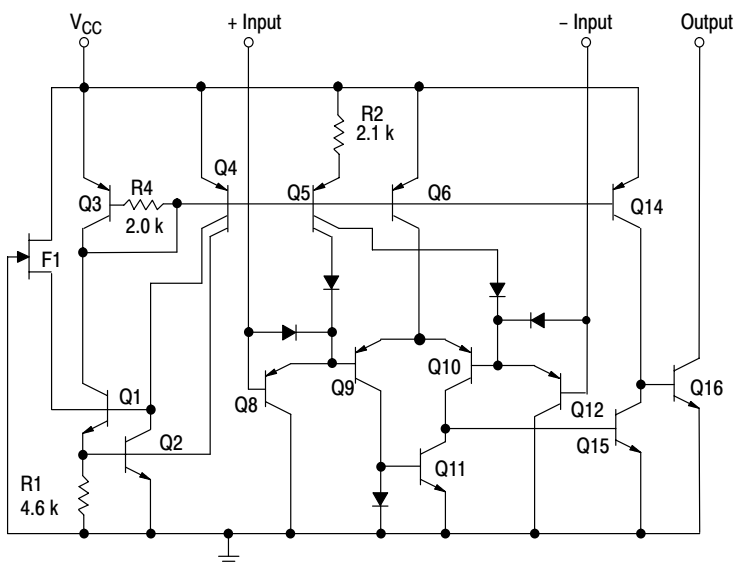


# LM393, LM293, LM2903, LM2903V, NCV2903

## 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.

- Wide Single-Supply Range: 2.0 Vdc to 36 Vdc
- Split-Supply Range:  $\pm 1.0$  Vdc to  $\pm 18$  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

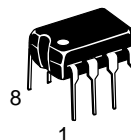


**Figure 1. Representative Schematic Diagram**  
(Diagram shown is for 1 comparator)



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**PDIP-8  
N SUFFIX  
CASE 626**

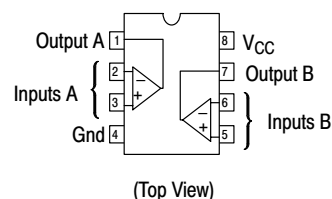


**SO-8  
D SUFFIX  
CASE 751**



**Micro8™  
DM SUFFIX  
CASE 846A**

### PIN CONNECTIONS



### ORDERING & DEVICE MARKING INFORMATION

See detailed ordering and shipping information and marking information in the package dimensions section on page 6 of this data sheet.

## LM393, LM293, LM2903, LM2903V, NCV2903

### MAXIMUM RATINGS

| Rating   | Symbol                     | Value  | Unit                       |
|--|----------------------------|--|----------------------------|
| Power Supply Voltage   | $V_{CC}$                   | +36 or $\pm 18$                                      | Vdc                        |
| Input Differential Voltage Range   | $V_{IDR}$                  | 36   | Vdc                        |
| Input Common Mode Voltage Range  | $V_{ICR}$                  | -0.3 to +36  | Vdc                        |
| Output Short Circuit-to-Ground<br>Output Sink Current (Note 1)                               | $I_{SC}$<br>$I_{Sink}$     | Continuous<br>20                                     | mA                         |
| Power Dissipation @ $T_A = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$              | $P_D$<br>$1/R_{\theta JA}$ | 570<br>5.7   | mW<br>mW/ $^\circ\text{C}$ |
| Operating Ambient Temperature Range<br>LM293<br>LM393<br>LM2903<br>LM2903V, NCV2903 (Note 2) | $T_A$                      | -25 to +85<br>0 to +70<br>-40 to +105<br>-40 to +125 | $^\circ\text{C}$           |
| Maximum Operating Junction Temperature<br>LM393, 2903, LM2903V<br>LM293, NCV2903             | $T_{J(max)}$               | 150<br>150   | $^\circ\text{C}$           |
| Storage Temperature Range  | $T_{stg}$                  | -65 to +150  | $^\circ\text{C}$           |

