

Binary Up/Down Counter

The MC14516B synchronous up/down binary counter is constructed with MOS P-channel and N-channel enhancement mode devices in a monolithic structure.

This counter can be preset by applying the desired value, in binary, to the Preset inputs (P0, P1, P2, P3) and then bringing the Preset Enable (PE) high. The direction of counting is controlled by applying a high (for up counting) or a low (for down counting) to the UP/DOWN input. The state of the counter changes on the positive transition of the clock input.

Cascading can be accomplished by connecting the Carry Out to the Carry In of the next stage while clocking each counter in parallel. The outputs (Q0, Q1, Q2, Q3) can be reset to a low state by applying a high to the reset (R) pin.

This CMOS counter finds primary use in up/down and difference counting. Other applications include: (1) Frequency synthesizer applications where low power dissipation and/or high noise immunity is desired, (2) Analog-to-digital and digital-to-analog conversions, and (3) Magnitude and sign generation.

- Diode Protection on All Inputs
- Supply Voltage Range = 3.0 Vdc to 18 Vdc
- Internally Synchronous for High Speed
- Logic Edge-Clocked Design — Count Occurs on Positive Going Edge of Clock
- Single Pin Reset
- Asynchronous Preset Enable Operation
- Capable of Driving Two Low-Power TTL Loads or One Low-Power Schottky Load Over the Rated Temperature Range

MAXIMUM RATINGS* (Voltages Referenced to V_{SS})

Symbol	Parameter	Value	Unit
V _{DD}	DC Supply Voltage	− 0.5 to + 18.0	V
V _{in} , V _{out}	Input or Output Voltage (DC or Transient)	− 0.5 to V _{DD} + 0.5	V
I _{in} , I _{out}	Input or Output Current (DC or Transient), per Pin	± 10	mA
P _D	Power Dissipation, per Package†	500	mW
T _{stg}	Storage Temperature	− 65 to + 150	°C
T _L	Lead Temperature (8-Second Soldering)	260	°C

* Maximum Ratings are those values beyond which damage to the device may occur.

† Temperature Derating:

Plastic "P and D/DW" Packages: − 7.0 mW/°C From 65°C To 125°C

Ceramic "L" Packages: − 12 mW/°C From 100°C To 125°C

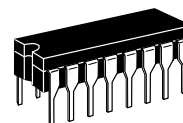
TRUTH TABLE

Carry In	Up/Down	Preset Enable	Reset	Clock	Action
1	X	0	0	X	No Count
0	1	0	0	↗	Count Up
0	0	0	0	↘	Count Down
X	X	1	0	X	Preset
X	X	X	1	X	Reset

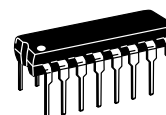
X = Don't Care

NOTE: When counting up, the Carry Out signal is normally high and is low only when Q0 through Q3 are high and Carry In is low. When counting down, Carry Out is low only when Q0 through Q3 and Carry In are low.

MC14516B



L SUFFIX
CERAMIC
CASE 620



P SUFFIX
PLASTIC
CASE 648



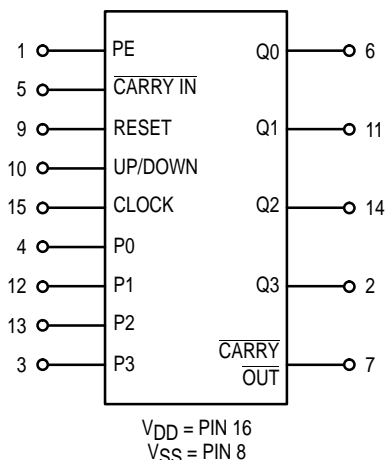
D SUFFIX
SOIC
CASE 751B

ORDERING INFORMATION

MC14XXXBCP	Plastic
MC14XXXBCL	Ceramic
MC14XXXBD	SOIC

T_A = − 55° to 125°C for all packages.

BLOCK DIAGRAM



This device contains protection circuitry to guard against damage due to high static voltages or electric fields. However, precautions must be taken to avoid applications of any voltage higher than maximum rated voltages to this high-impedance circuit. For proper operation, V_{in} and V_{out} should be constrained to the range V_{SS} ≤ (V_{in} or V_{out}) ≤ V_{DD}.

Unused inputs must always be tied to an appropriate logic voltage level (e.g., either V_{SS} or V_{DD}). Unused outputs must be left open.

