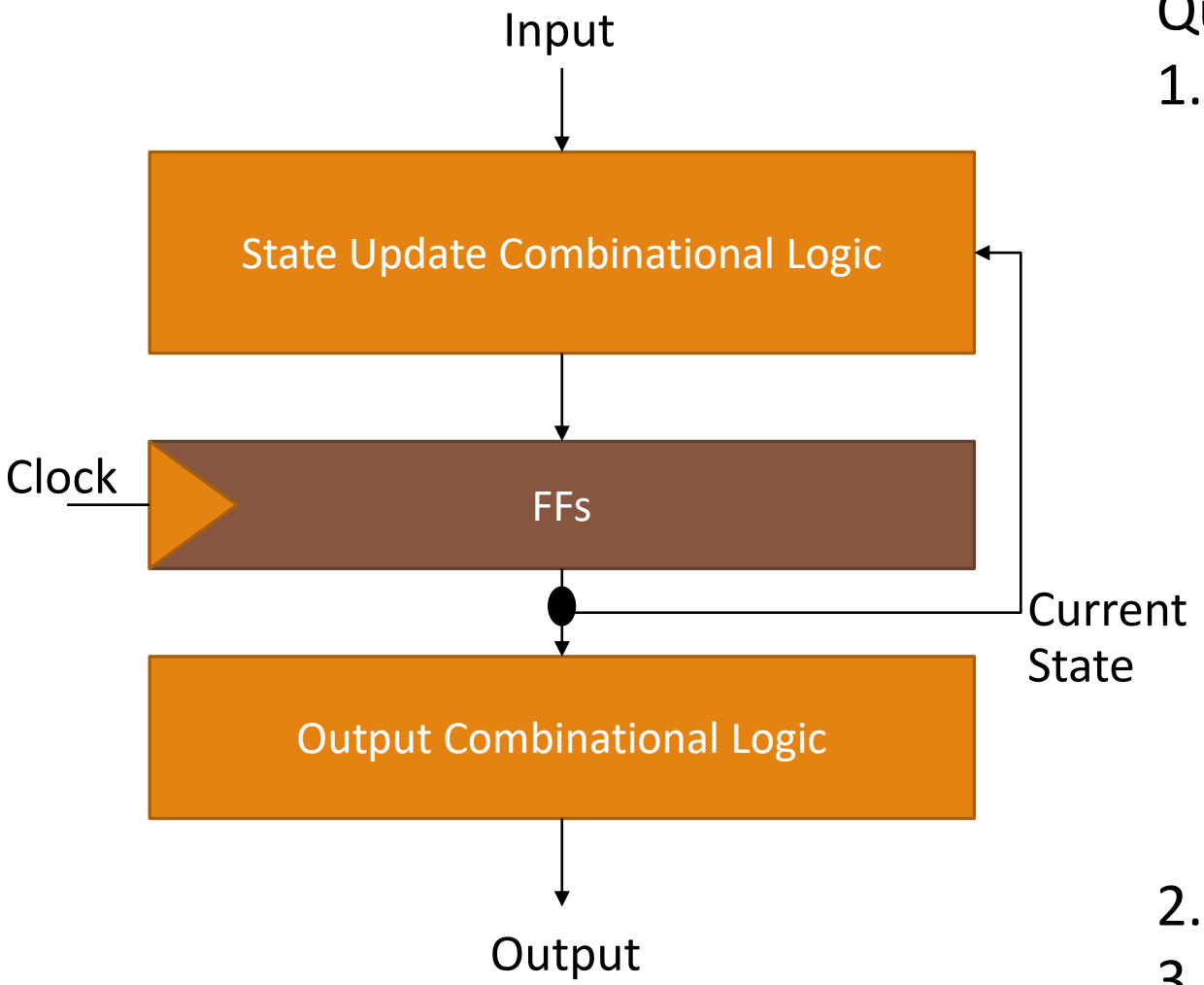
CS2100

TUTORIAL #9

SEQUENTIAL CIRCUITS

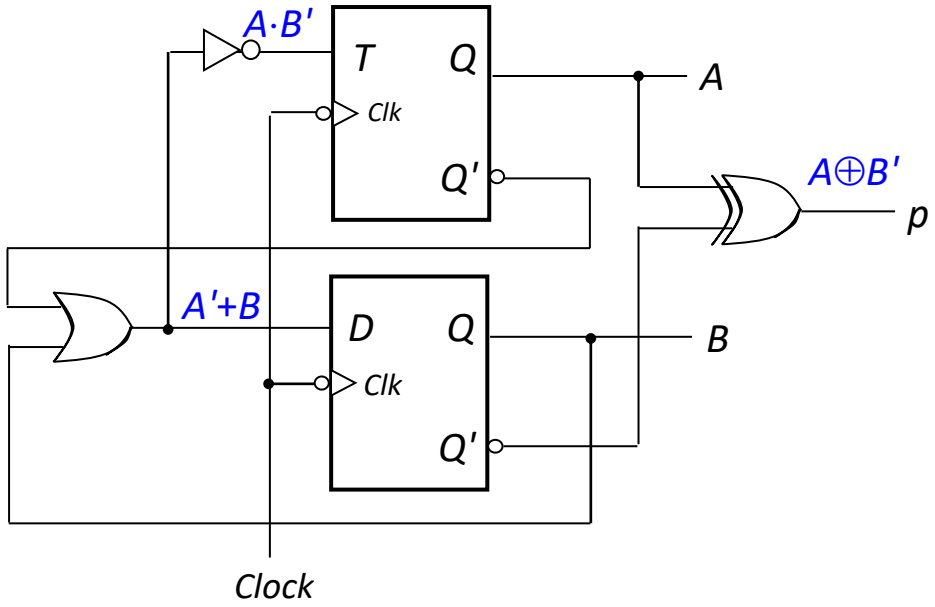
(PREPARED BY: AARON TAN)



