PRESETTABLE SYNCHRONOUS 4-BIT BINARY UP/DOWN COUNTER

FEATURES

- Synchronous reversible 4-bit binary counting
- Asynchronous parallel load
- Asynchronous reset
- Expandable without external logic
- Output capability: standard
- I_{CC} category: MSI

GENERAL DESCRIPTION

The 74HC/HCT193 are high-speed Si-gate CMOS devices and are pin compatible with low power Schottky TTL (LSTTL). They are specified in compliance with JEDEC standard no. 7A.

The 74HC/HCT193 are 4-bit synchronous binary up/down counters. Separate up/down clocks, CP_U and CP_D respectively, simplify operation. The outputs change state synchronously with the LOW-to-HIGH transition of either clock input. If the CP_U clock is pulsed while CP_D is held HIGH, the device will count up. If the CP_D clock is pulsed while CP_U is held HIGH, the device will count down. Only one clock input can be held HIGH at any time, or erroneous operation will result. The device can be cleared at any time by the asynchronous master reset input (MR); it may also be loaded in parallel by activating the asynchronous parallel load input ($\overline{PL}$).

The "193" contains four master-slave JK flip-flops with the necessary steering logic to provide the asynchronous reset, load, and synchronous count up and count down functions.

Each flip-flop contains JK feedback from slave to master, such that a LOW-to-HIGH transition on the CP_D input will decrease the count by one, while a similar transition on the CP_U input will advance the count by one.

(continued on next page)

SYMBOL	PARAMETER	CONDITIONS	TYPICAL		UNIT
			HC	HCT	
t_{PHL}/t_{PLH}	propagation delay CP_D, CP_U to Q_n	C_L = 15 pF; V_{CC} = 5 V	20	20	ns
f_{max}	maximum clock frequency		45	47	MHz
C_I	input capacitance		3.5	3.5	pF
C_{PD}	power dissipation capacitance per package	notes 1 and 2	24	26	pF

GND = 0 V; T_{amb} = 25 °C; $t_r = t_f$ = 6 ns

Notes

1. C_{PD} is used to determine the dynamic power dissipation (P_D in μW):
   $P_D = C_{PD} \times V_{CC}^2 \times f_i + \Sigma (C_L \times V_{CC}^2 \times f_o)$ where:
   f_i = input frequency in MHz; C_L = output load capacitance in pF
   f_o = output frequency in MHz; V_{CC} = supply voltage in V
   $\Sigma (C_L \times V_{CC}^2 \times f_o)$ = sum of outputs
2. For HC the condition is V_I = GND to V_{CC}
   For HCT the condition is V_I = GND to V_{CC} − 1.5 V

PACKAGE OUTLINES

SEE PACKAGE INFORMATION SECTION

PIN DESCRIPTION

PIN NO.	SYMBOL	NAME AND FUNCTION
3, 2, 6, 7	Q_0 to Q_3	flip-flop outputs
4	CP_D	count down clock input*
5	CP_U	count up clock input*
8	GND	ground (0 V)
11	$\overline{PL}$	asynchronous parallel load input (active LOW)
12	$\overline{TC}_U$	terminal count up (carry) output (active LOW)
13	$\overline{TC}_D$	terminal count down (borrow) output (active LOW)
14	MR	asynchronous master reset input (active HIGH)
15, 1, 10, 9	D_0 to D_3	data inputs
16	V_{CC}	positive supply voltage

* LOW-to-HIGH, edge triggered

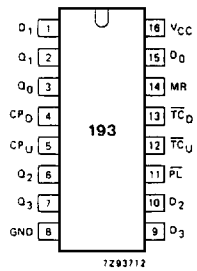


Fig. 1 Pin configuration.

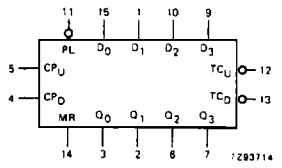


Fig. 2 Logic symbol.

