

# SN54HC590A, SN74HC590A 8-BIT BINARY COUNTERS WITH 3-STATE OUTPUT REGISTERS

SCLS039C – DECEMBER 1982 – REVISED MAY 1997

- 8-Bit Counter With Register
- High-Current 3-State Parallel Register Outputs Can Drive up to 15 LSTTL Loads
- Counter Has Direct Clear
- Package Options Include Plastic Small-Outline (D, DW), and Ceramic Flat (W) Packages, Ceramic Chip Carriers (FK), and Standard Plastic (N) and Ceramic (J) 300-mil DIPs

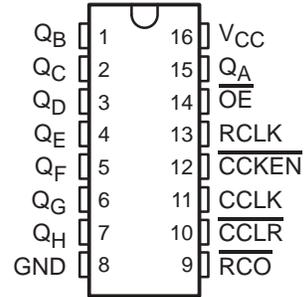
## description

The 'HC590A contain an 8-bit binary counter that feeds an 8-bit storage register. The storage register has parallel outputs. Separate clocks are provided for both the binary counter and storage register. The binary counter features direct clear ( $\overline{\text{CCLR}}$ ) and count-enable ( $\overline{\text{CCKEN}}$ ) inputs. A ripple-carry output ( $\overline{\text{RCO}}$ ) is provided for cascading. Expansion is easily accomplished for two stages by connecting  $\overline{\text{RCO}}$  of the first stage to  $\overline{\text{CCKEN}}$  of the second stage. Cascading for larger count chains can be accomplished by connecting  $\overline{\text{RCO}}$  of each stage to the counter clock (CCLK) input of the following stage.

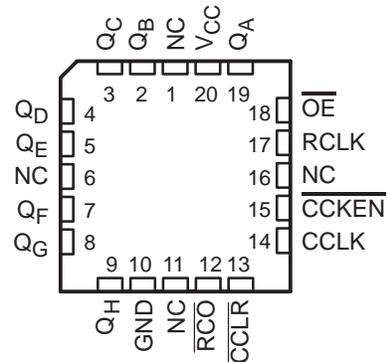
Both CCLK and the register clock (RCLK) input are positive-edge triggered. If both clocks are connected together, the counter state is always one count ahead of the register. Internal circuitry prevents clocking from the clock enable.

The SN54HC590A is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SN74HC590A is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

SN54HC590A . . . J OR W PACKAGE  
SN74HC590A . . . D, DW, OR N PACKAGE  
(TOP VIEW)



SN54HC590A . . . FK PACKAGE  
(TOP VIEW)



