

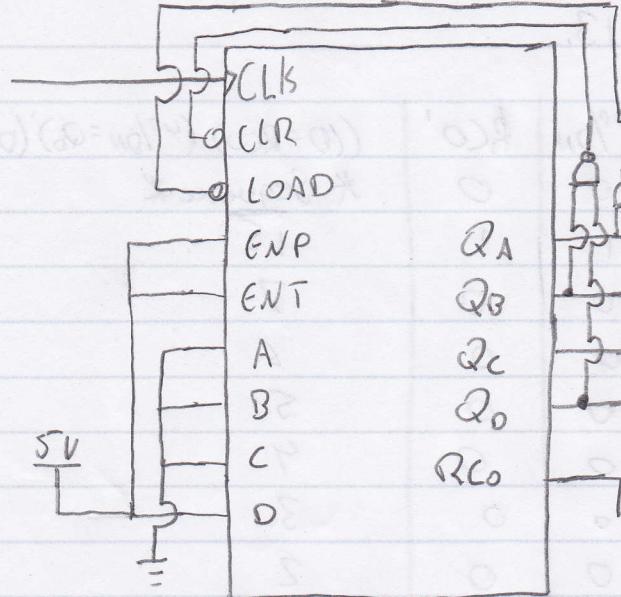
Brian Faure DLD Hw #10 RUID:150003563 Pg 1

Textbook Chapter Eight

#13) Counting sequence of Figure X8.13...

| Q_3 | Q_2 | Q_1 | Q_0 | D | C | B | A | CD' | up/DN | RCO' | $((D=RCO) \wedge (up/DN = Q_0)) \wedge (D = Q_0')$ |
|-------|-------|-------|-------|---|---|---|---|-------|-------|--------|--|
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | * Sequence * |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 7 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 8 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 9 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 10 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 11 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 12 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 13 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 14 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 7 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 3 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 8 |

#14) ENP, ENT, D always HIGH A, B, C always low $QD = (QA \cdot QC)'$
 $CLR_L = (QB \cdot QD)'$



| <u>Q_D Q_C Q_B Q_A</u> | <u>CLR_L LOAD_L</u> | |
|--|---------------------|----|
| 1 0 0 0 0 | 1 1 1 1 | 0 |
| 1 0 0 0 1 | 1 1 1 1 | 1 |
| 1 0 0 1 0 | 1 1 1 1 | 2 |
| 1 0 0 1 1 | 1 1 1 1 | 3 |
| 1 0 1 0 1 | 1 1 1 0 | 4 |
| 1 0 1 0 0 | 1 1 1 1 | 8 |
| 1 0 0 1 1 | 1 1 1 1 | 9 |
| 1 0 1 0 0 | 1 1 1 1 | 10 |
| 0 0 0 0 0 | 1 1 1 1 | 0 |
| 0 0 0 0 1 | 1 1 1 1 | 1 |
| 0 0 0 1 0 | 1 1 1 1 | 2 |
| 0 0 0 1 1 | 1 1 1 1 | 3 |
| 0 0 1 0 1 | 1 1 1 0 | 4 |
| 0 0 1 0 0 | 1 1 1 1 | 8 |
| 0 0 0 1 1 | 1 1 1 1 | 9 |
| 0 0 1 1 0 | 1 1 1 1 | 10 |
| 0 0 0 0 0 | 1 1 1 1 | 0 |

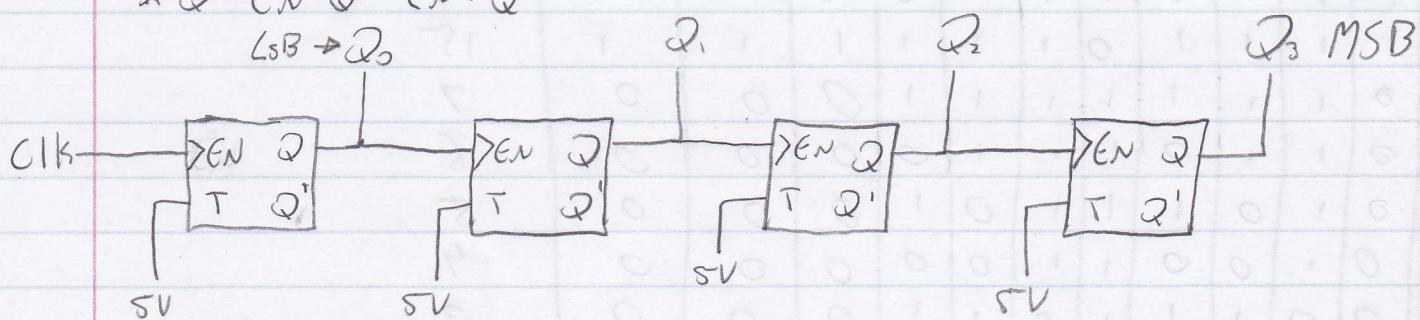
AND NAND

| | | | | |
|-----------|---|-----------|-----------|----|
| 0 0 0 0 1 | 1 | 1 0 1 0 1 | 1 1 0 0 0 | 0 |
| 0 1 0 0 1 | 0 | 0 1 0 0 0 | 1 1 1 1 1 | 8 |
| 1 0 0 0 1 | 0 | 1 1 0 0 1 | 1 1 1 1 1 | 9 |
| 1 1 1 0 0 | 0 | 1 0 1 0 0 | 0 1 1 1 1 | 10 |
| 1 1 1 1 1 | 1 | 1 0 0 0 0 | 1 1 1 1 1 | 0 |

