Single Supply Quad Operational Amplifiers


The LM324 series are low-cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features
- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC–Q100 Qualified and PPAP Capable
- These Devices are Pb–Free, Halogen Free/BFR Free and are RoHS Compliant

PIN CONNECTIONS

ORDERING INFORMATION
See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION
See general marking information in the device marking section on page 11 of this data sheet.
MAXIMUM RATINGS (T<sub>A</sub> = +25°C, unless otherwise noted.)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltages</td>
<td>V&lt;sub&gt;CC&lt;/sub&gt;, V&lt;sub&gt;EE&lt;/sub&gt;</td>
<td>32, ±16</td>
<td>V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>Input Differential Voltage Range (Note 1)</td>
<td>V&lt;sub&gt;IDR&lt;/sub&gt;</td>
<td>±32</td>
<td>V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>Input Common Mode Voltage Range</td>
<td>V&lt;sub&gt;ICR&lt;/sub&gt;</td>
<td>−0.3 to 32</td>
<td>V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output Short Circuit Duration</td>
<td>I&lt;sub&gt;SC&lt;/sub&gt;</td>
<td>Continuous</td>
<td></td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>T&lt;sub&gt;J&lt;/sub&gt;</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Resistance, Junction–to–Air (Note 2)</td>
<td>R&lt;sub&gt;thJA&lt;/sub&gt;</td>
<td>118, 156, 190</td>
<td>°C/W</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>T&lt;sub&gt;stg&lt;/sub&gt;</td>
<td>−65 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Ambient Temperature Range</td>
<td>T&lt;sub&gt;A&lt;/sub&gt;</td>
<td>−25 to +85, 0 to +70, −40 to +105, −40 to +125</td>
<td>°C</td>
</tr>
</tbody>
</table>

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

2. All R<sub>thJA</sub> measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.
3. NCV2902 is qualified for automotive use.

ESD RATINGS

<table>
<thead>
<tr>
<th>Rating</th>
<th>HBM</th>
<th>MM</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD Protection at any Pin (Human Body Model – HBM, Machine Model – MM)</td>
<td>2000</td>
<td>200</td>
<td>V</td>
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<tr>
<td>NCV2902 (Note 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM324E, LM2902E</td>
<td>2000</td>
<td>200</td>
<td>V</td>
</tr>
<tr>
<td>LM324DG/DR2G, LM2902DG/DR2G</td>
<td>200</td>
<td>100</td>
<td>V</td>
</tr>
<tr>
<td>All Other Devices</td>
<td>2000</td>
<td>200</td>
<td>V</td>
</tr>
</tbody>
</table>
### Electrical Characteristics

(V<sub>CC</sub> = 5.0 V, V<sub>EE</sub> = GND, T<sub>A</sub> = 25°C, unless otherwise noted.)