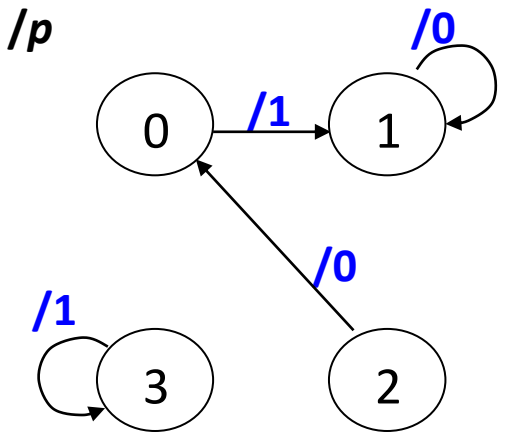
Question on analyzing sequential circuit:

1. Build state table
   a) Express inputs to FF and circuit output in terms of current state and circuit inputs (if any)
   b) For each row, use current state and circuit inputs (if any) to derive FF inputs
   c) For each row, use current state, FF inputs and characteristic table to obtain next state
   d) For each row, use current state (and circuit inputs) to derive circuit output
2. Use state table to derive state diagram
3. Answer questions regarding the circuit

Q1.



Present state		Output	Flip-flop inputs		Next state	
A	B	$p = A \oplus B'$	$TA = A \cdot B'$	$DB = A' + B$	A^+	B^+
0	0	1	0	1	0	1
0	1	0	0	1	0	1
1	0	0	1	0	0	0
1	1	1	0	1	1	1



Q1. (b) Assuming that the circuit is initially at state 0, what is the final state and the outputs generated after 3 clock cycles?

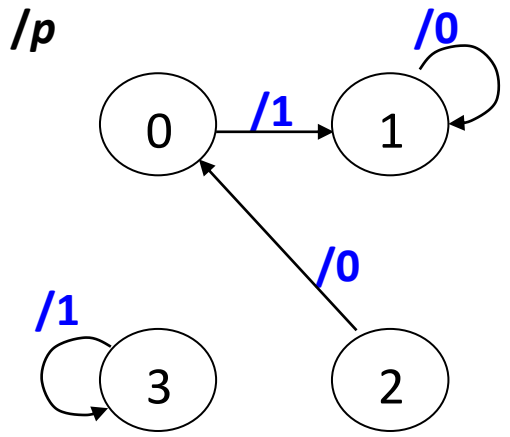
State 1; output: 100.

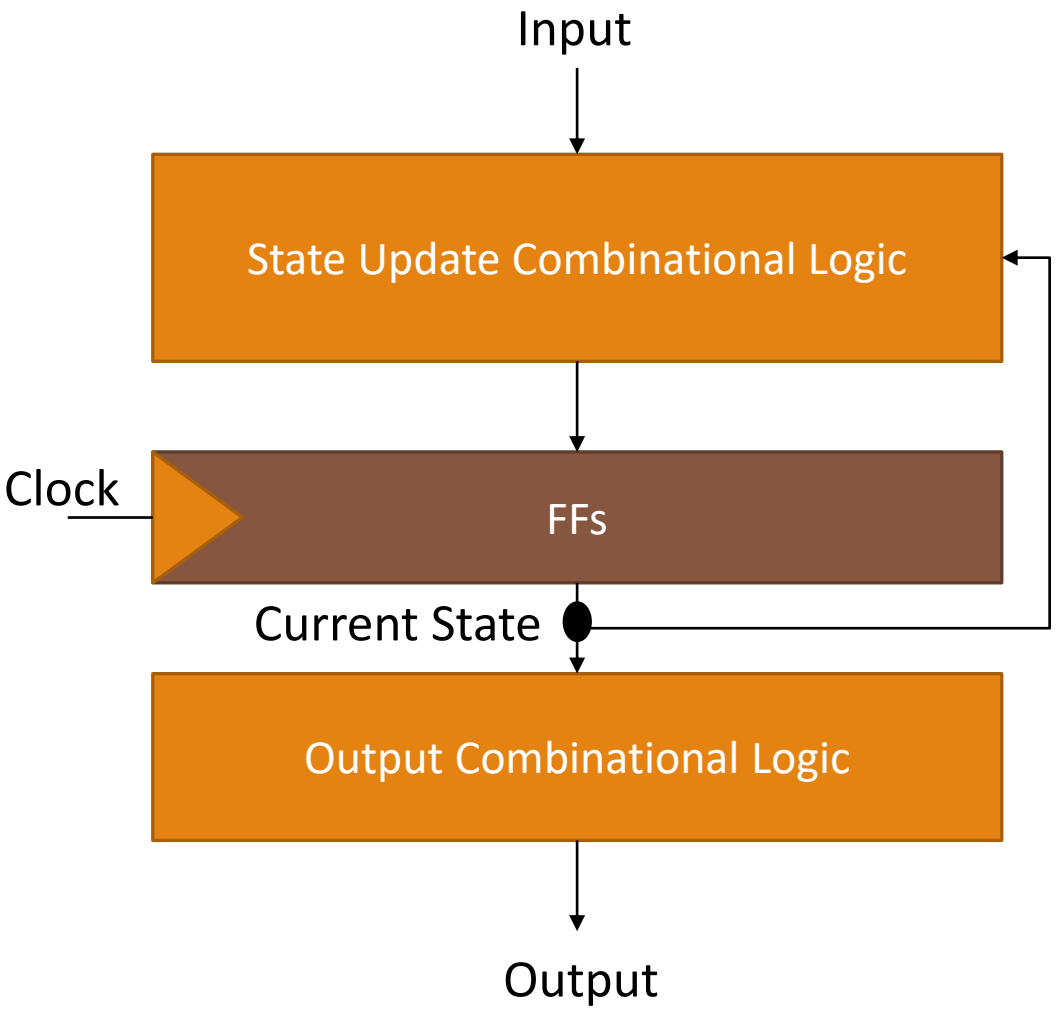
(c) A state is a sink if once the circuit enters this state, it never moves out of that state. How many sinks are there?