#26) Design 4-Bit ripple down counter using 4 T flip-flops & no other components

$$* Q = EN \cdot Q' + EN' \cdot Q$$

Lsb $\Rightarrow Q_0$



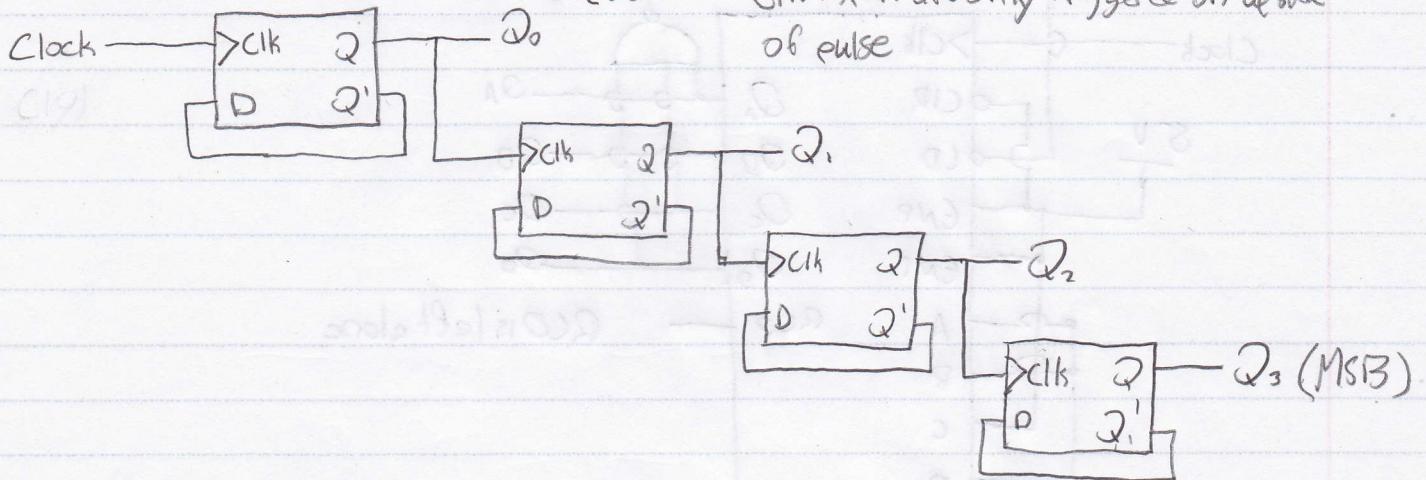
* Starts at 1111 and counts down to 0000

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#27) 4-Bit ripple down using D FF's

5/5B

- CLK inputs are only triggered on upside of pulse



#35) Has to load a 4 → 0100
DCBA Never will have to clear (clear to power)

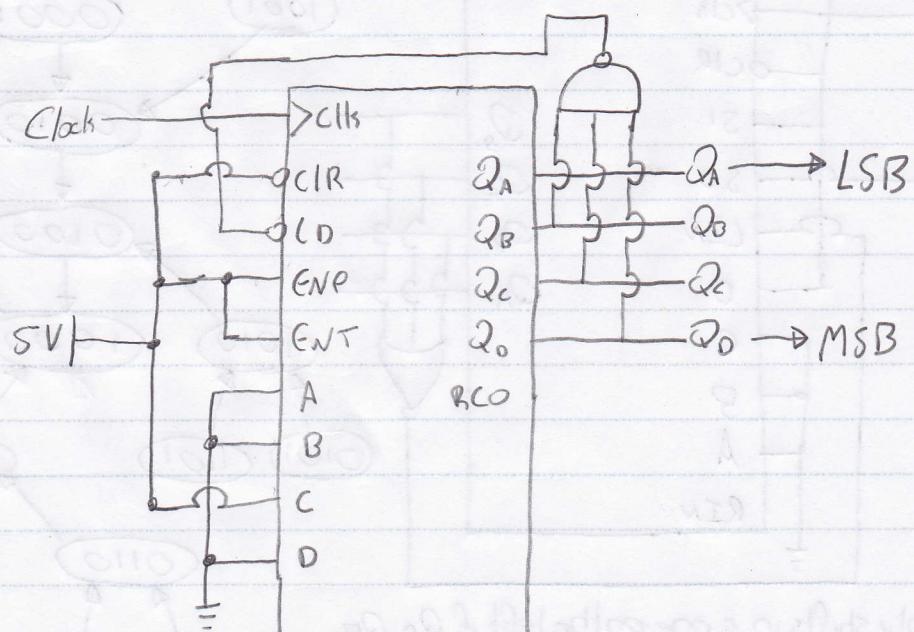
Load is activated when at value of 14 \rightarrow 1 1 1 0
 $Q_0 Q_1 Q_2 Q_3 Q_4$
 Load - 1 = $(Q_0 Q_1 Q_2 Q_3 Q_4)$ D C B A

