The LM148 series is a true quad 741. It consists of four independent, high gain, internally compensated, low power operational amplifiers which have been designed to provide functional characteristics identical to those of the familiar 741 operational amplifier. In addition the total supply current for all four amplifiers is comparable to the supply current of a single 741 type op amp. Other features include input offset currents and input bias current which are much less than those of a standard 741. Also, excellent isolation between amplifiers has been achieved by independently biasing each amplifier and using layout techniques which minimize thermal coupling.

The LM148 can be used anywhere multiple 741 or 1558 type amplifiers are being used and in applications where amplifier matching or high packing density is required. For lower power refer to LF444.

Features
- 741 op amp operating characteristics
- Class AB output stage — no crossover distortion
- Pin compatible with the LM124
- Overload protection for inputs and outputs
- Low supply current drain: 0.6 mA/Amplifier
- Low input offset voltage: 1 mV
- Low input offset current: 4 nA
- Low input bias current: 30 nA
- High degree of isolation between amplifiers: 120 dB
- Gain bandwidth product
- LM148 (unity gain): 1.0 MHz

Schematic Diagram

* 1 pF in the LM149
**Absolute Maximum Ratings** *(Note 4)*

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LM148</th>
<th>LM248</th>
<th>LM348</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply Voltage</strong></td>
<td>±22V</td>
<td>±18V</td>
<td>±18V</td>
</tr>
<tr>
<td><strong>Differential Input Voltage</strong></td>
<td>±44V</td>
<td>±36V</td>
<td>±36V</td>
</tr>
<tr>
<td><strong>Output Short Circuit Duration</strong></td>
<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>Power Dissipation (Pd at 25˚C)</strong></td>
<td>750 mW</td>
<td>100˚C/W</td>
<td>700 mW</td>
</tr>
<tr>
<td><strong>Thermal Resistance (θJA)</strong></td>
<td>100˚C/W</td>
<td>110˚C/W</td>
<td>110˚C/W</td>
</tr>
<tr>
<td><strong>Maximum Junction Temperature</strong></td>
<td>150˚C</td>
<td>110˚C</td>
<td>100˚C</td>
</tr>
<tr>
<td><strong>Operating Temperature Range</strong></td>
<td>−55˚C to +125˚C</td>
<td>−25˚C to +85˚C</td>
<td>0˚C to +70˚C</td>
</tr>
<tr>
<td><strong>Storage Temperature Range</strong></td>
<td>−65˚C to +150˚C</td>
<td>−65˚C to +150˚C</td>
<td>−65˚C to +150˚C</td>
</tr>
<tr>
<td><strong>Lead Temperature (Soldering)</strong></td>
<td>300˚C</td>
<td>300˚C</td>
<td>300˚C</td>
</tr>
<tr>
<td><strong>Lead Temperature (Soldering)</strong></td>
<td>260˚C</td>
<td>260˚C</td>
<td>260˚C</td>
</tr>
<tr>
<td><strong>Soldering Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual-In-Line Package</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soldering (10 seconds)</td>
<td>260˚C</td>
<td>260˚C</td>
<td>260˚C</td>
</tr>
<tr>
<td>Small Outline Package</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor Phase (60 seconds)</td>
<td>215˚C</td>
<td>215˚C</td>
<td>215˚C</td>
</tr>
<tr>
<td>Infrared (15 seconds)</td>
<td>220˚C</td>
<td>220˚C</td>
<td>220˚C</td>
</tr>
<tr>
<td><strong>ESD tolerance</strong></td>
<td>500V</td>
<td>500V</td>
<td>500V</td>
</tr>
</tbody>
</table>

