the devices.

Thus for the LH0033:

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

and for the LH0063:

$$\left(\frac{\Delta V_{IN}}{\Delta t}\right) \times C_L \leq I_{OUT} \leq \pm 500\ mA$$

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

$P_D pkg. \geq P_{DC} + P_{AC}$

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

$P_{AC} \cong (Vp\text{-}p)^2 \times f \times C_L$

where:

Vp-p = 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 LM6218, LM6361 or LH0032. An isolation resistor of 47Ω should be used between the op amp output and the input of LH0033. The wide bandwidths and high slew rates of the LH0033 and LH0063 assure that the loop has the characteristics of the op amp and that additional rolloff is not required.

HARDWARE

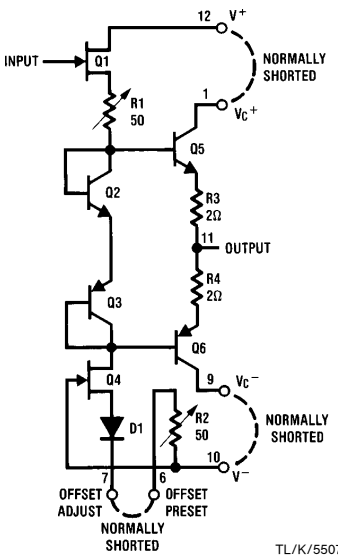
In order to utilize the full drive capabilities of both devices, each should be mounted with a heat sink particularly for extended temperature operation. The cases of both are isolated from the circuit and may be connected to the system chassis.

DESIGN PRECAUTION

Power supply bypassing is necessary to prevent oscillation with both the LH0033 and LH0063 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 μF in parallel for the LH0033; adding a 4.7 μF solid tantalum capacitor will help in troublesome instances. For the LH0063, two 0.1 μF ceramic and one 4.7 μF solid tantalum capacitors in parallel will be necessary on each supply lead.