NC – No internal connection



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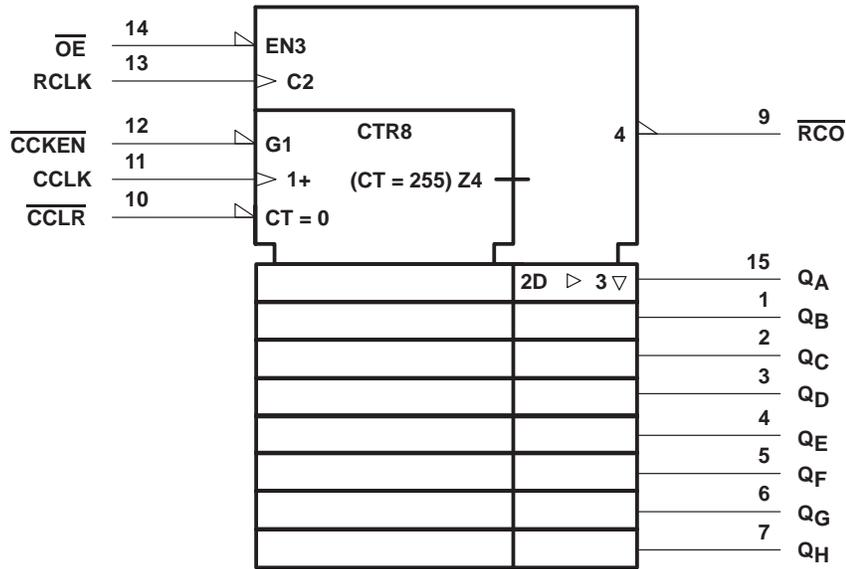
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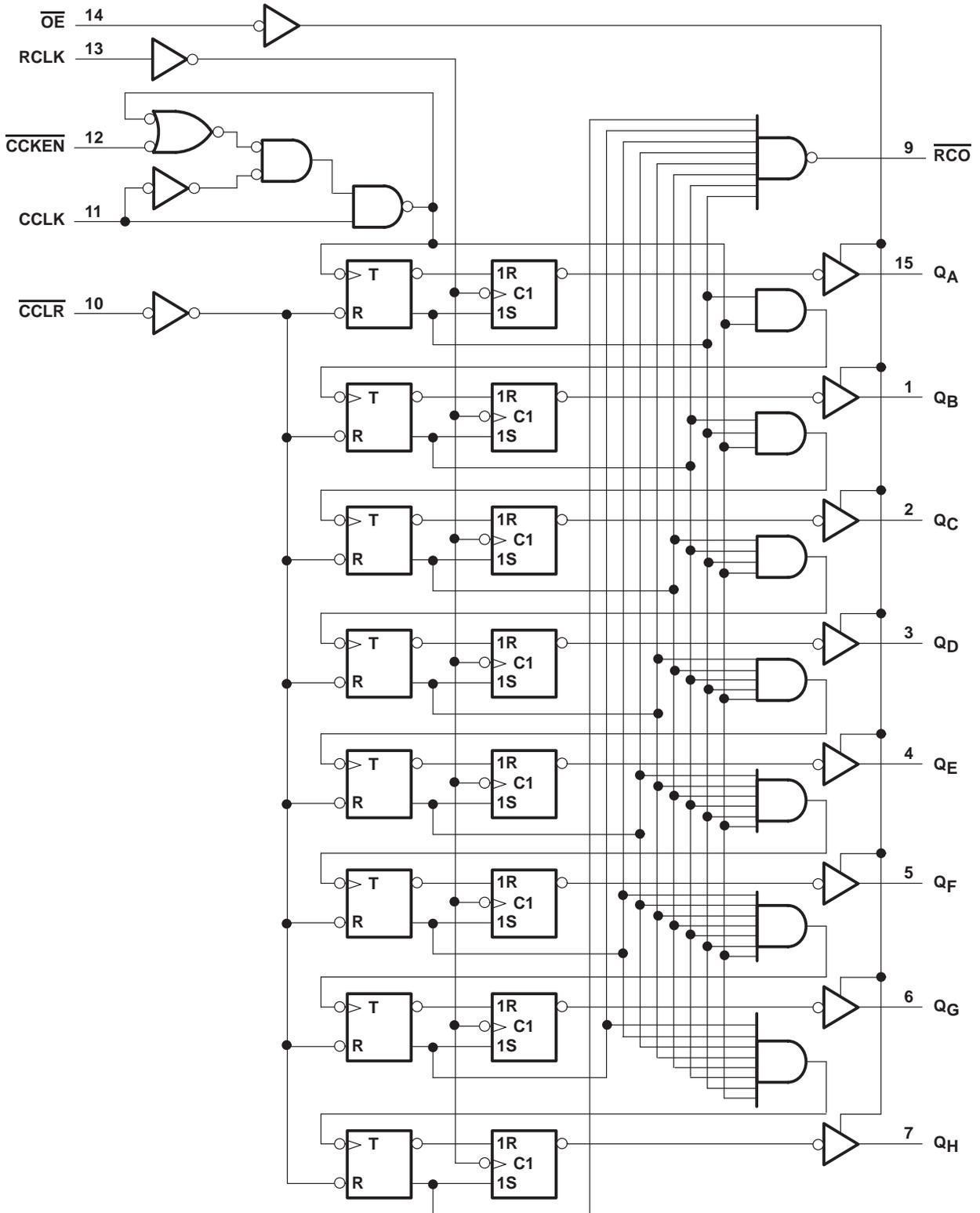
**SN54HC590A, SN74HC590A**  
**8-BIT BINARY COUNTERS**  
**WITH 3-STATE OUTPUT REGISTERS**  
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**logic symbol†**



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12. Pin numbers shown are for the D, DW, J, N, and W packages.

logic diagram (positive logic)



Pin numbers shown are for the D, DW, J, N, and W packages.

