

Tue Oct 29 2019

(Note: We're using slides from 2018.)

Quiz #3 is next Tuesday.Exercise 1 - let's skip thisExercise 2

$$R=0, S=0 \quad \text{gate 1: } Q = \overline{(S \cdot QN)} = \overline{QN}$$

$$\text{gate 2: } QN = \overline{(R \cdot Q)} = \overline{Q}$$

Two solutions:  $(Q, QN) = (0, 1)$ ,  $(Q, QN) = (1, 0)$ 

$$R=0, S=1 \quad \text{gate 1: } Q = \overline{(S \cdot QN)} = \overline{0} = 1$$

$$\text{gate 2: } QN = \overline{(R \cdot Q)} = \overline{Q} = 0$$

$$R=1, S=0 \quad \text{gate 2: } QN = \overline{(R \cdot Q)} = \overline{0} = 1$$

$$\text{gate 1: } Q = \overline{(S \cdot QN)} = \overline{QN} = 0$$

$$R=1, S=1 \quad \text{gate 1: } Q = \overline{(S \cdot QN)} = \overline{0} = 1$$

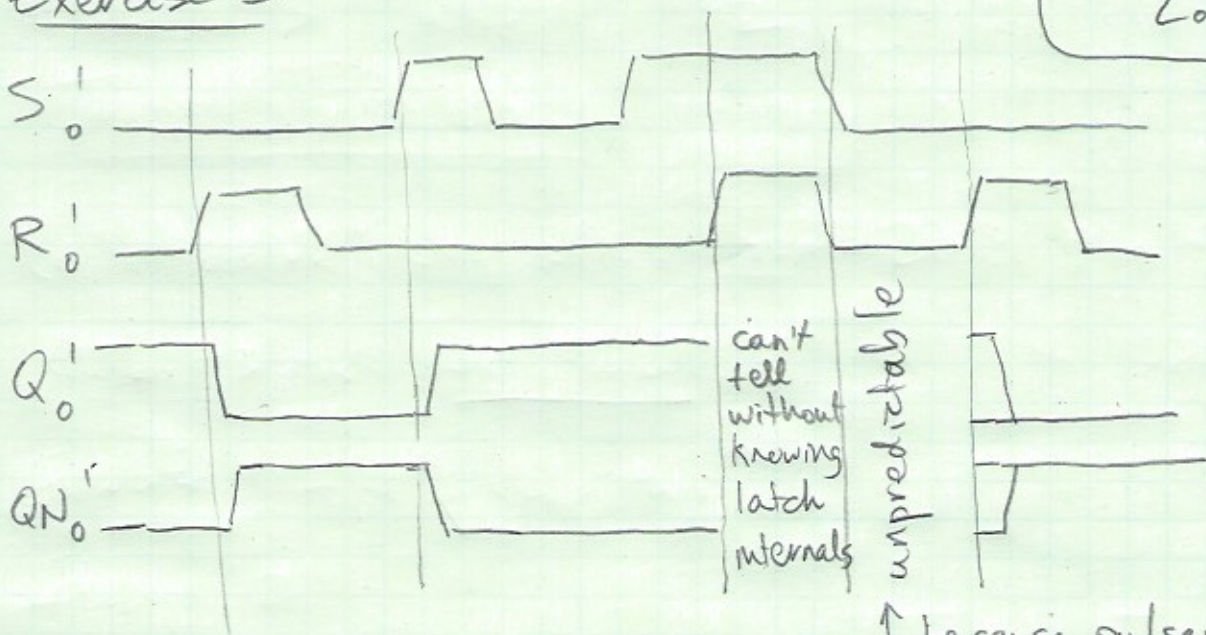
$$\text{gate 2: } QN = \overline{(R \cdot Q)} = \overline{0} = 1$$

Summary

R	S	Q	QN
0	0	same as for NOR-based latch	
0	1	1	0
1	0	0	1
1	1	1	1

← different from NOR-based latch

Exercise 3



↑ unpredictable

↑ because pulses ended together

Exercise 4

(i) D latch

When CLK is LOW, Q is whatever D was when CLK last went 1 → 0 ← opaque behaviour.

