National Semiconductor

November 1994

# LM110/LM210/LM310 Voltage Follower

## General Description

The LM110 series are monolithic operational amplifiers internally connected as unity-gain non-inverting amplifiers. They use super-gain transistors in the input stage to get low bias current without sacrificing speed. Directly interchangeable with 101, 741 and 709 in voltage follower applications, these devices have internal frequency compensation and provision for offset balancing.

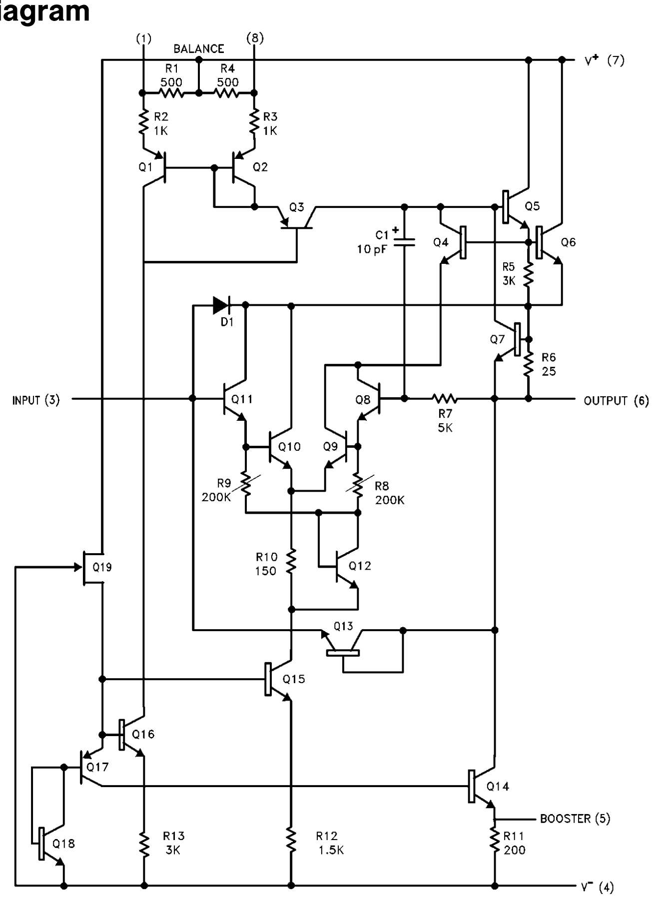
The LM110 series are useful in fast sample and hold circuits, active filters, or as general-purpose buffers. Further, the frequency response is sufficiently better than standard IC amplifiers that the followers can be included in the feedback loop without introducing instability. They are plug-in replacements for the LM102 series voltage followers, offering lower offset voltage, drift, bias current and noise in addition to higher speed and wider operating voltage range.

The LM110 is specified over a temperature range $-55°C \leq T_A \leq +125°C$, the LM210 from $-25°C \leq T_A \leq +85°C$ and the LM310 from $0°C \leq T_A \leq +70°C$.

## Features

- Input current — 10 nA max over temperature
- Small signal bandwidth — 20 MHz
- Slew rate — 30 V/µs
- Supply voltage range — ±5V to ±18V

## Schematic Diagram

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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. (Note 6)**

| | |
|---|---|
| Supply Voltage | ±18V |
| Power Dissipation (Note 1) | 500 mW |
| Input Voltage (Note 2) | ±15V |
| Output Short Circuit Duration (Note 3) | Indefinite |
| Operating Temperature Range | |
| LM110 | −55°C to +125°C |
| LM210 | −25°C to +85°C |
| LM310 | 0°C to +70°C |
| Storage Temperature Range | −65°C to +150°C |
| Lead Temperature (Soldering, 10 sec.) | 260°C |
| Soldering Information | |
| Dual-In-Line Package | |
| Soldering (10 sec.) | 260°C |
| Small Outline Package | |
| Vapor Phase (60 sec.) | 215°C |
| Infrared (15 sec.) | 220°C |

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD rating to be determined.

## Electrical Characteristics (Note 4)

| Parameter | Conditions | LM110 | | | LM210 | | | LM310 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $T_A = 25°C$ | | 1.5 | 4.0 | | 1.5 | 4.0 | | 2.5 | 7.5 | mV |
| Input Bias Current | $T_A = 25°C$ | | 1.0 | 3.0 | | 1.0 | 3.0 | | 2.0 | 7.0 | nA |
| Input Resistance | $T_A = 25°C$ | $10^{10}$ | $10^{12}$ | | $10^{10}$ | $10^{12}$ | | $10^{10}$ | $10^{12}$ | | Ω |
| Input Capacitance | | | 1.5 | | | 1.5 | | | 1.5 | | pF |
| Large Signal Voltage Gain | $T_A = 25°C$, $V_S = \pm 15V$<br>$V_{OUT} = \pm 10V$, $R_L = 8\ k\Omega$ | 0.999 | 0.9999 | | 0.999 | 0.9999 | | 0.999 | 0.9999 | | V/V |
| Output Resistance | $T_A = 25°C$ | | 0.75 | 2.5 | | 0.75 | 2.5 | | 0.75 | 2.5 | Ω |
| Supply Current | $T_A = 25°C$ | | 3.9 | 5.5 | | 3.9 | 5.5 | | 3.9 | 5.5 | mA |
| Input Offset Voltage | | | | 6.0 | | | 6.0 | | | 10 | mV |
| Offset Voltage Temperature Drift | $-55°C \le T_A \le +85°C$<br>$+85 \le T_A \le 125°C$<br>$0°C \le T_A \le +70°C$ | | 6<br>12 | | | 6 | | | <br><br>10 | | μV/°C<br>μV/°C<br>μV/°C |
| Input Bias Current | | | | 10 | | | 10 | | | 10 | nA |
| Large Signal Voltage Gain | $V_S = \pm 15V$, $V_{OUT} = \pm 10V$<br>$R_L = 10\ k\Omega$ | 0.999 | | | 0.999 | | | 0.999 | | | V/V |
| Output Voltage Swing (Note 5) | $V_S = \pm 15V$, $R_L = 10\ k\Omega$ | ±10 | | | ±10 | | | ±10 | | | V |
| Supply Current | $T_A = 125°C$ | | 2.0 | 4.0 | | 2.0 | 4.0 | | | | mA |
| Supply Voltage Rejection Ratio | $\pm 5V \le V_S \le \pm 18V$ | 70 | 80 | | 70 | 80 | | 70 | 80 | | dB |

**Note 1:** The maximum junction temperature of the LM110 is 150°C, of the LM210 is 100°C, and of the LM310 is 85°C. For operating at elevated temperatures, devices in the HO8 package must be derated based on a thermal resistance of 165°C/W, junction to ambient, or 22°C/W, junction to case. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

**Note 2:** For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

**Note 3:** Continuous short circuit for the LM110 and LM210 is allowed for case temperatures to 125°C and ambient temperatures to 70°C, and for the LM310, 70°C case temperature or 55°C ambient temperature. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted. $R_S$ = 5k min, 10k typical is recommended for dynamic stability in all applications.

