

# LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903



ON Semiconductor®

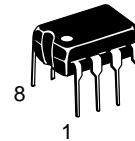
[www.onsemi.com](http://www.onsemi.com)

## 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:  $\pm 1.0$  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
- 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



PDIP-8  
N SUFFIX  
CASE 626

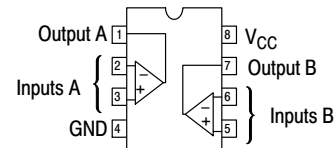


SOIC-8  
D SUFFIX  
CASE 751



Micro8™  
DM SUFFIX  
CASE 846A

### PIN CONNECTIONS



(Top View)

### DEVICE MARKING AND ORDERING INFORMATION

See detailed marking information and ordering and shipping information on pages 6 and 7 of this data sheet.

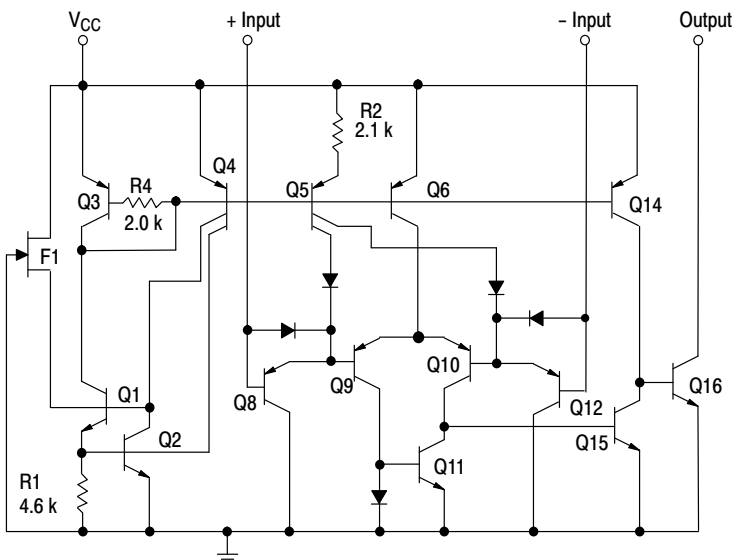


Figure 1. Representative Schematic Diagram  
(Diagram shown is for 1 comparator)

# LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903

## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Voltage	$V_{CC}$	+36 or $\pm 18$	V
Input Differential Voltage	$V_{IDR}$	36	V
Input Common Mode Voltage Range (Note 1)	$V_{ICR}$	-0.3 to +36	V
Output Voltage	$V_O$	36	V
Output Short Circuit-to-Ground Output Sink Current (Note 2)	$I_{SC}$ $I_{Sink}$	Continuous 20	mA
Power Dissipation @ $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$ $1/R_{\theta JA}$	570 5.7	mW mW/ $^\circ\text{C}$
Operating Ambient Temperature Range LM293 LM393, LM393E LM2903, LM2903E LM2903V, NCV2903 (Note 3)	$T_A$	-25 to +85 0 to +70 -40 to +105 -40 to +125	$^\circ\text{C}$
Maximum Operating Junction Temperature LM393, LM393E, LM2903, LM2903E, LM2903V LM293, NCV2903	$T_{J(max)}$	150 150	$^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	-65 to +150	$^\circ\text{C}$

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.

- For supply voltages less than 36 V, the absolute maximum input voltage is equal to the supply voltage.
- 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.
- NCV2903 is qualified for automotive use.

## ESD RATINGS

Rating	HBM	MM	Unit
ESD Protection at any Pin (Human Body Model – HBM, Machine Model – MM)			
NCV2903 (Note 3)	2000	200	V
LM393E, LM2903E	1500	150	V
LM393DR2G, LM2903DR2G	250	100	V
All Other Devices	1500	150	V

# LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903

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

Characteristic	Symbol	LM293, LM393, LM393E			LM2903/E/V, NCV2903			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage (Note 5) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{IO}$	–	$\pm 1.0$	$\pm 5.0$	–	$\pm 2.0$	$\pm 7.0$	mV
		–	–	$\pm 9.0$	–	$\pm 9.0$	$\pm 15$	
Input Offset Current $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IO}$	–	$\pm 5.0$	$\pm 50$	–	$\pm 5.0$	$\pm 50$	nA
		–	–	$\pm 150$	–	$\pm 50$	$\pm 200$	
Input Bias Current (Note 6) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IB}$	–	20	250	–	20	250	nA
		–	–	400	–	20	500	
Input Common Mode Voltage Range (Note 6) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{ICR}$	0	–	$V_{CC} - 1.5$	0	–	$V_{CC} - 1.5$	V
		0	–	$V_{CC} - 2.0$	0	–	$V_{CC} - 2.0$	
Voltage Gain $R_L \geq 15$ k $\Omega$ , $V_{CC} = 15$ Vdc, $T_A = 25^\circ\text{C}$	$A_{VOL}$	50	200	–	25	200	–	V/mV
Large Signal Response Time $V_{in} =$ TTL Logic Swing, $V_{ref} = 1.4$ Vdc $V_{RL} = 5.0$ Vdc, $R_L = 5.1$ k $\Omega$ , $T_A = 25^\circ\text{C}$	–	–	300	–	–	300	–	ns
Response Time (Note 8) $V_{RL} = 5.0$ 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 9) All $V_{in} \geq$ GND or $V^-$ Supply (if used)	$V_{ID}$	–	–	$V_{CC}$	–	–	$V_{CC}$	V
Output Sink Current $V_{in} \geq 1.0$ 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 $V_{in} \geq 1.0$ Vdc, $V_{in+} = 0$ , $I_{Sink} \leq 4.0$ mA, $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{OL}$	–	150	400	–	–	400	mV
		–	–	700	–	200	700	
Output Leakage Current $V_{in-} = 0$ V, $V_{in+} \geq 1.0$ Vdc, $V_O = 5.0$ Vdc, $T_A = 25^\circ\text{C}$ $V_{in-} = 0$ V, $V_{in+} \geq 1.0$ Vdc, $V_O = 30$ Vdc, $T_{low} \leq T_A \leq T_{high}$	$I_{OL}$	–	0.1	–	–	0.1	–	nA
		–	–	1000	–	–	1000	
Supply Current $R_L = \infty$ Both Comparators, $T_A = 25^\circ\text{C}$ $R_L = \infty$ Both Comparators, $V_{CC} = 30$ V	$I_{CC}$	–	0.4	1.0	–	0.4	1.0	mA
		–	–	2.5	–	–	2.5	

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

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

LM393, LM393E  $T_{low} = 0^\circ\text{C}$ ,  $T_{high} = +70^\circ\text{C}$

LM2903, LM2903E  $T_{low} = -40^\circ\text{C}$ ,  $T_{high} = +105^\circ\text{C}$

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

NCV2903 is qualified for automotive use.

4. 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.
5. At output switch point,  $V_O \approx 1.4$  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).
6. 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.
7. 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.
8. 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.
9. 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.