$$CIR - L = \text{Power}$$

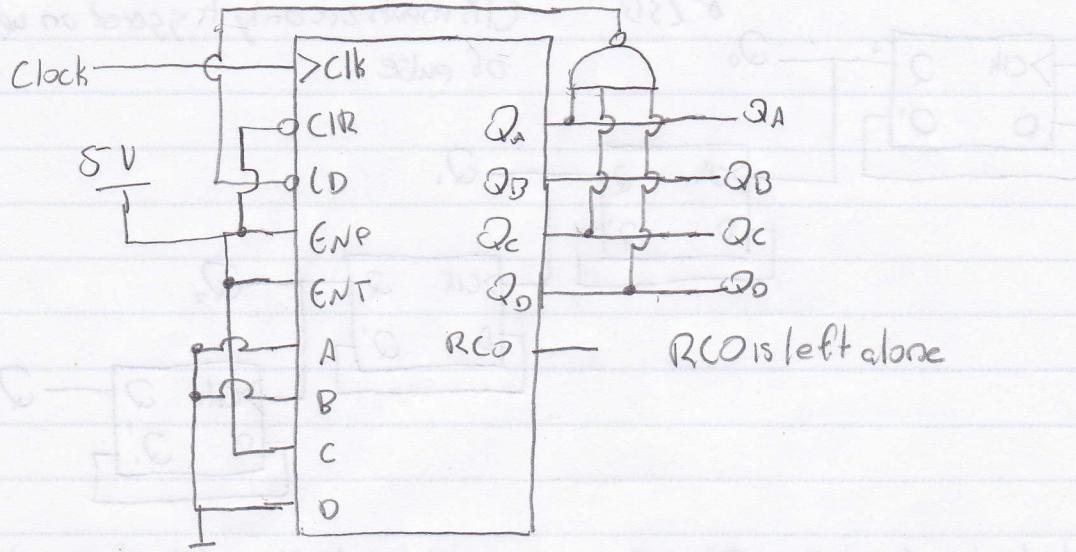
$$D, B, A = GND$$

C = Power

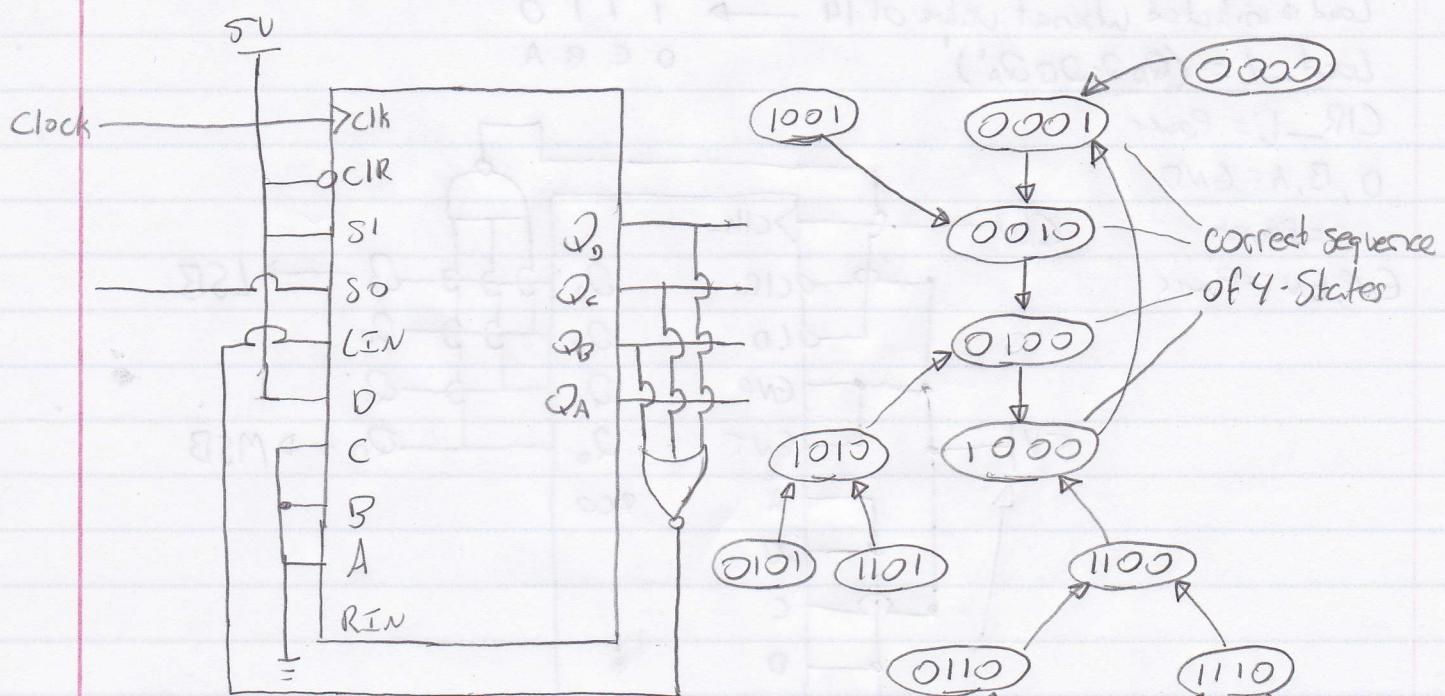
$E_N P, E_N T = \text{Power}$



#1) 163 Counter counts from 4 to 13 // will back to loading a 4 $\rightarrow Q_c = 1, Q_1, Q_2, Q_0 = 0$
 at output of 13 $\rightarrow (D_L = (Q_0 \cdot Q_c \cdot Q_A))'$



#2) 4 Bit Self Starting Ring Counter



* Only shifts in a one on the left if Q_D, Q_B and Q_C are all zero (always will get back)

back on track)

