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MOTOROLA

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# LM393, LM393A, LM293, LM2903, LM2903V

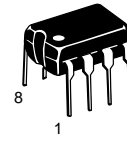
## Low Offset Voltage Dual Comparators

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.

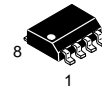
- Wide Single-Supply Range: 2.0 Vdc to 36 Vdc
- Split-Supply Range:  $\pm 1.0$  Vdc to  $\pm 18$  Vdc
- Very Low Current Drain Independent of Supply Voltage: 0.4 mA
- Low Input Bias Current: 25 nA
- Low Input Offset Current: 5.0 nA
- Low Input Offset Voltage: 2.0 mV (max) LM393A  
5.0 mV (max) LM293/393
- 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

### SINGLE SUPPLY, LOW POWER DUAL COMPARATORS

#### SEMICONDUCTOR TECHNICAL DATA



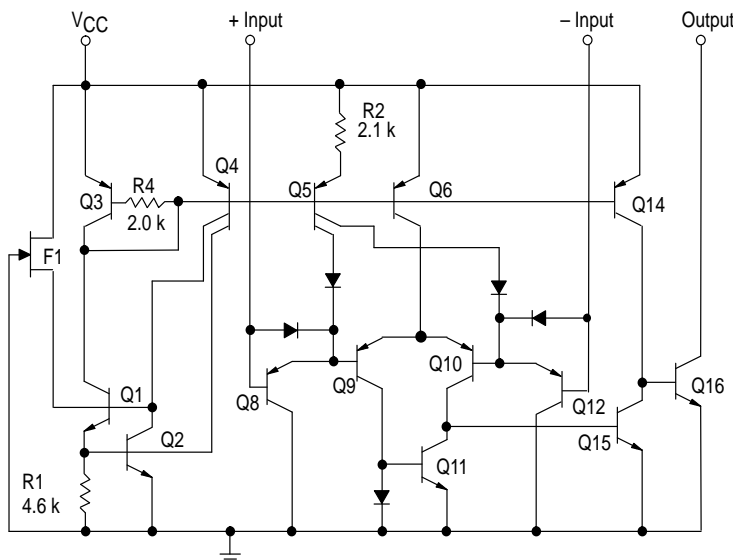
**N SUFFIX**  
PLASTIC PACKAGE  
CASE 626



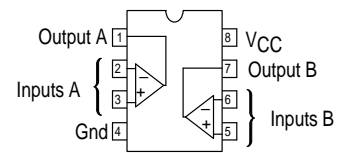
**D SUFFIX**  
PLASTIC PACKAGE  
CASE 751  
(SO-8)

### Representative Schematic Diagram

(Diagram shown is for 1 comparator)



### PIN CONNECTIONS



(Top View)

### ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM293D	$T_A = -25^\circ$ to $+85^\circ\text{C}$	SO-8
LM393D	$T_A = 0^\circ$ to $+70^\circ\text{C}$	SO-8
LM393AN,N		Plastic DIP
LM2903D	$T_A = -40^\circ$ to $+105^\circ\text{C}$	SO-8
LM2903N		Plastic DIP
LM2903VD	$T_A = -40^\circ$ to $+125^\circ\text{C}$	SO-8
LM2903VN		Plastic DIP

# LM393, LM393A, LM293, LM2903, LM2903V

## 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 Output Sink Current (Note 1)	$I_{SC}$ $I_{Sink}$	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, 393A LM2903 LM2903V	$T_A$	-25 to +85 0 to +70 -40 to +105 -40 to +125	$^\circ\text{C}$
Maximum Operating Junction Temperature LM393, 393A, 2903, LM2903V LM293	$T_{J(max)}$	125 150	$^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	-65 to +150	$^\circ\text{C}$