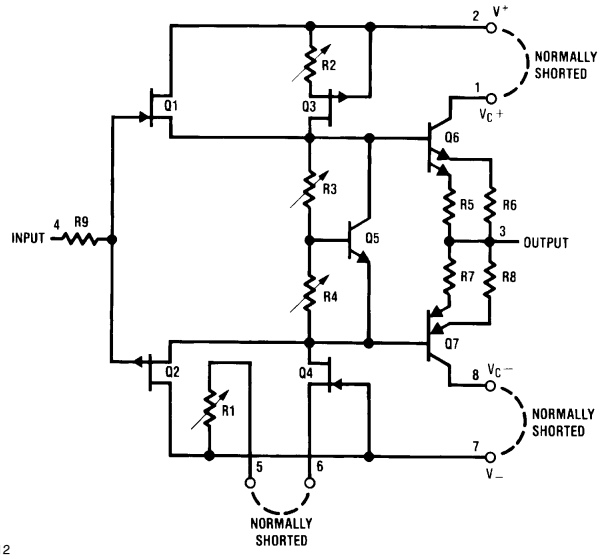
Schematic Diagrams

LH0033/LH0033A



TL/K/5507–12

LH0063

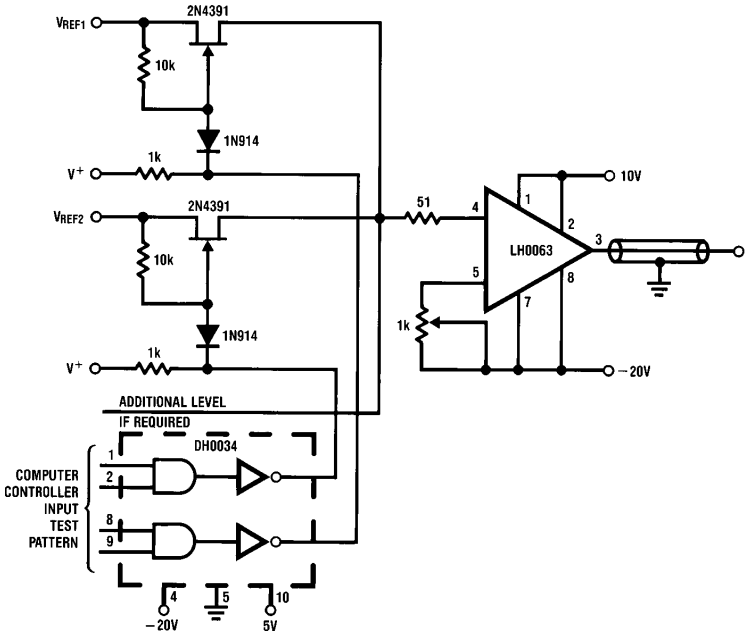


TL/K/5507–13

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

Typical Applications

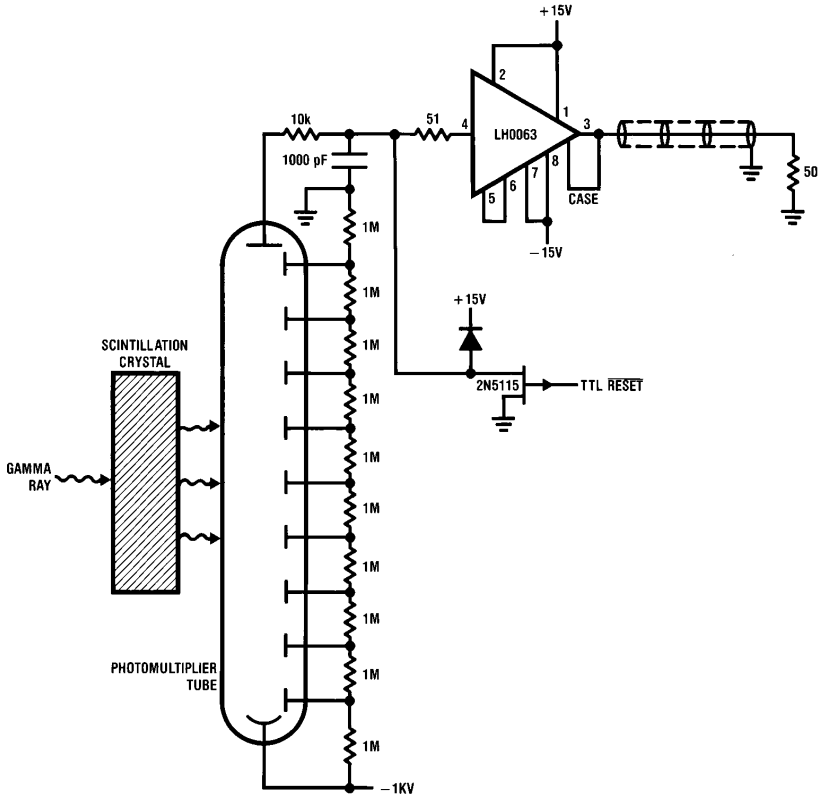
High Speed Automatic Test Equipment
Forcing Function Generator



TL/K/5507–14

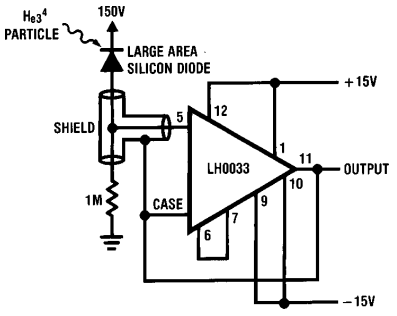
Typical Applications (Continued)

Gamma Ray Pulse Integrator



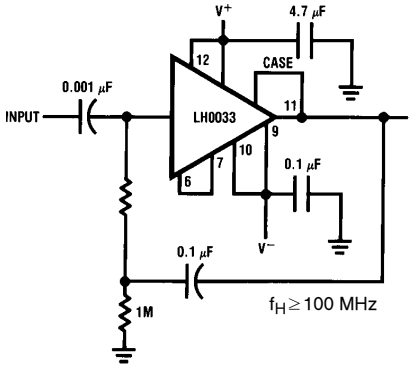
TL/K/5507–15

Nuclear Particle Detector



TL/K/5507–16

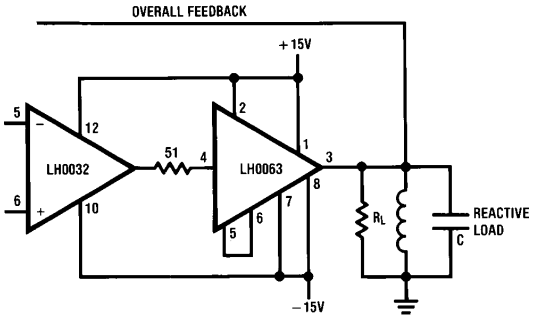
High Input Impedance AC Coupled Amplifier