00 0 1

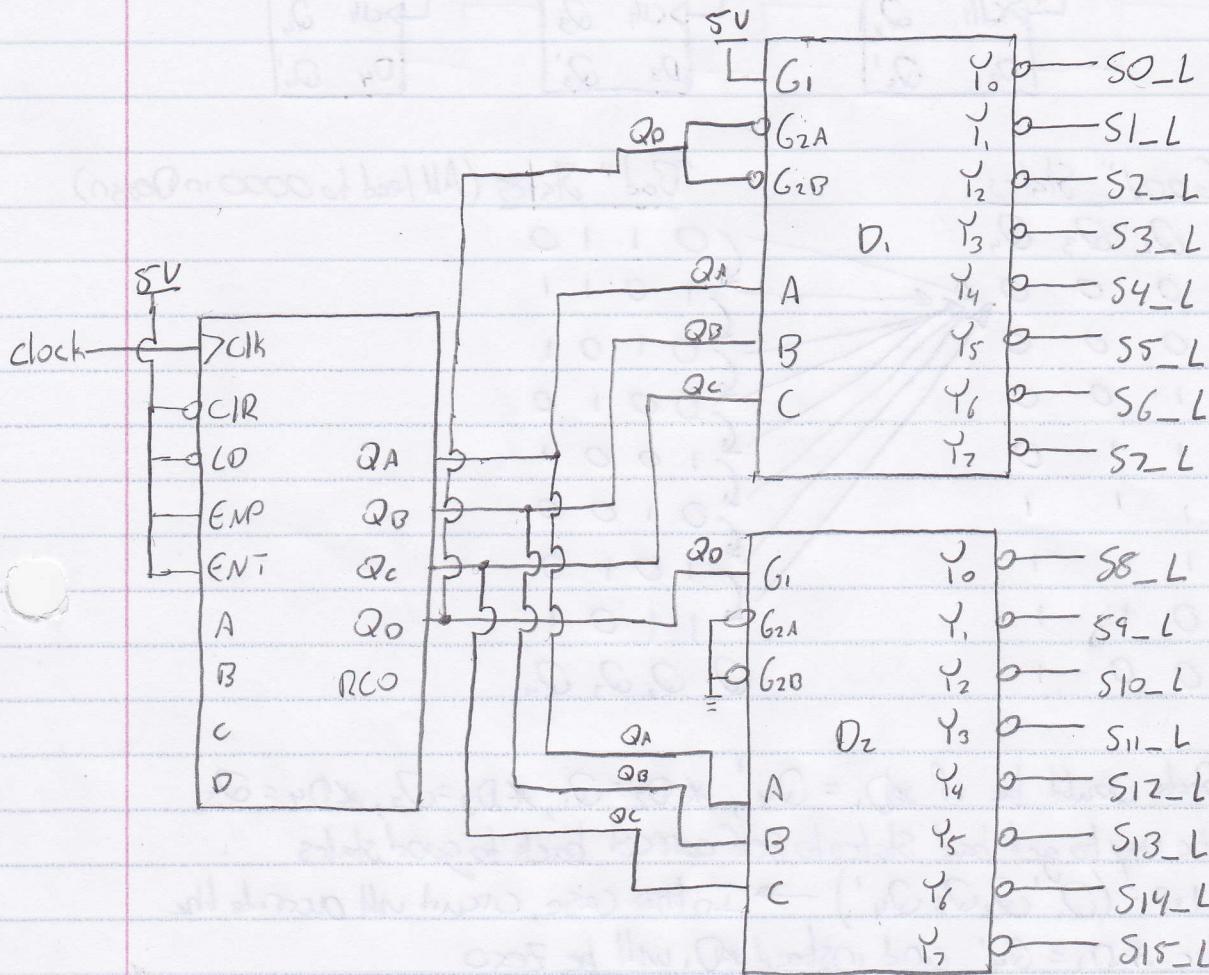
01 1 0

10 1 0

11 1 0

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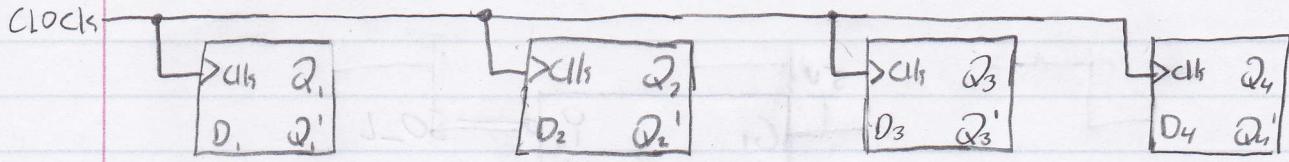
#3) 16 Bit ring counter w/ one 1632 Z 138's



* Outputs are active low

* Q₀ decides which Decoder to enable, when it is on, enables D₂ and the higher value outputs only

#4) Self-Starting 4 Bit Johnson Counter



"Good" States

$Q_1 \quad Q_2 \quad Q_3 \quad Q_4$

- (0 0 0 0)
- (1 0 0 0)
- (1 1 0 0)
- (1 1 1 0)
- (1 1 1 1)
- (0 1 1 1)
- (0 0 1 1)
- (0 0 0 1)

"Bad" States (All lead to 0000 in Design)

$Q_1 \quad Q_2 \quad Q_3 \quad Q_4$

- (0 1 1 0)
- (1 0 1 1)
- (0 1 0 1)
- (0 0 1 0)
- (1 0 0 1)
- (0 1 0 0)
- (1 0 1 0)
- (1 1 0 1)

- Good State would be if $*D_1 = Q_4'$, $*D_2 = Q_1$, $*D_3 = Q_2$, $*D_4 = Q_3$
 - Need a way to get bad states to self correct back to good states
 - $0110 = (Q_1'Q_2Q_3Q_4')$ → In this case, circuit will override the regular $*D_1 = Q_4'$ and instead $*D_1$ will be zero
- * Any of the "Bad States" will cause the circuit to be reset to 0000 *

| | | <u>$*Q_1$</u> | | | |
|-------------------------------|----------------|--------------------------|----|----|----|
| | | 00 | 01 | 11 | 10 |
| Q ₃ Q ₂ | Q ₁ | 0 | 1 | 1 | 0 |
| | D | 0 | 0 | 0 | 0 |
| 00 | 0 | 0 | 0 | 0 | 0 |
| 01 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 1 | 0 | 0 |

| | | <u>$*Q_2$</u> | | | |
|-------------------------------|----------------|--------------------------|----|----|----|
| | | 00 | 01 | 11 | 10 |
| Q ₃ Q ₂ | Q ₁ | 0 | 0 | 1 | 1 |
| | D | 0 | 0 | 0 | 0 |
| 00 | 0 | 0 | 0 | 0 | 0 |
| 01 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 1 | 0 |
| 10 | 0 | 0 | 1 | 0 | 0 |

$$*Q_1 = Q_1Q_3Q_4 + Q_1Q_2Q_4 + Q_1'Q_3'Q_4'$$

$$*Q_2 = Q_1Q_3'Q_4' + Q_1Q_2Q_3 + Q_1Q_2Q_4'$$

$$*D_1 = Q_1Q_3'Q_4' + Q_1Q_2Q_4' + Q_1'Q_3'Q_4'$$

$$*D_2 = Q_1Q_3'Q_4' + Q_1Q_2Q_3 + Q_1Q_2Q_4'$$

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* Q_3

| $Q_3 Q_4$ | 00 | 01 | 11 | 10 |
|-----------|----|----|----|----|
| 00 | 0 | 0 | 1 | 0 |
| 01 | 0 | 0 | 0 | 0 |
| 11 | 0 | 1 | 1 | 0 |
| 10 | 0 | 0 | 1 | 0 |