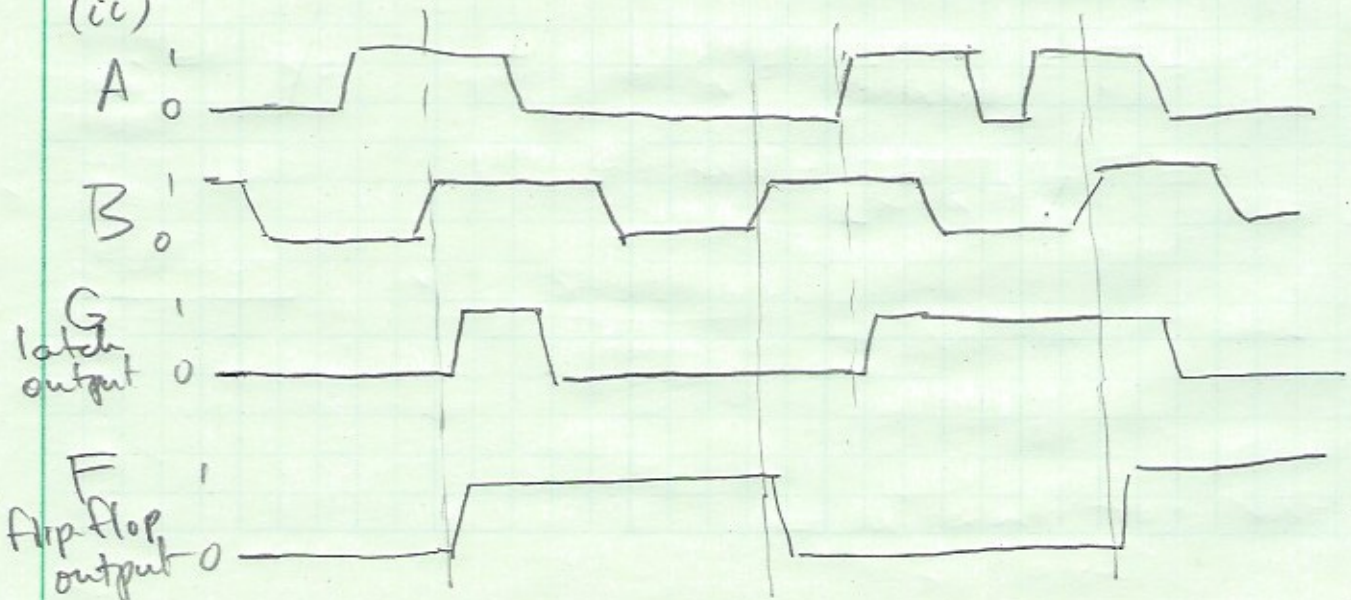
When CLK is HIGH, Q follows D ← transparent behaviour

D Flip-flop (preview of Oct 30 2019 lecture)

Q follows D on the rising edge of CLK.

Q is constant at all other times.

(ii)



## Exercise 5

Overall  $t_{cd}$  The short path (which has multiple instances) has 2 NAND gates

$$\text{overall } t_{cd} = 2 \times 29 \text{ ps} = 58 \text{ ps.}$$

$t_{pd}$  calculations

$$\text{From A or B to S : } 6 \times 40 \text{ ps} = 240 \text{ ps}$$

$$\text{From A or B to } C_{out} \quad 5 \times 40 \text{ ps} = 200 \text{ ps}$$

$$\text{From } C_{in} \text{ to S} \quad 3 \times 40 \text{ ps} = 120 \text{ ps}$$

$$\text{From } C_{in} \text{ to } C_{out} \quad 2 \times 40 \text{ ps} = 80 \text{ ps}$$

ENEL 353 T02  
Oct 29 2019  
3 of 3