2 sinks: states 1 and 3.

(d) Which is likely an unused state in this circuit?

Likely to be state 3.



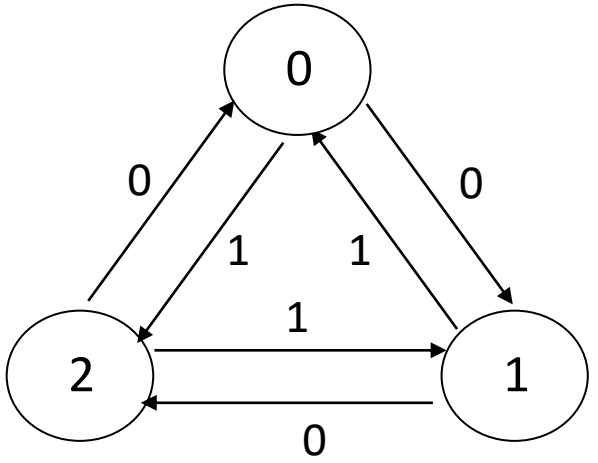


Question on designing sequential circuit:

1. Derive state table (if not provided) from description of the circuit behavior
2. Use circuit state table and FF excitation table to derive inputs to FFs
3. Express inputs to FFs as a function of current state and circuit inputs (if any)
4. Express output of circuit (if any) as a function of current state and circuit inputs (if any)
5. Build the circuit

Q2.

Present state		Input	Next state		Flip-flop *A*		Flip-flop *B*	
A	*B*	*x*	A^+	B^+	*JA*	*KA*	*JB*	*KB*
0	0	0	0	1	0	d	1	d
0	0	1	1	0	1	d	0	d
0	1	0	1	0	1	d	d	1
0	1	1	0	0	0	d	d	1
1	0	0	0	0	d	1	0	d
1	0	1	0	1	d	1	1	d
1	1	0	d	d	d	d	d	d
1	1	1	d	d	d	d	d	d



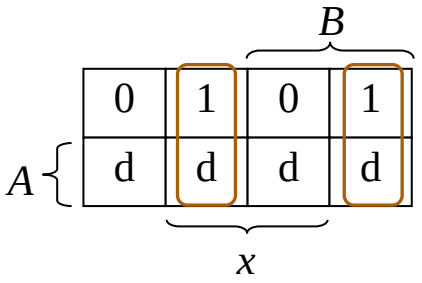
Q	Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Excitation table for JK Flip-flop

Q2.

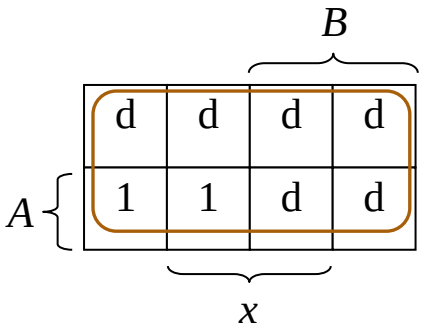
Present state		Input	Next state		Flip-flop *A*		Flip-flop *B*	
A	*B*	*x*	A^+	B^+	*JA*	*KA*	*JB*	*KB*
0	0	0	0	1	0	d	1	d
0	0	1	1	0	1	d	0	d
0	1	0	1	0	1	d	d	1
0	1	1	0	0	0	d	d	1
1	0	0	0	0	d	1	0	d
1	0	1	0	1	d	1	1	d
1	1	0	d	d	d	d	d	d
1	1	1	d	d	d	d	d	d

JA



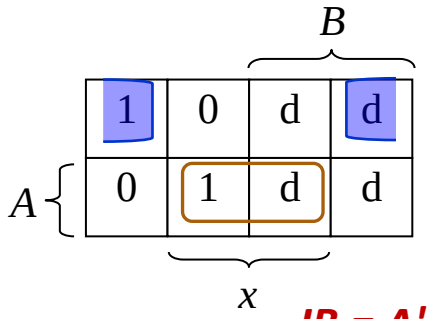
$JA = B \cdot x' + B' \cdot x = B \oplus x$

KA



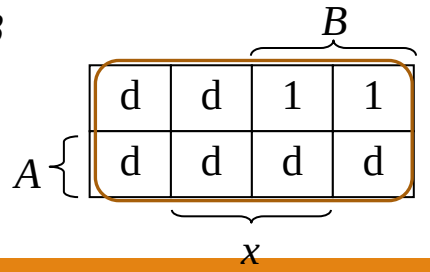
$KA = 1$

JB



$JB = A' \cdot x' + A \cdot x = A \odot x$

KB



$KB = 1$

Q2.