**Note 4:** These specifications apply for $\pm 5V \le V_S \le \pm 18V$ and $-55°C \le T_A$ 125°C for the LM110, $-25°C \le T_A \le 85°C$ for the LM210, and $0°C \le T_A \le 70°C$ for the LM310 unless otherwise specified.

**Note 5:** Increased output swing under load can be obtained by connecting an external resistor between the booster and $V^-$ terminals. See curve.

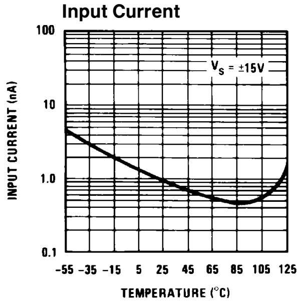
**Note 6:** Refer to RETS110X for LM110H, LM110J military specifications.

## Application Hint

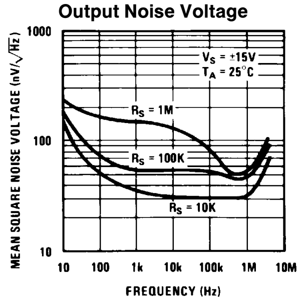
The input must be driven from a source impedance of typically 10 kΩ (5 kΩ min.) to maintain stability. The total source impedance will be reduced at high frequencies if there is stray capacitance at the input pin. In these cases, a 10 kΩ resistor should be inserted in series with the input, physically close to the input pin to minimize the stray capacitance and prevent oscillation.

## Typical Performance Characteristics (LM110/LM210)

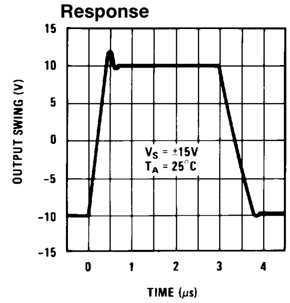
### Input Current



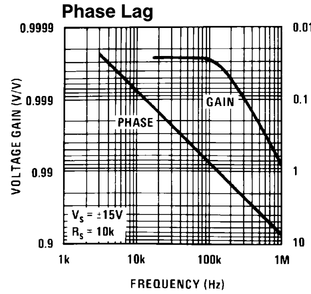

### Output Noise Voltage



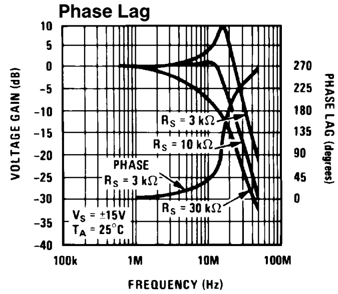

### Large Signal Pulse Response



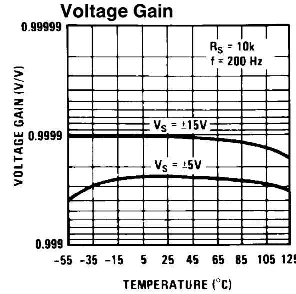

### Voltage Gain and Phase Lag



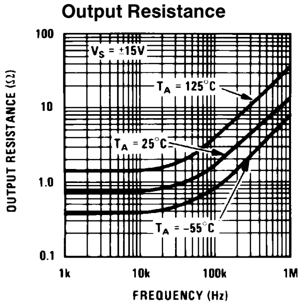

### Voltage Gain and Phase Lag



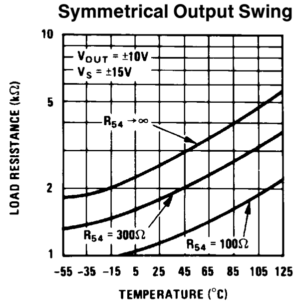

### Voltage Gain



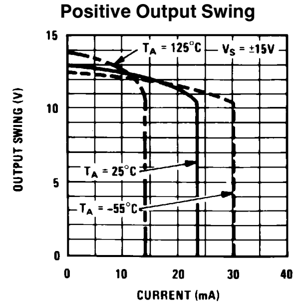

### Output Resistance



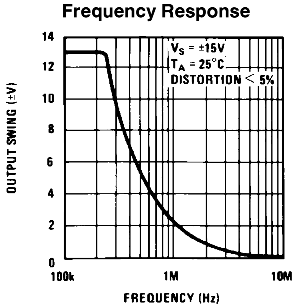

### Symmetrical Output Swing



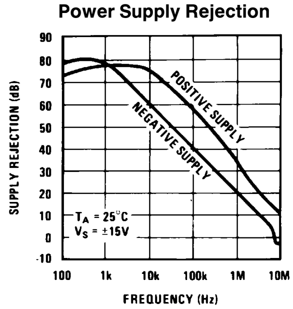

### Positive Output Swing



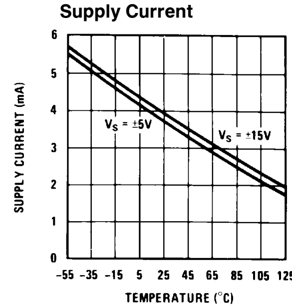

### Large Signal Frequency Response




### Power Supply Rejection




### Supply Current

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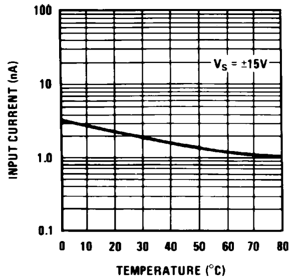
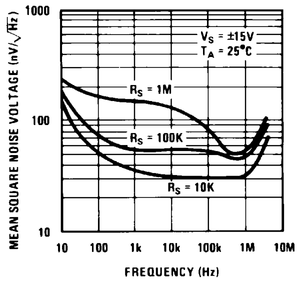
## Typical Performance Characteristics (LM310)

