الدارات التتابعية
Sequential Circuits

إعداد د. حسن الأحمد

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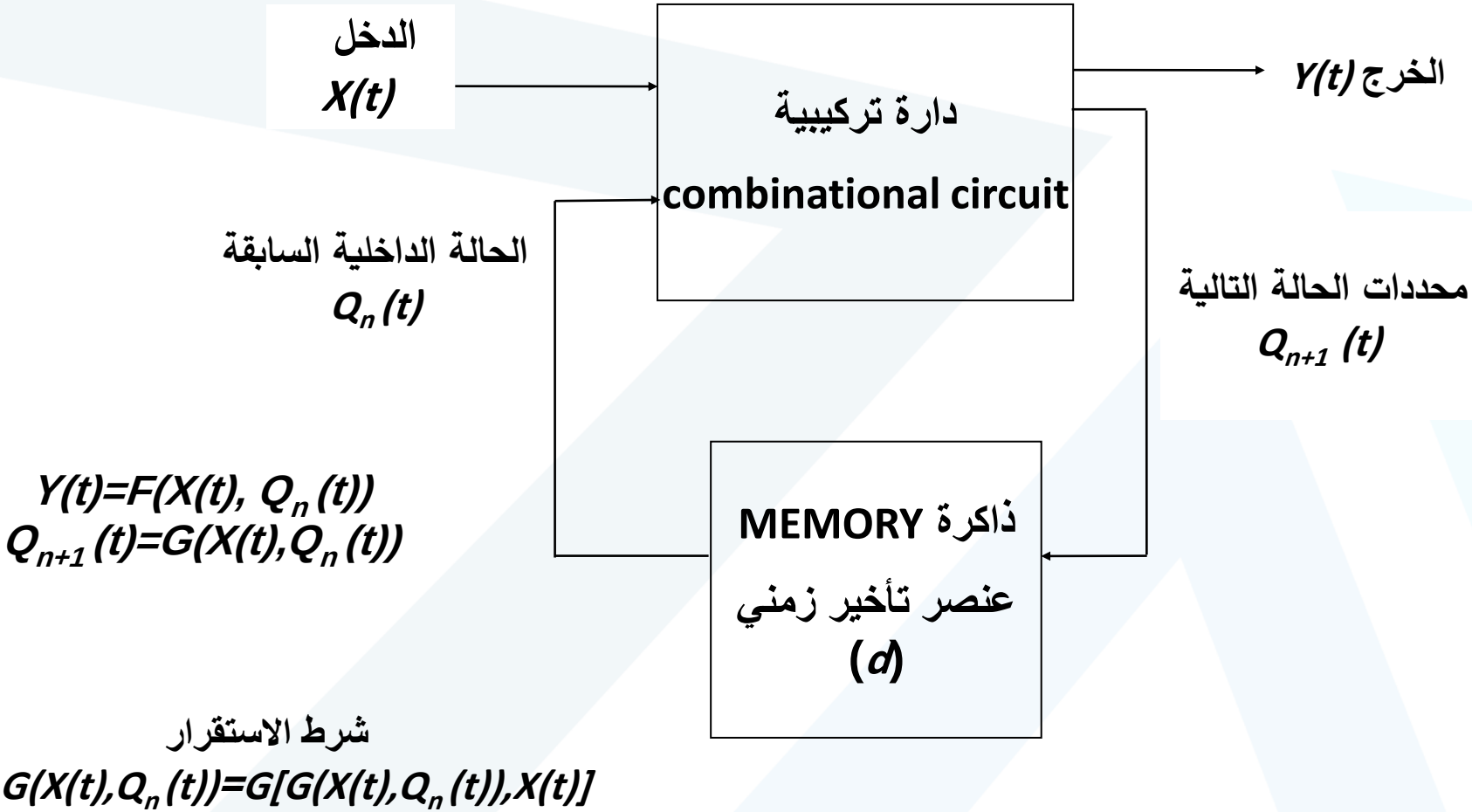
Sequential Circuit الدارة التتابعية



$$Y(t)=F(X(t), Q_n(t))$$
$$Q_{n+1}(t)=G(X(t),Q_n(t))$$

شرط الاستقرار

$$G(X(t),Q_n(t))=G[G(X(t),Q_n(t)),X(t)]$$

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ما هي الآلية (Automata)

الآلية هي تجهيزة تعمل دون تدخل العنصر البشري. تقوم هذه التجهيزة بقيادة ومعالجة وإخراج العناصر المعالَجة من مواد أو قدرة أو معلومات وفقاً لخطة محددة موضوعة مسبقاً.

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الآلية الرقمية

الآليات التي تتعامل مع معلومات دخل وخرج وحالة (x, y, q) ذات قيم رقمية باعتبار الزمن.

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توصيف الآليات التتابعية

تابع الخرج:

$$Y(t)=F(X(t), Q_n(t))$$

تابع الانتقال

$$Q_{n+1}(t)=G(X(t),Q_n(t))$$

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وصف وتمثيل النظم التتابعية

الوصف بلغة طبيعية

الوصف بلغة رياضية

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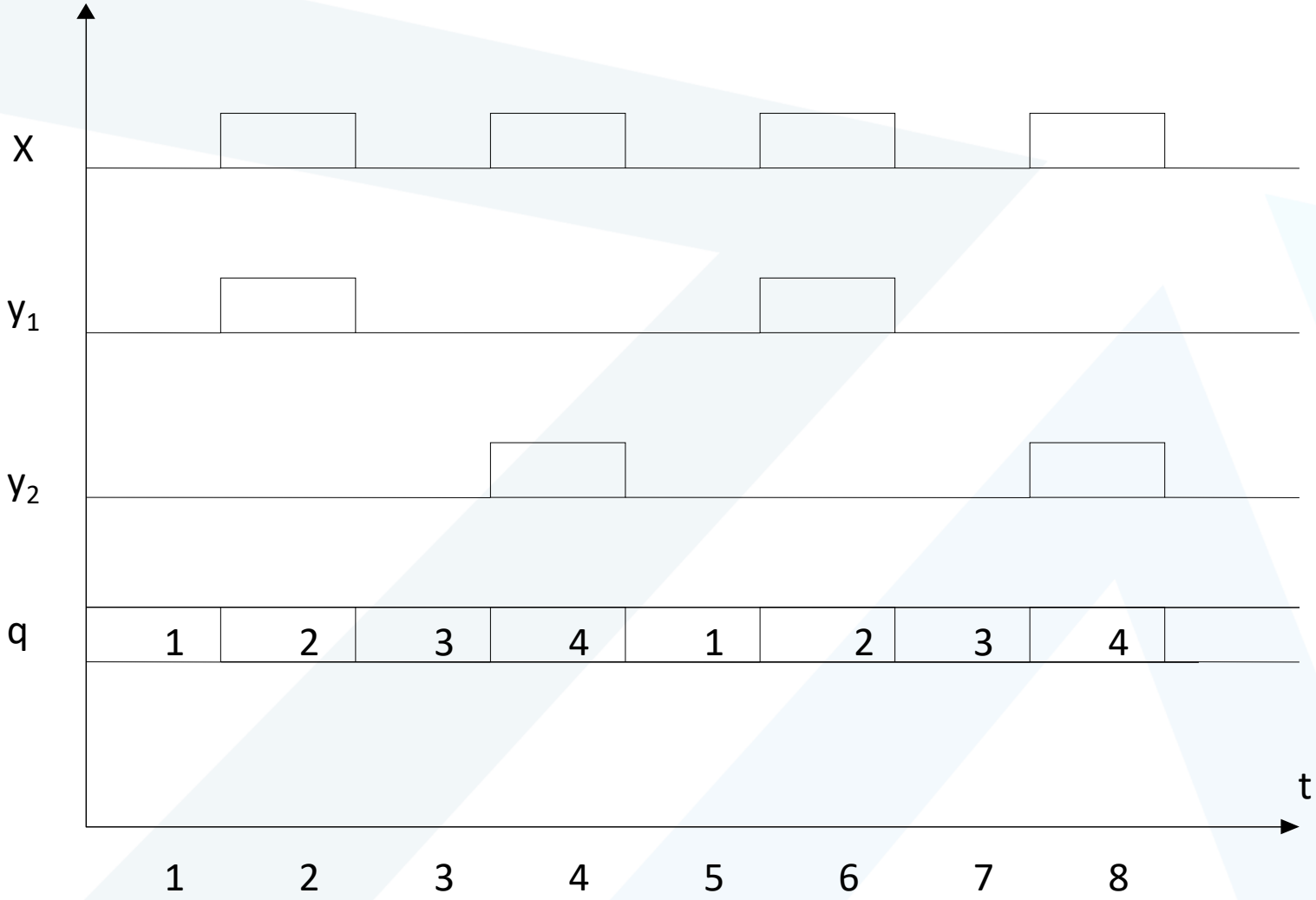
وصف وتمثيل النظم التتابعية



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الوصف بواسطة تركيبات الدخل/الخرج

- تركيبات الدخل/الخرج لكل حالة متميزة في النظام التتابعي.
- ثنائيات [X/Y]،
- توافق كل ثنائية الحالة في لحظة زمنية ما (t).
- ويظهر النظام على شكل سلسلة لها الشكل التالي.

$$B_i = <^{t}(X/Y), ^{t+1}(X/Y), \ldots ^{t+n}(X/Y)>$$

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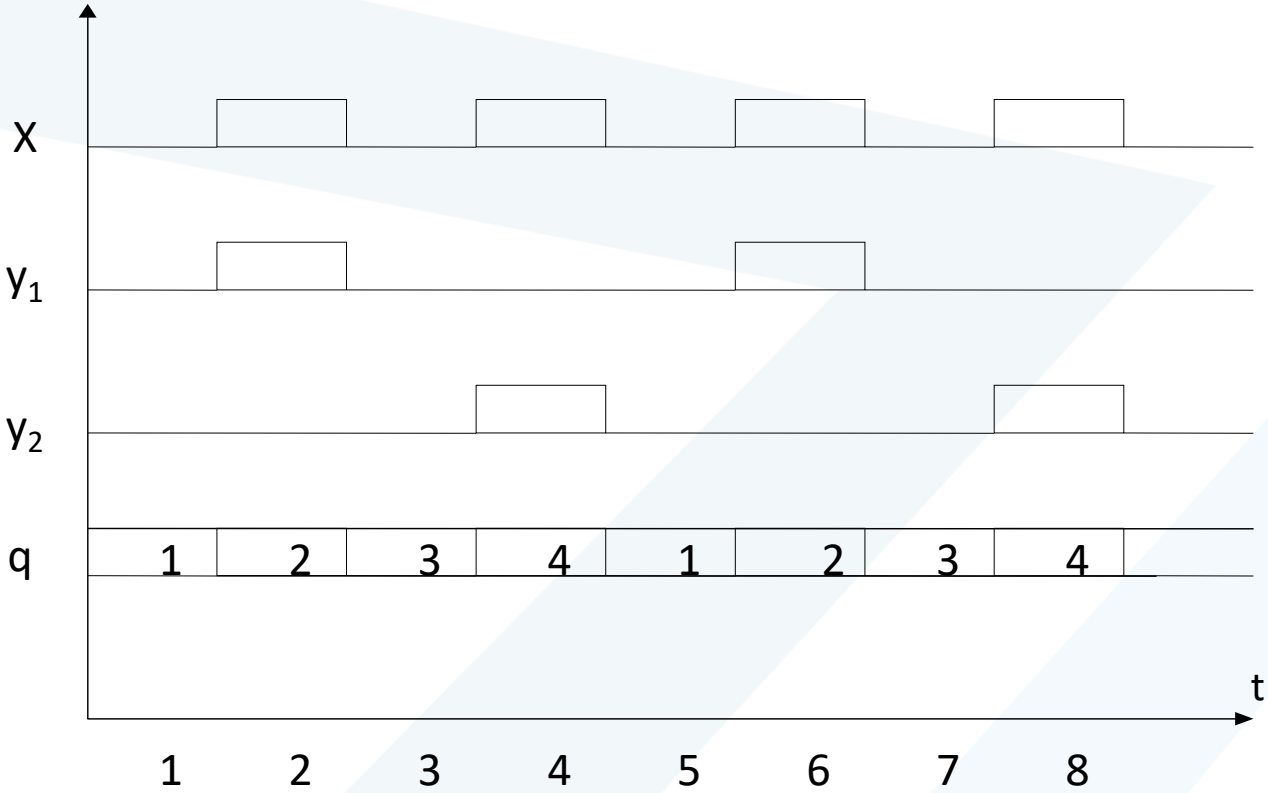
الوصف بواسطة تركيبات الدخل/الخرج



$$B = <^{1}(0/00),^{2}(1/10),^{3}(0/00),^{4}(1/01)>$$

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جدول سير العمل

$Q := F(Q,X)$
$Y := G(Q,X)$

^{t}Q	X	^{t+1}Q	Y
q_1	0	-	-
q_1	1	q_2	10
q_2	1	-	-
q_2	0	q_3	00
q_3	0	-	-
q_3	1	q_4	01
q_4	1	-	-
q_4	0	q_1	00

(a)

$Q := F(Q,X)$
$Y := G((Q,X),X)$
$F(Q,X) = F(F(Q,X),X)$

^{t}Q	X	^{t+1}Q	Y
q_1	0	q_1	00
q_1	1	q_2	-
q_2	1	q_2	10
q_2	0	q_3	-
q_3	0	q_3	00
q_3	1	q_4	-
q_4	1	q_4	01
q_4	0	q_1	-

(b)

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جداول الحالة

F(Q,X)		
Q \ X	0	1
q_1	-	q_2
q_2	q_3	-
q_3	-	q_4
q_4	q_1	-

(a)

F(Q,X)		
Q \ X	0	1
q_1	q_1	q_2
q_2	q_3	q_2
q_3	q_3	q_4
q_4	q_1	q_4

(b)

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جداول الحالة

G(Q,X)		
Q \ X	0	1
q_1	-	10
q_2	00	-
q_3	-	01
q_4	00	-

(c)

G(Q(Q,X),X)		
Q \ X	0	1
q_1	00	-
q_2	-	10
q_3	00	-
q_4	-	01

(d)

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جداول الحالة

F(Q,X)/G(Q,Z)		
Q \ X	0	1
q_1	-	$q_2/10$
q_2	$q_3/00$	-
q_3	-	$q_4/01$
q_4	$q_1/00$	-

(e)

F(Q,X)/G(F(G,X),X)		
Q \ X	0	1
q_1	$q_1/00$	q_2
q_2	q_3	$q_2/10$
q_3	$q_3/00$	q_4
q_4	q_1	$q_4/01$

(f)

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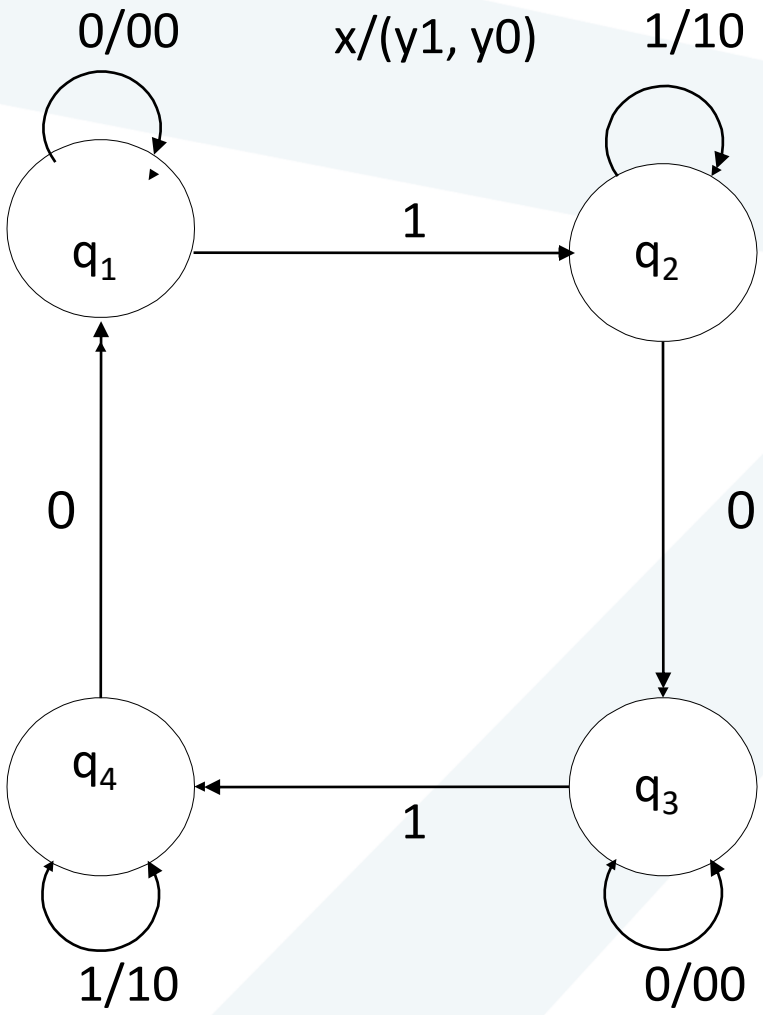
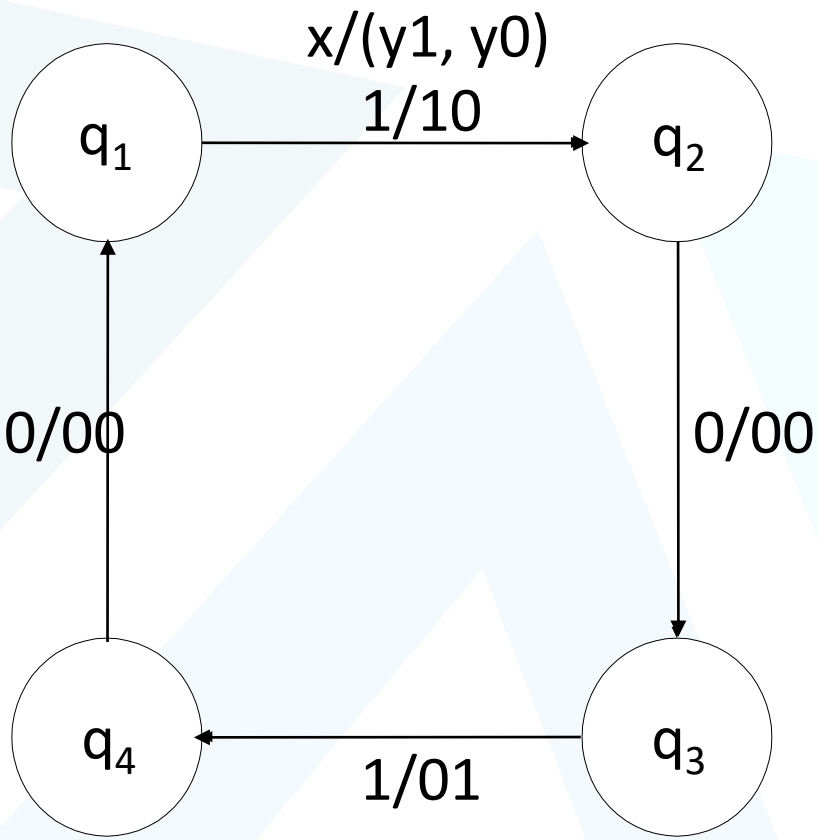
بيان أو مخطط الحالة





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القلابات Flip Flops

- القلاّب (Flip Flop) هو اصطلاح يُطلق على الأجهزة الإلكترونية التي لها حالتين مستقرتين على خرجها، وتبدل من حالة خرجها بالتعاكس وفقاً لإشارات دخل هذه الأجهزة.

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القلابات Flip Flops

- تستخدم القلابات بسبب خاصية استقرار حالتها في تخزين خانة ثنائية واحدة (BIT) حيث يكون بإمكانها الاحتفاظ بالرقم 1 أو 0 المنطقي على خرجها.

- والقلابات هي دارات تتابعية يرتبط خرجها بدخلها وبالحالة السابقة.
- هنالك أنواع متعددة من القلابات أساسها القلاب الذي يطلق عليه اسم قلاّب أو خازن (SR-Flip Flop or Latch) SR.