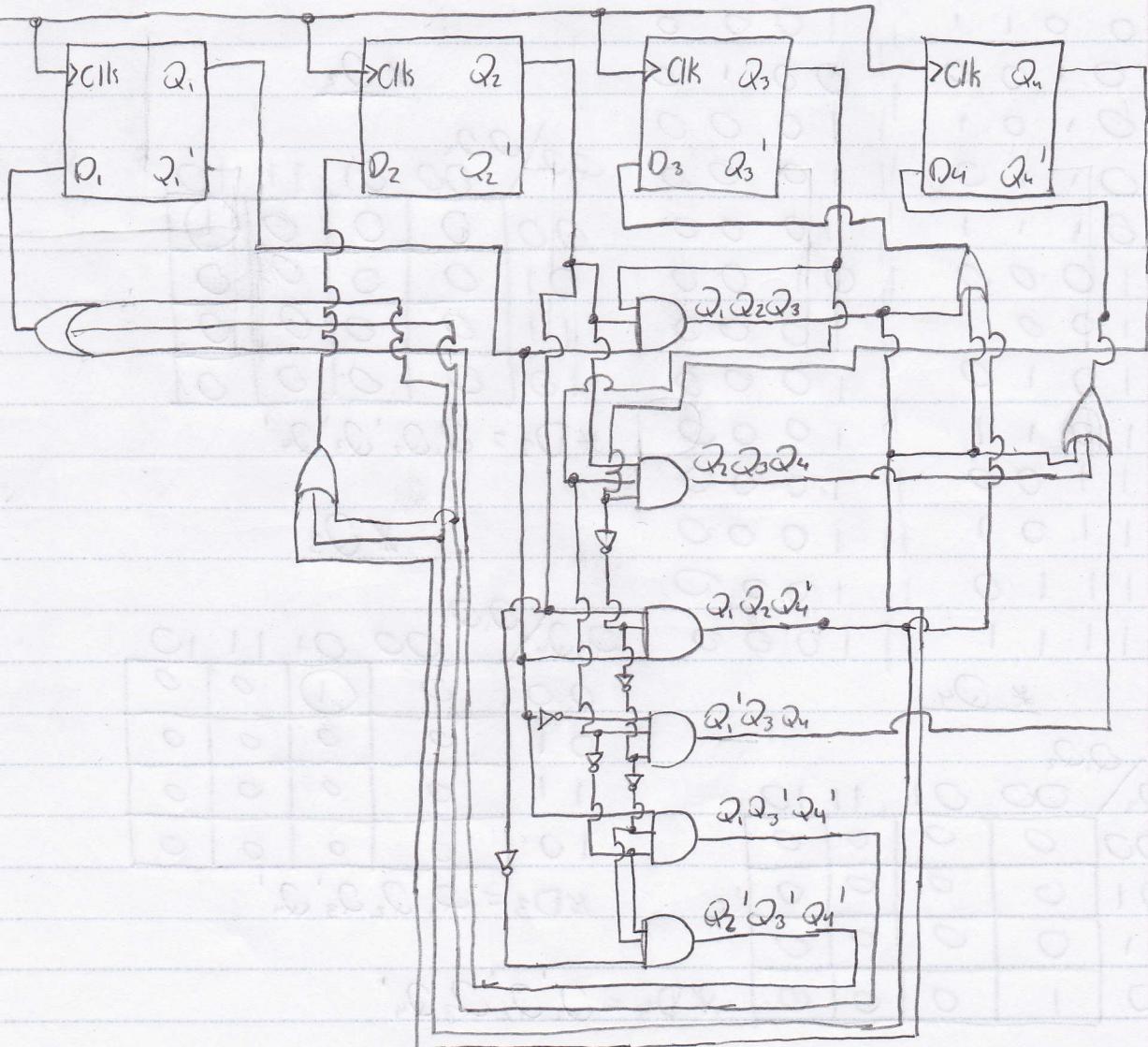
* Q_4

| $Q_3 Q_4$ | 00 | 01 | 11 | 10 |
|-----------|----|----|----|----|
| 00 | 0 | 0 | 0 | 0 |
| 01 | 0 | 0 | 0 | 0 |
| 11 | 1 | 1 | 1 | 0 |
| 10 | 0 | 0 | 1 | 0 |

$$* Q_3 = Q_2 Q_3 Q_4 + Q_2 Q_2 Q_4 + Q_1 Q_2 Q_3$$

$$* D_3 = Q_2 Q_3 Q_4 + Q_2 Q_2 Q_3 + Q_1 Q_2 Q_4' \quad * D_4 = Q_1 Q_3 Q_4 + Q_2 Q_3 Q_4 + Q_1 Q_2 Q_3$$

CLOCK



#5) Self-Start 4 Bit Ring Counter w/ 0 FF's

correct flow of states \rightarrow All other states will be sent back to initial: 1000

| <u>Q</u> | <u>Q₂</u> | <u>Q₃</u> | <u>Q₄</u> |
|---|---|----------------------|----------------------|
| 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 |
| <u>Current State</u> | <u>Next State</u> | | |
| Q ₁ Q ₂ Q ₃ Q ₄ | Q ₁ Q ₂ Q ₃ Q ₄ | | |
| 0 0 0 0 | 1 0 0 0 | | |
| 0 0 0 1 | 1 0 0 0 | | |
| 0 0 1 0 | 0 0 0 1 | | |
| 0 0 1 1 | 1 0 0 0 | | |
| 0 1 0 0 | 0 0 1 0 | | |
| 0 1 0 1 | 1 0 0 0 | | |
| 0 1 1 0 | 1 0 0 0 | | |
| 0 1 1 1 | 1 0 0 0 | | |
| 1 0 0 0 | 0 1 0 0 | | |
| 1 0 0 1 | 1 0 0 0 | | |
| 1 0 1 0 | 1 0 0 0 | | |
| 1 0 1 1 | 1 0 0 0 | | |
| 1 1 0 0 | 1 0 0 0 | | |
| 1 1 0 1 | 1 0 0 0 | | |
| 1 1 1 0 | 1 0 0 0 | | |
| 1 1 1 1 | 1 0 0 0 | | |

| | | |
|-----------------------|---|-------------|
| <u>*Q₁</u> | Q ₃ Q ₂ \ Q ₁ Q ₂ | 00 01 11 10 |
| 00 | 0 0 0 1 | 0 0 0 0 |
| 01 | 0 1 1 1 | 0 1 1 1 |
| 11 | 1 1 1 1 | 1 1 1 1 |
| 10 | 0 1 1 0 | 1 0 1 0 |

$*Q_1 = Q_4 + Q_1 Q_2 + Q_1' Q_2' Q_3' + Q_2 Q_3 + Q_2 Q_3'$

$*D_1 = Q_4 + Q_1 Q_2 + Q_1 Q_3 + Q_2 Q_3 + Q_1' Q_2' Q_3'$

| | | |
|-----------------------|---|-------------|
| <u>*Q₂</u> | Q ₃ Q ₂ \ Q ₁ Q ₂ | 00 01 11 10 |
| 00 | 0 0 0 1 | 0 0 0 1 |
| 01 | 0 1 0 0 | 0 1 0 0 |
| 11 | 1 0 0 0 | 1 0 0 0 |
| 10 | 0 0 0 0 | 0 0 0 0 |

