

## Dual J-K Flip-Flop with Set and Reset Negative-Edge Trigger

March 1998

### Features

- Hysteresis on Clock Inputs for Improved Noise Immunity and Increased Input Rise and Fall Times
- Asynchronous Set and Reset
- Complementary Outputs
- Buffered Inputs
- Typical  $f_{MAX} = 60\text{MHz}$  at  $V_{CC} = 5\text{V}$ ,  $C_L = 15\text{pF}$ ,  $T_A = 25^\circ\text{C}$
- Fanout (Over Temperature Range)
  - Standard Outputs . . . . . 10 LSTTL Loads
  - Bus Driver Outputs . . . . . 15 LSTTL Loads
- Wide Operating Temperature Range . . .  $-55^\circ\text{C}$  to  $125^\circ\text{C}$
- Balanced Propagation Delay and Transition Times
- Significant Power Reduction Compared to LSTTL Logic ICs
- HC Types
  - 2V to 6V Operation
  - High Noise Immunity:  $N_{IL} = 30\%$ ,  $N_{IH} = 30\%$  of  $V_{CC}$  at  $V_{CC} = 5\text{V}$
- HCT Types
  - 4.5V to 5.5V Operation
  - Direct LSTTL Input Logic Compatibility,  $V_{IL} = 0.8\text{V (Max)}$ ,  $V_{IH} = 2\text{V (Min)}$
  - CMOS Input Compatibility,  $I_I \leq 1\mu\text{A}$  at  $V_{OL}$ ,  $V_{OH}$

### Description

The Harris CD74HC112 and CD74HCT112 utilize silicon-gate CMOS technology to achieve operating speeds equivalent to LSTTL parts. They exhibit the low power consumption of standard CMOS integrated circuits, together with the ability to drive 10 LSTTL loads.

These flip-flops have independent J, K, Set, Reset, and Clock inputs and Q and  $\bar{Q}$  outputs. They change state on the negative-going transition of the clock pulse. Set and Reset are accomplished asynchronously by low-level inputs.

The 74HCT logic family is functionally as well as pin-compatible with the standard 74LS logic family.

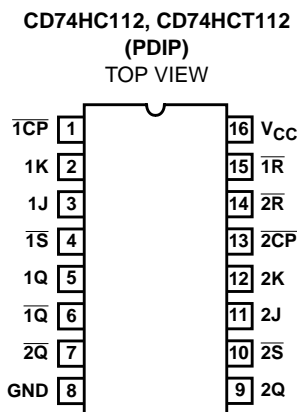
### Ordering Information

| PART NUMBER | TEMP. RANGE<br>( $^\circ\text{C}$ ) | PACKAGE    | PKG.<br>NO. |
|-------------|-------------------------------------|------------|-------------|
| CD74HC112E  | -55 to 125                          | 16 Ld PDIP | E16.3       |
| CD74HCT112E | -55 to 125                          | 16 Ld PDIP | E16.3       |

#### NOTES:

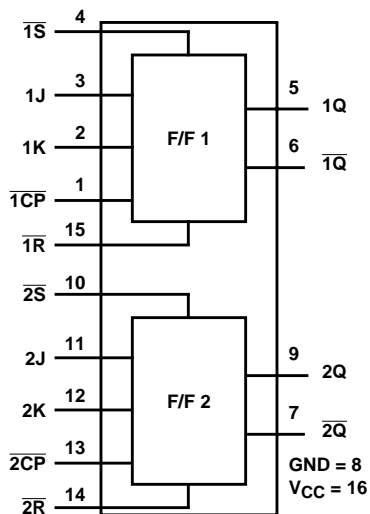
1. When ordering, use the entire part number. Add the suffix 96 to obtain the variant in the tape and reel.
2. Wafer and die is available which meets all electrical specifications. Please contact your local sales office or Harris customer service for ordering information.

