LM393, LM293, LM2903, LM2903V, NCV2903

Low Offset Voltage Dual Comparators

The LM393 series are dual independent precision voltage comparators capable of single or split supply operation. These devices are designed to permit a common mode range—to—ground level with single supply operation. Input offset voltage specifications as low as 2.0 mV make this device an excellent selection for many applications in consumer, automotive, and industrial electronics.

Features

• Wide Single−Supply Range: 2.0 Vdc to 36 Vdc
• Split−Supply Range: ±1.0 Vdc to ±18 Vdc
• Very Low Current Drain Independent of Supply Voltage: 0.4 mA
• Low Input Bias Current: 25 nA
• Low Input Offset Current: 5.0 nA
• Low Input Offset Voltage: 5.0 mV (max) LM293/393
• Input Common Mode Range to Ground Level
• Differential Input Voltage Range Equal to Power Supply Voltage
• Output Voltage Compatible with DTL, ECL, TTL, MOS, and CMOS Logic Levels
• ESD Clamps on the Inputs Increase the Ruggedness of the Device without Affecting Performance
• NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes
• Pb−Free Packages are Available

Figure 1. Representative Schematic Diagram
(Diagram shown is for 1 comparator)
## MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>Rating</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>$V_{CC}$</td>
<td>+36 or ±18</td>
<td>Vdc</td>
</tr>
<tr>
<td>Input Differential Voltage Range</td>
<td>$V_{IDR}$</td>
<td>36</td>
<td>Vdc</td>
</tr>
<tr>
<td>Input Common Mode Voltage Range</td>
<td>$V_{ICR}$</td>
<td>0.3 to +36</td>
<td>Vdc</td>
</tr>
<tr>
<td>Output Short Circuit–to–Ground</td>
<td>$I_{SC}$</td>
<td>Continuous</td>
<td>mA</td>
</tr>
<tr>
<td>Output Sink Current (Note 1)</td>
<td>$I_{Sink}$</td>
<td>20</td>
<td>mA</td>
</tr>
<tr>
<td>Power Dissipation @ $T_A = 25^\circ$C</td>
<td>$P_D$</td>
<td>570</td>
<td>mW</td>
</tr>
<tr>
<td>Derate above $25^\circ$C</td>
<td>$1/R_{JA}$</td>
<td>5.7</td>
<td>mW/°C</td>
</tr>
<tr>
<td>Operating Ambient Temperature Range</td>
<td>$T_A$</td>
<td>−25 to +85&lt;br&gt;0 to +70&lt;br&gt;−40 to +105&lt;br&gt;−40 to +125</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum Operating Junction Temperature</td>
<td>$T_{J(max)}$</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>LM293, LM293, LM2903, LM2903V, NCV2903 (Note 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$T_{stg}$</td>
<td>−65 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>ESD Protection at any Pin</td>
<td>$V_{esd}$</td>
<td>2000&lt;br&gt;200</td>
<td>V</td>
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</tbody>
</table>