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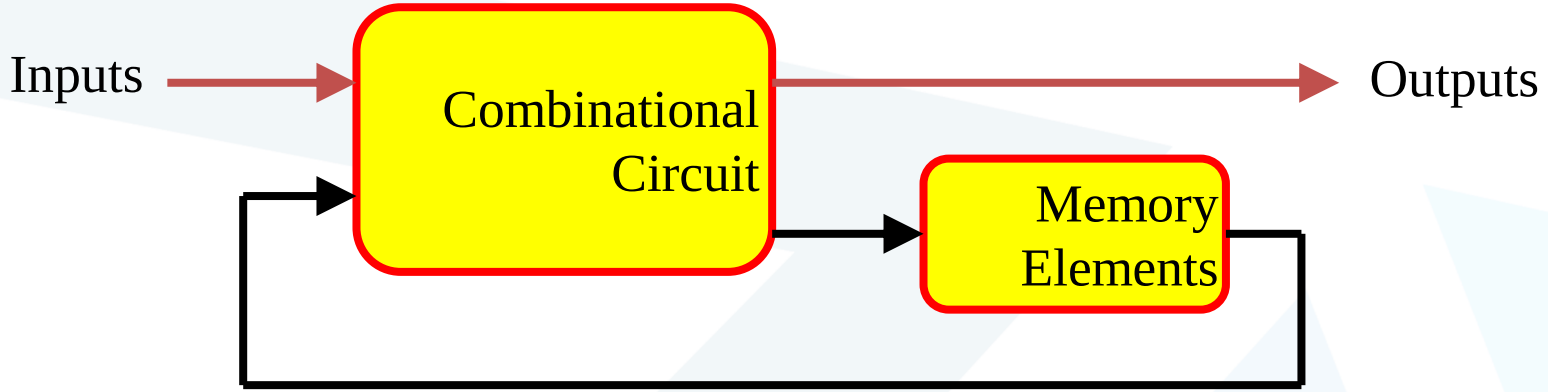
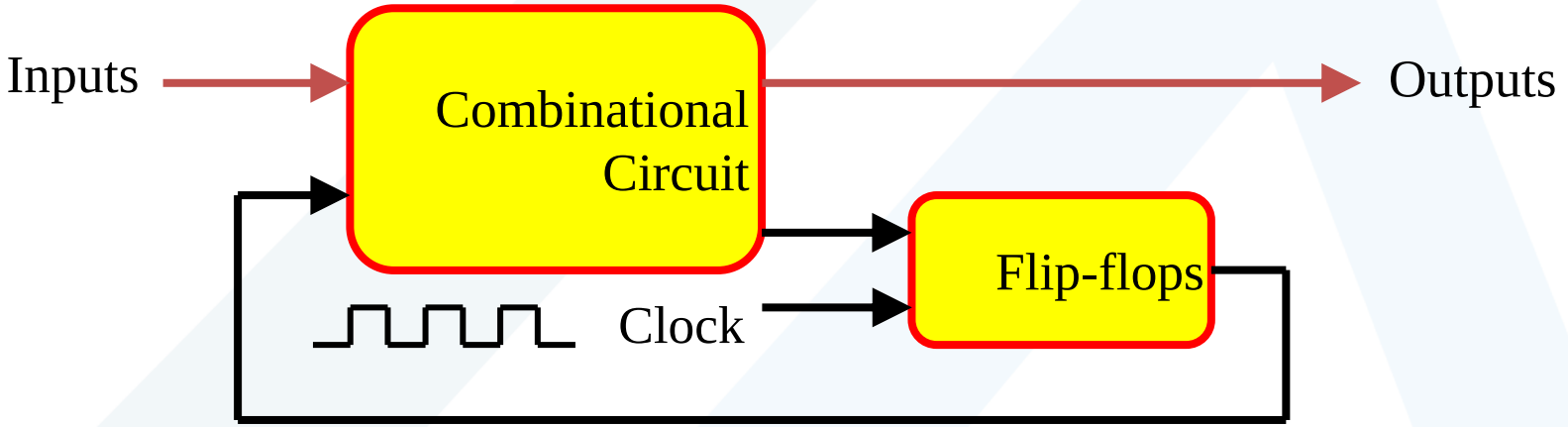
الدارات التتابعية المتواقتة وغير المتواقتة

- غير المتواقتة (غير المتزامنة) دون نبضات ساعة CLK



- المتواقتة (المتزامنة) تغيير الحالة مرتبط بنبضات الساعة Clock



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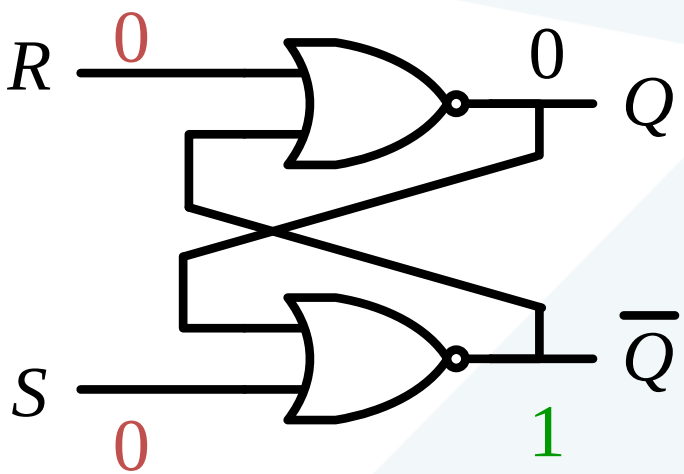
Latches الخوازن

- *SR* Latch خازن

S	R	Q_0	Q	Q'
0	0	0	0	1

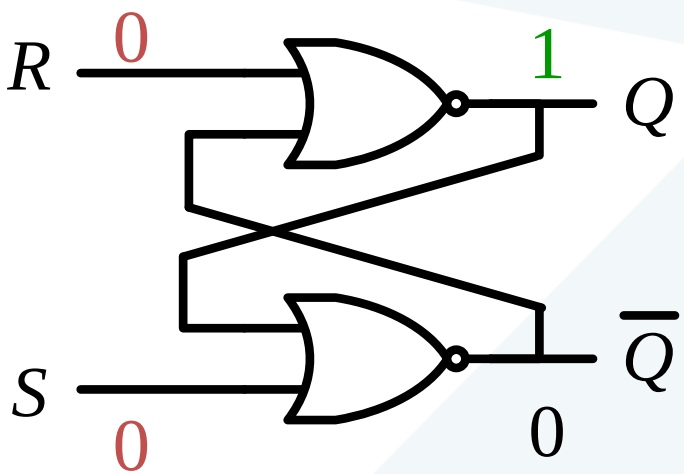
$Q = Q_0$



القيمة الأولية
Initial Value

Latches الخوازن

- *SR* Latch



S	R	Q_0	Q	Q'
0	0	0	0	1
0	0	1	1	0

$Q = Q_0$

$Q = Q_0$

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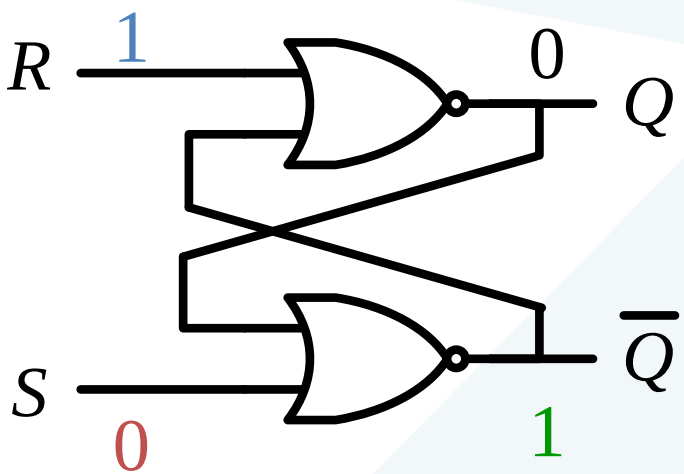
Latches الخوازن

- *SR* Latch



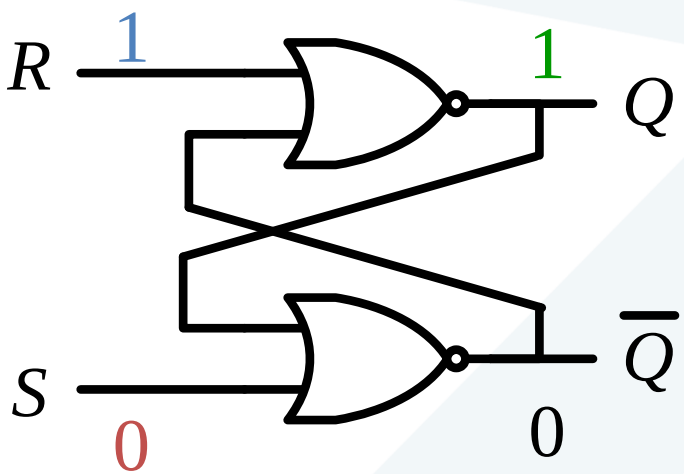
S	R	Q_0	Q	Q'
0	0	0	0	1
0	0	1	1	0
0	1	0	0	1

$Q = Q_0$

$Q = 0$

Latches الخوازن

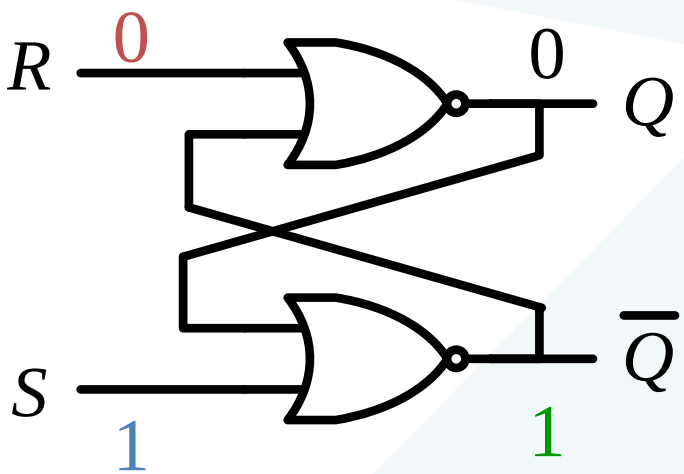
- *SR* Latch



S	R	Q_0	Q	Q'	
0	0	0	0	1	$Q = Q_0$
0	0	1	1	0	
0	1	0	0	1	$Q = 0$
0	1	1	0	1	$Q = 0$

Latches الخوازن

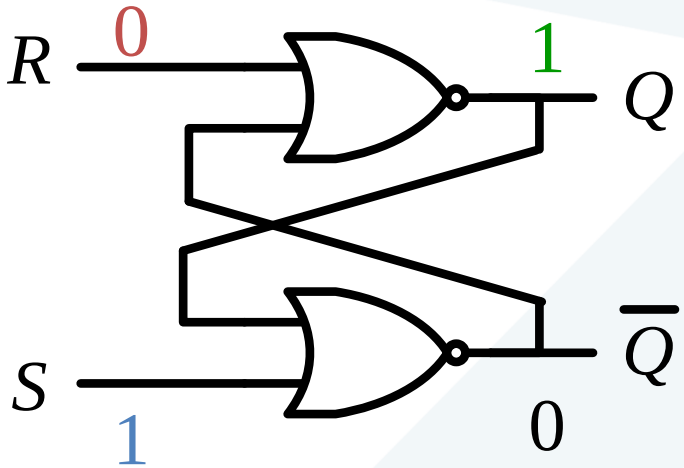
- *SR* Latch



S	R	Q_0	Q	Q'	
0	0	0	0	1	$Q = Q_0$
0	0	1	1	0	
0	1	0	0	1	$Q = 0$
0	1	1	0	1	
1	0	0	1	0	$Q = 1$

Latches الخوازن

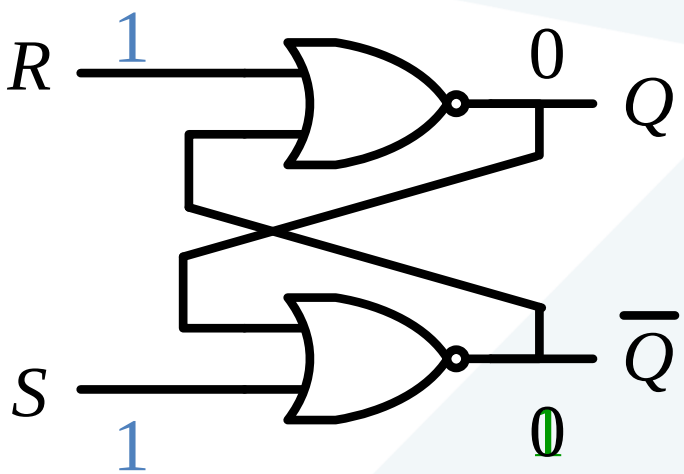
- *SR* Latch



S	R	Q_0	Q	$\overline{Q}$	
0	0	0	0	1	$Q = Q_0$
0	0	1	1	0	
0	1	0	0	1	$Q = 0$
0	1	1	0	1	
1	0	0	1	0	$Q = 1$
1	0	1	1	0	$Q = 1$

Latches الخوازن

- *SR* Latch



S	R	Q_0	Q	Q'	
0	0	0	0	1	$Q = Q_0$
0	0	1	1	0	
0	1	0	0	1	$Q = 0$
0	1	1	0	1	
1	0	0	1	0	$Q = 1$
1	0	1	1	0	
1	1	0	0	0	$Q = Q'$

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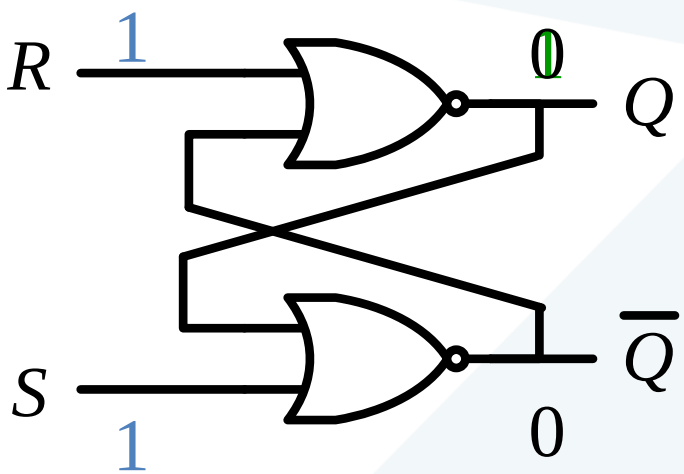
Latches الخوازن

- *SR* Latch



S	R	Q_0	Q	Q'	
0	0	0	0	1	$Q = Q_0$
0	0	1	1	0	
0	1	0	0	1	$Q = 0$
0	1	1	0	1	
1	0	0	1	0	$Q = 1$
1	0	1	1	0	
1	1	0	0	0	$Q = Q'$
1	1	1	0	0	$Q = Q'$

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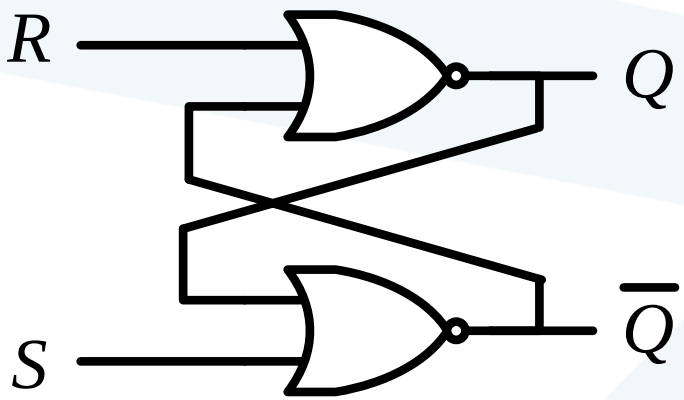
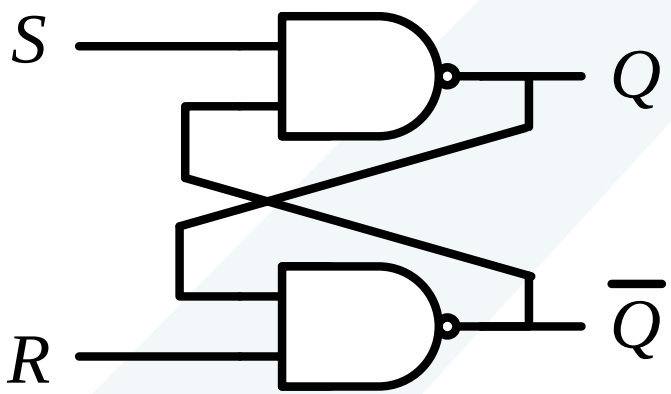
Latches الخوازن

- *SR* Latch



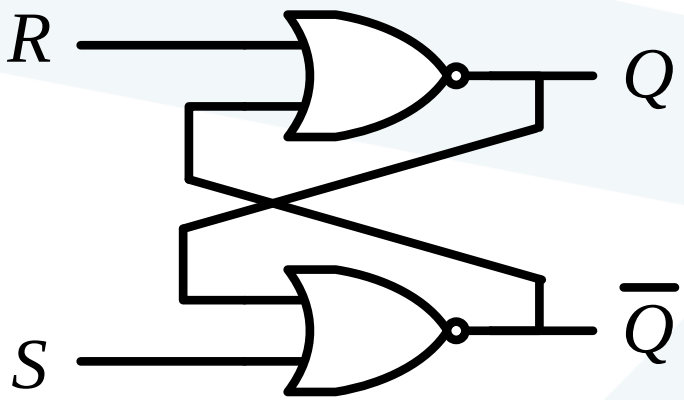
S	R	Q	
0	0	Q_0	No change
0	1	0	Reset
1	0	1	Set
1	1	$Q=Q'=0$	Invalid



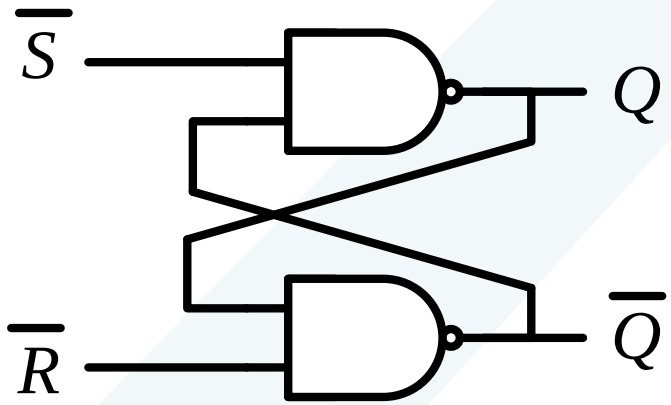
S	R	Q	
0	0	$Q=Q'=1$	Invalid
0	1	1	Set
1	0	0	Reset
1	1	Q_0	No change

Latches الخوازن

- *SR* Latch



S R	Q	
0 0	Q_0	No change
0 1	0	Reset
1 0	1	Set
1 1	$Q=Q'=0$	Invalid



S' R'	Q	
0 0	$Q=Q'=1$	Invalid
0 1	1	Set
1 0	0	Reset
1 1	Q_0	No change

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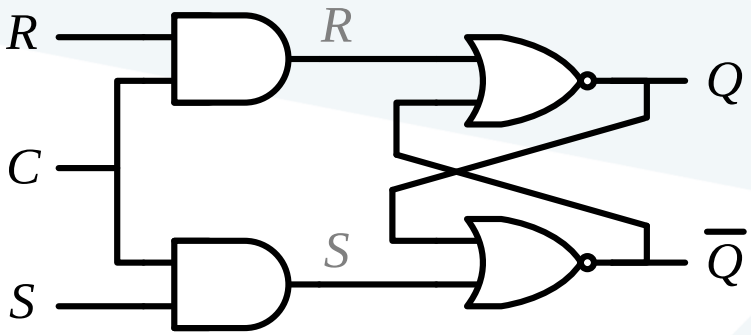
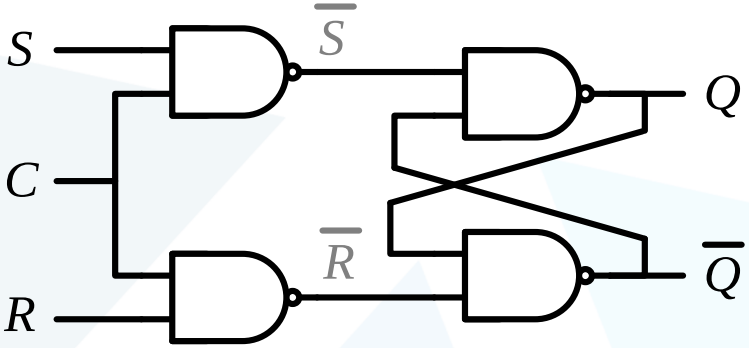
Controlled Latches الخوازن المتحكم بها

- *SR* Latch with Control Input





C S R	Q	
0 x x	Q_0	No change
1 0 0	Q_0	No change
1 0 1	0	Reset
1 1 0	1	Set
1 1 1	$Q=Q'$	Invalid

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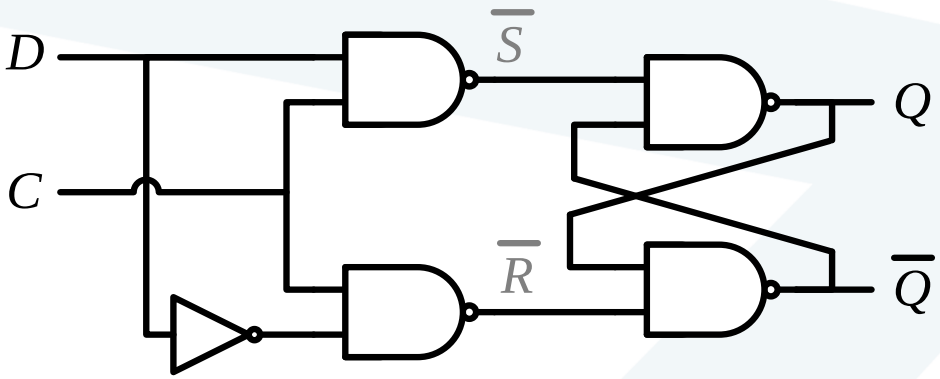
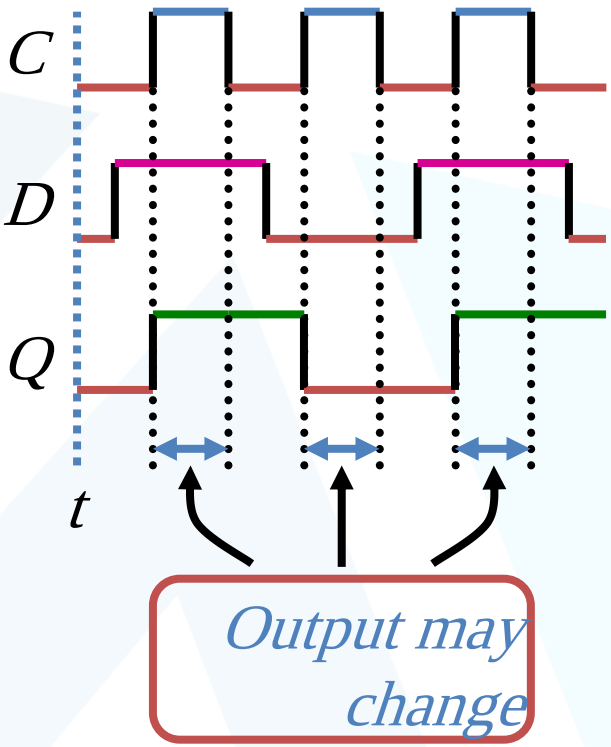
Controlled Latches الخوازن المتحكم بها

- *D* Latch (*D* = *Data*)



Timing Diagram



C D	Q	
0 x	Q_0	No change
1 0	0	Reset
1 1	1	Set

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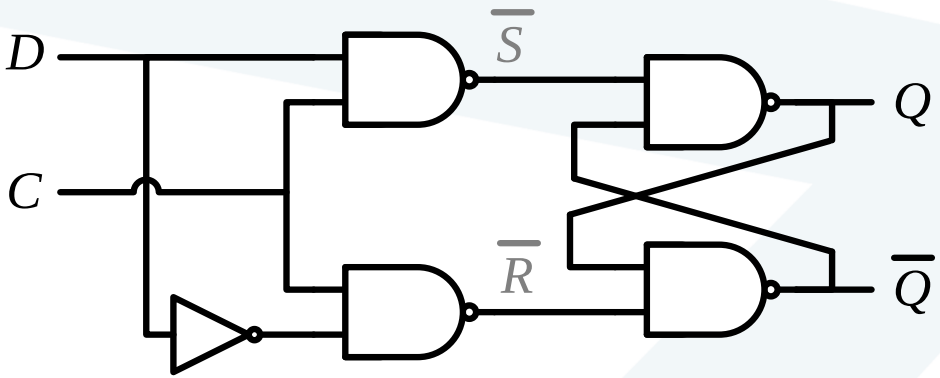
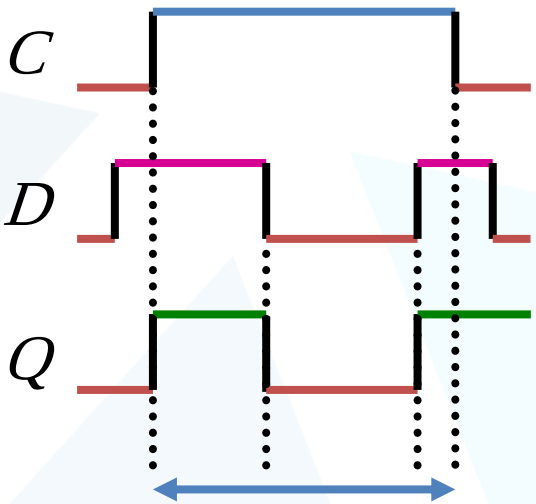
Controlled Latches الخوازن المتحكم بها

- *D* Latch (*D* = *Data*)



Timing Diagram



Output may change

C D	Q	
0 x	Q_0	No change
1 0	0	Reset
1 1	1	Set

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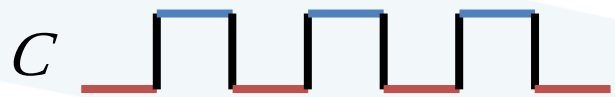
Flip-Flops القلابات

