

# 74VHC161

## Synchronous Presettable Binary Counter

### General Description

The VHC161 is an advanced high-speed CMOS device fabricated with silicon gate CMOS technology. It achieves the high-speed operation similar to equivalent Bipolar Schottky TTL while maintaining the CMOS low power dissipation. The VHC161 is a high-speed synchronous modulo-16 binary counter. This device is synchronously presettable for application in programmable dividers and have two types of Count Enable inputs plus a Terminal Count output for versatility in forming synchronous multistage counters. The VHC161 has an asynchronous Master Reset input that overrides all other inputs and forces the outputs LOW. An input protection circuit insures that 0V to 7V can be applied to the input pins without regard to the supply voltage. This device can be used to interface 5V to 3V systems and two

supply systems such as battery backup. This circuit prevents device destruction due to mismatched supply and input voltages.

### Features

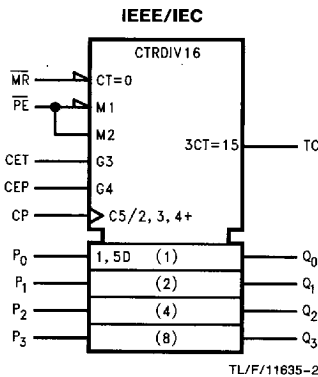
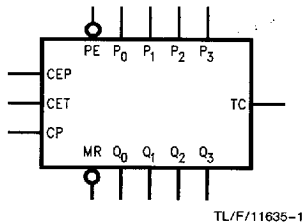
- Synchronous counting and loading
- High-speed synchronous expansion
- Low power dissipation:  
 $I_{CC} = 4 \mu A$  (max) at  $T_A = 25^\circ C$
- High noise immunity:  $V_{NIH} = V_{NIL} = 28\% V_{CC}$  (min)
- All inputs are equipped with a power down protection function
- Balanced propagation delays:  $t_{PLH} \approx t_{PHL}$
- Low noise:  $V_{OLP} = 0.8V$  (max)
- Pin and function compatible with 74HC161

### Ordering Code: See Section 6

Commercial	Package Number	Package Description
74VHC161M	M16A	16-Lead Molded JEDEC SOIC
74VHC161SJ	M16D	16-Lead Molded EIAJ SOIC
74VHC161MSC	MSC16	16-Lead Molded EIAJ Type 1 SSOP
74VHC161MTC	MTC16	16-Lead Molded JEDEC Type 1 TSSOP
74VHC161N	N16E	16-Lead Molded DIP

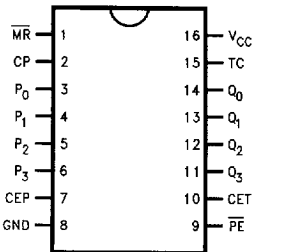
**Note:** Surface mount packages are also available on Tape and Reel. Specify by appending the suffix letter "X" to the ordering code. EIAJ Type 1 SSOP available on Tape and Reel only, order MSCX.

### Logic Symbols



### Connection Diagram

Pin Assignment for DIP, SSOP, TSSOP and SOIC



Pin Names	Description
CEP	Count Enable Parallel Input
CET	Count Enable Trickle Input
CP	Clock Pulse Input
MR	Asynchronous Master Reset Input
P <sub>0</sub> -P <sub>3</sub>	Parallel Data Inputs
PE	Parallel Enable Inputs
Q <sub>0</sub> -Q <sub>3</sub>	Flip-Flop Outputs
TC	Terminal Count Output

## Functional Description

The VHC161 counts in modulo-16 binary sequence. From state 15 (HHHH) it increments to state 0 (LLLL). The clock inputs of all flip-flops are driven in parallel through a clock buffer. Thus all changes of the Q outputs (except due to Master Reset of the '161) occur as a result of, and synchronous with, the LOW-to-HIGH transition of the CP input signal. The circuits have four fundamental modes of operation, in order of precedence: asynchronous reset, parallel load, count-up and hold. Five control inputs—Master Reset, Parallel Enable ( $\overline{PE}$ ), Count Enable Parallel (CEP) and Count Enable Trickle (CET)—determine the mode of operation, as shown in the Mode Select Table. A LOW signal on  $\overline{MR}$  overrides all other inputs and asynchronously forces all outputs LOW. A LOW signal on  $\overline{PE}$  overrides counting and allows information on the Parallel Data ( $P_n$ ) inputs to be loaded into the flip-flops on the next rising edge of CP. With  $\overline{PE}$  and  $\overline{MR}$  HIGH, CEP and CET permit counting when both are HIGH. Conversely, a LOW signal on either CEP or CET inhibits counting.