# SN54HC590A, SN74HC590A 8-BIT BINARY COUNTERS WITH 3-STATE OUTPUT REGISTERS

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## absolute maximum ratings over operating free-air temperature†

|   |                |
|---|----------------|
| Supply voltage range, $V_{CC}$  | -0.5 V to 7 V  |
| Input clamp current, $I_{IK}$ ( $V_I < 0$ or $V_I > V_{CC}$ ) (see Note 1)  | $\pm 20$ mA    |
| Output clamp current, $I_{OK}$ ( $V_O < 0$ or $V_O > V_{CC}$ ) (see Note 1) | $\pm 20$ mA    |
| Continuous output current, $I_O$ ( $V_O = 0$ to $V_{CC}$ )                  | $\pm 35$ mA    |
| Continuous current through $V_{CC}$ or GND                                  | $\pm 70$ mA    |
| Package thermal impedance, $\theta_{JA}$ (see Note 2): D package            | 113°C/W        |
| DW package  | 105°C/W        |
| N package   | 78°C/W         |
| Storage temperature range, $T_{stg}$  | -65°C to 150°C |

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.  
2. The package thermal impedance is calculated in accordance with JESD 51, except for through-hole packages, which use a trace length of zero.

## recommended operating conditions

|                |                                       | SN54HC590A       |          |      | SN74HC590A |          |      | UNIT |
|----------------|---------------------------------------|------------------|----------|------|------------|----------|------|------|
|                |                                       | MIN              | NOM      | MAX  | MIN        | NOM      | MAX  |      |
| $V_{CC}$       | Supply voltage                        | 2                | 5        | 6    | 2          | 5        | 6    | V    |
| $V_{IH}$       | High-level input voltage              | $V_{CC} = 2$ V   |          | 1.5  | 1.5        |          | V    |      |
|                |                                       | $V_{CC} = 4.5$ V |          | 3.15 | 3.15       |          |      |      |
|                |                                       | $V_{CC} = 6$ V   |          | 4.2  | 4.2        |          |      |      |
| $V_{IL}$       | Low-level input voltage               | $V_{CC} = 2$ V   |          | 0    | 0.5        | 0        | 0.5  | V    |
|                |                                       | $V_{CC} = 4.5$ V |          | 0    | 1.35       | 0        | 1.35 |      |
|                |                                       | $V_{CC} = 6$ V   |          | 0    | 1.8        | 0        | 1.8  |      |
| $V_I$          | Input voltage                         | 0                | $V_{CC}$ |      | 0          | $V_{CC}$ |      | V    |
| $V_O$          | Output voltage                        | 0                | $V_{CC}$ |      | 0          | $V_{CC}$ |      | V    |
| $t_t^\ddagger$ | Input transition (rise and fall) time | $V_{CC} = 2$ V   |          | 0    | 1000       | 0        | 1000 | ns   |
|                |                                       | $V_{CC} = 4.5$ V |          | 0    | 500        | 0        | 500  |      |
|                |                                       | $V_{CC} = 6$ V   |          | 0    | 400        | 0        | 400  |      |
| $T_A$          | Operating free-air temperature        | -55              | 125      |      | -40        | 85       |      | °C   |

‡ If this device is used in the threshold region (from  $V_{ILmax} = 0.5$  V to  $V_{IHmin} = 1.5$  V), there is a potential to go into the wrong state from induced grounding, causing double clocking. Operating with the inputs at  $t_t = 1000$  ns and  $V_{CC} = 2$  V does not damage the device; however, functionally, the CLK inputs are not ensured while in the shift, count, or toggle operating modes.