- تعمل الخوازن المتحكم بها عادةً بقدح المستوي level-triggered



- تعمل القلابات بقدح الحافة edge-triggered

حافة موجبة
Positive Edge

حافة سالبة
Negative Edge

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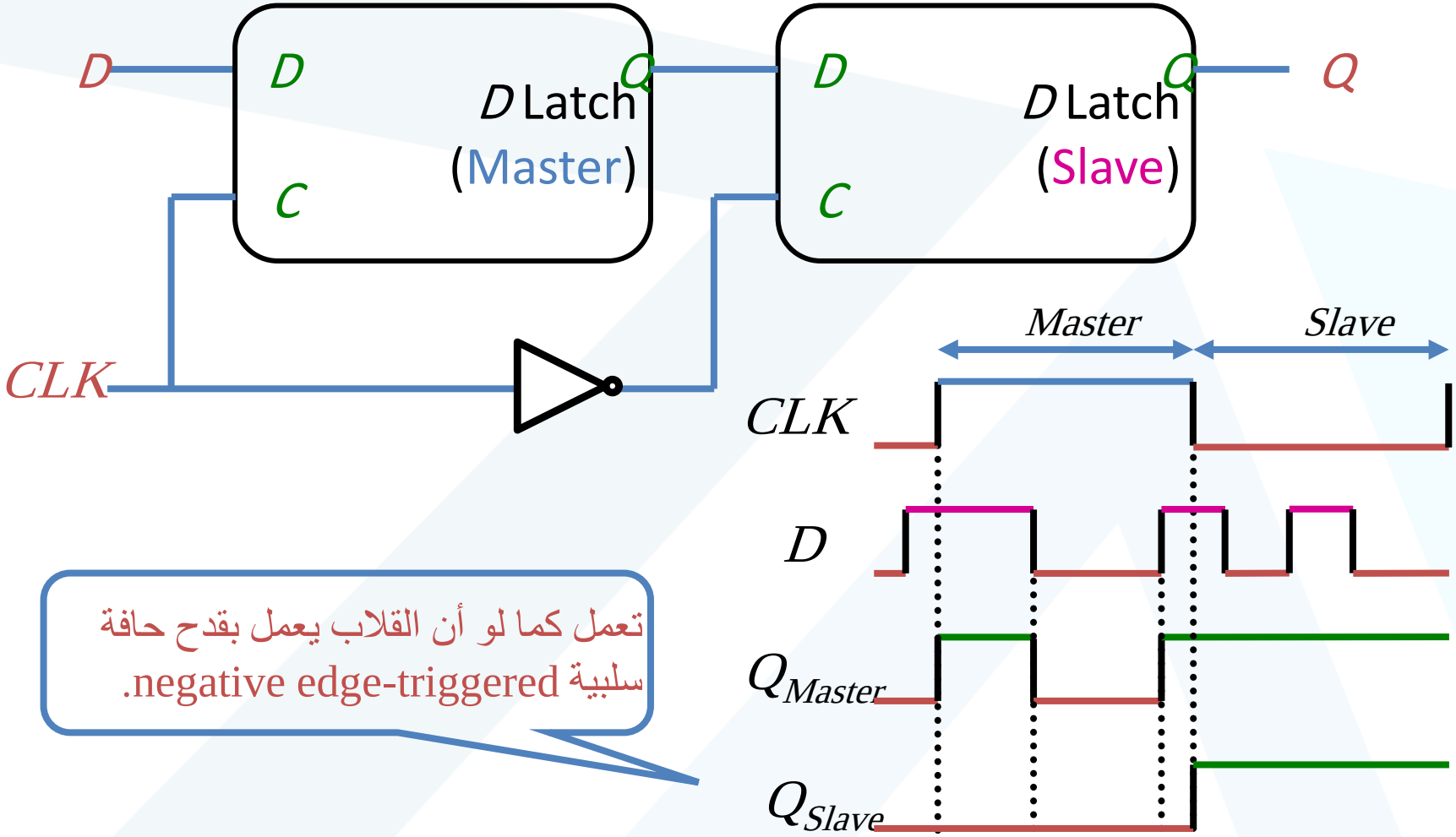
Flip-Flops القلابات

- قلاب D السيد الخادم Master-Slave *D* Flip-Flop

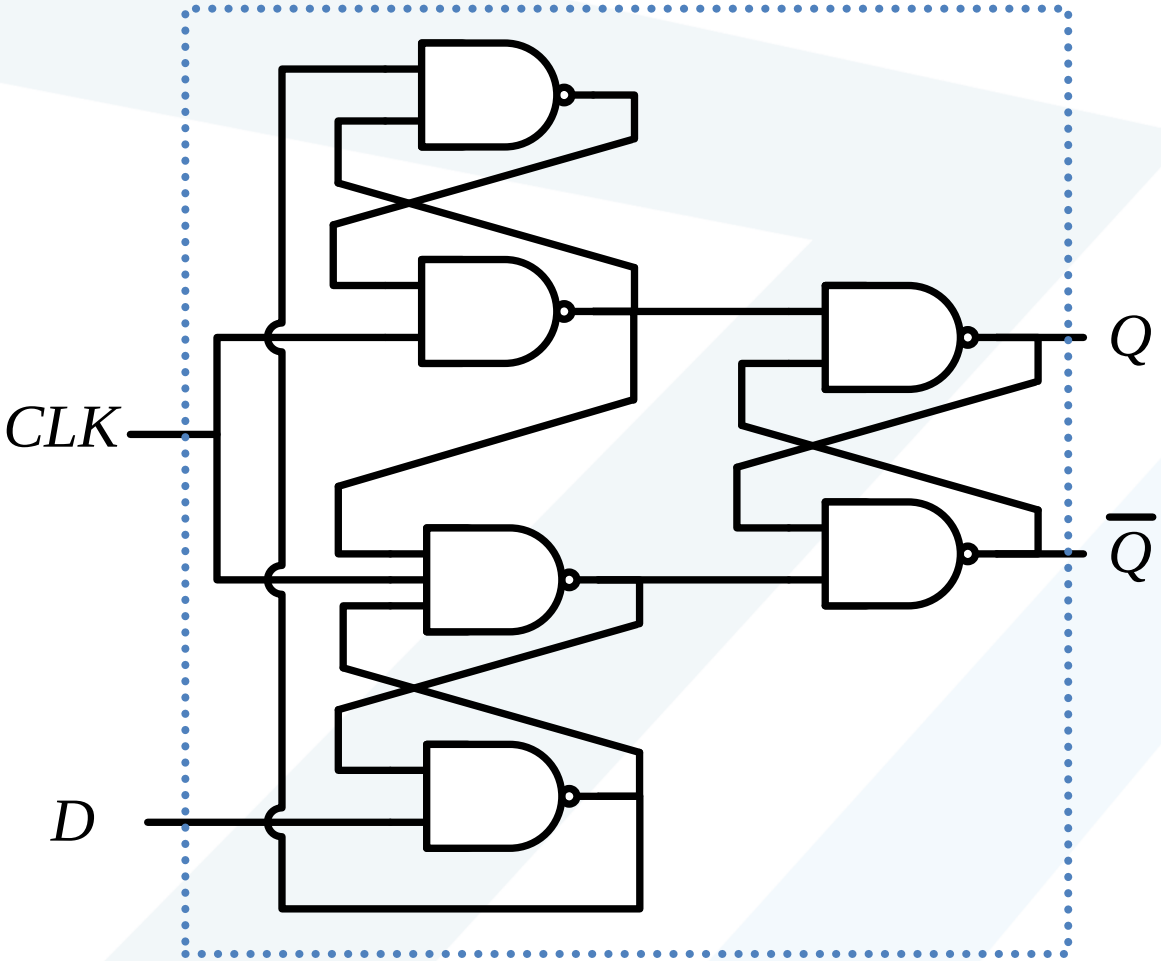


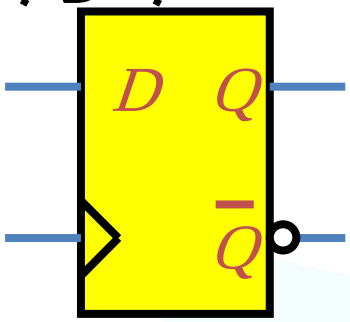
تعمل كما لو أن القلاب يعمل بقدح حافة سلبية negative edge-triggered.

Flip-Flops القلابات

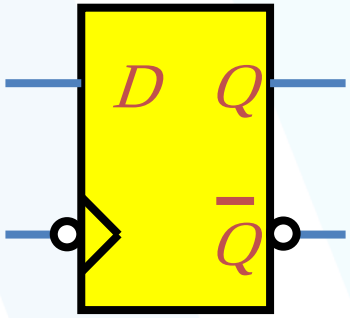
Edge-Triggered *D* Flip-Flop

- قلاب D بقدح الحافة





Positive Edge



Negative Edge

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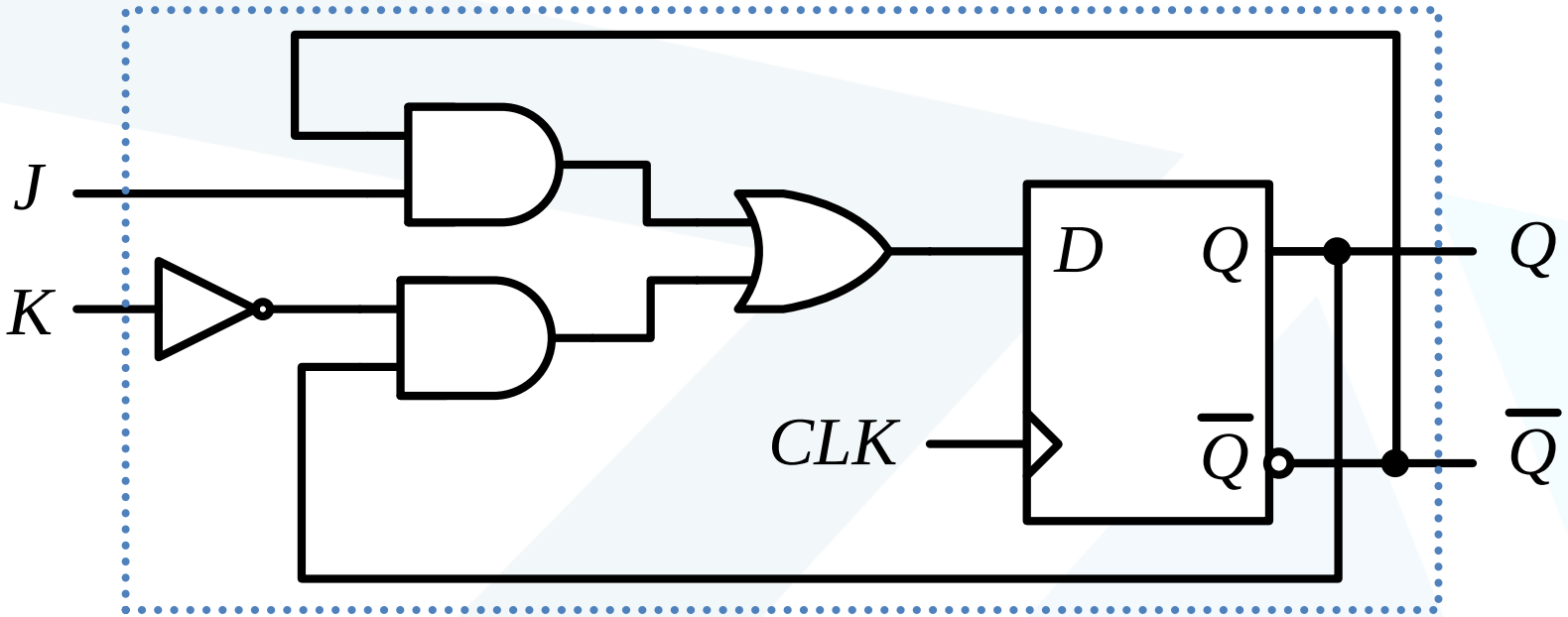
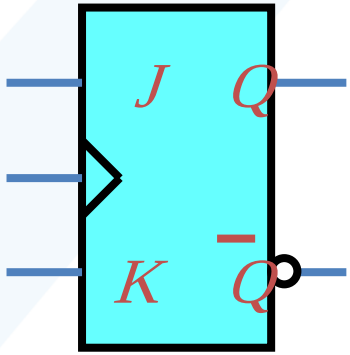
Flip-Flops القلابات

- *JK* Flip-Flop



$$D = JQ' + K'Q$$



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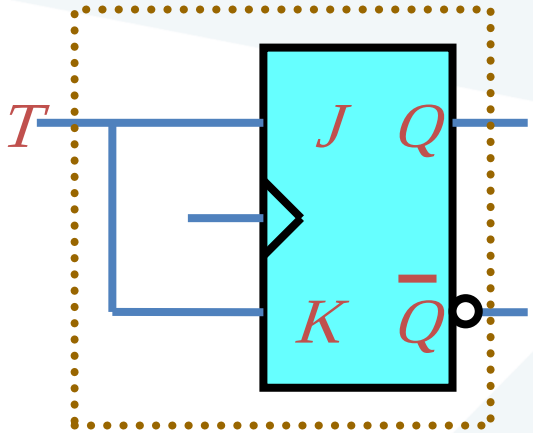
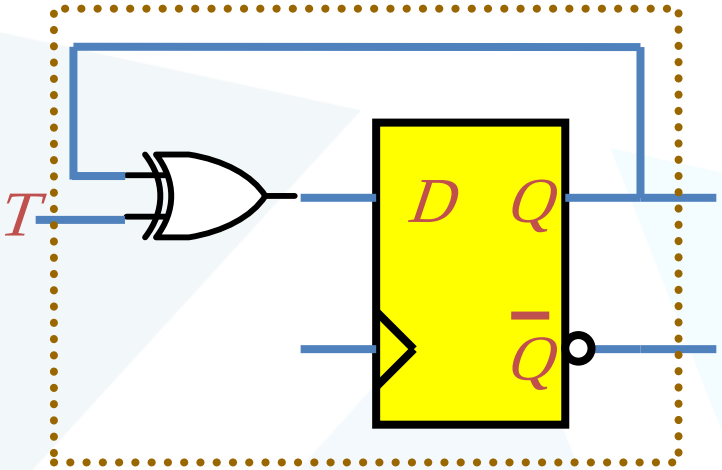
Flip-Flops القلابات

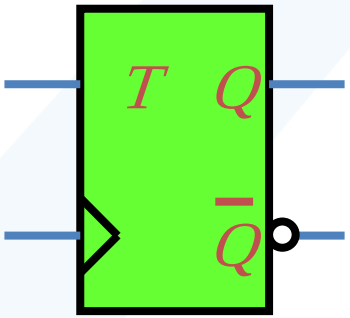
- *T* Flip-Flop





$$D = JQ' + K'Q$$

$$D = TQ' + T'Q = T \oplus Q$$



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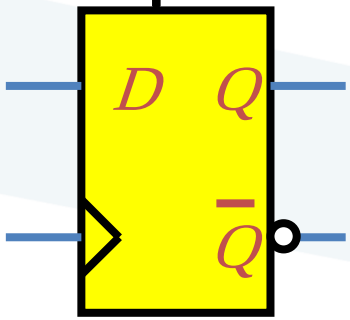
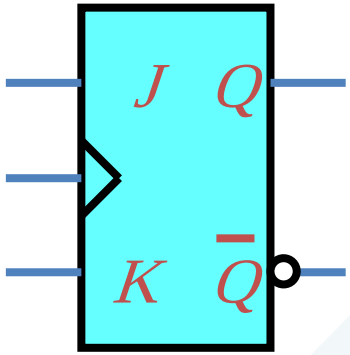
جداول خصائص القلابات

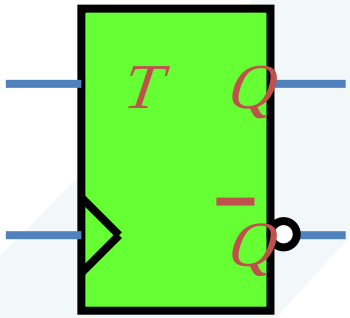
Flip-Flop Characteristic Tables



D	$Q(t+1)$	
0	0	Reset
1	1	Set



J	K	$Q(t+1)$	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$\overline{Q}(t)$	Toggle



T	$Q(t+1)$	
0	$Q(t)$	No change
1	$\overline{Q}(t)$	Toggle

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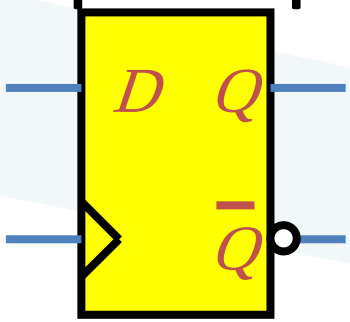
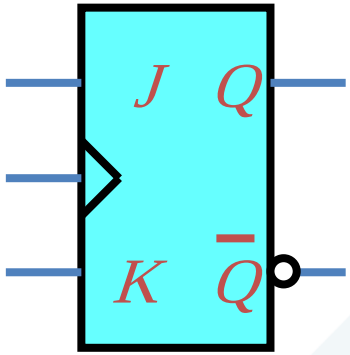
معادلات خصائص القلابات

Flip-Flop Characteristic Equations



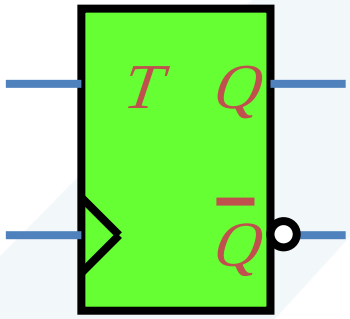
D	$Q(t+1)$
0	0
1	1

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



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

$$Q(t+1) = J\,\bar{Q} + K\,\bar{Q}$$



T	$Q(t+1)$
0	$Q(t)$
1	$\bar{Q}(t)$

$$Q(t+1) = T \oplus Q$$

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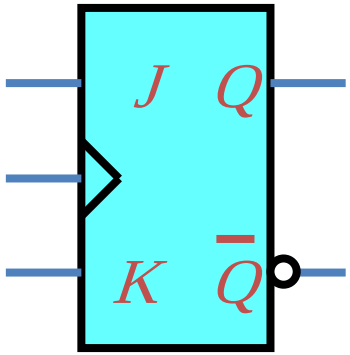
معادلات خصائص القلابات

Flip-Flop Characteristic Equations

- Analysis / Derivation



J	K	$Q(t)$	$Q(t+1)$
0	0	0	0
0	0	1	1
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

No change

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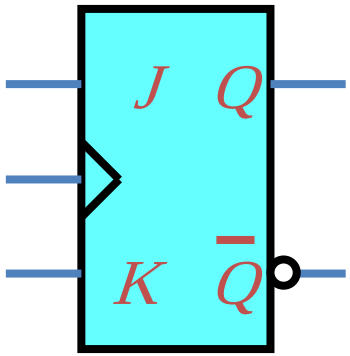
معادلات خصائص القلابات

Flip-Flop Characteristic Equations

- Analysis / Derivation



J	K	$Q(t)$	$Q(t+1)$	
0	0	0	0	No change
0	0	1	1	
0	1	0	0	Reset
0	1	1	0	
1	0	0		
1	0	1		
1	1	0		Tog
1	1	1		

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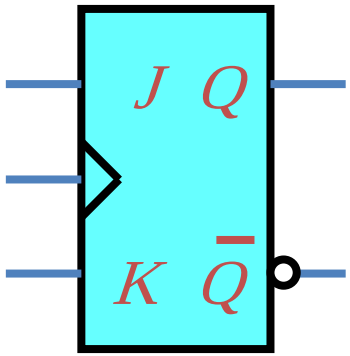
معادلات خصائص القلابات

Flip-Flop Characteristic Equations

- Analysis / Derivation



J	K	$Q(t)$	$Q(t+1)$	
0	0	0	0	No change
0	0	1	1	
0	1	0	0	Reset
0	1	1	0	
1	0	0	1	Set
1	0	1	1	
1	1	0		Tog
1	1	1		

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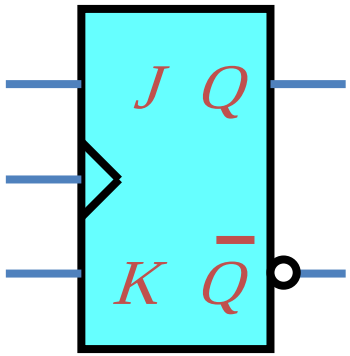
معادلات خصائص القلابات

Flip-Flop Characteristic Equations

- Analysis / Derivation



J	K	$Q(t)$	$Q(t+1)$	
0	0	0	0	No change
0	0	1	1	
0	1	0	0	Reset
0	1	1	0	
1	0	0	1	Set
1	0	1	1	
1	1	0	1	Toggle
1	1	1	0	

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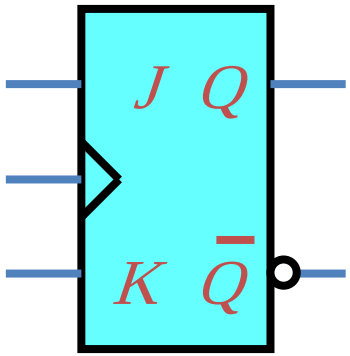
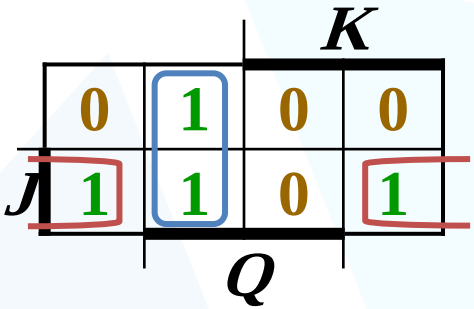
معادلات خصائص القلابات

Flip-Flop Characteristic Equations

- التحليل /الاشتقاق Analysis / Derivation



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



$$Q(t+1) = J\,\bar{Q} + \bar{K}Q$$

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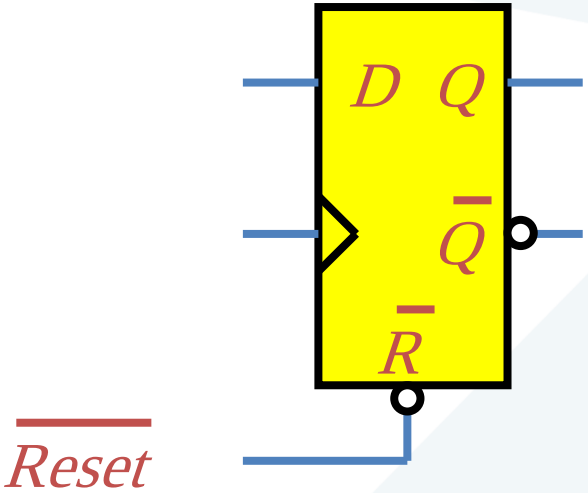
القلابات ذات الدخل المباشر

- التصفير غير المتزامن Asynchronous Reset



R'	D	CLK	$Q(t+1)$
0	x	x	0

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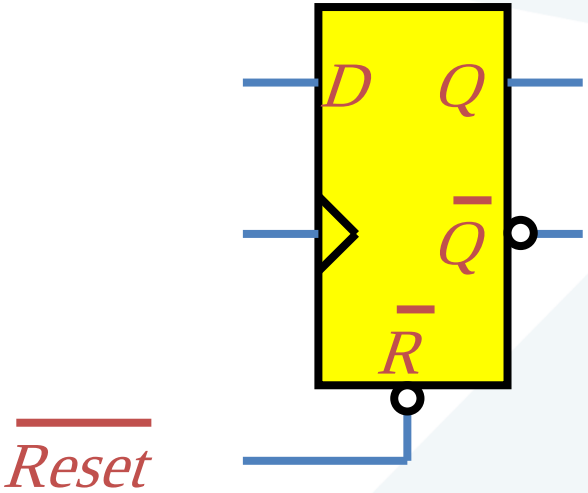
القلابات ذات الدخل المباشر

