ELEN0040 – REPETITION 5

Analyse de circuits séquentiels

Circuits séquentiels - Rappels

Systèmes séquentiels $\Rightarrow$ circuits combinatoires + éléments mémoire

2 types

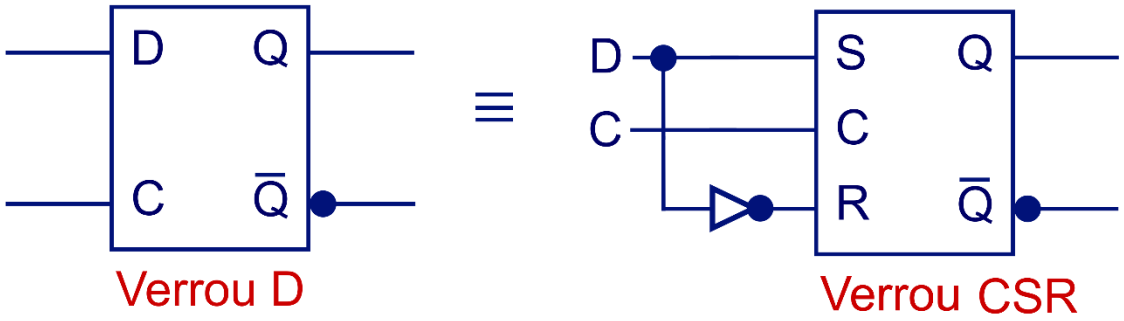
- *Synchrones*

  $\Rightarrow$ Les éléments mémoire varient tous **avec la clock** !

- *Asynchrones*

  $\Rightarrow$ Les éléments mémoire ne varient **pas nécessairement avec la clock** !

Verrous et flip-flops - Rappels



Verrou D — Verrou CSR

Verrou CSR : avec $S = \overline{R} = D$

C	S	R	Q(t+1)
0	X	X	Q(t)
~~1~~	~~0~~	~~0~~	~~Q(t)~~
1	0	1	0
1	1	0	1
~~1~~	~~1~~	~~1~~	~~X~~

= D

Verrou D :

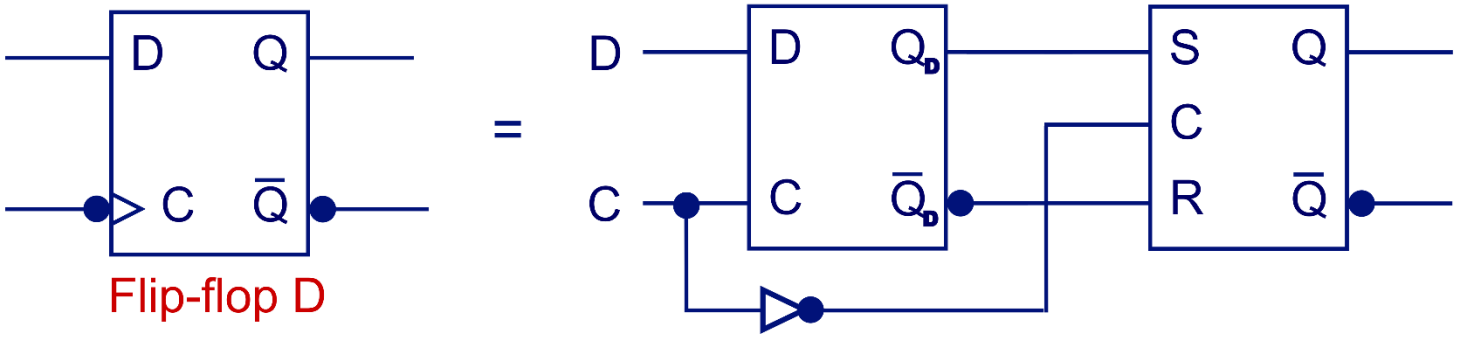
C	D(t)	Q(t+1)
0	X	Q(t)
1	0	0
1	1	1

$Q(t+1) = \overline{C}\, Q(t) + C\, D(t)$

Mode MEMO (C=0):
Q(t+1) = Q(t)

Mode transparent (C=1):
Q(t+1) = D(t)

Verrous et flip-flops - Rappels



Flip-flop D

Actif lors de la transition 1 - 0 de la clock (C) :

$Q(t+1) = D(t)$

Sinon, $Q(t+1) = Q(t)$

Verrou D :

C	D(t)	$Q_D(t+1)$
0	X	$Q_D(t)$
1	0	0
1	1	1

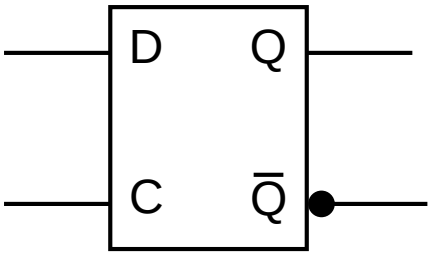
Verrou CSR : avec $S = \overline{R}$

C	S	R	Q(t+1)
1	X	X	Q(t)
0	0	1	0
0	1	0	1

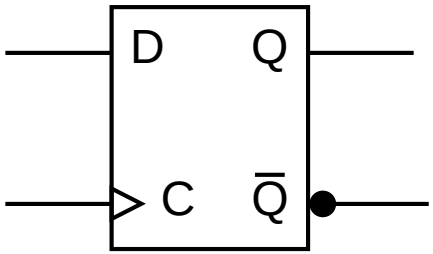
$= S = Q_D$

Verrous et flip-flops - Rappels

- Verrou : actif sur un **niveau** d'horloge
- Flip-flop : actif sur une **transition** d'horloge



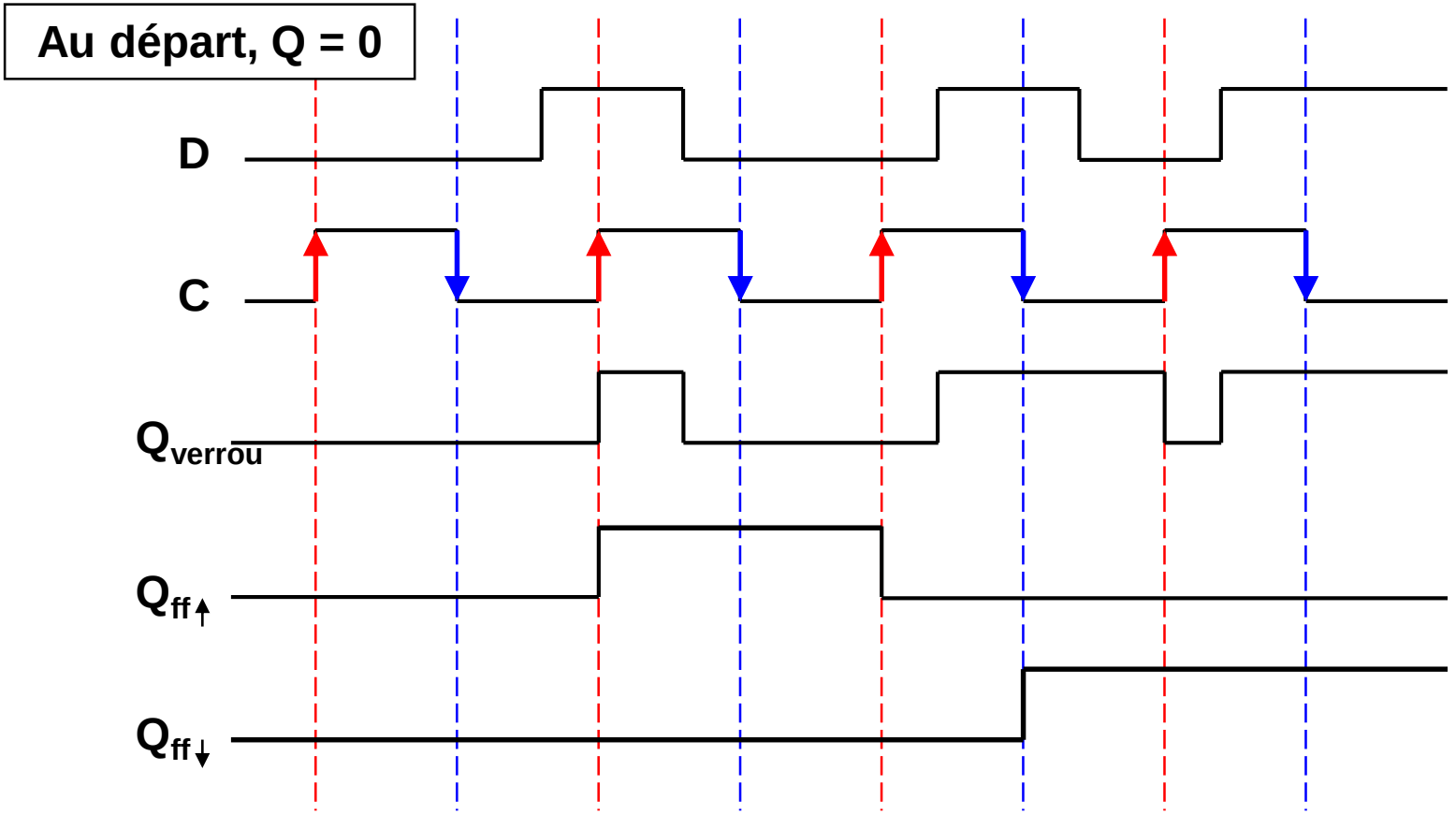
Verrou D



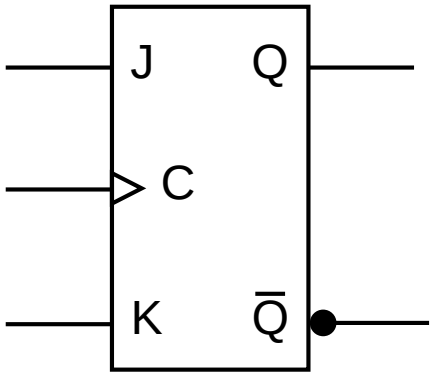
Flip-flop D

D(t)	Q(t+1)
0	0
1	1

Ex. 1 : Verrou et FF D

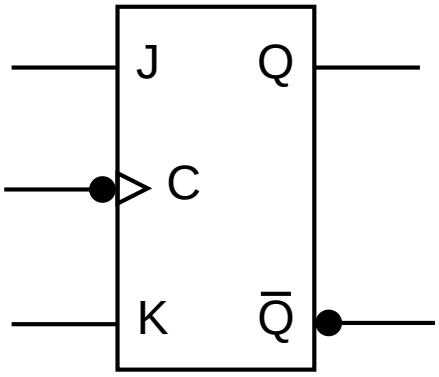


Flip-flops JK - Rappels



FF JK

Actif sur flanc montant



FF JK

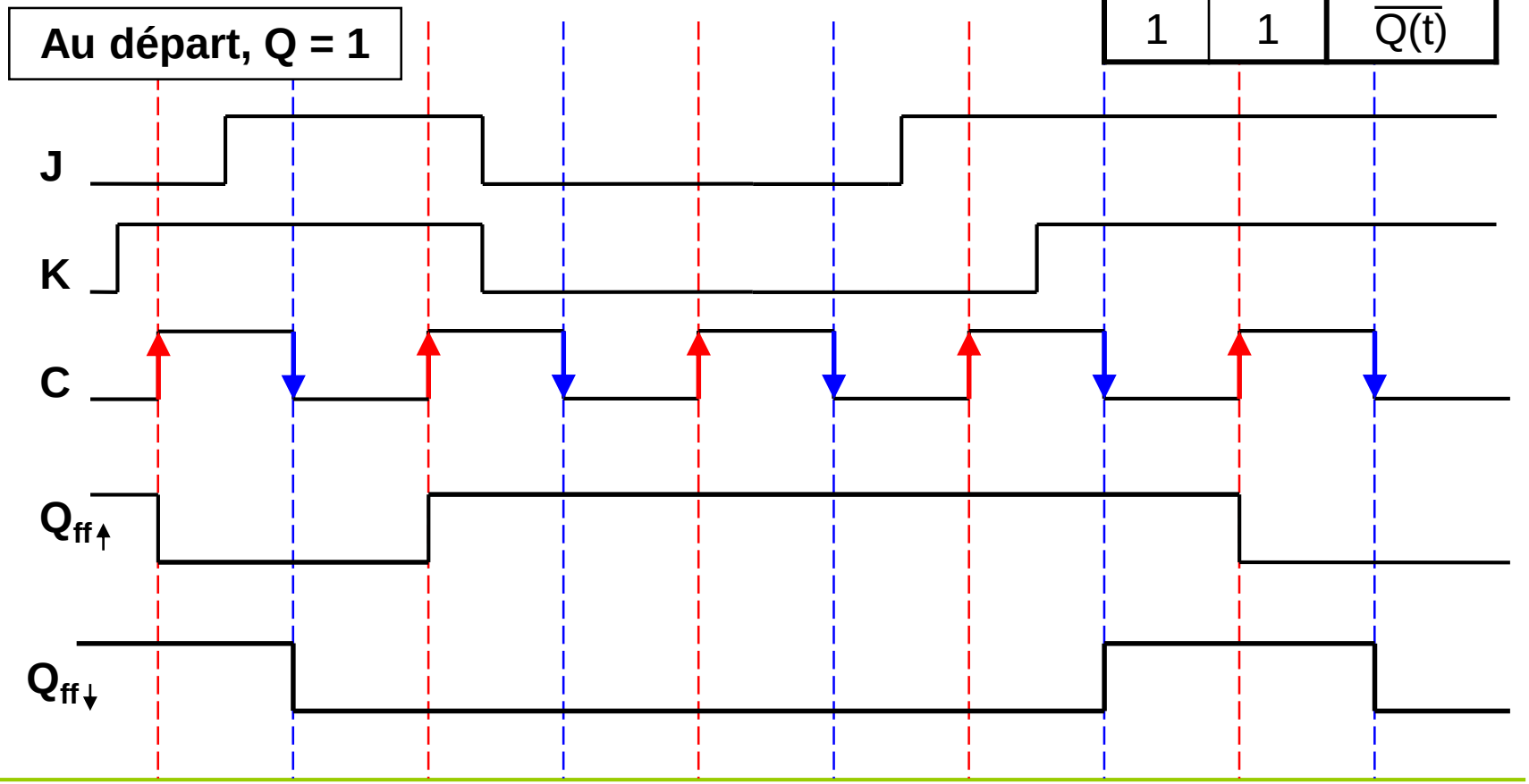
Actif sur flanc descendant

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

$$Q(t+1) = J.\overline{Q(t)} + \overline{K}.Q(t)$$

Ex. 1 : FF JK

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$



Analyse

Point de départ : schéma/circuit logique

1) Déterminer si le circuit est synchrone / asynchrone ?
   Si asynchrone, définir l'ordre de déclenchement des FF