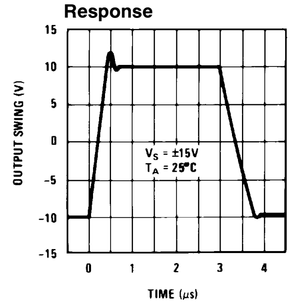
### Input Current



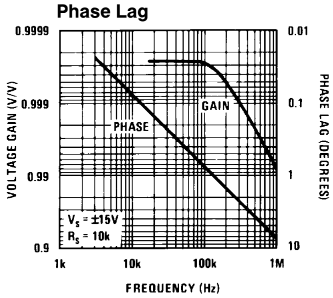

### Output Noise Voltage



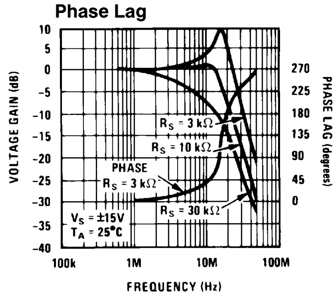

### Large Signal Pulse Response



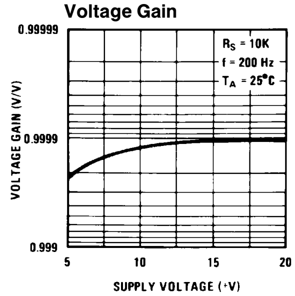

### Voltage Gain and Phase Lag



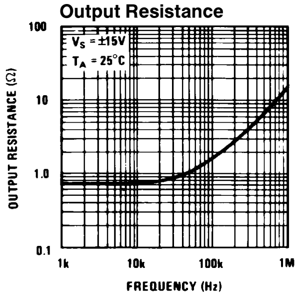

### Voltage Gain and Phase Lag



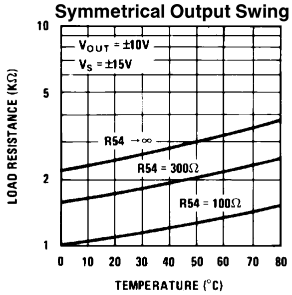

### Voltage Gain



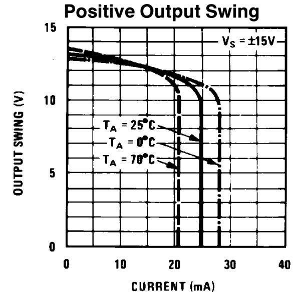

### Output Resistance



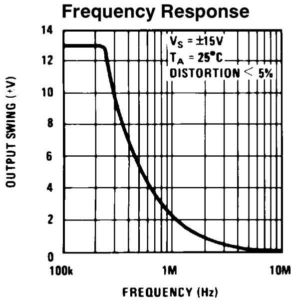

### Symmetrical Output Swing



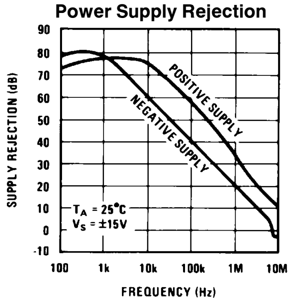

### Positive Output Swing



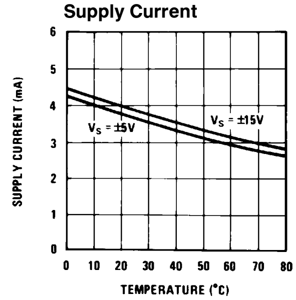

### Large Signal Frequency Response




### Power Supply Rejection




### Supply Current

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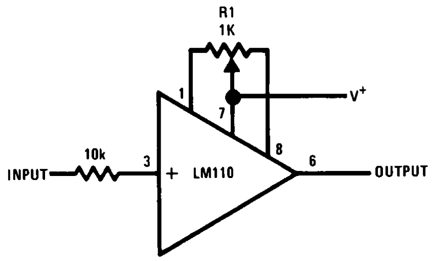
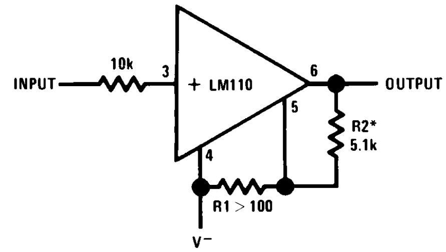
## Auxiliary Circuits