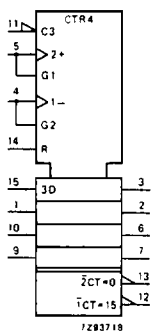


Fig. 3 IEC logic symbol.

GENERAL DESCRIPTION

One clock should be held HIGH while counting with the other, otherwise the circuit will either count by two's or not at all, depending on the state of the first flip-flop, which cannot toggle as long as either clock input is LOW. Applications requiring reversible operation must make the reversing decision while the activating clock is HIGH to avoid erroneous counts.

The terminal count up ($\overline{TC}_U$) and terminal count down ($\overline{TC}_D$) outputs are normally HIGH. When the circuit has reached the maximum count state of 15,the next HIGH-to-LOW transition of CP_U will cause $\overline{TC}_U$ to go LOW.
$\overline{TC}_U$ will stay LOW until CP_U goes HIGH again, duplicating the count up clock.

Likewise, the $\overline{TC}_D$ output will go LOW when the circuit is in the zero state and the CP_D goes LOW. The terminal count outputs can be used as the clock input signals to the next higher order circuit in a multistage counter, since they duplicate the clock waveforms. Multistage counters will not be fully synchronous, since there is a slight delay time difference added for each stage that is added.

The counter may be preset by the asynchronous parallel load capability of the circuit. Information present on the parallel data inputs (D_0 to D_3) is loaded into the counter and appears on the outputs (Q_0 to Q_3) regardless of the conditions of the clock inputs when the parallel load ($\overline{PL}$) input is LOW. A HIGH level on the master reset (MR) input will disable the parallel load gates, override both clock inputs and set all outputs (Q_0 to Q_3) LOW. If one of the clock inputs is LOW during and after a reset or load operation, the next LOW-to-HIGH transition of that clock will be interpreted as a legitimate signal and will be counted.

FUNCTION TABLE

OPERATING MODE	INPUTS								OUTPUTS					
	MR	$\overline{PL}$	CP_U	CP_D	D_0	D_1	D_2	D_3	Q_0	Q_1	Q_2	Q_3	$\overline{TC}_U$	$\overline{TC}_D$
reset (clear)	H	X	X	L	X	X	X	X	L	L	L	L	H	L
	H	X	X	H	X	X	X	X	L	L	L	L	H	H
parallel load	L	L	X	L	L	L	L	L	L	L	L	L	H	L
	L	L	X	H	L	L	L	L	L	L	L	L	H	H
	L	L	L	X	H	H	H	H	H	H	H	H	L	H
	L	L	H	X	H	H	H	H	H	H	H	H	H	H
count up	L	H	↑	H	X	X	X	X	count up				H*	H
count down	L	H	H	↑	X	X	X	X	count down				H	H**

H = HIGH voltage level
L = LOW voltage level
X = don't care
↑ = LOW-to-HIGH clock transition

* $\overline{TC}_U$ = CP_U at terminal count up (HHHH)
** $\overline{TC}_D$ = CP_D at terminal count down (LLLL)

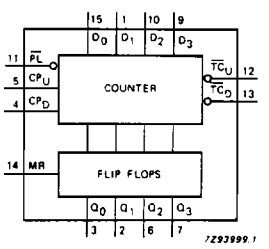
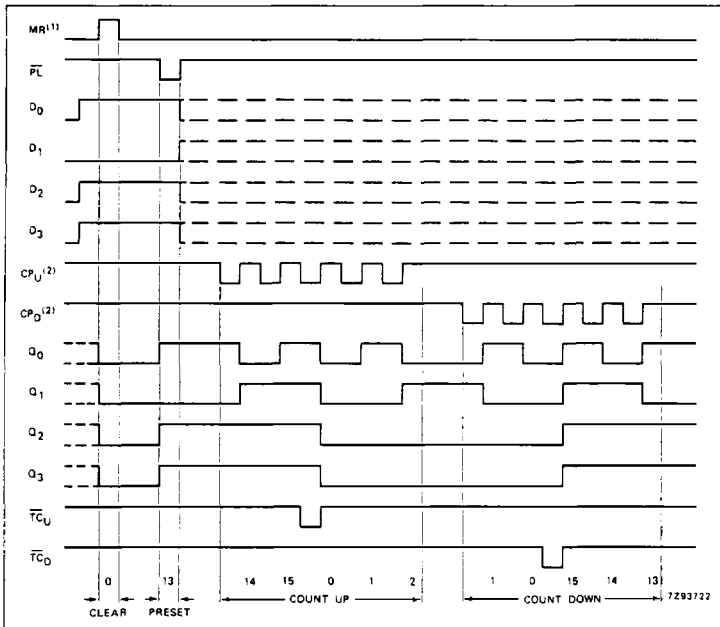