2) Définir les entrées / sorties du circuit global
   + 1 variable d'état pour chaque FF
   + variables intermédiaires utiles

3) Donner les équations caractéristiques des variables intermédiaires, d'état et de sortie

4) Etablir la table de vérité = table d'états du circuit (remplissage dans l'ordre de déclenchement des FF)

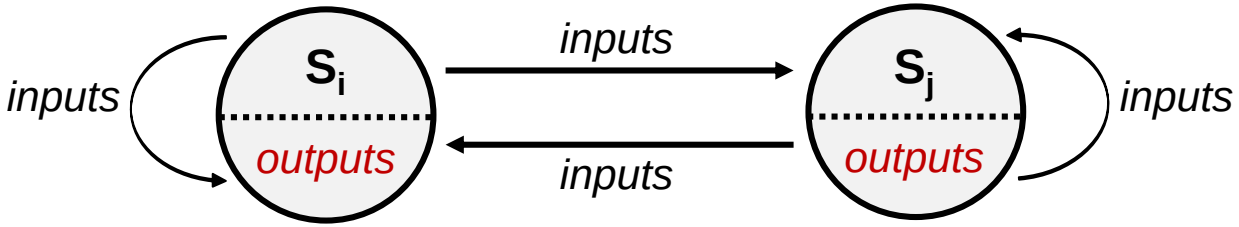
5) ((Représenter le diagramme d'états du système))

Diagramme d'états

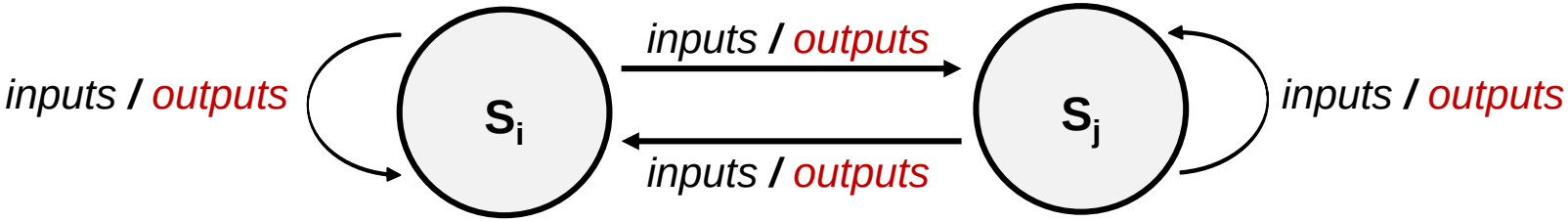
Chaque état est numéroté par une combinaison de valeurs des variables d'état (1 variable /FF)

n FF → 2^n états

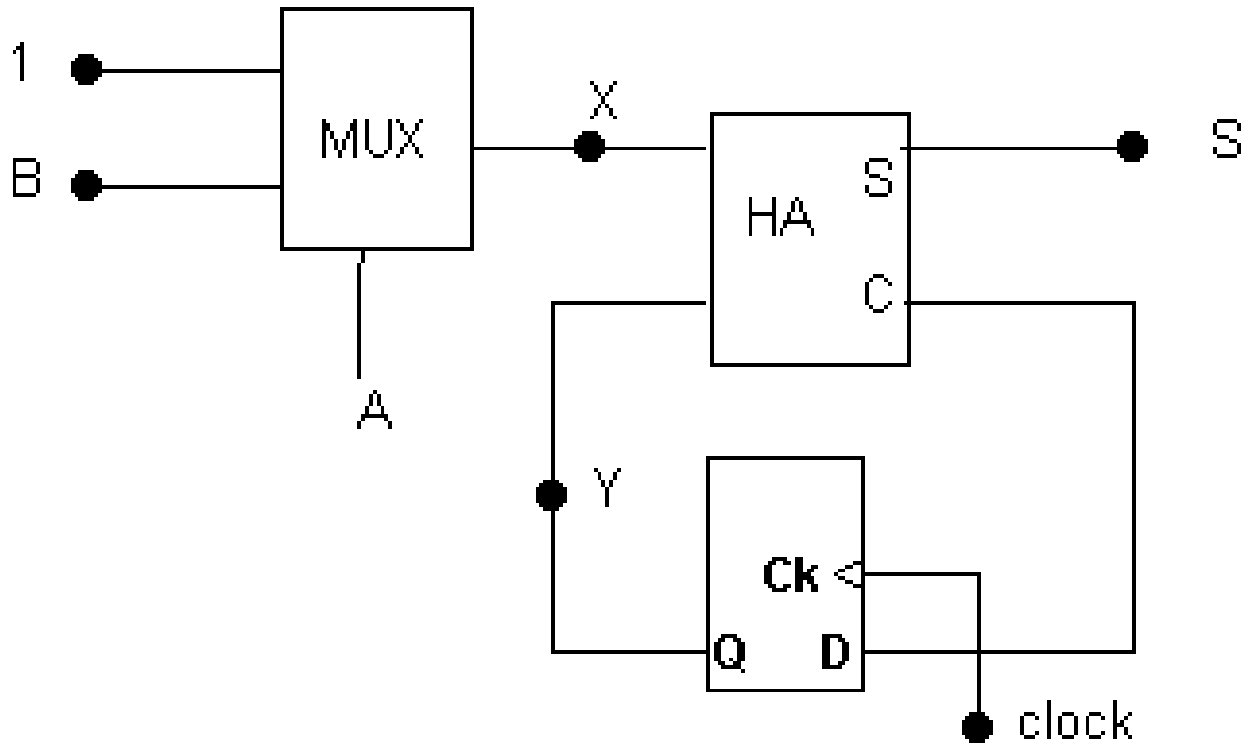
Modèle de Moore: outputs = F(state)



Modèle de Mealy: outputs = F(state, inputs)

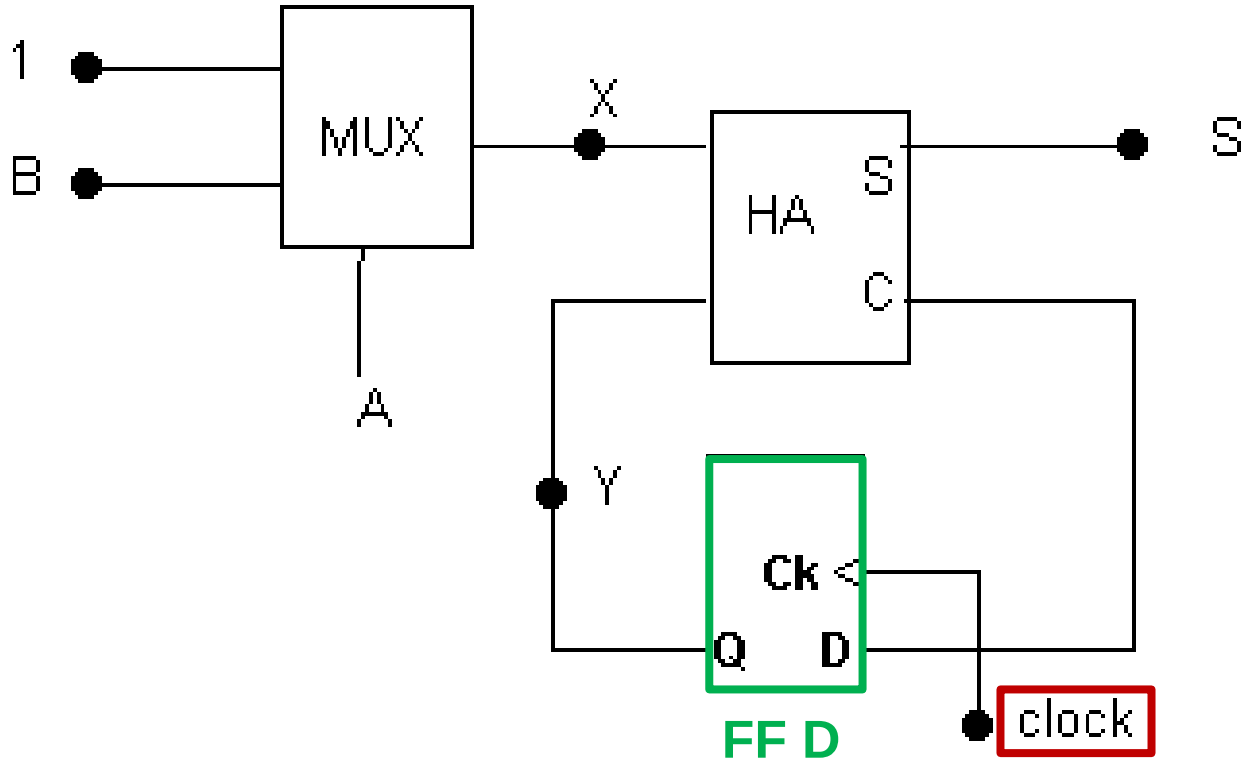


Ex.3 : Analyse



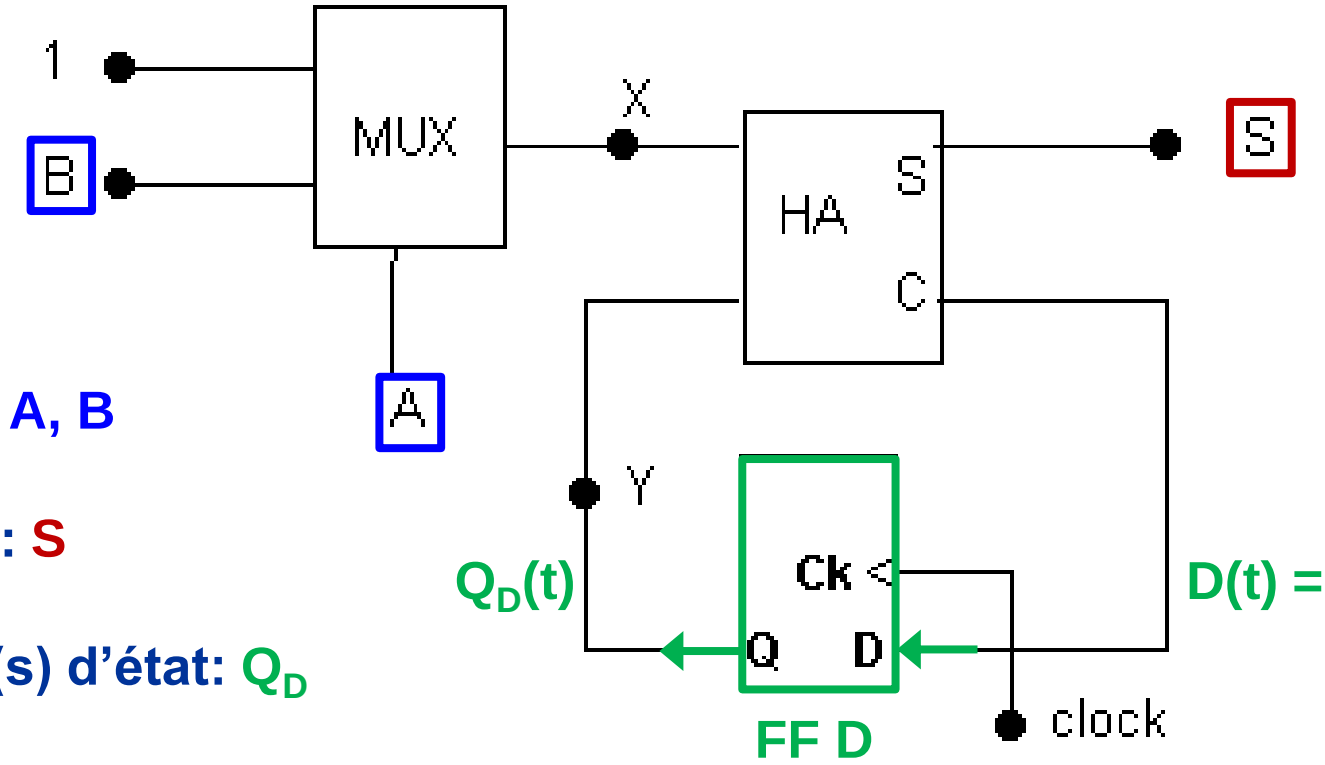
Ex.3 : Analyse

1) Synchrone



Ex.3 : Analyse

2) Entrées / Sorties:



Entrées: A, B

Sortie(s): S

Variable(s) d'état: Q_D

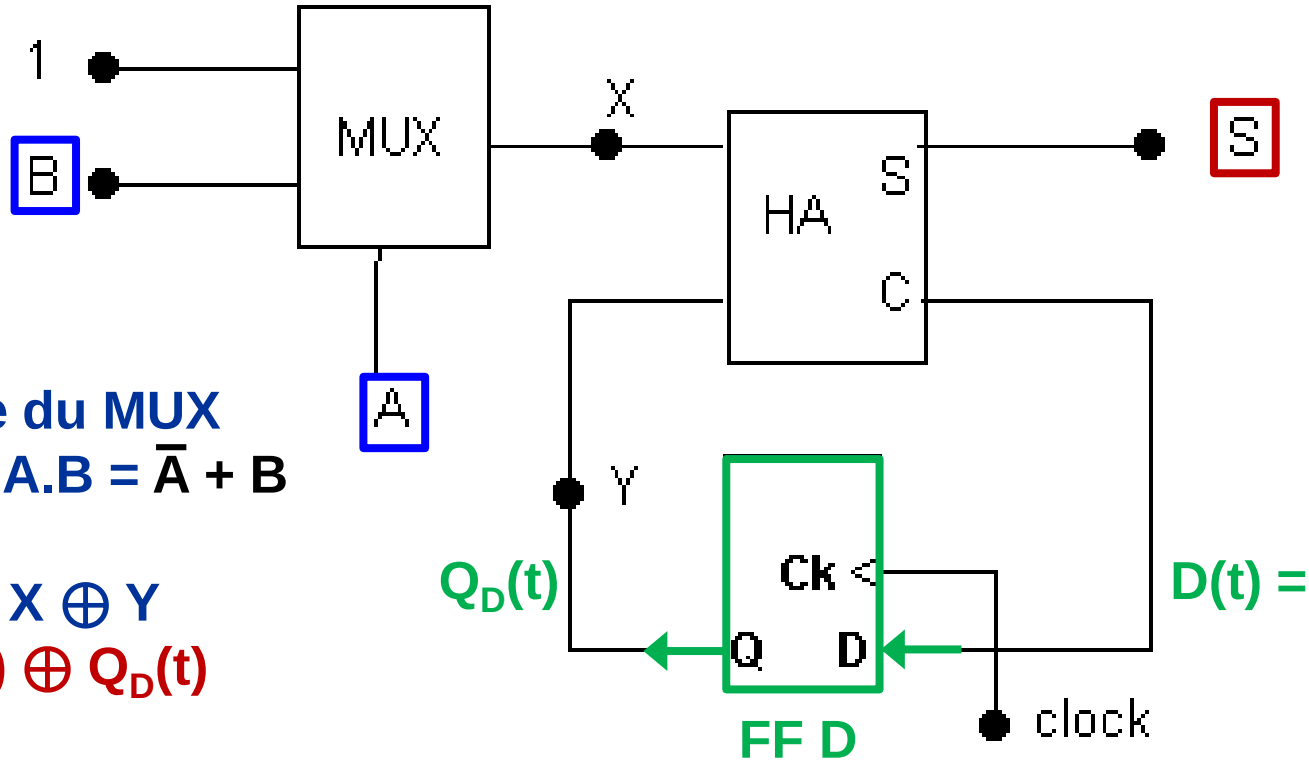
Variables intermédiaires: X, Y = $Q_D(t)$