ELECTRICAL CHARACTERISTICS (Voltages Referenced to V_{SS})

Characteristic	Symbol	V _{DD} Vdc	– 55°C		25°C			125°C		Unit
			Min	Max	Min	Typ #	Max	Min	Max	
Output Voltage V _{in} = V _{DD} or 0	V _{OL}	5.0	—	0.05	—	0	0.05	—	0.05	Vdc
		10	—	0.05	—	0	0.05	—	0.05	
		15	—	0.05	—	0	0.05	—	0.05	
	V _{OH}	5.0	4.95	—	4.95	5.0	—	4.95	—	Vdc
		10	9.95	—	9.95	10	—	9.95	—	
		15	14.95	—	14.95	15	—	14.95	—	
Input Voltage (V _O = 4.5 or 0.5 Vdc) (V _O = 9.0 or 1.0 Vdc) (V _O = 13.5 or 1.5 Vdc)	V _{IL}	5.0	—	1.5	—	2.25	1.5	—	1.5	Vdc
		10	—	3.0	—	4.50	3.0	—	3.0	
		15	—	4.0	—	6.75	4.0	—	4.0	
	V _{IH}	5.0	3.5	—	3.5	2.75	—	3.5	—	Vdc
		10	7.0	—	7.0	5.50	—	7.0	—	
		15	11	—	11	8.25	—	11	—	
Output Drive Current (V _{OH} = 2.5 Vdc) (V _{OH} = 4.6 Vdc) (V _{OH} = 9.5 Vdc) (V _{OH} = 13.5 Vdc)	Source	5.0	– 3.0	—	– 2.4	– 4.2	—	– 1.7	—	mAdc
		5.0	– 0.64	—	– 0.51	– 0.88	—	– 0.36	—	
		10	– 1.6	—	– 1.3	– 2.25	—	– 0.9	—	
		15	– 4.2	—	– 3.4	– 8.8	—	– 2.4	—	
	Sink	5.0	0.64	—	0.51	0.88	—	0.36	—	mAdc
		10	1.6	—	1.3	2.25	—	0.9	—	
Input Current	I _{in}	15	—	± 0.1	—	± 0.00001	± 0.1	—	± 1.0	μAdc
		15	—	± 0.1	—	± 0.00001	± 0.1	—	± 1.0	
Input Capacitance (V _{in} = 0)	C _{in}	—	—	—	—	5.0	7.5	—	—	pF
Quiescent Current (Per Package)	I _{DD}	5.0	—	5.0	—	0.005	5.0	—	150	μAdc
		10	—	10	—	0.010	10	—	300	
		15	—	20	—	0.015	20	—	600	
Total Supply Current**† (Dynamic plus Quiescent, Per Package) (C _L = 50 pF on all outputs, all buffers switching)	I _T	5.0 10 15	I _T = (0.58 μA/kHz) f + I _{DD} I _T = (1.20 μA/kHz) f + I _{DD} I _T = (1.70 μA/kHz) f + I _{DD}							μAdc

#Data labelled “Typ” is not to be used for design purposes but is intended as an indication of the IC’s potential performance.

** The formulas given are for the typical characteristics only at 25°C.

† To calculate total supply current at loads other than 50 pF:

$$I_T(C_L) = I_T(50 \text{ pF}) + (C_L - 50) V_{fk}$$

where: I_T is in μA (per package), C_L in pF, V = (V_{DD} – V_{SS}) in volts, f in kHz is input frequency, and k = 0.001.

PIN ASSIGNMENT

PE	1	16	V _{DD}
Q3	2	15	C
P3	3	14	Q2
P0	4	13	P2
CARRY IN	5	12	P1
Q0	6	11	Q1
CARRY OUT	7	10	U/D
V _{SS}	8	9	R

SWITCHING CHARACTERISTICS* ($C_L = 50 \text{ pF}$, $T_A = 25^\circ\text{C}$)