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>V&lt;sub&gt;IO&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>V&lt;sub&gt;CC&lt;/sub&gt; = 5.0 V to 30 V</td>
<td></td>
<td>-2.0</td>
<td>5.0</td>
<td>-2.0</td>
<td>3.0</td>
<td>-2.0</td>
<td>7.0</td>
<td></td>
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<tr>
<td>V&lt;sub&gt;ICR&lt;/sub&gt; = 0 V to V&lt;sub&gt;CC&lt;/sub&gt;</td>
<td></td>
<td>-7.0</td>
<td></td>
<td>-5.0</td>
<td></td>
<td>-9.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;D&lt;/sub&gt; = 0 V, R&lt;sub&gt;S&lt;/sub&gt; = 0 Ω</td>
<td></td>
<td>-7.0</td>
<td></td>
<td>-5.0</td>
<td></td>
<td>-9.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; (Note 4)</td>
<td></td>
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<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;low&lt;/sub&gt; (Note 4)</td>
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<tr>
<td>Average Temperature Coefficient of Input Offset Voltage</td>
<td>ΔV&lt;sub&gt;IO&lt;/sub&gt;/ΔT</td>
<td>-7.0</td>
<td>-7.0</td>
<td>30</td>
<td>-7.0</td>
<td>-7.0</td>
<td>-7.0</td>
<td>μV/°C</td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Notes 4 and 6)</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>I&lt;sub&gt;IO&lt;/sub&gt;</td>
<td>-3.0</td>
<td>30</td>
<td>-5.0</td>
<td>30</td>
<td>-5.0</td>
<td>50</td>
<td>nA</td>
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<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Note 4)</td>
<td></td>
<td>-75</td>
<td>100</td>
<td>-100</td>
<td>75</td>
<td>-150</td>
<td></td>
<td></td>
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<tr>
<td>Average Temperature Coefficient of Input Offset Current</td>
<td>ΔI&lt;sub&gt;IO&lt;/sub&gt;/ΔT</td>
<td>10</td>
<td>10</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>pA/°C</td>
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<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Notes 4 and 6)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>I&lt;sub&gt;IB&lt;/sub&gt;</td>
<td>-90</td>
<td>-150</td>
<td>-45</td>
<td>-100</td>
<td>-90</td>
<td>-250</td>
<td>nA</td>
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<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Note 4)</td>
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<td>-75</td>
<td>-300</td>
<td>-200</td>
<td>-500</td>
<td>-500</td>
<td></td>
<td></td>
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<tr>
<td>Average Common Mode Voltage Range</td>
<td>V&lt;sub&gt;ICR&lt;/sub&gt;</td>
<td>28.3</td>
<td>0</td>
<td>28.3</td>
<td>0</td>
<td>28.3</td>
<td>0</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;CC&lt;/sub&gt; = 30 V</td>
<td></td>
<td>28.3</td>
<td>0</td>
<td>28.3</td>
<td>0</td>
<td>28.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = +25°C</td>
<td></td>
<td>28</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Note 4)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential Input Voltage Range</td>
<td>V&lt;sub&gt;IDR&lt;/sub&gt;</td>
<td>-28.3</td>
<td>-28.3</td>
<td>-28.3</td>
<td>0</td>
<td>28.3</td>
<td>0</td>
<td></td>
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<tr>
<td>Large Signal Open Loop Voltage Gain</td>
<td>A&lt;sub&gt;VOL&lt;/sub&gt;</td>
<td>50</td>
<td>100</td>
<td>-</td>
<td>25</td>
<td>100</td>
<td>-</td>
<td>V/mV</td>
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<tr>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 2.0 kΩ, V&lt;sub&gt;CC&lt;/sub&gt; = 15 V, for Large V&lt;sub&gt;0&lt;/sub&gt; Swing</td>
<td></td>
<td>25</td>
<td>-</td>
<td>15</td>
<td>-</td>
<td>15</td>
<td>-</td>
<td></td>
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<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = T&lt;sub&gt;high&lt;/sub&gt; to T&lt;sub&gt;low&lt;/sub&gt; (Note 4)</td>
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<td>Channel Separation</td>
<td>CS</td>
<td>-120</td>
<td>-</td>
<td>-120</td>
<td>-</td>
<td>-120</td>
<td>-</td>
<td>dB</td>
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<td>10 kHz ≤ f ≤ 20 kHz, Input Referenced</td>
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<tr>
<td>Common Mode Rejection</td>
<td>CMR</td>
<td>70</td>
<td>85</td>
<td>-</td>
<td>65</td>
<td>70</td>
<td>-</td>
<td>dB</td>
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<td>R&lt;sub&gt;S&lt;/sub&gt; ≤ 10 kΩ</td>
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<tr>
<td>Power Supply Rejection</td>
<td>PSR</td>
<td>65</td>
<td>100</td>
<td>-</td>
<td>65</td>
<td>100</td>
<td>-</td>
<td>dB</td>
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</tbody>
</table>

4. LM224: T<sub>low</sub> = -25°C, T<sub>high</sub> = +85°C
LM324/LM324A/LM324E: T<sub>low</sub> = 0°C, T<sub>high</sub> = +70°C
LM2902/LM2902E: T<sub>low</sub> = -40°C, T<sub>high</sub> = +105°C
LM2902V & NCV2902: T<sub>low</sub> = -40°C, T<sub>high</sub> = +125°C
NCV2902 is qualified for automotive use.

5. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V<sub>CC</sub> - 1.7 V, but either or both inputs can go to +32 V without damage, independent of the magnitude of V<sub>CC</sub>.

6. Guaranteed by design.
### ELECTRICAL CHARACTERISTICS

(VCC = 5.0 V, VEE = GND, TA = 25°C, unless otherwise noted.)

<table>
<thead>
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<tbody>
<tr>
<td>Output Voltage - High Limit</td>
<td>VOH</td>
<td>Min</td>
<td>Typ</td>
<td>Min</td>
<td>Typ</td>
<td>Min</td>
<td>Typ</td>
<td>Min</td>
<td>3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 -</td>
</tr>
<tr>
<td>VCC = 5.0 V, RL = 2.0 kΩ, TA = 25°C</td>
<td></td>
<td>3.3</td>
<td>3.5</td>
<td>3.3</td>
<td>3.5</td>
<td>3.3</td>
<td>3.5</td>
<td>3.3</td>
<td>3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 - 3.3 3.5 -</td>
</tr>
<tr>
<td>VCC = 30 V, RL = 2.0 kΩ, (TA = Tlow to Thigh) (Note 7)</td>
<td></td>
<td>26</td>
<td>-</td>
<td>26</td>
<td>-</td>
<td>26</td>
<td>-</td>
<td>26</td>
<td>26 - 26 - 26 - 26 - 26 - 26 - 26 - 26 -</td>
</tr>
<tr>
<td>Output Voltage - Low Limit, VCC = 5.0 V, RL = 10 kΩ, (TA = Thigh to Tlow) (Note 7)</td>
<td>VOL</td>
<td>-</td>
<td>5.0</td>
<td>20</td>
<td>-</td>
<td>5.0</td>
<td>20</td>
<td>-</td>
<td>100 - 5.0 500 mV</td>
</tr>
<tr>
<td>Output Source Current, (VID = +1.0 V, VCC = 15 V)</td>
<td>IO+</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>20 40 - 20 40 - 20 40 - 20 40 - 20 40 - 20 40 - 20 40 - 20 40 -</td>
</tr>
<tr>
<td>TA = 25°C</td>
<td></td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 -</td>
</tr>
<tr>
<td>Output Sink Current, (VID = -1.0 V, VO = 200 mV, TA = 25°C)</td>
<td>IO-</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 - 10 20 -</td>
</tr>
<tr>
<td>TA = Thigh to Tlow (Note 7)</td>
<td></td>
<td>5.0</td>
<td>8.0</td>
<td>5.0</td>
<td>8.0</td>
<td>5.0</td>
<td>8.0</td>
<td>5.0</td>
<td>5.0 8.0 - 5.0 8.0 - 5.0 8.0 - 5.0 8.0 - 5.0 8.0 - 5.0 8.0 - 5.0 8.0 - 5.0 8.0 -</td>
</tr>
<tr>
<td>Power Supply Current, (TA = Thigh to Tlow) (Note 7)</td>
<td>ICC</td>
<td>-</td>
<td>3.0</td>
<td>-</td>
<td>1.4</td>
<td>-</td>
<td>3.0</td>
<td>-</td>
<td>- - 3.0 - - 3.0 - - 3.0 - - 3.0 - - 3.0 - - 3.0 - - 3.0 - - 3.0 - - 3.0 -</td>
</tr>
<tr>
<td>VCC = 30 V, RL = ∞</td>
<td></td>
<td>-</td>
<td>3.0</td>
<td>-</td>
<td>1.2</td>
<td>-</td>
<td>1.2</td>
<td>-</td>
<td>- - 1.2 - - 1.2 - - 1.2 - - 1.2 - - 1.2 - - 1.2 - - 1.2 - - 1.2 - - 1.2 -</td>
</tr>
</tbody>
</table>

7. LM224: Tlow = −25°C, Thigh = +85°C
   LM324/LM324A/LM324E: Tlow = 0°C, Thigh = +70°C
   LM2902/LM2902E: Tlow = −40°C, Thigh = +105°C
   LM2902V & NCV2902: Tlow = −40°C, Thigh = +125°C
   NCV2902 is qualified for automotive use.

8. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is VCC −1.7 V, but either or both inputs can go to +32 V without damage, independent of the magnitude of VCC.