### Pinout



# CD74HC112, CD74HCT112

## Functional Diagram



TRUTH TABLE

| INPUTS    |           |            |   |   | OUTPUTS    |            |
|-----------|-----------|------------|---|---|------------|------------|
| $\bar{S}$ | $\bar{R}$ | $\bar{CP}$ | J | K | Q          | $\bar{Q}$  |
| L         | H         | X          | X | X | H          | L          |
| H         | L         | X          | X | X | L          | H          |
| L         | L         | X          | X | X | H (Note 3) | H (Note 3) |
| H         | H         | ↓          | L | L | No Change  |            |
| H         | H         | ↓          | H | L |            |            |
| H         | H         | ↓          | L | H |            |            |
| H         | H         | ↓          | H | H | Toggle     |            |
| H         | H         | H          | X | X | No Change  |            |

### NOTE:

H = High Level (Steady State)

L = Low Level (Steady State)

X = Don't Care

↓ = High-to-Low Transition

- Output states unpredictable if both  $\bar{S}$  and  $\bar{R}$  go High simultaneously after both being low at the same time.

# CD74HC112, CD74HCT112

## Absolute Maximum Ratings

DC Supply Voltage,  $V_{CC}$  ..... -0.5V to 7V  
 DC Input Diode Current,  $I_{IK}$   
 For  $V_I < -0.5V$  or  $V_I > V_{CC} + 0.5V$  .....  $\pm 20mA$   
 DC Drain Current, per Output,  $I_O$   
 For  $-0.5V < V_O < V_{CC} + 0.5V$  .....  $\pm 25mA$   
 DC Output Diode Current,  $I_{OK}$   
 For  $V_O < -0.5V$  or  $V_O > V_{CC} + 0.5V$  .....  $\pm 20mA$   
 DC Output Source or Sink Current per Output Pin,  $I_O$   
 For  $V_O > -0.5V$  or  $V_O < V_{CC} + 0.5V$  .....  $\pm 25mA$   
 DC  $V_{CC}$  or Ground Current,  $I_{CC}$  .....  $\pm 50mA$

## Thermal Information

Thermal Resistance (Typical, Note 4)  $\theta_{JA}$  ( $^{\circ}C/W$ )  
 PDIP Package ..... 90  
 Maximum Junction Temperature (Hermetic Package or Die) ... 175 $^{\circ}C$   
 Maximum Junction Temperature (Plastic Package) ..... 150 $^{\circ}C$   
 Maximum Storage Temperature Range ..... -65 $^{\circ}C$  to 150 $^{\circ}C$   
 Maximum Lead Temperature (Soldering 10s) ..... 300 $^{\circ}C$

## Operating Conditions

Temperature Range,  $T_A$  ..... -55 $^{\circ}C$  to 125 $^{\circ}C$   
 Supply Voltage Range,  $V_{CC}$   
 HC Types ..... 2V to 6V  
 HCT Types ..... 4.5V to 5.5V  
 DC Input or Output Voltage,  $V_I$ ,  $V_O$  ..... 0V to  $V_{CC}$   
 Input Rise and Fall Time,  $t_r$ ,  $t_f$   
 2V ..... 1.0ms (Max)  
 4.5V ..... 1.0ms (Max)  
 6V ..... 1.0ms (Max)

**CAUTION:** Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

- $\theta_{JA}$  is measured with the component mounted on an evaluation PC board in free air.