**SN54HC590A, SN74HC590A**  
**8-BIT BINARY COUNTERS**  
**WITH 3-STATE OUTPUT REGISTERS**  
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electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER       | TEST CONDITIONS   |                          | V <sub>CC</sub>  | T <sub>A</sub> = 25°C |       |      | SN54HC590A |     | SN74HC590A |     | UNIT |
|-----------------|---|--------------------------|--|-----------------------|-------|------|------------|-----|------------|-----|------|
|                 |   |                          |  | MIN                   | TYP   | MAX  | MIN        | MAX | MIN        | MAX |      |
| V <sub>OH</sub> | V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>       | I <sub>OH</sub> = -20 μA | 2 V  | 1.9                   | 1.998 |      | 1.9        |     | 1.9        | V   |      |
|                 |   |                          | 4.5 V  | 4.4                   | 4.499 |      | 4.4        |     | 4.4        |     |      |
|                 |   |                          | 6 V  | 5.9                   | 5.999 |      | 5.9        |     | 5.9        |     |      |
|                 |   | 4.5 V                    | $\overline{RCO}$ , I <sub>OH</sub> = -4 mA                 | 3.98                  | 4.3   |      | 3.7        |     | 3.84       |     |      |
|                 |   |                          | Q <sub>A</sub> -Q <sub>H</sub> , I <sub>OH</sub> = -6 mA   | 3.98                  | 4.3   |      | 3.7        |     | 3.84       |     |      |
|                 |   | 6 V                      | $\overline{RCO}$ , I <sub>OH</sub> = -5.2 mA               | 5.48                  | 5.8   |      | 5.2        |     | 5.34       |     |      |
|                 |   |                          | Q <sub>A</sub> -Q <sub>H</sub> , I <sub>OH</sub> = -7.8 mA | 5.48                  | 5.8   |      | 5.2        |     | 5.34       |     |      |
| V <sub>OL</sub> | V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>       | I <sub>OL</sub> = 20 μA  | 2 V  |                       | 0.002 | 0.1  |            | 0.1 |            | V   |      |
|                 |   |                          | 4.5 V  |                       | 0.001 | 0.1  |            | 0.1 |            |     |      |
|                 |   |                          | 6 V  |                       | 0.001 | 0.1  |            | 0.1 |            |     |      |
|                 |   | 4.5 V                    | $\overline{RCO}$ , I <sub>OL</sub> = 4 mA                  |                       | 0.17  | 0.26 |            | 0.4 |            |     | 0.33 |
|                 |   |                          | Q <sub>A</sub> -Q <sub>H</sub> , I <sub>OL</sub> = 6 mA    |                       | 0.17  | 0.26 |            | 0.4 |            |     | 0.33 |
|                 |   | 6 V                      | $\overline{RCO}$ , I <sub>OL</sub> = 5.2 mA                |                       | 0.15  | 0.26 |            | 0.4 |            |     | 0.33 |
|                 |   |                          | Q <sub>A</sub> -Q <sub>H</sub> , I <sub>OL</sub> = 7.8 mA  |                       | 0.15  | 0.26 |            | 0.4 |            |     | 0.33 |
| I <sub>I</sub>  | V <sub>I</sub> = V <sub>CC</sub> or 0                     | 6 V                      |  | ±0.1                  | ±100  |      | ±1000      |     | ±1000      | nA  |      |
| I <sub>OZ</sub> | V <sub>O</sub> = V <sub>CC</sub> or 0                     | 6 V                      |  | ±0.01                 | ±0.5  |      | ±10        |     | ±5         | μA  |      |
| I <sub>CC</sub> | V <sub>I</sub> = V <sub>CC</sub> or 0, I <sub>O</sub> = 0 | 6 V                      |  |                       | 8     |      | 160        |     | 80         | μA  |      |
| C <sub>i</sub>  |   | 2 V<br>to 6 V            |  | 3                     | 10    |      | 10         |     | 10         | pF  |      |

**SN54HC590A, SN74HC590A**  
**8-BIT BINARY COUNTERS**  
**WITH 3-STATE OUTPUT REGISTERS**

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timing requirements over recommended operating free-air temperature range (unless otherwise noted)