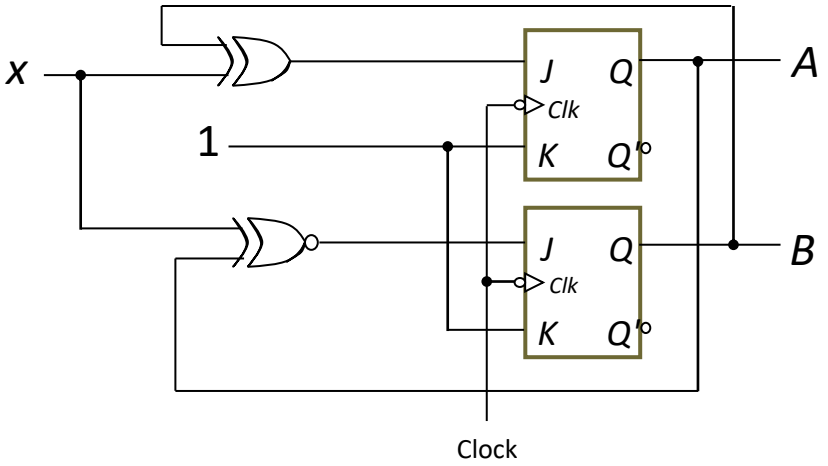
Present state		Input	Next state		Flip-flop *A*		Flip-flop *B*	
A	*B*	*x*	A^+	B^+	*JA*	*KA*	*JB*	*KB*
0	0	0	0	1	0	d(1)	1	d(1)
0	0	1	1	0	1	d(1)	0	d(1)
0	1	0	1	0	1	d(1)	d(1)	1
0	1	1	0	0	0	d(1)	d(0)	1
1	0	0	0	0	d(0)	1	0	d(1)
1	0	1	0	1	d(1)	1	1	d(1)
1	1	0	d(0)	d(0)	d(1)	d(1)	d(0)	d(1)
1	1	1	d(0)	d(0)	d(0)	d(1)	d(1)	d(1)

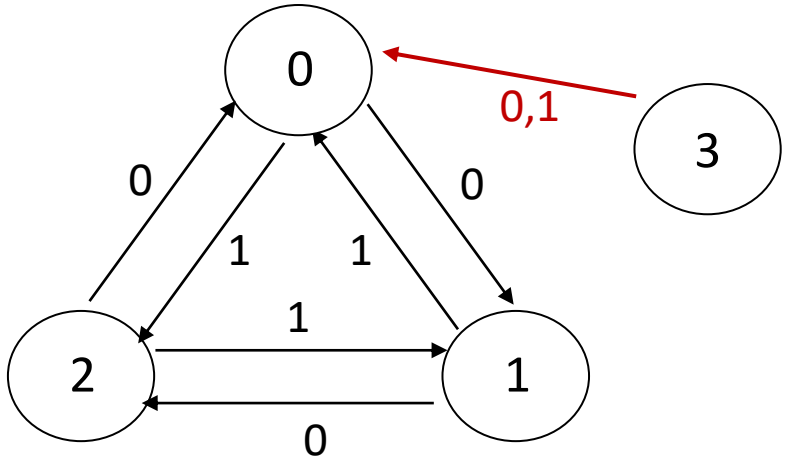
$JA = B \cdot x' + B' \cdot x = B \oplus x$

$KA = 1$

$JB = A' \cdot x' + A \cdot x = A \odot x$

$KB = 1$

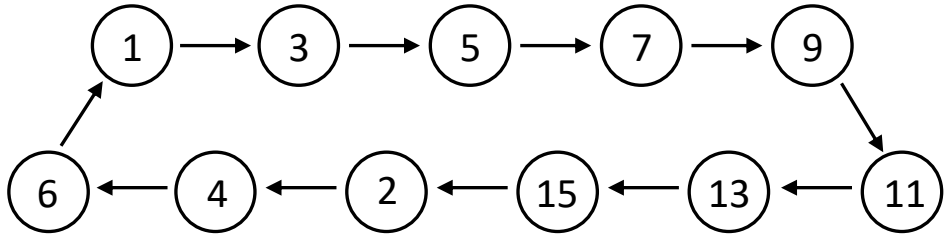




A circuit is self-correcting if after entering into any unused state, the circuit is able to transit to a valid state after a finite number of transition.

Is this circuit self-correcting? Yes

Q3.



Q	Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Excitation table for JK Flip-flop