- التصفير غير المتزامن Asynchronous Reset



R'	D	CLK	$Q(t+1)$
0	x	x	0
1	0	↑	0
1	1	↑	1

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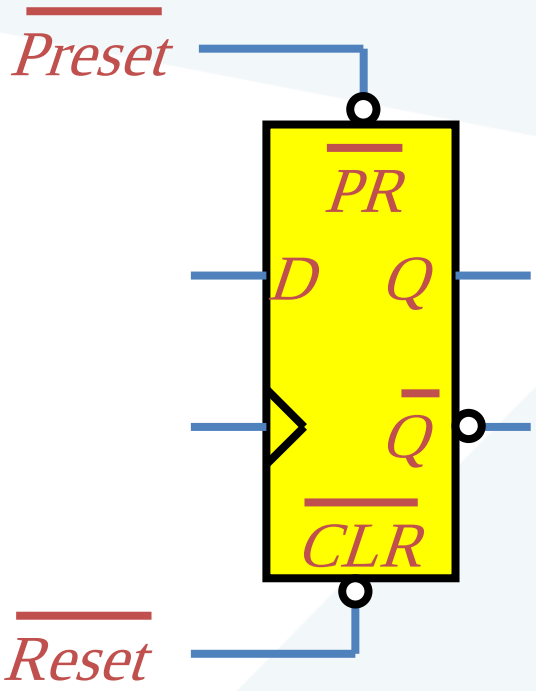
القلابات ذات الدخل المباشر

- وضع 1 قسرياً أو التصفير غير المتزامن Asynchronous Preset and Clear



PR'	CLR'	D	CLK	Q(t+1)
1	0	x	x	0

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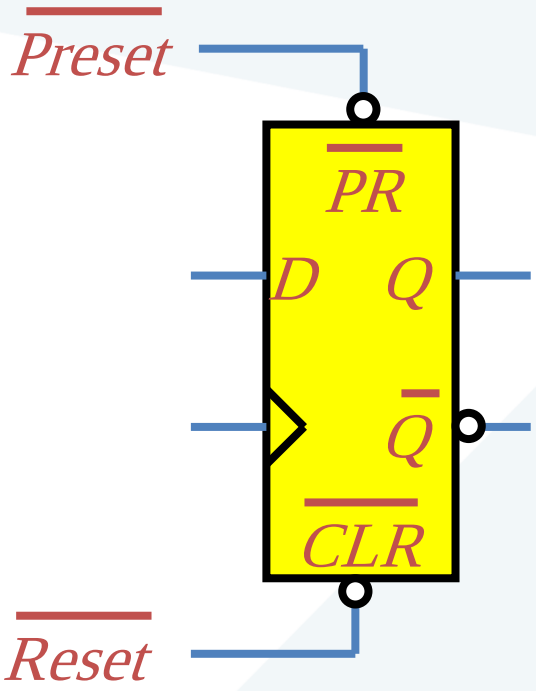
القلابات ذات الدخل المباشر

- وضع 1 قسرياً أو التصفير غير المتزامن Asynchronous Preset and Clear



PR'	CLR'	D	CLK	Q(t+1)
1	0	x	x	0
0	1	x	x	1

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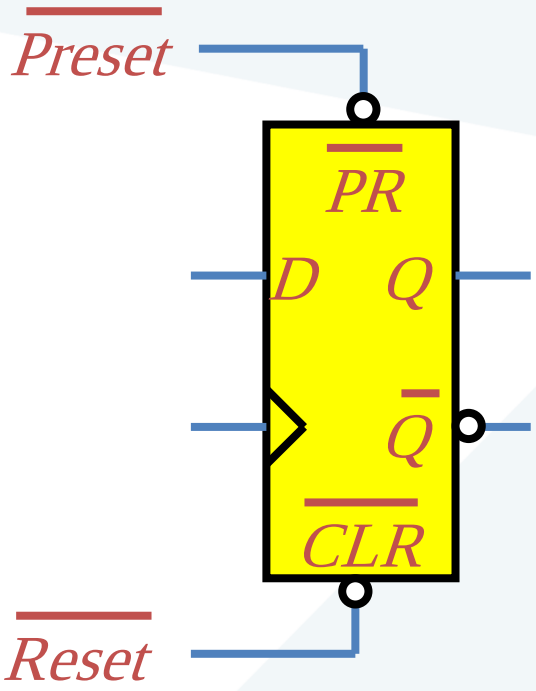
القلابات ذات الدخل المباشر

- وضع 1 قسرياً أو التصفير غير المتزامن Asynchronous Preset and Clear



PR'	CLR'	D	CLK	Q(t+1)
1	0	x	x	0
0	1	x	x	1
1	1	0	↑	0
1	1	1	↑	1

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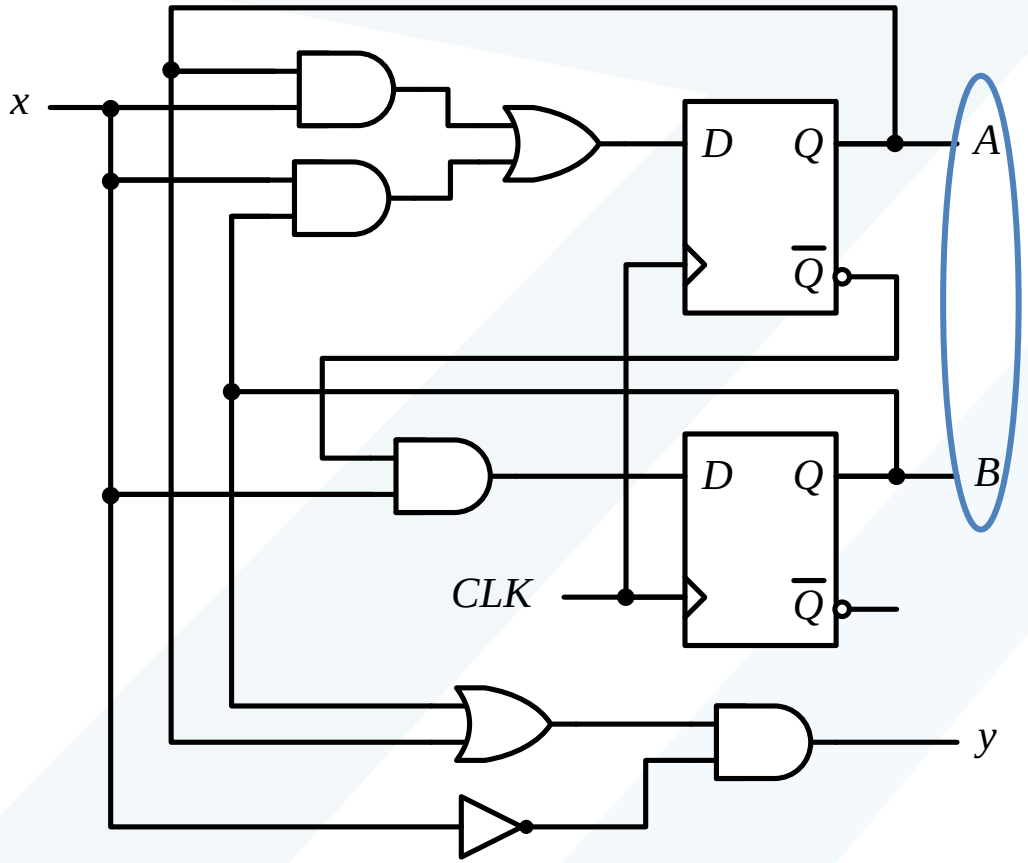
تحليل الدارات التتابعية المتواقتة

- الحالة
  - الحالة = قيم جميع القلابات



مثال

$A\ B = 0\ 0$

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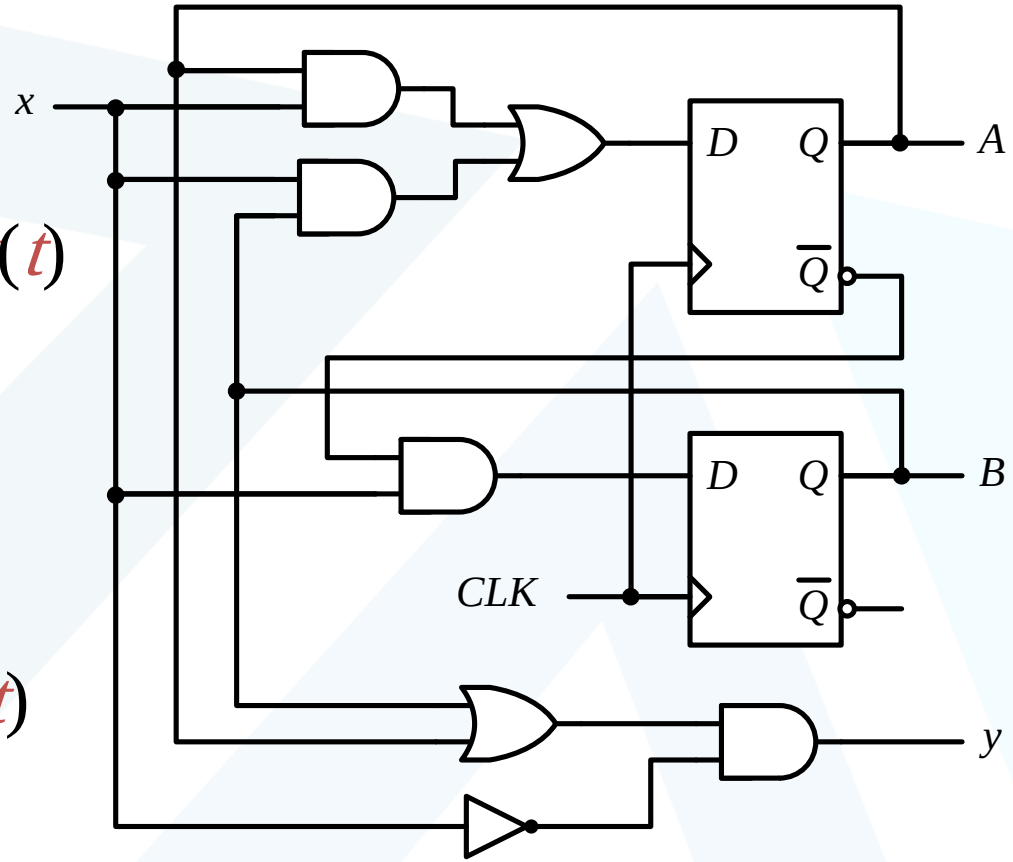
تحليل الدارات التتابعية المتواقتة

- معادلات الحالة State Equations

$$A(t+1) = D_A$$
$$= A(t)\,x(t) + B(t)\,x(t)$$
$$= A\,x + B\,x$$
$$B(t+1) = D_B$$
$$= A'(t)\,x(t)$$
$$= A'\,x$$
$$y(t) = [A(t) + B(t)]\,x'(t)$$
$$= (A + B)\,x'$$



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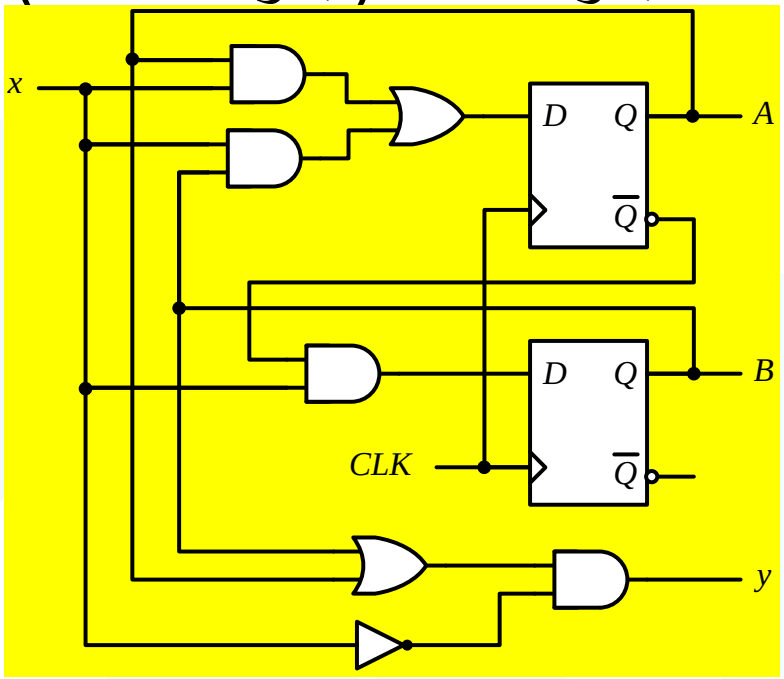
تحليل الدارات التتابعية المتواقتة

- جدول الحالة (جدول الانتقال) State Table (Transition Table)

Present State		Input	Next State		Output
A	B	x	A	B	y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

t $t+1$ t



$$A(t+1) = A\,x + B\,x$$
$$B(t+1) = A'\,x$$
$$y(t) = (A + B)\,x'$$

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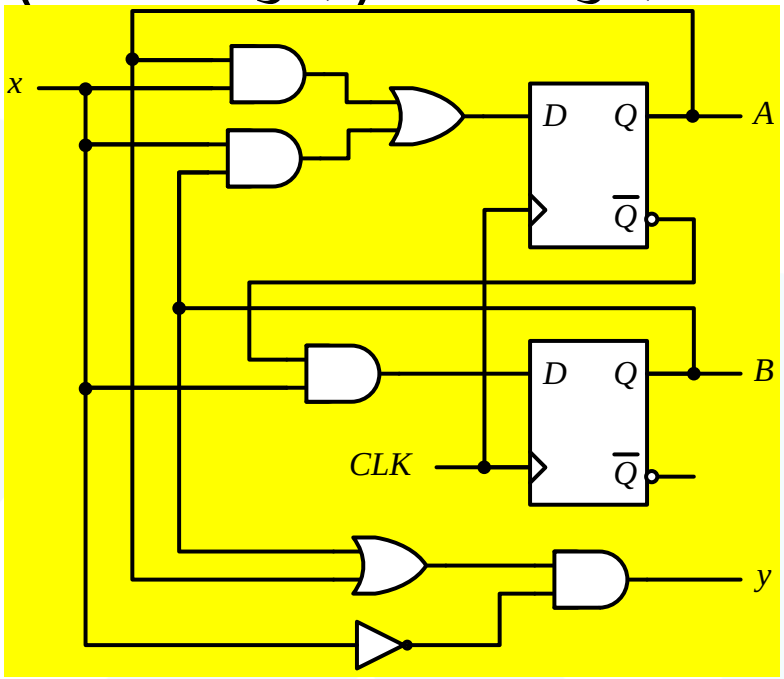
تحليل الدارات التتابعية المتواقتة

- جدول الحالة (جدول الانتقال) State Table (Transition Table)

Present State	Next State				Output	
	$x = 0$		$x = 1$		$x = 0$	$x = 1$
A B	A	B	A	B	y	y
0 0	0	0	0	1	0	0
0 1	0	0	1	1	1	0
1 0	0	0	1	0	1	0
1 1	0	0	1	0	1	0

t $t+1$ t



$$A(t+1) = A\,x + B\,x$$
$$B(t+1) = A'\,x$$
$$y(t) = (A + B)\,x'$$

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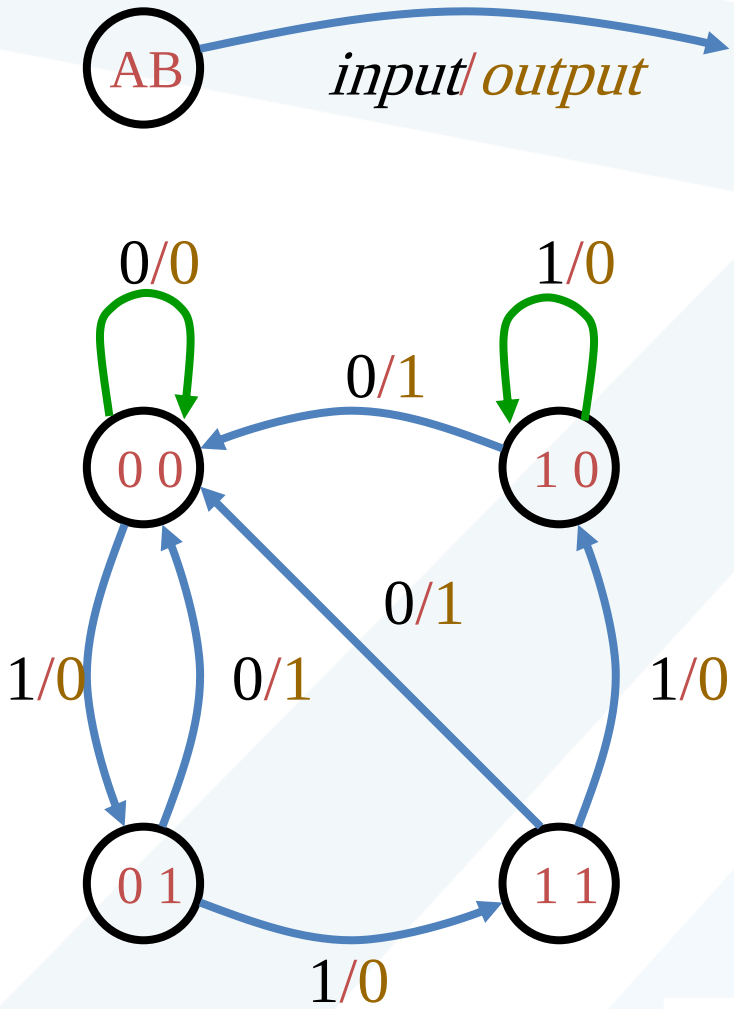
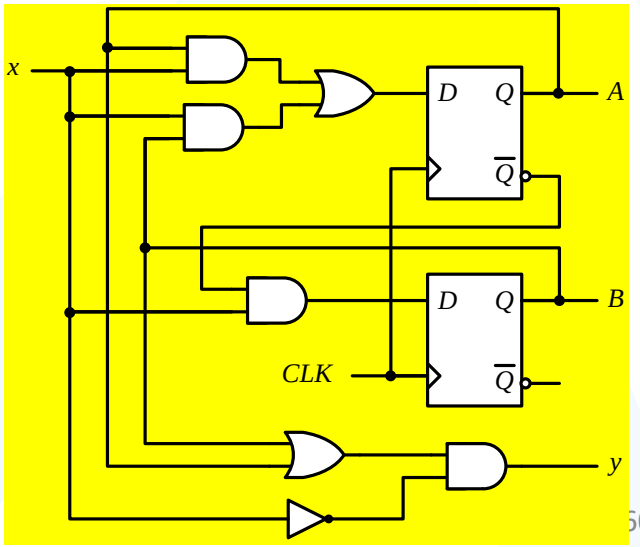
تحليل الدارات التتابعية المتواقتة

State Diagram مخطط الحالة

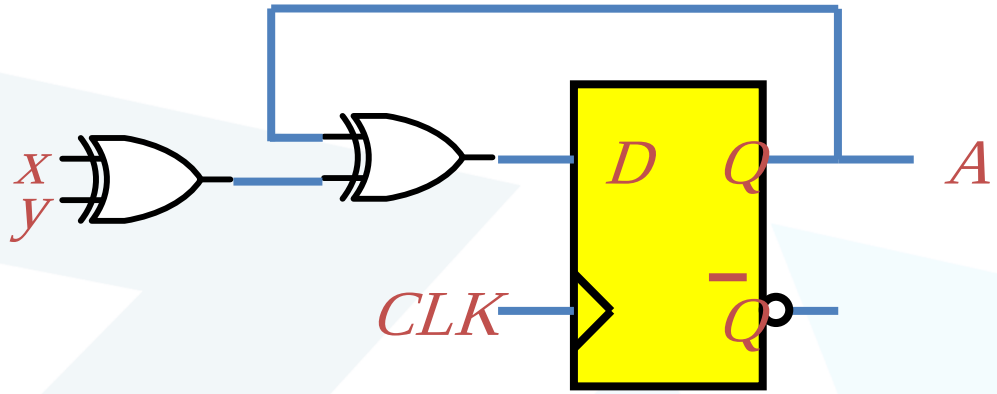


Present State	Next State				Output	
	$x = 0$		$x = 1$		$x = 0$	$x = 1$
A B	A	B	A	B	y	y
0 0	0	0	0	1	0	0
0 1	0	0	1	1	1	0
1 0	0	0	1	0	1	0
1 1	0	0	1	0	1	0



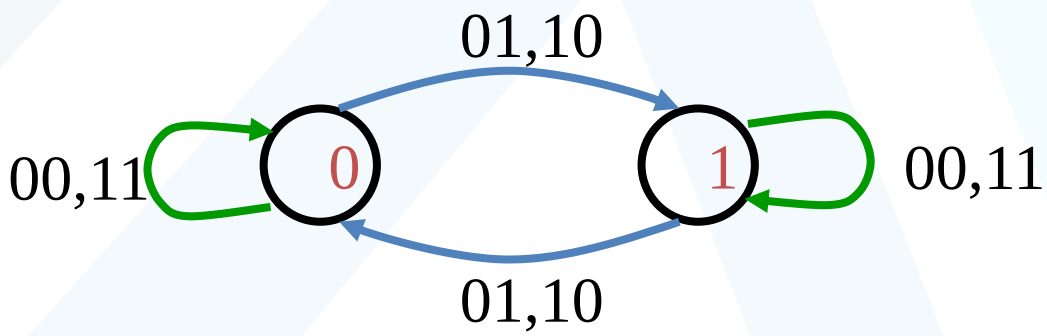
تحليل الدارات التتابعية المتواقتة

- مثال: *D* Flip-Flops



Present State	Input		Next State
A	x	y	A
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

$$A(t+1) = D_A = A \oplus x \oplus y$$



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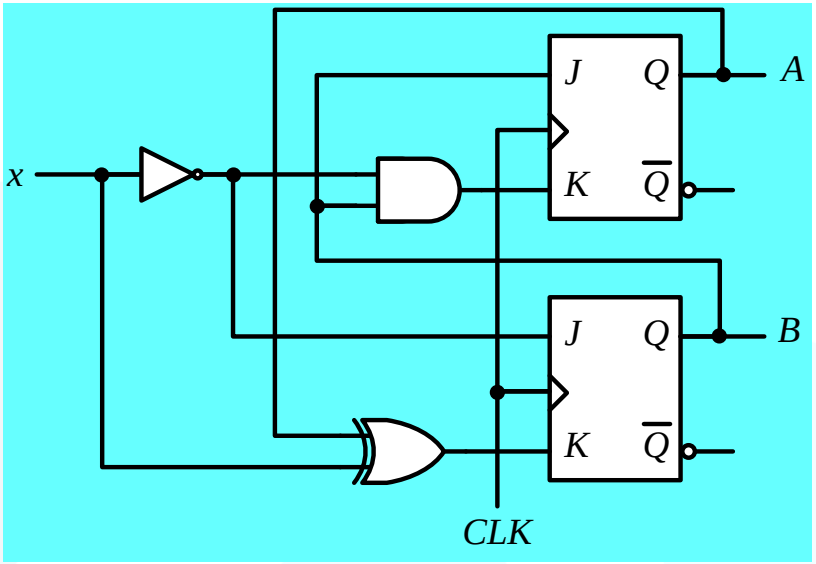
تحليل الدارات التتابعية المتواقتة