The VHC161 uses D-type edge-triggered flip-flops and changing the  $\overline{PE}$ , CEP and CET inputs when the CP is in either state does not cause errors, provided that the recommended setup and hold times, with respect to the rising edge of CP, are observed.

The Terminal Count (TC) output is HIGH when CET is HIGH and counter is in state 15. To implement synchronous multi-stage counters, the TC outputs can be used with the CEP and CET inputs in two different ways.

*Figure 1* shows the connections for simple ripple carry, in which the clock period must be longer than the CP to TC delay of the first stage, plus the cumulative  $\overline{CET}$  to TC delay of the intermediate stages, plus the  $\overline{CET}$  to CP setup time of the last stage. This total delay plus setup time sets the upper limit on clock frequency. For faster clock rates, the carry lookahead connections shown in *Figure 2* are recommended. In this scheme the ripple delay through the intermediate stages commences with the same clock that causes the first stage to tick over from max to min in the Up mode, or min to max in the Down mode, to start its final cycle. Since this final cycle requires 16 clocks to complete, there is plenty of time for the ripple to progress through the intermediate stages. The critical timing that limits the clock period is the CP to TC delay of the first stage plus the CEP to CP setup time of the last stage. The TC output is subject to decoding spikes due to internal race conditions and is therefore not recommended for use as a clock or asynchronous reset for flip-flops, registers or counters.

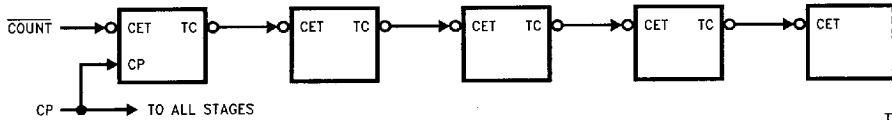


FIGURE 1. Multistage Counter with Ripple Carry

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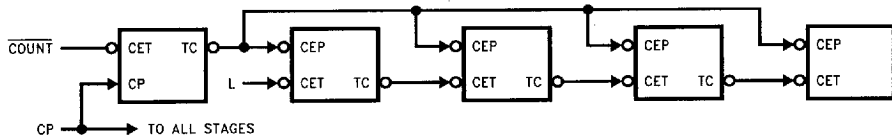


FIGURE 2. Multistage Counter with Lookahead Carry

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### Functional Description (Continued)

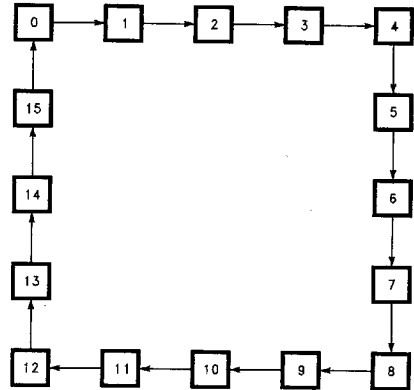
Logic Equations: Count Enable =  $CEP \cdot CET \cdot \overline{PE}$   
 TC =  $Q_0 \cdot Q_1 \cdot Q_2 \cdot Q_3 \cdot CET$

Mode Select Table

$\overline{PE}$	CET	CEP	Action on the Rising Clock Edge (↗)
X	X	X	Reset (Clear)
L	X	X	Load ( $P_n \rightarrow Q_n$ )
H	H	H	Count (Increment)
H	L	X	No Change (Hold)
H	X	L	No Change (Hold)