**Offset Balancing Circuit**




TL/H/7761–2

**Increasing Negative Swing Under Load**

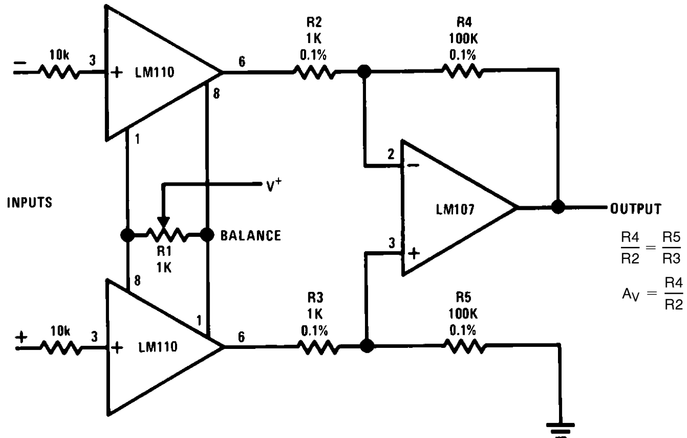



TL/H/7761–3

*May be added to reduce internal dissipation

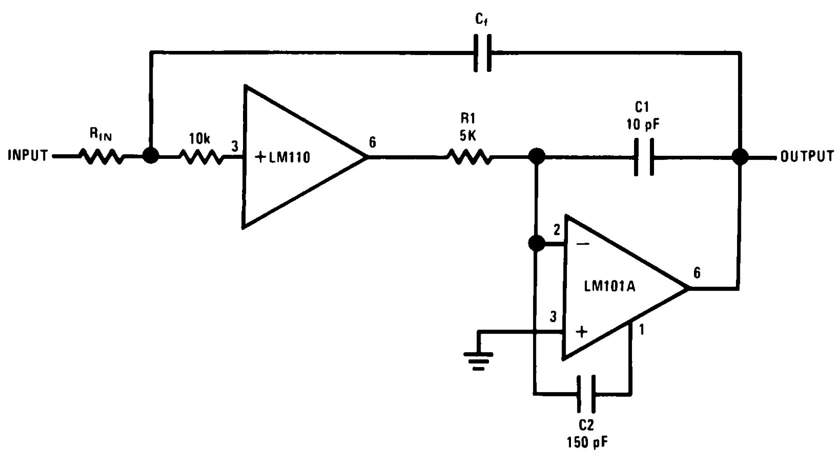
## Typical Applications

**Differential Input Instrumentation Amplifier**




TL/H/7761–4

**Fast Integrator with Low Input Current**

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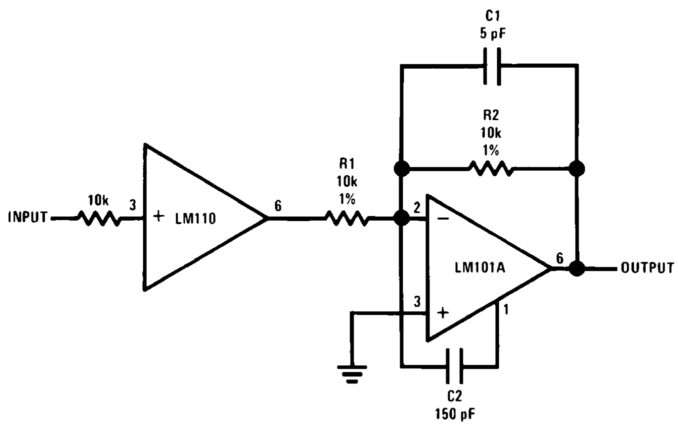
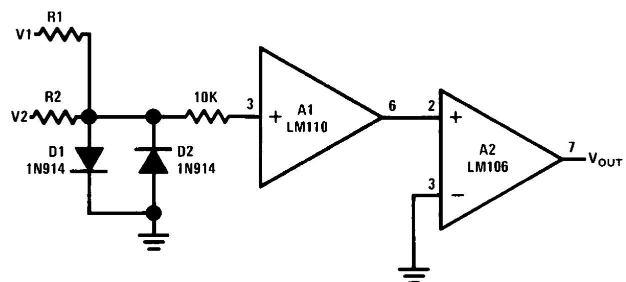
## Typical Applications (Continued)

### Fast Inverting Amplifier with High Input Impedance



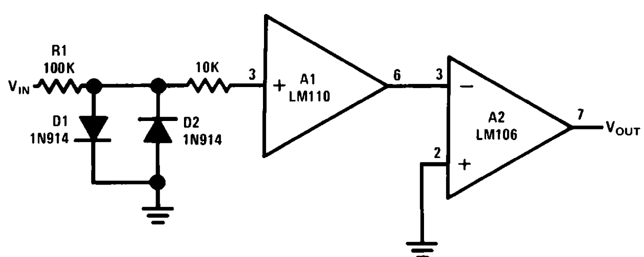

TL/H/7761–6

### Comparator for Signals of Opposite Polarity




TL/H/7761–7

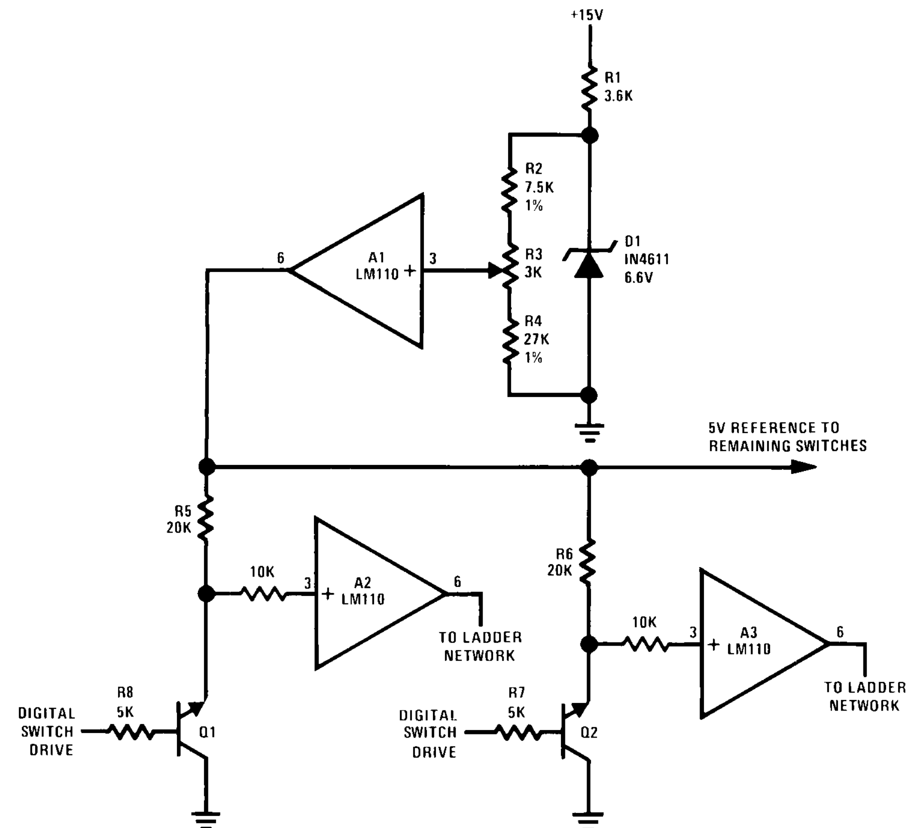
### Zero Crossing Detector




TL/H/7761–9

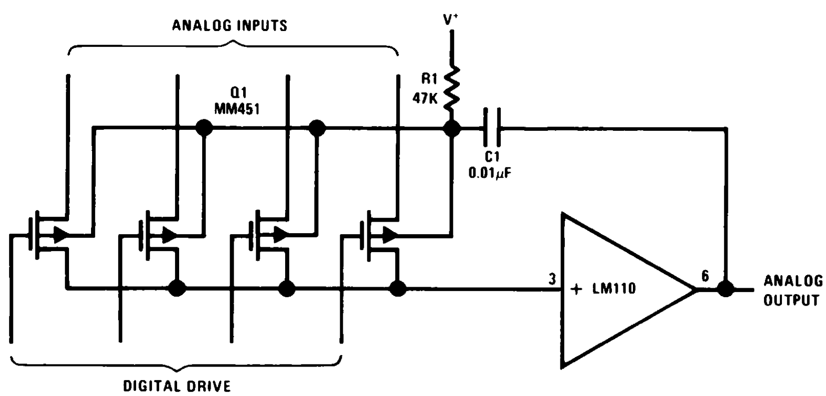
## Typical Applications (Continued)