Product parametric performance is indicated in the Electrical Characteristics if operated under different conditions.
Figure 1. Representative Circuit Diagram
(One-Fourth of Circuit Shown)
The LM324 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single–ended converter. The second stage consists of a standard current source load amplifier stage.

Each amplifier is biased from an internal voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.
Figure 11. Voltage Reference

\[ V_O = 2.5V \left(1 + \frac{R_1}{R_2}\right) \]

Figure 12. Wien Bridge Oscillator

\[ f_0 = \frac{1}{2\pi R C} \]

For: \( f_0 = 1.0 \text{ kHz} \)
- \( R = 16 \text{ k\Omega} \)
- \( C = 0.01 \text{ \mu F} \)

Figure 13. High Impedance Differential Amplifier

\[ e_o = C (1 + a + b) (e_2 - e_1) \]

Figure 14. Comparator with Hysteresis

\[ V_{inL} = \frac{R_1}{R_1 + R_2} (V_{OL} - V_{ref}) + V_{ref} \]
\[ V_{inH} = \frac{R_1}{R_1 + R_2} (V_{OH} - V_{ref}) + V_{ref} \]
\[ H = \frac{R_1}{R_1 + R_2} (V_{OH} - V_{OL}) \]

Figure 15. Bi–Quad Filter

\[ f_0 = \frac{1}{2\pi R C} \]

For: \( f_0 = 1.0 \text{ kHz} \)
- \( Q = 10 \)
- \( T_{BP} = 1 \)
- \( T_N = 1 \)

Where:
- \( T_{BP} = \text{Center Frequency Gain} \)
- \( T_N = \text{Passband Notch Gain} \)

For: \( f_0 = 1.0 \text{ kHz} \)
- \( R = 160 \text{ k\Omega} \)
- \( C = 0.001 \text{ \mu F} \)
- \( R_1 = 1.6 \text{ M\Omega} \)
- \( R_2 = 1.6 \text{ M\Omega} \)
- \( R_3 = 1.6 \text{ M\Omega} \)
For less than 10% error from operational amplifier, if source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

Given:
- $f_o = \text{center frequency}$
- $A(f_o) = \text{gain at center frequency}$

Choose value $f_o$, $C$

Then:
- $R3 = \frac{Q}{\pi f_o C}$
- $R1 = \frac{R3}{2 A(f_o)}$
- $R2 = \frac{R1 R3}{4Q^2 R1 - R3}$

For less than 10% error from operational amplifier, $Q f_o / BW < 0.1$ where $f_o$ and BW are expressed in Hz.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.
<table>
<thead>
<tr>
<th>Device</th>
<th>Operating Temperature Range</th>
<th>Package</th>
<th>Shipping†</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM224DR2G</td>
<td>−25°C to +85°C</td>
<td>SOIC−14 (Pb−Free)</td>
<td>2500/Tape &amp; Reel</td>
</tr>
<tr>
<td>LM224DTBR2G</td>
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<td>TSSOP−14 (Pb−Free)</td>
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†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

*NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable.
MARKING DIAGRAMS

SOIC–14
D SUFFIX
CASE 751A

TSSOP–14
DTB SUFFIX
CASE 948G

X = 2 or 3
A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week
G or * = Pb−Free Package
(Note: Microdot may be in either location)
*This marking diagram also applies to NCV2902.
MECHANICAL CASE OUTLINE
PACKAGE DIMENSIONS

PDIP–14
CASE 646–06
ISSUE S

DATE 22 APR 2015

NOTES:
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACK-
   AGE SEATED IN JEDEC SEATING PLANE GAUGE GS–3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH
   OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE
   NOT TO EXCEED 0.10 INCH.
5. DIMENSION C IS MEASURED AT A POINT 0.015 BELOW DATUM
   PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR
   TO DATUM C.
6. DIMENSION b2 IS MEASURED AT THE LEAD TIPS WITH THE
   LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF
   THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE
   CORNERS).