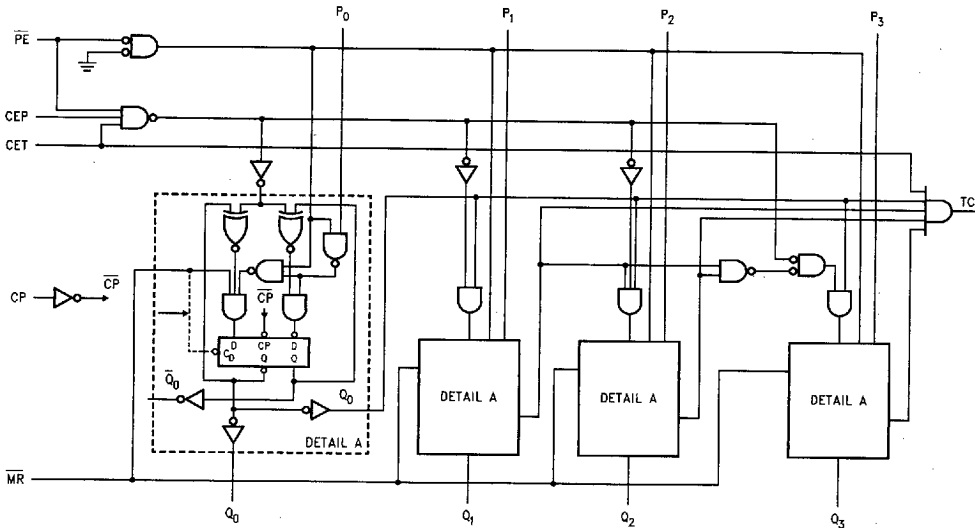
H = HIGH Voltage Level  
 L = LOW Voltage Level  
 X = Immaterial

### State Diagram



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### Block Diagram



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Please note that this diagram is provided only for the understanding of logic operations and should not be used to estimate propagation delays.

**Absolute Maximum Ratings** (Note 1)

Supply Voltage ( $V_{CC}$ )	-0.5V to +7.0V
DC Input Voltage ( $V_{IN}$ )	-0.5V to +7.0V
DC Output Voltage ( $V_{OUT}$ )	-0.5V to $V_{CC} + 0.5V$
Input Diode Current ( $I_{IK}$ )	-20 mA
Output Diode Current ( $I_{OK}$ )	$\pm 20$ mA
DC Output Current ( $I_{OUT}$ )	$\pm 25$ mA
DC $V_{CC}$ /GND Current ( $I_{CC}$ )	$\pm 50$ mA
Storage Temperature ( $T_{STG}$ )	-65°C to +150°C
Lead Temperature ( $T_L$ ) (Soldering, 10 seconds)	260°C

Note 1: *Absolute Maximum Ratings* are values beyond which the device may be damaged or have its useful life impaired. The databook specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. National does not recommend operation outside databook specifications.

**Recommended Operating Conditions**

Supply Voltage ( $V_{CC}$ )	2.0V to +5.5V
Input Voltage ( $V_{IN}$ )	0V to +5.5V
Output Voltage ( $V_{OUT}$ )	0V to $V_{CC}$
Operating Temperature ( $T_{OPR}$ )	-40°C to +85°C
Input Rise and Fall Time ( $t_r, t_f$ )	0 ~ 100 ns/V
$V_{CC} = 3.3V \pm 0.3V$	0 ~ 20 ns/V
$V_{CC} = 5.0V \pm 0.5V$	

