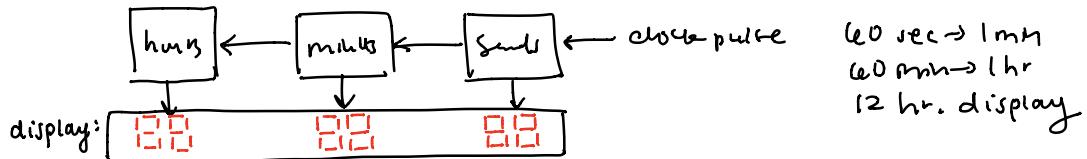


Amy Seo

I completed this assignment entirely on my own.

Sketch/outline:

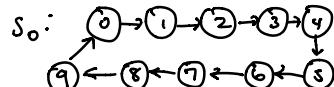
- Display digital clock w/ seconds, minutes, hours



- Seconds Display: $S_1 \quad S_0$ S_1 = 6 state counter, S_0 = 10 state counter

\hookrightarrow Can also be used for min. (set $S_1 = M_1$, $S_0 = m_0$) $M_1 \quad M_0$

- state diagram:



- S_1 state table:

current	0	1	2	3	4	5
next	1	2	3	4	5	0

- S_0 state table:

current	0	1	2	3	4	5	6	7	8	9
next	1	2	3	4	5	6	7	8	9	0

- # of flip-flops:

$$S_1 = \log_2(6) \approx 3$$

$$S_0 = \log_2(10) \approx 4$$

- State assignment

S_1 :

state	FF A	FF B	FF C
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1

S_0 :

state	FF A	FF B	FF C	FF D
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

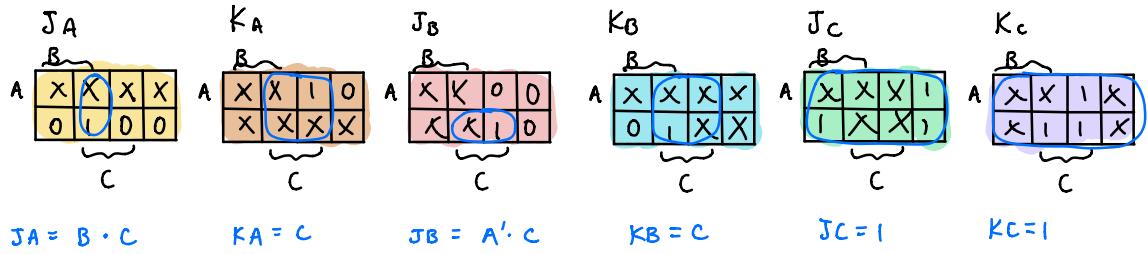
- full-state table + K-maps

S ₁ state	current state			next state			FF A		FF B		FF C	
	A	B	C	A	B	C	J _A	K _A	J _B	K _B	J _C	K _C
0	0	0	0	0	0	1	0	X	0	X	1	X
1	0	0	1	0	1	0	0	X	1	X	X	1
2	0	1	0	0	1	1	0	X	X	0	1	X
3	0	1	1	1	0	0	1	X	X	1	X	1
4	1	0	0	1	0	1	X	0	0	X	1	X
5	1	0	1	0	0	0	X	1	0	X	X	1