$Q_D(t)$

$D(t) = Q_D(t+1)$

Ex.3 : Analyse

3) Equations caractéristiques:



X = sortie du MUX
$= \bar{A}.1 + A.B = \bar{A} + B$

$S = S_{HA} = X \oplus Y$
$= (\bar{A}+B) \oplus Q_D(t)$

$Q_D(t+1) = D(t) = C_{HA}$
$= X.Y = (\bar{A}+B).Q_D(t)$

Ex.3 : Analyse

*variables d'état en **t+1**,*
variables de sortie,
variables intermédiaires

$Q_D(t)$	A	B	$Q_D(t+1)$	X	S
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

*variables d'état en **t***
puis variables d'entrée

4) Table d'états

Ex.3 : Analyse

$Q_D(t)$	A	B	$Q_D(t+1)$	$\overline{A}+B$	S
0	0	0	0	1	1
0	0	1	0	1	1
0	1	0	0	0	0
0	1	1	0	1	1
1	0	0	1	1	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	1	1	1	0

4) Table d'états

$X = \overline{A} + B$

$S = (\overline{A}+B) \oplus Q_D(t)$

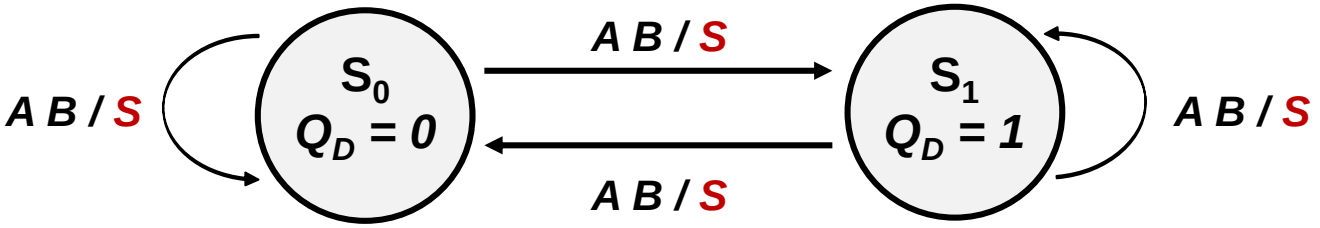
$Q_D(t+1) = (\overline{A}+B).Q_D(t)$

Ex.3 : Analyse

5) Diagramme d'états: 1 FF → 2 états

Légende:

A B / S

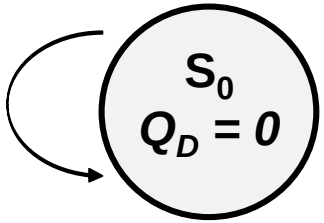


➡ **Transitions dans la table d'états**

Ex.3 : Analyse

$Q_D(t)$	A	B	$Q_D(t+1)$	S
0	0	0	**0**	1
0	0	1	**0**	1
0	1	0	**0**	0
0	1	1	**0**	1
1	0	0	1	0
1	0	1	1	0
1	1	0	0	1
1	1	1	1	0

Légende:

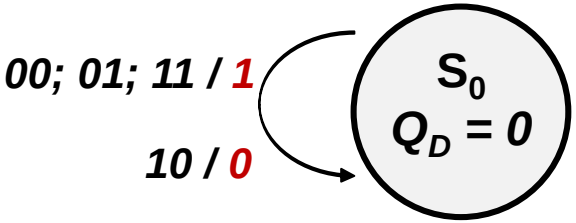


Ex.3 : Analyse

$Q_D(t)$	A	B	$Q_D(t+1)$	S
0	**0**	**0**	**0**	**1**
0	**0**	**1**	**0**	**1**
0	**1**	**0**	**0**	**0**
0	**1**	**1**	**0**	**1**
1	0	0	1	0
1	0	1	1	0
1	1	0	0	1
1	1	1	1	0

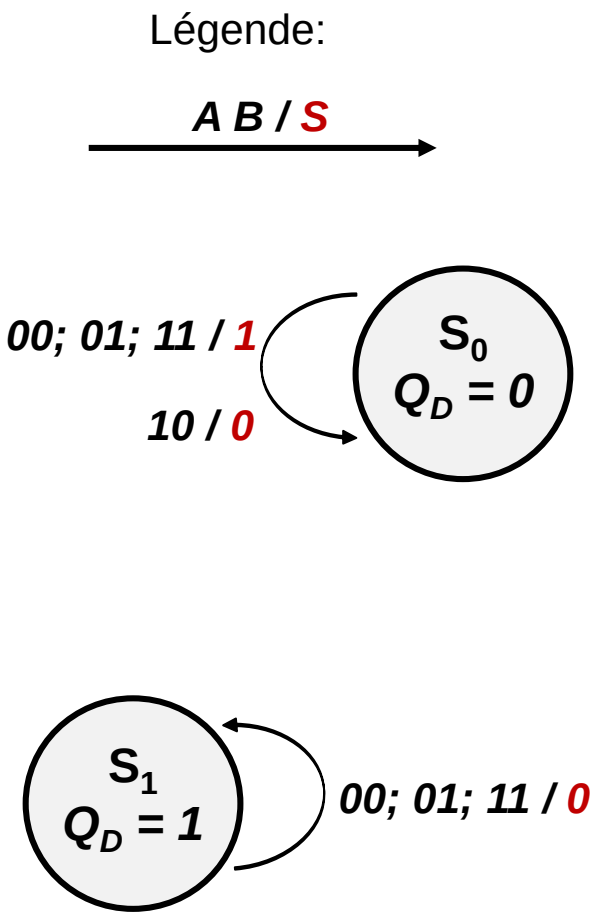
Légende:

A B / S



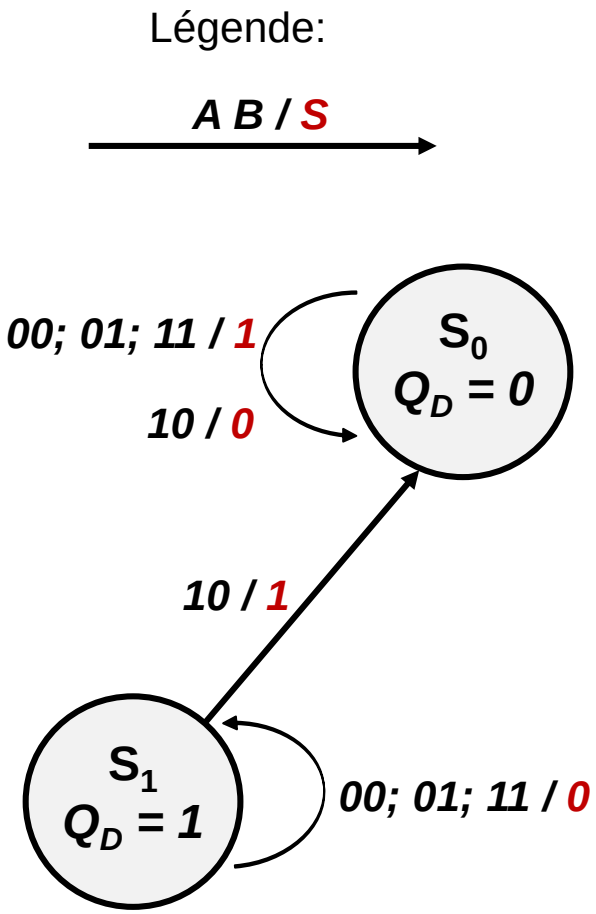
Ex.3 : Analyse

$Q_D(t)$	A	B	$Q_D(t+1)$	S
0	0	0	0	1
0	0	1	0	1
0	1	0	0	0
0	1	1	0	1
1	**0**	**0**	**1**	**0**
1	**0**	**1**	**1**	**0**
1	1	0	0	1
1	**1**	**1**	**1**	**0**



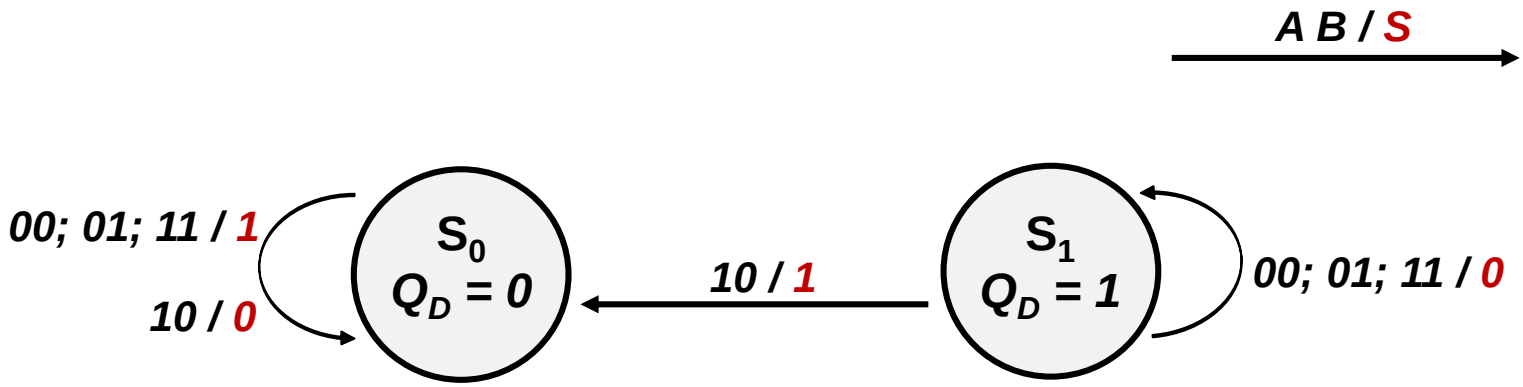
Ex.3 : Analyse

$Q_D(t)$	A	B	$Q_D(t+1)$	S
0	0	0	0	1
0	0	1	0	1
0	1	0	0	0
0	1	1	0	1
1	0	0	1	0
1	0	1	1	0
1	**1**	**0**	**0**	**1**
1	1	1	1	0