**DC Characteristics for 'VHC Family Devices**

Symbol	Parameter	$V_{CC}$ (V)	74VHC				Units	Conditions	
			$T_A = 25^\circ\text{C}$			$T_A = -40^\circ\text{C}$ to +85°C			
			Min	Typ	Max	Min			Max
$V_{IH}$	High Level Input Voltage	2.0 3.0-5.5	1.50 0.7 $V_{CC}$			1.50 0.7 $V_{CC}$	V		
$V_{IL}$	Low Level Input Voltage	2.0 3.0-5.5		0.50 0.3 $V_{CC}$		0.50 0.3 $V_{CC}$	V		
$V_{OH}$	High Level Output Voltage	2.0 3.0 4.5	1.9 2.9 4.4	2.0 3.0 4.5		1.9 2.9 4.4	V	$V_{IN} = V_{IH}$ or $V_{IL}$  $I_{OH} = -50 \mu\text{A}$	
		3.0 4.5	2.58 3.94			2.48 3.80	V		$I_{OH} = -4 \text{ mA}$ $I_{OH} = -8 \text{ mA}$
$V_{OL}$	Low Level Output Voltage	2.0 3.0 4.5		0.0 0.0 0.1		0.1 0.1 0.1	V	$V_{IN} = V_{IH}$ or $V_{IL}$  $I_{OL} = 50 \mu\text{A}$	
		3.0 4.5			0.36 0.36		0.44 0.44		V
$I_{IN}$	Input Leakage Current	0-5.5			$\pm 0.1$	$\pm 1.0$	$\mu\text{A}$	$V_{IN} = 5.5V$ or GND	
$I_{CC}$	Quiescent Supply Current	5.5			4.0	40.0	$\mu\text{A}$	$V_{IN} = V_{CC}$ or GND	

**DC Characteristics for 'VHC Family Devices:** See Section 2 for Waveforms

Symbol	Parameter	V <sub>CC</sub> (V)	74VHC		Units	Conditions	Fig. No.
			T <sub>A</sub> = 25°C				
			Typ	Limits			
V <sub>OLP</sub> *	Quiet Output Maximum Dynamic V <sub>OL</sub>	5.0	0.4	0.8	V	C <sub>L</sub> = 50 pF	2-11, 12
V <sub>OLV</sub> *	Quiet Output Minimum Dynamic V <sub>OL</sub>	5.0	-0.4	-0.8	V	C <sub>L</sub> = 50 pF	2-11, 12
V <sub>IHD</sub> *	Minimum High Level Dynamic Input Voltage	5.0		3.5	V	C <sub>L</sub> = 50 pF	2-11, 12
V <sub>ILD</sub> *	-Maximum Low Level Dynamic Input Voltage	5.0		1.5	V	C <sub>L</sub> = 50 pF	2-11, 12

\*Parameter guaranteed by design.

## AC Electrical Characteristics for 'VHC Family Devices: See Section 2 for Waveforms

Symbol	Parameter	V <sub>CC</sub> (V)	74VHC		74VHC		Units	Conditions	Fig. No.	
			T <sub>A</sub> = 25°C			T <sub>A</sub> = -40° to +85°C				
			Min	Typ	Max	Min				Max
t <sub>PLH</sub> , t <sub>PHL</sub>	Propagation Delay Time (CP-Q <sub>n</sub> )	3.3 ± 0.3	8.3	12.8	1.0	15.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			10.8	16.3	1.0	18.5		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	4.9	8.1	1.0	9.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			6.4	10.1	1.0	11.5		C <sub>L</sub> = 50 pF	2-5, 6	
t <sub>PLH</sub> , t <sub>PHL</sub>	Propagation Delay Time (CP-TC, Count)	3.3 ± 0.3	8.7	13.6	1.0	16.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			11.2	17.1	1.0	19.5		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	4.9	8.1	1.0	9.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			6.4	10.1	1.0	11.5		C <sub>L</sub> = 50 pF	2-5, 6	
t <sub>PLH</sub> , t <sub>PHL</sub>	Propagation Delay Time (CP-TC, Load)	3.3 ± 0.3	11.0	17.2	1.0	20.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			13.5	20.7	1.0	23.5		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	6.2	10.3	1.0	12.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			7.7	12.3	1.0	14.0		C <sub>L</sub> = 50 pF	2-5, 6	
t <sub>PLH</sub> , t <sub>PHL</sub>	Propagation Delay Time (CET-TC)	3.3 ± 0.3	7.5	12.3	1.0	14.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			10.5	15.8	1.0	18.0		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	4.9	8.1	1.0	9.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			6.4	10.1	1.0	11.5		C <sub>L</sub> = 50 pF	2-5, 6	
t <sub>PHL</sub>	Propagation Delay Time (MR-Q <sub>n</sub> )	3.3 ± 0.3	8.9	13.6	1.0	16.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			11.2	17.1	1.0	19.5		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	5.5	9.0	1.0	10.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			7.0	11.0	1.0	12.5		C <sub>L</sub> = 50 pF	2-5, 6	
t <sub>PHL</sub>	Propagation Delay Time (MR-TC)	3.3 ± 0.3	8.4	13.2	1.0	15.5	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			10.9	16.7	1.0	19.0		C <sub>L</sub> = 50 pF	2-5, 6	
		5.0 ± 0.5	5.0	8.6	1.0	10.0	ns	C <sub>L</sub> = 15 pF	2-5, 6	
			6.5	10.6	1.0	12.0		C <sub>L</sub> = 50 pF	2-5, 6	
f <sub>max</sub>	Maximum Clock Frequency	3.3 ± 0.3	80	130	70		MHz	C <sub>L</sub> = 15 pF		
			55	85	50			C <sub>L</sub> = 50 pF		
		5.0 ± 0.5	135	185	115		MHz	C <sub>L</sub> = 15 pF		
			95	125	85			C <sub>L</sub> = 50 pF		
C <sub>IN</sub>	Input Capacitance		4	10	10		pF	V <sub>CC</sub> = Open		
C <sub>PD</sub>	Power Dissipation Capacitance		23				pF	(Note 1)		