J-K flip flop Excitation Table

Q _t	Q _{t+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

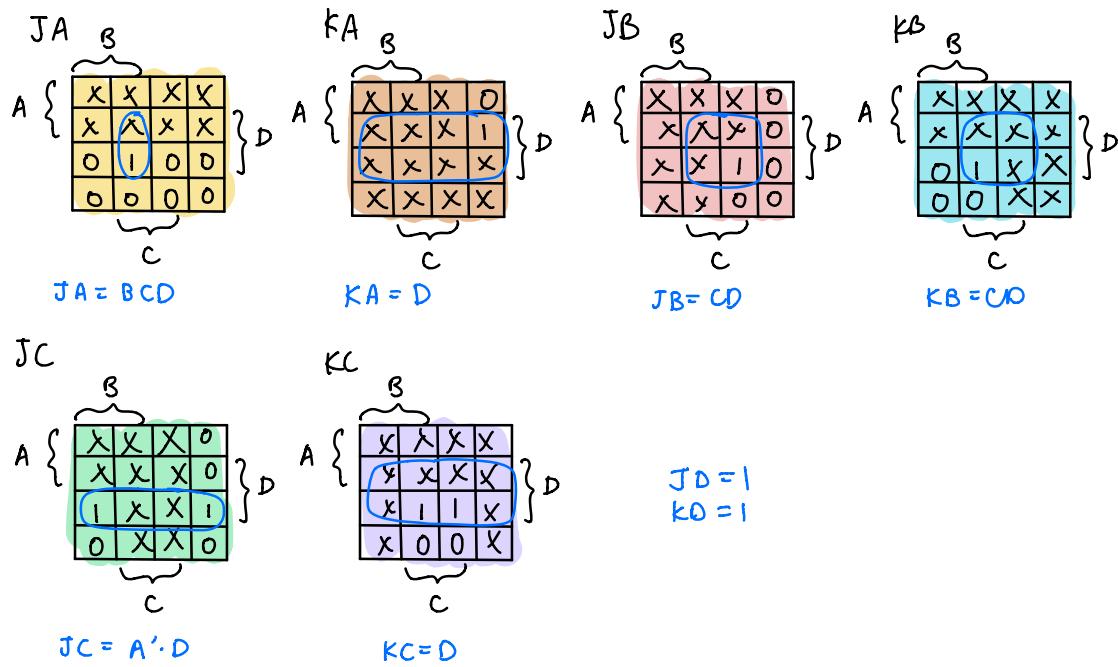
k-maps S_1 :



S_0	current state				next state				FFA		FFB		FFC		FFD	
	A	B	C	D	A	B	C	D	JA	KA	JB	KB	JC	KC	JD	KD
0	0	0	0	0	0	0	0	1	0	X	0	0	0	1	0	X
1	0	0	0	1	0	0	1	0	0	X	0	0	1	X	1	X
2	0	0	1	0	0	0	1	1	0	X	0	0	1	X	1	X
3	0	0	1	1	0	1	0	0	0	X	0	1	X	1	X	1
4	0	1	0	0	0	0	1	0	0	X	0	0	1	X	1	X
5	0	1	0	1	0	1	1	0	0	X	0	0	1	X	1	X
6	0	1	1	0	0	0	1	1	0	X	0	1	0	1	X	1
7	0	1	1	1	1	0	0	0	0	X	0	1	0	1	X	1
8	1	0	0	0	0	1	0	0	1	X	0	0	1	X	1	X
9	1	0	0	1	0	0	0	0	0	X	0	0	0	1	X	1

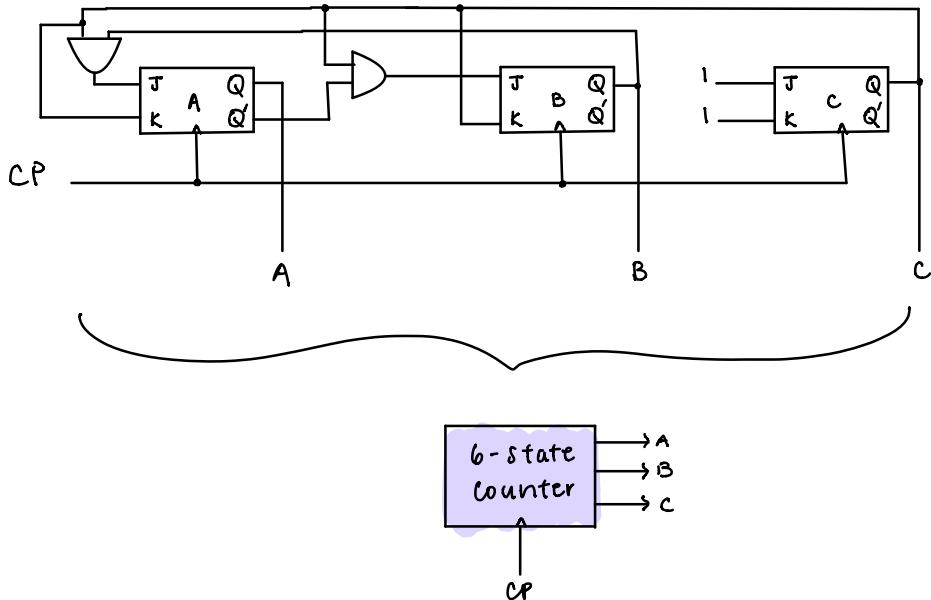
Arrows point from the last row of the table to the K-maps for S_0 .

