

Exercise 3 : Solution

EX1:

a) Signal propagation paths:

- Input-to-Reg

- Reg-to-Reg

- Reg-to-Output

- Input-to-Output

~~Not present: Input-to-output~~

Critical path delays:

$$t_{is}^{max} = 2t_{pd,c} = 1.6\text{ns} \quad t_{is}^{min} = t_{od,c} = 0.8\text{ns}$$

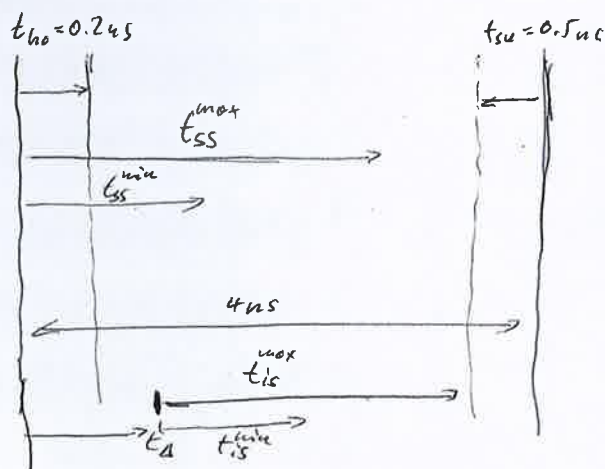
$$t_{ss}^{max} = t_{pd,ff} + 2t_{pd,c} = 2.5\text{ns} \quad t_{ss}^{min} = t_{od,ff} = 0.9\text{ns}$$

$$t_{so}^{max} = t_{pd,ff} + 2t_{pd,c} = 2.5\text{ns} \quad (03+50)$$

$$t_{so}^{min} = t_{pd,ff} = 0.9\text{ns} \quad (\text{e.g. } 02+50)$$

$$t_{io}^{max} = t_{io}^{min} = 2t_{pd,c} = 1.6\text{ns}$$

Timing diagram



Max clock speed: - Assume $t_A = 0\text{ns}$ (clock hold: $0\text{ns} + t_{is}^{min} > t_{ho} \rightarrow \checkmark$)

- check: $t_A + t_{is}^{max} < T_{clk} - t_{su} \Rightarrow T_{clk} > 2.1\text{ns}$

$$t_{ss}^{max} < T_{clk} - t_{su} \Rightarrow T_{clk} > 3\text{ns}$$

Range for stimuli appl.: given $T_{clk} = 3\text{ns}$

$$t_A + t_{is}^{max} < T_{clk} - t_{su} \rightarrow t_A < 0.9\text{ns}$$

$$t_A + t_{is}^{min} > t_{ho} \rightarrow t_A > -0.6\text{ns}$$

Output sampling: $t_T > t_A + t_{io}^{max}$ $t_T > t_{so}^{max}$ $t_A = 0 \rightarrow t_T > 2.5\text{ns}$

$$t_T < t_A + t_{io}^{min} + T \quad t_T < t_{so}^{min} + T$$

Interface parameters :

$$t_{pd} = t_{\text{to}}^{\text{max}}$$

$$t_{su} = t_{is}^{\text{max}} + t_{su} = 2.1 \text{ ns}$$

$$t_{ho} = t_{ho} - t_{is}^{\text{min}} = -0.6 \text{ ns}$$

Task 2.1

a) t_{io} ($t_{in} - t_{out}$ is not meaningful here)

b) $t_{is}^{min} = 0.1ns = t_{is}^{max}$

$t_{so}^{min} = t_{cd}^{ff} = 0.2ns$ $t_{so}^{max} = t_{pd}^{ff} + t_{pc}^c = 0.3ns$

$t_{ss}^{min} = t_{cd}^{ff} + t_{cd}^c = 0.3ns$ $t_{ss}^{max} = t_{rd}^{ff} + 2t_{pd}^c = 0.4ns$

c) $t_A = 0ns$

$t_A + t_{ic}^{max} < T_{clk} + t_{su}^{ff}$

$t_{ss}^{max} < T_{clk} - t_{so}^{ff}$

$t_A + t_{ic}^{max} = 0.1ns$

$t_{ss}^{max} = 0.4ns$

$\rightarrow T_{clk} < 0.8ns$

d)

$t_A = 0.4ns$

$t_A + t_{is}^{max} = 0.5ns$

$t_{ss}^{max} = 0.4ns$

$\rightarrow T_{clk} < 0.9ns$ (now set by t_{is})

e)

$t_A = 0ns$

$t_A + t_{is}^{min} > t_{ho} \rightarrow \text{not met} \quad \square$

$t_{ss}^{min} > t_{ho} \rightarrow \text{OK}$

Task 2.2

a) assume $t_A = 0ns$

From input through one gate to a FF

b) $t_{is} + t_A = t_A + t_{cd}^c < t_{ho}$

c) Not met!