**Driver for A/D Ladder Network**




TL/H/7761–8

**Buffer for Analog Switch***

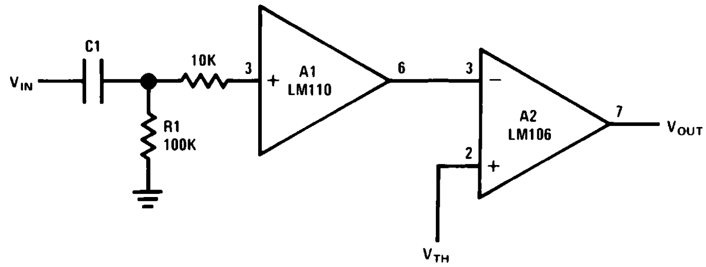



TL/H/7761–10

*Switch substrates are boot-strapped to reduce output capacitance of switch.

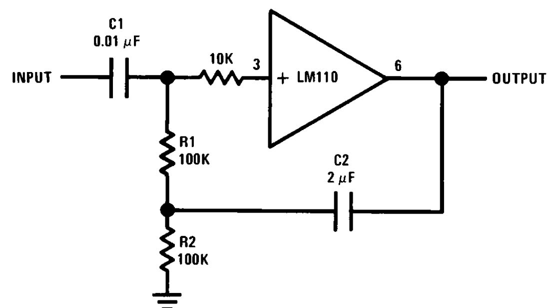
## Typical Applications (Continued)

**Comparator for AC Coupled Signals**



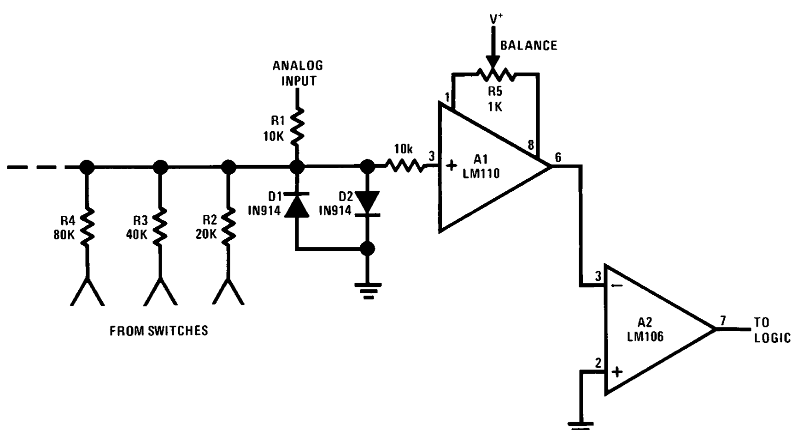

TL/H/7761–11

**High Input Impedance AC Amplifier**




TL/H/7761–12

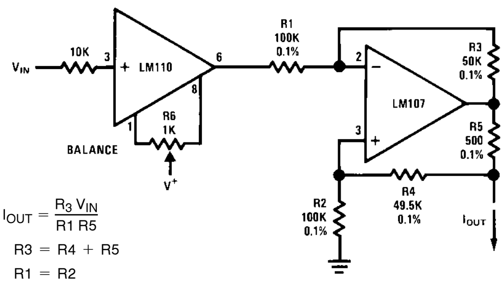
**Comparator for A/D Converter Using a Binary-Weighted Network**




TL/H/7761–13

## Typical Applications (Continued)

### Bilateral Current Source



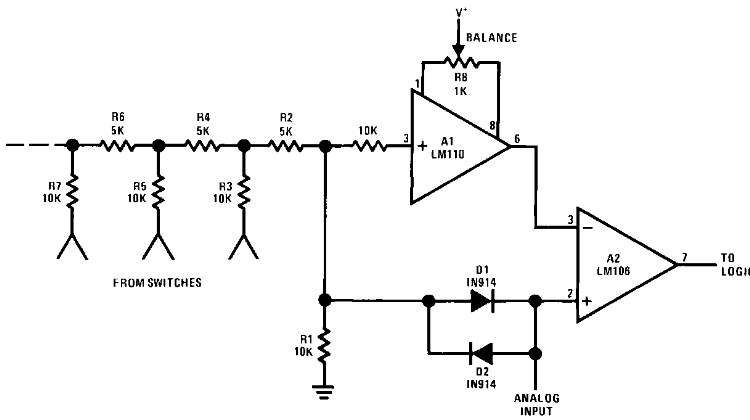

$$I_{OUT} = \frac{R_3 V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

TL/H/7761–14

### Comparator for A/D Converter Using a Ladder Network

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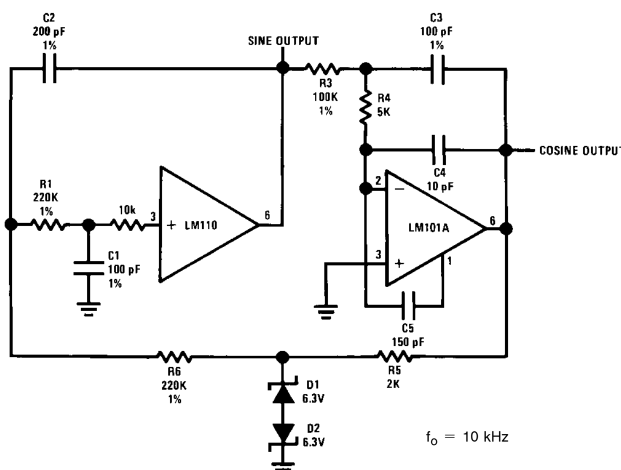
### Sine Wave Oscillator