## DC Electrical Specifications

| PARAMETER                               | SYMBOL          | TEST CONDITIONS                       |                     | V <sub>CC</sub> (V) | 25°C |     |      | -40°C TO 85°C |      | -55°C TO 125°C |      | UNITS |
|---|-----------------|---------------------------------------|---------------------|---------------------|------|-----|------|---------------|------|----------------|------|-------|
|   |                 | V <sub>I</sub> (V)                    | I <sub>O</sub> (mA) |                     | MIN  | TYP | MAX  | MIN           | MAX  | MIN            | MAX  |       |
| HC TYPES                                |                 |                                       |                     |                     |      |     |      |               |      |                |      |       |
| High Level Input Voltage                | V <sub>IH</sub> | -                                     | -                   | 2                   | 1.5  | -   | -    | 1.5           | -    | 1.5            | -    | V     |
|   |                 |                                       |                     | 4.5                 | 3.15 | -   | -    | 3.15          | -    | 3.15           | -    | V     |
|   |                 |                                       |                     | 6                   | 4.2  | -   | -    | 4.2           | -    | 4.2            | -    | V     |
| Low Level Input Voltage                 | V <sub>IL</sub> | -                                     | -                   | 2                   | -    | -   | 0.5  | -             | 0.5  | -              | 0.5  | V     |
|   |                 |                                       |                     | 4.5                 | -    | -   | 1.35 | -             | 1.35 | -              | 1.35 | V     |
|   |                 |                                       |                     | 6                   | -    | -   | 1.8  | -             | 1.8  | -              | 1.8  | V     |
| High Level Output Voltage<br>CMOS Loads | V <sub>OH</sub> | V <sub>IH</sub> or<br>V <sub>IL</sub> | -0.02               | 2                   | 1.9  | -   | -    | 1.9           | -    | 1.9            | -    | V     |
|   |                 |                                       |                     | 4.5                 | 4.4  | -   | -    | 4.4           | -    | 4.4            | -    | V     |
|   |                 |                                       |                     | 6                   | 5.9  | -   | -    | 5.9           | -    | 5.9            | -    | V     |
| High Level Output Voltage<br>TTL Loads  |                 |                                       | -                   | -                   | -    | -   | -    | -             | -    | -              | -    | V     |
|   |                 |                                       | -4                  | 4.5                 | 3.98 | -   | -    | 3.84          | -    | 3.7            | -    | V     |
|   |                 |                                       | -5.2                | 6                   | 5.48 | -   | -    | 5.34          | -    | 5.2            | -    | V     |
| Low Level Output Voltage<br>CMOS Loads  | V <sub>OL</sub> | V <sub>IH</sub> or<br>V <sub>IL</sub> | 0.02                | 2                   | -    | -   | 0.1  | -             | 0.1  | -              | 0.1  | V     |
|   |                 |                                       |                     | 4.5                 | -    | -   | 0.1  | -             | 0.1  | -              | 0.1  | V     |
|   |                 |                                       |                     | 6                   | -    | -   | 0.1  | -             | 0.1  | -              | 0.1  | V     |
| Low Level Output Voltage<br>TTL Loads   |                 |                                       | -                   | -                   | -    | -   | -    | -             | -    | -              | -    | V     |
|   |                 |                                       | 4                   | 4.5                 | -    | -   | 0.26 | -             | 0.33 | -              | 0.4  | V     |
|   |                 |                                       | 5.2                 | 6                   | -    | -   | 0.26 | -             | 0.33 | -              | 0.4  | V     |
| Input Leakage Current                   | I <sub>I</sub>  | V <sub>CC</sub> or<br>GND             | -                   | 6                   | -    | -   | ±0.1 | -             | ±1   | -              | ±1   | μA    |