LM293/393

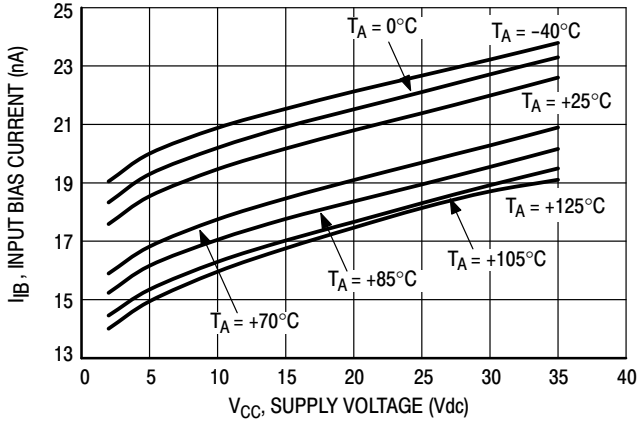


Figure 2. Input Bias Current versus Power Supply Voltage

LM2903

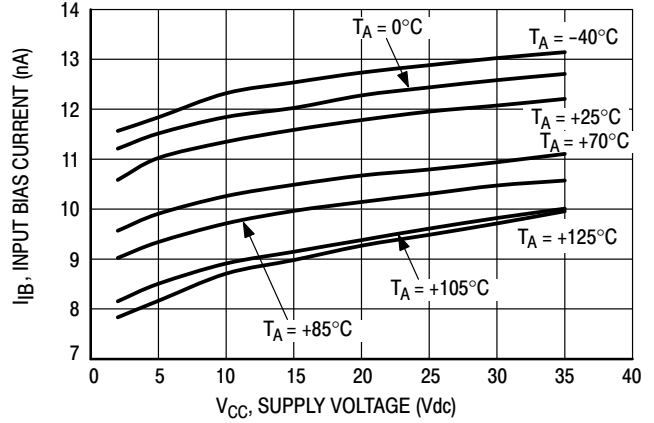


Figure 3. Input Bias Current versus Power Supply Voltage

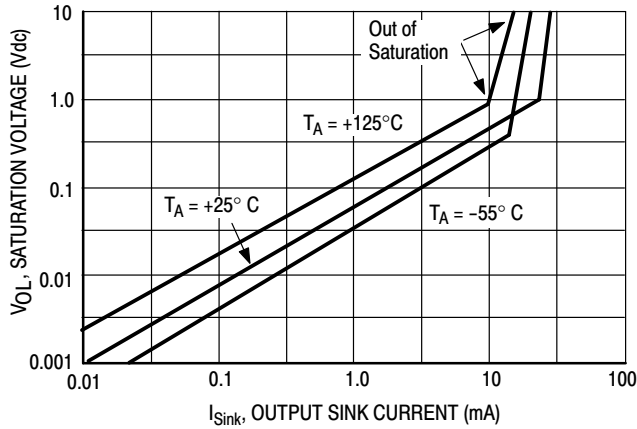


Figure 4. Output Saturation Voltage versus Output Sink Current

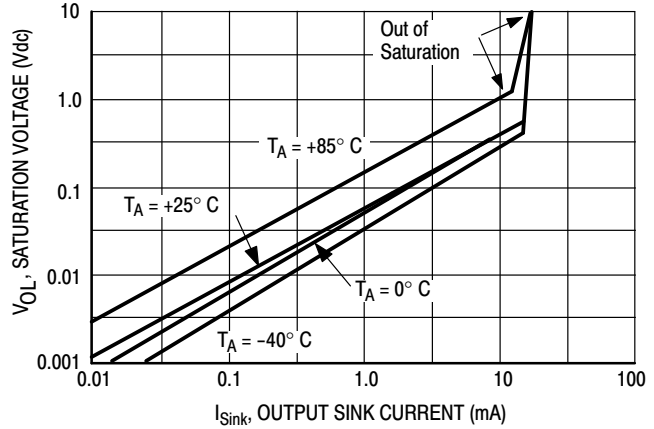


Figure 5. Output Saturation Voltage versus Output Sink Current

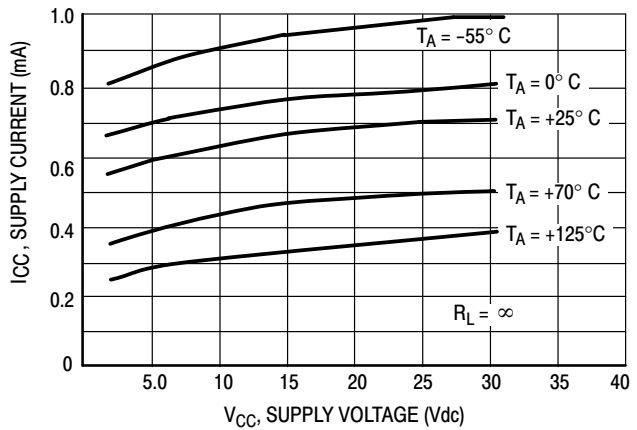


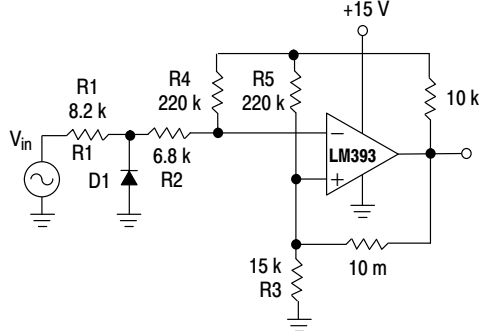
Figure 6. Power Supply Current versus Power Supply Voltage



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.