**Electrical Characteristics** *(Note 3)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM148 Min</th>
<th>Typical</th>
<th>Max</th>
<th>LM248 Min</th>
<th>Typical</th>
<th>Max</th>
<th>LM348 Min</th>
<th>Typical</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>TA = 25˚C, RB ≤ 10 kΩ</td>
<td>1.0</td>
<td>5.0</td>
<td></td>
<td>1.0</td>
<td>6.0</td>
<td></td>
<td>1.0</td>
<td>6.0</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>TA = 25˚C</td>
<td>4</td>
<td>25</td>
<td></td>
<td>4</td>
<td>50</td>
<td></td>
<td>4</td>
<td>50</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>TA = 25˚C</td>
<td>30</td>
<td>100</td>
<td></td>
<td>30</td>
<td>200</td>
<td></td>
<td>30</td>
<td>200</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>Input Resistance</td>
<td>TA = 25˚C</td>
<td>0.8</td>
<td>2.5</td>
<td></td>
<td>0.8</td>
<td>2.5</td>
<td></td>
<td>0.8</td>
<td>2.5</td>
<td>MΩ</td>
<td></td>
</tr>
<tr>
<td>Supply Current All Amplifiers</td>
<td>TA = 25˚C, VB = ±15V</td>
<td>2.4</td>
<td>3.6</td>
<td></td>
<td>2.4</td>
<td>4.5</td>
<td></td>
<td>2.4</td>
<td>4.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>TA = 25˚C, VB = ±15V</td>
<td>50</td>
<td>160</td>
<td></td>
<td>25</td>
<td>160</td>
<td></td>
<td>25</td>
<td>160</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td>Amplifier to Amplifier Coupling</td>
<td>TA = 25˚C, f = 1 Hz to 20 kHz (Input Referred)</td>
<td>−120</td>
<td></td>
<td></td>
<td>−120</td>
<td></td>
<td></td>
<td>−120</td>
<td>dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Signal Bandwidth</td>
<td>TA = 25˚C, LM148 Series</td>
<td>1.0</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td>1.0</td>
<td>MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase Margin</td>
<td>TA = 25˚C, LM148 Series (A = 1)</td>
<td>60</td>
<td></td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td>60</td>
<td>degrees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew Rate</td>
<td>TA = 25˚C, LM148 Series (A = 1)</td>
<td>0.5</td>
<td></td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
<td>0.5</td>
<td>V/µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Short Circuit Current</td>
<td>TA = 25˚C</td>
<td>25</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>25</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>RB ≤ 10 kΩ</td>
<td>6.0</td>
<td></td>
<td></td>
<td>7.5</td>
<td></td>
<td></td>
<td>7.5</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Current</td>
<td></td>
<td>75</td>
<td></td>
<td></td>
<td>125</td>
<td></td>
<td></td>
<td>100</td>
<td>nA</td>
<td></td>
<td></td>
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</tbody>
</table>
### Electrical Characteristics (Continued)

(Note 3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM148</th>
<th>LM248</th>
<th>LM348</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td></td>
<td>325</td>
<td>500</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>$V_S = \pm 15V$, $V_{OUT} = \pm 10V$, $R_L &gt; 2\ k\Omega$</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>400</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>$V_S = \pm 15V$, $R_L = 10\ k\Omega$, $R_L = 2\ k\Omega$</td>
<td>±12</td>
<td>±13</td>
<td>±12</td>
<td>±13</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>$V_S = \pm 15V$</td>
<td>±12</td>
<td></td>
<td>±12</td>
<td></td>
</tr>
<tr>
<td>Common-Mode Rejection Ratio</td>
<td>$R_S \leq 10\ k\Omega$</td>
<td>70</td>
<td>90</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>Supply Voltage Rejection</td>
<td>$R_S \leq 10\ k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$</td>
<td>77</td>
<td>96</td>
<td>77</td>
<td>96</td>
</tr>
</tbody>
</table>

**Note 1:** Any of the amplifier outputs can be shorted to ground indefinitely; however, more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

**Note 2:** The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by $T_{JMAX}$, $\theta_{JA}$, and the ambient temperature, $T_A$. The maximum available power dissipation at any temperature is $P_d = (T_{JMAX} - T_A)/\theta_{JA}$ or the 25˚C $P_{DMAX}$, whichever is less.

**Note 3:** These specifications apply for $V_S = \pm 15V$ and over the absolute maximum operating temperature range ($T_L \leq T_A \leq T_H$) unless otherwise noted.

