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 \( \pm 10 \text{ mA} \) into 1 k\( \Omega \) loads (\( \pm 100 \text{ mA peak} \)) at slew rates of 1500 V/\( \mu \text{s} \). The LH0063 will provide \( \pm 250 \text{ mA} \) into 50\( \Omega \) loads (\( \pm 500 \text{ mA peak} \)) at slew rates up to 6000 V/\( \mu \text{s} \). 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 50\( \Omega \) 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 \(- 55^\circ \text{C} \) to \(+ 125^\circ \text{C} \); the LH0033C and the LH0063C are specified from \(- 25^\circ \text{C} \) to \(+ 85^\circ \text{C} \). 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/\( \mu \text{s} \)
- Wide range single or dual supply operation
- Wide power bandwidth: DC to 100 MHz
- High output drive: \( \pm 10 \text{ V} \) with 50\( \Omega \) 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

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

Top View
Case is electrically isolated

Order Number LH0063K
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 ± 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
- LH0063C -65°C to +150°C

Storage Temperature Range
- LH0033C ± 65°C to ± 150°C
- LH0063C ± 55°C to ± 125°C

DC Electrical Characteristics V_S = ± 15V, T_MIN = TA ≤ T_MAX, unless otherwise specified, (Note 1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LH0033</th>
<th>LH0033C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Offset Voltage</td>
<td>R_S = 1000Ω, T_J = 25°C, V_IN = 0V (Note 2)</td>
<td>5.0</td>
<td>10</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>25</td>
<td>Typ</td>
</tr>
<tr>
<td>Average Temperature Coefficient</td>
<td>R_S = 1000Ω, V_IN = 0V (Note 3)</td>
<td>50</td>
<td>100</td>
<td>Max</td>
</tr>
<tr>
<td>of Offset Voltage</td>
<td></td>
<td>50</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>V_IN = 0V, T_J = 25°C (Note 2)</td>
<td>250</td>
<td>500</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td>T_A = 25°C (Note 4)</td>
<td>2.5</td>
<td>5.0</td>
<td>Typ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>20</td>
<td>Max</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>V_O = ± 10V, R_S = 1000Ω, R_L = 1kΩ</td>
<td>0.97</td>
<td>0.98</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.00</td>
<td>0.98</td>
<td>Typ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.00</td>
<td>0.98</td>
<td>Max</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>R_L = 1 kΩ</td>
<td>10^10</td>
<td>10^11</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10^10</td>
<td>10^11</td>
<td>Typ</td>
</tr>
<tr>
<td>Output Impedance</td>
<td>V_IN = ± 10V, R_L = 1.0kΩ</td>
<td>6.0</td>
<td>10</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
<td>10</td>
<td>Typ</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>V_IN = ± 14V, R_L = 1.0kΩ</td>
<td>± 12</td>
<td>± 12</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td>V_IN = ± 10.5V, R_L = 100kΩ, T_A = 25°C</td>
<td>± 9.0</td>
<td>± 9.0</td>
<td>Typ</td>
</tr>
<tr>
<td>Supply Current</td>
<td>V_IN = 0V (Note 5)</td>
<td>20</td>
<td>22</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>24</td>
<td>Typ</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>V_IN = 0V</td>
<td>600</td>
<td>660</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>630</td>
<td>720</td>
<td>Typ</td>
</tr>
</tbody>
</table>

AC Electrical Characteristics T_J = 25°C, V_S = ± 15V, R_S = 50Ω, R_L = 1.0 kΩ (Note 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LH0033</th>
<th>LH0033C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slew Rate</td>
<td>V_IN = ± 10V</td>
<td>1000</td>
<td>1500</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>1400</td>
<td>Typ</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>V_IN = 1.0 Vrms</td>
<td>100</td>
<td>100</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>100</td>
<td>Typ</td>
</tr>
<tr>
<td>Phase Non-Linearity</td>
<td>8W - 1.0Hz to 20 MHz</td>
<td>2.0</td>
<td>2.0</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
<td>2.0</td>
<td>Typ</td>
</tr>
<tr>
<td>Rise Time</td>
<td>ΔV_IN = 0.5V</td>
<td>2.9</td>
<td>3.2</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.9</td>
<td>3.2</td>
<td>Typ</td>
</tr>
<tr>
<td>Propagation Delay</td>
<td>ΔV_IN = 0.5V</td>
<td>1.2</td>
<td>1.5</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2</td>
<td>1.5</td>
<td>Typ</td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td>f &gt; 1 kHz</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>Typ</td>
</tr>
</tbody>
</table>