Ex.3 : Analyse

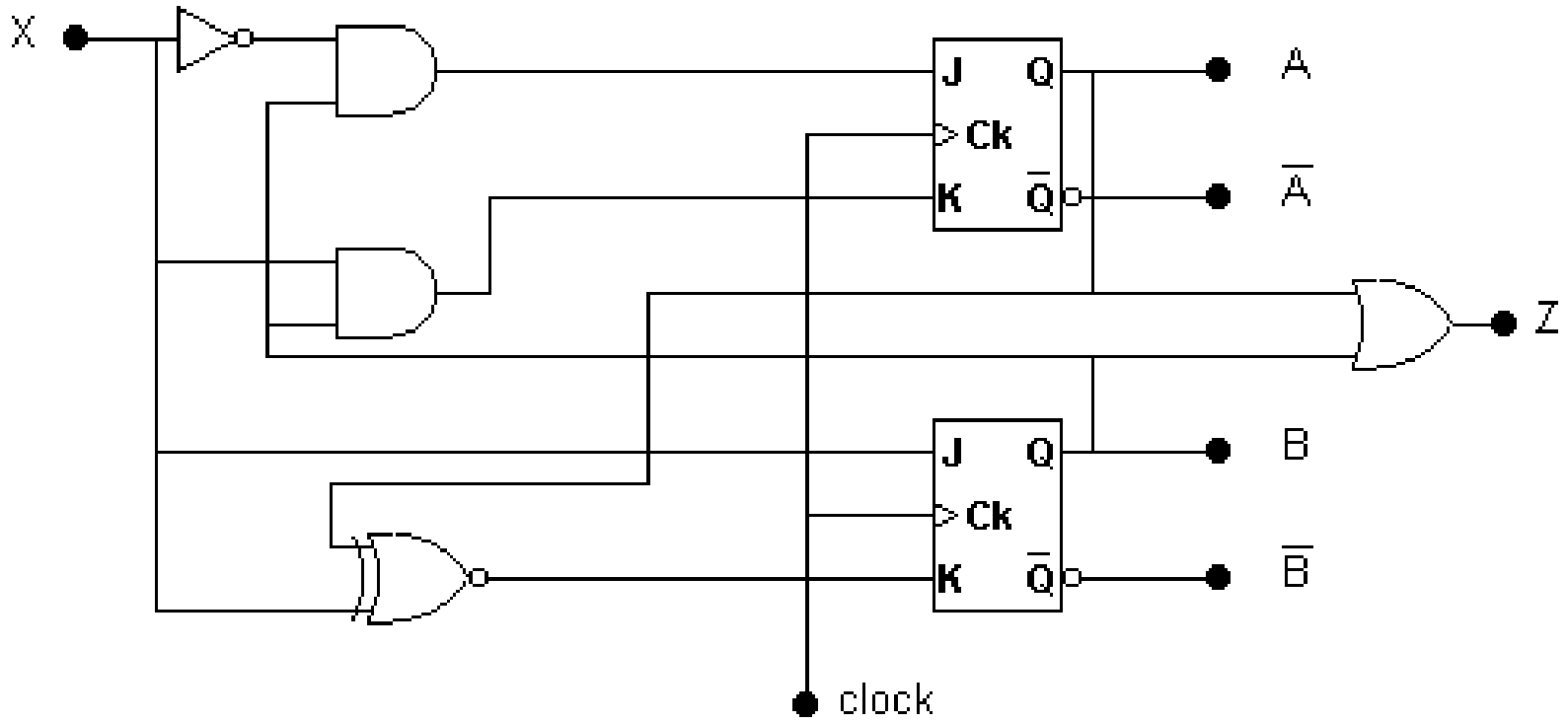
5) Diagramme d'états: 1 FF → 2 états



La sortie dépend de l'état du système et des variables d'entrées

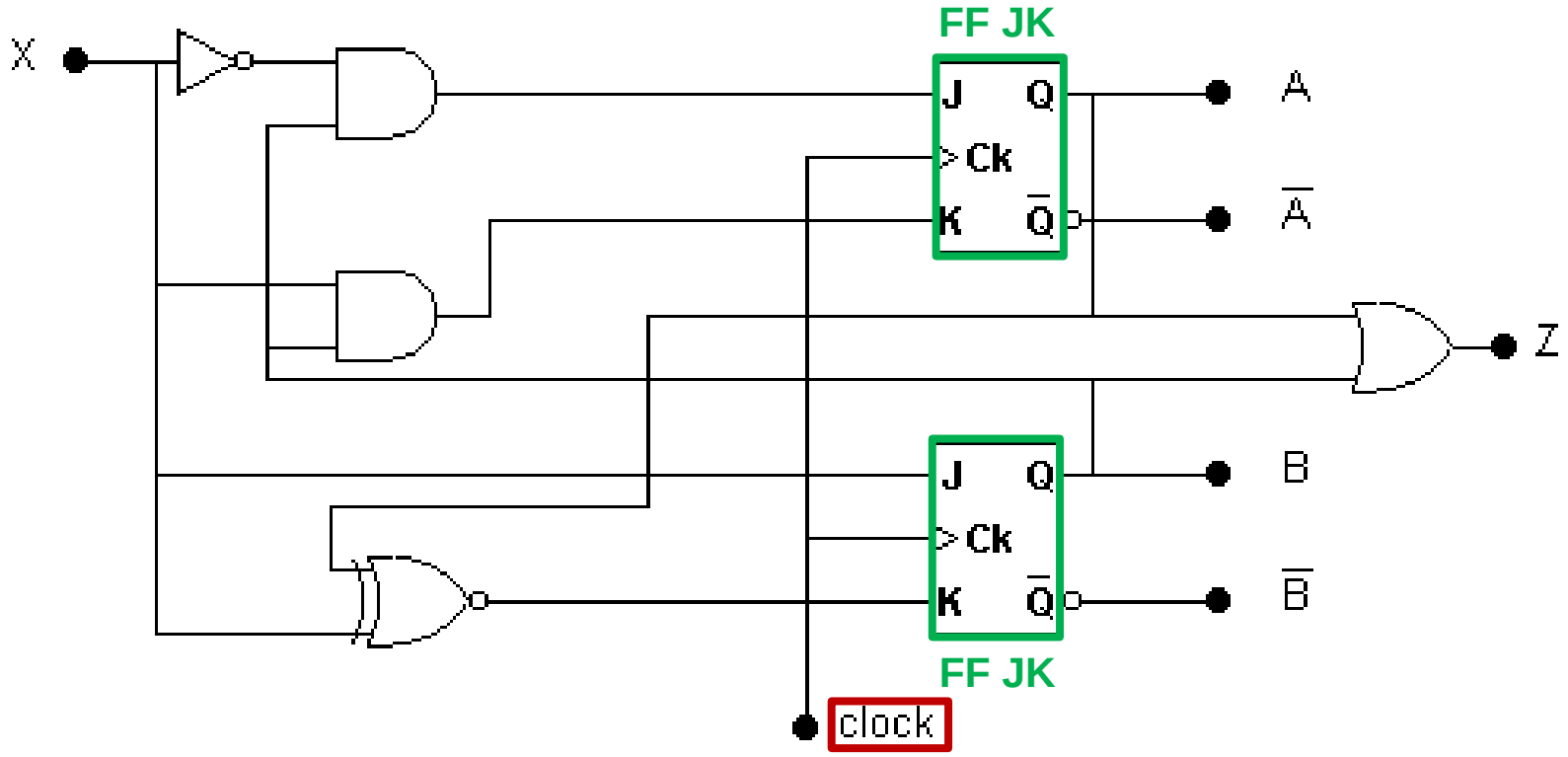
⟹ **Diagramme de Mealy**

Ex.7 : Analyse



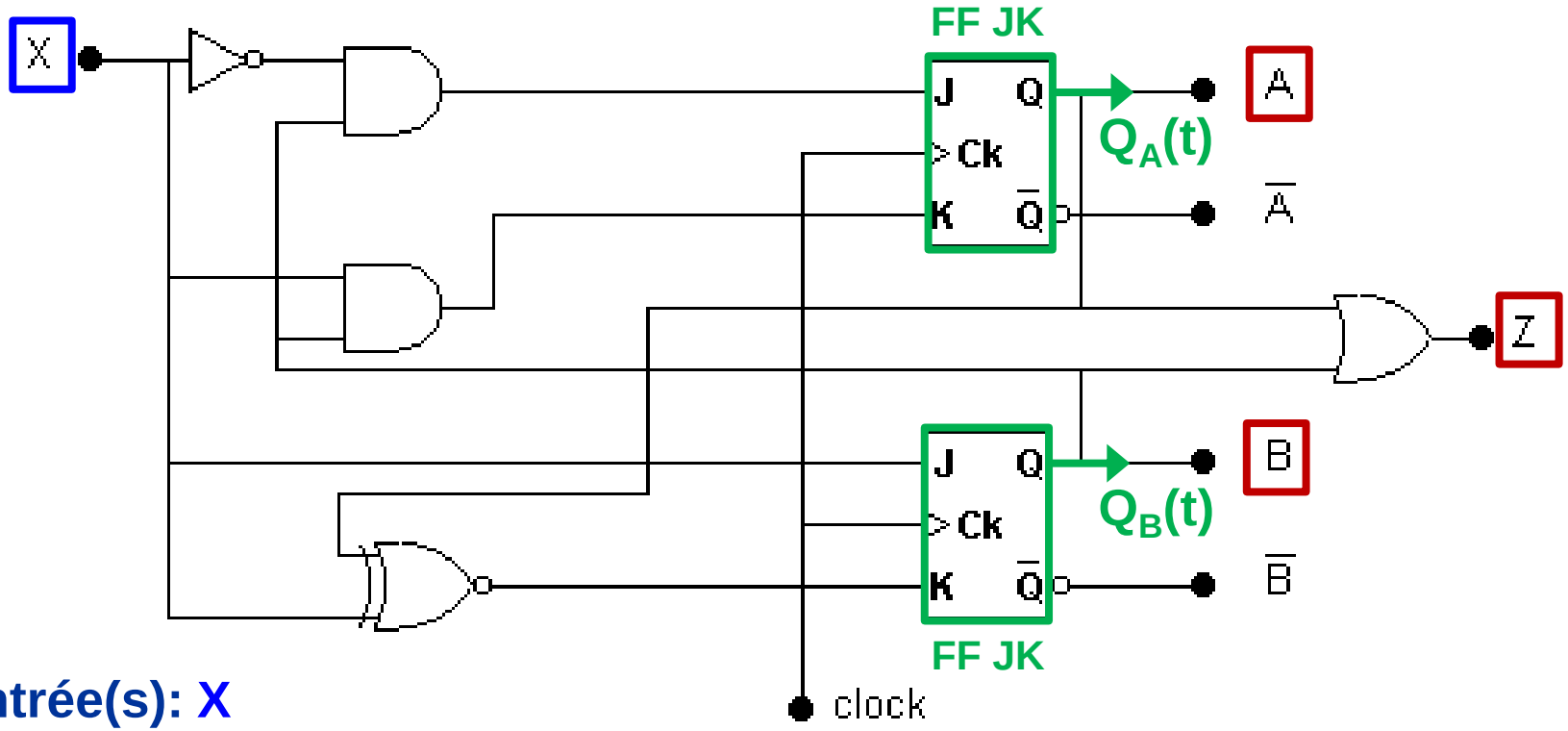
Ex.7 : Analyse

1) Synchrone



Ex.7 : Analyse

2) Entrées / Sorties:



Entrée(s): X

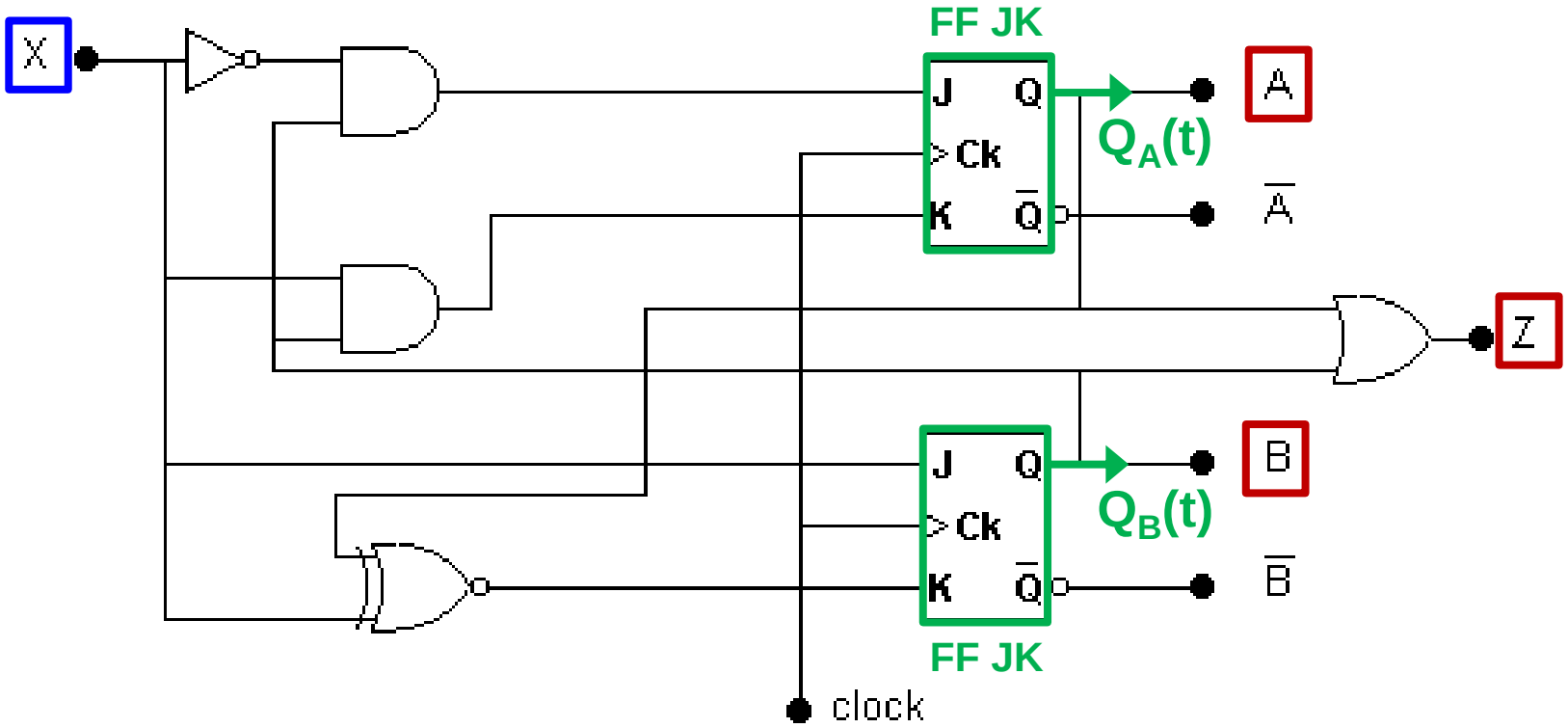
Sorties: Z, A = Q_A, B = Q_B

Variables d'état: Q_A, Q_B

Variables intermédiaires: J_A, K_A, J_B, K_B

Ex.7 : Analyse

3) Equations caractéristiques:



$J_A = \overline{X}.Q_B(t)$; $K_A = X.Q_B(t)$; $J_B = X$; $K_B = \overline{X \oplus Q_A(t)}$

$Q_A(t+1) = J_A.\overline{Q_A(t)} + \overline{K}_A.Q_A(t)$; $Q_B(t+1) = J_B.\overline{Q_B(t)} + \overline{K}_B.Q_B(t)$

$Z = Q_A(t) + Q_B(t)$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0							
0	0	1							
0	1	0							
0	1	1							
1	0	0							
1	0	1							
1	1	0							
1	1	1							

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0			0				
0	0	1			0				
0	1	0			**1**				
0	1	1			0				
1	0	0			0				
1	0	1			0				
1	1	0			**1**				
1	1	1			0				

$$J_A = \bar{X}.Q_B(t)$$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0			0	0			
0	0	1			0	0			
0	1	0			1	0			
0	1	1			0	**1**			
1	0	0			0	0			
1	0	1			0	0			
1	1	0			1	0			
1	1	1			0	**1**			

$$K_A = X.Q_B(t)$$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	**0**		0	0			
0	0	1	**0**		0	0			
0	1	0			1	0			
0	1	1			0	1			
1	0	0	**1**		0	0			
1	0	1	**1**		0	0			
1	1	0			1	0			
1	1	1			0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0		0	0			
0	0	1	0		0	0			
0	1	0			1	0			
0	1	1	**0**		0	1			
1	0	0	1		0	0			
1	0	1	1		0	0			
1	1	0			1	0			
1	1	1	**0**		0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0		0	0			
0	0	1	0		0	0			
0	1	0	**1**		1	0			
0	1	1	0		0	1			
1	0	0	1		0	0			
1	0	1	1		0	0			
1	1	0	**1**		1	0			
1	1	1	0		0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0		0	0	**0**		
0	0	1	0		0	0	**1**		
0	1	0	1		1	0	**0**		
0	1	1	0		0	1	**1**		
1	0	0	1		0	0	**0**		
1	0	1	1		0	0	**1**		
1	1	0	1		1	0	**0**		
1	1	1	0		0	1	**1**		

$J_B = X$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0		0	0	0	**1**	
0	0	1	0		0	0	1	**0**	
0	1	0	1		1	0	0	**1**	
0	1	1	0		0	1	1	**0**	
1	0	0	1		0	0	0	**0**	
1	0	1	1		0	0	1	**1**	
1	1	0	1		1	0	0	**0**	
1	1	1	0		0	1	1	**1**	

$$K_B = \overline{X \oplus Q_A(t)}$$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0		0	0	0	1	
0	0	1	0		0	0	1	0	
0	1	0	1		1	0	0	1	
0	1	1	0		0	1	1	0	
1	0	0	1	**0**	0	0	0	0	
1	0	1	1		0	0	1	1	
1	1	0	1	**1**	1	0	0	0	
1	1	1	0		0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0	**0**	0	0	0	1	
0	0	1	0		0	0	1	0	
0	1	0	1	**0**	1	0	0	1	
0	1	1	0		0	1	1	0	
1	0	0	1	0	0	0	0	0	
1	0	1	1		0	0	1	1	
1	1	0	1	1	1	0	0	0	
1	1	1	0		0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0	0	0	0	0	1	
0	0	1	0	**1**	0	0	1	0	
0	1	0	1	0	1	0	0	1	
0	1	1	0	**1**	0	1	1	0	
1	0	0	1	0	0	0	0	0	
1	0	1	1		0	0	1	1	
1	1	0	1	1	1	0	0	0	
1	1	1	0		0	1			