TL/K/5507–17

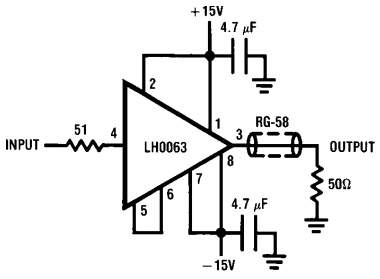
Typical Applications (Continued)

Isolation Buffer



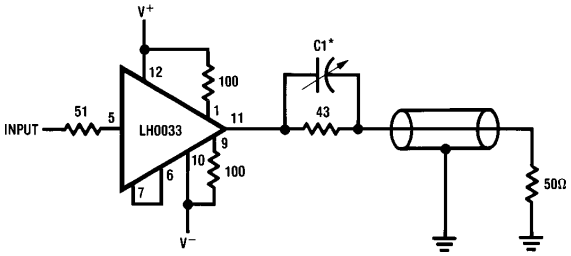
TL/K/5507–18

Coaxial Cable Driver



TL/K/5507–19

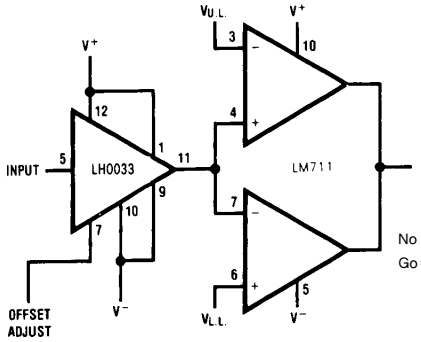
Coaxial Cable Driver



TL/K/5507–20

*Select C1 for optimum pulse response

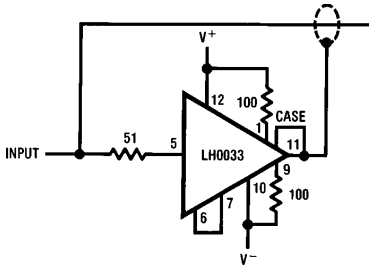
High Input Impedance Comparator with Offset Adjust



No go = logic "1"
Go = logic "0"

TL/K/5507–21

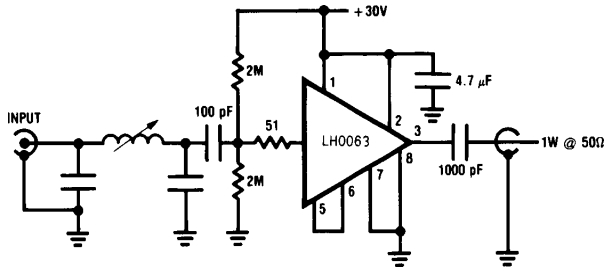
Instrumentation Shield/Line Driver



TL/K/5507–22

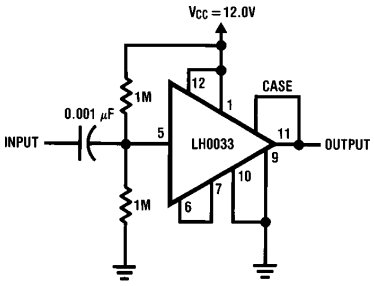
Typical Applications (Continued)