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

1. The maximum output current may be as high as 20 mA, independent of the magnitude of $V_{CC}$, output short circuits to $V_{CC}$ can cause excessive heating and eventual destruction.
2. NCV2903 is qualified for automotive use.
## ELECTRICAL CHARACTERISTICS (V<sub>CC</sub> = 5.0 Vdc, T<sub>low</sub> ≤ T<sub>A</sub> ≤ T<sub>high</sub>, unless otherwise noted.)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>LM293, LM393</th>
<th>LM2903, LM2903V, NCV2903</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Input Offset Voltage (Note 4)</td>
<td>V&lt;sub&gt;IO&lt;/sub&gt;</td>
<td>Min ±1.0</td>
<td>Min ±2.0</td>
<td>mV</td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ ±5.0</td>
<td>Typ ±5.0</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
<td></td>
<td>Max ±2.0</td>
<td>Max ±7.0</td>
<td></td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>I&lt;sub&gt;IO&lt;/sub&gt;</td>
<td>Min ±5.0</td>
<td>Min ±5.0</td>
<td>nA</td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ ±50</td>
<td>Typ ±50</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
<td></td>
<td>Max ±50</td>
<td>Max ±200</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current (Note 5)</td>
<td>I&lt;sub&gt;IB&lt;/sub&gt;</td>
<td>Min 25</td>
<td>Min 25</td>
<td>nA</td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 250</td>
<td>Typ 250</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
<td></td>
<td>Max 400</td>
<td>Max 500</td>
<td></td>
</tr>
<tr>
<td>Input Common Mode Voltage Range (Note 5)</td>
<td>V&lt;sub&gt;ICR&lt;/sub&gt;</td>
<td>0 – V&lt;sub&gt;CC&lt;/sub&gt; -1.5</td>
<td>0 – V&lt;sub&gt;CC&lt;/sub&gt; -2.0</td>
<td>V</td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>V&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
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<td></td>
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<tr>
<td>Voltage Gain</td>
<td>A&lt;sub&gt;VOL&lt;/sub&gt;</td>
<td>50</td>
<td>25</td>
<td>V/mV</td>
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<tr>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 15 kΩ, V&lt;sub&gt;CC&lt;/sub&gt; = 15 Vdc, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 200</td>
<td>Max 200</td>
<td></td>
</tr>
<tr>
<td>Large Signal Response Time</td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>V&lt;sub&gt;in&lt;/sub&gt; = TTL Logic Swing, V&lt;sub&gt;ref&lt;/sub&gt; = 1.4 Vdc</td>
<td></td>
<td>Min 300</td>
<td>Max 300</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;RL&lt;/sub&gt; = 5.0 Vdc, R&lt;sub&gt;L&lt;/sub&gt; = 5.1 kΩ, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response Time (Note 7)</td>
<td>t&lt;sub&gt;TLH&lt;/sub&gt;</td>
<td>1.3</td>
<td>1.5</td>
<td>µs</td>
</tr>
<tr>
<td>V&lt;sub&gt;RL&lt;/sub&gt; = 5.0 Vdc, R&lt;sub&gt;L&lt;/sub&gt; = 5.1 kΩ, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Differential Voltage (Note 8)</td>
<td>V&lt;sub&gt;ID&lt;/sub&gt;</td>
<td>Min V&lt;sub&gt;in&lt;/sub&gt;</td>
<td>Min V&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>V</td>
</tr>
<tr>
<td>All V&lt;sub&gt;in&lt;/sub&gt; ≥ GND or V&lt;sub&gt;–&lt;/sub&gt; Supply (if used)</td>
<td></td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Sink Current</td>
<td>I&lt;sub&gt;Sink&lt;/sub&gt;</td>
<td>6.0</td>
<td>6.0</td>
<td>mA</td>
</tr>
<tr>
<td>V&lt;sub&gt;in&lt;/sub&gt; ≥ 1.0 Vdc, V&lt;sub&gt;in&lt;/sub&gt; = 0 Vdc, V&lt;sub&gt;O&lt;/sub&gt; ≤ 1.5 Vdc, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 16</td>
<td>Typ 16</td>
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<tr>
<td>Output Saturation Voltage</td>
<td>V&lt;sub&gt;OL&lt;/sub&gt;</td>
<td>Min 150</td>
<td>Min 700</td>
<td>mV</td>
</tr>
<tr>
<td>V&lt;sub&gt;in&lt;/sub&gt; ≥ 1.0 Vdc, V&lt;sub&gt;in&lt;/sub&gt; = 0, I&lt;sub&gt;Sink&lt;/sub&gt; ≤ 4.0 mA, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 400</td>
<td>Typ 700</td>
<td></td>
</tr>
<tr>
<td>Output Leakage Current</td>
<td>I&lt;sub&gt;OL&lt;/sub&gt;</td>
<td>Min 0.1</td>
<td>Min 0.1</td>
<td>nA</td>
</tr>
<tr>
<td>V&lt;sub&gt;in&lt;/sub&gt; = 0 V, V&lt;sub&gt;in&lt;/sub&gt; ≥ 1.0 Vdc, V&lt;sub&gt;OL&lt;/sub&gt; = 5.0 Vdc, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 1000</td>
<td>Typ 1000</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;in&lt;/sub&gt; = 0 V, V&lt;sub&gt;in&lt;/sub&gt; ≥ 1.0 Vdc, V&lt;sub&gt;OL&lt;/sub&gt; = 30 Vdc, T&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
<td></td>
<td>V&lt;sub&gt;low&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;high&lt;/sub&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Current</td>
<td>I&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>Min 0.4</td>
<td>Min 0.4</td>
<td>mA</td>
</tr>
<tr>
<td>R&lt;sub&gt;L&lt;/sub&gt; = = Both Comparators, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>Typ 1.0</td>
<td>Typ 1.0</td>
<td></td>
</tr>
<tr>
<td>R&lt;sub&gt;L&lt;/sub&gt; = = Both Comparators, V&lt;sub&gt;CC&lt;/sub&gt; = 30 V</td>
<td></td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LM293 T<sub>low</sub> = −25°C, T<sub>high</sub> = +85°C
LM393 T<sub>low</sub> = 0°C, T<sub>high</sub> = +70°C
LM2903 T<sub>low</sub> = −40°C, T<sub>high</sub> = +105°C
LM2903V & NCV2903 T<sub>low</sub> = −40°C, T<sub>high</sub> = +125°C
NCV2903 is qualified for automotive use.