**Note 1:** C<sub>PD</sub> is defined as the value of the internal equivalent capacitance which is calculated from the operating current consumption without load. Average operating current can be obtained by the equation: I<sub>CC (opr)</sub> = C<sub>PD</sub> \* V<sub>CC</sub> \* f<sub>IN</sub> + I<sub>CC</sub>.

When the outputs drive a capacitive load, total current consumption is the sum of C<sub>PD</sub>, and ΔI<sub>CC</sub> which is obtained from the following formula:

$$\Delta I_{CC} = F_{CP} \cdot V_{CC} \left( \frac{C_{Q0}}{2} + \frac{C_{Q1}}{4} + \frac{C_{Q2}}{8} + \frac{C_{Q3}}{16} + \frac{C_{TC}}{16} \right)$$

C<sub>Q0</sub>-C<sub>Q3</sub> and C<sub>TC</sub> are the capacitances at Q0-Q3 and TC, respectively. F<sub>CP</sub> is the input frequency of the CP.

**AC Operating Requirements for VHC Family Devices:** See Section 2 for Waveforms

Symbol	Parameter	*V <sub>CC</sub> (V)	74VHC		74VHC		Units	Conditions	Fig. No.
			T <sub>A</sub> = 25°C		T <sub>A</sub> = -40°C to +85°C				
			Typ	Guaranteed Minimum					
t <sub>s</sub>	Minimum Setup Time (P <sub>n</sub> -CP)	3.3		5.5	6.5	ns		2-9	
		5.0		4.5	4.5				
t <sub>s</sub>	Minimum Setup Time (PE-CP)	3.3		8.0	9.5	ns		2-9	
		5.0		5.0	6.0				
t <sub>s</sub>	Minimum Setup Time (CEP or CET-CP)	3.3		7.5	9.0	ns		2-9	
		5.0		5.0	6.0				
t <sub>H</sub>	Minimum Hold Time (P <sub>n</sub> -CP)	3.3		1.0	1.0	ns		2-9	
		5.0		1.0	1.0				
t <sub>H</sub>	Minimum Hold Time (PE-CP)	3.3		1.0	1.0	ns		2-9	
		5.0		1.0	1.0				
t <sub>H</sub>	Minimum Hold Time (CEP or CET-CP)	3.3		1.0	1.0	ns		2-9	
		5.0		1.0	1.0				
t <sub>W(L)</sub> t <sub>W(H)</sub>	Minimum Pulse Width CP (Count)	3.3		5.0	5.0	ns		2-6	
		5.0		5.0	5.0				
t <sub>W(L)</sub>	Minimum Pulse Width (MR)	3.3		5.0	5.0	ns		2-6	
		5.0		5.0	5.0				
t <sub>rem</sub>	Minimum Removal Time	3.3		2.5	2.5	ns		2-6, 9	
		5.0		1.5	1.5				

\*V<sub>CC</sub> is 3.3 ± 0.3V or 5.0 ± 0.5V