Characteristic	Symbol	V_{DD}	All Types			Unit
			Min	Typ #	Max	
Output Rise and Fall Time t_{TLH} , $t_{THL} = (1.5 \text{ ns/pF}) C_L + 25 \text{ ns}$ t_{TLH} , $t_{THL} = (0.75 \text{ ns/pF}) C_L + 12.5 \text{ ns}$ t_{TLH} , $t_{THL} = (0.55 \text{ ns/pF}) C_L + 9.5 \text{ ns}$	t_{TLH} , t_{THL}	5.0 10 15	— — —	100 50 40	200 100 80	ns
Propagation Delay Time Clock to Q t_{PLH} , $t_{PHL} = (1.7 \text{ ns/pF}) C_L + 230 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.66 \text{ ns/pF}) C_L + 97 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.5 \text{ ns/pF}) C_L + 75 \text{ ns}$ Clock to $\overline{\text{Carry Out}}$ t_{PLH} , $t_{PHL} = (1.7 \text{ ns/pF}) C_L + 230 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.66 \text{ ns/pF}) C_L + 97 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.5 \text{ ns/pF}) C_L + 75 \text{ ns}$ $\overline{\text{Carry In}}$ to $\overline{\text{Carry Out}}$ t_{PLH} , $t_{PHL} = (1.7 \text{ ns/pF}) C_L + 230 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.66 \text{ ns/pF}) C_L + 97 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.5 \text{ ns/pF}) C_L + 75 \text{ ns}$ Preset or Reset to Q t_{PLH} , $t_{PHL} = (1.7 \text{ ns/pF}) C_L + 230 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.66 \text{ ns/pF}) C_L + 97 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.5 \text{ ns/pF}) C_L + 75 \text{ ns}$ Preset or Reset to $\overline{\text{Carry Out}}$ t_{PLH} , $t_{PHL} = (1.7 \text{ ns/pF}) C_L + 465 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.66 \text{ ns/pF}) C_L + 192 \text{ ns}$ t_{PLH} , $t_{PHL} = (0.5 \text{ ns/pF}) C_L + 125 \text{ ns}$	t_{PLH} , t_{PHL}	5.0 10 15	— — —	315 130 100	630 260 200	ns
	t_{PLH} , t_{PHL}	5.0 10 15	— — —	315 130 100	630 260 200	ns
	t_{PLH} , t_{PHL}	5.0 10 15	— — —	180 80 60	360 160 120	ns
	t_{PLH} , t_{PHL}	5.0 10 15	— — —	315 130 100	630 360 200	ns
	t_{PLH} , t_{PHL}	5.0 10 15	— — —	550 225 150	1100 450 300	ns
Reset Pulse Width	t_w	5.0 10 15	380 200 160	190 100 80	— — —	ns
Clock Pulse Width	t_{WH}	5.0 10 15	350 170 140	200 100 75	— — —	ns
Clock Pulse Frequency	f_{cl}	5.0 10 15	— — —	3.0 6.0 8.0	1.5 3.0 4.0	MHz
Preset or Reset Removal Time The Preset or Reset signal must be low prior to a positive-going transition of the clock.	t_{rem}	5.0 10 15	650 230 180	325 115 90	— — —	ns
Clock Rise and Fall Time	t_{TLH} , t_{THL}	5.0 10 15	— — —	— — —	15 5 4	μs
Setup Time $\overline{\text{Carry In}}$ to Clock	t_{su}	5.0 10 15	260 120 100	130 60 50	— — —	ns
Hold Time Clock to $\overline{\text{Carry In}}$	t_h	5.0 10 15	0 20 20	– 60 – 20 0	— — —	ns
Setup Time Up/Down to Clock	t_{su}	5.0 10 15	500 200 150	250 100 75	— — —	ns
Hold Time Clock to Up/Down	t_h	5.0 10 15	– 70 – 10 0	– 160 – 60 – 40	— — —	ns
Setup Time P_n to PE	t_{su}	5.0 10 15	– 40 – 30 – 25	– 120 – 70 – 50	— — —	ns
Hold Time PE to P_n	t_h	5.0 10 15	480 420 420	240 210 210	— — —	ns
Preset Enable Pulse Width	t_{WH}	5.0 10 15	200 100 80	100 50 40	— — —	ns

* The formulas given are for the typical characteristics only at 25°C .

#Data labelled "Typ" is not to be used for design purposes but is intended as an indication of the IC's potential performance.