$f_o = 10$ kHz

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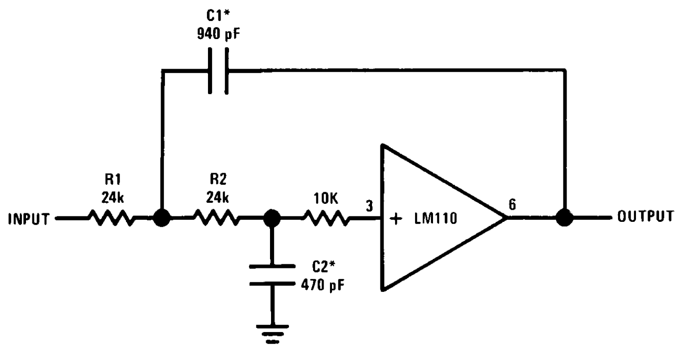
## Typical Applications (Continued)

### Low Pass Active Filter

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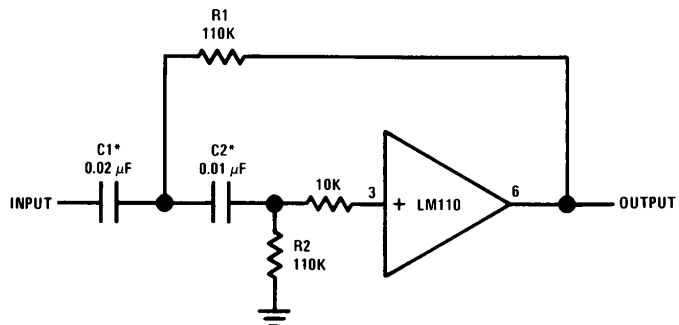
*Values are for 10 kHz cutoff. Use silvered mica capacitors for good temperature stability.

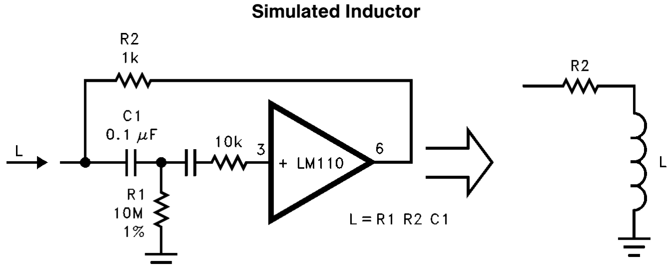
### High Pass Active Filter




TL/H/7761–19

*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability.