3. The maximum output current may be as high as 20 mA, independent of the magnitude of V<sub>CC</sub>, output short circuits to V<sub>CC</sub> can cause excessive heating and eventual destruction.
4. At output switch point, V<sub>O</sub> = 1.4 Vdc, R<sub>S</sub> = 0 Ω with V<sub>CC</sub> from 5.0 Vdc to 30 Vdc, and over the full input common mode range (0 V to V<sub>CC</sub> = −1.5 V).
5. Due to the PNP transistor inputs, bias current will flow out of the inputs. This current is essentially constant, independent of the output state, therefore, no loading changes will exist on the input lines.
6. Input common mode of either input should not be permitted to go more than 0.3 V negative of ground or minus supply. The upper limit of common mode range is V<sub>CC</sub> = −1.5 V.
7. Response time is specified with a 100 mV step and 5.0 mV of overdrive. With larger magnitudes of overdrive faster response times are obtainable.
8. The comparator will exhibit proper output state if one of the inputs becomes greater than V<sub>CC</sub>, the other input must remain within the common mode range. The low input state must not be less than −0.3 V of ground or minus supply.
Figure 2. Input Bias Current versus Power Supply Voltage

Figure 3. Input Bias Current versus Power Supply Voltage

Figure 4. Output Saturation Voltage versus Output Sink Current

Figure 5. Output Saturation Voltage versus Output Sink Current

Figure 6. Power Supply Current versus Power Supply Voltage

Figure 7. Power Supply Current versus Power Supply Voltage
These dual comparators feature high gain, wide bandwidth characteristics. This gives the device oscillation tendencies if the outputs are capacitively coupled to the inputs via stray capacitance. This oscillation manifests itself during output transitions (V_{OL} to V_{OH}). To alleviate this situation, input resistors <10 kΩ should be used.

The addition of positive feedback (<10 mV) is also recommended. It is good design practice to ground all unused pins.

Differential input voltages may be larger than supply voltage without damaging the comparator’s inputs. Voltages more negative than ~0.3 V should not be used.

D1 prevents input from going negative by more than 0.6 V.

**Figure 8. Zero Crossing Detector (Single Supply)**

V_{in(min)} = 0.4 V peak for 1% phase distortion (ΔΘ).

**Figure 9. Zero Crossing Detector (Split Supply)**

"ON" for t > t_{O} + Δt

where:

\[ Δt = RC \left( \frac{V_{ref}}{V_{CC}} \right) \]

**Figure 10. Free–Running Square–Wave Oscillator**

**Figure 11. Time Delay Generator**

\[ R_S = R_1 || R_2 \]

\[ V_{th1} = V_{ref} + \frac{(V_{CC} - V_{ref}) R_1}{R_1 + R_2 + R_L} \]

\[ V_{th2} = V_{ref} - \frac{(V_{ref} - V_{OL} \text{ Low}) R_1}{R_1 + R_2} \]

**Figure 12. Comparator with Hysteresis**
MARKING DIAGRAMS

LM393N, LM293N, LM2903N, LM2903V, NCV2903

PDIP–8
N SUFFIX
CASE 626

LM393N
AWL
YYWW

LM2903N
AWL
YYWW

Micro8
DM SUFFIX
CASE 846A

x93
AWL
YYWW

2903
AYW

SOIC–8
D SUFFIX
CASE 751

x93
ALYW

2903
ALYW

2903V
ALYW

x = 2 or 3
A = Assembly Location
WL, L = Wafеr Lot
YY, Y = Year
WW, W = Work Week