K-maps S_0 :

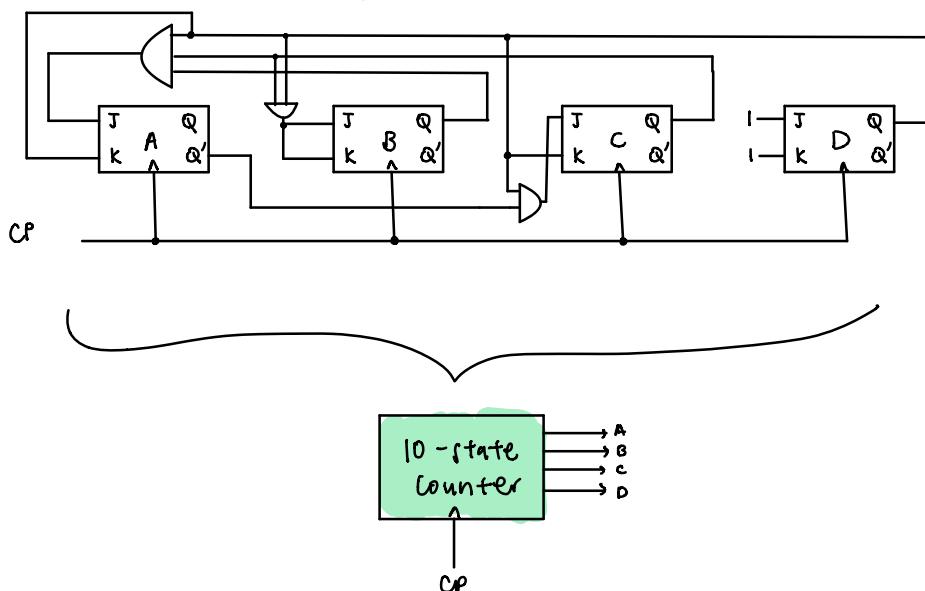


- Circuit Diagrams:

6-state counter circuit:



10-state counter circuit



- check unused states

S ₁	current state			FF A		FF B		FF C		next state			Valid?
	A	B	C	J _A	K _A	J _B	K _B	J _C	K _C	A	B	C	
6	1	1	0	0	0	0	0	1	1	1	1	1	111 → 000✓
7	1	1	1	1	1	0	1	1	1	0	0	0	✓

$J_A = B \cdot C$ $J_B = A' \cdot C$ $J_C = 1$
 $K_A = C$ $K_B = C$ $K_C = 1$

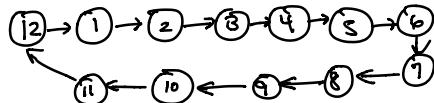
S ₀	current state				FFA		FFB		FFC		FFD		next state				valid?
	A	B	C	D	J _A	K _A	J _B	K _B	J _C	K _C	J _D	K _D	A	B	C	D	
10	1	0	1	0	0	0	0	0	0	0	1	1	1	0	1	1	1011 → 0100 ✓
11	1	0	1	1	0	1	1	1	0	1	1	1	0	1	0	0	✓
12	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1101 → 0100 ✓
13	1	1	0	1	0	1	0	0	0	1	1	1	0	1	0	0	✓
14	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1111 → 0000 ✓
15	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	✓

$$\begin{aligned} JA &= BCD \\ KA &= D \\ JB &= CD \\ KB &= C\bar{D} \\ JC &= A'D \\ KC &= D \\ JD &= \bar{I} \\ KO &= \bar{I} \end{aligned}$$

Now we have 6-state & 10-state counters.