# CD74HC112, CD74HCT112

## DC Electrical Specifications (Continued)

| PARAMETER  | SYMBOL          | TEST CONDITIONS      |            | $V_{CC}$ (V) | 25°C |     |           | -40°C TO 85°C |         | -55°C TO 125°C |         | UNITS   |
|--|-----------------|----------------------|------------|--------------|------|-----|-----------|---------------|---------|----------------|---------|---------|
|  |                 | $V_I$ (V)            | $I_O$ (mA) |              | MIN  | TYP | MAX       | MIN           | MAX     | MIN            | MAX     |         |
| Quiescent Device Current                                       | $I_{CC}$        | $V_{CC}$ or GND      | 0          | 6            | -    | -   | 4         | -             | 40      | -              | 80      | $\mu A$ |
| <b>HCT TYPES</b>   |                 |                      |            |              |      |     |           |               |         |                |         |         |
| High Level Input Voltage                                       | $V_{IH}$        | -                    | -          | 4.5 to 5.5   | 2    | -   | -         | 2             | -       | 2              | -       | V       |
| Low Level Input Voltage  | $V_{IL}$        | -                    | -          | 4.5 to 5.5   | -    | -   | 0.8       | -             | 0.8     | -              | 0.8     | V       |
| High Level Output Voltage<br>CMOS Loads                        | $V_{OH}$        | $V_{IH}$ or $V_{IL}$ | -          | 4.5          | 4.4  | -   | -         | 4.4           | -       | 4.4            | -       | V       |
| High Level Output Voltage<br>TTL Loads                         |                 |                      | -0.02      | 4.5          | 3.98 | -   | -         | 3.84          | -       | 3.7            | -       | V       |
| Low Level Output Voltage CMOS Loads                            | $V_{OL}$        | $V_{IH}$ or $V_{IL}$ | -4         | 4.5          | -    | -   | 0.1       | -             | 0.1     | -              | 0.1     | V       |
| Low Level Output Voltage<br>TTL Loads                          |                 |                      | 0.02       | 4.5          | -    | -   | 0.26      | -             | 0.33    | -              | 0.4     | V       |
| Input Leakage Current  | $I_I$           | $V_{CC}$ and GND     | 4          | 5.5          | -    |     | $\pm 0.1$ | -             | $\pm 1$ | -              | $\pm 1$ | $\mu A$ |
| Quiescent Device Current                                       | $I_{CC}$        | $V_{CC}$ or GND      | 0          | 5.5          | -    | -   | 4         | -             | 40      | -              | 80      | $\mu A$ |
| Additional Quiescent Device Current Per Input Pin: 1 Unit Load | $\Delta I_{CC}$ | $V_{CC} - 2.1$       | -          | 4.5 to 5.5   | -    | 100 | 360       | -             | 450     | -              | 490     | $\mu A$ |

NOTE:

- For dual-supply systems theoretical worst case ( $V_I = 2.4V$ ,  $V_{CC} = 5.5V$ ) specification is 1.8mA.

## HCT Input Loading Table

| INPUT            | UNIT LOADS |
|------------------|------------|
| 1S, 2S           | 0.5        |
| 1K, 2K           | 0.6        |
| 1R, 2R           | 0.65       |
| 1J, 2J, 1CP, 2CP | 1          |

NOTE: Unit Load is  $\Delta I_{CC}$  limit specified in DC Electrical Specifications table, e.g., 360 $\mu A$  max at 25°C.

## Prerequisite For Switching Specifications

| PARAMETER                   | SYMBOL         | TEST<br>CONDITIONS | V <sub>CC</sub><br>(V) | 25°C |     |     | -40°C TO 85°C |     | -55°C TO 125°C |     | UNITS |
|-----------------------------|----------------|--------------------|------------------------|------|-----|-----|---------------|-----|----------------|-----|-------|
|                             |                |                    |                        | MIN  | TYP | MAX | MIN           | MAX | MIN            | MAX |       |
| HC TYPES                    |                |                    |                        |      |     |     |               |     |                |     |       |
| Pulse Width $\overline{CP}$ | t <sub>W</sub> | -                  | 2                      | 80   | -   | -   | 100           | -   | 120            | -   | ns    |
|                             |                |                    | 4.5                    | 16   | -   | -   | 20            | -   | 24             | -   | ns    |
|                             |                |                    | 6                      | 14   | -   | -   | 17            | -   | 20             | -   | ns    |