*This marking diagram also applies to NCV2903DR2.
## ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Shipping†</th>
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</thead>
<tbody>
<tr>
<td>LM293D</td>
<td>SOIC–8</td>
<td>98 Units / Rail</td>
</tr>
<tr>
<td>LM293DR2</td>
<td>SOIC–8</td>
<td>2500 Units / Reel</td>
</tr>
<tr>
<td>LM293DR2G</td>
<td>SOIC–8 (Pb–Free)</td>
<td></td>
</tr>
<tr>
<td>LM293DMR2</td>
<td>Micro8</td>
<td>4000 Tape and Reel</td>
</tr>
<tr>
<td>LM393D</td>
<td>SOIC–8</td>
<td>98 Units / Rail</td>
</tr>
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<td>LM393DG</td>
<td>SOIC–8 (Pb–Free)</td>
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<tr>
<td>LM393DR2</td>
<td>SOIC–8</td>
<td>2500 Units / Reel</td>
</tr>
<tr>
<td>LM393DR2G</td>
<td>SOIC–8 (Pb–Free)</td>
<td></td>
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<td>LM393N</td>
<td>PDIP–8</td>
<td>50 Units / Rail</td>
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<td>LM393NG</td>
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<td>LM393DMR2</td>
<td>Micro8</td>
<td>4000 Tape and Reel</td>
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<td>LM393DMR2G</td>
<td>Micro8 (Pb–Free)</td>
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<tr>
<td>LM2903D</td>
<td>SOIC–8</td>
<td>98 Units / Reel</td>
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<td>SOIC–8</td>
<td>2500 Units / Reel</td>
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<tr>
<td>LM2903N</td>
<td>PDIP–8</td>
<td>50 Units / Rail</td>
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<td>Micro8</td>
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<td>SOIC–8</td>
<td>2500 Units / Reel</td>
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<td>SOIC–8 (Pb–Free)</td>
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<td>LM2903VN</td>
<td>PDIP–8</td>
<td>50 Units / Rail</td>
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<td>NCV2903DR2 (Note 9)</td>
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<td>2500 Tape and Reel</td>
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<tr>
<td>NCV2903DMR2 (Note 9)</td>
<td>Micro8</td>
<td>4000 Tape and Reel</td>
</tr>
</tbody>
</table>

9. NCV2903 is qualified for automotive use.
†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.
PACKAGE DIMENSIONS

PDIP–8
N SUFFIX
CASE 626–05
ISSUE L

NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).

<table>
<thead>
<tr>
<th>DIM</th>
<th>MILLIMETERS</th>
<th>INCHES</th>
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<tbody>
<tr>
<td>A</td>
<td>9.40</td>
<td>0.370</td>
</tr>
<tr>
<td>B</td>
<td>6.10</td>
<td>0.240</td>
</tr>
<tr>
<td>C</td>
<td>3.94</td>
<td>0.155</td>
</tr>
<tr>
<td>D</td>
<td>0.38</td>
<td>0.015</td>
</tr>
<tr>
<td>F</td>
<td>1.02</td>
<td>0.040</td>
</tr>
<tr>
<td>G</td>
<td>2.34</td>
<td>0.092</td>
</tr>
<tr>
<td>H</td>
<td>0.76</td>
<td>0.030</td>
</tr>
<tr>
<td>J</td>
<td>0.20</td>
<td>0.008</td>
</tr>
<tr>
<td>K</td>
<td>2.92</td>
<td>0.115</td>
</tr>
<tr>
<td>L</td>
<td>7.62</td>
<td>0.300</td>
</tr>
<tr>
<td>N</td>
<td>0.76</td>
<td>0.030</td>
</tr>
</tbody>
</table>

+ 0.13 (0.005) ± T A ± B ±

http://onsemi.com
LM393, LM293, LM2903, LM2903V, NCV2903

SOIC–8
D SUFFIX
CASE 751–07
ISSUE AC

NOTES:
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

<table>
<thead>
<tr>
<th>DIM</th>
<th>MIN</th>
<th>MAX</th>
<th>MIN</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.80</td>
<td>5.00</td>
<td>0.189</td>
<td>0.197</td>
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<tr>
<td>B</td>
<td>3.80</td>
<td>4.00</td>
<td>0.150</td>
<td>0.157</td>
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<tr>
<td>C</td>
<td>1.35</td>
<td>1.75</td>
<td>0.053</td>
<td>0.069</td>
</tr>
<tr>
<td>D</td>
<td>0.33</td>
<td>0.51</td>
<td>0.013</td>
<td>0.020</td>
</tr>
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<td>G</td>
<td>1.27 BSC</td>
<td>0.50 BSC</td>
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<td></td>
</tr>
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<td>H</td>
<td>0.10</td>
<td>0.25</td>
<td>0.004</td>
<td>0.010</td>
</tr>
<tr>
<td>J</td>
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<td>0.25</td>
<td>0.007</td>
<td>0.010</td>
</tr>
<tr>
<td>K</td>
<td>0.40</td>
<td>1.27</td>
<td>0.016</td>
<td>0.050</td>
</tr>
</tbody>
</table>
| M   | 0" | 8" | 0" | 8.0"
| N   | 0.25| 0.50| 0.010| 0.020|
| S   | 5.80| 6.20| 0.228| 0.244|

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.
### PACKAGE DIMENSIONS

**Micro8**

**DM SUFFIX**

**CASE 846A–02**

**ISSUE F**

**NOTES:**

2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.060) 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. ISSUE F OBSOLETE, NEW STANDARD 846A–02.

<table>
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<th>MILLIMETERS</th>
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**SEATING PLANE**

**GPIN 1 ID**

**PL 8**

**0.038 (0.0015)**

**SOLDERING FOOTPRINT**

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