1W CW Final Amplifier



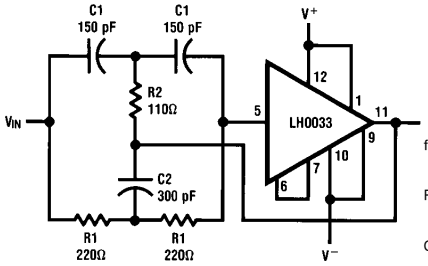
TL/K/5507–23

Single Supply AC Amplifier



TL/K/5507–24

4.5 MHz Notch Filter



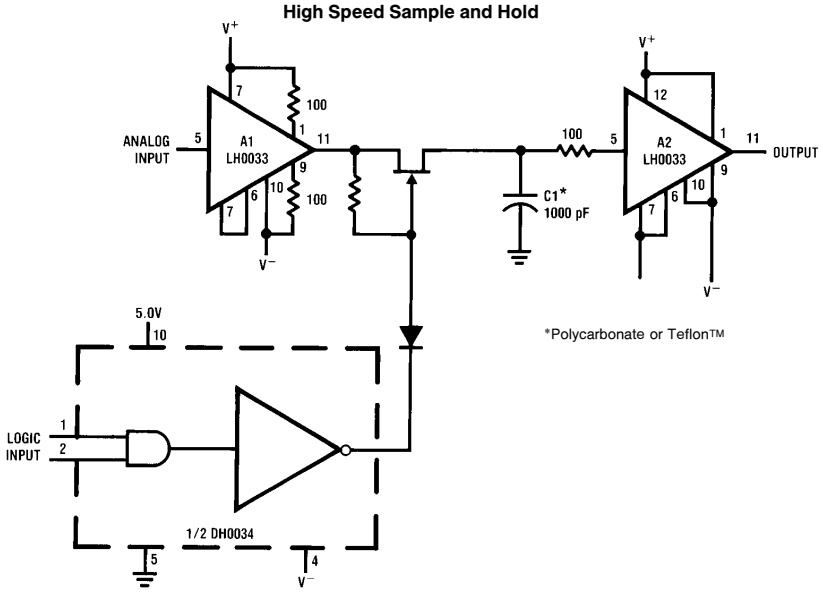
$$f_O = \frac{1}{2\pi R1C1}$$

$$R1 = 2\ R2$$

$$C1 = \frac{C2}{2}$$

TL/K/5507–25

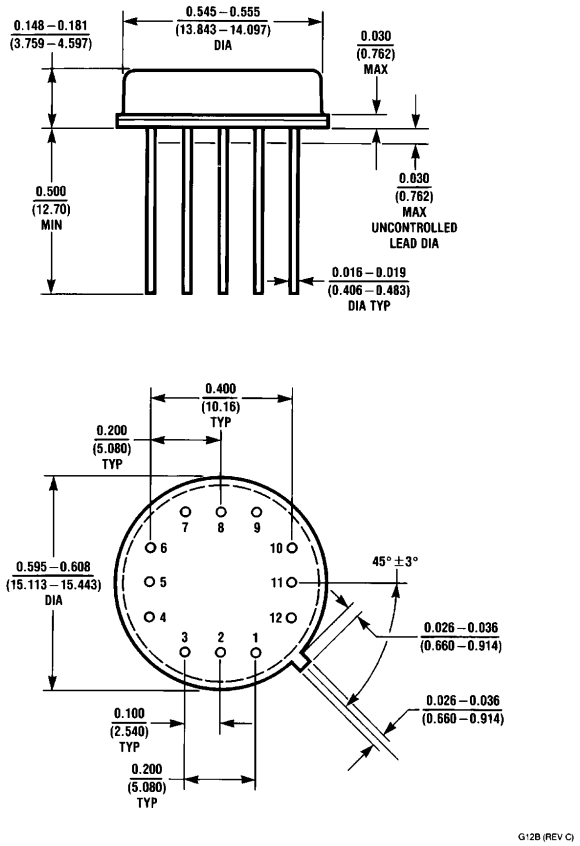
High Speed Sample and Hold



*Polycarbonate or Teflon™

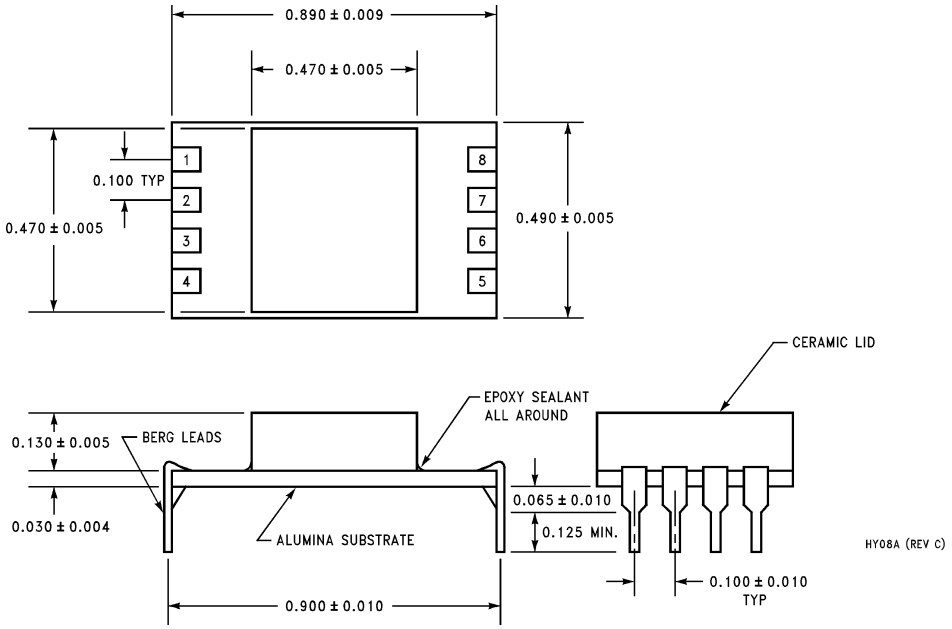
TL/K/5507–26

Physical Dimensions inches (millimeters)