Let's move onto hours display:

- word description: 12 state counter
- state diagram:



J-K Flip Flop Truth Table

J	K	Q _t	Q _{t+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

- state table:

current state	12	1	2	3	4	5	6	7	8	9	10	11	12
next state	1	2	3	4	5	6	7	8	9	10	11	12	

- # of flip-flops: $\log_2(12) \approx 4$

- state assignment

state	FFA	FFB	FFC	FFD
12	1	1	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1

J-K flip flop

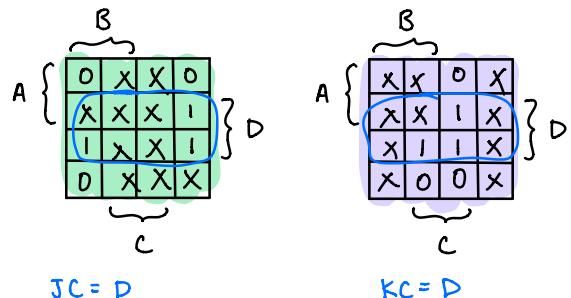
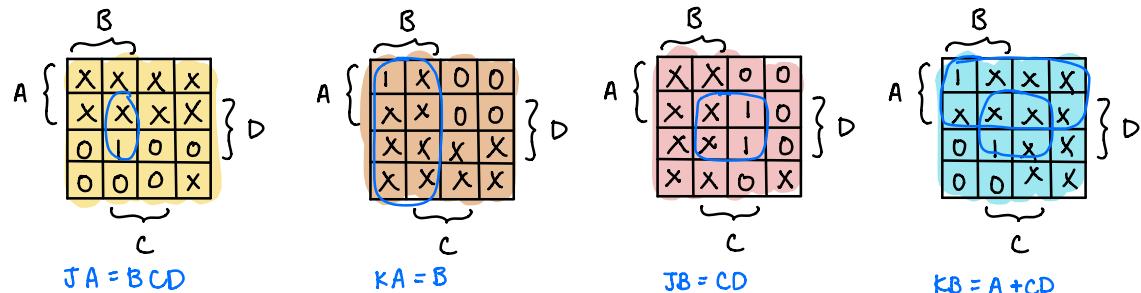
Excitation Table

Q _t	Q _{t+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

- Full state table w/ J-K flip-flops

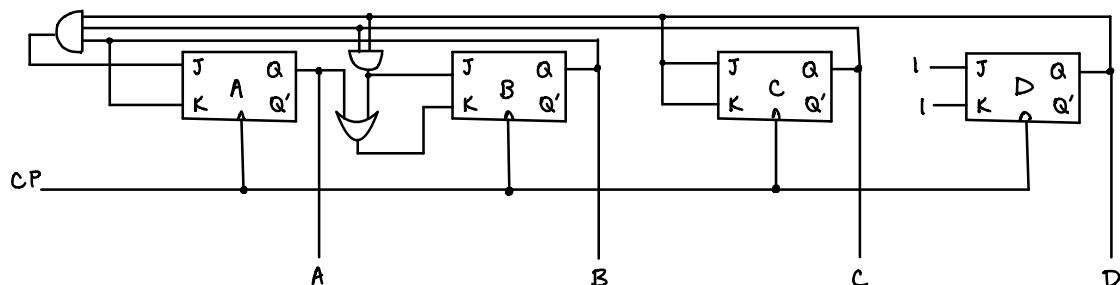
state	current state				next state				FFA		FFB		FFC		FFD	
	A	B	C	D	A	B	C	D	JA	KA	JB	KB	JC	KC	JD	KD
12	1	1	0	0	0	0	0	0	1	X	1	X	0	X	1	X
1	0	0	0	1	0	0	1	0	0	X	0	X	1	X	0	1
2	0	0	1	0	0	0	1	1	0	0	X	0	1	X	1	X
3	0	0	1	1	0	1	0	0	0	X	1	X	0	1	X	1
4	0	1	0	0	0	1	0	1	0	X	X	0	1	X	1	X
5	0	1	0	1	0	1	1	0	0	X	X	0	0	X	1	X
6	0	1	1	0	0	1	1	1	0	X	X	0	1	X	1	X
7	0	1	1	1	1	0	0	0	0	X	X	1	X	1	X	1
8	1	0	0	0	0	1	0	0	1	X	0	X	0	X	1	X
9	1	0	0	1	1	0	1	0	1	X	0	0	1	X	1	X
10	1	0	1	0	1	1	0	1	1	X	0	0	1	X	1	X
11	1	0	1	1	1	1	1	0	0	X	1	X	1	X	1	X