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.*

# LM393, LM293, LM2903, LM2903V, NCV2903

## ELECTRICAL CHARACTERISTICS ( $V_{CC} = 5.0$ Vdc, $T_{low} \leq T_A \leq T_{high}$ , unless otherwise noted.)

| Characteristic   | Symbol     | LM293, LM393 |           |                | LM2903, LM2903V,<br>NCV2903 |           |                | Unit          |
|--|------------|--------------|-----------|----------------|-----------------------------|-----------|----------------|---------------|
|  |            | Min          | Typ       | Max            | Min                         | Typ       | Max            |               |
| Input Offset Voltage (Note 4)<br>$T_A = 25^\circ\text{C}$<br>$T_{low} \leq T_A \leq T_{high}$  | $V_{IO}$   | –            | $\pm 1.0$ | $\pm 5.0$      | –                           | $\pm 2.0$ | $\pm 7.0$      | mV            |
|  |            | –            | –         | 9.0            | –                           | 9.0       | 15             |               |
| Input Offset Current<br>$T_A = 25^\circ\text{C}$<br>$T_{low} \leq T_A \leq T_{high}$   | $I_{IO}$   | –            | $\pm 5.0$ | $\pm 50$       | –                           | $\pm 5.0$ | $\pm 50$       | nA            |
|  |            | –            | –         | $\pm 150$      | –                           | $\pm 50$  | $\pm 200$      |               |
| Input Bias Current (Note 5)<br>$T_A = 25^\circ\text{C}$<br>$T_{low} \leq T_A \leq T_{high}$  | $I_{IB}$   | –            | 25        | 250            | –                           | 25        | 250            | nA            |
|  |            | –            | –         | 400            | –                           | 200       | 500            |               |
| Input Common Mode Voltage Range (Note 5)<br>$T_A = 25^\circ\text{C}$<br>$T_{low} \leq T_A \leq T_{high}$   | $V_{ICR}$  | 0            | –         | $V_{CC} - 1.5$ | 0                           | –         | $V_{CC} - 1.5$ | V             |
|  |            | 0            | –         | $V_{CC} - 2.0$ | 0                           | –         | $V_{CC} - 2.0$ |               |
| Voltage Gain<br>$R_L \geq 15$ k $\Omega$ , $V_{CC} = 15$ Vdc, $T_A = 25^\circ\text{C}$   | $A_{VOL}$  | 50           | 200       | –              | 25                          | 200       | –              | V/mV          |
| Large Signal Response Time<br>$V_{in} =$ TTL Logic Swing, $V_{ref} = 1.4$ Vdc<br>$V_{RL} = 5.0$ Vdc, $R_L = 5.1$ k $\Omega$ , $T_A = 25^\circ\text{C}$   | –          | –            | 300       | –              | –                           | 300       | –              | ns            |
| Response Time (Note 7)<br>$V_{RL} = 5.0$ Vdc, $R_L = 5.1$ k $\Omega$ , $T_A = 25^\circ\text{C}$  | $t_{TLH}$  | –            | 1.3       | –              | –                           | 1.5       | –              | $\mu\text{s}$ |
| Input Differential Voltage (Note 8)<br>All $V_{in} \geq$ Gnd or V– Supply (if used)  | $V_{ID}$   | –            | –         | $V_{CC}$       | –                           | –         | $V_{CC}$       | V             |
| Output Sink Current<br>$V_{in} \geq 1.0$ Vdc, $V_{in+} = 0$ Vdc, $V_O \leq 1.5$ Vdc $T_A = 25^\circ\text{C}$   | $I_{Sink}$ | 6.0          | 16        | –              | 6.0                         | 16        | –              | mA            |
| Output Saturation Voltage<br>$V_{in} \geq 1.0$ Vdc, $V_{in+} = 0$ , $I_{Sink} \leq 4.0$ mA, $T_A = 25^\circ\text{C}$<br>$T_{low} \leq T_A \leq T_{high}$   | $V_{OL}$   | –            | 150       | 400            | –                           | –         | 400            | mV            |
|  |            | –            | –         | 700            | –                           | 200       | 700            |               |
| Output Leakage Current<br>$V_{in-} = 0$ V, $V_{in+} \geq 1.0$ Vdc, $V_O = 5.0$ Vdc, $T_A = 25^\circ\text{C}$<br>$V_{in-} = 0$ V, $V_{in+} \geq 1.0$ Vdc, $V_O = 30$ Vdc,<br>$T_{low} \leq T_A \leq T_{high}$ | $I_{OL}$   | –            | 0.1       | –              | –                           | 0.1       | –              | nA            |
|  |            | –            | –         | 1000           | –                           | –         | 1000           |               |
| Supply Current<br>$R_L = \infty$ Both Comparators, $T_A = 25^\circ\text{C}$<br>$R_L = \infty$ Both Comparators, $V_{CC} = 30$ V  | $I_{CC}$   | –            | 0.4       | 1.0            | –                           | 0.4       | 1.0            | mA            |
|  |            | –            | –         | 2.5            | –                           | –         | 2.5            |               |