Fig. 4 Functional diagram.



(1) Clear overrides load, data and count inputs.

(2) When counting up the count down clock input (CP_D) must be HIGH, when counting down the count up clock input (CP_U) must be HIGH.

Sequence

Clear (reset outputs to zero);

load (preset) to binary thirteen;

count up to fourteen, fifteen, terminal count up, zero, one and two;

count down to one, zero, terminal count down, fifteen, fourteen and thirteen.

Fig. 5 Typical clear, load and count sequence.

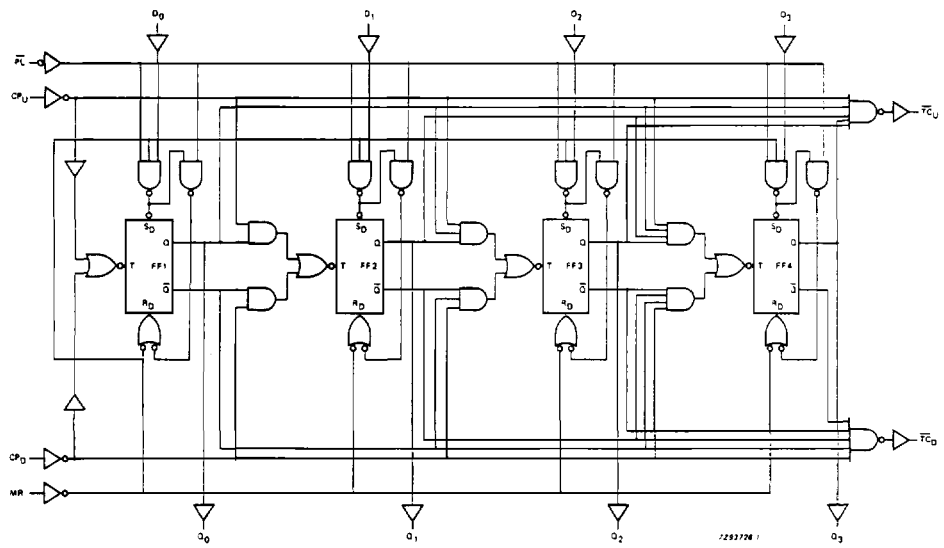


Fig. 6 Logic diagram.

DC CHARACTERISTICS FOR 74HC

For the DC characteristics see chapter "HCMOS family characteristics", section "Family specifications".