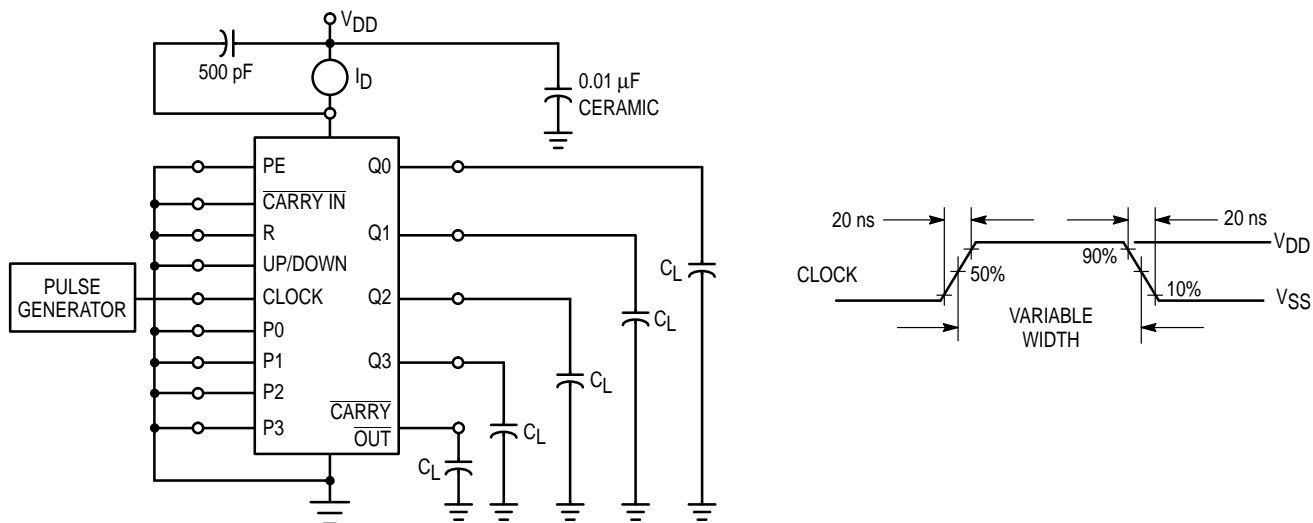
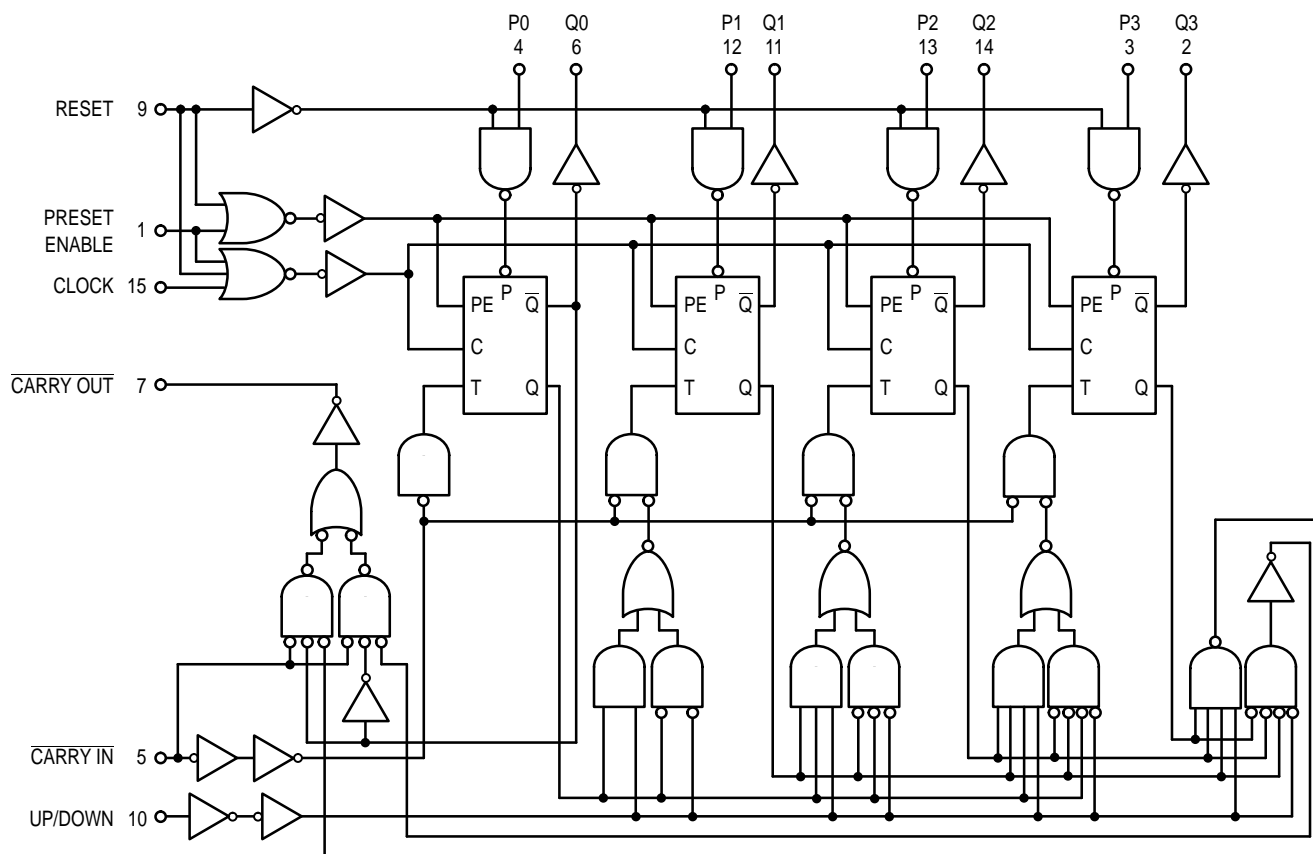
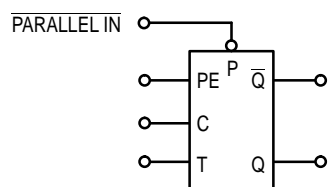


Figure 1. Power Dissipation Test Circuit and Waveform

LOGIC DIAGRAM



TOGGLE FLIP-FLOP



FLIP-FLOP FUNCTIONAL TRUTH TABLE

Preset Enable	Clock	T	Q_{n+1}
1	X	X	Parallel In
0	↗	0	Q_n
0	↘	1	\bar{Q}_n
0	↖	X	Q_n