مثال: *JK* Flip-Flops



Present State		I/P	Next State		Flip-Flop Inputs			
A	B	x	A	B	J_A	K_A	J_B	K_B
0	0	0	0	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0

$K_A = B\,x'$ $\qquad J_A = B$

$K_B = A \oplus x$ $\qquad J_B = x'$

$$A(t+1) = J_A Q'_A + K'_A Q_A$$
$$= A'B + AB' + Ax$$

$$B(t+1) = J_B Q'_B + K'_B Q_B$$
$$= B'x' + ABx + A'Bx'$$

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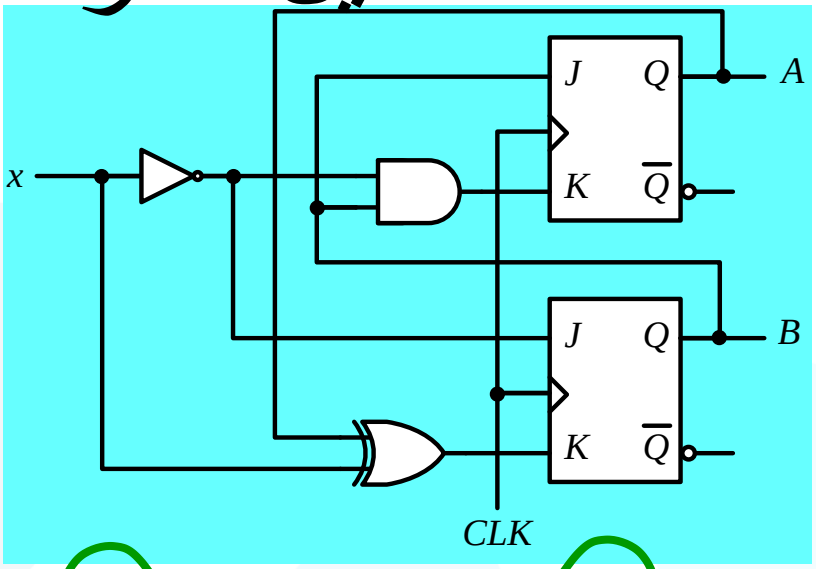
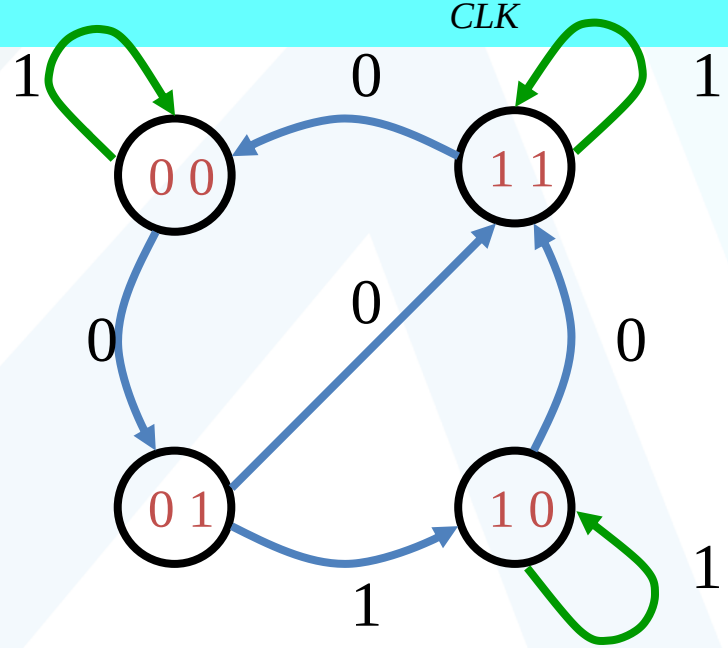
تحليل الدارات التتابعية المتواقتة

مثال: *JK* Flip-Flops



Present State		I/P	Next State		Flip-Flop Inputs			
A	B	x	A	B	J_A	K_A	J_B	K_B
0	0	0	0	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0



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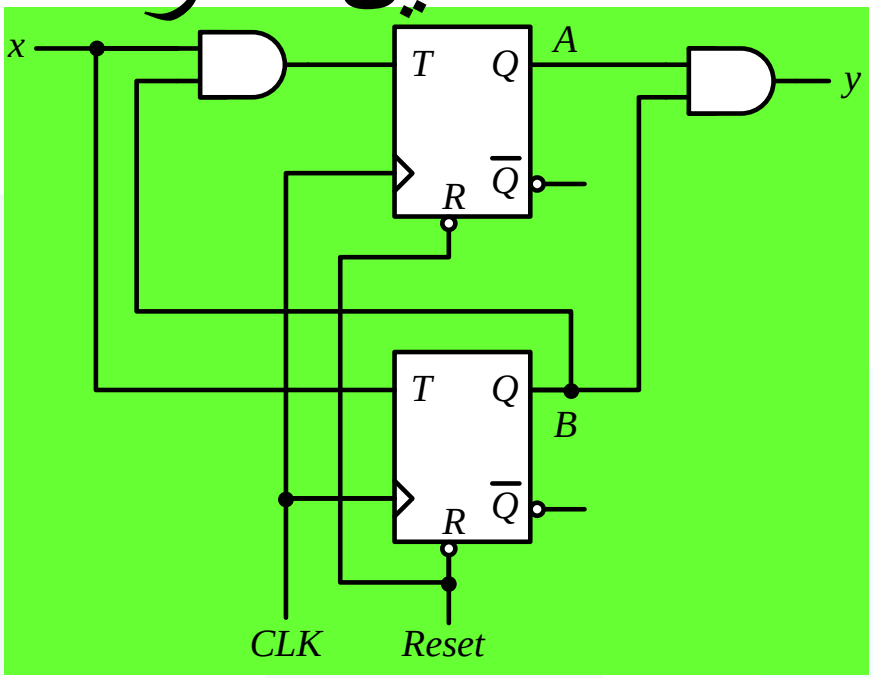
تحليل الدارات التتابعية المتواقتة

مثال: *T* Flip-Flops



Present State		I/P	Next State		F.F Inputs		O/P
A	B	x	A	B	T_A	T_B	y
0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0
0	1	0	0	1	0	0	0
0	1	1	1	0	1	1	0
1	0	0	1	0	0	0	0
1	0	1	1	1	0	1	0
1	1	0	1	1	0	0	1
1	1	1	0	0	1	1	1

$$T_B = x \qquad T_A = B\,x$$

$$y = A\,B$$

$$A(t+1) = T_A Q'_A + T'_A Q_A$$
$$= AB' + Ax' + A'Bx$$

$$B(t+1) = T_B Q'_B + T'_B Q_B$$
$$= x \oplus B$$

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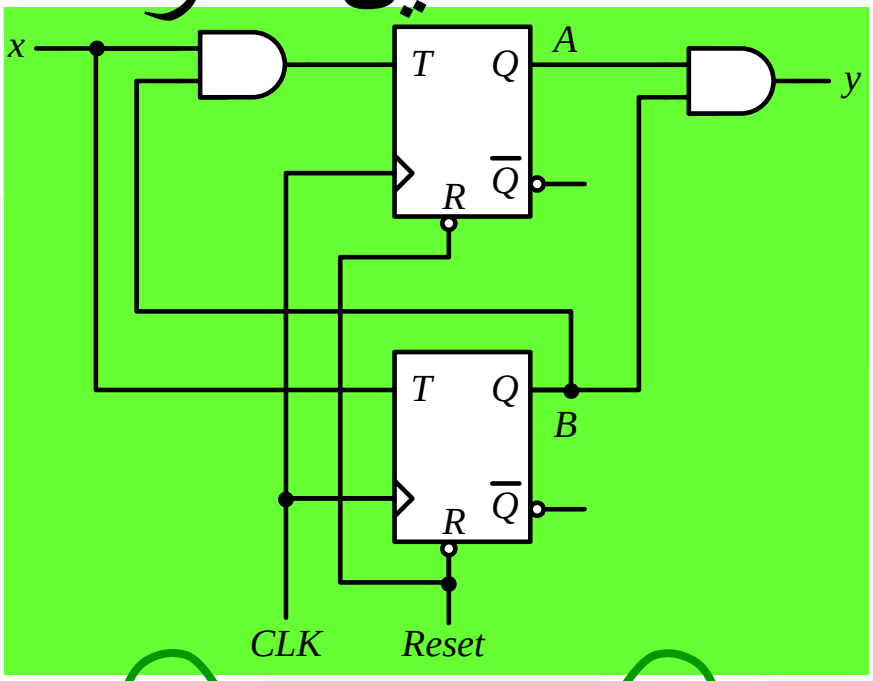
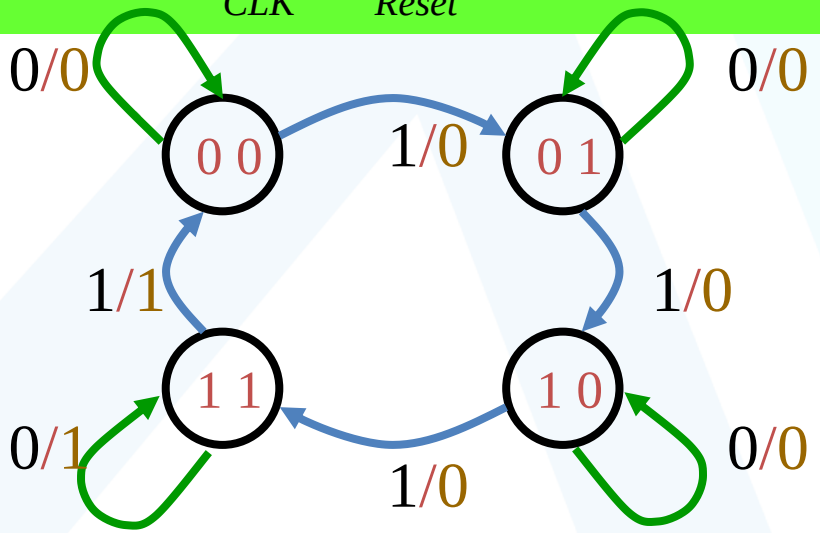
تحليل الدارات التتابعية المتواقتة

مثال: *T* Flip-Flops

Present State		I/P	Next State		F.F Inputs		O/P
A	B	x	A	B	T_A	T_B	y
0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0
0	1	0	0	1	0	0	0
0	1	1	1	0	1	1	0
1	0	0	1	0	0	0	0
1	0	1	1	1	0	1	0
1	1	0	1	1	0	0	1
1	1	1	0	0	1	1	1





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نماذج Mealy و Moore

Mealy

Present State		I/P	Next State		O/P
A	*B*	*x*	*A*	*B*	*y*
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

يتغير الخرج بتغير الدخل لنفس الحالة

For the same state,
the output changes with the input

Moore

Present State		I/P	Next State		O/P
A	*B*	*x*	*A*	*B*	*y*
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	1	0
0	1	1	1	0	0
1	0	0	1	0	0
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	1

لايتغير الخرج بتغير الدخل لنفس الحالة

For the same state,
the output does not change with the input

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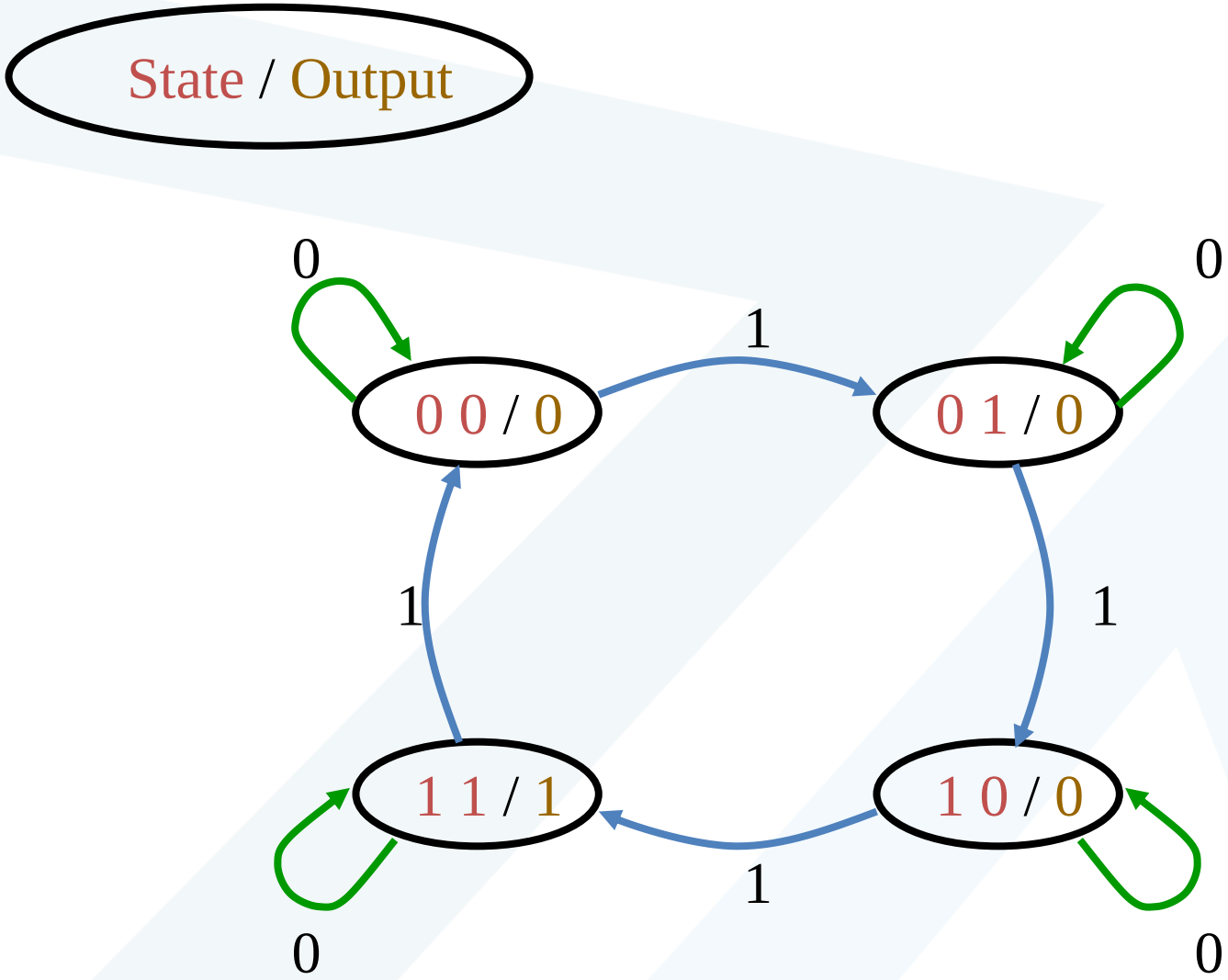
Moore State Diagram مخططات حالة مور



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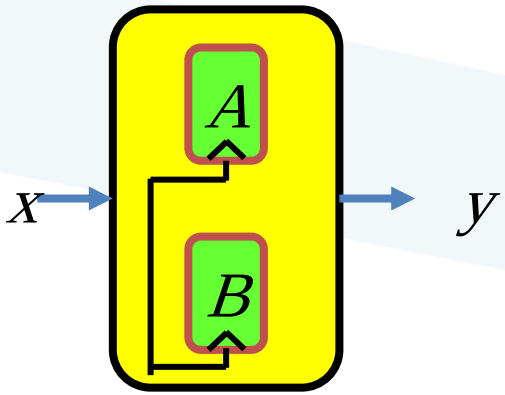
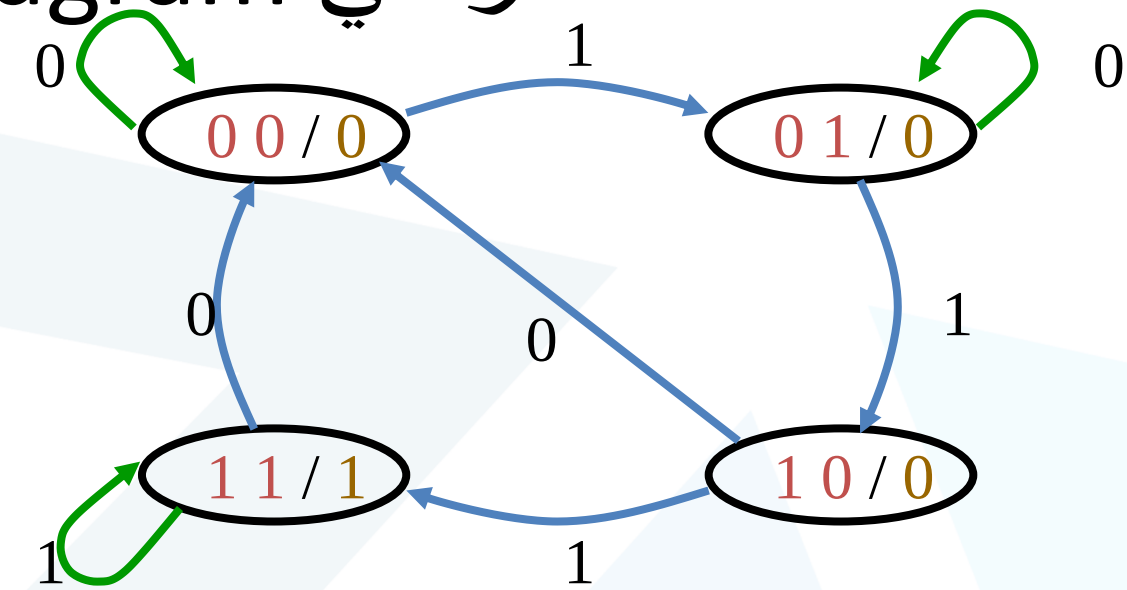
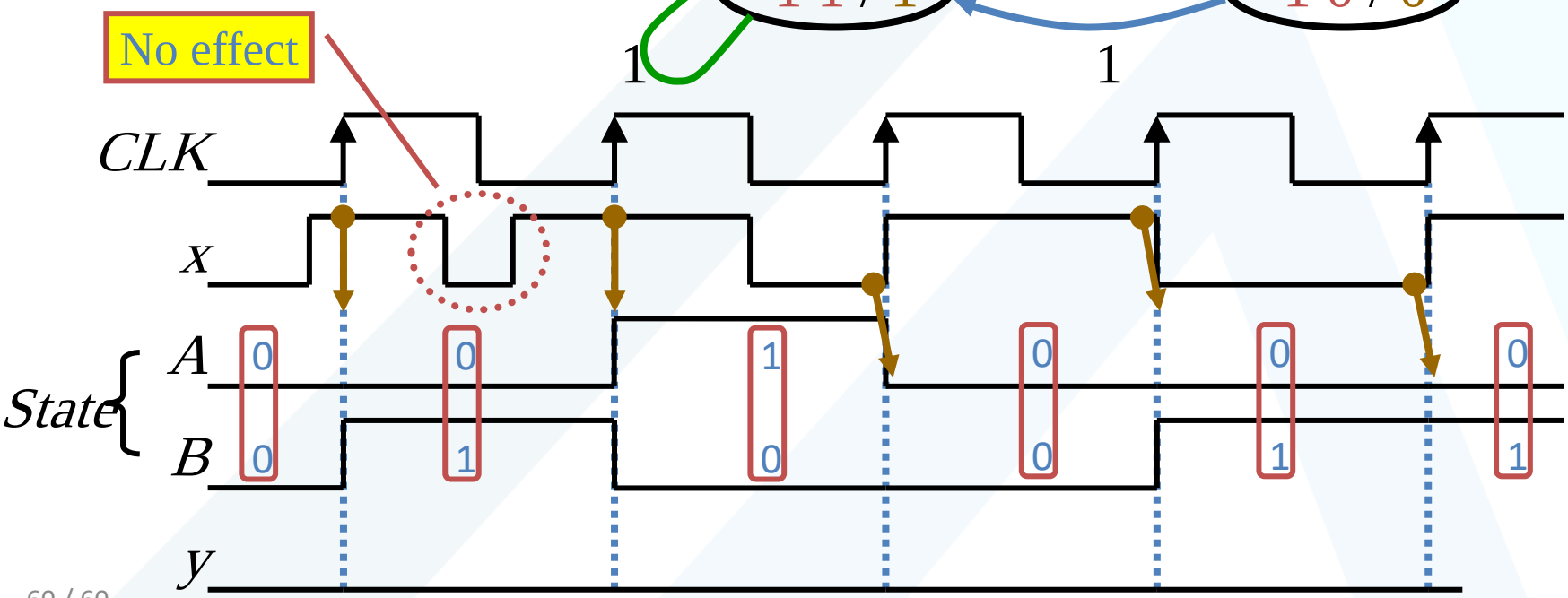
Timing Diagram المخطط الزمني







