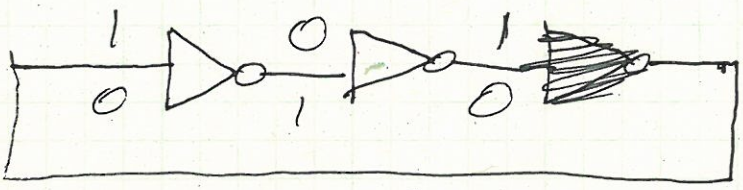
Combinational Logic - outputs depend on current inputs

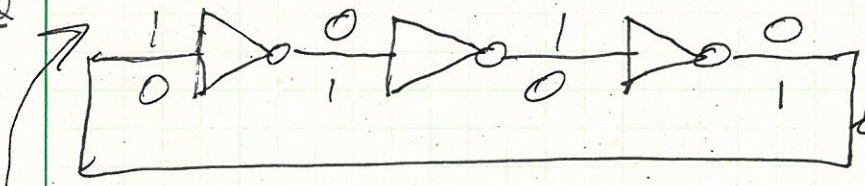
Sequential Logic - outputs depends on current & prior inputs

⇒ requires memory - somewhere to store prior inputs.



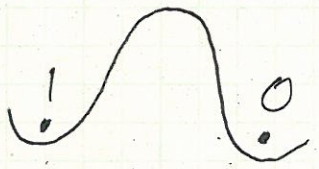
Bistable Element

Fundamental building block of memory

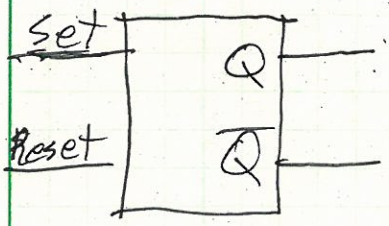


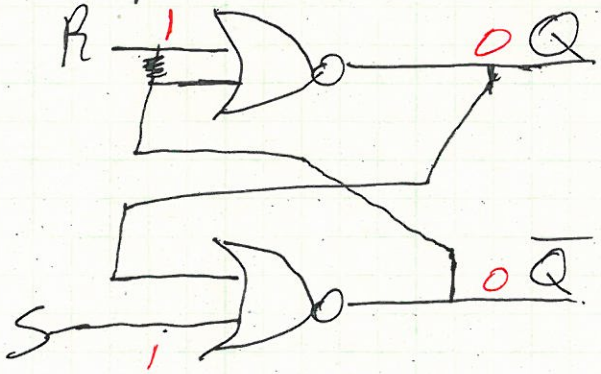
astable Element

Book calls it a ring oscilator



SR Latch: simplest sequential circuits





S	R	Q : Q̄
1	0	1 : 0
0	0	Qprev
0	1	0 : 1
0	0	Qprev
1	1	0 : 0

← set state (1)

← reset state (0)

← undefined & we have no idea what the next state will be

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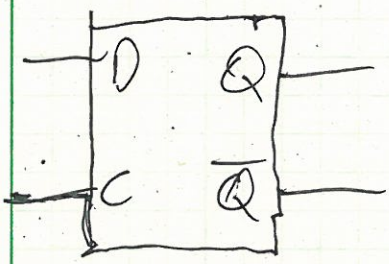
D-Latch: Solves the issues of the SR-Latch when S&R are both asserted



C	D	Q
0	X	Qprev
1	0	0
1	1	1

Transparent: when control is High Q will follow input (D)