X = Don't Care

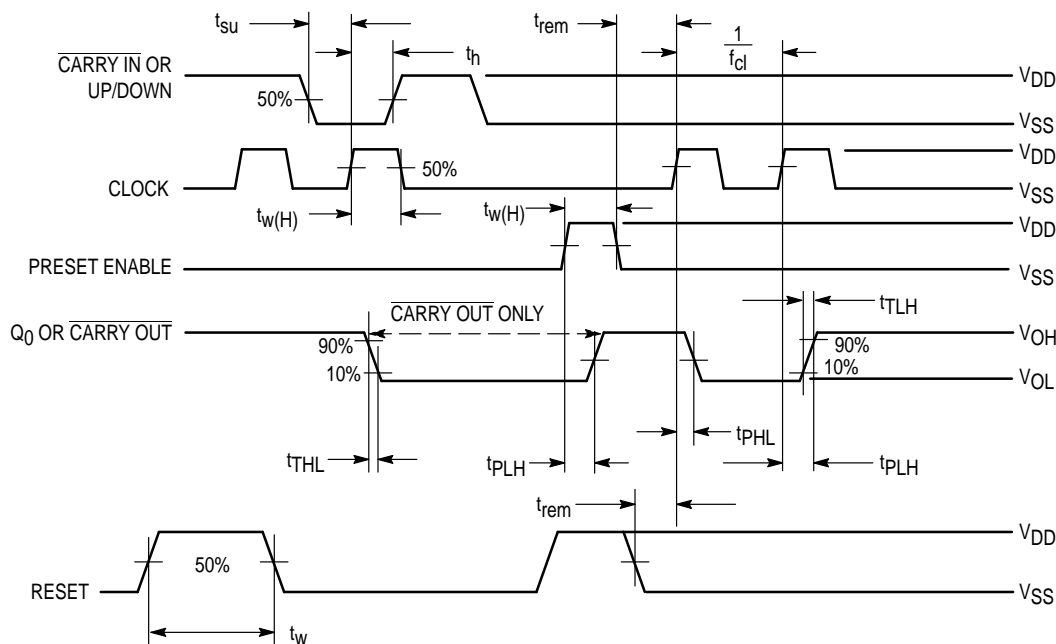


Figure 2. Switching Time Waveforms

PIN DESCRIPTIONS

INPUTS

P0, P1, P2, P3, Preset Inputs (Pins 4, 12, 13, 3) — Data on these inputs is loaded into the counter when PE is taken high.

Carry In, (Pin 5) — This active-low input is used when Cascading stages. Carry In is usually connected to Carry Out of the previous stage. While high, Clock is inhibited.

Clock, (Pin 15) — Binary data is incremented or decremented, depending on the direction of count, on the positive transition of this input.

OUTPUTS

Q0, Q1, Q2, Q3, Binary outputs (Pins 6, 11, 14, 2) — Binary data is present on these outputs with Q0 corresponding to the least significant bit.

Carry Out, (Pin 7) — Used when cascading stages, Carry Out is usually connected to Carry In of the next stage. This

synchronous output is active low and may also be used to indicate terminal count.

CONTROLS

PE, Preset Enable, (Pin 1) — Asynchronously loads data on the Preset Inputs. This pin is active high and inhibits the clock when high.

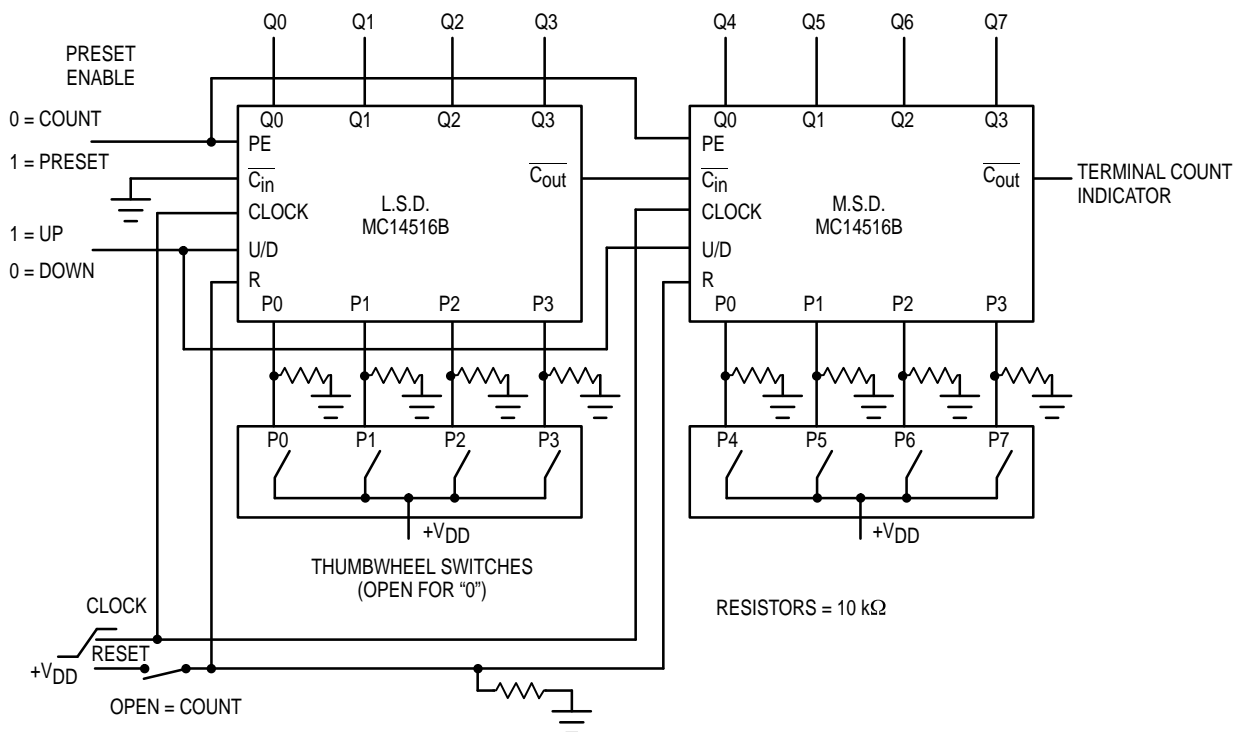
R, Reset, (Pin 9) — Asynchronously resets the Q outputs to a low state. This pin is active high and inhibits the clock when high.