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

Characteristic	Symbol	LM393A			Unit
		Min	Typ	Max	
Input Offset Voltage (Note 2) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{IO}$	-	$\pm 1.0$	$\pm 2.0$ 4.0	mV
Input Offset Current $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IO}$	-	$\pm 50$	$\pm 50$ $\pm 150$	nA
Input Bias Current (Note 3) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IB}$	-	25	250 400	nA
Input Common Mode Voltage Range (Note 4) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{ICR}$	0 0	-	$V_{CC} - 1.5$ $V_{CC} - 2.0$	V
Voltage Gain $R_L \geq 15$ k $\Omega$ , $V_{CC} = 15$ Vdc, $T_A = 25^\circ\text{C}$	$A_{VOL}$	50	200	-	V/mV
Large Signal Response Time $V_{in} = \text{TTL Logic Swing}$ , $V_{ref} = 1.4$ Vdc $V_{RL} = 5.0$ Vdc, $R_L = 5.1$ k $\Omega$ , $T_A = 25^\circ\text{C}$	-	-	300	-	ns
Response Time (Note 5) $V_{RL} = 5.0$ Vdc, $R_L = 5.1$ k $\Omega$ , $T_A = 25^\circ\text{C}$	$t_{TLH}$	-	1.3	-	$\mu\text{s}$
Input Differential Voltage (Note 6) All $V_{in} \geq \text{Gnd}$ or $V^-$ Supply (if used)	$V_{ID}$	-	-	$V_{CC}$	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	-	mA
Output Saturation Voltage $V_{in} \geq 1.0$ Vdc, $V_{in+} = 0$ Vdc, $I_{Sink} \leq 4.0$ mA, $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{OL}$	-	150	400 700	mV

\*  $T_{low} = 0^\circ\text{C}$ ,  $T_{high} = +70^\circ\text{C}$  for LM393/393A

- NOTES:**
- 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.
  - 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).
  - 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.
  - 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.
  - 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.
  - 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, LM393A, LM293, LM2903, LM2903V

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

Characteristic	Symbol	LM393A			Unit
		Min	Typ	Max	
Output Leakage Current $V_{in-} = 0 \text{ V}$ , $V_{in+} \geq 1.0 \text{ Vdc}$ , $V_O = 5.0 \text{ Vdc}$ , $T_A = 25^\circ\text{C}$ $V_{in-} = 0 \text{ V}$ , $V_{in+} \geq 1.0 \text{ Vdc}$ , $V_O = 30 \text{ Vdc}$ , $T_{low} \leq T_A \leq T_{high}$	$I_{OL}$	–	0.1	–	$\mu\text{A}$
Supply Current $R_L = \infty$ Both Comparators, $T_A = 25^\circ\text{C}$ $R_L = \infty$ Both Comparators, $V_{CC} = 30 \text{ V}$	$I_{CC}$	–	0.4	1.0	$\text{mA}$
		–	1.0	2.5	

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

Characteristic	Symbol	LM392, LM393			LM2903, LM2903V			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage (Note 2) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{IO}$	–	$\pm 1.0$	$\pm 5.0$	–	$\pm 2.0$	$\pm 7.0$	$\text{mV}$
		–	–	9.0	–	9.0	15	
Input Offset Current $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IO}$	–	$\pm 5.0$	$\pm 50$	–	$\pm 5.0$	$\pm 50$	$\text{nA}$
		–	–	$\pm 150$	–	$\pm 50$	$\pm 200$	
Input Bias Current (Note 3) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$I_{IB}$	–	25	250	–	25	250	$\text{nA}$
		–	–	400	–	200	500	
Input Common Mode Voltage Range (Note 3) $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{ICR}$	0	–	$V_{CC} - 1.5$	0	–	$V_{CC} - 1.5$	$\text{V}$
		0	–	$V_{CC} - 2.0$	0	–	$V_{CC} - 2.0$	
Voltage Gain $R_L \geq 15 \text{ k}\Omega$ , $V_{CC} = 15 \text{ Vdc}$ , $T_A = 25^\circ\text{C}$	$A_{VOL}$	50	200	–	25	200	–	$\text{V/mV}$
Large Signal Response Time $V_{in} = \text{TTL Logic Swing}$ , $V_{ref} = 1.4 \text{ Vdc}$ $V_{RL} = 5.0 \text{ Vdc}$ , $R_L = 5.1 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	–	–	300	–	–	300	–	$\text{ns}$
Response Time (Note 5) $V_{RL} = 5.0 \text{ Vdc}$ , $R_L = 5.1 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	$t_{TLH}$	–	1.3	–	–	1.5	–	$\mu\text{s}$
Input Differential Voltage (Note 6) All $V_{in} \geq \text{Gnd}$ or $V^-$ Supply (if used)	$V_{ID}$	–	–	$V_{CC}$	–	–	$V_{CC}$	$\text{V}$
Output Sink Current $V_{in} \geq 1.0 \text{ Vdc}$ , $V_{in+} = 0 \text{ Vdc}$ , $V_O \leq 1.5 \text{ Vdc}$ , $T_A = 25^\circ\text{C}$	$I_{Sink}$	6.0	16	–	6.0	16	–	$\text{mA}$
Output Saturation Voltage $V_{in} \geq 1.0 \text{ Vdc}$ , $V_{in+} = 0$ , $I_{Sink} \leq 4.0 \text{ mA}$ , $T_A = 25^\circ\text{C}$ $T_{low} \leq T_A \leq T_{high}$	$V_{OL}$	–	150	400	–	–	400	$\text{mV}$
		–	–	700	–	200	700	
Output Leakage Current $V_{in-} = 0 \text{ V}$ , $V_{in+} \geq 1.0 \text{ Vdc}$ , $V_O = 5.0 \text{ Vdc}$ , $T_A = 25^\circ\text{C}$ $V_{in-} = 0 \text{ V}$ , $V_{in+} \geq 1.0 \text{ Vdc}$ , $V_O = 30 \text{ Vdc}$ , $T_{low} \leq T_A \leq T_{high}$	$I_{OL}$	–	0.1	–	–	0.1	–	$\text{nA}$
		–	–	1000	–	–	1000	
Supply Current $R_L = \infty$ Both Comparators, $T_A = 25^\circ\text{C}$ $R_L = \infty$ Both Comparators, $V_{CC} = 30 \text{ V}$	$I_{CC}$	–	0.4	1.0	–	0.4	1.0	$\text{mA}$
		–	–	2.5	–	–	2.5	