J(t)	K(t)	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0	0	0	0	0	1	
0	0	1	0	1	0	0	1	0	
0	1	0	1	0	1	0	0	1	
0	1	1	0	1	0	1	1	0	
1	0	0	1	0	0	0	0	0	
1	0	1	1	**1**	0	0	1	1	
1	1	0	1	1	1	0	0	0	
1	1	1	0	**0**	0	1	1	1	

J(t)	K(t)	Q(t+1)
1	1	$\overline{Q(t)}$

Ex.7 : Analyse

4) Table d'états

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	J_A	K_A	J_B	K_B	Z
0	0	0	0	0	0	0	0	1	0
0	0	1	0	1	0	0	1	0	0
0	1	0	1	0	1	0	0	1	**1**
0	1	1	0	1	0	1	1	0	**1**
1	0	0	1	0	0	0	0	0	**1**
1	0	1	1	1	0	0	1	1	**1**
1	1	0	1	1	1	0	0	0	**1**
1	1	1	0	0	0	1	1	1	**1**

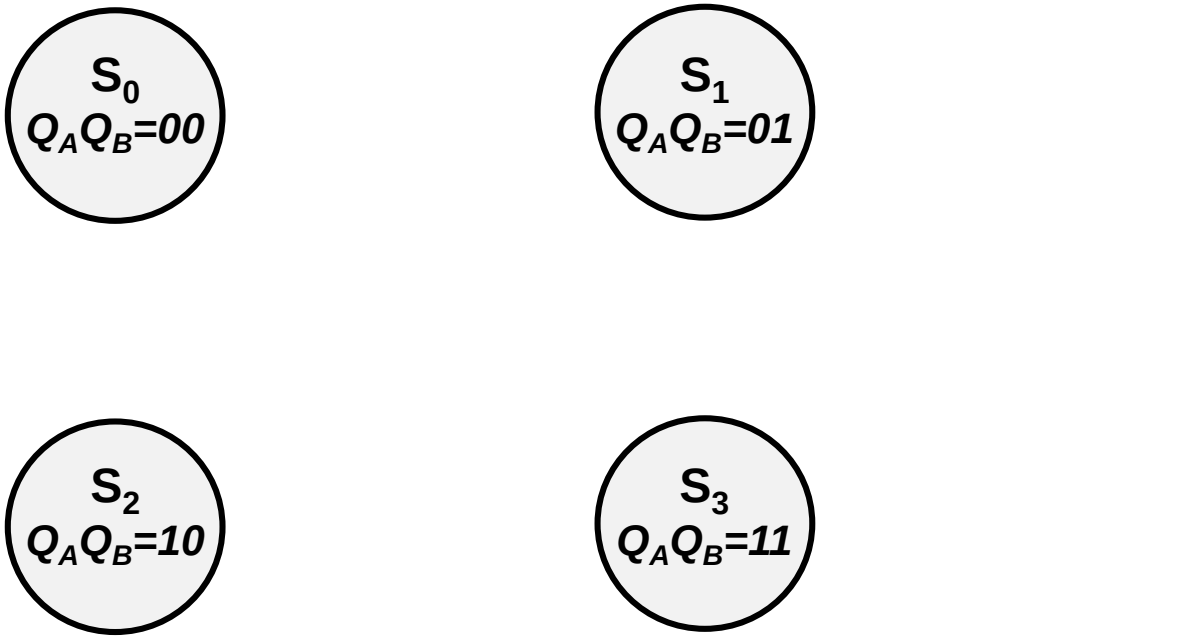
$$Z = Q_A(t) + Q_B(t)$$

Ex.7 : Analyse

5) Diagramme d'états: 2 FF → 4 états

Légende:

X / Z



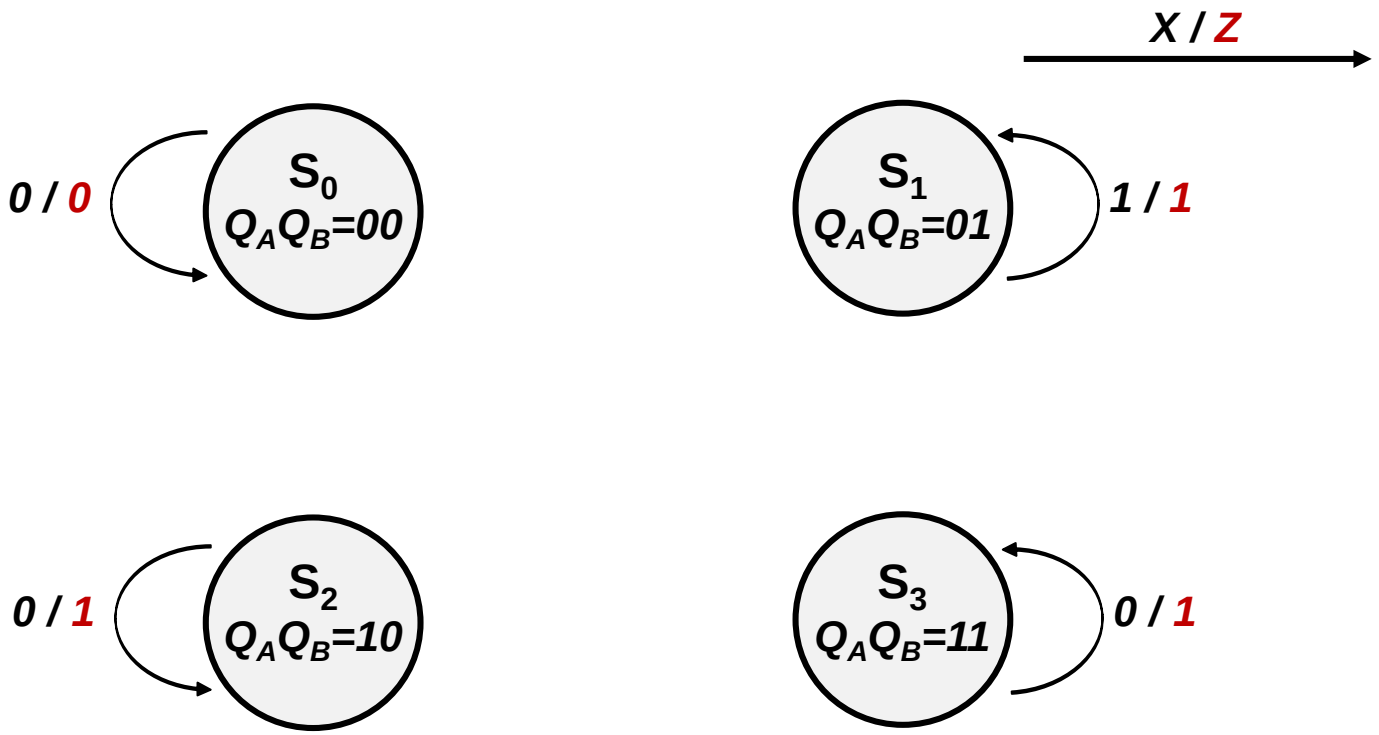
⟹ **Transitions dans la table d'états**

Ex.7 : Analyse

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	Z
0	**0**	**0**	**0**	**0**	**0**
0	0	1	0	1	0
0	1	0	1	0	1
0	**1**	**1**	**0**	**1**	**1**
1	**0**	**0**	**1**	**0**	**1**
1	0	1	1	1	1
1	**1**	**0**	**1**	**1**	**1**
1	1	1	0	0	1

Ex.7 : Analyse

5) Diagramme d'états: 2 FF → 4 états

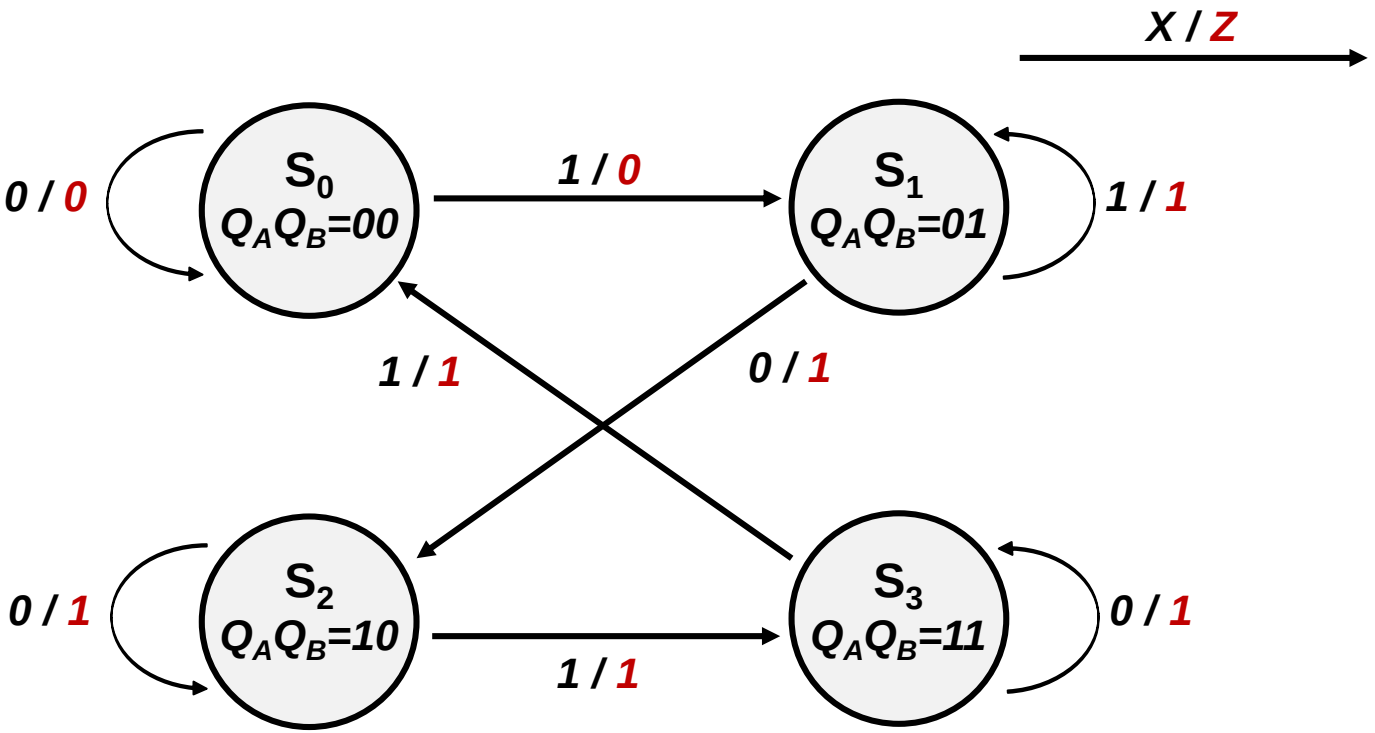


Ex.7 : Analyse

$Q_A(t)$	$Q_B(t)$	X	$Q_A(t+1)$	$Q_B(t+1)$	Z
0	0	0	0	0	0
0	**0**	**1**	**0**	**1**	**0**
0	**1**	**0**	**1**	**0**	**1**
0	1	1	0	1	1
1	0	0	1	0	1
1	**0**	**1**	**1**	**1**	**1**
1	1	0	1	1	1
1	**1**	**1**	**0**	**0**	**1**