Up/Down, (Pin 10) — Controls the direction of count, high for up count, low for down count.

SUPPLY PINS

VSS, Negative Supply Voltage, (Pin 8) — This pin is usually connected to ground.

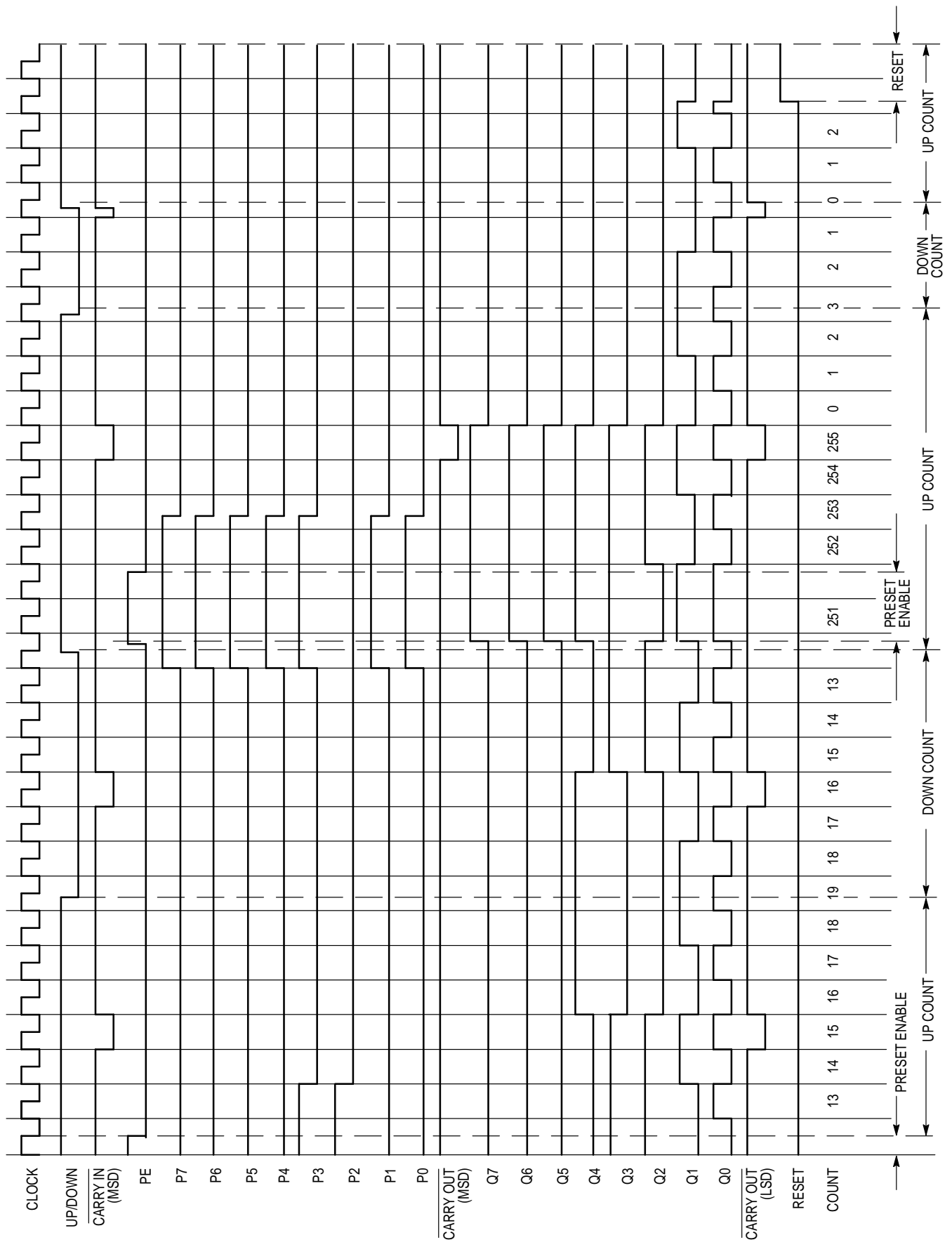
VDD, Positive Supply Voltage, (Pin 16) — This pin is connected to a positive supply voltage ranging from 3.0 volts to 18.0 volts.