**Note 4:** Refer to RETS 148X for LM148 military specifications.

**Note 5:** Human body model, 1.5 kΩ in series with 100 pF.

### Cross Talk Test Circuit

$V_S = \pm 15V$

---

![Cross Talk Test Circuit Diagram](image)
Typical Performance Characteristics

Supply Current

- Supply Voltage (V) vs. Supply Current (mA)
  - @ 25°C
  - @ -55°C
  - @ +125°C

Input Bias Current

- Temperature (°C) vs. Input Bias Current (mA)
  - -20 V
  - -15 V
  - -10 V
  - -5 V
  - 0 V
  - +5 V

Voltage Swing

- Supply Voltage (V) vs. Peak to Peak Output Swing (V)
  - TA = 25°C

Positive Current Limit

- Output Source Current (mA) vs. Positive Output Voltage Swing (V)
  - VS = -15
  - +25°C
  - -55°C

Negative Current Limit

- Output Sink Current (mA) vs. Negative Output Voltage Swing (V)
  - VC = -15V
  - +25°C
  - +125°C

Output Impedance

- Frequency (Hz) vs. Output Impedance (Ω)
  - AV = 100
  - AV = 10
  - AV = 1

LM148/LM248/LM348

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Typical Performance Characteristics (Continued)

Common-Mode Rejection Ratio

Open Loop Frequency Response

Bode Plot LM148

Large Signal Pulse Response (LM148)

Small Signal Pulse Response (LM148)

Undistorted Output Voltage Swing
Typical Performance Characteristics (Continued)

Gain Bandwidth

Slew Rate

Inverting Large Signal Pulse Response (LM148)

Input Noise Voltage and Noise Current

Positive Common-Mode Input Voltage Limit

Negative Common-Mode Input Voltage Limit
Application Hints

The LM148 series are quad low power 741 op amps. In the proliferation of quad op amps, these are the first to offer the convenience of familiar, easy to use operating characteristics of the 741 op amp. In those applications where 741 op amps have been employed, the LM148 series op amps can be employed directly with no change in circuit performance. The package pin-outs are such that the inverting input of each amplifier is adjacent to its output. In addition, the amplifier outputs are located in the corners of the package which simplifies PC board layout and minimizes package related capacitive coupling between amplifiers.

The input characteristics of these amplifiers allow differential input voltages which can exceed the supply voltages. In addition, if either of the input voltages is within the operating common-mode range, the phase of the output remains correct. If the negative limit of the operating common-mode range is exceeded at both inputs, the output voltage will be positive. For input voltages which greatly exceed the maximum supply voltages, either differentially or common-mode, resistors should be placed in series with the inputs to limit the current.

Like the LM741, these amplifiers can easily drive a 100 pF capacitive load throughout the entire dynamic output voltage and current range. However, if very large capacitive loads must be driven by a non-inverting unity gain amplifier, a resistor should be placed between the output (and feedback connection) and the capacitance to reduce the phase shift resulting from the capacitive loading.

Typical Applications—LM148

One Decade Low Distortion Sinewave Generator

The output current of each amplifier in the package is limited. Short circuits from an output to either ground or the power supplies will not destroy the unit. However, if multiple output shorts occur simultaneously, the time duration should be short to prevent the unit from being destroyed as a result of excessive power dissipation in the IC chip.

As with most amplifiers, care should be taken lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize “pickup” and maximize the frequency of the feedback pole which capacitance from the input to ground creates.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

\[ f_{\text{MAX}} = 5 \text{ kHz}, \quad \text{THD} \leq 0.03\% \]

\[ f = \frac{1}{2 \pi R1C1} \times \sqrt{R2C3} \times \frac{K}{R3} \left( \frac{1}{R4} + \frac{1}{R6} + \frac{1}{R5} \right) \]

\[ f_{\text{DS}} = \frac{R_{ON}}{1 - \frac{V_{GS}}{V_{TH}}} \]

A simpler version with some distortion degradation at high frequencies can be made by using A1 as a simple inverting amplifier, and by putting back to back zeners in the feedback loop of A3.

\[ R1 = 100k \text{ pot.}, \quad C1 = 0.0047 \mu F, \quad C2 = 0.01 \mu F, \quad C3 = 0.1 \mu F, \quad R2 = R6 = R7 = 1M, \]

\[ R3 = 5.1k, \quad R4 = 12\Omega, \quad R5 = 240\Omega, \quad Q = \text{NS5102}, \quad D1 = \text{1N914}, \quad D2 = 3.6V \text{ avalanche diode (ex. LM103), } V_S = \pm 15V \]
Typical Applications—LM148 (Continued)

Low Cost Instrumentation Amplifier

\[ V_{OUT} = 2 \left( \frac{2R}{R_1} + 1 \right), \quad V_S - 3V \leq V_{IN,CM} \leq V_S + 3V. \]