$DA = A \cdot B' + A \cdot C' + A' \cdot B \cdot C \cdot D$

$TB = C$

$TC = A' + B' + C'$

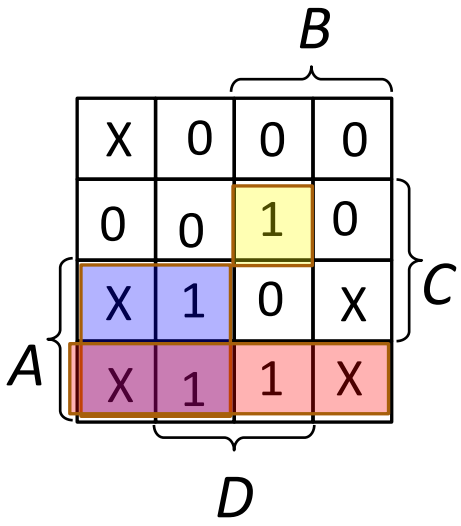
$JD = B \cdot C$

$KD = A \cdot B \cdot C$

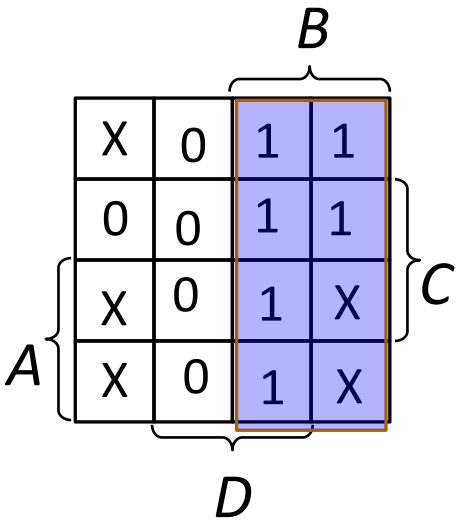
Current state				Next state				Flip-flop inputs			
A	B	C	D	$DA=A^+$	B^+	C^+	D^+	TB	TC	JD	KD
0	0	0	0	X	X	X	X	X	X	X	X
0	0	0	1	0	0	1	1	0	1	X	0
0	0	1	0	0	1	0	0	1	1	0	X
0	0	1	1	0	1	0	1	1	1	X	0
0	1	0	0	0	1	1	0	0	1	0	X
0	1	0	1	0	1	1	1	0	1	X	0
0	1	1	0	0	0	0	1	1	1	1	X
0	1	1	1	1	0	0	1	1	1	X	0
1	0	0	0	X	X	X	X	X	X	X	X
1	0	0	1	1	0	1	1	0	1	X	0
1	0	1	0	X	X	X	X	X	X	X	X
1	0	1	1	1	1	0	1	1	1	X	0
1	1	0	0	X	X	X	X	X	X	X	X
1	1	0	1	1	1	1	1	0	1	X	0
1	1	1	0	X	X	X	X	X	X	X	X
1	1	1	1	0	0	1	0	1	0	X	1

Q3.

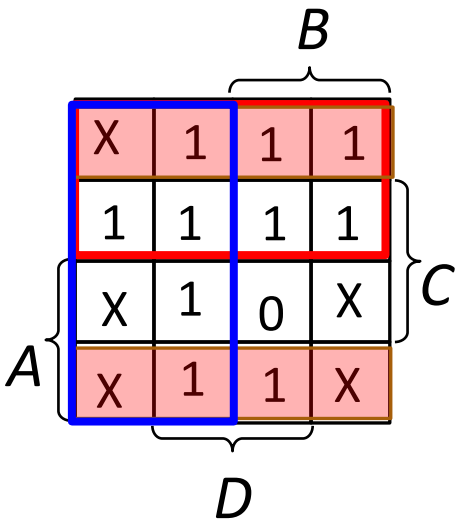
$DA = A \cdot B' + A \cdot C' + A' \cdot B \cdot C \cdot D$



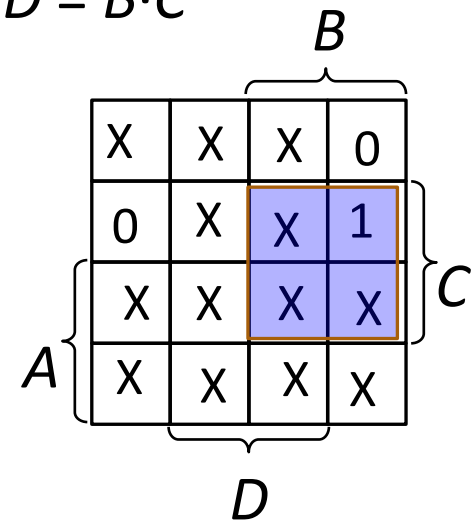
$TB = C$



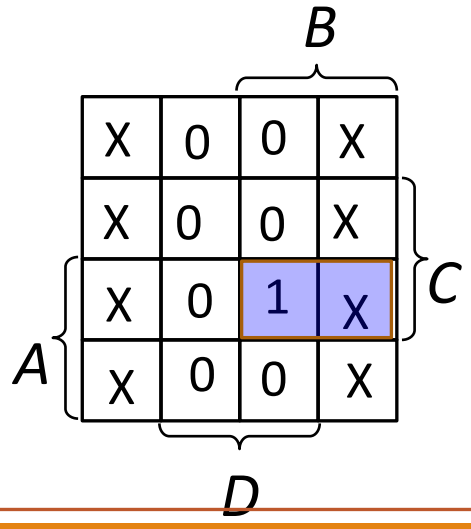
$TC = A' + B' + C'$



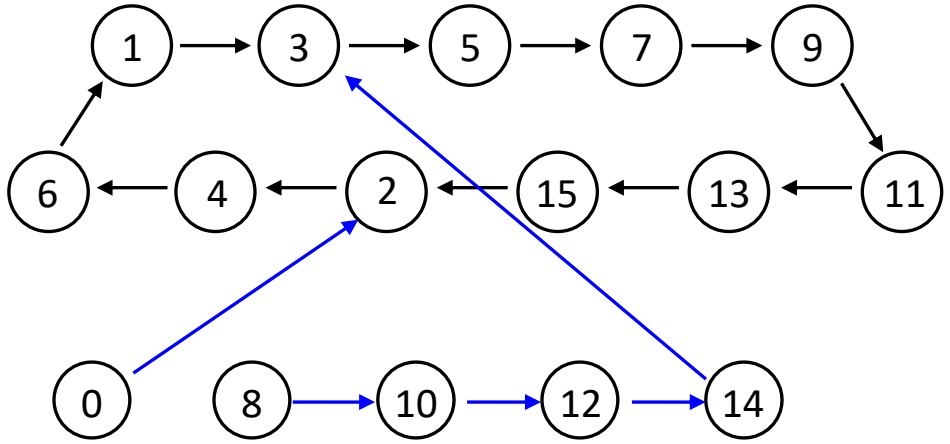
$JD = B \cdot C$



$KD = A \cdot B \cdot C$



Q3.