Output capability: standard
I_{CC} category: MSI

AC CHARACTERISTICS FOR 74HC

GND = 0 V; $t_r = t_f$ = 6 ns; C_L = 50 pF

SYMBOL	PARAMETER	T_{amb} (°C)							UNIT	TEST CONDITIONS	
		74HC								V_{CC} V	WAVEFORMS
		+25			−40 to +85		−40 to +125				
		min.	typ.	max.	min.	max.	min.	max.			
t_{PHL}/t_{PLH}	propagation delay CP_U, CP_D to Q_n		63 23 18	215 43 37		270 54 46		325 65 55	ns	2.0 4.5 6.0	Fig. 7
t_{PHL}/t_{PLH}	propagation delay CP_U to $\overline{TC}_U$		39 14 11	125 25 21		155 31 26		190 38 32	ns	2.0 4.5 6.0	Fig. 8
t_{PHL}/t_{PLH}	propagation delay CP_D to $\overline{TC}_D$		39 14 11	125 25 21		155 31 26		190 38 32	ns	2.0 4.5 6.0	Fig. 8
t_{PHL}/t_{PLH}	propagation delay $\overline{PL}$ to Q_n		69 25 20	220 44 37		275 55 47		330 66 56	ns	2.0 4.5 6.0	Fig. 9
t_{PHL}	propagation delay MR to Q_n		58 21 17	200 40 34		250 50 43		300 60 51	ns	2.0 4.5 6.0	Fig. 10
t_{PHL}/t_{PLH}	propagation delay D_n to Q_n		69 25 20	210 42 36		265 53 45		315 63 54	ns	2.0 4.5 6.0	Fig. 9
t_{PHL}/t_{PLH}	propagation delay $\overline{PL}$ to $\overline{TC}_U$, $\overline{PL}$ to $\overline{TC}_D$		80 29 23	290 58 49		365 73 62		435 87 74	ns	2.0 4.5 6.0	Fig. 12
t_{PHL}/t_{PLH}	propagation delay MR to $\overline{TC}_U$, MR to $\overline{TC}_D$		74 27 22	285 57 48		355 71 60		430 86 73	ns	2.0 4.5 6.0	Fig. 12
t_{PHL}/t_{PLH}	propagation delay D_n to $\overline{TC}_U$, D_n to $\overline{TC}_D$		80 29 23	290 58 49		365 73 62		435 87 74	ns	2.0 4.5 6.0	Fig. 12
t_{THL}/t_{TLH}	output transition time		19 7 6	75 15 13		95 19 16		110 22 19	ns	2.0 4.5 6.0	Fig. 10
t_W	up, down clock pulse width HIGH or LOW	100 20 17	22 8 6		125 25 21		150 30 26		ns	2.0 4.5 6.0	Fig. 7
t_W	master reset pulse width HIGH	100 20 17	25 9 7		125 25 21		150 30 26		2 ns	2.0 4.5 6.0	Fig. 10
t_W	parallel load pulse width LOW	100 20 17	19 7 6		125 25 21		150 30 26		ns	2.0 4.5 6.0	Fig. 9

SYMBOL	PARAMETER	T_{amb} (°C)							UNIT	TEST CONDITIONS	
		74HC								V_{CC} V	WAVEFORMS
		+25			−40 to +85		−40 to +125				
		min.	typ.	max.	min.	max.	min.	max.			
t_{rem}	removal time $\overline{PL}$ to CP_U, CP_D	50 10 9	8 3 2		65 13 11		75 15 13		ns	2.0 4.5 6.0	Fig. 9
t_{rem}	removal time MR to CP_U, CP_D	50 10 9	0 0 0		65 13 11		75 15 13		ns	2.0 4.5 6.0	Fig. 10
t_{su}	set-up time D_n to $\overline{PL}$	80 16 14	22 8 6		100 20 17		120 24 20		ns	2.0 4.5 6.0	Fig. 11 note: CP_U = CP_D = HIGH
t_h	hold time D_n to $\overline{PL}$	0 0 0	−14 −5 −4		0 0 0		0 0 0		ns	2.0 4.5 6.0	Fig. 11
t_h	hold time CP_U to CP_D, CP_D to CP_U	80 16 8	22 8 6		100 20 17		120 24 20		ns	2.0 4.5 6.0	Fig. 13
f_{max}	maximum up, down clock pulse frequency	4.0 20 24	13.5 41 49		3.2 16 19		2.6 13 15		MHz	2.0 4.5 6.0	Fig. 7

DC CHARACTERISTICS FOR 74HCT

For the DC characteristics see chapter "HCMOS family characteristics", section "Family specifications.

Output capability: standard
I_{CC} category: MSI

Note to HCT types

The value of additional quiescent supply current (ΔI_{CC}) for a unit load of 1 is given in the family specifications. To determine ΔI_{CC} per input, multiply this value by the unit load coefficient shown in the table below.