\*  $T_{low} = 0^\circ\text{C}$ ,  $T_{high} = +70^\circ\text{C}$  for LM393/393A

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

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

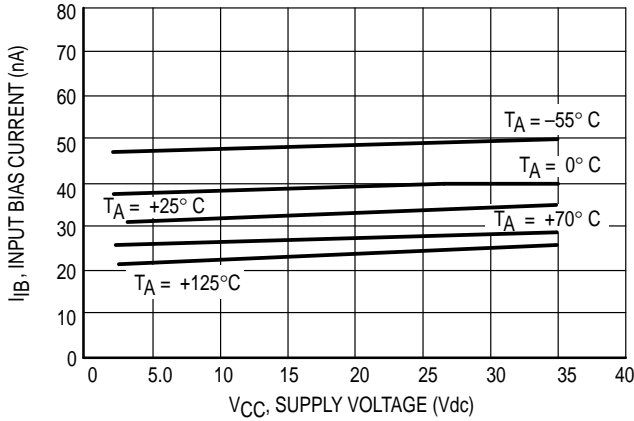
LM2903V  $T_{low} = -40^\circ\text{C}$ ,  $T_{high} = +125^\circ\text{C}$

- NOTES:**
- At output switch point,  $V_O = 1.4 \text{ Vdc}$ ,  $R_S = 0 \Omega$  with  $V_{CC}$  from  $5.0 \text{ Vdc}$  to  $30 \text{ Vdc}$ , and over the full input common mode range ( $0 \text{ V}$  to  $V_{CC} = -1.5 \text{ V}$ ).
  - 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.
  - Response time is specified with a  $100 \text{ mV}$  step and  $5.0 \text{ mV}$  of overdrive. With larger magnitudes of overdrive faster response times are obtainable.
  - 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  $-0.3 \text{ V}$  of ground or minus supply.