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)

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.



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

Figure 9. Zero Crossing Detector (Split Supply)

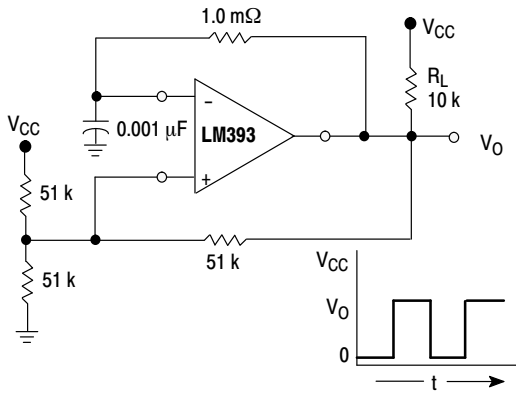
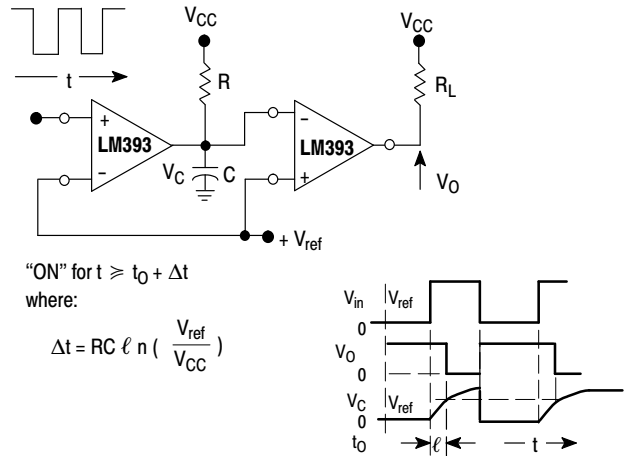


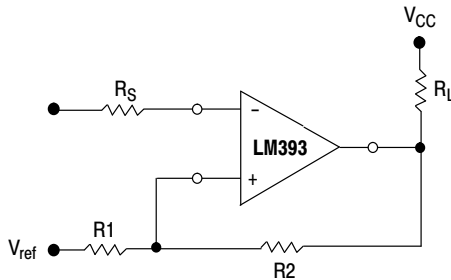
Figure 10. Free-Running Square-Wave Oscillator



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

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

Figure 11. Time Delay Generator



$$R_S = R1 \parallel R2$$

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

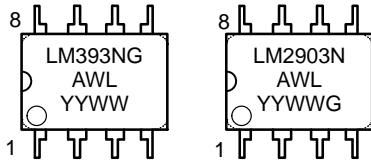
$$V_{th2} = V_{ref} - \frac{(V_{ref} - V_{O\text{ Low}}) R1}{R1 + R2}$$

Figure 12. Comparator with Hysteresis

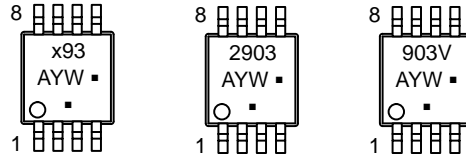
LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903

MARKING DIAGRAMS

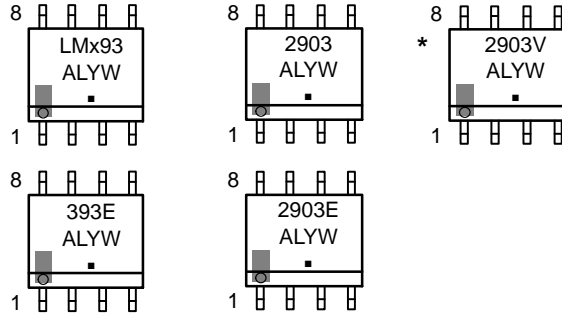
PDIP-8  
CASE 626



Micro8  
CASE 846A



SOIC-8  
CASE 751



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

(Note: Microdot may be in either location)