# CD74HC112, CD74HCT112

## Prerequisite For Switching Specifications (Continued)

| PARAMETER  | SYMBOL    | TEST CONDITIONS | V <sub>CC</sub><br>(V) | 25°C |     |     | -40°C TO 85°C |     | -55°C TO 125°C |     | UNITS |
|--|-----------|-----------------|------------------------|------|-----|-----|---------------|-----|----------------|-----|-------|
|  |           |                 |                        | MIN  | TYP | MAX | MIN           | MAX | MIN            | MAX |       |
| Pulse Width $\bar{R}$ , $\bar{S}$                              | $t_W$     | -               | 2                      | 80   | -   | -   | 100           | -   | 120            | -   | ns    |
|  |           |                 | 4.5                    | 16   | -   | -   | 20            | -   | 24             | -   | ns    |
|  |           |                 | 6                      | 14   | -   | -   | 17            | -   | 20             | -   | ns    |
| Setup Time J, K, to $\bar{CP}$                                 | $t_{SU}$  | -               | 2                      | 80   | -   | -   | 100           | -   | 120            | -   | ns    |
|  |           |                 | 4.5                    | 16   | -   | -   | 20            | -   | 24             | -   | ns    |
|  |           |                 | 6                      | 14   | -   | -   | 17            | -   | 20             | -   | ns    |
| Hold Time J, K, to $\bar{CP}$                                  | $t_H$     | -               | 2                      | 0    | -   | -   | 0             | -   | 0              | -   | ns    |
|  |           |                 | 4.5                    | 0    | -   | -   | 0             | -   | 0              | -   | ns    |
|  |           |                 | 6                      | 0    | -   | -   | 0             | -   | 0              | -   | ns    |
| Removal Time $\bar{R}$ to $\bar{CP}$ , $\bar{S}$ to $\bar{CP}$ | $t_{REM}$ | -               | 2                      | 80   | -   | -   | 100           | -   | 120            | -   | ns    |
|  |           |                 | 4.5                    | 16   | -   | -   | 20            | -   | 24             | -   | ns    |
|  |           |                 | 6                      | 14   | -   | -   | 17            | -   | 20             | -   | ns    |
| $\bar{CP}$ Frequency   | $f_{MAX}$ | -               | 2                      | 6    | -   | -   | 5             | -   | 4              | -   | MHz   |
|  |           |                 | 4.5                    | 30   | -   | -   | 25            | -   | 20             | -   | MHz   |
|  |           |                 | 6                      | 35   | -   | -   | 29            | -   | 23             | -   | MHz   |

### HCT TYPES

|  |           |   |     |    |   |   |    |   |    |   |     |
|--|-----------|---|-----|----|---|---|----|---|----|---|-----|
| Pulse Width $\bar{CP}$   | $t_{SU}$  | - | 4.5 | 16 | - | - | 20 | - | 24 | - | ns  |
| Pulse Width $\bar{R}$ , $\bar{S}$                              | $t_W$     | - | 4.5 | 18 | - | - | 23 | - | 27 | - | ns  |
| Setup Time J, K, to $\bar{CP}$                                 | $t_H$     | - | 4.5 | 16 | - | - | 20 | - | 24 | - | ns  |
| Hold Time J, K, to $\bar{CP}$                                  | $t_{REM}$ | - | 4.5 | 3  | - | - | 3  | - | 3  | - | ns  |
| Removal Time $\bar{R}$ to $\bar{CP}$ , $\bar{S}$ to $\bar{CP}$ | $t_W$     | - | 4.5 | 20 | - | - | 25 | - | 30 | - | ns  |
| $\bar{CP}$ Frequency   | $f_{MAX}$ | - | 4.5 | 30 | - | - | 25 | - | 20 | - | MHz |