LM293  $T_{low} = -25^\circ\text{C}$ ,  $T_{high} = +85^\circ\text{C}$

LM393  $T_{low} = 0^\circ\text{C}$ ,  $T_{high} = +70^\circ\text{C}$

LM2903  $T_{low} = -40^\circ\text{C}$ ,  $T_{high} = +105^\circ\text{C}$

LM2903V & NCV2903  $T_{low} = -40^\circ\text{C}$ ,  $T_{high} = +125^\circ\text{C}$

NCV2903 is qualified for automotive use.

3. The maximum output current may be as high as 20 mA, independent of the magnitude of  $V_{CC}$ , output short circuits to  $V_{CC}$  can cause excessive heating and eventual destruction.
4. At output switch point,  $V_O = 1.4$  Vdc,  $R_S = 0$   $\Omega$  with  $V_{CC}$  from 5.0 Vdc to 30 Vdc, and over the full input common mode range (0 V to  $V_{CC} = -1.5$  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  $V_{CC} - 1.5$  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  $V_{CC}$ , 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.

LM393, LM293, LM2903, LM2903V, NCV2903

LM293/393

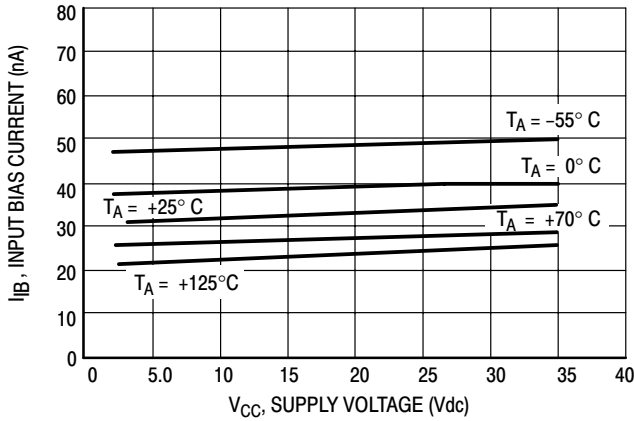


Figure 2. Input Bias Current versus Power Supply Voltage

LM2903

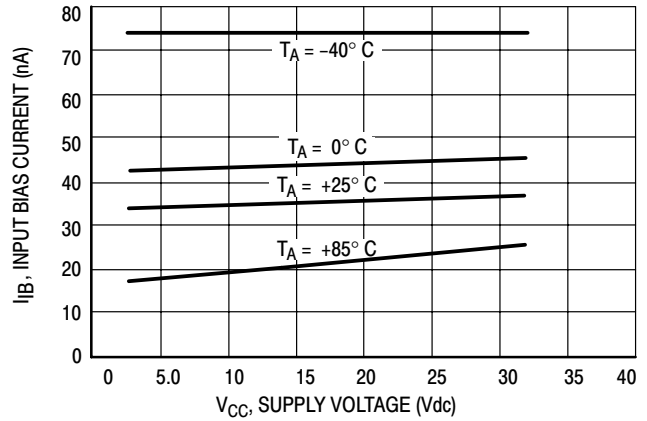


Figure 3. Input Bias Current versus Power Supply Voltage

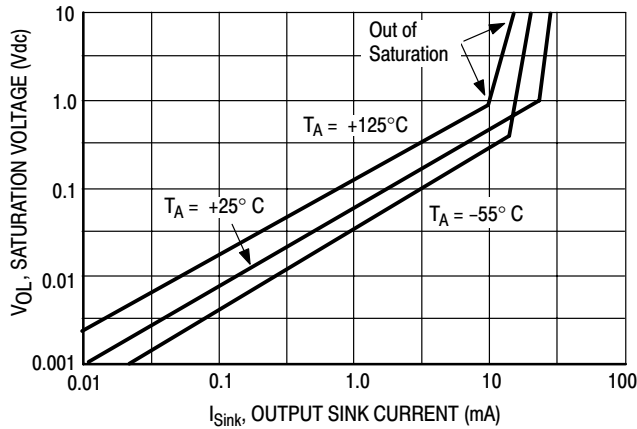


Figure 4. Output Saturation Voltage versus Output Sink Current

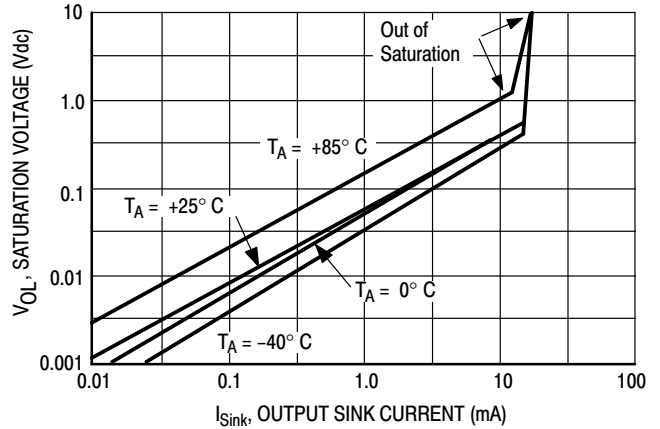


Figure 5. Output Saturation Voltage versus Output Sink Current

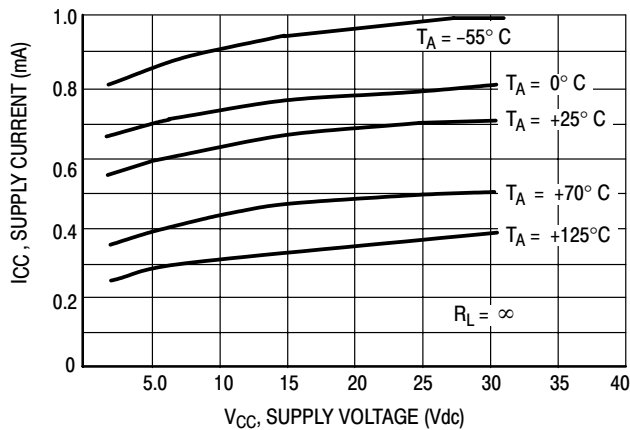


Figure 6. Power Supply Current versus Power Supply Voltage

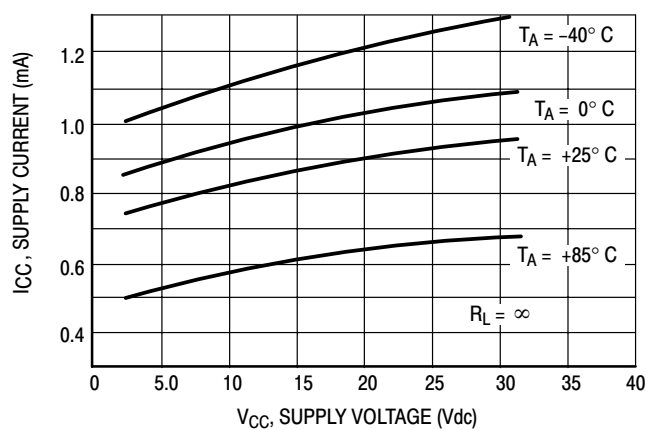


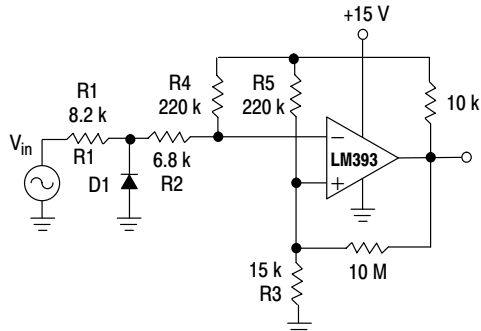
Figure 7. Power Supply Current versus Power Supply Voltage

APPLICATIONS INFORMATION

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  $<10\text{ k}\Omega$  should be used.

The addition of positive feedback ( $<10\text{ mV}$ ) 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  $-0.3\text{ V}$  should not be used.