VS = ±15V
R = R2, trim R2 to boost CMRR

Low Drift Peak Detector with Bias Current Compensation

Adjust R for minimum drift
D3 low leakage diode
D1 added to improve speed
VS = ±15V
Typical Applications—LM148 (Continued)

Universal State-Variable Filter

Tune Q through R0,
For predictable results: \( f_0 \leq 4 \times 10^4 \)
Use Band Pass output to tune for Q

\[
\begin{align*}
V_{in} &= \frac{N_{hp}(s)}{D(s)} \quad D(s) = s^2 + \frac{S_{dc}}{Q} + \omega_0^2 \\
N_{hp}(s) &= s^2 H_{OHP}, \quad N_{BP}(s) = -\frac{s\omega_0 H_{OBP}}{Q} \quad N_{LP} = \omega_0^2 H_{OLP}.
\end{align*}
\]

\[
\begin{align*}
\omega_0 &= \frac{1}{2\pi} \sqrt{R_5} \sqrt{\frac{1}{1 + R_1^2}} \quad Q &= \frac{1 + (R_4 R_3 + R_4 R_0)}{1 + (R_6 + R_5)} \left( \frac{R_6 \tau_2}{R_5 \tau_2} \right) \\
F_{notch} &= \frac{1}{2\pi} \left( \frac{R_{in}}{R_1 \tau_1 \tau_2} \right)^{1/2} \quad H_{OHP} &= \frac{1 + R_4 R_3 + R_4 R_0}{1 + R_3 R_0 + R_3 R_4} \quad H_{OBP} = \frac{1 + R_3 R_0 + R_3 R_4}{1 + R_4 + R_3 R_4} \\
H_{OLP} &= \frac{1 + R_5 R_6}{1 + R_3 R_0 + R_3 R_4}
\end{align*}
\]
Typical Applications—LM148 (Continued)

A 1 kHz 4 Pole Butterworth

Use general equations, and tune each section separately

\[ Q_{1\text{st SECTION}} = 0.541, \quad Q_{2\text{nd SECTION}} = 1.306 \]

The response should have 0 dB peaking

A 3 Amplifier Bi-Quad Notch Filter

\[ f_{\text{NOTCH}} = \frac{1}{2\pi \sqrt{R6(R3R5R7/C1C2)}} \]

Ex: \( f_{\text{NOTCH}} = 3 \text{ kHz}, \quad Q = 5, \quad R1 = 270k, \quad R2 = R3 = 20k, \quad R4 = 27k, \quad R5 = 20k, \quad R6 = R8 = 10k, \quad R7 = 100k, \quad C1 = C2 = 0.001 \mu F \)

Better noise performance than the state-space approach.
A 4th Order 1 kHz Elliptic Filter (4 Poles, 4 Zeros)

\[ R1C1 = R2C2 = t \]
\[ R'1C'1 = R'2C'2 = t' \]

\[ f_C = 1 \text{ kHz}, \quad f_S = 2 \text{ kHz}, \quad f_p = 0.543, \quad f_z = 2.14, \quad Q = 0.841, \quad \Gamma_p = 0.987, \quad \Gamma_z = 4.92, \quad Q' = 4.403, \text{ normalized to ripple BW} \]

Use the BP outputs to tune \( Q, Q' \), tune the 2 sections separately

\[ R1 = R2 = 92.6k, \quad R3 = R4 = R5 = 100k, \quad R6 = 10k, \quad R0 = 107.8k, \quad R_L = 100k, \quad R'1 = R'2 = 50.9k, \quad R'4 = R'5 = 100k, \quad R'6 = 10k, \quad R'0 = 5.78k, \quad R'_L = 100k, \quad R'14 = 248.12k, \quad R'1 = 100k. \text{ All capacitors are 0.001 \( \mu \)F.} \]
Typical Simulation
LM148/LM741 Macromodel for Computer Simulation


Note 6: $\omega_1 = \frac{1}{\tau_{IS} \omega_1} = 8 \times 10^7$

Note 7: $\omega_2 = \frac{1}{\tau_{C2} \omega_2} = 6 \times 10^6$ for LM148

LM148/LM248/LM348

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Connection Diagram

See NS Package Number J14A, M14A or N14A
LM148J is available per JM38510/11001
Physical Dimensions  inches (millimeters)
unless otherwise noted

Ceramic Dual-In-Line Package (J)
NS Package Number J14A

S.O. Package (M)
Order Number LM348M or LM348MX
NS Package Number M14A
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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.

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