Is the circuit self-correcting? Yes

$DA = A \cdot B' + A \cdot C' + A' \cdot B \cdot C \cdot D$

$TB = C$

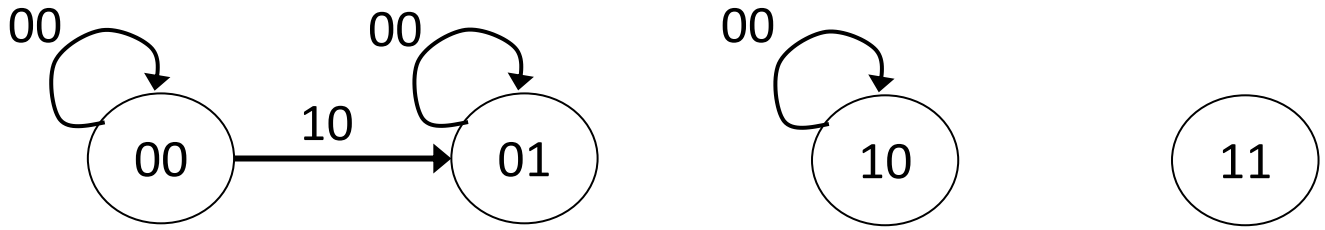
$TC = A' + B' + C'$

$JD = B \cdot C$

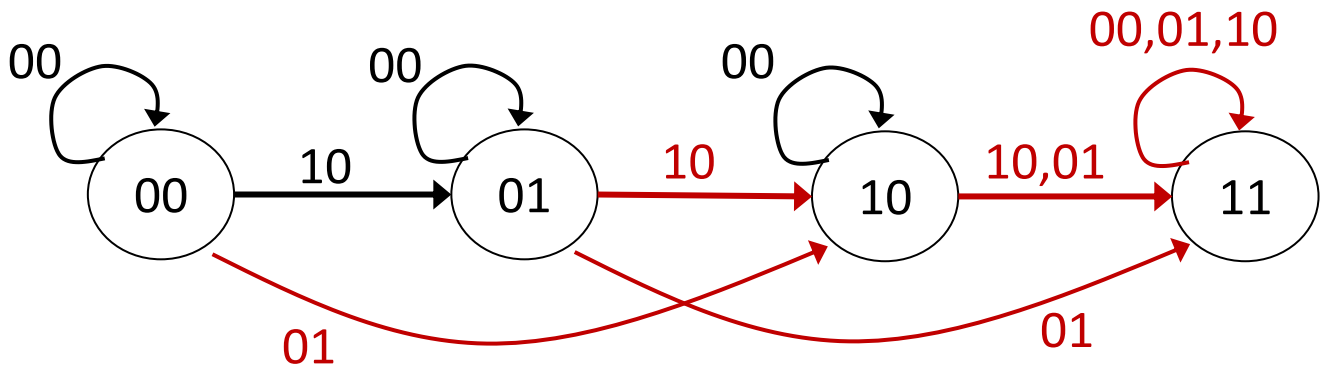
$KD = A \cdot B \cdot C$

Current state				Next state				Flip-flop inputs			
A	B	C	D	$DA=A^+$	B^+	C^+	D^+	TB	TC	JD	KD
0	0	0	0	X(0)	X0	X1	X0	X0	X1	X0	X0
0	0	0	1	0	0	1	1	0	1	X	0
0	0	1	0	0	1	0	0	1	1	0	X
0	0	1	1	0	1	0	1	1	1	X	0
0	1	0	0	0	1	1	0	0	1	0	X
0	1	0	1	0	1	1	1	0	1	X	0
0	1	1	0	0	0	0	1	1	1	1	X
0	1	1	1	1	0	0	1	1	1	X	0
1	0	0	0	X(1)	X0	X1	X0	X0	X1	X0	X0
1	0	0	1	1	0	1	1	0	1	X	0
1	0	1	0	X(1)	X1	X0	X0	X1	X1	X0	X0
1	0	1	1	1	1	0	1	1	1	X	0
1	1	0	0	X(1)	X1	X1	X0	X0	X1	X0	X0
1	1	0	1	1	1	1	1	0	1	X	0
1	1	1	0	X(0)	X0	X1	X1	X1	X0	X1	X1
1	1	1	1	0	0	1	0	1	0	X	1

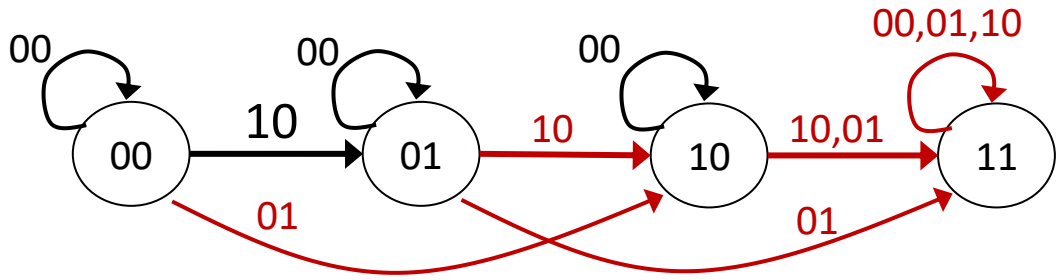
Q4(a).