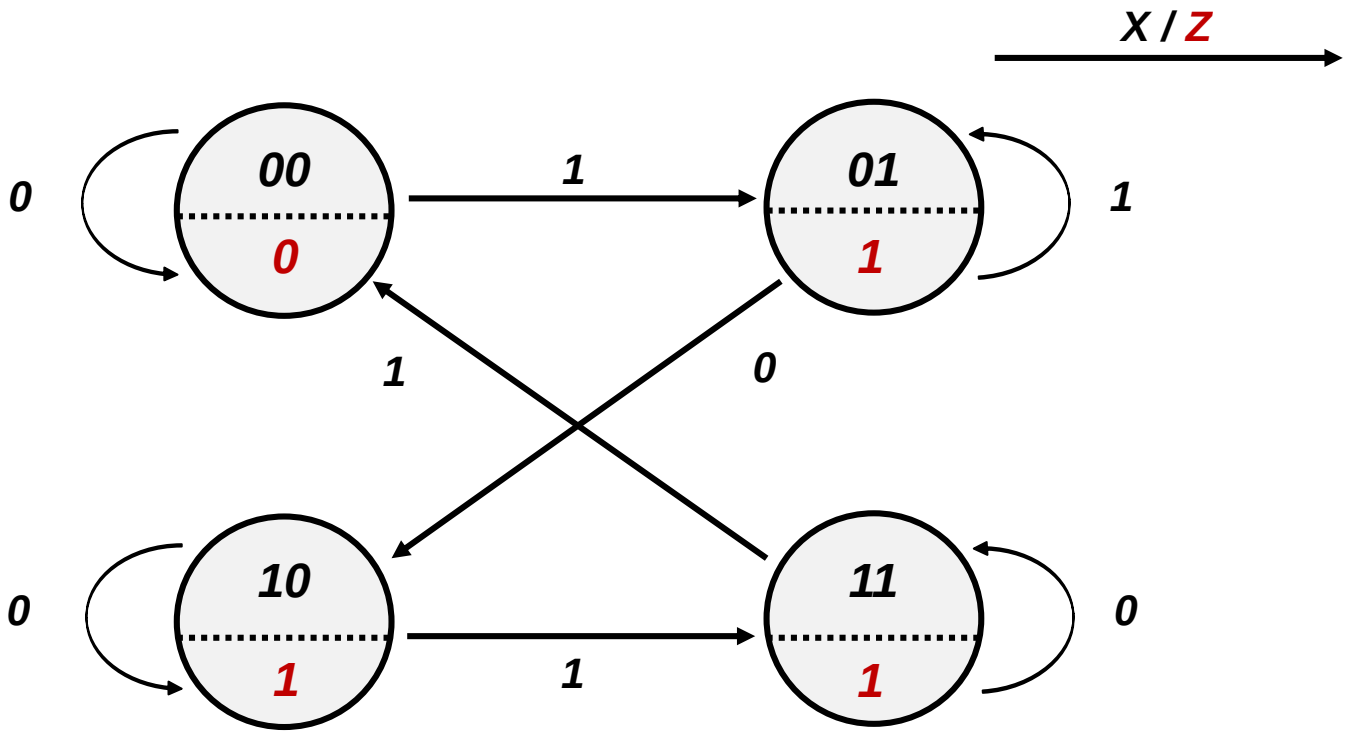
Ex.7 : Analyse

5) Diagramme d'états: 2 FF → 4 états



Ex.7 : Analyse

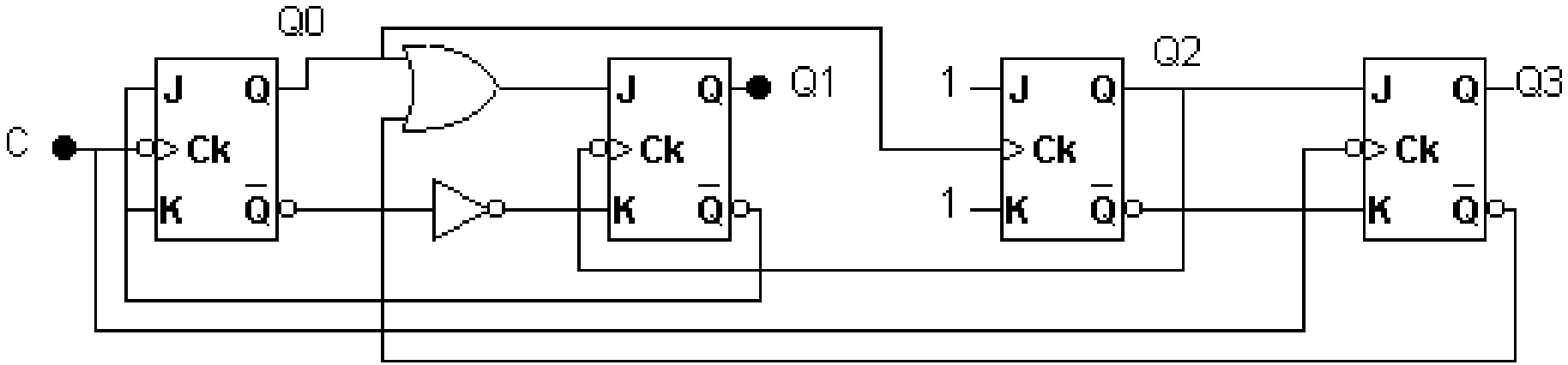
5) Diagramme d'états: 2 FF → 4 états $Q_A Q_B$



La valeur de Z ne dépend que de l'état du système (cf: table)

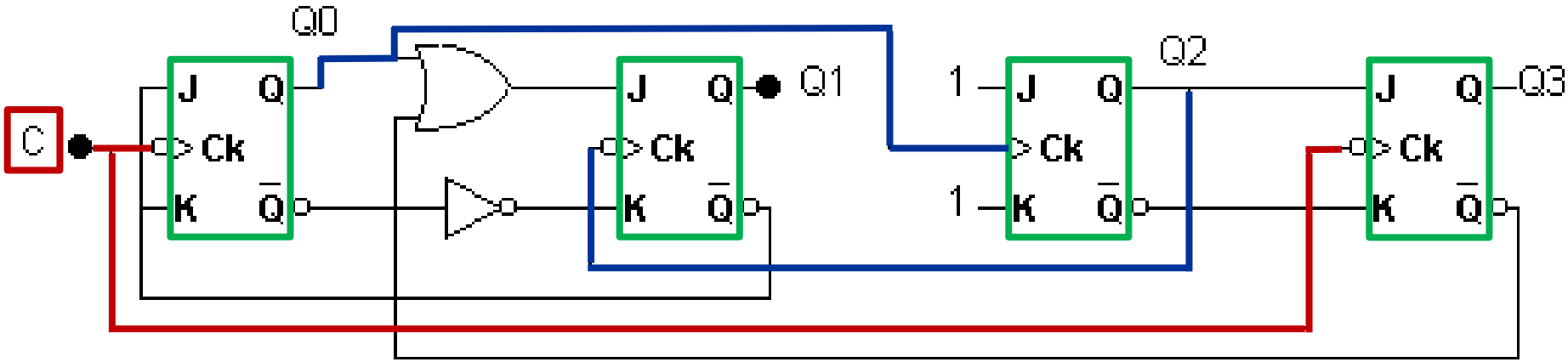
⟹ **Diagramme de Moore**

Ex.11 : Analyse



Ex.11 : Analyse

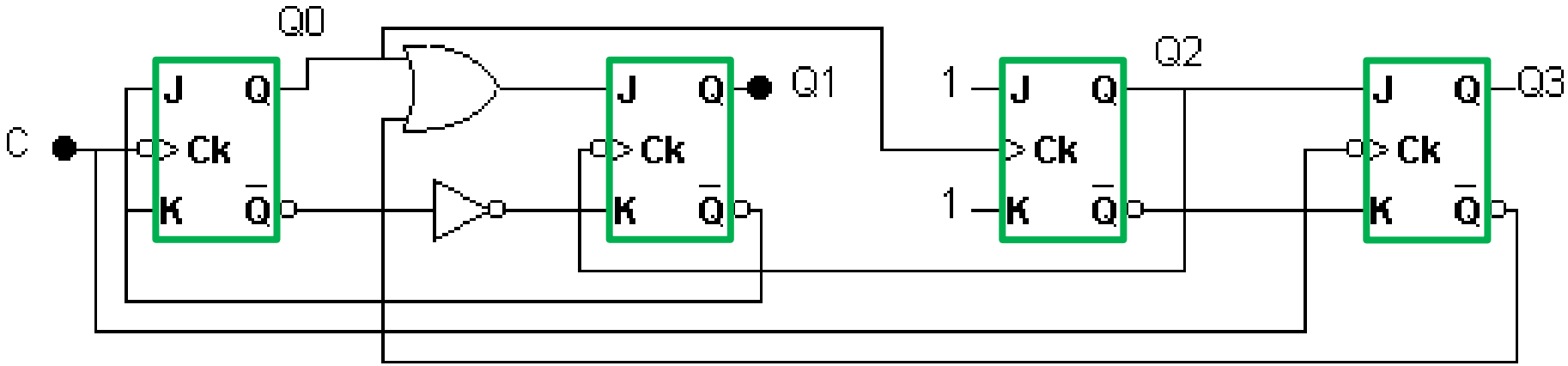
1) Asynchrone



Ordre de déclenchement: FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2)
FF3↓(Ck)

Ex.11 : Analyse

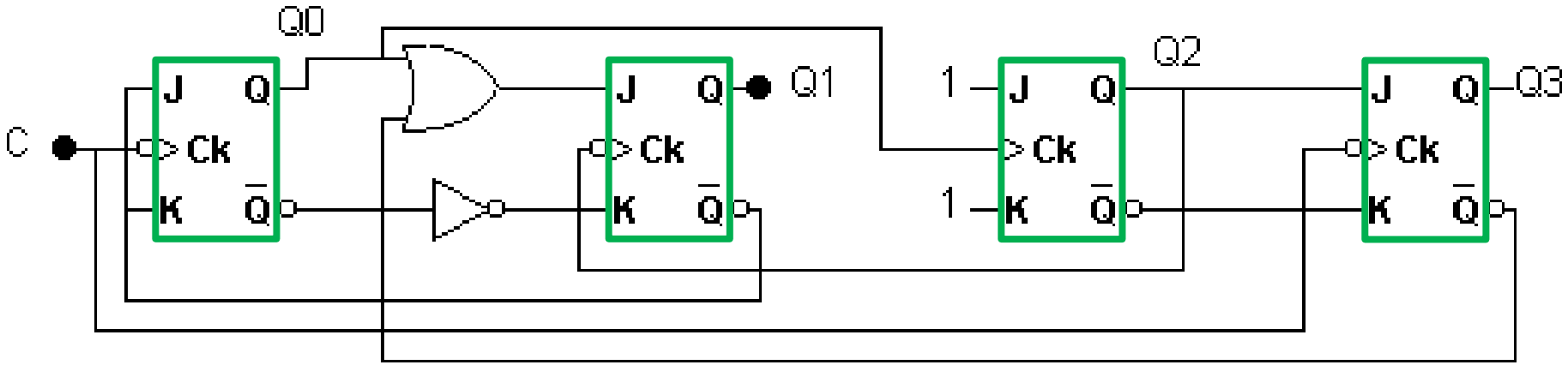
2) Entrées / Sorties:



Entrées: /
Sorties: /
Variables d'état: Q_0, Q_1, Q_2, Q_3
Variables intermédiaires: $J_{\{0, 1, 2, 3\}}$, $K_{\{0, 1, 2, 3\}}$

Ex.11 : Analyse

3) Equations caractéristiques: **FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2)**
FF3↓(Ck)

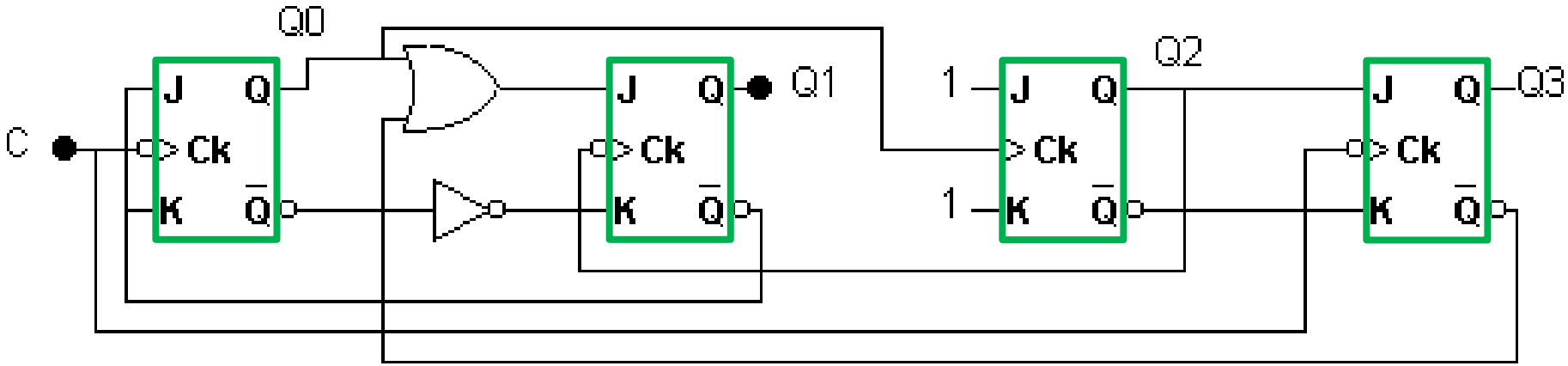


!!! Remplir la table au fur et à mesure !!!

en respectant l'ordre de déclenchement

Ex.11 : Analyse

3) Equations caractéristiques: **FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2)**
FF3↓(Ck)



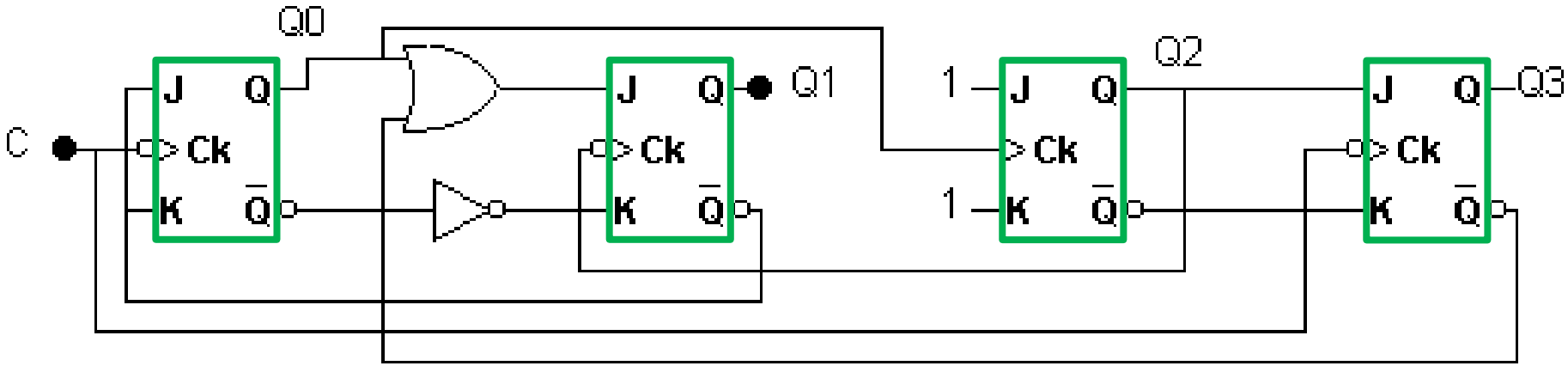
FF0: $J_0 = K_0 = \overline{Q_1(t)} \rightarrow J_0K_0 = 00 \rightarrow Q_0(t+1) = Q_0(t)$

$= 11 \rightarrow Q_0(t+1) = \overline{Q_0(t)}$

$Q_3(t)$	$Q_2(t)$	$Q_1(t)$	$Q_0(t)$	$Q_3(t+1)$	$Q_2(t+1)$	$Q_1(t+1)$	$Q_0(t+1)$	J_0	K_0
0	0	0	0				**1**	1	1
0	0	0	1				**0**	1	1
0	0	1	0				**0**	0	0
0	0	1	1				**1**	0	0
0	1	0	0				**1**	1	1
0	1	0	1				**0**	1	1
0	1	1	0				**0**	0	0
0	1	1	1				**1**	0	0
1	0	0	0				**1**	1	1
1	0	0	1				**0**	1	1
1	0	1	0				**0**	0	0
1	0	1	1				**1**	0	0
1	1	0	0				**1**	1	1
1	1	0	1				**0**	1	1
1	1	1	0				**0**	0	0
1	1	1	1				**1**	0	0

Ex.11 : Analyse

3) Equations caractéristiques: **FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2) FF3↓(Ck)**



FF3: $J_3 = Q_2(t) = \overline{K_3} \rightarrow J_3K_3 = 01 \rightarrow Q_3(t+1) = 0$