$*D_2 = Q_1 Q_2' Q_3' Q_4'$

| | | |
|-----------------------|---|-------------|
| <u>*Q₃</u> | Q ₃ Q ₂ \ Q ₁ Q ₂ | 00 01 11 10 |
| 00 | 0 0 0 1 | 0 0 0 1 |
| 01 | 0 1 0 0 | 0 1 0 0 |
| 11 | 1 0 0 0 | 1 0 0 0 |
| 10 | 0 0 0 0 | 0 0 0 0 |

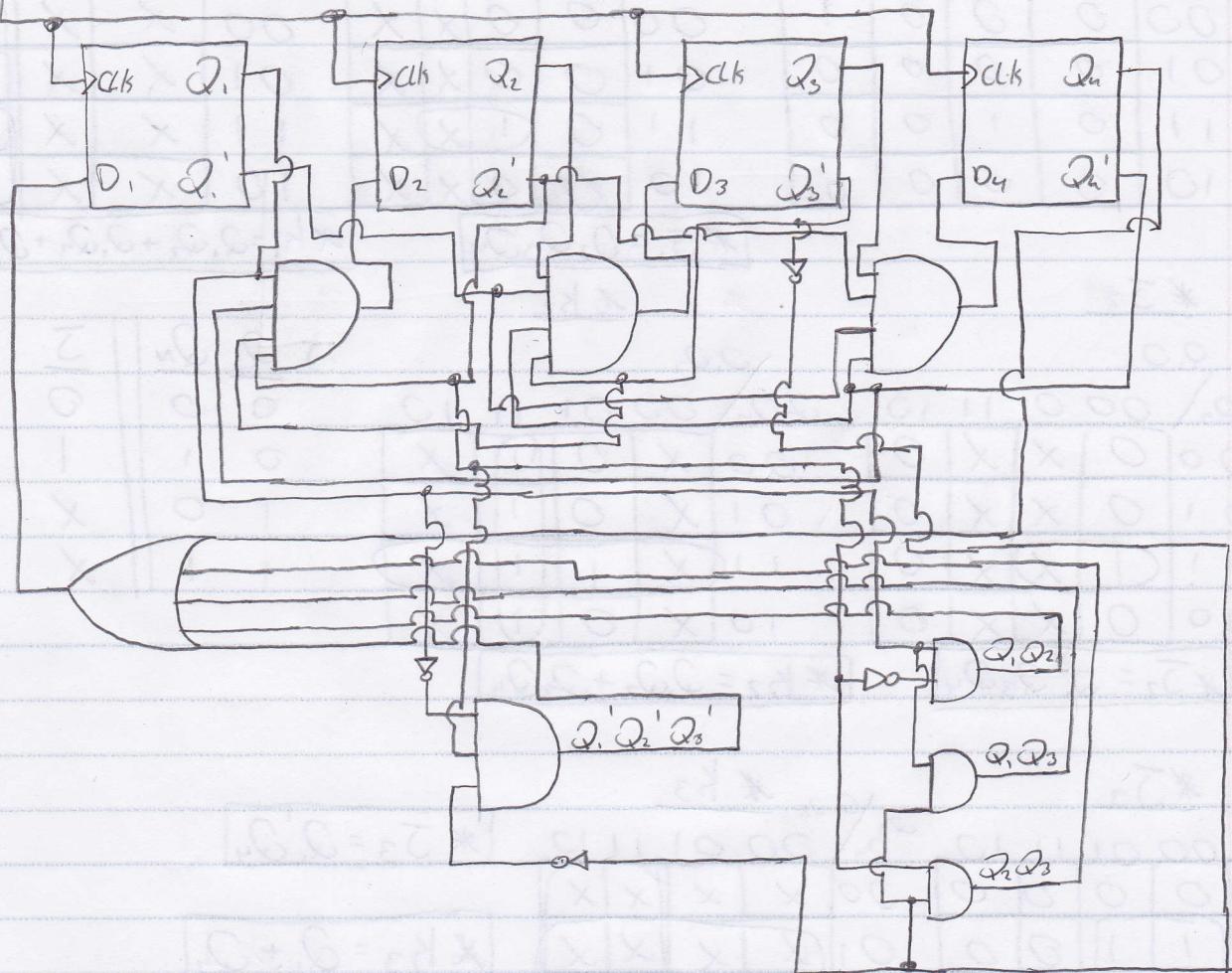
$*D_3 = Q_1' Q_2 Q_3' Q_4'$

| | | |
|-----------------------|---|-------------|
| <u>*Q₄</u> | Q ₃ Q ₂ \ Q ₁ Q ₂ | 00 01 11 10 |
| 00 | 0 0 0 0 | 0 0 0 0 |
| 01 | 0 0 0 0 | 0 0 0 0 |
| 11 | 0 0 0 0 | 0 0 0 0 |
| 10 | 1 0 0 0 | 0 0 0 0 |

$*D_4 = Q_1' Q_2' Q_3 Q_4'$

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Clock



#6) Self Start synchronous decade counter from 0 to 9

| <u>Current State</u> | <u>Next State</u> | <u>Current State</u> | <u>Next State</u> | → Anything past 1001 (9) will get reset back to 0000 then proceed normally from there |
|--|--|--|--|--|
| <u>Q₁ Q₂ Q₃ Q₄</u> | |
| 0 0 0 0 | 1 0 0 0 | 1 1 0 0 | 1 0 0 1 | |
| 0 0 0 1 | 0 0 1 0 | 1 0 0 1 | 0 0 0 0 | |
| 0 0 1 0 | 0 0 1 1 | 1 0 1 0 | 0 0 0 0 | |
| 0 0 1 1 | 0 1 0 0 | 1 0 1 1 | 0 0 0 0 | |
| 0 1 0 0 | 0 1 0 1 | 1 1 0 0 | 0 0 0 0 | |
| 0 1 0 1 | 0 1 1 0 | 1 1 0 1 | 0 0 0 0 | |
| 0 1 1 0 | 0 1 1 1 | 1 1 1 0 | 0 0 0 0 | |
| 0 1 1 1 | 1 0 0 0 | 1 1 1 1 | 0 0 0 0 | |