\*This marking diagram also applies to NCV2903DR2G

**LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903**

**ORDERING INFORMATION**

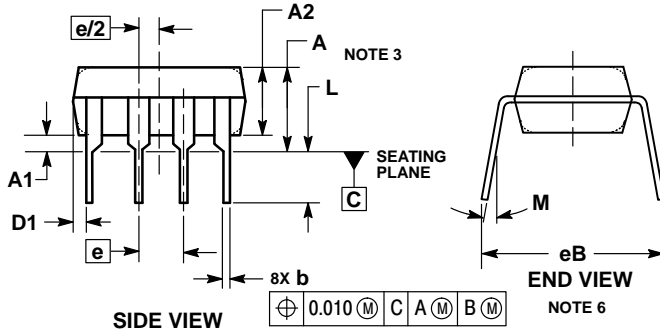
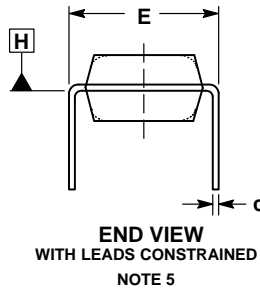
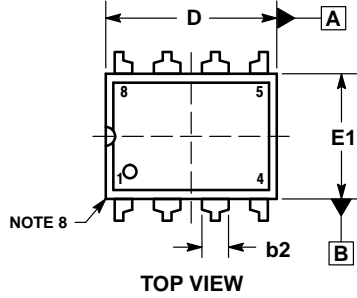
Device	Operating Temperature Range	Package	Shipping†
LM293DG	-25°C to +85°C	SOIC-8 (Pb-Free)	98 Units / Rail
LM293DR2G			2500 / Tape & Reel
LM293DMR2G		Micro8 (Pb-Free)	4000 / Tape and Reel
LM393DG	0°C to +70°C	SOIC-8 (Pb-Free)	98 Units / Rail
LM393DR2G			2500 / Tape & Reel
LM393EDR2G		SOIC-8 (Pb-Free)	2500 / Tape & Reel
LM393NG		PDIP-8 (Pb-Free)	50 Units / Rail
LM393DMR2G		Micro8 (Pb-Free)	4000 / Tape and Reel
LM2903DG	-40°C to +105°C	SOIC-8 (Pb-Free)	98 Units / Rail
LM2903DR2G			2500 / Tape & Reel
LM2903EDR2G		SOIC-8 (Pb-Free)	2500 / Tape & Reel
LM2903DMR2G		Micro8 (Pb-Free)	4000 / Tape and Reel
LM2903NG		PDIP-8 (Pb-Free)	50 Units / Rail
LM2903VDG	-40°C to +125°C	SOIC-8 (Pb-Free)	98 Units / Rail
LM2903VDR2G			2500 / Tape & Reel
LM2903VNG		PDIP-8 (Pb-Free)	50 Units / Rail
NCV2903DR2G*		SOIC-8 (Pb-Free)	2500 / Tape & Reel
NCV2903DMR2G*		Micro8 (Pb-Free)	4000 / Tape & Reel

†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.

PACKAGE DIMENSIONS

PDIP-8  
N, AN, VN SUFFIX  
CASE 626-05  
ISSUE P



NOTES:

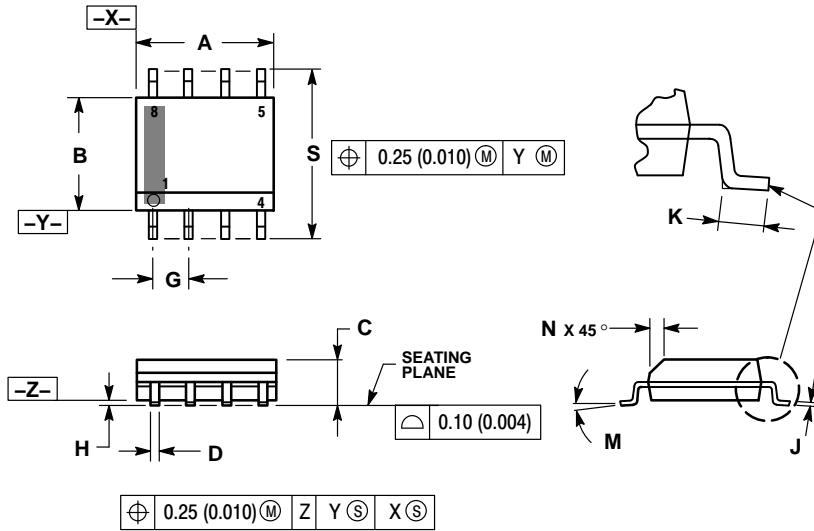
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS-3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION eB 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).

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	----	0.210	----	5.33
A1	0.015	----	0.38	----
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.355	0.400	9.02	10.16
D1	0.005	----	0.13	----
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	----	0.430	----	10.92
L	0.115	0.150	2.92	3.81
M	----	10°	----	10°



PACKAGE DIMENSIONS

SOIC-8 NB  
CASE 751-07  
ISSUE AK

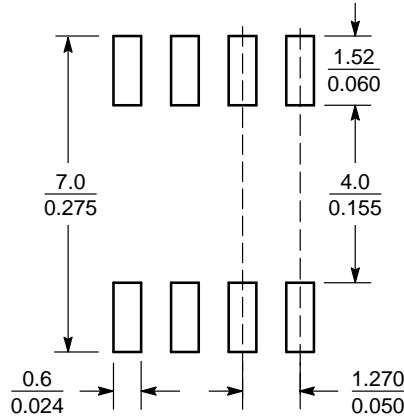


NOTES:

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

SOLDERING FOOTPRINT\*



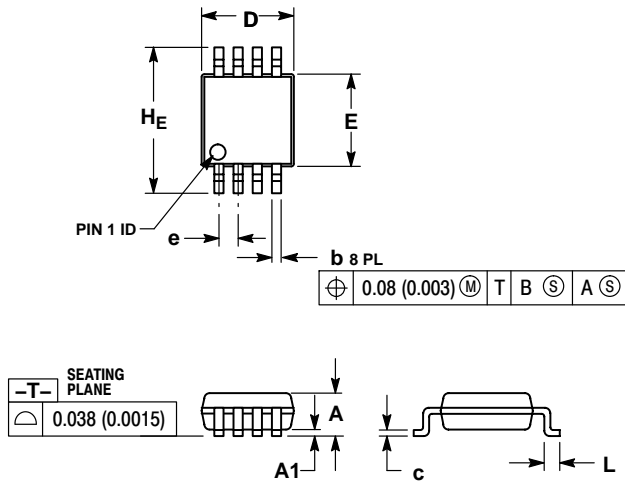
SCALE 6:1 (mm/inches)

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

# LM393, LM393E, LM293, LM2903, LM2903E, LM2903V, NCV2903

## PACKAGE DIMENSIONS

Micro8™  
CASE 846A-02  
ISSUE J

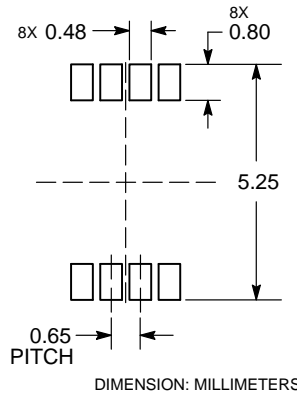


### NOTES:

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	NOM	MAX	MIN	NOM	MAX
A	---	---	1.10	---	---	0.043
A1	0.05	0.08	0.15	0.002	0.003	0.006
b	0.25	0.33	0.40	0.010	0.013	0.016
c	0.13	0.18	0.23	0.005	0.007	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	2.90	3.00	3.10	0.114	0.118	0.122
e	0.65 BSC			0.026 BSC		
L	0.40	0.55	0.70	0.016	0.021	0.028
HE	4.75	4.90	5.05	0.187	0.193	0.199

### RECOMMENDED 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.

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