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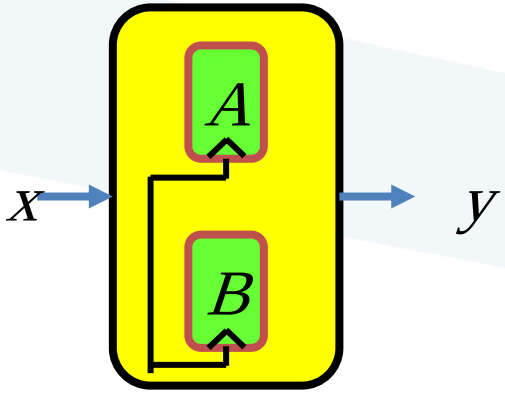
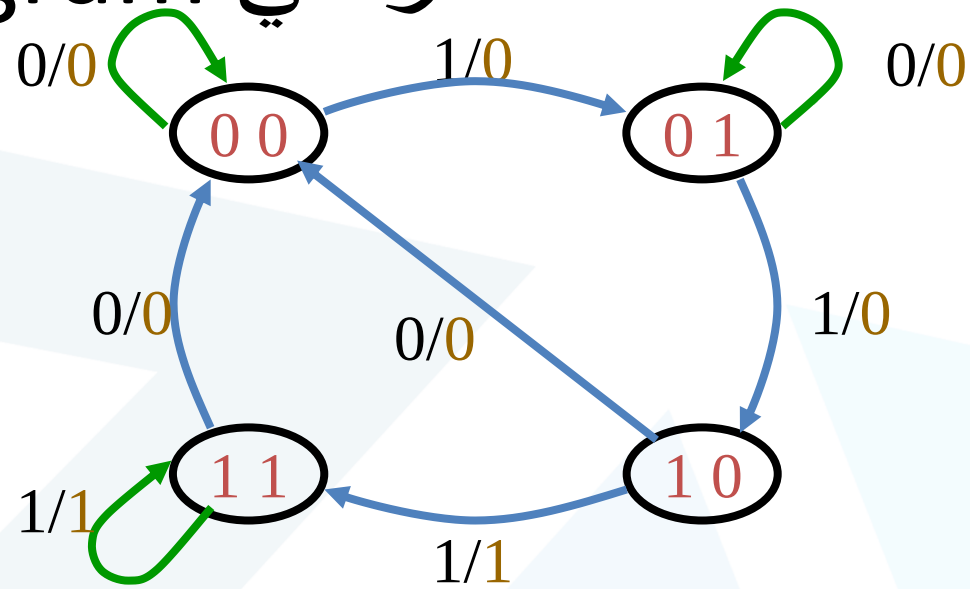
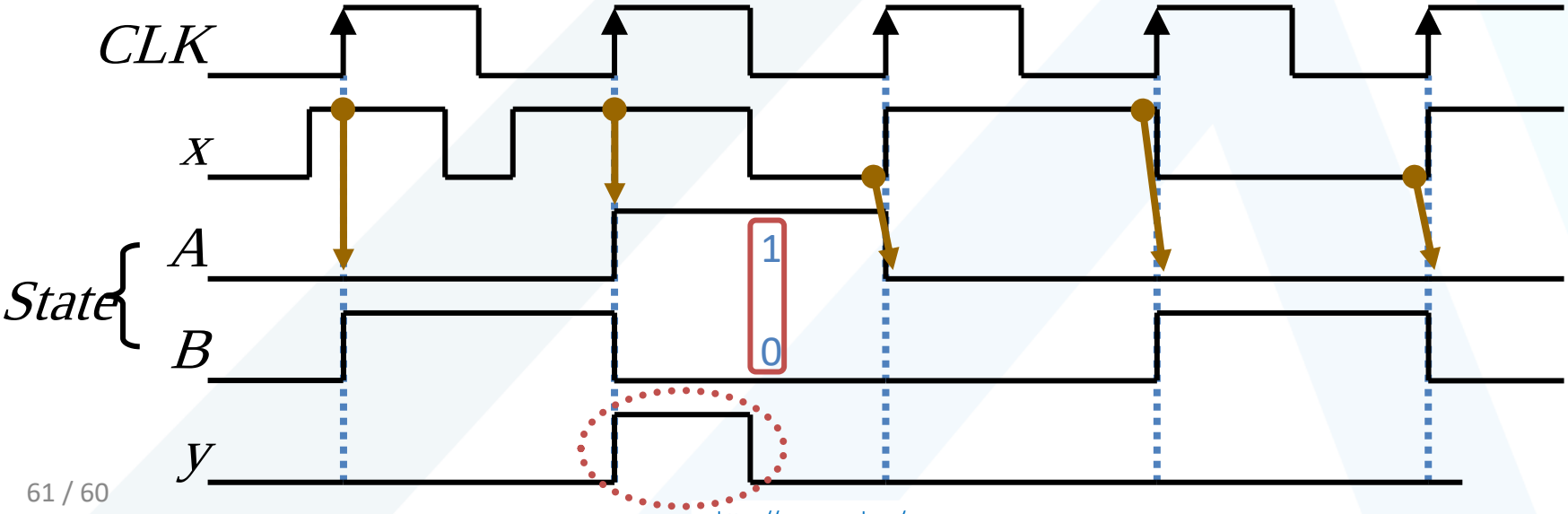
Timing Diagram المخطط الزمني







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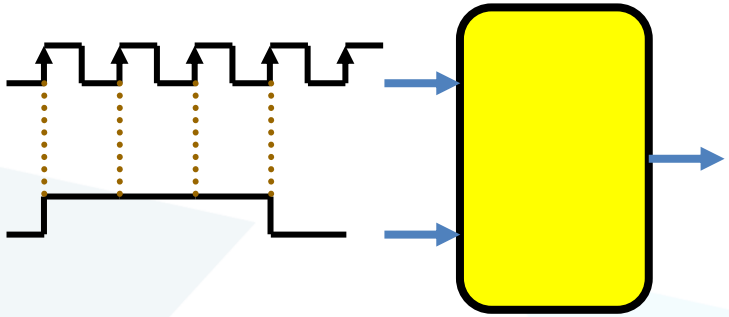
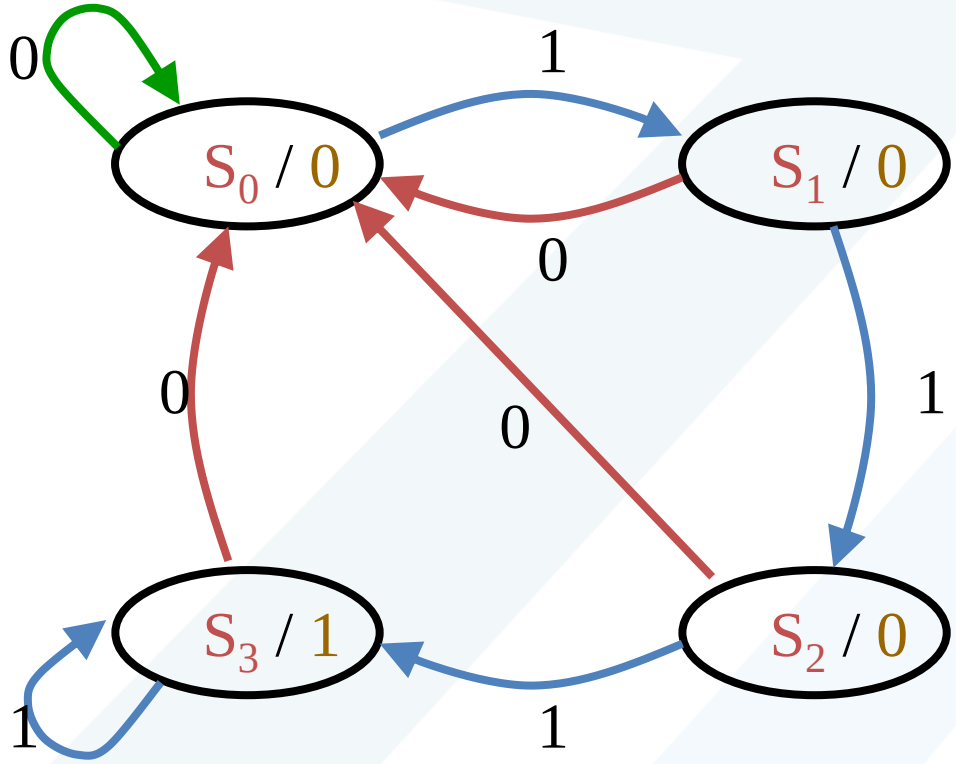
تصميم الدارات التتابعية المتواقتة

- مثال:

كشف ورود 3 واحدات متتالية





State	A B
S_0	0 0
S_1	0 1
S_2	1 0
S_3	1 1

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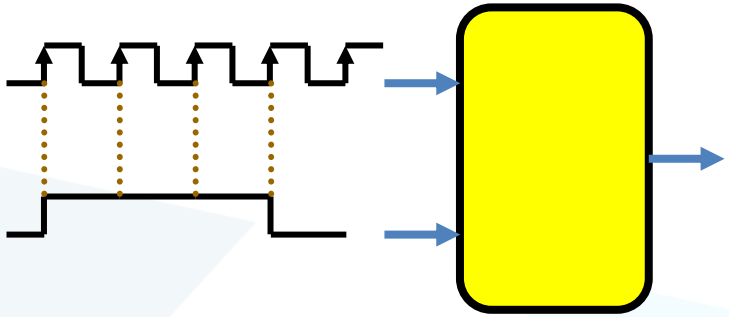
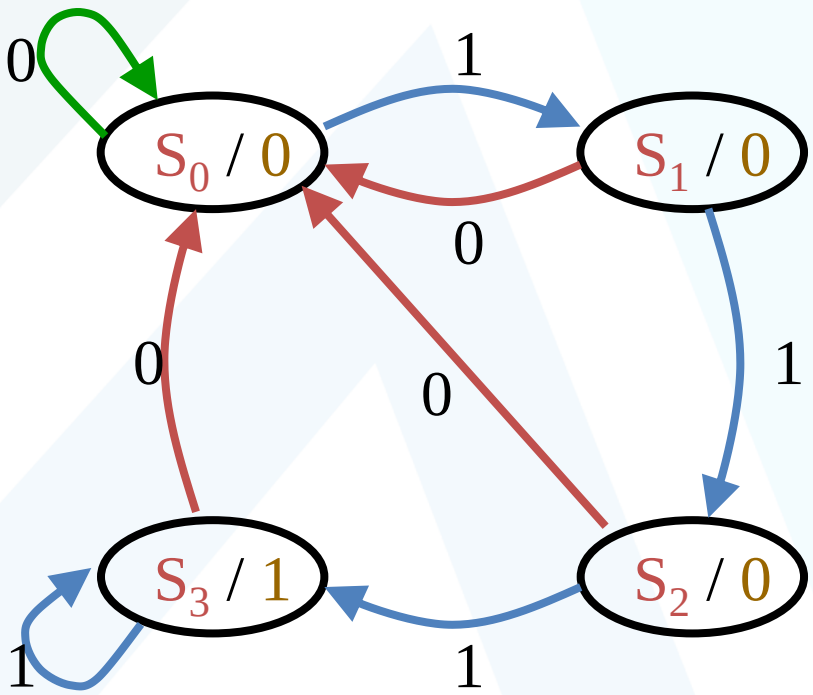
تصميم الدارات التتابعية المتواقتة

- مثال:

كشف ورود 3 واحدات متتالية



Present State		Input	Next State		Output
A	*B*	*x*	*A*	*B*	*y*
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	1	1	1	1



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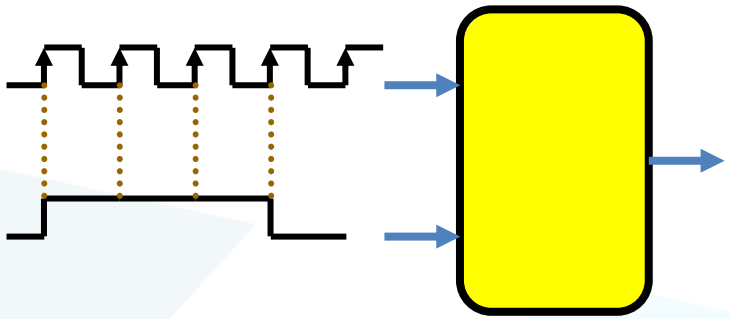
تصميم الدارات التتابعية المتواقتة

- مثال:

كشف ورود 3 واحدات متتالية



Present State		Input	Next State		Output
A	B	x	A	B	y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	1	1	1	1

Synthesis using D Flip-Flops

$$A(t+1) = D_A(A, B, x) = \sum(3, 5, 7)$$

$$B(t+1) = D_B(A, B, x) = \sum(1, 5, 7)$$

$$y(A, B, x) = \sum(6, 7)$$

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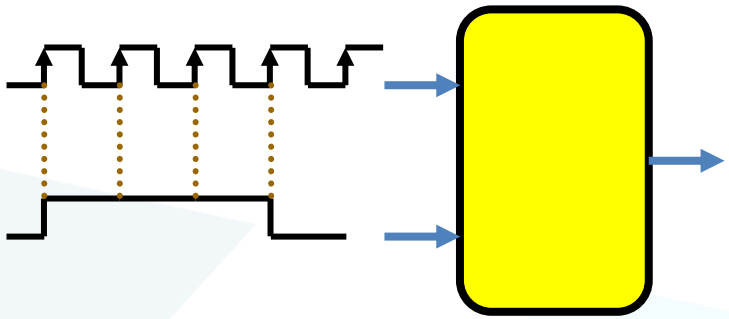
تصميم الدارات التتابعية المتواقتة بقلابات D F.F.

- مثال:

كشف ورود 3 واحدات متتالية



التحقيق باستخدام قلابات D

$$D_A(A, B, x) = \sum(3, 5, 7)$$
$$= A\,x + B\,x$$

$$D_B(A, B, x) = \sum(1, 5, 7)$$
$$= A\,x + B'x$$

$$y(A, B, x) = \sum(6, 7)$$
$$= A\,B$$

		B	
0	0	1	0
0	1	1	0

A, x

		B	
0	1	0	0
0	1	1	0

A, x

		B	
0	0	0	0
0	0	1	1

A, x

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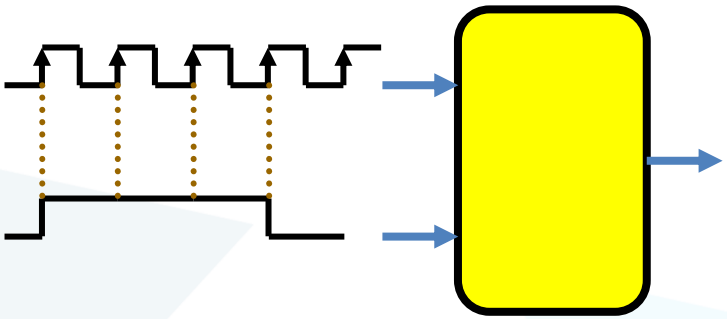
تصميم الدارات التتابعية المتواقتة بقلابات D F.F.

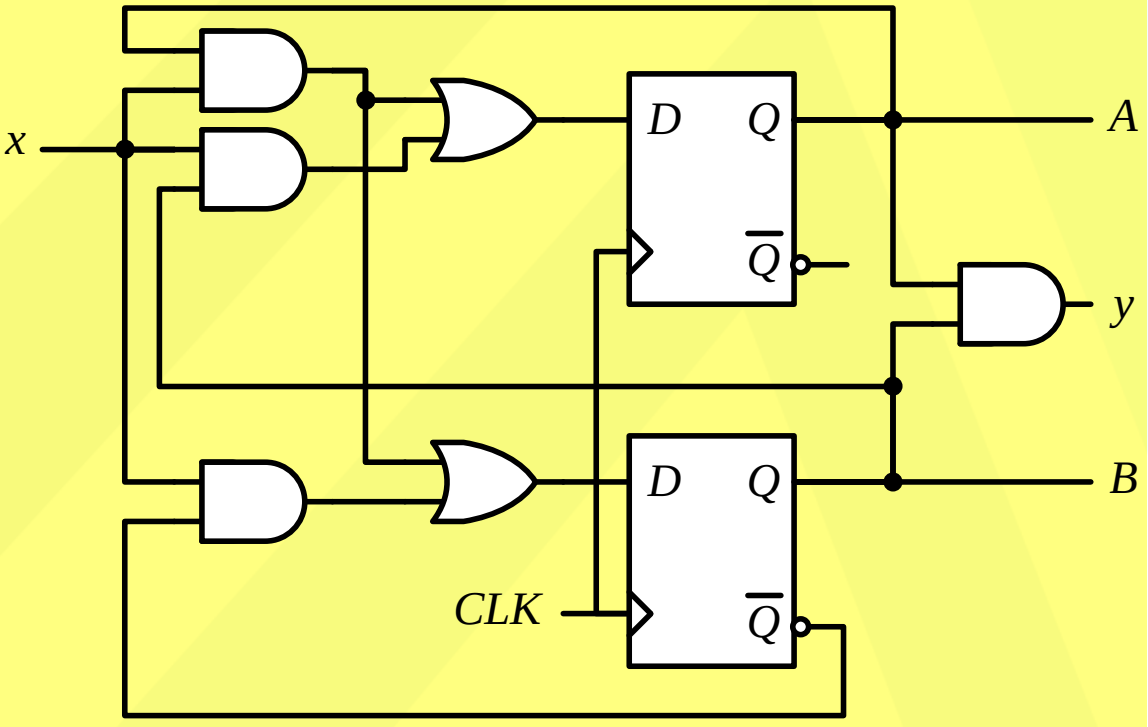
- مثال:

كشف ورود 3 واحدات متتالية



Synthesis using *D* Flip-Flops

$$D_A = A\,x + B\,x$$
$$D_B = A\,x + B'x$$
$$y = A\,B$$



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Flip-Flop Excitation Tables جداول التحريض

Present State	Next State	F.F. Input
$Q(t)$	$Q(t+1)$	D
0	0	0
0	1	1
1	0	0
1	1	1

Present State	Next State	F.F. Input	
$Q(t)$	$Q(t+1)$	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

0 0 (No change)
0 1 (Reset)

1 0 (Set)
1 1 (Toggle)

0 1 (Reset)
1 1 (Toggle)

0 0 (No change)
1 0 (Set)

$Q(t)$	$Q(t+1)$	T
0	0	0
0	1	1
1	0	1
1	1	0

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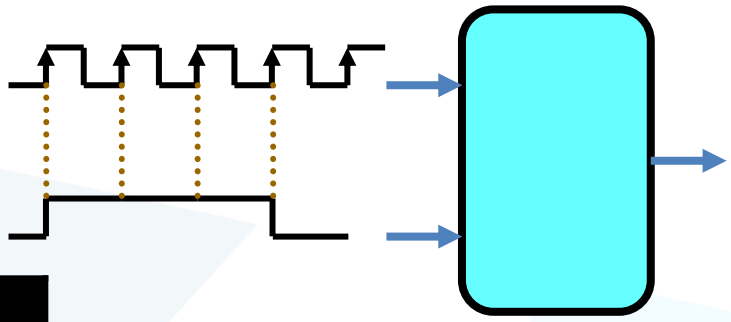
تصميم الدارات التتابعية المتواقتة بقلابات *J-K* F.F.

- مثال:

كشف ورود 3 واحدات متتالية



Present State		Input	Next State		Flip-Flop Inputs			
A	B	x	A	B	J_A	K_A	J_B	K_B
0	0	0	0	0	0	x	0	x
0	0	1	0	1	0	x	1	x
0	1	0	0	0	0	x	x	1
0	1	1	1	0	1	x	x	1
1	0	0	0	0	x	1	0	x
1	0	1	1	1	x	0	1	x
1	1	0	0	0	x	1	x	1
1	1	1	1	1	x	0	x	0

Synthesis using *JK* F.F.

$J_A(A, B, x) = \sum(3)$

$d_{JA}(A, B, x) = \sum(4,5,6,7)$

$K_A(A, B, x) = \sum(4, 6)$

$d_{KA}(A, B, x) = \sum(0,1,2,3)$

$J_B(A, B, x) = \sum(1, 5)$

$d_{JB}(A, B, x) = \sum(2,3,6,7)$

$K_B(A, B, x) = \sum(2, 3, 6)$

$d_{KB}(A, B, x) = \sum(0,1,4,5)$

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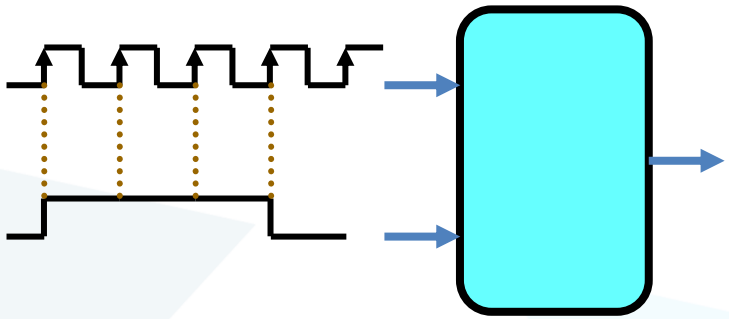
تصميم الدارات التتابعية المتواقتة بقلابات J-K F.F.

- مثال:

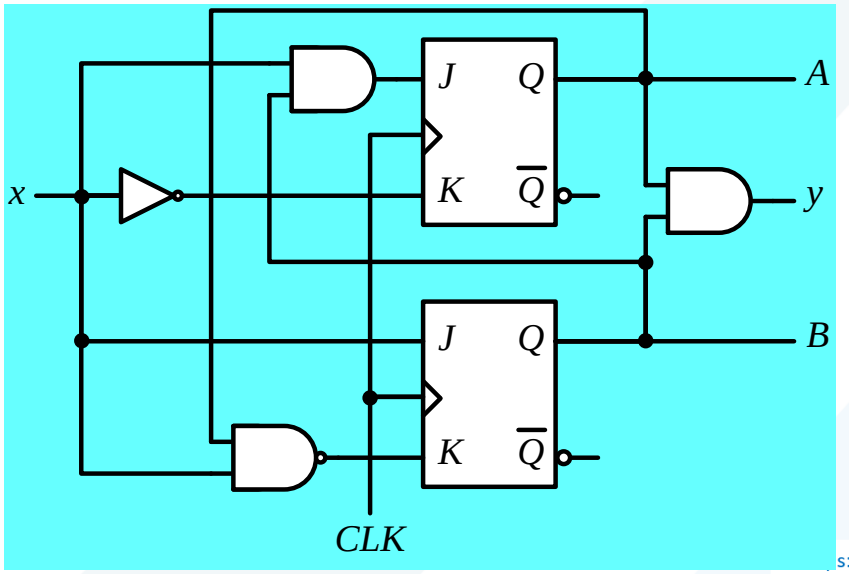
كشف ورود 3 واحدات متتالية

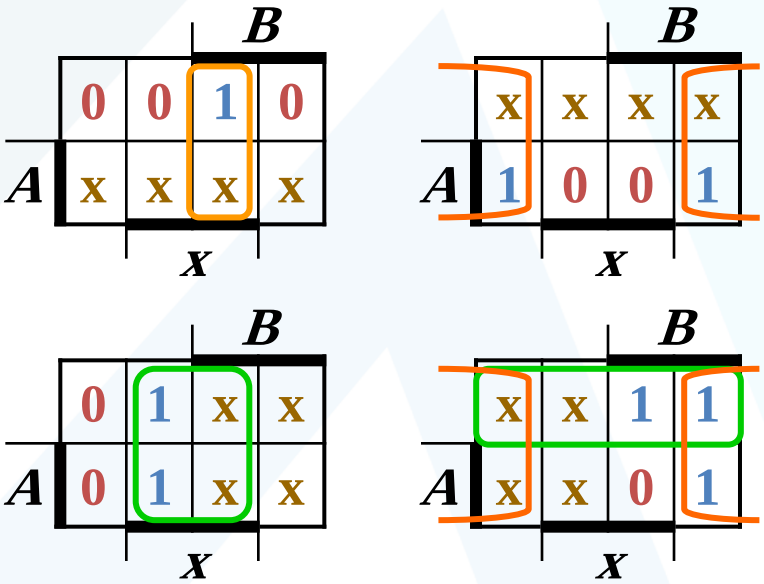


Synthesis using *JK* Flip-Flops

$K_A = x'$ $\quad J_A = B\,x$

$K_B = A' + x'$ $\quad J_B = x$

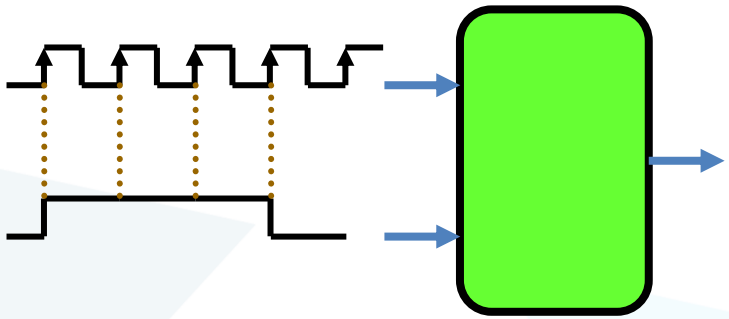




تصميم الدارات التتابعية المتواقتة بقلابات T- F.F.