* Q_1 (Next State)

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|--|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | 0 | 0 | 1 | |
| 00 | 0 | 0 | 0 | 0 | 1 | |
| 01 | 0 | 0 | 0 | 0 | 0 | |
| 11 | 0 | 1 | 0 | 0 | 0 | |
| 10 | 0 | 0 | 0 | 0 | 0 | |

* J_1

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | 0 | 0 | X | X |
| 00 | 0 | 0 | 0 | X | X | |
| 01 | 0 | 0 | 0 | X | X | |
| 11 | 0 | 1 | X | X | X | |
| 10 | 0 | 0 | X | X | X | |

* K_1

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | X | X | 1 | 0 |
| 00 | X | X | 1 | 0 | 0 | |
| 01 | X | X | 1 | 1 | 1 | |
| 11 | X | X | 1 | 1 | 1 | |
| 10 | X | X | 1 | 1 | 1 | |

* J_2

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | 0 | X | X | 0 |
| 00 | 0 | X | X | 0 | 0 | |
| 01 | 0 | X | X | 0 | 0 | |
| 11 | 1 | X | X | 0 | 0 | |
| 10 | 0 | X | X | 0 | 0 | |

$$* \bar{J}_2 = Q_1' Q_3 Q_4$$

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | X | 0 | 1 | X |
| 00 | X | 0 | 1 | X | X | |
| 01 | X | 0 | 1 | X | X | |
| 11 | X | 1 | 1 | X | X | |
| 10 | X | 0 | 1 | X | X | |

$$* K_2 = Q_1 Q_2 + Q_3 Q_4$$

| | | Q ₁ Q ₂ | | | |
|-------------------------------|---|-------------------------------|---|---|---|
| | | 0 | 0 | 1 | 1 |
| Q ₃ Q ₄ | | 0 | 0 | 0 | X |
| 0 | 0 | 0 | 0 | 0 | X |
| 0 | 1 | 0 | 0 | 1 | X |
| 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 1 | 0 | 0 |

* J_3

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | X | X | X | X |
| 00 | X | X | X | X | X | |
| 01 | X | X | X | X | X | |
| 11 | X | X | X | X | X | |
| 10 | X | X | X | X | X | |

* k_3

$$* J_3 = Q_1' Q_4$$

$$* K_3 = Q_1 + Q_4$$

* J_4

$$* J_4 = Q_1' + Q_2' Q_3'$$

* K_4

$$* K_4 = \text{To Power}(\log \text{HIGH})$$

| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | 1 | 1 | 0 | 1 |
| 00 | 1 | 1 | 0 | 1 | 1 | |
| 01 | X | X | X | X | X | |
| 11 | X | X | X | X | X | |
| 10 | 1 | 1 | 0 | 0 | 0 | |

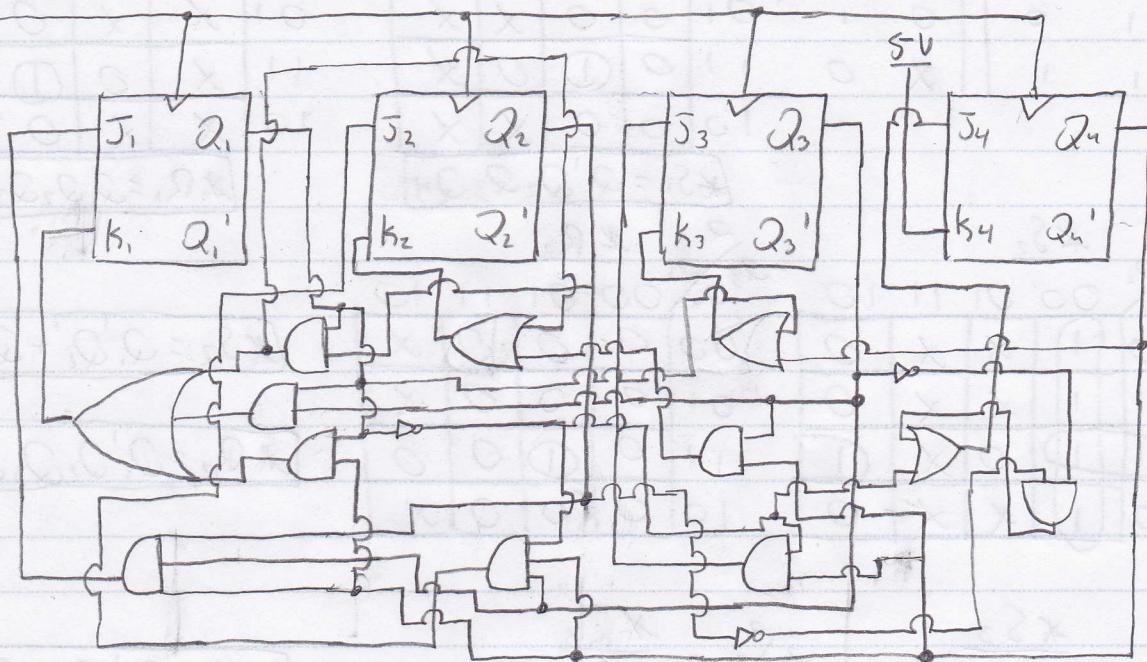
| | | Q ₁ Q ₂ | | | | |
|-------------------------------|---|-------------------------------|----|----|----|---|
| | | 00 | 01 | 11 | 10 | |
| Q ₃ Q ₄ | | 00 | X | X | X | X |
| 00 | X | X | X | X | X | |
| 01 | 1 | 1 | 1 | 1 | 1 | |
| 11 | 1 | 1 | 1 | 1 | 1 | |
| 10 | X | X | X | X | X | |

Eg 11

$$J_1 = Q_2 Q_3 Q_4 \quad J_2 = Q_1' Q_3 Q_4 \quad J_3 = Q_1' Q_4 \quad J_4 = Q_1' + Q_1' Q_3'$$

$$K_1 = Q_1 Q_2 + Q_1 Q_4 + Q_1 Q_3 \quad K_2 = Q_1 Q_2 + Q_3 Q_4 \quad K_3 = Q_1 + Q_4 \quad K_4 = \text{HIGH}$$