## Switching Specifications Input $t_r$ , $t_f$ = 6ns

| PARAMETER                         | SYMBOL                              | TEST CONDITIONS       | V <sub>CC</sub> (V) | 25°C |     |     | -40°C TO 85°C |     | -55°C TO 125°C |     | UNITS |
|-----------------------------------|-------------------------------------|-----------------------|---------------------|------|-----|-----|---------------|-----|----------------|-----|-------|
|                                   |                                     |                       |                     | MIN  | TYP | MAX | MIN           | MAX | MIN            | MAX |       |
| HC TYPES                          |                                     |                       |                     |      |     |     |               |     |                |     |       |
| Propagation Delay,<br>CP to Q, Q̄ | t <sub>PLH</sub> , t <sub>PHL</sub> | C <sub>L</sub> = 50pF | 2                   | -    | -   | 175 | -             | 220 | -              | 265 | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 4.5                 | -    | -   | 35  | -             | 44  | -              | 53  | ns    |
|                                   |                                     | C <sub>L</sub> = 15pF | 5                   | -    | 14  | -   | -             | -   | -              | -   | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 6                   | -    | -   | 30  | -             | 37  | -              | 45  | ns    |
| Propagation Delay,<br>S to Q, Q̄  | t <sub>PLH</sub> , t <sub>PHL</sub> | C <sub>L</sub> = 50pF | 2                   | -    | -   | 155 | -             | 195 | -              | 235 | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 4.5                 | -    | -   | 31  | -             | 39  | -              | 47  | ns    |
|                                   |                                     | C <sub>L</sub> = 15pF | 5                   | -    | 13  | -   | -             | -   | -              | -   | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 6                   | -    | -   | 26  | -             | 33  | -              | 40  | ns    |
| Propagation Delay,<br>R to Q, Q̄  | t <sub>PLH</sub> , t <sub>PHL</sub> | C <sub>L</sub> = 50pF | 2                   | -    | -   | 180 | -             | 225 | -              | 270 | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 4.5                 | -    | -   | 36  | -             | 45  | -              | 54  | ns    |
|                                   |                                     | C <sub>L</sub> = 15pF | 5                   | -    | 15  | -   | -             | -   | -              | -   | ns    |
|                                   |                                     | C <sub>L</sub> = 50pF | 6                   | -    | -   | 31  | -             | 38  | -              | 46  | ns    |

# CD74HC112, CD74HCT112

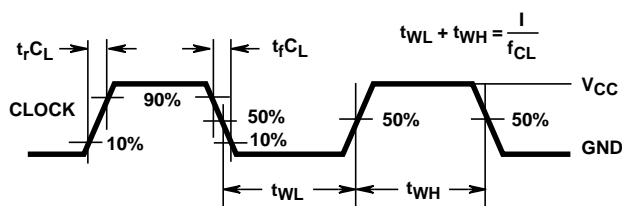
## Switching Specifications Input $t_r, t_f = 6\text{ns}$ (Continued)