- مثال:

كشف ورود 3 واحدات متتالية



Present State		Input	Next State		F.F. Input	
A	B	x	A	B	T_A	T_B
0	0	0	0	0	0	0
0	0	1	0	1	0	1
0	1	0	0	0	0	1
0	1	1	1	0	1	1
1	0	0	0	0	1	0
1	0	1	1	1	0	1
1	1	0	0	0	1	1
1	1	1	1	1	0	0

Synthesis using T Flip-Flops

$$T_A(A, B, x) = \sum(3, 4, 6)$$
$$T_B(A, B, x) = \sum(1, 2, 3, 5, 6)$$

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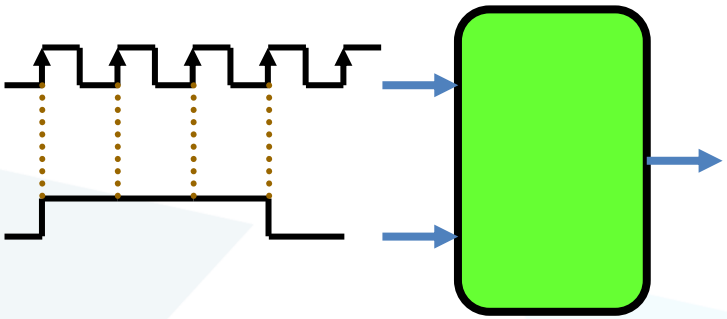
تصميم الدارات التتابعية المتواقتة بقلابات T- F.F.

- مثال:

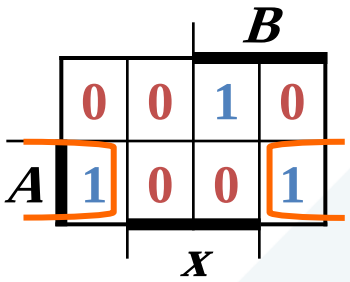
كشف ورود 3 واحدات متتالية

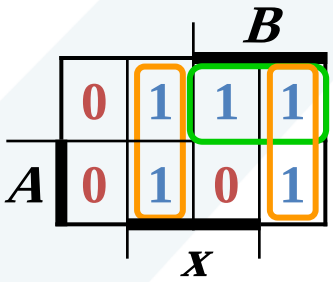


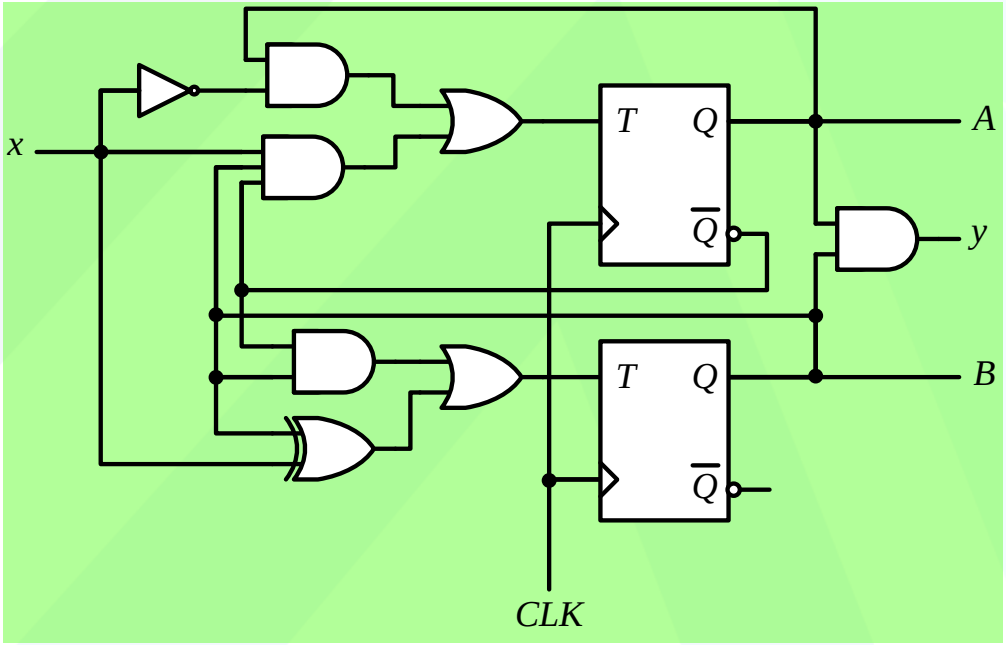
Synthesis using T Flip-Flops

$$T_A = A\,x' + A'B\,x$$

$$T_B = A'B + B \oplus x$$







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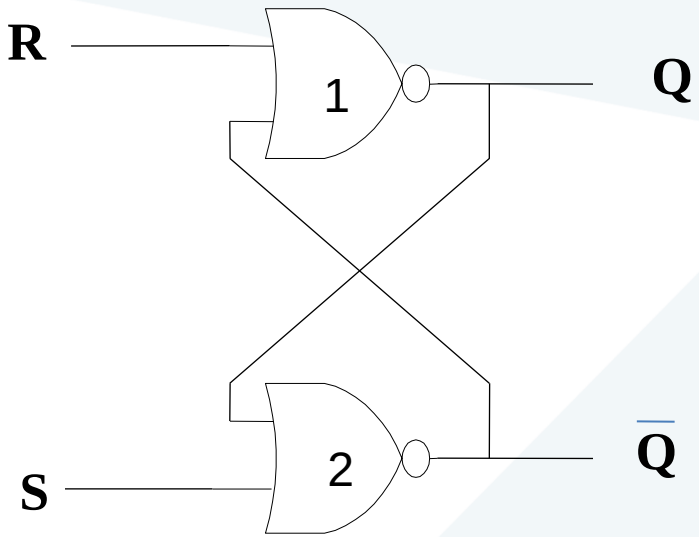
القلاب R-S



العمود	1	2	3	4
الصف	R	S	Q_n	Q_{n+1}
1	0	0	0	0
2	0	0	1	1
3	0	1	0	1
4	0	1	1	1
5	1	0	0	0
6	1	0	1	0
7	1	1	0	عدم تعيين
8	1	1	1	عدم تعيين

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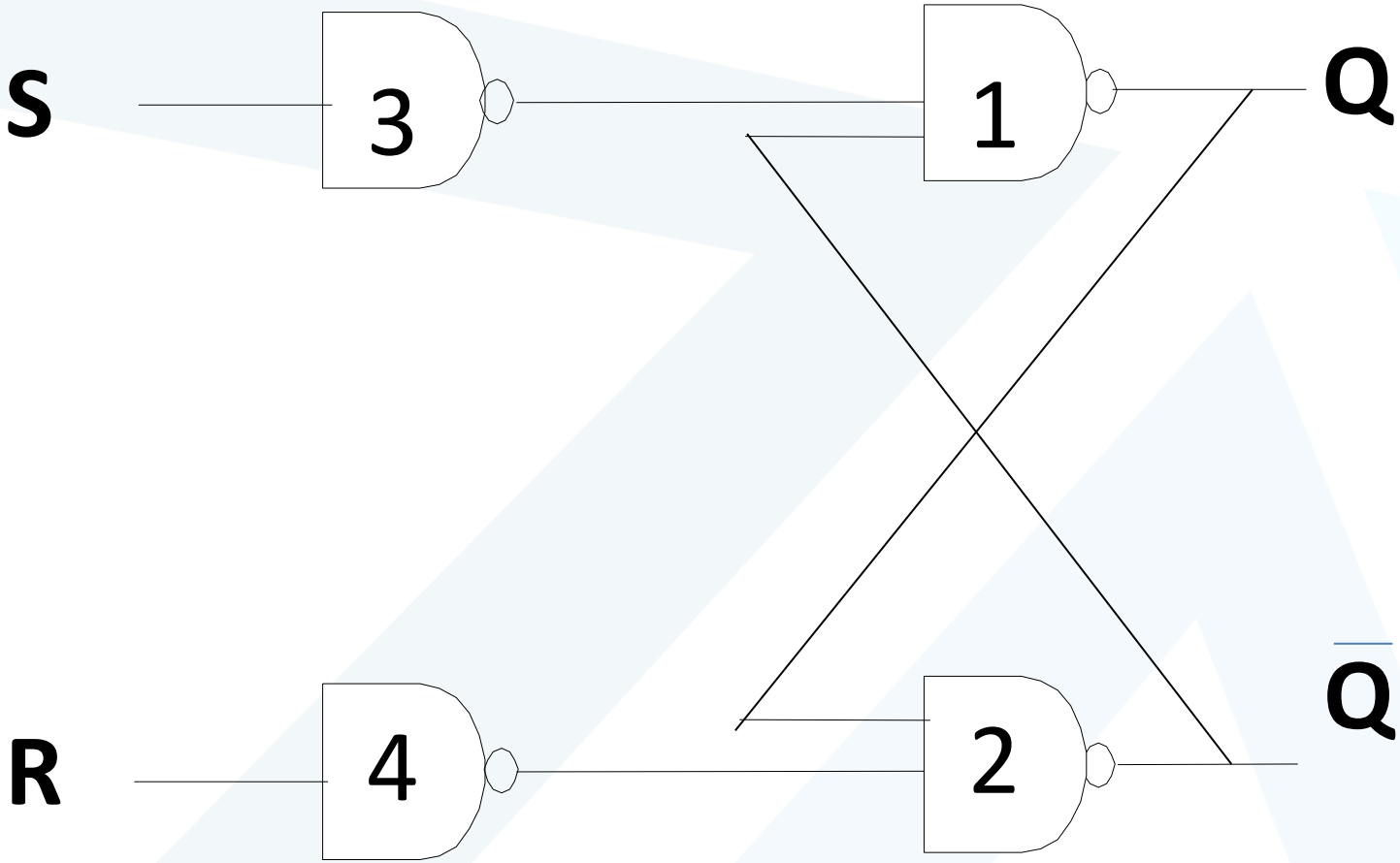
القلاب R-S (NAND)



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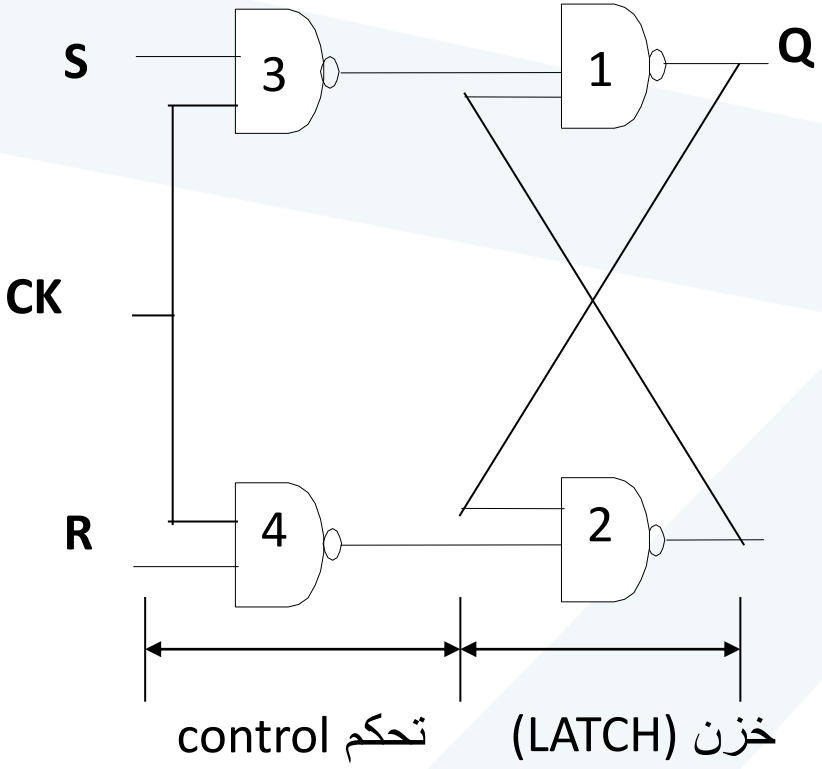
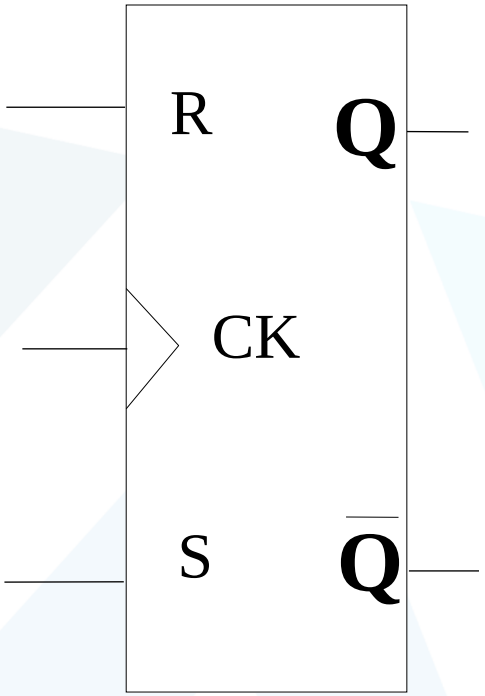
مشكلة التأخير (التواقت)



(a)



(b)

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جدول الحالة

خرج 3 و 4 هو ⇐ 1 يحافظ كل من Q و على حالته السابقة (نظام خزن)	R=d	S=d	Ck=0
خرج 3 و 4 هو ⇐ 1يحافظ كل من Q و على حالته السابقة (نظام خزن)	R=0	S=0	Ck=1
خرج 3 هو 0 وخرج 4 هو Q=1 ⇐ 1 و	R=0	S=1	Ck=1
خرج 3 هو 1 وخرج 4 هو Q=0 ⇐ ٠0 و	R=1	S=0	Ck=1
خرج 3 و 4 هو ⇐ 0يأخذ كل من Q و $\overline{Q}$ قيمة الواحد (حالة ممنوعة)	R=1	S=1	Ck=1

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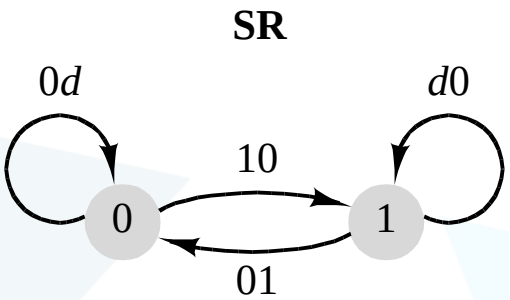
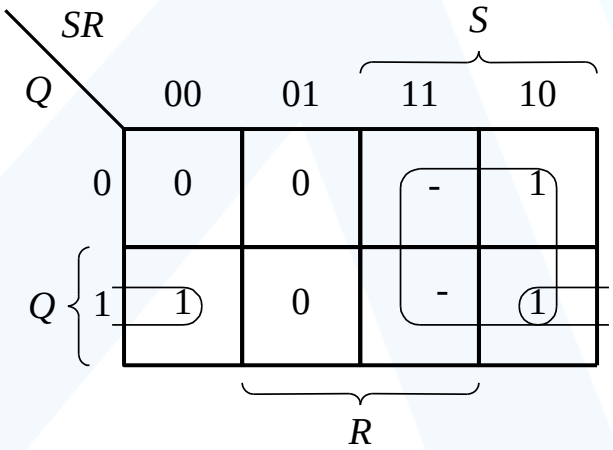
مواصفات خازن SR
SR latch characteristics

Excitation inputs S	R	Present state Q	Next state Q^*	
0	0	0	0	No change
0	0	1	1	
0	1	0	0	Reset
0	1	1	0	
1	0	0	1	Set
1	0	1	1	
1	1	0	×	Not allowed
1	1	1	×	

(a) Excitation table



(b) State diagram



(c) K-map of latch output Q*

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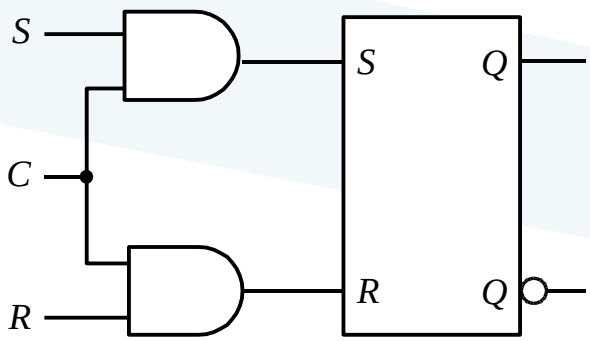
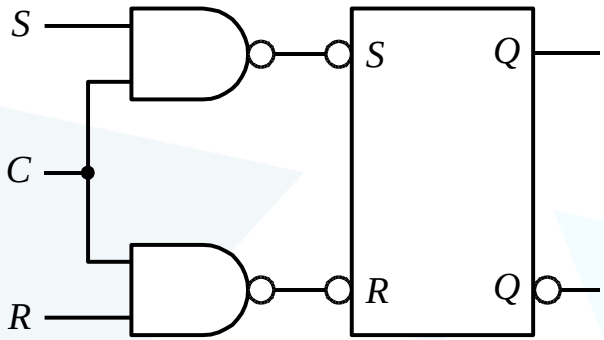
خازن SR مع نبضات التواقت (الساعة)

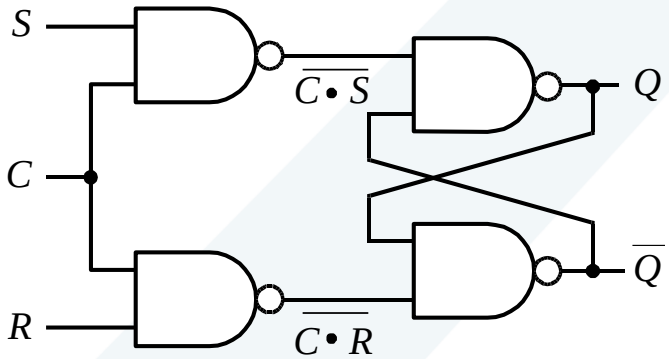
Gated SR Latch



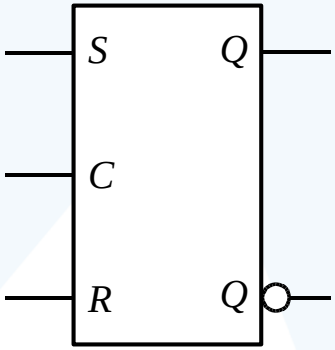
(a) With NOR SR latch



(b) With NAND SR latch



(c) NAND logic diagram



(d) logic symbol

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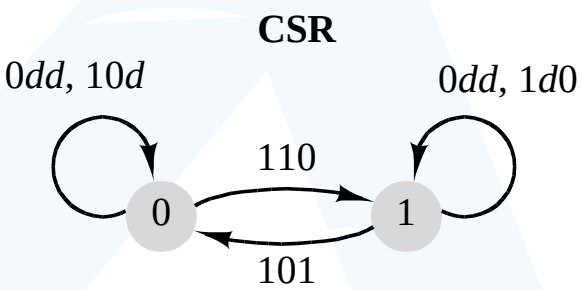
مواصفات SR المتواقت

Gated SR Latch Characteristicsl

Enable inputs C	Excitation inputs S	R	Present state Q	Next state Q^*	
0	×	×	0	0	Hold
0	×	×	1	1	
1	0	0	0	0	No change
1	0	0	1	1	
1	0	1	0	0	Reset
1	0	1	1	0	
1	1	0	0	1	Set
1	1	0	1	1	
1	1	1	0	×	Not allowed
1	1	1	1	×	

(a)



(b)

State diagram

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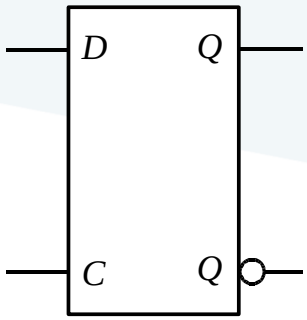
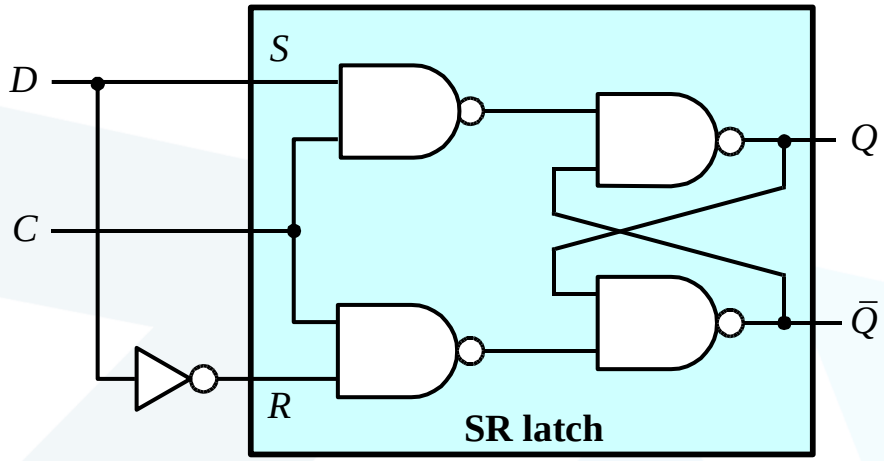
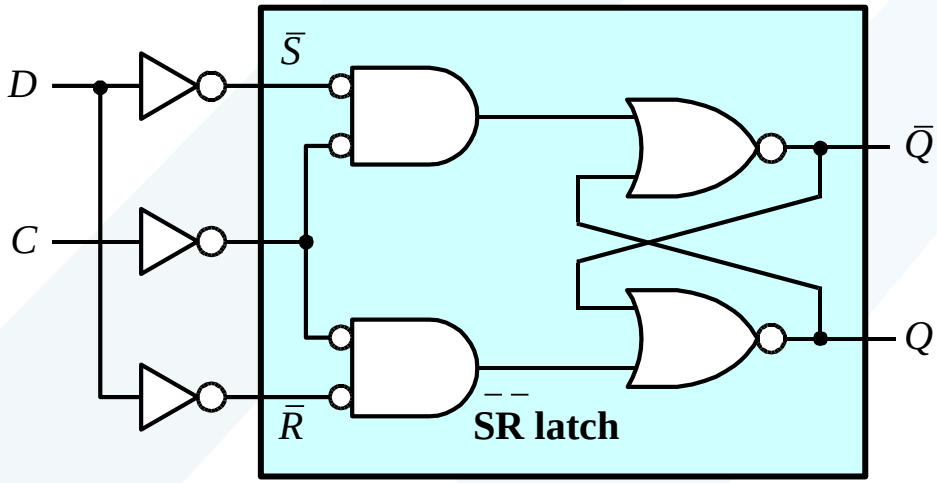
Delay Latch (D latch)



(a) Logic symbol



(b) NAND implementation

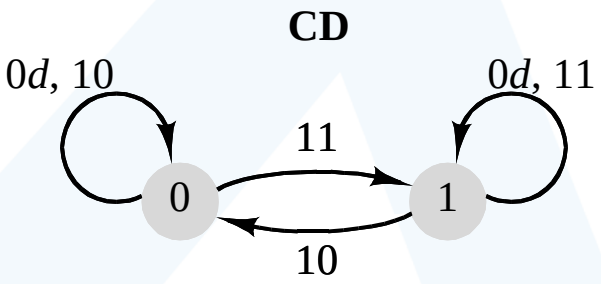


(c) NOR implementation

D Latch Characteristics

Enable input C	Excitation input D	Present state Q	Next state Q^*	
0	×	0	0	Hold
0	×	1	1	
1	0	0	0	Store 0
1	0	1	0	
1	1	0	1	Store 1
1	1	1	1	

(a)



(b)