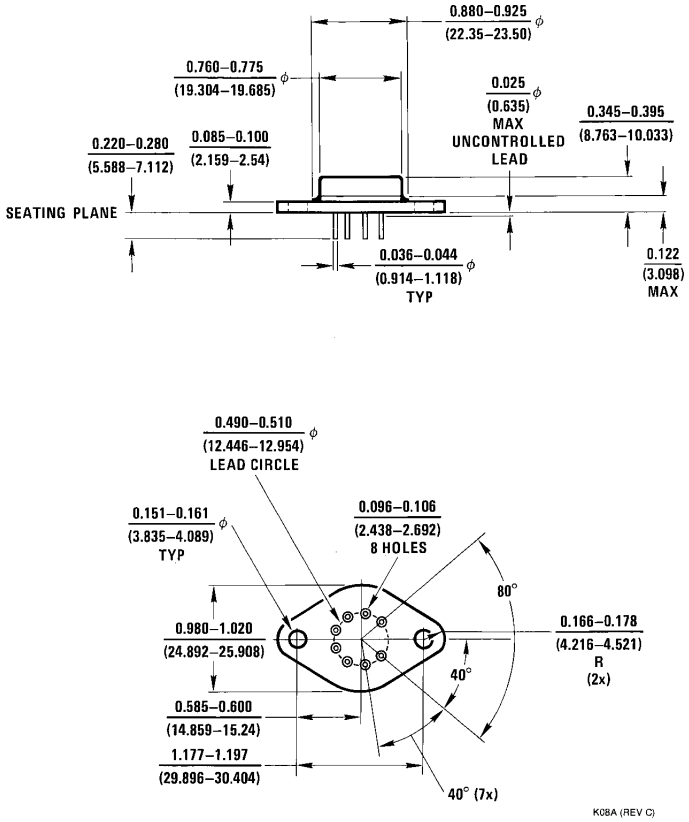
Metal Can Package (G)
Order Number LH0033G,
LH0033G-MIL or LH0033CG
NS Package Number G12B

Physical Dimensions inches (millimeters) (Continued)



Dual-In-Line Package (J)
Order Number LH0033J or LH0033CJ
NS Package Number HY08A

Physical Dimensions inches (millimeters) (Continued)



TO-3 Metal Can Package (K)
Order Number LH0063K, LH0063K-MIL or LH0063CK
NS Package Number K08A

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