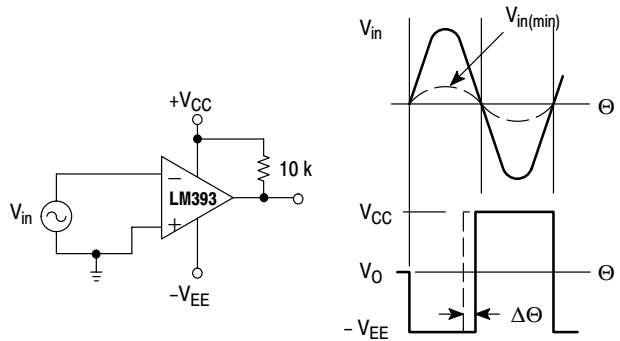


D1 prevents input from going negative by more than 0.6 V.

$$R1 + R2 = R3$$

$$R3 \leq \frac{R5}{10} \text{ for small error in zero crossing.}$$

Figure 8. Zero Crossing Detector (Single Supply)



$$V_{in(min)} \approx 0.4\text{ V peak for } 1\% \text{ phase distortion } (\Delta\Theta).$$

Figure 9. Zero Crossing Detector (Split Supply)

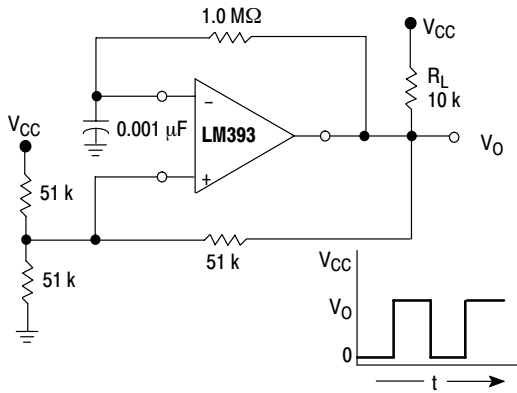
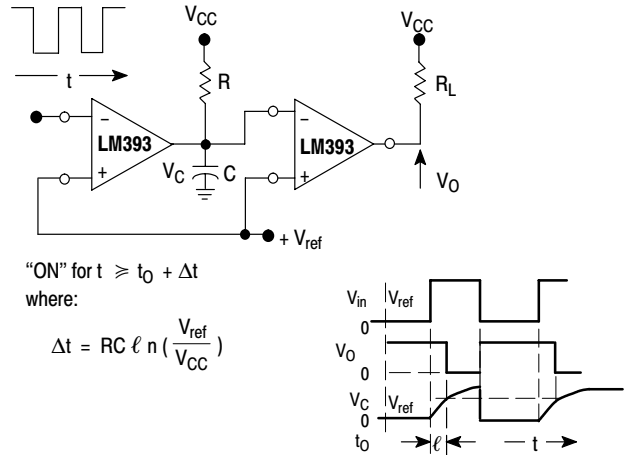


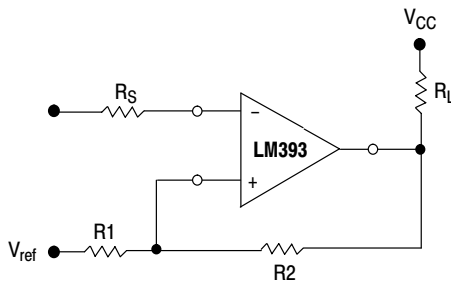
Figure 10. Free-Running Square-Wave Oscillator



"ON" for  $t \geq t_0 + \Delta t$   
where:

$$\Delta t = RC \ln \left( \frac{V_{ref}}{V_{CC}} \right)$$

Figure 11. Time Delay Generator



$$R_S = R1 \parallel R2$$

$$V_{th1} = V_{ref} + \frac{(V_{CC} - V_{ref}) R1}{R1 + R2 + R_L}$$

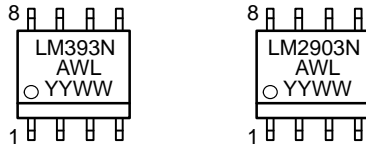
$$V_{th2} = V_{ref} - \frac{(V_{ref} - V_{O\text{ Low}}) R1}{R1 + R2}$$

Figure 12. Comparator with Hysteresis

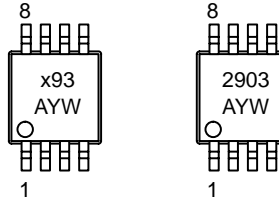
# LM393, LM293, LM2903, LM2903V, NCV2903

## MARKING DIAGRAMS

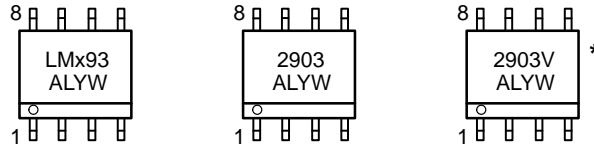
**PDIP-8  
N SUFFIX  
CASE 626**



**Micro8  
DM SUFFIX  
CASE 846A**



**SO-8  
D SUFFIX  
CASE 751**



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

\*This marking diagram also applies to NCV2903DR2.