# LM393, LM393A, LM293, LM2903, LM2903V

LM293/393,A

Figure 1. Input Bias Current versus Power Supply Voltage



LM2903

Figure 2. Input Bias Current versus Power Supply Voltage

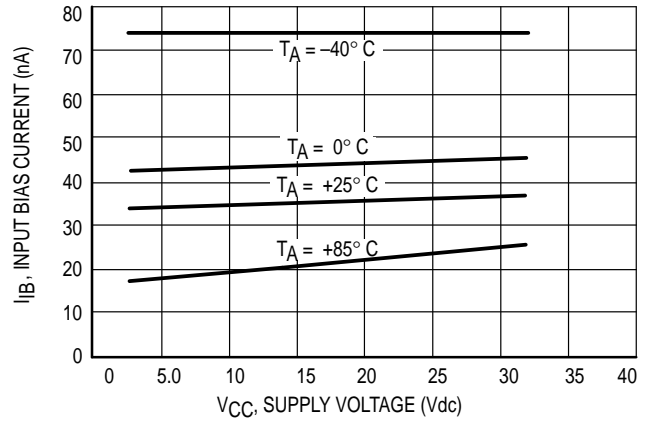


Figure 3. Output Saturation Voltage versus Output Sink Current

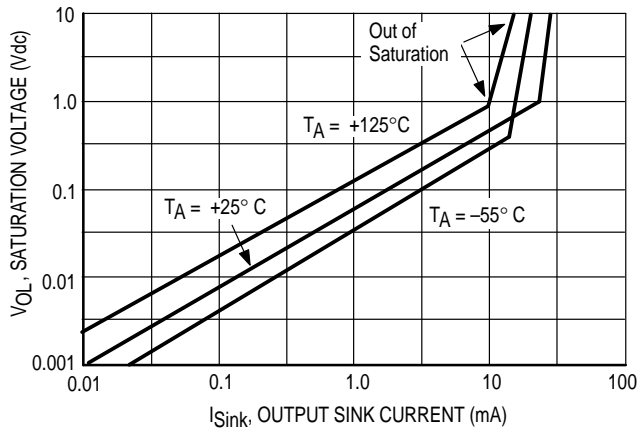


Figure 4. Output Saturation Voltage versus Output Sink Current

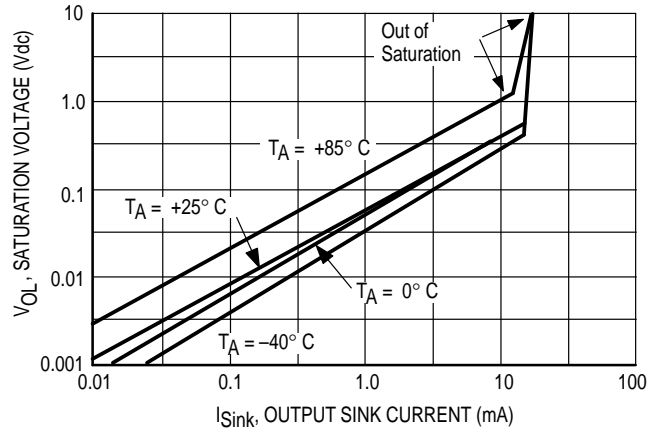


Figure 5. Power Supply Current versus Power Supply Voltage

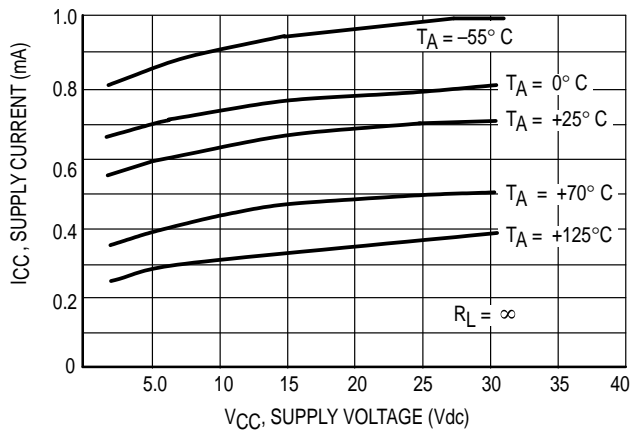
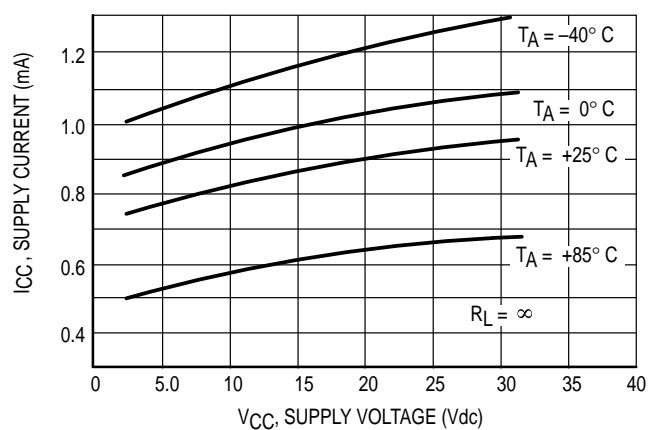


Figure 6. Power Supply Current versus Power Supply Voltage



# LM393, LM393A, LM293, LM2903, LM2903V

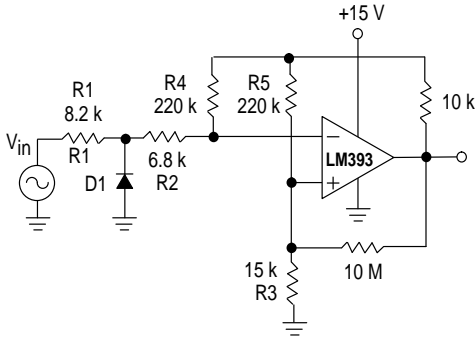
## APPLICATIONS INFORMATION

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.