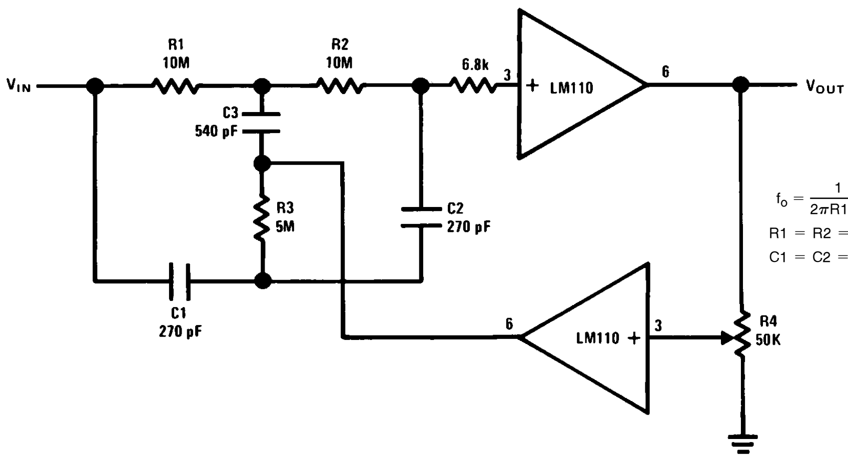
### Simulated Inductor




TL/H/7761–21

## Typical Applications (Continued)

**Adjustable Q Notch Filter**



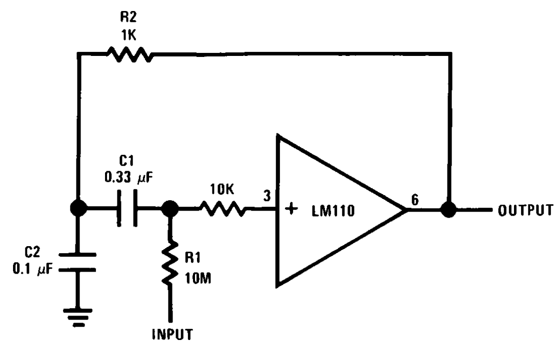

$f_o = \frac{1}{2\pi R1C1}$

R1 = R2 = 2R3

C1 = C2 = C3/2

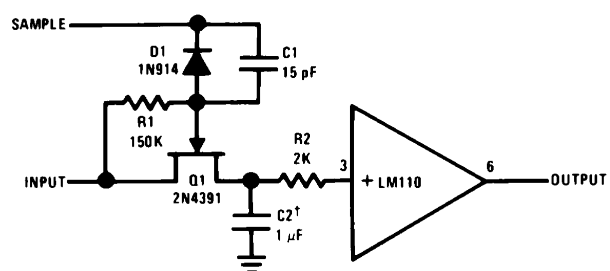
TL/H/7761–22

**Bandpass Filter**




TL/H/7761–23

**Sample and Hold**

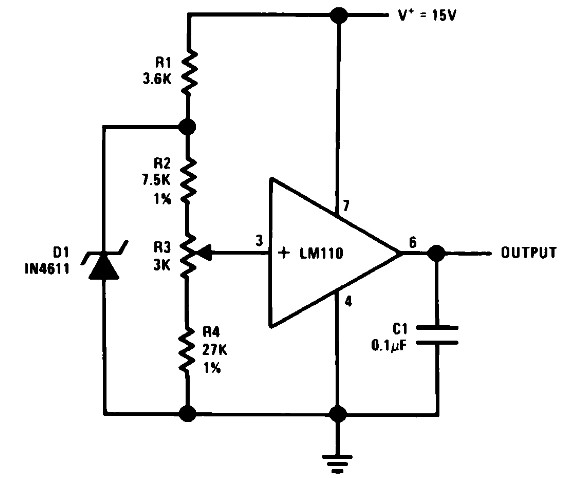



TL/H/7761–24

†Use capacitor with polycarbonate teflon or polythylene dietetric

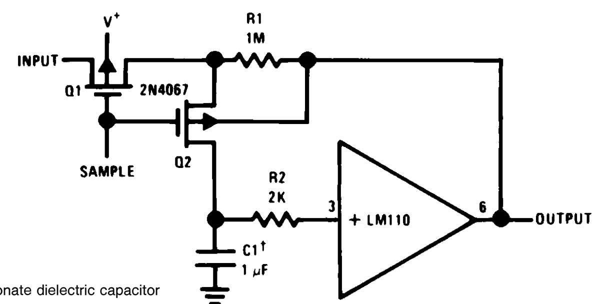
## Typical Applications (Continued)

**Buffered Reference Source**




TL/H/7761–25

**Low Drift Sample and Hold***



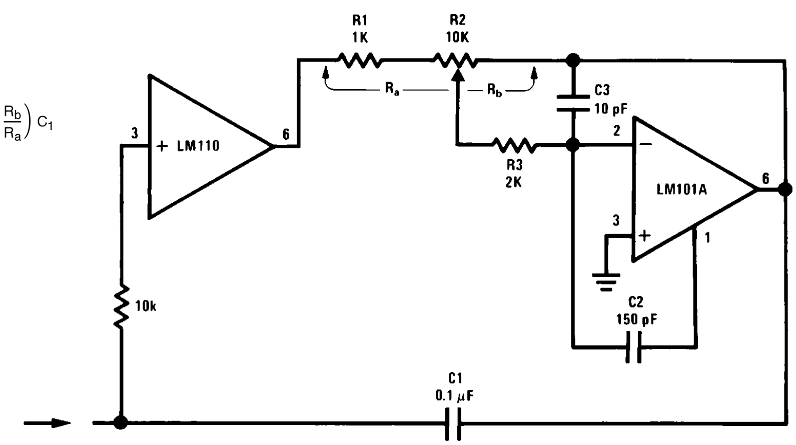

†Teflon polyethylene or polycarbonate dielectric capacitor

*Worst case drift less than 3 mV/sec

TL/H/7761–26

**Variable Capacitance Multiplier**

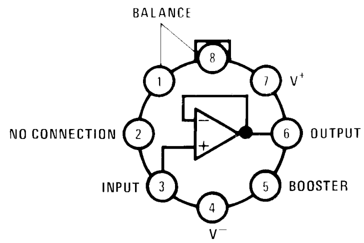
$C = \left(1 + \frac{R_b}{R_a}\right) C_1$




TL/H/7761–27

## Connection Diagrams

**Metal Can Package**



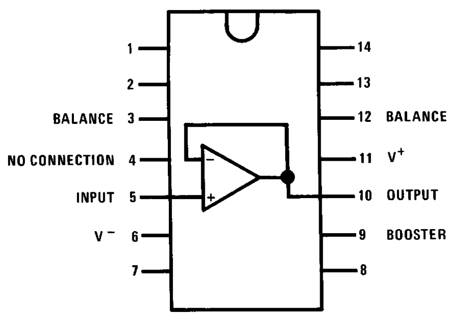

TL/H/7761–30

Package is connected to Pin 4 (V−)