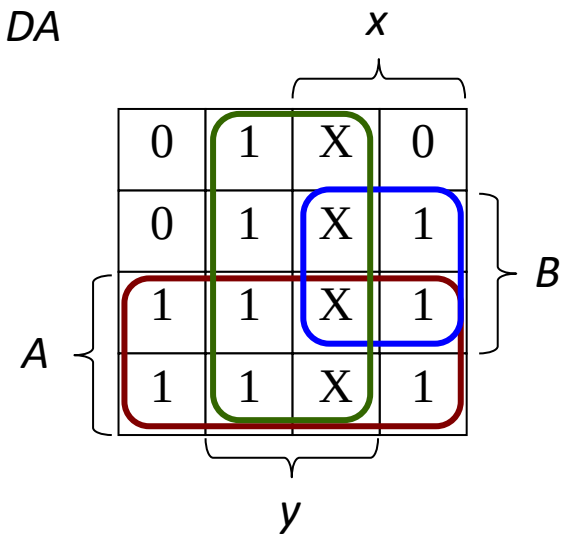


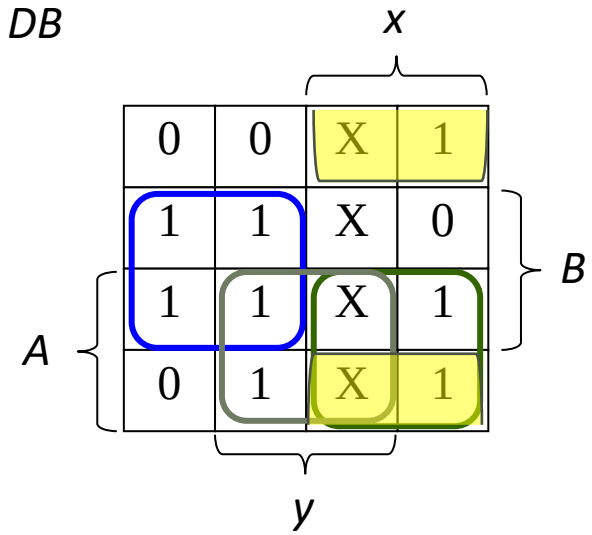
Q4(a).



Q4(b).







$DA = A + y + B \cdot x$

$DB = B \cdot x' + B' \cdot x + A \cdot y + A \cdot x$

or $DB = B \cdot x' + B' \cdot x + A \cdot y + A \cdot B$

Present		Inputs		Next	
A	***B***	***x***	***y***	A^+	B^+
0	0	0	0	0	0
0	0	0	1	1	0
0	0	1	0	0	1
0	0	1	1	X	X
0	1	0	0	0	1
0	1	0	1	1	1
0	1	1	0	1	0
0	1	1	1	X	X
1	0	0	0	1	0
1	0	0	1	1	1
1	0	1	0	1	1
1	0	1	1	X	X
1	1	0	0	1	1
1	1	0	1	1	1
1	1	1	0	1	1
1	1	1	1	X	X

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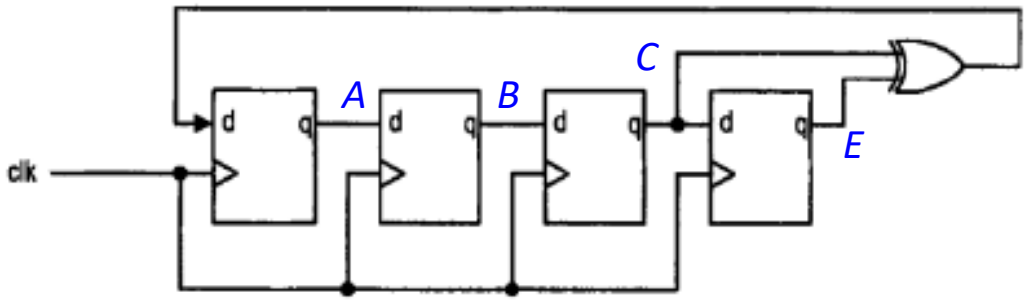
Additional Question 1

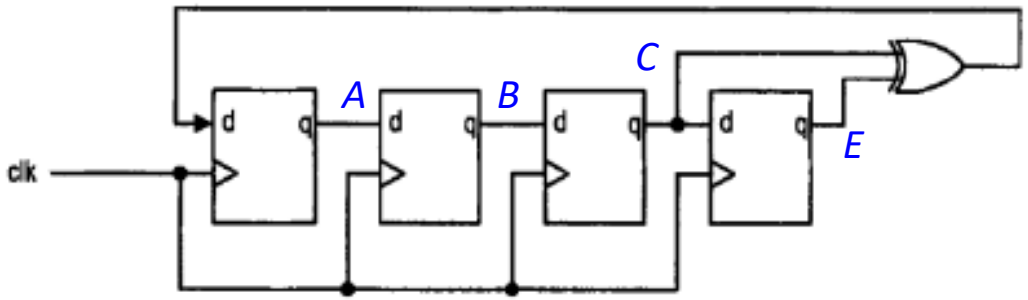
Fill in the table for the circuit shown on the right.



Present state				Flip-flop inputs				Next state			
A	B	C	E	DA	DB	DC	DE	A^+	B^+	C^+	E^+
0	1	1	0								

Answer

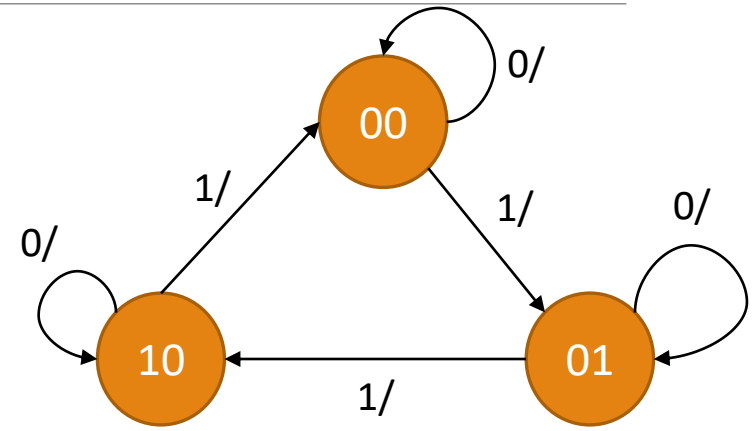
Fill in the table for the circuit shown on the right.