| PARAMETER                                       | SYMBOL             | TEST CONDITIONS     | $V_{CC}$<br>(V) | 25°C |     |     | -40°C TO 85°C |     | -55°C TO 125°C |     | UNITS |
|---|--------------------|---------------------|-----------------|------|-----|-----|---------------|-----|----------------|-----|-------|
|   |                    |                     |                 | MIN  | TYP | MAX | MIN           | MAX | MIN            | MAX |       |
| Output Transition Time                          | $t_{TLH}, t_{THL}$ | $C_L = 50\text{pF}$ | 2               | -    | -   | 75  | -             | 95  | -              | 110 | ns    |
|   |                    | $C_L = 50\text{pF}$ | 4.5             | -    | -   | 15  | -             | 19  | -              | 22  | ns    |
|   |                    | $C_L = 50\text{pF}$ | 6               | -    | -   | 13  | -             | 16  | -              | 19  | ns    |
| Input Capacitance                               | $C_I$              | -                   | -               | -    | -   | 10  | -             | 10  | -              | 10  | pF    |
| CP Frequency                                    | $f_{MAX}$          | $C_L = 15\text{pF}$ | 5               | -    | 60  | -   | -             | -   | -              | -   | MHz   |
| Power Dissipation Capacitance<br>(Notes 6, 7)   | $C_{PD}$           | -                   | 5               | -    | 12  | -   | -             | -   | -              | -   | pF    |
| <b>HCT TYPES</b>                                |                    |                     |                 |      |     |     |               |     |                |     |       |
| Propagation Delay,<br>CP to Q, $\bar{Q}$        | $t_{PLH}, t_{PHL}$ | $C_L = 50\text{pF}$ | 4.5             | -    | -   | 35  | -             | 44  | -              | 53  | ns    |
|   |                    | $C_L = 15\text{pF}$ | 5               | -    | 14  | -   | -             | -   | -              | -   | ns    |
| Propagation Delay,<br>$\bar{S}$ to Q, $\bar{Q}$ | $t_{PLH}, t_{PHL}$ | $C_L = 50\text{pF}$ | 4.5             | -    | -   | 32  | -             | 40  | -              | 48  | ns    |
|   |                    | $C_L = 15\text{pF}$ | 5               | -    | 13  | -   | -             | -   | -              | -   | ns    |
| Propagation Delay,<br>$\bar{R}$ to Q, $\bar{Q}$ | $t_{PLH}, t_{PHL}$ | $C_L = 50\text{pF}$ | 4.5             | -    | -   | 37  | -             | 46  | -              | 56  | ns    |
|   |                    | $C_L = 15\text{pF}$ | 5               | -    | 14  | -   | -             | -   | -              | -   | ns    |
| Output Transition Time                          | $t_{TLH}, t_{THL}$ | $C_L = 50\text{pF}$ | 4.5             | -    | -   | 15  | -             | 19  | -              | 22  | ns    |
| Input Capacitance                               | $C_I$              | -                   | -               | -    | -   | 10  | -             | 10  | -              | 10  | pF    |
| CP Frequency                                    | $f_{MAX}$          | $C_L = 15\text{pF}$ | 5               | -    | 60  | -   | -             | -   | -              | -   | MHz   |
| Power Dissipation Capacitance<br>(Notes 6, 7)   | $C_{PD}$           | -                   | 5               | -    | 20  | -   | -             | -   | -              | -   | pF    |

### NOTES:

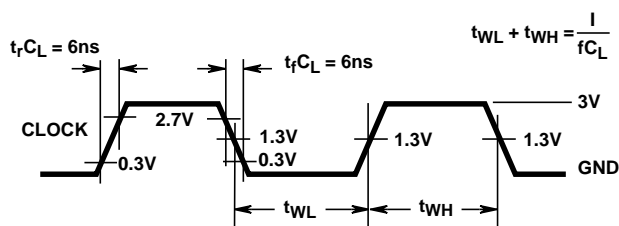
- $C_{PD}$  is used to determine the dynamic power consumption, per flip-flop.
- $P_D = C_{PD} V_{CC}^2 f_i + \sum C_L f_o$  where  $f_i$  = input frequency,  $f_o$  = output frequency,  $C_L$  = output load capacitance,  $V_{CC}$  = supply voltage.

## Test Circuits and Waveforms



NOTE: Outputs should be switching from 10%  $V_{CC}$  to 90%  $V_{CC}$  in accordance with device truth table. For  $f_{MAX}$ , input duty cycle = 50%.

**FIGURE 1. HC CLOCK PULSE RISE AND FALL TIMES AND PULSE WIDTH**



NOTE: Outputs should be switching from 10%  $V_{CC}$  to 90%  $V_{CC}$  in accordance with device truth table. For  $f_{MAX}$ , input duty cycle = 50%.

**FIGURE 2. HCT CLOCK PULSE RISE AND FALL TIMES AND PULSE WIDTH**

Test Circuits and Waveforms (Continued)

