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 \(-55^\circ C < T_A < 125^\circ C\), the LM210 from \(-25^\circ C < T_A < +85^\circ C\) and the LM310 from \(0^\circ C < T_A < +70^\circ C\).

Features

- Input current 10 nA max over temperature
- Small signal bandwidth 20 MHz
- Slew rate 30 V/\(\mu\)s
- Supply voltage range \(\pm 5\) V to \(\pm 18\) V

Schematic Diagram
### Absolute Maximum Ratings

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

(Not 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM110</th>
<th>LM210</th>
<th>LM310</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>±18V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Dissipation (Note 1)</td>
<td>500 mW</td>
<td></td>
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<td></td>
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<tr>
<td>Input Voltage (Note 2)</td>
<td>±15V</td>
<td></td>
<td></td>
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<tr>
<td>Output Voltage (Note 3)</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Output Short Circuit Duration</td>
<td>Indefinite</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Operating Temperature Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM110</td>
<td>−55°C to +125°C</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>LM210</td>
<td>−25°C to +85°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM310</td>
<td>0°C to +70°C</td>
<td></td>
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</tbody>
</table>

### Electrical Characteristics (Note 4)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM110</th>
<th>LM210</th>
<th>LM310</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>$T_A = 25^\circ C$</td>
<td>1.5</td>
<td>4.0</td>
<td>1.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>$T_A = 25^\circ C$</td>
<td>1.0</td>
<td>3.0</td>
<td>1.0</td>
<td>3.0</td>
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<tr>
<td>Input Resistance</td>
<td>$T_A = 25^\circ C$</td>
<td>$10^{10}$</td>
<td>$10^{12}$</td>
<td>$10^{10}$</td>
<td>$10^{12}$</td>
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<tr>
<td>Input Capacitance</td>
<td></td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>$V_{OUT} = \pm 10V, R_L = 8 \Omega$</td>
<td>0.999</td>
<td>0.999</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>Output Resistance</td>
<td>$T_A = 25^\circ C$</td>
<td>0.75</td>
<td>2.5</td>
<td>0.75</td>
<td>2.5</td>
</tr>
<tr>
<td>Supply Current</td>
<td>$T_A = 25^\circ C$</td>
<td>3.9</td>
<td>5.5</td>
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<td>5.5</td>
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<tr>
<td>Input Offset Voltage</td>
<td></td>
<td>6.0</td>
<td>6.0</td>
<td>10</td>
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</tr>
<tr>
<td>Offset Voltage Temperature Drift</td>
<td>$-55^\circ C \leq T_A \leq +85^\circ C$</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>10</td>
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<tr>
<td></td>
<td>$+85^\circ C \leq T_A \leq +125^\circ C$</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>$0^\circ C \leq T_A \leq +70^\circ C$</td>
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<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>$V_S = \pm 15V$</td>
<td>0.999</td>
<td>0.999</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Swing (Note 5)</td>
<td>$V_S = \pm 15V, R_L = 10 \Omega$</td>
<td>±10</td>
<td>±10</td>
<td>±10</td>
<td></td>
</tr>
<tr>
<td>Supply Current</td>
<td>$T_A = 125^\circ C$</td>
<td>2.0</td>
<td>4.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Supply Voltage Rejection Ratio</td>
<td>$\pm 5V \leq V_S \leq \pm 18V$</td>
<td>70</td>
<td>80</td>
<td>70</td>
<td>80</td>
</tr>
</tbody>
</table>

**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 case.

**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 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. $R_S = 5k \Omega$, 10k is typical for dynamic stability in all applications.

**Note 4:** These specifications apply for $\pm 5V \leq V_S \leq \pm 18V$ and $-55^\circ C \leq T_A \leq 125^\circ C$ for the LM110, $-25^\circ C \leq T_A \leq 85^\circ C$ for the LM210, and $0^\circ C \leq T_A \leq 70^\circ C$ 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**
  - \( I_{in} \) vs. Temperature (°C)

- **Output Noise Voltage**
  - Mean Square Noise Voltage (mV/

- **Large Signal Pulse Response**
  - Output Drive (mA)

- **Phase Lag**
  - Voltage Gain and Phase Lag

- **Voltage Gain**
  - Voltage Gain vs. Frequency (Hz)
  - Voltage Gain vs. Temperature (°C)

- **Output Resistance**
  - Output Resistance vs. Frequency (Hz)

- **Symmetrical Output Swing**
  - Swing Resistance (Ω)

- **Power Supply Rejection**
  - Supply Rejection (dB)

- **Supply Current**
  - Supply Current vs. Temperature (°C)

TL/1/2781–28
Typical Performance Characteristics (LM310)

- **Input Current**
- **Output Noise Voltage**
- **Large Signal Pulse Response**
- **Voltage Gain and Phase Lag**
- **Supply Current**
Auxiliary Circuits

Offset Balancing Circuit

Increasing Negative Swing Under Load

*May be added to reduce internal dissipation

Typical Applications

Differential Input Instrumentation Amplifier

Fast Integrator with Low Input Current
Typical Applications (Continued)

Fast Inverting Amplifier with High Input Impedance

Comparator for Signals of Opposite Polarity

Zero Crossing Detector
Typical Applications (Continued)

Driver for A/D Ladder Network

Buffer for Analog Switch

*Switch substrates are boot-strapped to reduce output capacitance of switch.
Typical Applications (Continued)

Comparator for AC Coupled Signals

High Input Impedance AC Amplifier

Comparator for A/D Converter Using a Binary-Weighted Network
**Typical Applications (Continued)**

**Bilateral Current Source**

\[
I_{out} = \frac{R_3}{R_1 + R_3} \frac{V_{IN}}{R_3}
\]

\[
R_3 = R_4 + R_5
\]

\[
R_1 = R_2
\]

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

\[
V_{BALANCE}
\]

\[
V_{OUT}
\]

**Sine Wave Oscillator**

\[
I_0 = 10 \text{ kHz}
\]
Typical Applications (Continued)

Low Pass Active Filter

![Low Pass Active Filter Diagram]

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

High Pass Active Filter

![High Pass Active Filter Diagram]

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

Simulated Inductor

![Simulated Inductor Diagram]

\[ L = R_1 R_2 C_1 \]
Typical Applications (Continued)

Adjustable Q Notch Filter

![Circuit diagram for Adjustable Q Notch Filter]

\[ f_0 = \frac{1}{2\pi R_1 C_1} \]
\[ R_1 = R_2 = 2R_3 \]
\[ C_1 = C_2 = C_3/2 \]

Bandpass Filter

![Circuit diagram for Bandpass Filter]

Sample and Hold

![Circuit diagram for Sample and Hold]

¹ Use capacitor with polycarbonate teflon or polyethylene dielectric
Typical Applications (Continued)

Buffered Reference Source

Low Drift Sample and Hold

Variable Capacitance Multiplier

1 Teflon polyethylene or polycarbonate dielectric capacitor

* Worst case drift less than 3 mV/sec
Connection Diagrams

Metal Can Package

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

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

Dual-In-Line Package

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
LM110/LM210/LM310 Voltage Follower

Physical Dimensions inches (millimeters) (Continued)

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