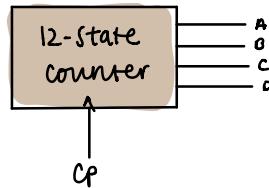
- K-maps



$$JD = 1 \\ KD = 1$$

- Circuit Diagram - 12-state counter



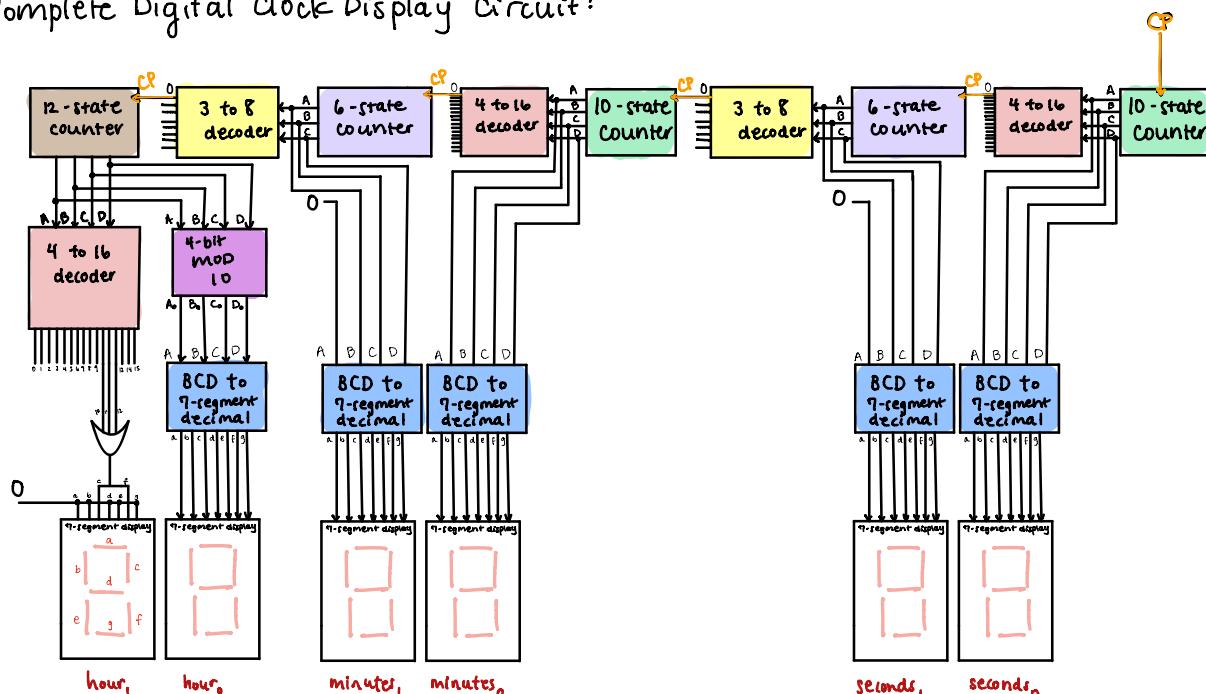


- check unused states

	current state				PFA		FFB		FFC		FFD		next state				valid?
	A	B	C	D	JA	KA	JB	KB	JC	KC	JD	KD	A	B	C	D	
0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	✓
13	1	1	0	1	0	1	0	1	1	1	1	1	0	0	1	0	✓
14	1	1	1	0	0	1	0	1	0	0	1	1	0	0	1	1	✓
15	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0000 \rightarrow 0001 ✓