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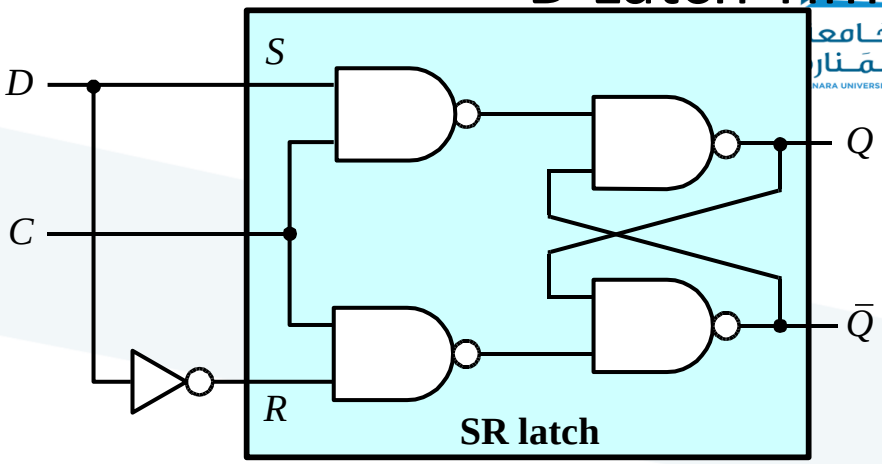
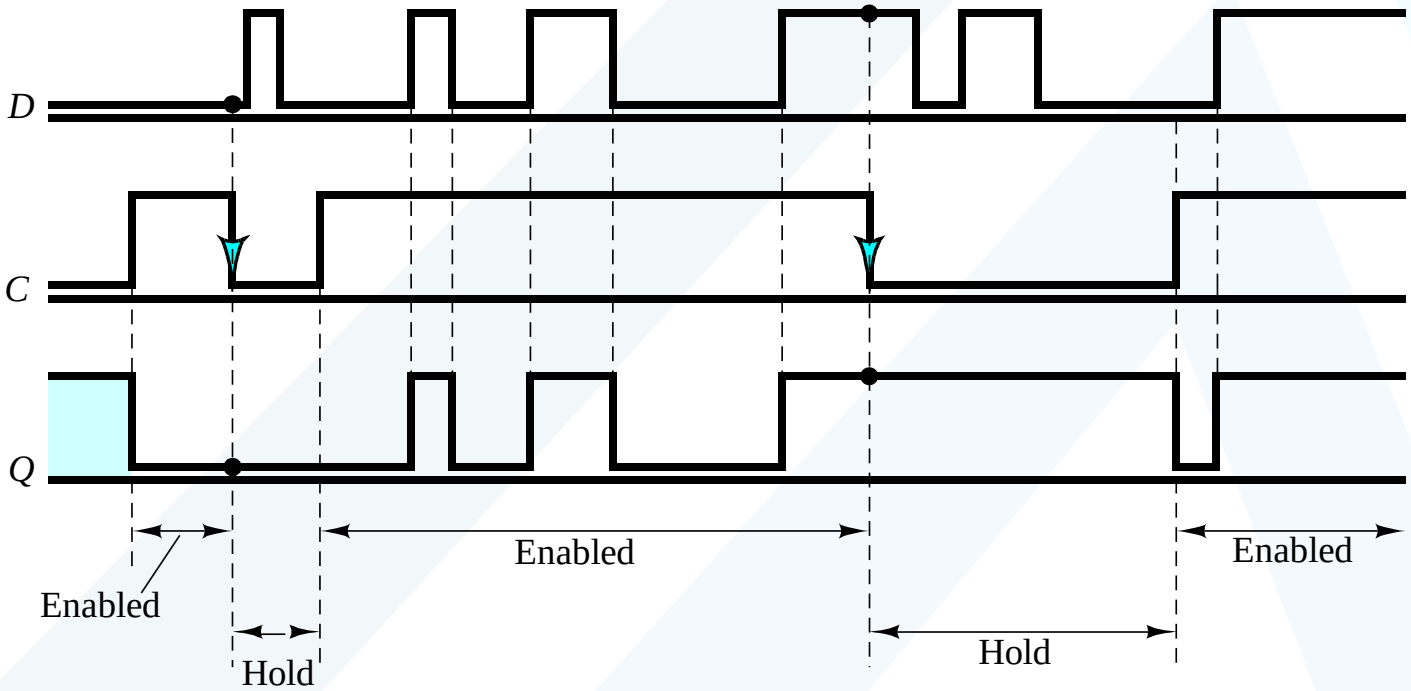
D Latch Timing Diagram



(b)



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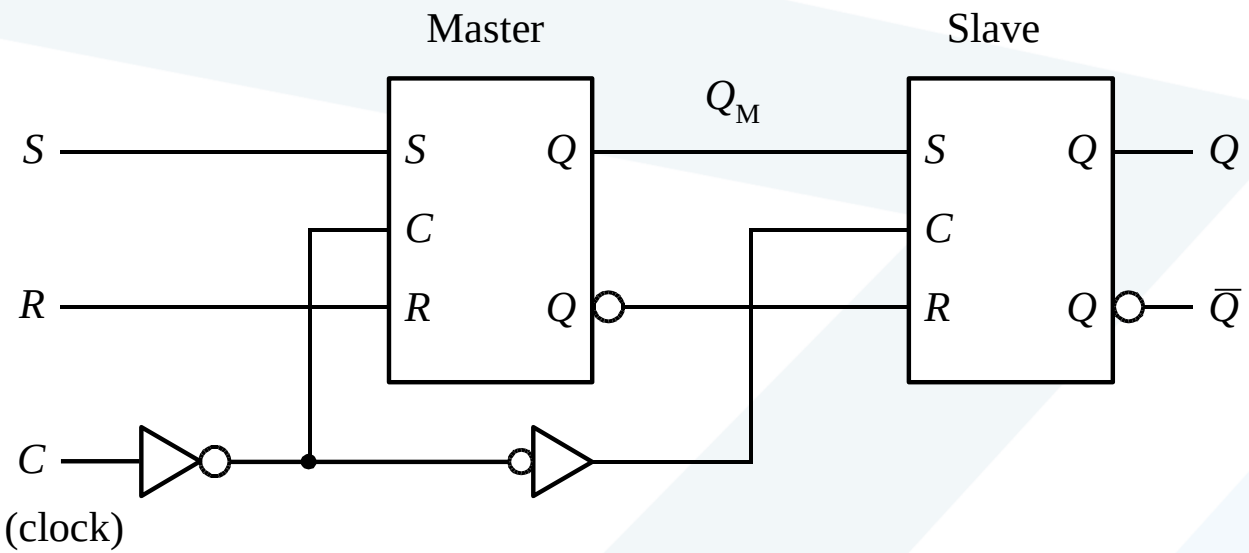
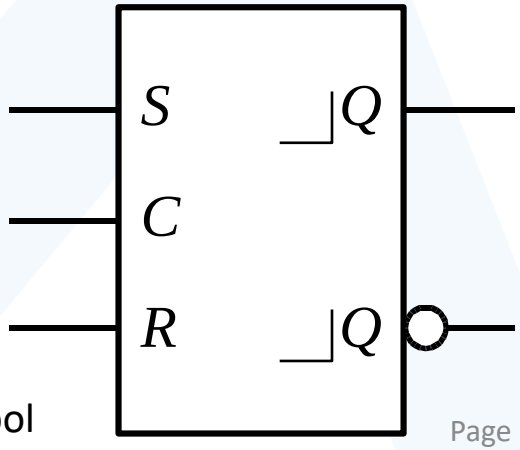
Master-slave SR flip-flop



(a) Logic diagram



(b) Pulse-triggered device logic symbol

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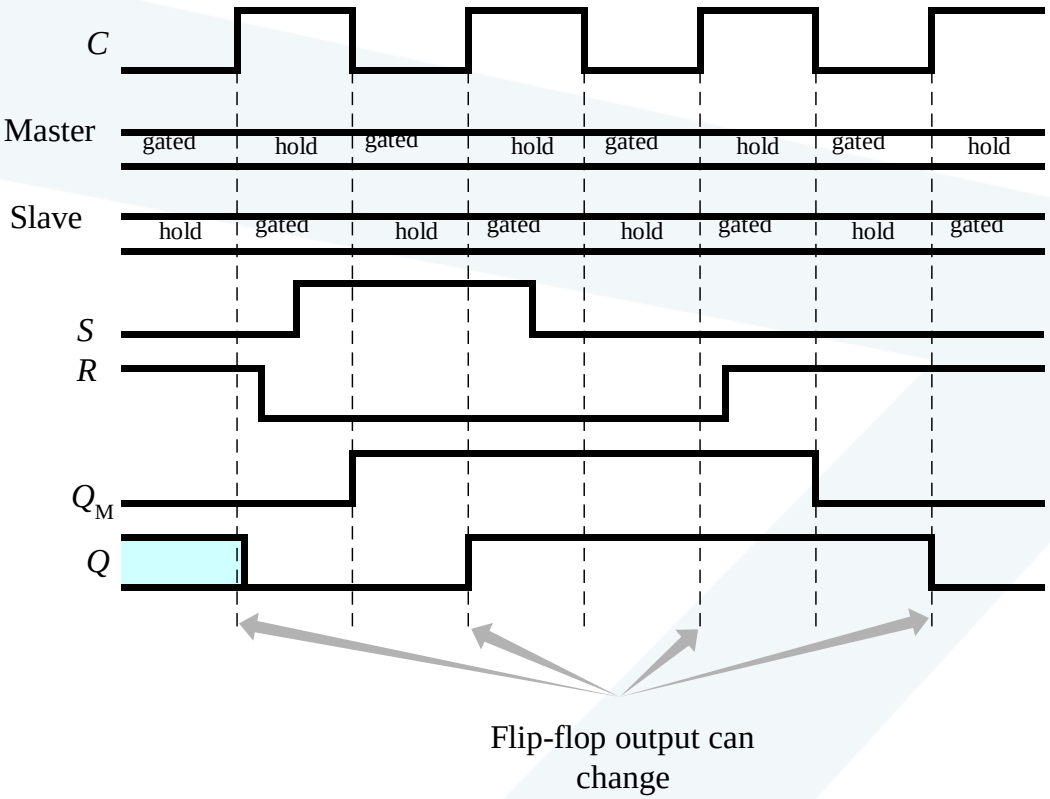
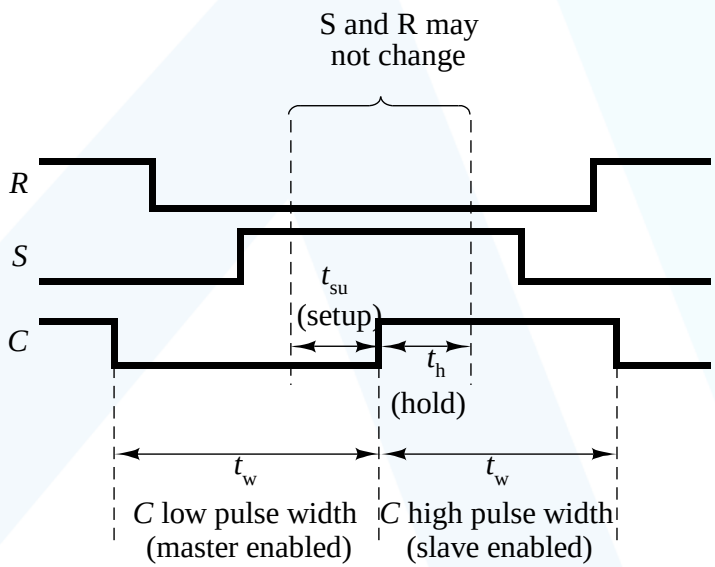
Master-slave SR flip-flop (continued)



(c) Timing behavior



(d) Timing constraints

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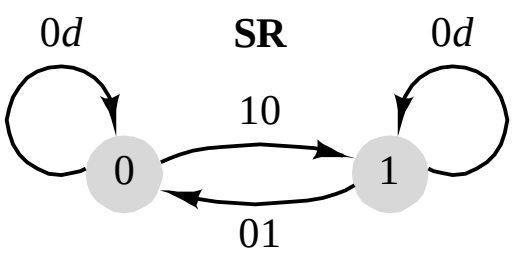
SR Master-Slave Flip-Flop Characteristics

S	R	Q	C	Q^*	
0	0	0	⎍	0	No change
0	0	1	⎍	1	
0	1	0	⎍	0	Reset
0	1	1	⎍	0	
1	0	0	⎍	1	Set
1	0	1	⎍	1	
1	1	0	⎍	×	Not allowed
1	1	1	⎍	×	

(a)



(b)

$$Q^* = S + RQ$$

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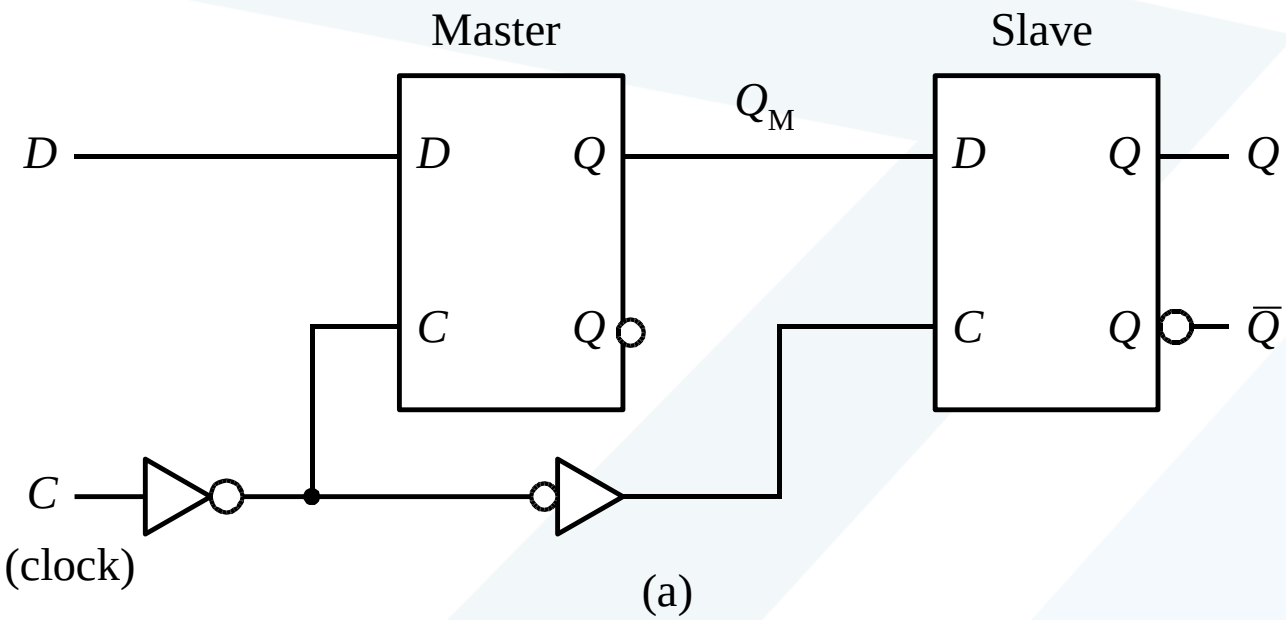
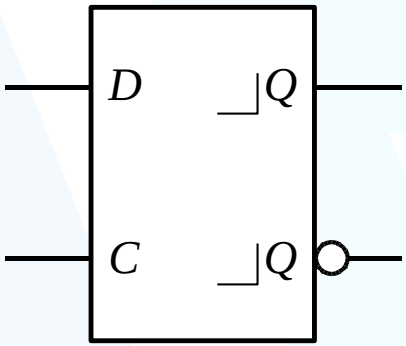
Master-Slave D Flip-Flop





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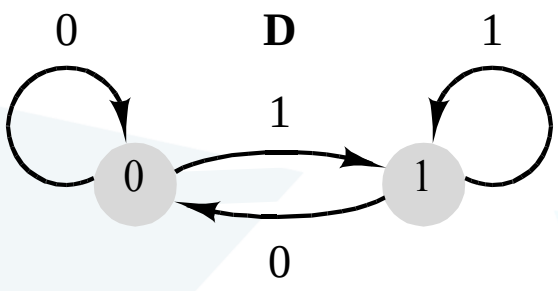
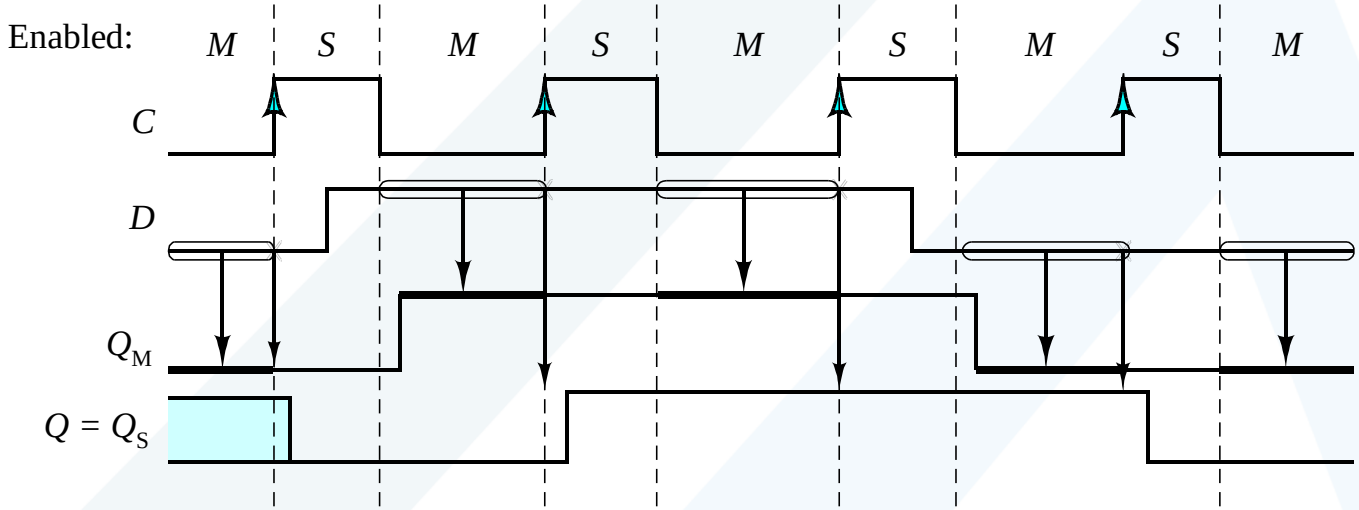
Master-slave D flip-flop characteristics

D	Q	C	Q*	
0	0	↑	0	Store 0
0	1	↑	0	
1	0	↑	1	Store 1
1	1	↑	1	





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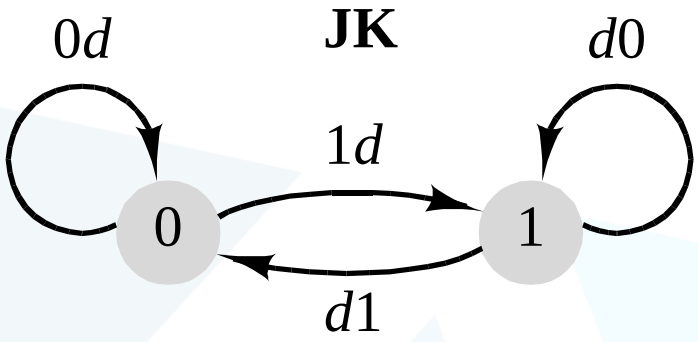
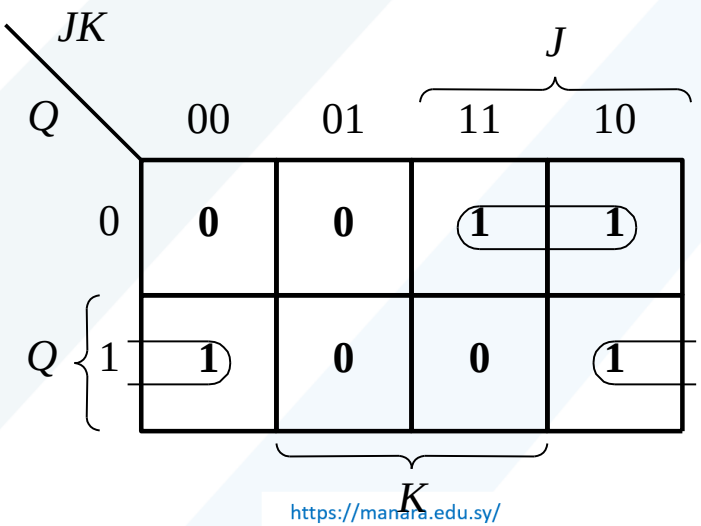
Pulse-triggered JK flip-flop characteristics

J	K	Q	C	Q^*	
0	0	0	⎍	0	Hold
0	0	1	⎍	1	
0	1	0	⎍	0	Reset
0	1	1	⎍	0	
1	0	0	⎍	1	Set
1	0	1	⎍	1	
1	1	0	⎍	1	Toggle
1	1	1	⎍	0	

(a) Excitation table



(b) State diagram



(c) K-map for Q*

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التحقيق بواسطة القلابات المختلفة

اشتقاق جدول التحريض للقلاب

Characteristic Table

J	K	Q(t)	Q(t+)
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

Excitation Table

Q(t)	Q(t+)	J	K
0	0		
0	1		
1	0		
1	1		

البحث عن الأسطر التي تعبر عن نفس قيم Q(t), Q(t+) ومتابعة القيم التي تأخذها كل من J,K

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التحقيق بواسطة القلابات المختلفة

اشتقاق جدول التحريض للقلاب

Characteristic Table

J	K	Q(t)	Q(t+)
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

Excitation Table

Q(t)	Q(t+)	J	K
0	0		
0	1		
1	0		
1	1		

البحث عن الأسطر التي تعبر عن نفس قيم Q(t), Q(t+) ومتابعة القيم التي تأخذها كل من J,K

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التحقيق بواسطة القلابات المختلفة

اشتقاق جدول التحريض للقلاب

Characteristic Table

J	K	Q(t)	Q(t+)
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

Excitation Table

Q(t)	Q(t+)	J	K
0	0	0	X
0	1		
1	0		
1	1		

البحث عن الأسطر التي تعبر عن نفس قيم Q(t), Q(t+) ومتابعة القيم التي تأخذها كل من J,K

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التحقيق بواسطة القلابات المختلفة

اشتقاق جدول التحريض للقلاب

Characteristic Table

J	K	Q(t)	Q(t+)
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

Excitation Table

Q(t)	Q(t+)	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

البحث عن الأسطر التي تعبر عن نفس قيم Q(t), Q(t+) ومتابعة القيم التي تأخذها كل من J,K

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التحقيق بواسطة القلابات المختلفة

اشتقاق جدول التحريض للقلابات T, D, SR, JK

Excitation Tables

Q(t)	Q(t+)	D	T	S	R	J	K
0	0	0	0	0	X	0	X
0	1	1	1	1	0	1	X
1	0	0	1	0	1	X	1
1	1	1	0	X	0	X	0

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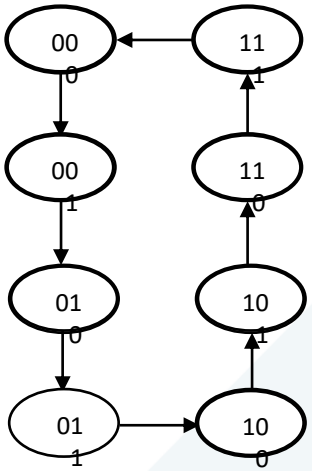
إجرائية تصميم عداد

Counter Design Procedure

Example: 3-bit Binary Upcounter



Present state			Next state		
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	1	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	0

Decide to implement with Toggle Flipflops

What inputs must be presented to the T FFs to get them to change to the desired state bit?

We need to use the T FF excitation table to translate the present/next state values to FF inputs

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