**Top View**

**Order Number LM110H, LM210H or LM310H**
**LM110H/883***
**See NS Package Number H08C**

**Dual-In-Line Package**

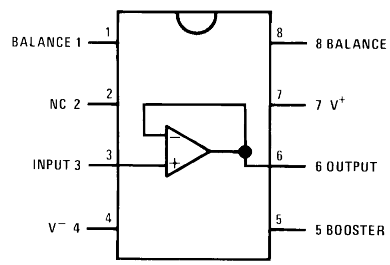



TL/H/7761–31

**Top View**

**Order Number LM110J, LM210J,**
**LM310J or LM110J/883***
**See NS Package Number J14A**

**Dual-In-Line Package**



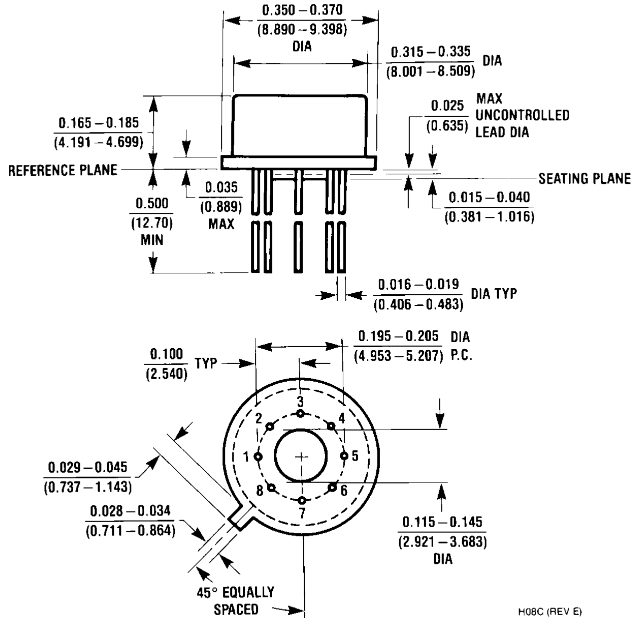

TL/H/7761–32

**Top View**

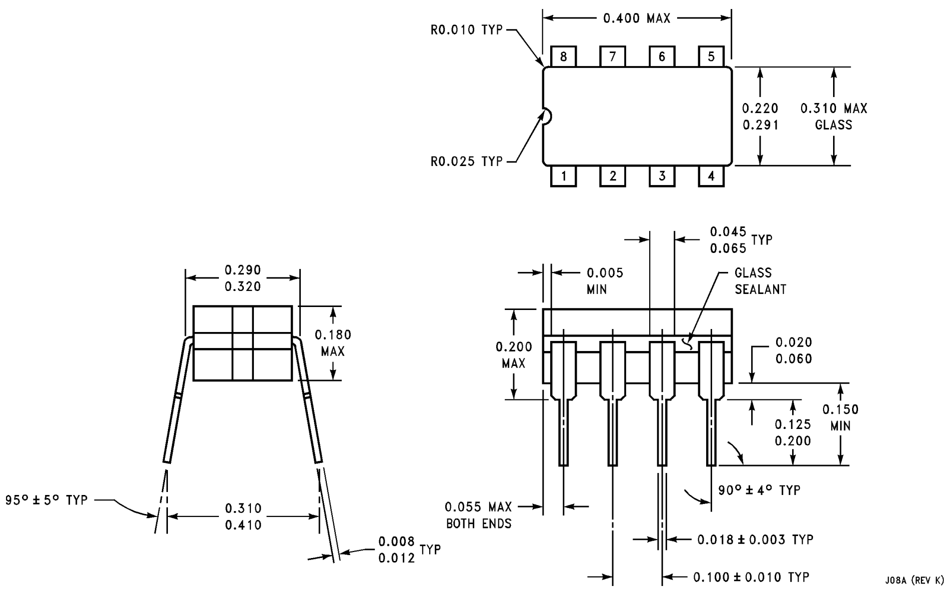
**Order Number LM310M, LM310N or LM110J-8/883***
**See NS Package Number J08A, M08A or N08E**

*Available per SMD# 5962-8760601

## Physical Dimensions inches (millimeters)

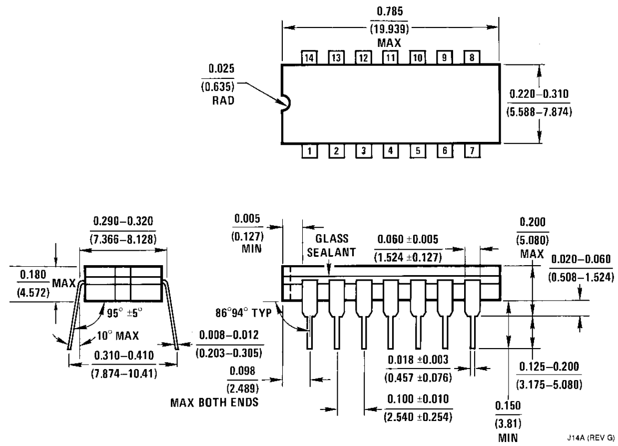



**Metal Can Package (H)**
**Order Number LM110H, LM110H/883, LM210H or LM310H**
**NS Package Number H08C**

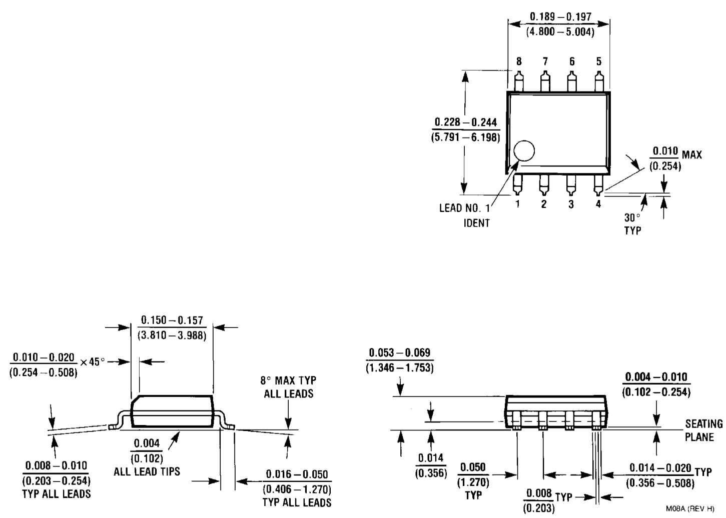



**Dual-In-Line Package (J)**
**Order Number LM110J-8/883**
**NS Package Number J08A**

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

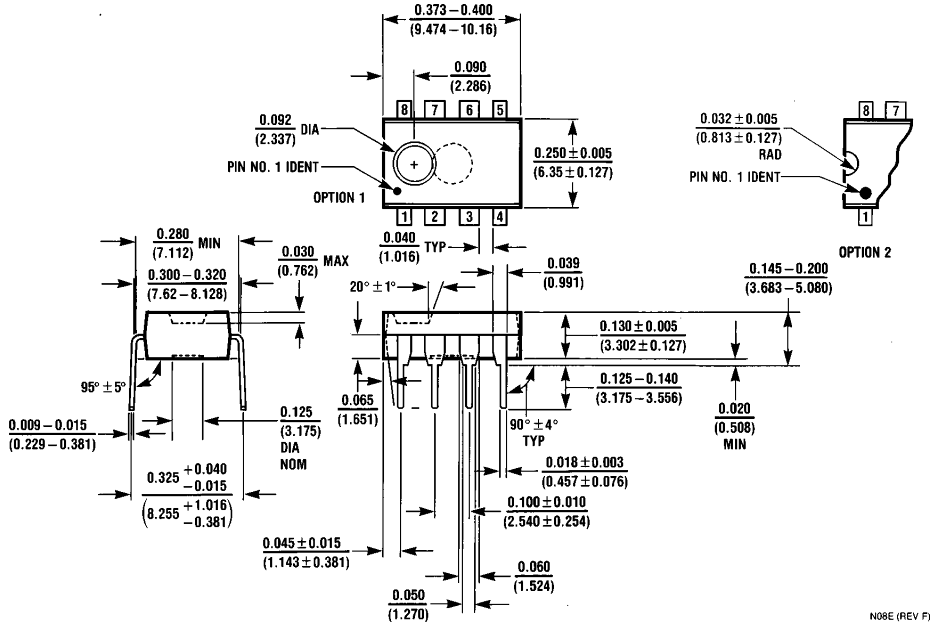



**Ceramic Dual-In-Line Package (J)**
**Order Number LM110J/883**
**NS Package Number J14A**




**S.O. Package (M)**
**Order Number LM310M**
**NS Package Number M08A**

## Physical Dimensions inches (millimeters) (Continued)




**Molded Dual-In-Line Package (N)**
**Order Number LM310N**
**NS Package Number N08E**

### LIFE SUPPORT POLICY

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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.

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

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

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

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