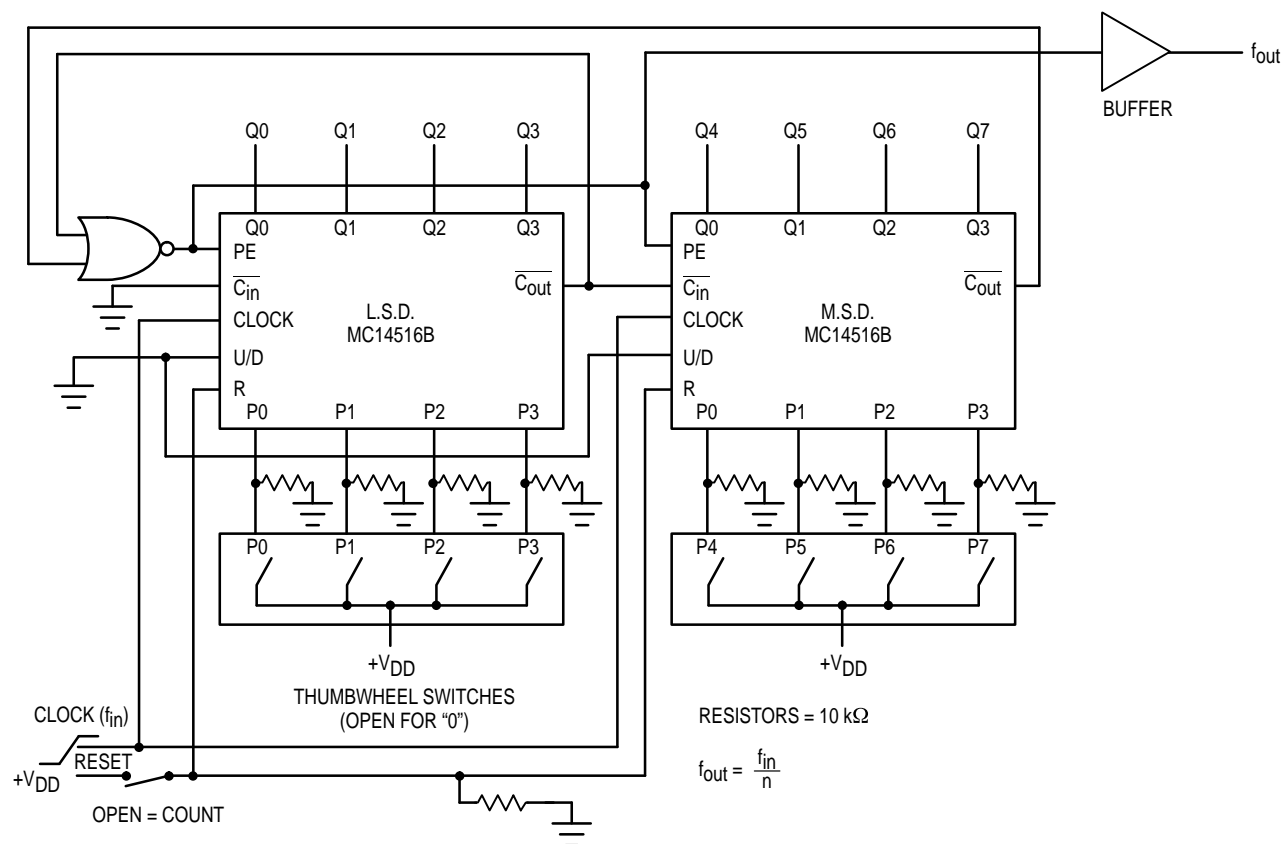


NOTE: The Least Significant Digit (L.S.D.) counts from a preset value once Preset Enable (PE) goes low. The Most Significant Digit (M.S.D.) is disabled while \overline{C}_{in} is high. When the count of the L.S.D. reaches 0 (count down mode) or reaches 15 (count up mode), \overline{C}_{out} goes low for one complete clock cycle, thus allowing the next counter to decrement/increment one count. (See Timing Diagram) The L.S.D. now counts through another cycle (15 clock pulses) and the above cycle is repeated.

Figure 3. Presettable Cascaded 8-Bit Up/Down Counter

TIMING DIAGRAM FOR THE PRESETTABLE CASCADED 8-BIT UP/DOWN COUNTER



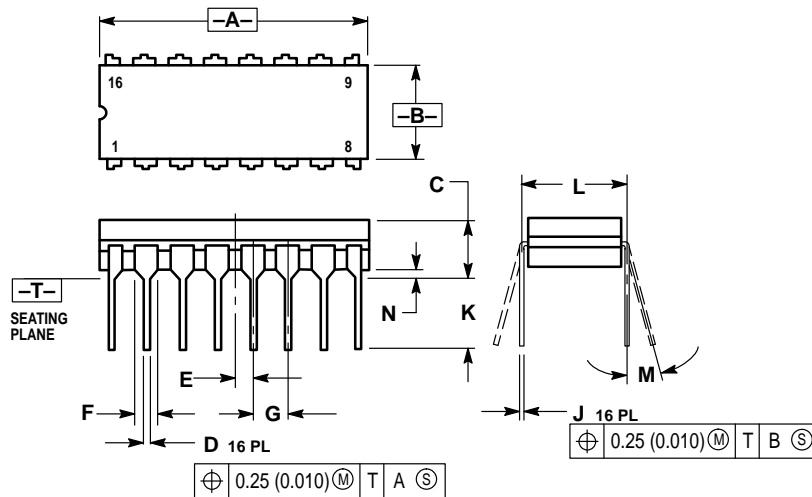


NOTE: The programmable frequency divider can be set by applying the desired divide ratio, in binary, to the preset inputs. For example, the maximum divide ratio of 255 may be obtained by applying a 1111 1111 to the preset inputs P0 to P7. For this divide operation, both counters should be configured in the count down mode. The divide ratio of zero is an undefined state and should be avoided.