$JA = BCD$
 $KA = B$
 $JB = CD$
 $KB = A + CD$
 $JC = D$
 $KC = D$
 $JD = 1$
 $KD = 1$

Complete Digital Clock Display Circuit:



BCD to 7-segment display: defined in HW2

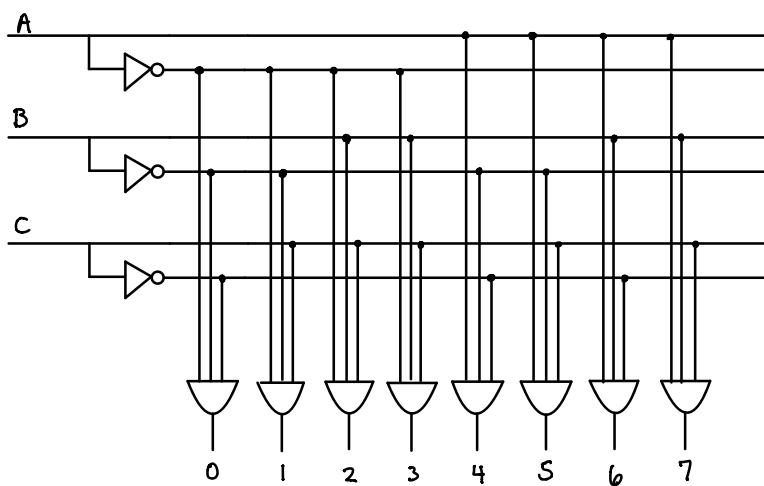
3 to 8 Decoder
 4 to 16 Decoder
 4-bit MOD 10

} defined below

3 to 8 Decoder: introduced in lecture, complete circuit here for clarity.

Inputs			Outputs							
A	B	C	D ₀	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	-	-	-	-
0	1	1	0	-	-	1	0	-	-	-
1	0	0	0	-	-	1	0	-	-	-
1	0	1	0	-	-	-	1	0	-	-
1	1	0	0	-	-	-	-	1	0	-
1	1	1	0	-	-	-	-	-	1	1

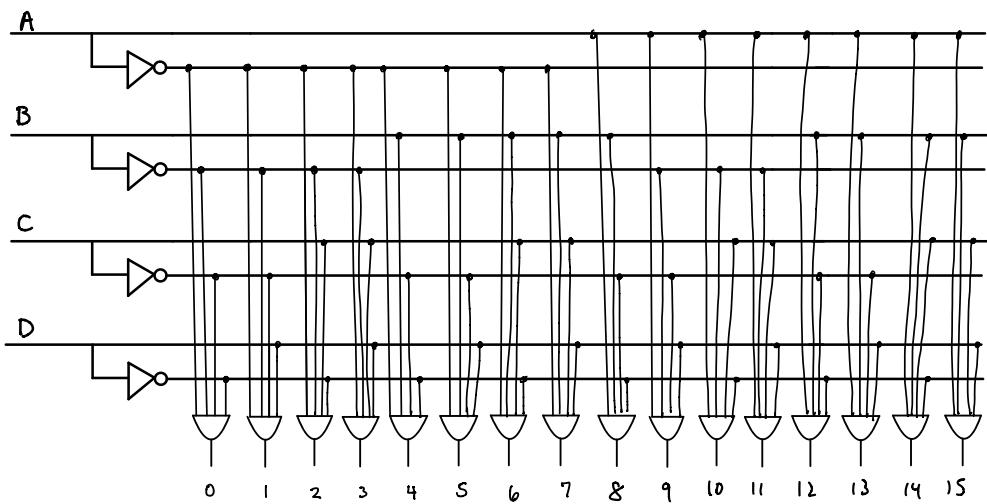
$$\begin{aligned}
 D_0 &= A'B'C' \\
 D_1 &= A'B'C \\
 D_2 &= A'BC' \\
 D_3 &= A'BC \\
 D_4 &= AB'C' \\
 D_5 &= AB'C \\
 D_6 &= ABC' \\
 D_7 &= ABC
 \end{aligned}$$