Clock



#7) Something but start at 0110 and go to 1111 & use SRFF's

| <u>Current State</u> | <u>Next State</u> | <u>Current State</u> | <u>Next State</u> |
|----------------------|-------------------|----------------------|-------------------|
|----------------------|-------------------|----------------------|-------------------|

| | | | |
|-------------------------|-------------------------|-------------------------|-------------------------|
| $Q_1 \ Q_2 \ Q_3 \ Q_4$ |
| 0 0 0 0 | 0 1 1 0 | 1 1 0 0 | 1 1 0 1 |

| | | | |
|---------|---------|---------|---------|
| 0 0 0 1 | 0 1 1 0 | 1 1 0 1 | 1 1 1 0 |
|---------|---------|---------|---------|

| | | | |
|---------|---------|---------|---------|
| 0 0 1 0 | 0 1 1 0 | 1 1 1 0 | 1 1 1 1 |
|---------|---------|---------|---------|

| | | | |
|---------|---------|---------|---------|
| 0 0 1 1 | 0 1 1 0 | 1 1 1 1 | 0 1 1 0 |
|---------|---------|---------|---------|

| | |
|---------|---------|
| 0 1 0 0 | 0 1 1 0 |
|---------|---------|

| | |
|---------|---------|
| 0 1 0 1 | 0 1 1 0 |
|---------|---------|

| | |
|---------|---------|
| 0 1 1 0 | 0 1 1 1 |
|---------|---------|

| | |
|---------|---------|
| 0 1 1 1 | 1 0 0 0 |
|---------|---------|

| | |
|---------|---------|
| 1 0 0 0 | 1 0 0 1 |
|---------|---------|

| | |
|---------|---------|
| 1 0 0 1 | 1 0 1 0 |
|---------|---------|

| | |
|---------|---------|
| 1 0 1 0 | 1 0 1 1 |
|---------|---------|

| | |
|---------|---------|
| 1 0 1 1 | 1 1 0 0 |
|---------|---------|

→ After 1111, resets back to 0110

→ Anything below 0110 will be reset to 0110

| Q | Q_N | S | R | $*S_1$ |
|-----|-------|-----|-----|-----------|
| 0 | 0 | 0 | X | 000011110 |
| 0 | 1 | 1 | 0 | 0000X0X0 |
| 1 | 0 | 0 | 1 | 0100X0X0 |
| 1 | 1 | X | 0 | 1101010X |
| | | | | 1000X0X0 |

$$*S_1 = Q_1'Q_2Q_3Q_4$$

| Q | Q_N | S | R | $*R_1$ |
|-----|-------|-----|-----|-----------|
| 0 | 0 | 0 | 0 | 000011110 |
| 0 | 1 | X | X | 00X00000 |
| 1 | 0 | X | X | 01X00000 |
| 1 | 1 | X | 0 | 11X01010 |
| | | | | 10X0X000 |

$$*R_1 = Q_1Q_2Q_3Q_4$$

| Q | Q_N | S | R | $*S_2$ |
|-----|-------|-----|-----|-----------|
| 0 | 0 | 0 | 0 | 000011110 |
| 0 | 1 | 1 | X | 0011X000 |
| 1 | 1 | 1 | X | 11110X00 |
| 1 | 0 | 0 | X | 110X0101 |
| 10 | 1 | X | X | 00X0X00 |

| Q | Q_N | S | R | $*R_2$ |
|-----|-------|-----|-----|----------|
| 0 | 0 | 0 | 0 | 0000000X |
| 0 | 1 | 0 | 0 | 0100000X |
| 1 | 0 | 0 | 0 | 1100000X |
| 1 | 1 | 0 | 0 | 11010000 |
| | | | | 1000000X |

$$*S_2 = Q_1'Q_2 + Q_2'Q_3Q_4$$

$$*R_2 = Q_1'Q_2Q_3Q_4$$

| Q | Q_N | S | R | $*S_3$ |
|-----|-------|------|-----|-----------|
| 0 | 0 | 0 | 0 | 000011110 |
| 0 | 1 | 1 | 0 | 01110000 |
| 1 | 1 | 1 | 1 | 11111111 |
| 1 | 0 | 0 | X | 110X0X00 |
| 10 | 0 | (X)X | X | (X)X0000 |

| Q | Q_N | S | R | $*R_3$ |
|-----|-------|-----|-----|----------|
| 0 | 0 | 0 | 0 | 0000000X |
| 0 | 1 | 0 | 0 | 01000000 |
| 1 | 0 | 0 | 0 | 11000000 |
| 1 | 1 | 0 | 0 | 11010000 |
| | | | | 10000000 |

$$*S_3 = Q_3'Q_4 + Q_1'Q_4'$$

$$*R_3 = Q_1'Q_2Q_3Q_4 + Q_1Q_2'Q_3Q_4$$

| Q | Q_N | S | R | $*S_4$ |
|-----|-------|-----|------|-----------|
| 0 | 0 | 0 | 0 | 000011110 |
| 0 | 1 | 0 | 0 | 00000000 |
| 1 | 0 | 0 | 0 | 11000000 |
| 1 | 1 | 0 | 0 | 11000000 |
| 10 | 0 | 0 | (D)1 | (D)10000 |

$$*S_4 = Q_1Q_4' + Q_2Q_3Q_4'$$

| Q | Q_N | S | R | $*R_4$ |
|-----|-------|-----|-----|----------|
| 0 | 0 | X | X | 00X00000 |
| 0 | 1 | 1 | 1 | 01111111 |
| 1 | 1 | 1 | 1 | 11111111 |
| 10 | 0 | X | 0 | 10000000 |

$$*R_4 = Q_4$$

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$$* S_1 = Q_1' Q_2 Q_3 Q_4 \quad * R_1 = Q_1 Q_2 Q_3 Q_4$$

$$* S_2 = Q_1' Q_2' + Q_1' Q_3 Q_4 \quad * R_2 = Q_1' Q_2 Q_3 Q_4$$

$$* S_3 = Q_3' Q_4 + Q_1' Q_4' \quad * R_3 = Q_1' Q_2 Q_3 Q_4 + Q_1 Q_2' Q_3 Q_4$$

$$* S_4 = Q_1 Q_4' + Q_2 Q_3 Q_4' \quad * R_4 = Q_4$$

CLOCK