|                    |                                   | V <sub>CC</sub>          | T <sub>A</sub> = 25°C |     | SN54HC590A |     | SN74HC590A |     | UNIT |
|--------------------|-----------------------------------|--------------------------|-----------------------|-----|------------|-----|------------|-----|------|
|                    |                                   |                          | MIN                   | MAX | MIN        | MAX | MIN        | MAX |      |
| f <sub>clock</sub> | Clock frequency                   | 2 V                      | 0                     | 4   | 0          | 2.5 | 0          | 3.2 | MHz  |
|                    |                                   | 4.5 V                    | 0                     | 20  | 0          | 13  | 0          | 16  |      |
|                    |                                   | 6 V                      | 0                     | 24  | 0          | 16  | 0          | 19  |      |
| t <sub>w</sub>     | Pulse duration                    | CCLK or RCLK high or low | 2 V                   | 125 |            | 200 |            | 155 | ns   |
|                    |                                   |                          | 4.5 V                 | 25  |            | 38  |            | 31  |      |
|                    |                                   |                          | 6 V                   | 21  |            | 32  |            | 26  |      |
|                    | CCLR low                          | 2 V                      | 100                   |     | 150        |     | 125        |     |      |
|                    |                                   | 4.5 V                    | 20                    |     | 30         |     | 25         |     |      |
|                    |                                   | 6 V                      | 17                    |     | 26         |     | 21         |     |      |
| t <sub>su</sub>    | Setup time                        | CCKEN low before CCLK↑   | 2 V                   | 100 |            | 150 |            | 125 | ns   |
|                    |                                   |                          | 4.5 V                 | 20  |            | 30  |            | 25  |      |
|                    |                                   |                          | 6 V                   | 17  |            | 26  |            | 21  |      |
|                    | CCLR high (inactive) before CCLK↑ | 2 V                      | 100                   |     | 150        |     | 125        |     |      |
|                    |                                   | 4.5 V                    | 20                    |     | 30         |     | 25         |     |      |
|                    |                                   | 6 V                      | 17                    |     | 26         |     | 21         |     |      |
|                    | CCLK↑ before RCLK↑†               | 2 V                      | 100                   |     | 150        |     | 125        |     |      |
|                    |                                   | 4.5 V                    | 20                    |     | 30         |     | 25         |     |      |
|                    |                                   | 6 V                      | 17                    |     | 26         |     | 21         |     |      |
| t <sub>h</sub>     | Hold time                         | CCKEN low after CCLK↑    | 2 V                   | 50  |            | 75  |            | 60  | ns   |
|                    |                                   |                          | 4.5 V                 | 10  |            | 15  |            | 12  |      |
|                    |                                   |                          | 6 V                   | 9   |            | 13  |            | 11  |      |

† This setup time ensures that the register gets stable data from the counter outputs. The clocks may be tied together, in which case the register is one clock pulse behind the counter.



**SN54HC590A, SN74HC590A**  
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switching characteristics over recommended operating free-air temperature range,  $C_L = 50 \text{ pF}$   
(unless otherwise noted) (see Figure 1)

| PARAMETER        | FROM<br>(INPUT)                    | TO<br>(OUTPUT)          | $V_{CC}$ | SN54HC590A               |     |     |     | UNIT |     |
|------------------|------------------------------------|-------------------------|----------|--------------------------|-----|-----|-----|------|-----|
|                  |                                    |                         |          | $T_A = 25^\circ\text{C}$ |     |     | MIN |      | MAX |
|                  |                                    |                         |          | MIN                      | TYP | MAX |     |      |     |
| $f_{\text{max}}$ |                                    |                         | 2 V      | 4                        | 8   | 2.5 | MHz |      |     |
|                  |                                    |                         | 4.5 V    | 20                       | 35  | 13  |     |      |     |
|                  |                                    |                         | 6 V      | 24                       | 40  | 16  |     |      |     |
| $t_{\text{pd}}$  | CCLK $\uparrow$                    | $\overline{\text{RCO}}$ | 2 V      | 80                       | 150 | 225 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 20                       | 31  | 45  |     |      |     |
|                  |                                    |                         | 6 V      | 15                       | 26  | 38  |     |      |     |
| $t_{\text{PLH}}$ | $\overline{\text{CCLR}}\downarrow$ | $\overline{\text{RCO}}$ | 2 V      | 70                       | 130 | 195 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 18                       | 28  | 39  |     |      |     |
|                  |                                    |                         | 6 V      | 14                       | 23  | 33  |     |      |     |
| $t_{\text{pd}}$  | RCLK $\uparrow$                    | Q                       | 2 V      | 70                       | 140 | 210 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 18                       | 31  | 42  |     |      |     |
|                  |                                    |                         | 6 V      | 14                       | 25  | 36  |     |      |     |
| $t_{\text{en}}$  | $\overline{\text{OE}}\downarrow$   | Q                       | 2 V      | 80                       | 125 | 185 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 20                       | 30  | 37  |     |      |     |
|                  |                                    |                         | 6 V      | 15                       | 28  | 31  |     |      |     |
| $t_{\text{dis}}$ | $\overline{\text{OE}}\uparrow$     | Q                       | 2 V      | 80                       | 125 | 185 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 20                       | 30  | 37  |     |      |     |
|                  |                                    |                         | 6 V      | 15                       | 28  | 31  |     |      |     |
| $t_t^*$          |                                    | $\overline{\text{RCO}}$ | 2 V      | 38                       | 75  | 110 | ns  |      |     |
|                  |                                    |                         | 4.5 V    | 8                        | 15  | 22  |     |      |     |
|                  |                                    |                         | 6 V      | 6                        | 13  | 19  |     |      |     |
|                  |                                    | Q                       | 2 V      | 38                       | 60  | 90  |     |      |     |
|                  |                                    |                         | 4.5 V    | 8                        | 12  | 18  |     |      |     |
|                  |                                    |                         | 6 V      | 6                        | 10  | 15  |     |      |     |