Opaque: when control is Low Q won't change

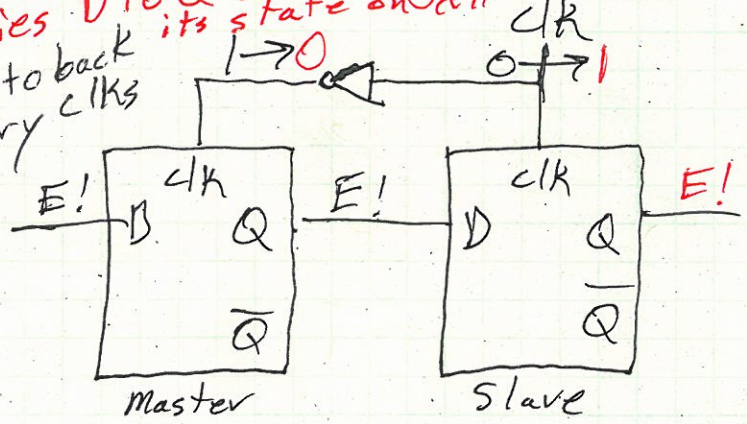
ADD D-Latch before SR

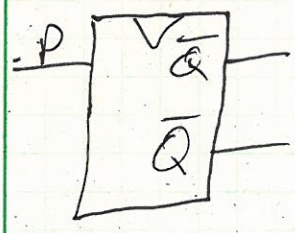
D	R	S	
X	0	0	
1	1	0	⇒
0	0	1	

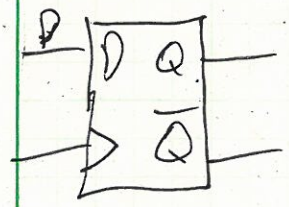
D-Latch updates its state continuously while clk is '1'

Flip Flops:

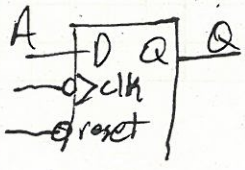
D-F/F: 2 D-latches back to back w complementary clks → copies D to Q on rising edge & remembers it, others its state on fall







clk	D (E!)	Q
0	0	Qprev
0	1	Qprev
1	0	Qprev
1	1	Qprev
↑ (rising edge)	0	0
↑	1	1



active low Reset

Negative (falling) edge triggered

if EN = 1 ⇒ no change to F/F

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Synchronous circuit - combinational circuit followed by flip flops

Properties:

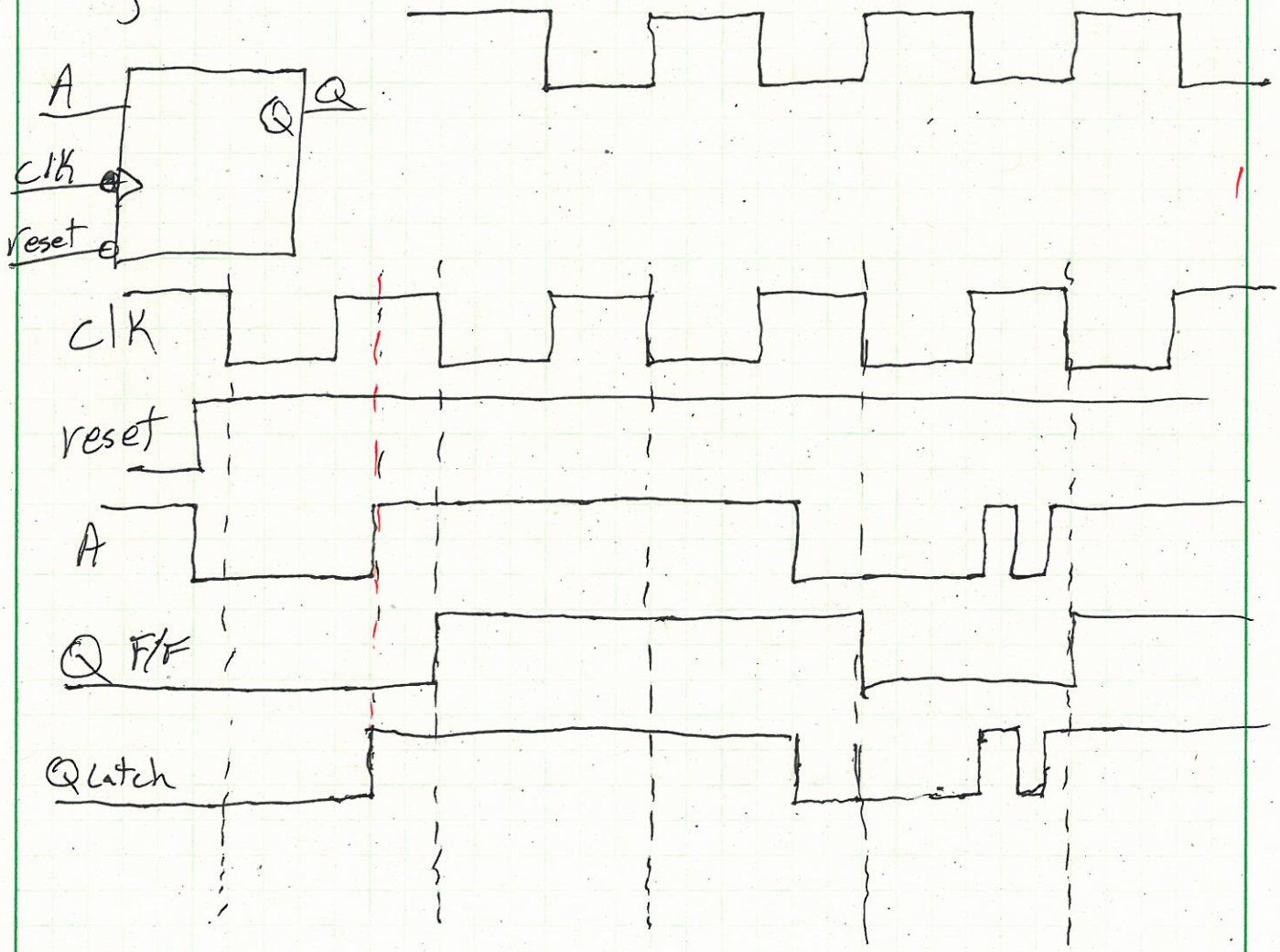
a) Every circuit element is either a register or a combinational circuit