Present state				Flip-flop inputs				Next state			
A	B	C	E	DA	DB	DC	DE	A^+	B^+	C^+	E^+
0	1	1	0	1	0	1	1	1	0	1	1

Additional Question 2

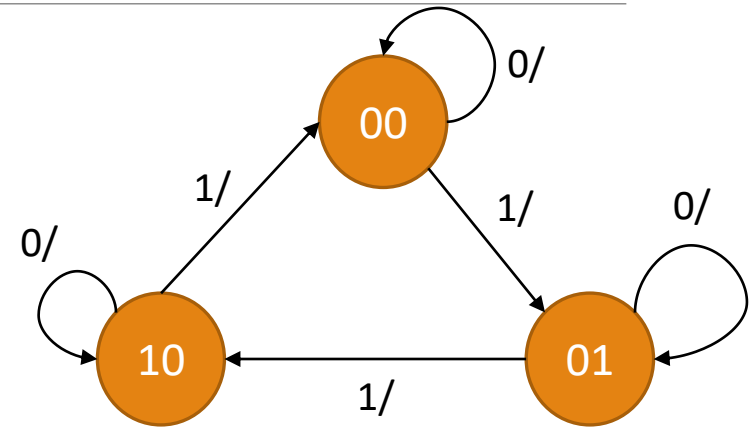
Fill in the table for the state diagram shown on the right.



Present state		Input	Next State		T Flip Flop inputs	
A	B	Y	A^+	B^+	TA	TB
0	0	1	1	0		
0	1	0	0	0		
1	0	1	0	0		

Answer

Fill in the table for the state diagram shown on the right.



Present state		Input	Next State		T Flip Flop inputs	
A	B	Y	A^+	B^+	TA	TB
0	0	1	1	0	1	0
0	1	0	0	0	0	1
1	0	1	0	0	1	0

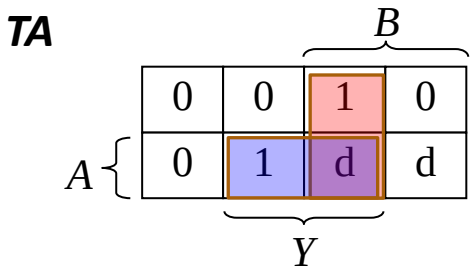
Additional Question

Give the simplified SOP expression for TA using the table.

Present state		Input	Next State		T Flip Flop inputs	
A	B	Y	A^+	B^+	TA	TB
0	0	0	0	0	0	0
0	0	1	0	1	0	1
0	1	0	0	1	0	0
0	1	1	1	0	1	1
1	0	0	1	0	0	0
1	0	1	0	0	1	0
1	1	0	d	d	d	d
1	1	1	d	d	d	d

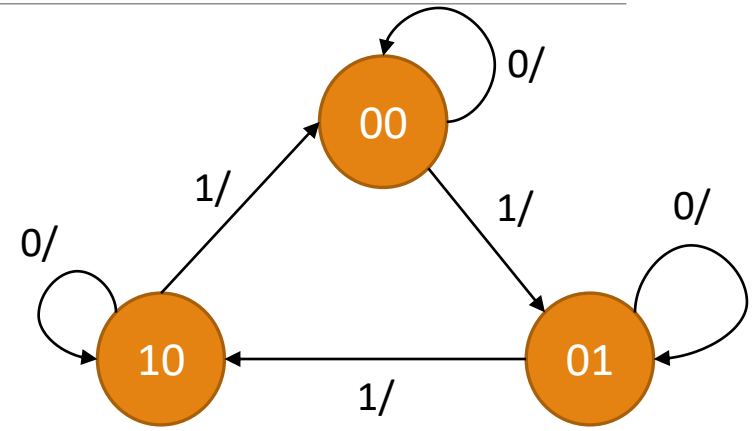
Answer

TA = BY + AY



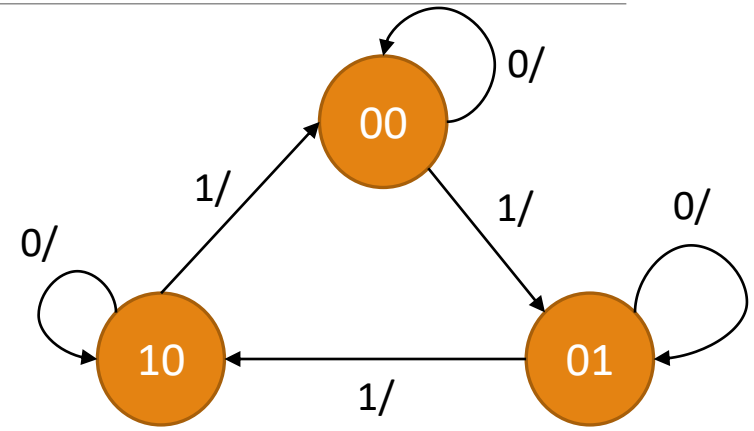
Additional Question

Describe (in one sentence) what the states in a circuit that implements the state diagram on the right keep track of. Assume that initial state is 00



Answer

Describe (in one sentence) what the states in a circuit that implements the state diagram on the right keep track of. Assume that initial state is 00



The states keep track of the number of times modulo 3 that the input is set to 1.