Figure 4. Programmable Cascaded Frequency Divider

OUTLINE DIMENSIONS

L SUFFIX CERAMIC DIP PACKAGE CASE 620-10 ISSUE V

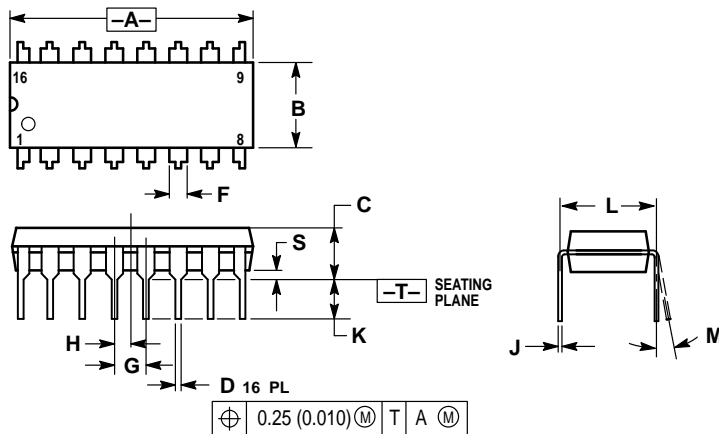


NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
4. DIMENSION F MAY NARROW TO 0.76 (0.030) WHERE THE LEAD ENTERS THE CERAMIC BODY.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.750	0.785	19.05	19.93
B	0.240	0.295	6.10	7.49
C	—	0.200	—	5.08
D	0.015	0.020	0.39	0.50
E	0.050	BSC	1.27	BSC
F	0.055	0.065	1.40	1.65
G	0.100	BSC	2.54	BSC
H	0.008	0.015	0.21	0.38
K	0.125	0.170	3.18	4.31
L	0.300	BSC	7.62	BSC
M	0°	15°	0°	15°
N	0.020	0.040	0.51	1.01

P SUFFIX PLASTIC DIP PACKAGE CASE 648-08 ISSUE R



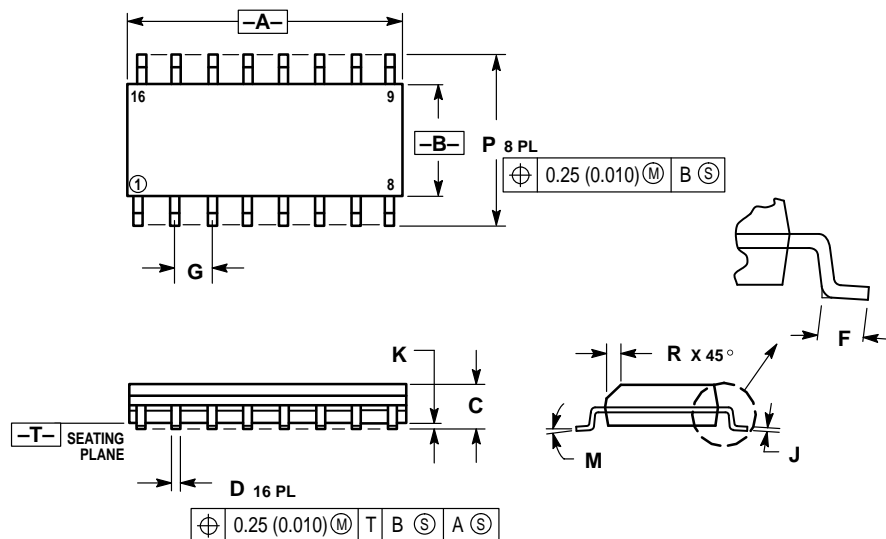
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.740	0.770	18.80	19.55
B	0.250	0.270	6.35	6.85
C	0.145	0.175	3.69	4.44
D	0.015	0.021	0.39	0.53
F	0.040	0.70	1.02	1.77
G	0.100	BSC	2.54	BSC
H	0.050	BSC	1.27	BSC
J	0.008	0.015	0.21	0.38
K	0.110	0.130	2.80	3.30
L	0.295	0.305	7.50	7.74
M	0°	10°	0°	10°
S	0.020	0.040	0.51	1.01

OUTLINE DIMENSIONS

D SUFFIX PLASTIC SOIC PACKAGE CASE 751B-05 ISSUE J



NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.80	10.00	0.386	0.393
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

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MOTOROLA

MC14516B/D