STYLES ON PAGE 2

**NOTES:**

2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACK-
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7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF
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6. DIMENSION b2 IS MEASURED AT THE LEAD TIPS WITH THE
   LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF
   THE LEADS, WHERE THE LEADS EXIT THE BODY.
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   LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF
   THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE
   CORNERS).
### STYLE 1:
- PIN 1: COLLECTOR
- PIN 2: BASE
- PIN 3: EMITTER
- PIN 4: NO CONNECTION
- PIN 5: EMITTER
- PIN 6: BASE
- PIN 7: COLLECTOR
- PIN 8: COLLECTOR
- PIN 9: BASE
- PIN 10: EMITTER
- PIN 11: NO CONNECTION
- PIN 12: EMITTER
- PIN 13: BASE
- PIN 14: COLLECTOR

### STYLE 2:
- PIN 1: COMMON CATHODE
- PIN 2: ANODE/CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: NO CONNECTION
- PIN 5: ANODE/CATHODE
- PIN 6: NO CONNECTION
- PIN 7: ANODE/CATHODE
- PIN 8: ANODE/CATHODE
- PIN 9: ANODE/CATHODE
- PIN 10: NO CONNECTION
- PIN 11: ANODE/CATHODE
- PIN 12: ANODE/CATHODE
- PIN 13: ANODE/CATHODE
- PIN 14: COMMON ANODE

### STYLE 3:
- PIN 1: NO CONNECTION
- PIN 2: ANODE
- PIN 3: ANODE
- PIN 4: NO CONNECTION
- PIN 5: ANODE
- PIN 6: NO CONNECTION
- PIN 7: ANODE
- PIN 8: ANODE
- PIN 9: ANODE
- PIN 10: NO CONNECTION
- PIN 11: ANODE
- PIN 12: ANODE
- PIN 13: NO CONNECTION
- PIN 14: COMMON CATHODE

### STYLE 4:
- PIN 1: DRAIN
- PIN 2: SOURCE
- PIN 3: GATE
- PIN 4: NO CONNECTION
- PIN 5: GATE
- PIN 6: SOURCE
- PIN 7: DRAIN
- PIN 8: DRAIN
- PIN 9: SOURCE
- PIN 10: GATE
- PIN 11: NO CONNECTION
- PIN 12: GATE
- PIN 13: SOURCE
- PIN 14: DRAIN

### STYLE 5:
- PIN 1: GATE
- PIN 2: DRAIN
- PIN 3: SOURCE
- PIN 4: NO CONNECTION
- PIN 5: SOURCE
- PIN 6: DRAIN
- PIN 7: GATE
- PIN 8: GATE
- PIN 9: DRAIN
- PIN 10: SOURCE
- PIN 11: NO CONNECTION
- PIN 12: SOURCE
- PIN 13: DRAIN
- PIN 14: GATE

### STYLE 6:
- PIN 1: COMMON CATHODE
- PIN 2: ANODE/CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: NO CONNECTION
- PIN 5: ANODE/CATHODE
- PIN 6: ANODE/CATHODE
- PIN 7: COMMON ANODE
- PIN 8: COMMON ANODE
- PIN 9: COMMON ANODE
- PIN 10: COMMON ANODE
- PIN 11: COMMON ANODE
- PIN 12: COMMON ANODE
- PIN 13: COMMON ANODE
- PIN 14: COMMON ANODE

### STYLE 7:
- PIN 1: NO CONNECTION
- PIN 2: CATHODE
- PIN 3: CATHODE
- PIN 4: NO CONNECTION
- PIN 5: CATHODE
- PIN 6: NO CONNECTION
- PIN 7: CATHODE
- PIN 8: CATHODE
- PIN 9: CATHODE
- PIN 10: NO CONNECTION
- PIN 11: CATHODE
- PIN 12: CATHODE
- PIN 13: NO CONNECTION
- PIN 14: COMMON ANODE

### STYLE 8:
- PIN 1: COMMON CATHODE
- PIN 2: COMMON CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: ANODE/CATHODE
- PIN 5: ANODE/CATHODE
- PIN 6: ANODE/CATHODE
- PIN 7: ANODE/CATHODE
- PIN 8: ANODE/CATHODE
- PIN 9: ANODE/CATHODE
- PIN 10: ANODE/CATHODE
- PIN 11: ANODE/CATHODE
- PIN 12: ANODE/CATHODE
- PIN 13: ANODE/CATHODE
- PIN 14: ANODE/CATHODE