\* This parameter is not production tested for the SN54HC590A.

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**8-BIT BINARY COUNTERS**  
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switching characteristics over recommended operating free-air temperature range,  $C_L = 50$  pF (unless otherwise noted) (see Figure 1)

| PARAMETER        | FROM (INPUT)        | TO (OUTPUT)      | V <sub>CC</sub> | SN74HC590A            |     |     |     | UNIT |     |
|------------------|---------------------|------------------|-----------------|-----------------------|-----|-----|-----|------|-----|
|                  |                     |                  |                 | T <sub>A</sub> = 25°C |     |     | MIN |      | MAX |
|                  |                     |                  |                 | MIN                   | TYP | MAX |     |      |     |
| f <sub>max</sub> |                     |                  | 2 V             | 4                     | 8   | 3.2 | MHz |      |     |
|                  |                     |                  | 4.5 V           | 20                    | 35  | 16  |     |      |     |
|                  |                     |                  | 6 V             | 24                    | 40  | 19  |     |      |     |
| t <sub>pd</sub>  | CCLK↑               | $\overline{RCO}$ | 2 V             |                       | 80  | 150 | 190 | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 20  | 30  | 38  |      |     |
|                  |                     |                  | 6 V             |                       | 15  | 26  | 33  |      |     |
| t <sub>PLH</sub> | $\overline{CCLR}$ ↓ | $\overline{RCO}$ | 2 V             |                       | 70  | 130 | 165 | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 18  | 26  | 33  |      |     |
|                  |                     |                  | 6 V             |                       | 14  | 22  | 28  |      |     |
| t <sub>pd</sub>  | RCLK↑               | Q                | 2 V             |                       | 70  | 140 | 175 | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 18  | 28  | 35  |      |     |
|                  |                     |                  | 6 V             |                       | 14  | 24  | 30  |      |     |
| t <sub>en</sub>  | $\overline{OE}$ ↓   | Q                | 2 V             |                       | 80  | 125 | 155 | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 20  | 25  | 31  |      |     |
|                  |                     |                  | 6 V             |                       | 15  | 21  | 26  |      |     |
| t <sub>dis</sub> | $\overline{OE}$ ↑   | Q                | 2 V             |                       | 80  | 125 | 155 | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 20  | 25  | 31  |      |     |
|                  |                     |                  | 6 V             |                       | 15  | 21  | 26  |      |     |
| t <sub>t</sub>   |                     | $\overline{RCO}$ | 2 V             |                       | 38  | 75  | 95  | ns   |     |
|                  |                     |                  | 4.5 V           |                       | 8   | 15  | 19  |      |     |
|                  |                     |                  | 6 V             |                       | 6   | 13  | 16  |      |     |
|                  |                     | Q                | 2 V             |                       | 38  | 60  | 75  |      |     |
|                  |                     |                  | 4.5 V           |                       | 8   | 12  | 15  |      |     |
|                  |                     |                  | 6 V             |                       | 6   | 10  | 13  |      |     |