Note 1: LH0033C is 100% production tested as specified at 29°C, 125°C, and -55°C. LH0033AC/ACC are 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 values 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. ΔV_OS/ΔT 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 pulsed 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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LH0063C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
</tr>
<tr>
<td>Output Offset Voltage</td>
<td>$R_S \leq 100k\Omega$, $T_J = -25^\circ C$, $R_L = 100\Omega$ (Note 2)</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Average Temperature Coefficient of Output Offset Voltage</td>
<td>$R_S \leq 100 \text{ k}\Omega$</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>$T_J = -25^\circ C$ (Note 2)</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>$V_{IN} = \pm 10V$, $R_S \leq 100 \text{ k}\Omega$, $R_L = 1 \text{ k}\Omega$</td>
<td>0.94</td>
<td>0.96</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>$V_{IN} = \pm 10V$, $R_S \leq 100 \text{ k}\Omega$, $R_L = 50\Omega$, $T_J = -25^\circ C$</td>
<td>0.91</td>
<td>0.93</td>
</tr>
<tr>
<td>Input Capacitance</td>
<td>Case Shorted to Output</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Output Impedance</td>
<td>$V_{OUT} = \pm 10V$, $R_S \leq 100 \text{ k}\Omega$, $R_L = 50\Omega$</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Output Current Swing</td>
<td>$V_{IN} = \pm 10V$, $R_S \leq 100 \text{ k}\Omega$</td>
<td>0.2</td>
<td>0.25</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>$R_L = 50\Omega$</td>
<td>$\pm 10$</td>
<td>$\pm 13$</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>$V_S = \pm 5.0V$, $R_L = 50\Omega$, $T_J = -25^\circ C$</td>
<td>5.09</td>
<td>7.0</td>
</tr>
<tr>
<td>Supply Current</td>
<td>$T_J = -25^\circ C$, $R_L = \infty$, $V_S = \pm 15V$</td>
<td>50</td>
<td>65</td>
</tr>
<tr>
<td>Supply Current</td>
<td>$V_S = \pm 5.0V$</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Power Consumption</td>
<td>$T_J = -25^\circ C$, $R_L = \infty$, $V_S = \pm 15V$</td>
<td>1.5</td>
<td>1.95</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>$V_S = \pm 5.0V$</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LH0063C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slew Rate</td>
<td>$R_L = 1.0 \text{ k}\Omega$, $V_{IN} = \pm 10V$</td>
<td></td>
<td>6000</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>$R_L = 50\Omega$, $V_{IN} = \pm 10V$, $T_J = -25^\circ C$</td>
<td>2000</td>
<td>2400</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>$V_{IN} = 1.0 \text{ Vrms}$</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Phase Non-Linearity</td>
<td>$BW = 1.0 \text{ Hz to 20 MHz}$</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$\Delta V_{IN} = 0.5V$</td>
<td></td>
<td>1.9</td>
</tr>
<tr>
<td>Propagation Delay</td>
<td>$\Delta V_{IN} = 0.5V$</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td>$&lt;0.1$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 $T_J = 25^\circ C$. 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 (Continued)

LH0033 Input Bias Current

vs Temperature

LH0063 Input Current

vs Temperature

LH0063 Frequency

Response

LH0033 Normalized Input

Bias Current During

Warm-Up

LH0063 Small Signal Rise

Time

LH0033 Input Bias Current

vs Input Voltage

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.

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

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 \( V^+ = +5\) V and \( V^- = -12\) V. 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:

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

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 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:

\[
R_{\text{lim}} = \frac{V^+ - V^-}{I_{\text{SC}}}
\]

where:
- \( I_{\text{SC}} \) \( \leq 100 \) mA for LH0033
- \( I_{\text{SC}} \) \( \leq 250 \) mA for LH0063

FIGURE 3. LH0033 Using Resistor Current Limiting

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 VC\textsuperscript{+} and VC\textsuperscript{−} 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 VC pins. Under fault conditions, the voltage decreases as required by the overload.

For Figure 5:

\[
R_{\text{LM}} = \frac{V_{\text{BE}}}{I_{\text{SC}}} = \frac{0.6V}{60\, \text{mA}} = 10\, \Omega
\]

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

\[
R_{\text{LM}} = \frac{V_{\text{BE}}}{1/3(I_{\text{SC}})} = \frac{0.6V}{1/3(200\, \text{mA})} = 8.2\, \Omega
\]

C 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 \((C \times \frac{dV}{dt})\) should be limited below absolute maximum peak current ratings for the devices.

Thus for the LH0033:

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

and for the LH0063:

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

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

\[
P_{\text{Dpkg}} = P_{\text{DC}} + P_{\text{AC}}
\]

\[
P_{\text{Dpkg}} = (V_{\text{pp}})^2 \times f \times C_L
\]

where:

- \(V_{\text{pp}}\) = 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 LM6218, LM6361 or LH0032. An isolation resistor of 47 \(\Omega\) 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 a fraction of the device package) to a ground plane. Capacitors should be one or two 0.1 \(\mu\text{F}\) in parallel for the LH0033; adding a 4.7 \(\mu\text{F}\) solid tantalum capacitor will help in troublesome instances. For the LH0063, 0.1 \(\mu\text{F}\) ceramic and one 4.7 \(\mu\text{F}\) solid tantalum capacitors in parallel will be necessary on each supply lead.
Schematic Diagrams

LH0033/LH0033A

Typical Applications

High Speed Automatic Test Equipment
Forcing Function Generator

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

Gamma Ray Pulse Integrator

Nuclear Particle Detector

High Input Impedance AC Coupled Amplifier
Typical Applications

Isolation Buffer

Overall Feedback

Coaxial Cable Driver

TL/K/5507–18

TL/K/5507–19

TL/K/5507–20

TL/K/5507–21

TL/K/5507–22

*Select C1 for optimum pulse response

High Input Impedance Comparator with Offset Adjust

Instrumentation Shield/Line Driver

No go = logic "1"

Go = logic "0"

TL/K/5507–21
**Typical Applications** (Continued)

1W CW Final Amplifier

![Circuit Diagram for 1W CW Final Amplifier](image)

Single Supply AC Amplifier

![Circuit Diagram for Single Supply AC Amplifier](image)

4.5 MHz Notch Filter

![Circuit Diagram for 4.5 MHz Notch Filter](image)

High Speed Sample and Hold

![Circuit Diagram for High Speed Sample and Hold](image)

*Polycarbonate or Teflon™*
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
**LIFE SUPPORT POLICY**

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1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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**Physical Dimensions inches (millimeters) (Continued)**

![Physical Dimensions Diagram]