### STYLE 9:
- PIN 1: COMMON CATHODE
- PIN 2: ANODE/CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: NO CONNECTION
- PIN 5: ANODE/CATHODE
- PIN 6: ANODE/CATHODE
- PIN 7: COMMON ANODE
- PIN 8: COMMON ANODE
- PIN 9: ANODE/CATHODE
- PIN 10: ANODE/CATHODE
- PIN 11: NO CONNECTION
- PIN 12: ANODE/CATHODE
- PIN 13: ANODE/CATHODE
- PIN 14: COMMON ANODE

### STYLE 10:
- PIN 1: COMMON CATHODE
- PIN 2: COMMON CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: ANODE/CATHODE
- PIN 5: ANODE/CATHODE
- PIN 6: ANODE/CATHODE
- PIN 7: COMMON ANODE
- PIN 8: COMMON ANODE
- PIN 9: ANODE/CATHODE
- PIN 10: ANODE/CATHODE
- PIN 11: NO CONNECTION
- PIN 12: ANODE/CATHODE
- PIN 13: ANODE/CATHODE
- PIN 14: COMMON ANODE

### STYLE 11:
- PIN 1: CATHODE
- PIN 2: CATHODE
- PIN 3: CATHODE
- PIN 4: CATHODE
- PIN 5: CATHODE
- PIN 6: CATHODE
- PIN 7: CATHODE
- PIN 8: ANODE
- PIN 9: ANODE
- PIN 10: ANODE
- PIN 11: ANODE
- PIN 12: ANODE
- PIN 13: ANODE
- PIN 14: ANODE

### STYLE 12:
- PIN 1: COMMON CATHODE
- PIN 2: COMMON CATHODE
- PIN 3: ANODE/CATHODE
- PIN 4: ANODE/CATHODE
- PIN 5: ANODE/CATHODE
- PIN 6: ANODE/CATHODE
- PIN 7: COMMON ANODE
- PIN 8: COMMON ANODE
- PIN 9: ANODE/CATHODE
- PIN 10: ANODE/CATHODE
- PIN 11: NO CONNECTION
- PIN 12: ANODE/CATHODE
- PIN 13: ANODE/CATHODE
- PIN 14: ANODE/CATHODE
MECHANICAL CASE OUTLINE
PACKAGE DIMENSIONS

SOIC-14 NB
CASE 751A-03
ISSUE L
DATE 03 FEB 2016

NOTES:
1. DIMENSIONING AND TOLERANCING PER
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b DOES NOT INCLUDE DAMBAR
   PROTRUSION. ALLOWABLE PROTRUSION
   SHALL BE 0.13 TOTAL IN EXCESS OF AT
   MAXIMUM MATERIAL CONDITION.
4. DIMENSIONS D AND E DO NOT INCLUDE
   MOLD PROTRUSIONS.
5. MAXIMUM MOLD PROTRUSION 0.15 PER
   SIDE.

SOLDERING FOOTPRINT*

*For additional information on our Pb–Free strategy and soldering
details, please download the ON Semiconductor Soldering and
Mounting Techniques Reference Manual, SOLDERRM/D.

GENERAL MARKING DIAGRAM*

*This information is generic. Please refer to
device data sheet for actual part marking.
Pb–Free indicator, “G” or microdot “*”,
may or may not be present.

DIMENSIONS: MILLIMETERS

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**Description:** SOIC–14 NB

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MECHANICAL CASE OUTLINE
PACKAGE DIMENSIONS

TSSOP–14 WB
CASE 948G
ISSUE C
DATE 17 FEB 2016

NOTES:
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. DIMENSION K DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE K DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
7. DIMENSION A AND B ARE TO BE DETERMINED AT DATUM PLANE − W.

SOLDERING FOOTPRINT

DIMENSIONS: MILLIMETERS

GOLDIC MARKING DIAGRAM*

A = Assembly Location
L = Wafer Lot
Y = Year
W = Work Week
* = Pb−Free Package

(Note: Microdot may be in either location)

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “•”, may or may not be present.