4 to 16 decoder: introduced in lecture/discussion, complete circuit for clarity.

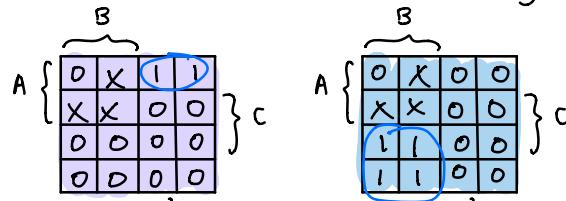
Inputs				Outputs															
A	B	C	D	D ₀	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉	D ₁₀	D ₁₁	D ₁₂	D ₁₃	D ₁₄	D ₁₅
0	0	0	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	
0	0	0	1	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	
0	0	1	0	0	-	1	0	-	-	-	-	-	-	-	-	-	-	-	
0	0	1	1	0	-	-	1	0	-	-	-	-	-	-	-	-	-	-	
0	1	0	0	0	-	-	-	1	0	-	-	-	-	-	-	-	-	-	
0	1	0	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-	
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1	0	0	1	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	0	1	0	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	0	1	1	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	1	0	0	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	1	0	1	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	1	1	0	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	
1	1	1	1	0	-	-	-	-	-	-	-	1	0	-	-	-	-	-	

$$\begin{aligned}
 D_0 &= A'B'C'D' \\
 D_1 &= A'B'C'D \\
 D_2 &= A'B'CD' \\
 D_3 &= A'B'CD \\
 D_4 &= A'BC'D' \\
 D_5 &= A'BC'D \\
 D_6 &= A'BCD' \\
 D_7 &= A'BCD \\
 D_8 &= AB'C'D' \\
 D_9 &= AB'C'D \\
 D_{10} &= AB'CD' \\
 D_{11} &= AB'CD \\
 D_{12} &= ABC'D' \\
 D_{13} &= ABC'D \\
 D_{14} &= ABCD' \\
 D_{15} &= ABCD
 \end{aligned}$$

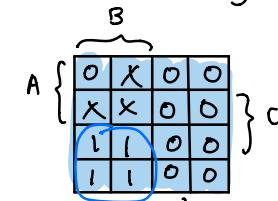


4-bit MOD 10 (only up to 12 as input) to parse one's place for hour display
b/c input is 12-state counter

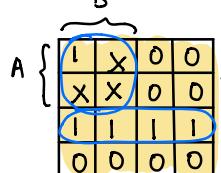
Input					Output			
	A	B	C	D	A _o	B _o	C _o	D _o
0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1
2	0	0	1	0	0	0	1	0
3	0	0	1	1	0	0	1	1
4	0	1	0	0	0	1	0	0
5	0	1	0	1	0	1	0	1
6	0	1	1	0	0	1	1	0
7	0	1	1	1	0	1	1	1
8	1	0	0	0	1	0	0	0
9	1	0	0	1	1	0	0	1
10	1	0	1	0	0	0	0	1
11	1	0	1	1	0	0	0	0
12	1	1	0	0	0	0	1	0



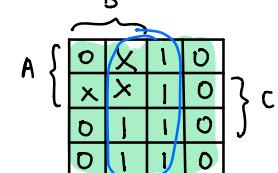
$$A_o = D \cdot AB'C'$$



$$B_o = D \cdot A'B$$



$$C_o = AB + A'C$$



$$D_o = D$$