INPUT	UNIT LOAD COEFFICIENT
D_n	0.35
CP_U, CP_D	1.40
$\overline{PL}$	0.65
MR	1.05

AC CHARACTERISTICS FOR 74HCT

GND = 0 V; $t_r = t_f$ = 6 ns; C_L = 50 pF

SYMBOL	PARAMETER	T_{amb} (°C)							UNIT	TEST CONDITIONS	
		74HCT								V_{CC} V	WAVEFORMS
		+25			−40 to +85		−40 to +125				
		min.	typ.	max.	min.	max.	min.	max.			
t_{PHL}/t_{PLH}	propagation delay CP_U, CP_D to Q_n		23	43		54		65	ns	4.5	Fig. 7
t_{PHL}/t_{PLH}	propagation delay CP_U to $\overline{TC}_U$		15	27		34		41	ns	4.5	Fig. 8
t_{PHL}/t_{PLH}	propagation delay CP_D to $\overline{TC}_D$		15	27		34		41	ns	4.5	Fig. 8
t_{PHL}/t_{PLH}	propagation delay $\overline{PL}$ to Q_n		26	46		58		69	ns	4.5	Fig. 9
t_{PHL}	propagation delay MR to Q_n		22	40		50		60	ns	4.5	Fig. 10
t_{PHL}/t_{PLH}	propagation delay D_n to Q_n		27	46		58		69	ns	4.5	Fig. 9
t_{PHL}/t_{PLH}	propagation delay $\overline{PL}$ to $\overline{TC}_U$, $\overline{PL}$ to $\overline{TC}_D$		31	55		69		83	ns	4.5	Fig. 12
t_{PHL}/t_{PLH}	propagation delay MR to $\overline{TC}_U$, MR to $\overline{TC}_D$		29	55		69		83	ns	4.5	Fig. 12
t_{PHL}/t_{PLH}	propagation delay D_n to $\overline{TC}_U$, D_n to $\overline{TC}_D$		32	58		73		87	ns	4.5	Fig. 12
t_{THL}/t_{TLH}	output transition time		7	15		19		22	ns	4.5	Fig. 10
t_W	up, down clock pulse width HIGH or LOW	25	11		31		38		ns	4.5	Fig. 7
t_W	master reset pulse width HIGH	20	7		25		30		ns	4.5	Fig. 10
t_W	parallel load pulse width LOW	20	8		25		30		ns	4.5	Fig. 9
t_{rem}	removal time $\overline{PL}$ to CP_U, CP_D	10	2		13		15		ns	4.5	Fig. 9
t_{rem}	removal time MR to CP_U, CP_D	10	0		13		15		ns	4.5	Fig. 10
t_{su}	set-up time D_n to $\overline{PL}$	16	8		20		24		ns	4.5	Fig. 11 note: $CP_U = CP_D$ = HIGH
t_h	hold time D_n to $\overline{PL}$	0	−6		0		0		ns	4.5	Fig. 11
t_h	hold time CP_U to CP_D, CP_D to CP_U	16	7		20		24		ns	4.5	Fig. 13
f_{max}	maximum up, down clock pulse frequency	20	43		16		13		MHz	4.5	Fig. 7

AC WAVEFORMS

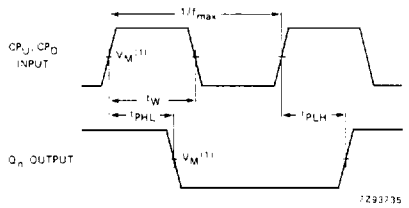


Fig. 7 Waveforms showing the clock (CP_U, CP_D) to output (Q_n) propagation delays, the clock pulse width and the maximum clock pulse frequency.