b) At least on circuit is a register

c) All registers have the same clock

d) Every cyclic path contains at least one register

Register - An N-bit Register is a bank of N-Flip Flops



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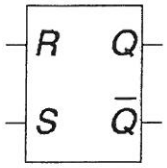
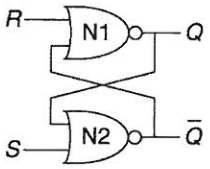
Lesson 10 – Introduction to Synchronous Circuits

Combinational logic –

Sequential logic –

SR Latch





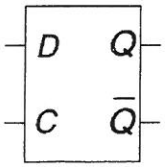
S	R	Q	Q'

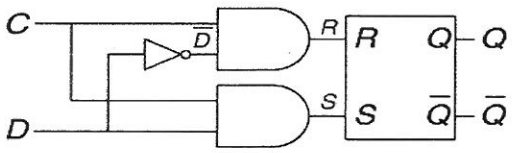
S =
R =
Q =

Q changes _____

Problem with SR latch:

D Latch





C	D	Q	Q'

C =
D =
Q =

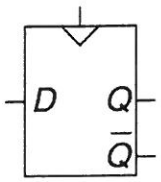
transparent –

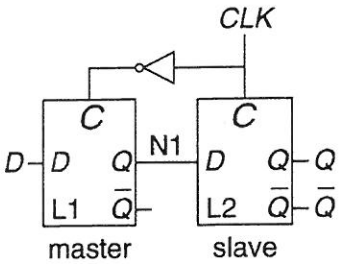
opaque –

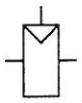
Q changes _____

Problem with D latch:

D Flip-Flop







CLK	D	Q	Q'
0	0		
0	1		
1	0		
1	1		
↑	0		
↑	1		

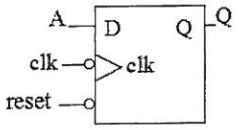
CLK =
D =
Q =

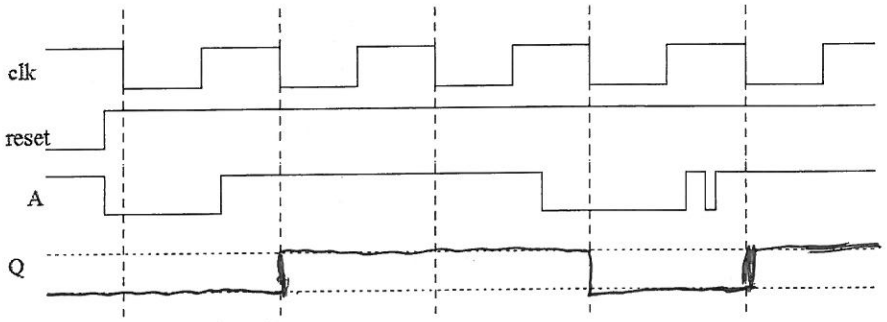
Comprised of:

Q changes _____

Enabled flip-flop –

Resettable flip-flop –





*What is the difference between a latch and a flip flop?

Register –

Synchronous circuit –

Properties: a)

b)

c)

d)

Example:

Asynchronous circuit –