**SN54HC590A, SN74HC590A**  
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switching characteristics over recommended operating free-air temperature range,  $C_L = 150$  pF (unless otherwise noted) (see Figure 1)

| PARAMETER | FROM (INPUT)    | TO (OUTPUT) | $V_{CC}$ | SN54HC590A               |     |     |     | UNIT |     |
|-----------|-----------------|-------------|----------|--------------------------|-----|-----|-----|------|-----|
|           |                 |             |          | $T_A = 25^\circ\text{C}$ |     |     | MIN |      | MAX |
|           |                 |             |          | MIN                      | TYP | MAX |     |      |     |
| $t_{pd}$  | RCLK $\uparrow$ | Q           | 2 V      | 100                      | 300 | 447 | ns  |      |     |
|           |                 |             | 4.5 V    | 24                       | 60  | 90  |     |      |     |
|           |                 |             | 6 V      | 20                       | 51  | 77  |     |      |     |
| $t_{en}$  | $\overline{OE}$ | Q           | 2 V      | 90                       | 200 | 300 | ns  |      |     |
|           |                 |             | 4.5 V    | 23                       | 40  | 60  |     |      |     |
|           |                 |             | 6 V      | 19                       | 34  | 51  |     |      |     |
| $t_t^*$   |                 | Q           | 2 V      | 45                       | 210 | 315 | ns  |      |     |
|           |                 |             | 4.5 V    | 17                       | 42  | 63  |     |      |     |
|           |                 |             | 6 V      | 13                       | 36  | 53  |     |      |     |

\* This parameter is not production tested for the SN54HC590A.

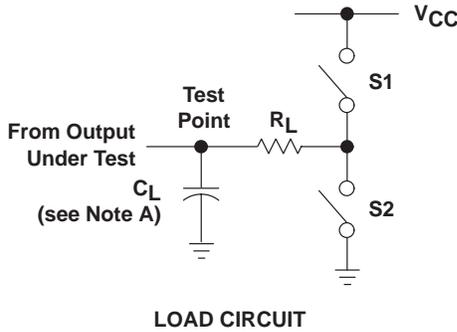
switching characteristics over recommended operating free-air temperature range,  $C_L = 150$  pF (unless otherwise noted) (see Figure 1)

| PARAMETER | FROM (INPUT)    | TO (OUTPUT) | $V_{CC}$ | SN74HC590A               |     |     |     | UNIT |     |
|-----------|-----------------|-------------|----------|--------------------------|-----|-----|-----|------|-----|
|           |                 |             |          | $T_A = 25^\circ\text{C}$ |     |     | MIN |      | MAX |
|           |                 |             |          | MIN                      | TYP | MAX |     |      |     |
| $t_{pd}$  | RCLK $\uparrow$ | Q           | 2 V      | 100                      | 300 | 380 | ns  |      |     |
|           |                 |             | 4.5 V    | 24                       | 60  | 76  |     |      |     |
|           |                 |             | 6 V      | 20                       | 51  | 65  |     |      |     |
| $t_{en}$  | $\overline{OE}$ | Q           | 2 V      | 90                       | 200 | 250 | ns  |      |     |
|           |                 |             | 4.5 V    | 23                       | 40  | 50  |     |      |     |
|           |                 |             | 6 V      | 19                       | 34  | 43  |     |      |     |
| $t_t$     |                 | Q           | 2 V      | 45                       | 210 | 265 | ns  |      |     |
|           |                 |             | 4.5 V    | 17                       | 42  | 53  |     |      |     |
|           |                 |             | 6 V      | 13                       | 36  | 45  |     |      |     |