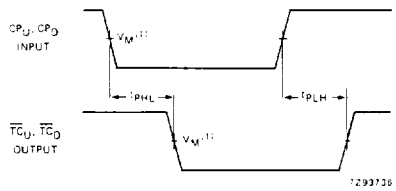


Fig. 8 Waveforms showing the clock (CP_U, CP_D) to terminal count output ($\overline{TC}_U$, $\overline{TC}_D$) propagation delays.

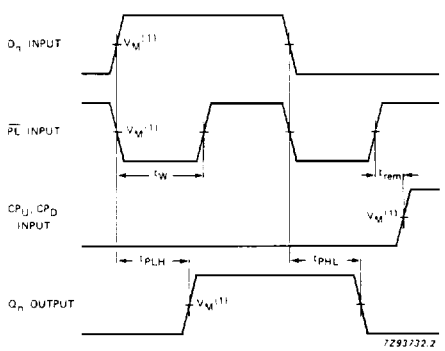


Fig. 9 Waveforms showing the parallel load input ($\overline{PL}$) and data (D_n) to Q_n output propagation delays and $\overline{PL}$ removal time to clock input (CP_U, CP_D).

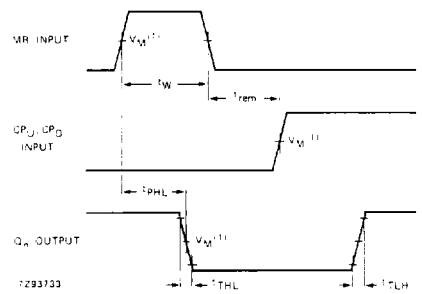


Fig. 10 Waveforms showing the master reset input (MR) pulse width, MR to Q_n propagation delays, MR to CP_U, CP_D removal time and output transition times.

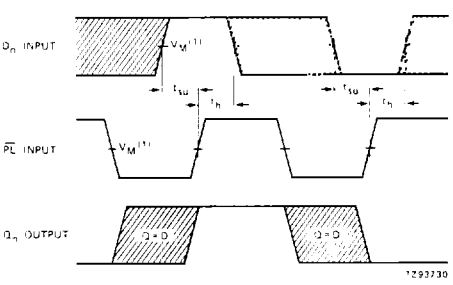


Fig. 11 Waveforms showing the data input (D_n) to parallel load input ($\overline{PL}$) set-up and hold times.

Note to Fig. 11

The shaded areas indicate when the input is permitted to change for predictable output performance.

AC WAVEFORMS (Cont'd)

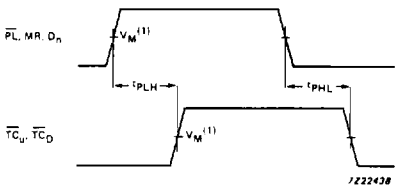


Fig. 12 Waveforms showing the data input (D_n), parallel load input ($\overline{PL}$) and the master reset input (MR) to the terminal count outputs ($\overline{TC}_U$, $\overline{TC}_D$) propagation delays.

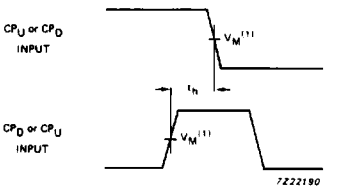


Fig. 13 Waveforms showing the CP_U to CP_D or CP_D to CP_U hold times.

Note to AC waveforms

(1) HC : V_M = 50%; V_I = GND to V_{CC}.
HCT: V_M = 1.3 V; V_I = GND to 3 V.

APPLICATION INFORMATION

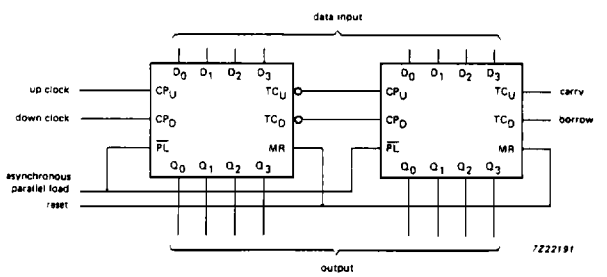


Fig. 14 Cascaded up/down counter with parallel load.