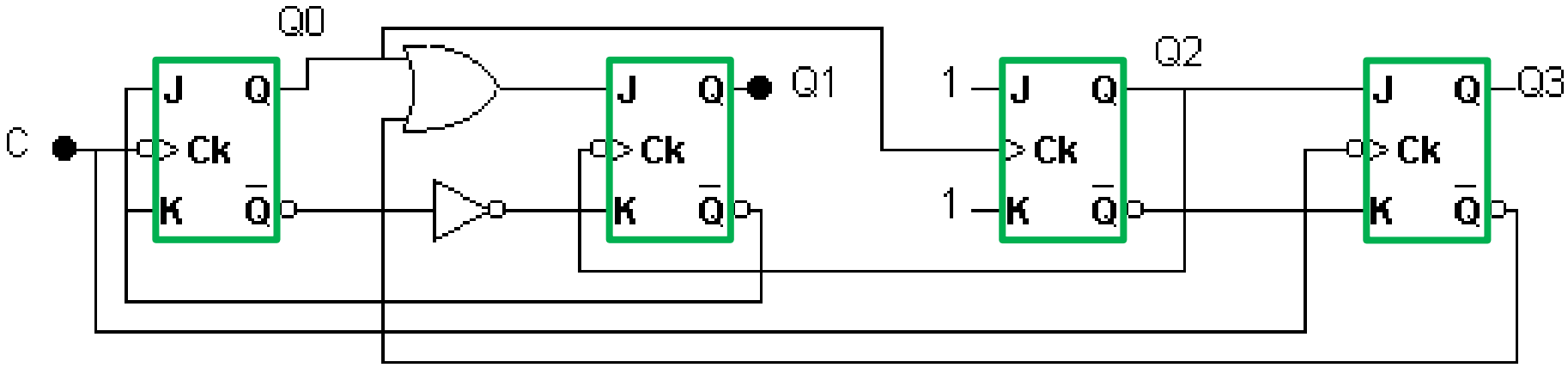
$= 10 \rightarrow Q_3(t+1) = 1$

Rq: Quand $J = \overline{K} \rightarrow Q(t+1) = J$

$Q_3(t)$	$Q_2(t)$	$Q_1(t)$	$Q_0(t)$	$Q_3(t+1)$	$Q_2(t+1)$	$Q_1(t+1)$	$Q_0(t+1)$	J_3	K_3
0	0	0	0	**0**			1	0	1
0	0	0	1	**0**			0	0	1
0	0	1	0	**0**			0	0	1
0	0	1	1	**0**			1	0	1
0	1	0	0	**1**			1	1	0
0	1	0	1	**1**			0	1	0
0	1	1	0	**1**			0	1	0
0	1	1	1	**1**			1	1	0
1	0	0	0	**0**			1	0	1
1	0	0	1	**0**			0	0	1
1	0	1	0	**0**			0	0	1
1	0	1	1	**0**			1	0	1
1	1	0	0	**1**			1	1	0
1	1	0	1	**1**			0	1	0
1	1	1	0	**1**			0	1	0
1	1	1	1	**1**			1	1	0

Ex.11 : Analyse

3) Equations caractéristiques: **FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2)**
FF3↓(Ck)



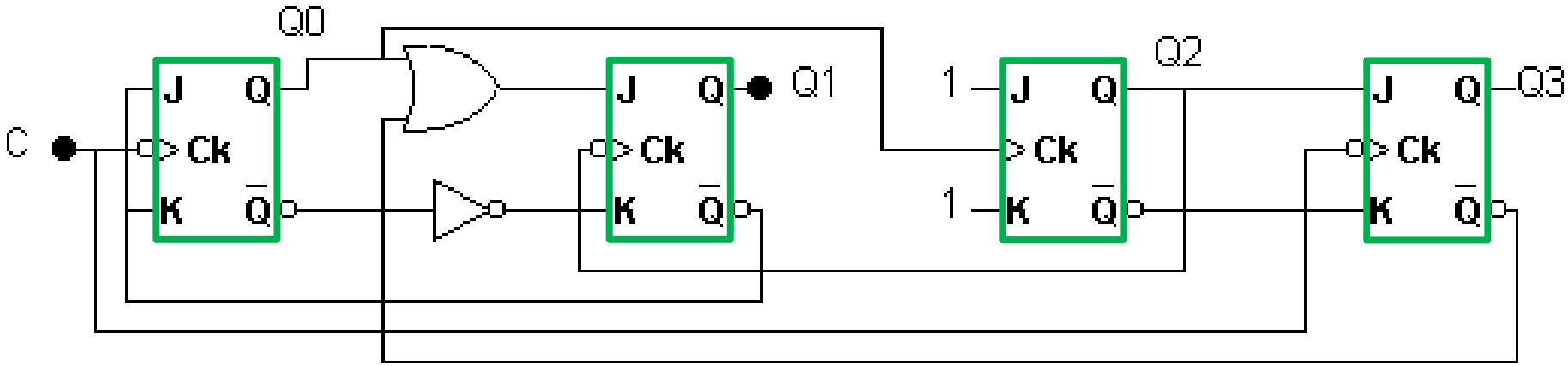
FF2: $J_2 = K_2 = 1 \rightarrow Q_2(t+1) = \overline{Q_2(t)}$ **quand** Q_0 **passe de 0 → 1**

$Ck = Q_0\uparrow$ $\quad Q_2(t+1) = Q_2(t)$ **sinon**

$Q_3(t)$	$Q_2(t)$	$Q_1(t)$	$Q_0(t)$	$Q_3(t+1)$	$Q_2(t+1)$	$Q_1(t+1)$	$Q_0(t+1)$	J_2	K_2
0	0	0	0	0	**1**		1	1	1
0	0	0	1	0	**0**		0		
0	0	1	0	0	**0**		0		
0	0	1	1	0	**0**		1		
0	1	0	0	1	**0**		1	1	1
0	1	0	1	1	**1**		0		
0	1	1	0	1	**1**		0		
0	1	1	1	1	**1**		1		
1	0	0	0	0	**1**		1	1	1
1	0	0	1	0	**0**		0		
1	0	1	0	0	**0**		0		
1	0	1	1	0	**0**		1		
1	1	0	0	1	**0**		1	1	1
1	1	0	1	1	**1**		0		
1	1	1	0	1	**1**		0		
1	1	1	1	1	**1**		1		

Ex.11 : Analyse

3) Equations caractéristiques: **FF0↓(Ck) → FF2↑(Q0) → FF1↓(Q2)**
FF3↓(Ck)



FF1: $J_1 = Q_0(t+1) + \overline{Q_3(t+1)}$

$K_1 = Q_0(t+1)$

!!! On utilise tjrs les colonnes les + à droite disponibles dans la table !!!

Ck: $Q_2\downarrow \rightarrow$ **si** Q_2 **1 → 0, on évalue** J_1K_1 **et on met à jour** Q_1

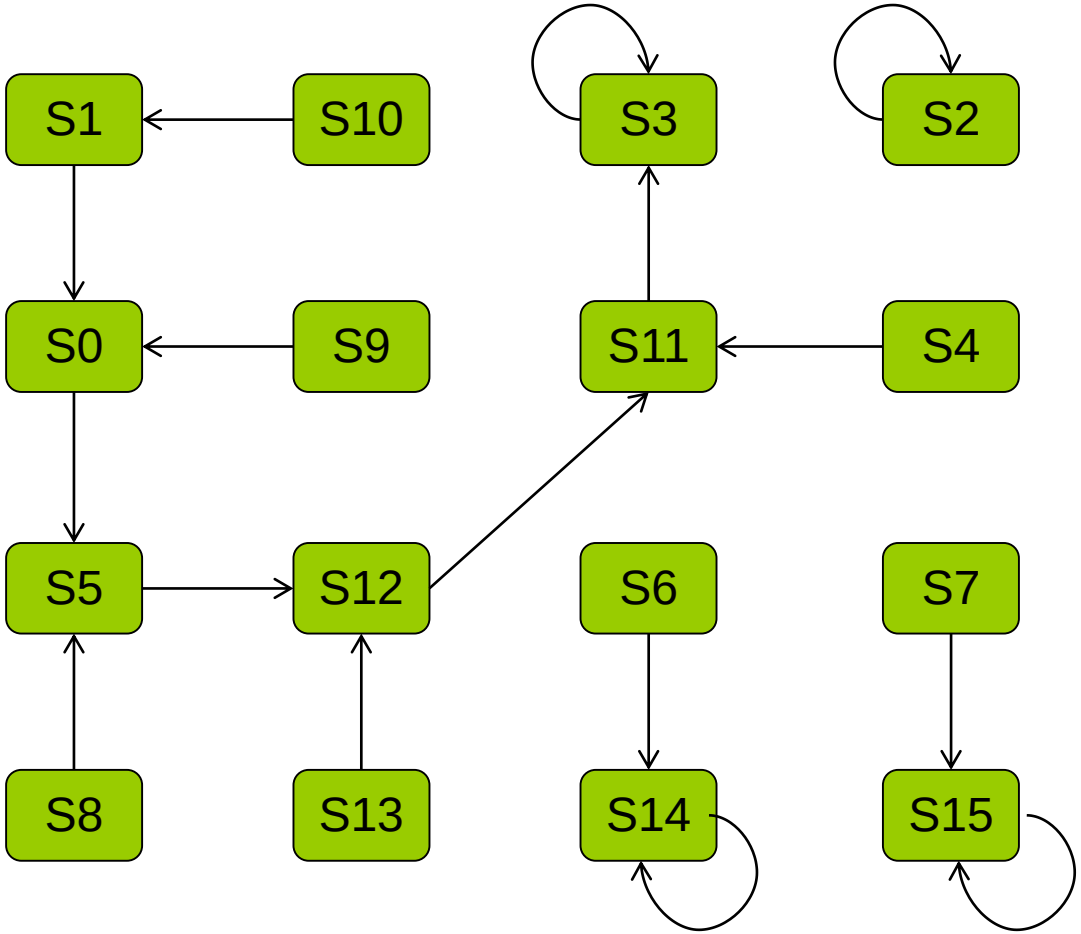
sinon, $Q_1(t+1) = Q_1(t)$

$Q_3(t)$	$Q_2(t)$	$Q_1(t)$	$Q_0(t)$	$Q_3(t+1)$	$Q_2(t+1)$	$Q_1(t+1)$	$Q_0(t+1)$	J_1	K_1
0	0	0	0	0	1	0	1		
0	0	0	1	0	0	0	0		
0	0	1	0	0	0	1	0		
0	0	1	1	0	0	1	1		
0	1	0	0	1	0	**1**	1	1	1
0	1	0	1	1	1	0	0		
0	1	1	0	1	1	1	0		
0	1	1	1	1	1	1	1		
1	0	0	0	0	1	0	1		
1	0	0	1	0	0	0	0		
1	0	1	0	0	0	1	0		
1	0	1	1	0	0	1	1		
1	1	0	0	1	0	**1**	1	1	1
1	1	0	1	1	1	0	0		
1	1	1	0	1	1	1	0		
1	1	1	1	1	1	1	1		

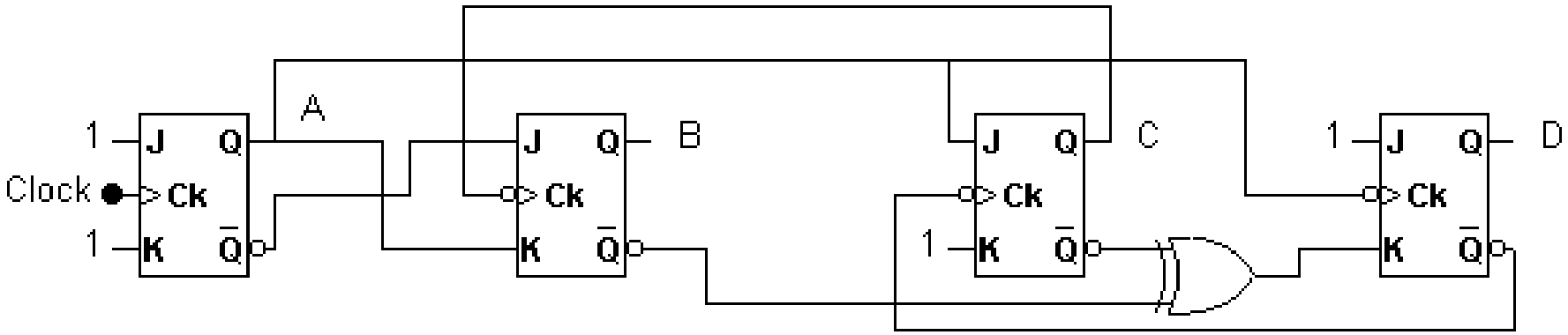
$Q_3(t)$	$Q_2(t)$	$Q_1(t)$	$Q_0(t)$	$Q_3(t+1)$	$Q_2(t+1)$	$Q_1(t+1)$	$Q_0(t+1)$
0	0	0	0	0	1	0	1
0	0	0	1	0	0	0	0
0	0	1	0	0	0	1	0
0	0	1	1	0	0	1	1
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	0
0	1	1	1	1	1	1	1
1	0	0	0	0	1	0	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	0
1	0	1	1	0	0	1	1
1	1	0	0	1	0	1	1
1	1	0	1	1	1	0	0
1	1	1	0	1	1	1	0
1	1	1	1	1	1	1	1

Ex.11 : Analyse

5) Diagramme d'états: 4 FF → 16 états

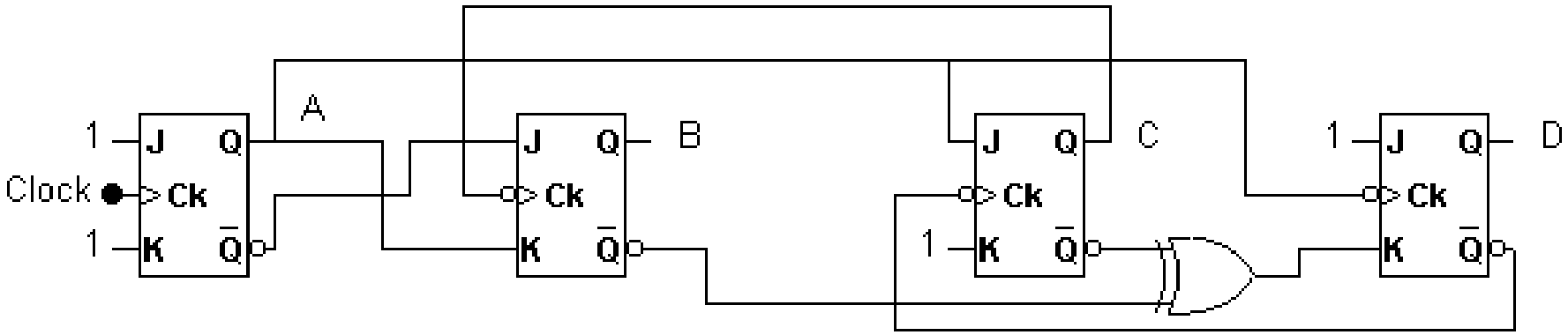


Ex.12 : Analyse



Ex.12 : Analyse

1) Asynchrone

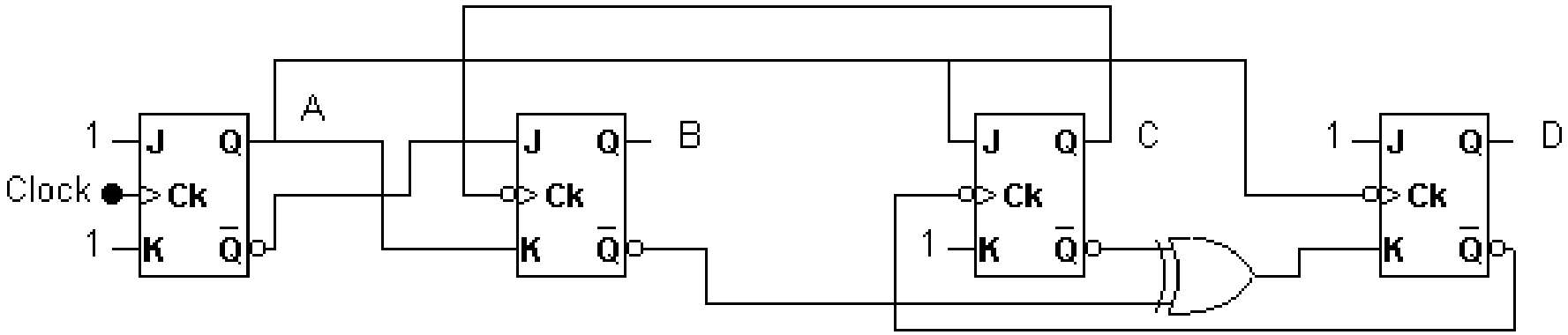


Ordre de déclenchement:

FFA ↑(Ck) → FFD↓(QA) → FFC↑(QD) → FFB↓(QC)

Ex.12 : Analyse

2) Entrées / Sorties:

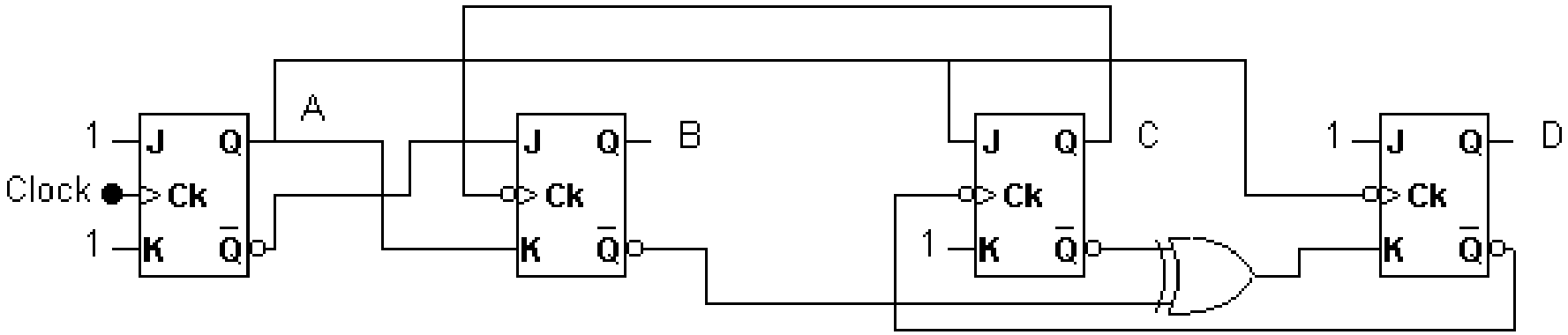


Entrées: /
Sorties: /
Variables d'état: Q_A, Q_B, Q_C, Q_D
Variables intermédiaires: $J_{\{A, B, C, D\}}$, $K_{\{A, B, C, D\}}$

Ex.12 : Analyse

3) Equations caractéristiques:

FFA ↑(Ck) → FFD↓(QA) → FFC↑(QD) → FFB↓(QC)



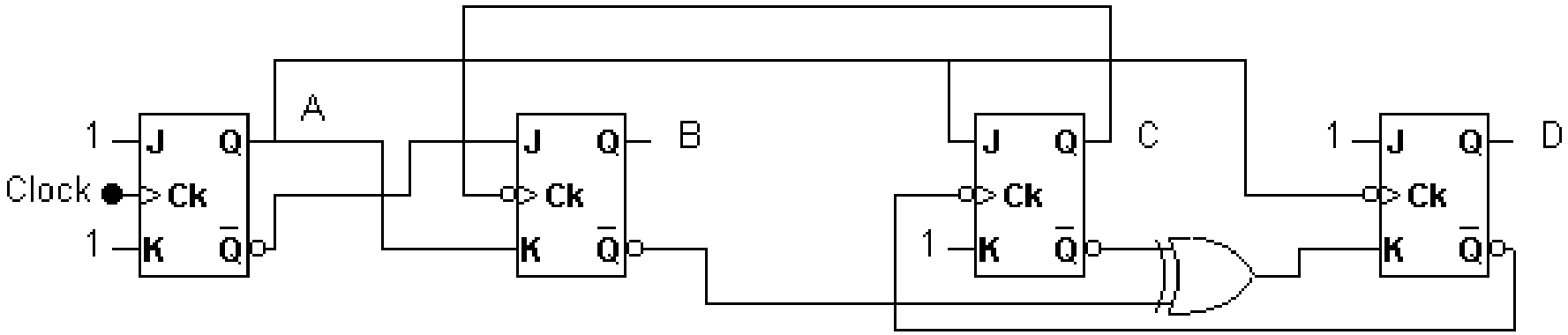
FFA: $J_A = K_A = 1 \rightarrow Q_A(t+1) = \overline{Q_A}(t)$

$Q_D(t)$	$Q_C(t)$	$Q_B(t)$	$Q_A(t)$	$Q_D(t+1)$	$Q_C(t+1)$	$Q_B(t+1)$	$Q_A(t+1)$	J_A	K_A
0	0	0	0				**1**	1	1
0	0	0	1				**0**	1	1
0	0	1	0				**1**	1	1
0	0	1	1				**0**	1	1
0	1	0	0				**1**	1	1
0	1	0	1				**0**	1	1
0	1	1	0				**1**	1	1
0	1	1	1				**0**	1	1
1	0	0	0				**1**	1	1
1	0	0	1				**0**	1	1
1	0	1	0				**1**	1	1
1	0	1	1				**0**	1	1
1	1	0	0				**1**	1	1
1	1	0	1				**0**	1	1
1	1	1	0				**1**	1	1
1	1	1	1				**0**	1	1

Ex.12 : Analyse

3) Equations caractéristiques:

FFA ↑(Ck) → FFD↓(QA) → FFC↑(QD) → FFB↓(QC)



FFD: $J_D = 1$

$$K_D = \overline{Q_C(t)} \oplus \overline{Q_B(t)} = Q_C(t) \oplus Q_B(t)$$

Ck: $Q_A\downarrow \rightarrow$ si Q_A 1 → 0, on évalue J_DK_D et on met à jour Q_D

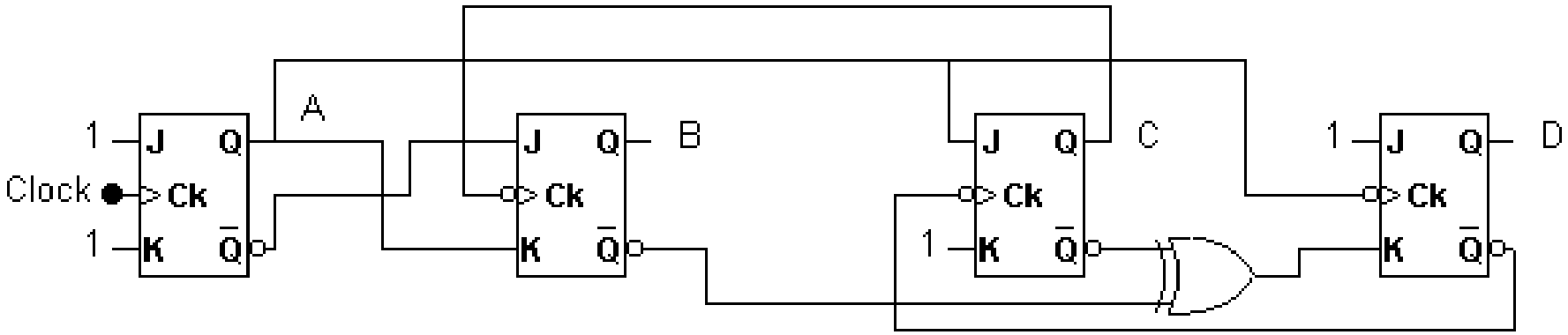
sinon, $Q_D(t+1) = Q_D(t)$

$Q_D(t)$	$Q_C(t)$	$Q_B(t)$	$Q_A(t)$	$Q_D(t+1)$	$Q_C(t+1)$	$Q_B(t+1)$	$Q_A(t+1)$	J_D	K_D
0	0	0	0	0			1		
0	0	0	1	1			0	1	0
0	0	1	0	0			1		
0	0	1	1	1			0	1	1
0	1	0	0	0			1		
0	1	0	1	1			0	1	1
0	1	1	0	0			1		
0	1	1	1	1			0	1	0
1	0	0	0	1			1		
1	0	0	1	1			0	1	0
1	0	1	0	1			1		
1	0	1	1	0			0	1	1
1	1	0	0	1			1		
1	1	0	1	0			0	1	1
1	1	1	0	1			1		
1	1	1	1	1			0	1	0

Ex.12 : Analyse

3) Equations caractéristiques:

FFA ↑(Ck) → FFD↓(QA) → FFC↑(QD) → FFB↓(QC)



FFC: $J_C = Q_A(t+1)$

$K_C = 1$

Ck: $Q_D\uparrow \rightarrow$ si Q_D 0 → 1, on évalue J_CK_C et on met à jour Q_C

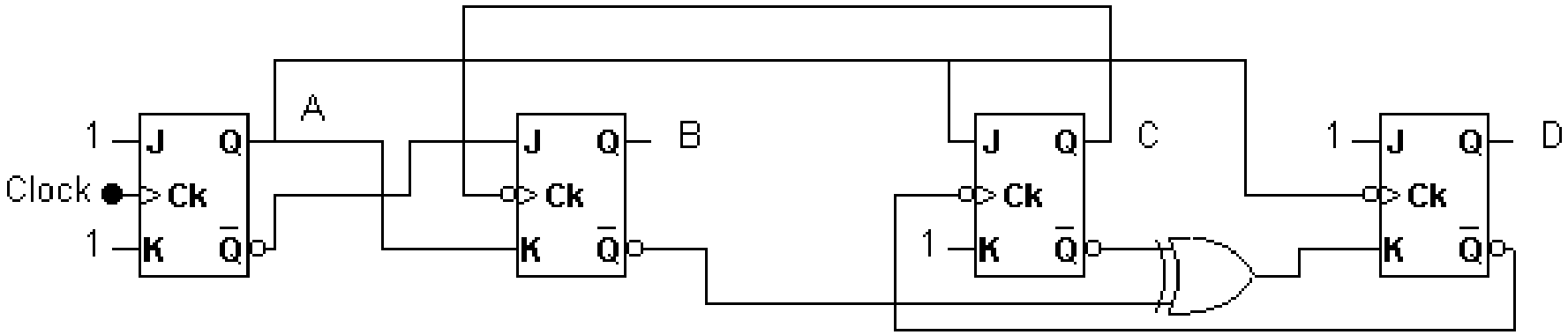
sinon, $Q_C(t+1) = Q_C(t)$

$Q_D(t)$	$Q_C(t)$	$Q_B(t)$	$Q_A(t)$	$Q_D(t+1)$	$Q_C(t+1)$	$Q_B(t+1)$	$Q_A(t+1)$	J_C	K_C
0	0	0	0	0	0		1		
0	0	0	1	1	**0**		0	**0**	**1**
0	0	1	0	0	0		1		
0	0	1	1	1	**0**		0	**0**	**1**
0	1	0	0	0	1		1		
0	1	0	1	1	**0**		0	**0**	**1**
0	1	1	0	0	1		1		
0	1	1	1	1	**0**		0	**0**	**1**
1	0	0	0	1	0		1		
1	0	0	1	1	0		0		
1	0	1	0	1	0		1		
1	0	1	1	0	0		0		
1	1	0	0	1	1		1		
1	1	0	1	0	1		0		
1	1	1	0	1	1		1		
1	1	1	1	1	1		0		

Ex.12 : Analyse

3) Equations caractéristiques:

FFA ↑(Ck) → FFD↓(QA) → FFC↑(QD) → FFB↓(QC)



FFB: $J_B = \overline{Q}_A(t+1) = \overline{K}_B$

Ck: $Q_C\downarrow \rightarrow$ **si** Q_C $1 \rightarrow 0$, $Q_B(t+1) = \overline{Q}_A(t+1)$

sinon, $Q_B(t+1) = Q_B(t)$

Rappel: Quand $J = \overline{K} \rightarrow Q(t+1) = J$

$Q_D(t)$	$Q_C(t)$	$Q_B(t)$	$Q_A(t)$	$Q_D(t+1)$	$Q_C(t+1)$	$Q_B(t+1)$	$Q_A(t+1)$	J_B	K_B
0	0	0	0	0	0	0	1		
0	0	0	1	1	0	0	0		
0	0	1	0	0	0	1	1		
0	0	1	1	1	0	1	0		
0	1	0	0	0	1	0	1		
0	1	0	1	1	0	**1**	0	**1**	**0**
0	1	1	0	0	1	1	1		
0	1	1	1	1	0	**1**	0	**1**	**0**
1	0	0	0	1	0	0	1		
1	0	0	1	1	0	0	0		
1	0	1	0	1	0	1	1		
1	0	1	1	0	0	1	0		
1	1	0	0	1	1	0	1		
1	1	0	1	0	1	0	0		
1	1	1	0	1	1	1	1		
1	1	1	1	1	1	1	0		

$Q_D(t)$	$Q_C(t)$	$Q_B(t)$	$Q_A(t)$	$Q_D(t+1)$	$Q_C(t+1)$	$Q_B(t+1)$	$Q_A(t+1)$
0	0	0	0	0	0	0	1
0	0	0	1	1	0	0	0
0	0	1	0	0	0	1	1
0	0	1	1	1	0	1	0
0	1	0	0	0	1	0	1
0	1	0	1	1	0	1	0
0	1	1	0	0	1	1	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	0	1
1	0	0	1	1	0	0	0
1	0	1	0	1	0	1	1
1	0	1	1	0	0	1	0
1	1	0	0	1	1	0	1
1	1	0	1	0	1	0	0
1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	0

Ex.12 : Analyse

5) Diagramme d'états: 4 FF → 16 états