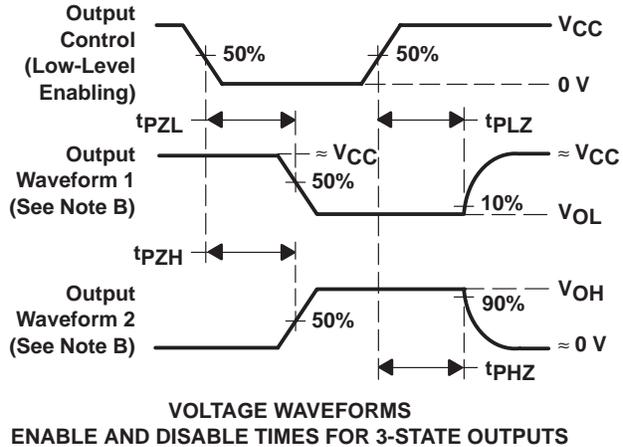
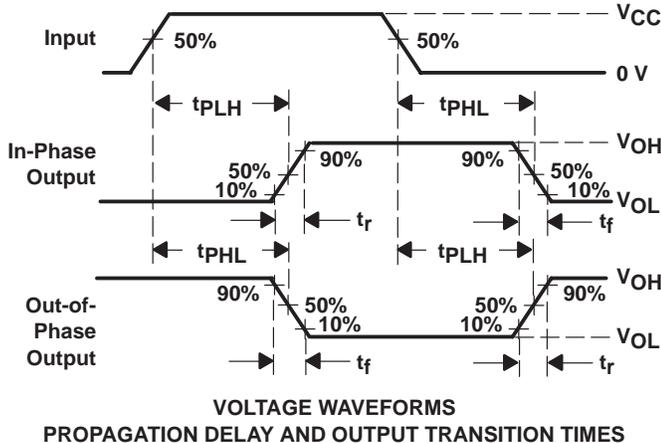
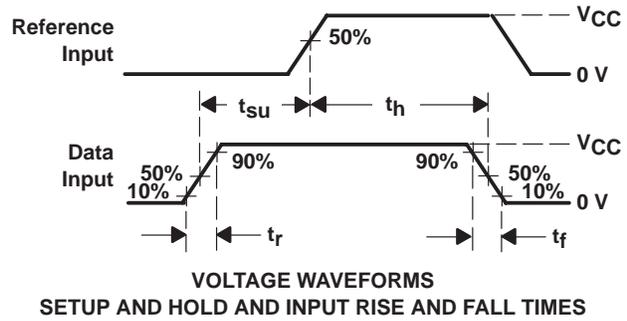
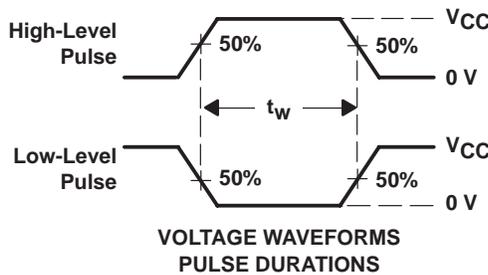
operating characteristics,  $T_A = 25^\circ\text{C}$

| PARAMETER                              | TEST CONDITIONS | TYP | UNIT |
|--|-----------------|-----|------|
| $C_{pd}$ Power dissipation capacitance | No load         | 250 | pF   |

PARAMETER MEASUREMENT INFORMATION



| PARAMETER         | $R_L$        | $C_L$           | S1     | S2     |
|-------------------|--------------|-----------------|--------|--------|
| $t_{en}$          | 1 k $\Omega$ | 50 pF or 150 pF | Open   | Closed |
|                   |              |                 | Closed | Open   |
| $t_{dis}$         | 1 k $\Omega$ | 50 pF           | Open   | Closed |
|                   |              |                 | Closed | Open   |
| $t_{pd}$ or $t_t$ | —            | 50 pF or 150 pF | Open   | Open   |



- NOTES: A.  $C_L$  includes probe and test-fixture capacitance.  
 B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.  
 C. Phase relationships between waveforms were chosen arbitrarily. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 1$  MHz,  $Z_O = 50 \Omega$ ,  $t_r = 6$  ns,  $t_f = 6$  ns.  
 D. For clock inputs,  $f_{max}$  is measured when the input duty cycle is 50%.  
 E. The outputs are measured one at a time with one input transition per measurement.  
 F.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .  
 G.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .  
 H.  $t_{PLH}$  and  $t_{PHL}$  are the same as  $t_{pd}$ .

Figure 1. Load Circuit and Voltage Waveforms

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