**Figure 7. Zero Crossing Detector (Single Supply)**

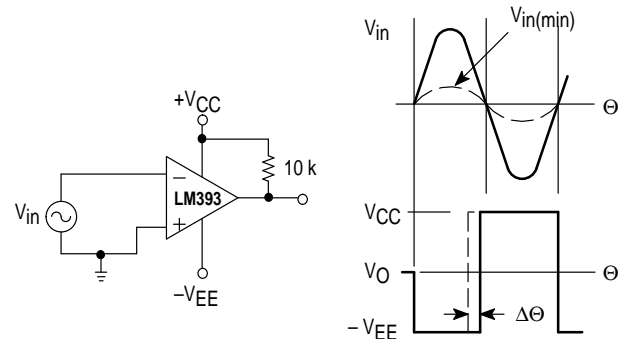


D1 prevents input from going negative by more than  $0.6\text{ V}$ .

$$R1 + R2 = R3$$

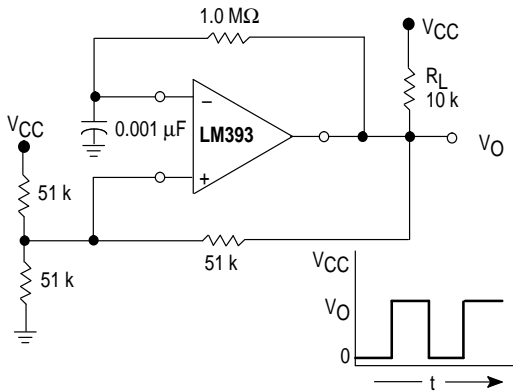
$$R3 \leq \frac{R5}{10} \text{ for small error in zero crossing.}$$

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

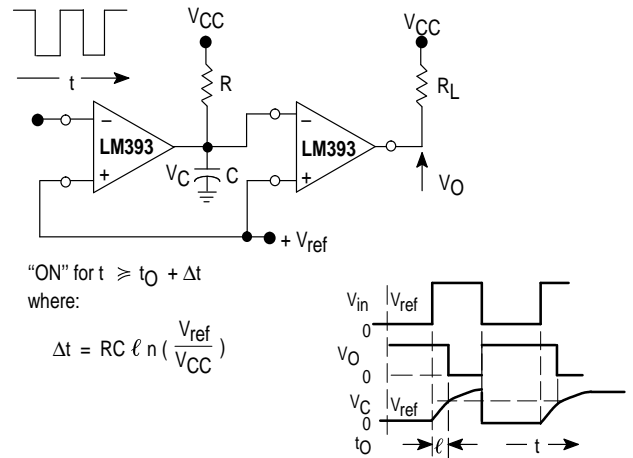


$$V_{in(\min)} \approx 0.4\text{ V peak for } 1\% \text{ phase distortion } (\Delta\Theta).$$