## ORDERING INFORMATION

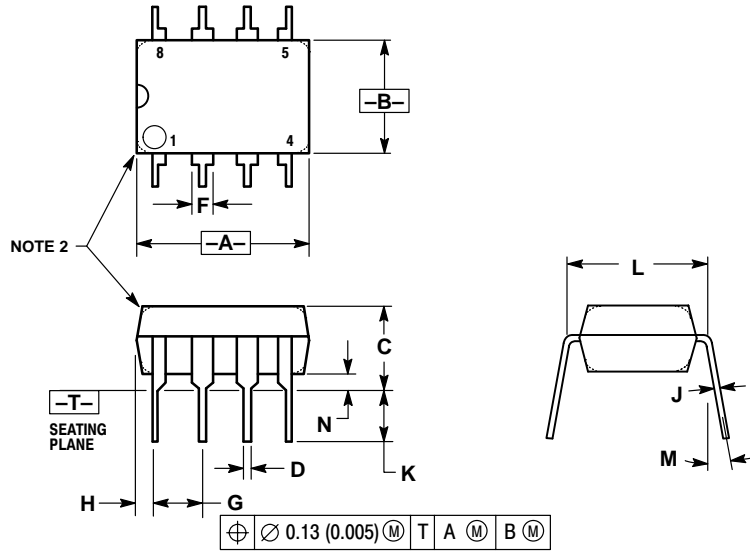
| Device               | Package | Shipping           |
|----------------------|---------|--------------------|
| LM293D               | SO-8    | 98 Units / Rail    |
| LM293DR2             | SO-8    | 2500 Units / Reel  |
| LM293DMR2            | Micro8  | 4000 Tape and Reel |
| LM393D               | SO-8    | 98 Units / Rail    |
| LM393DR2             | SO-8    | 2500 Units / Reel  |
| LM393N               | PDIP8   | 50 Units / Rail    |
| LM393DMR2            | Micro8  | 4000 Tape and Reel |
| LM2903D              | SO-8    | 98 Units / Reel    |
| LM2903DR2            | SO-8    | 2500 Units / Reel  |
| LM2903N              | PDIP8   | 50 Units / Rail    |
| LM2903DMR2           | Micro8  | 4000 Tape and Reel |
| LM2903VD             | SO-8    | 98 Units / Reel    |
| LM2903VDR2           | SO-8    | 2500 Units / Reel  |
| LM2903VN             | PDIP8   | 50 Units / Rail    |
| NCV2903DR2 (Note 9)  | SO-8    | 2500 Tape and Reel |
| NCV2903DMR2 (Note 9) | Micro8  | 4000 Tape and Reel |

9. NCV2903 is qualified for automotive use.

# LM393, LM293, LM2903, LM2903V, NCV2903

## PACKAGE DIMENSIONS

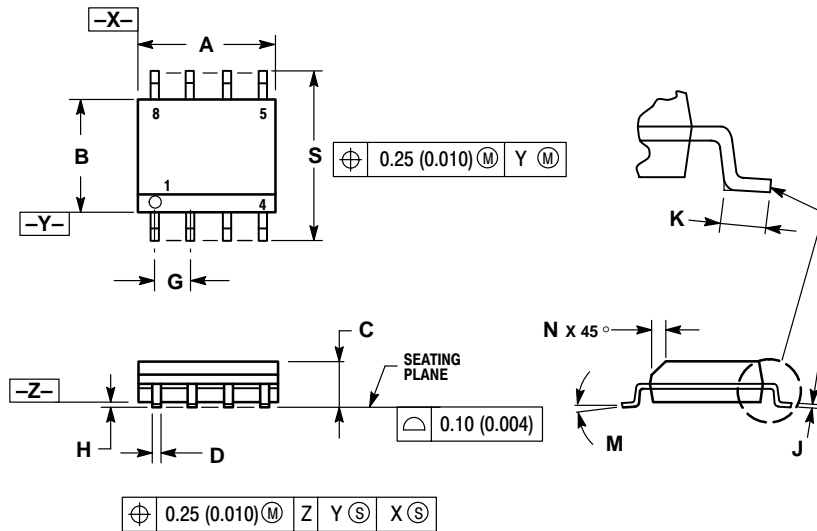
PDIP-8  
N SUFFIX  
CASE 626-05  
ISSUE L



- NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
  2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
  3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

| DIM | MILLIMETERS |       | INCHES    |       |
|-----|-------------|-------|-----------|-------|
|     | MIN         | MAX   | MIN       | MAX   |
| A   | 9.40        | 10.16 | 0.370     | 0.400 |
| B   | 6.10        | 6.60  | 0.240     | 0.260 |
| C   | 3.94        | 4.45  | 0.155     | 0.175 |
| D   | 0.38        | 0.51  | 0.015     | 0.020 |
| F   | 1.02        | 1.78  | 0.040     | 0.070 |
| G   | 2.54 BSC    |       | 0.100 BSC |       |
| H   | 0.76        | 1.27  | 0.030     | 0.050 |
| J   | 0.20        | 0.30  | 0.008     | 0.012 |
| K   | 2.92        | 3.43  | 0.115     | 0.135 |
| L   | 7.62 BSC    |       | 0.300 BSC |       |
| M   | ---         | 10°   | ---       | 10°   |
| N   | 0.76        | 1.01  | 0.030     | 0.040 |

SO-8  
D SUFFIX  
CASE 751-07  
ISSUE AA



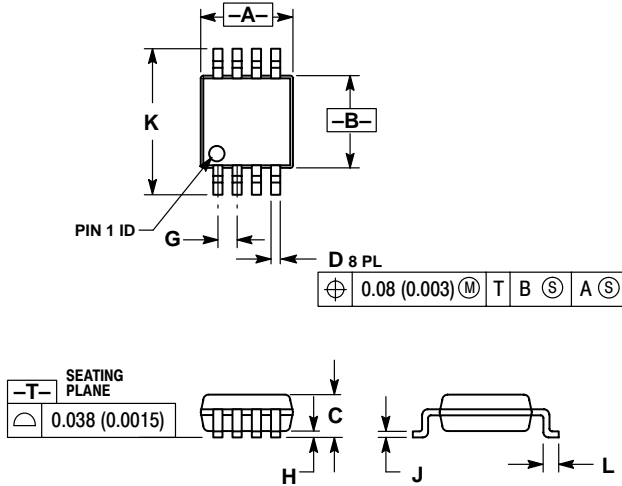
- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: MILLIMETER.
  3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
  4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
  5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
  6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 4.80        | 5.00 | 0.189     | 0.197 |
| B   | 3.80        | 4.00 | 0.150     | 0.157 |
| C   | 1.35        | 1.75 | 0.053     | 0.069 |
| D   | 0.33        | 0.51 | 0.013     | 0.020 |
| G   | 1.27 BSC    |      | 0.050 BSC |       |
| H   | 0.10        | 0.25 | 0.004     | 0.010 |
| J   | 0.19        | 0.25 | 0.007     | 0.010 |
| K   | 0.40        | 1.27 | 0.016     | 0.050 |
| M   | 0°          | 8°   | 0°        | 8°    |
| N   | 0.25        | 0.50 | 0.010     | 0.020 |
| S   | 5.80        | 6.20 | 0.228     | 0.244 |

# LM393, LM293, LM2903, LM2903V, NCV2903

## PACKAGE DIMENSIONS

Micro8  
DM SUFFIX  
CASE 846A-02  
ISSUE F




### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
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 (0.006) 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. 846A-01 OBSOLETE, NEW STANDARD 846A-02.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 2.90        | 3.10 | 0.114     | 0.122 |
| B   | 2.90        | 3.10 | 0.114     | 0.122 |
| C   | ---         | 1.10 | ---       | 0.043 |
| D   | 0.25        | 0.40 | 0.010     | 0.016 |
| G   | 0.65 BSC    |      | 0.026 BSC |       |
| H   | 0.05        | 0.15 | 0.002     | 0.006 |
| J   | 0.13        | 0.23 | 0.005     | 0.009 |
| K   | 4.75        | 5.05 | 0.187     | 0.199 |
| L   | 0.40        | 0.70 | 0.016     | 0.028 |

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