

## ENEZ 353 Section 02 Lecture

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Quiz 4 - tomorrow

- circuits with DFFs, FSMs
- no questions about timing

Lab 4 - Wed for Section B03

- do the prelab carefully!

Set 9, Slide 26 (continued)

Previous lecture: We ruled out the possibility of a setup-time violation.

Let's check for hold-time violations. The constraint

$$is \quad t_{ccq} + t_{cd} \geq t_{hold}$$

For the Foo FF,  $t_{hold} = 1 \text{ ns}$

$$t_{ccq} + t_{cd} = \underbrace{30 \text{ ns}}_{\text{BAR}} + \underbrace{9 \text{ ns}}_{\text{NOT}} = 39 \text{ ns}$$

There is no violation at the D input of the Foo FF.

For the Bar FF,  $t_{hold}$  is 7 ns

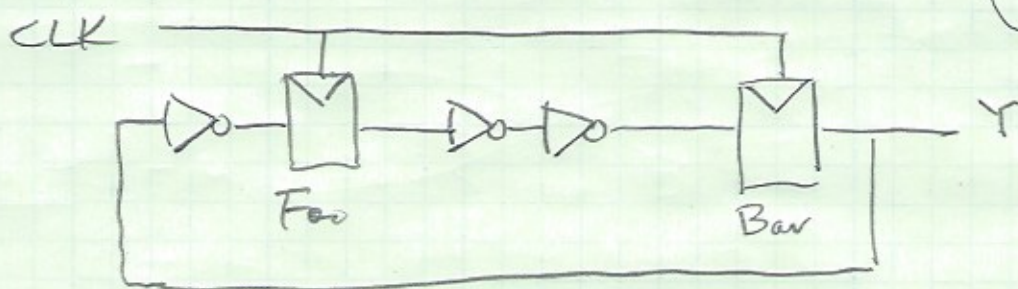
$$t_{ccq} + t_{cd} = \underbrace{5 \text{ ns}}_{\text{Foo}} + \underbrace{0 \text{ ns}}_{\text{wire}} = 5 \text{ ns}$$

There is a hold-time violation at the D input of the Bar FF. The relatively fast

Foo FF contaminates the input of the slower Bar FF.

One possible fix

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Now for the Bar FF,

$$t_{cq} + t_{cd} = \underbrace{5 \text{ ns}}_{\text{Foo } t_{cq}} + \underbrace{2 \times 9 \text{ ns}}_{\text{NOT gates}} = 23 \text{ ns}$$

$23 \text{ ns} \geq t_{\text{hold}}$  for Bar, so the violation has been fixed.

Slide 33

After a rising edge on CLK1, a rising edge may arrive at R2 on CLK2 as soon as  $T_c - t_{\text{skew}}$  later in time. In the worst case D2 takes  $t_{pcq} + t_{pd}$  to be ready.

$$t_{pcq} + t_{pd} \leq T_c - t_{\text{skew}} - t_{\text{setup}}$$

$$t_{pd} \leq T_c - (t_{pcq} + t_{\text{setup}} + t_{\text{skew}})$$

### Slide 34

D2 must stay "clean" until the hold time for R2 has passed.

$$t_{ccq} + t_{cd} \geq t_{skew} + t_{hold}$$

$$t_{cd} \geq t_{hold} + t_{skew} - t_{ccq}$$

### Slide 39

Q<sub>3</sub>: Correct response, despite the setup time violation - violation does not imply that bad behaviour is certain.

Q<sub>0</sub>: Here Q failed to copy D on the rising edge of the clock.

Q<sub>1</sub> and Q<sub>2</sub> are examples of what is called metastable response - voltage gets "stuck" part way between 0 and V<sub>DD</sub> for a while before resolving to either logic 0 or logic 1.

Important The response of Q to a setup or hold violation is inherently unpredictable.

This experiment could be run many times, possibly with different results every time.

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Slide 41 The ball cannot sit at the top of the hill forever. A tiny vibration or puff of wind will soon cause the ball to roll down into one of the valleys.

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