**Figure 9. Free-Running Square-Wave Oscillator**



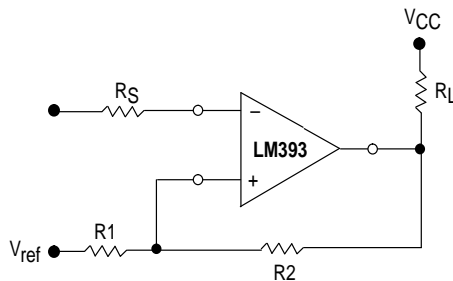
**Figure 10. Time Delay Generator**



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

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

**Figure 11. Comparator with Hysteresis**



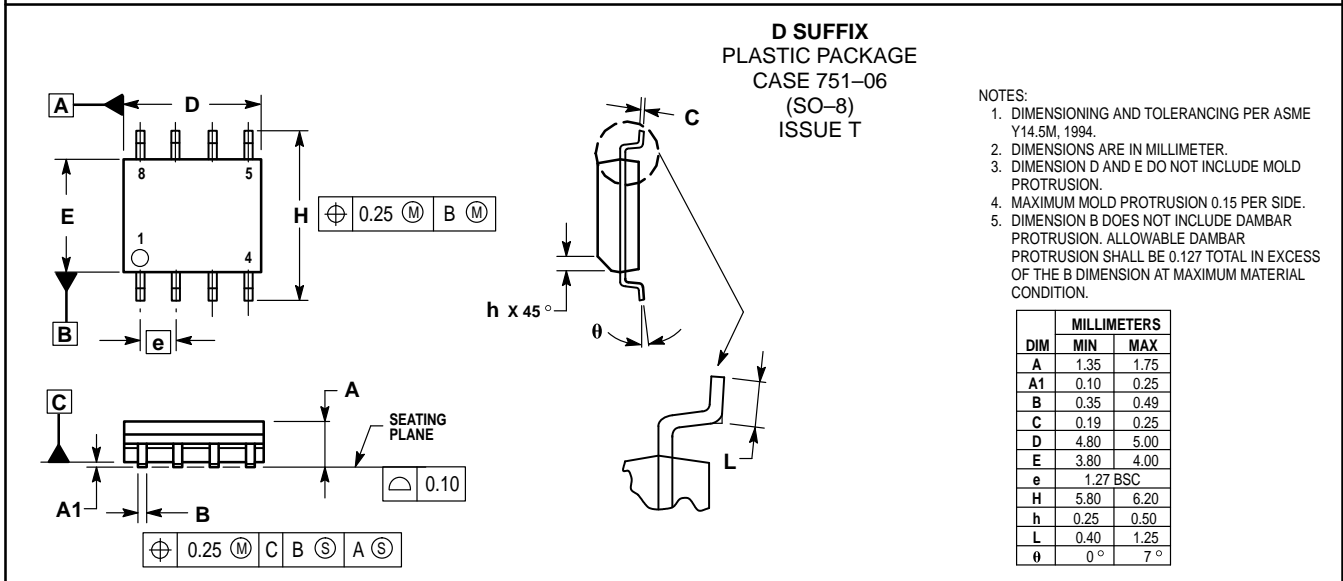
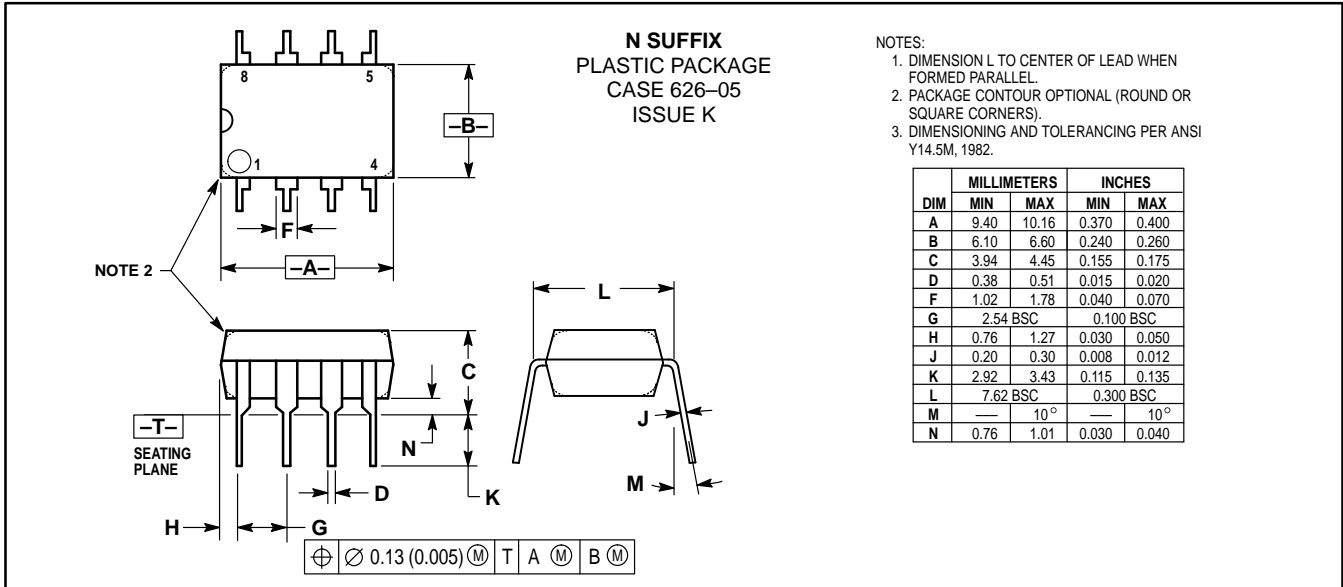
$$R_S = R1 \parallel R2$$

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

$$V_{th2} = V_{ref} - \frac{(V_{ref} - V_{OL}) R1}{R1 + R2}$$

# LM393, LM393A, LM293, LM2903, LM2903V

## OUTLINE DIMENSIONS



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