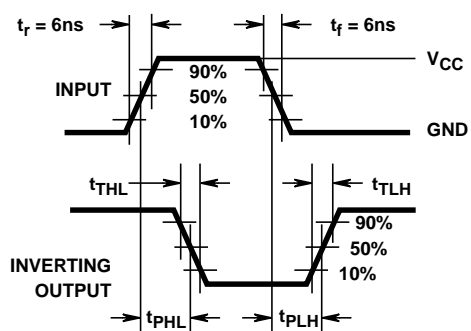


FIGURE 3. HC AND HCU TRANSITION TIMES AND PROPAGATION DELAY TIMES, COMBINATION LOGIC

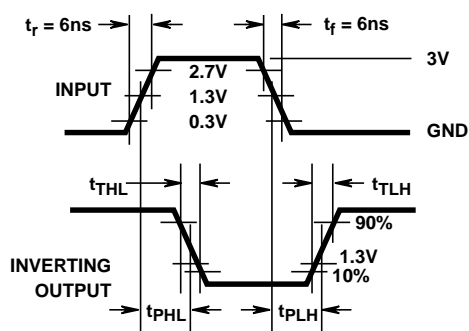


FIGURE 4. HCT TRANSITION TIMES AND PROPAGATION DELAY TIMES, COMBINATION LOGIC

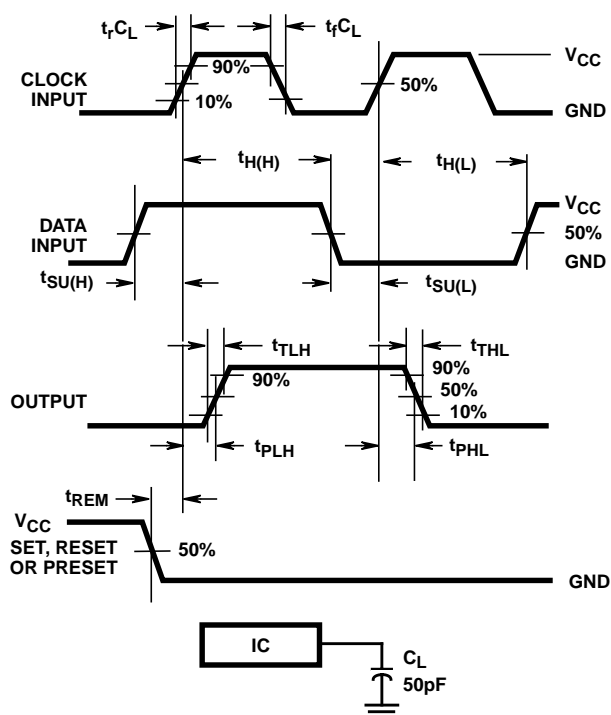


FIGURE 5. HC SETUP TIMES, HOLD TIMES, REMOVAL TIME, AND PROPAGATION DELAY TIMES FOR EDGE TRIGGERED SEQUENTIAL LOGIC CIRCUITS

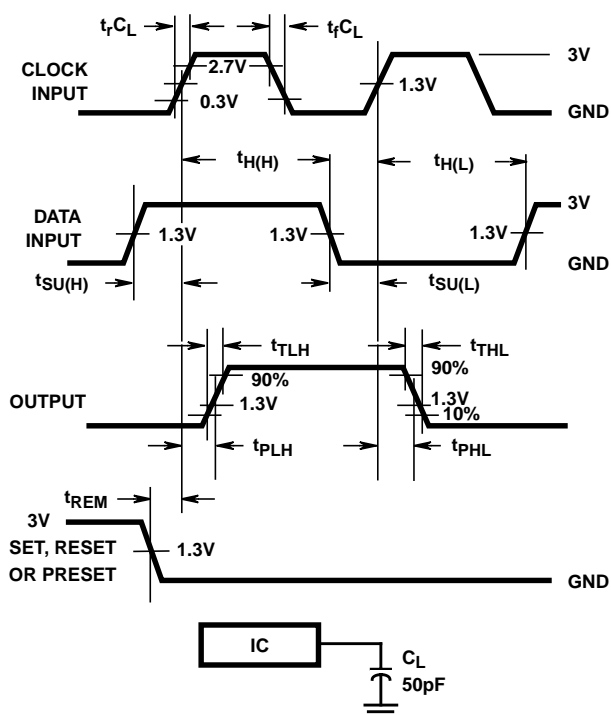


FIGURE 6. HCT SETUP TIMES, HOLD TIMES, REMOVAL TIME, AND PROPAGATION DELAY TIMES FOR EDGE TRIGGERED SEQUENTIAL LOGIC CIRCUITS