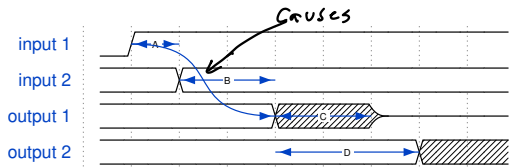


Timing Analysis

Exercise 1:



Label the specifications A through D as requirements or guaranteed responses. Which specifications are measured to a signal being in a high-impedance state? Which are measured from a rising edge only? From either?

	from	to	
A :	in 1	in 2	requirement
B :	in 2	out 1	guaranteed
C :	out 1	out 1	guaranteed
D :	out 1	out 2	guaranteed

Exercise 2: Is t_{PD} a requirement or a guaranteed response?

guaranteed response.

Exercise 3: Is t_{SU} a requirement or a guaranteed response? How about t_H ?

t_{SU} & t_H are both measured to an input \Rightarrow both requirements

Exercise 4:

$$t_{SU}(\text{avail}) = T_{\text{clock}} - t_{CO}(\text{max}) - t_{PD}(\text{max})$$

Which of the specifications in the formula above decrease the available setup time as they increase? Which increase it?

t_{CO} & t_{PD} decrease $t_{SU}(\text{avail})$ as they increase
 T_{clock} increase $t_{SU}(\text{avail})$ as it increases

Exercise 5: For a particular circuit f_{clock} is 50 MHz, t_{co} is 2 ns (maximum), the worst-case (maximum) t_{pd} in a circuit is 15 ns and the minimum setup time requirement is 5 ns. What is the setup time slack? Will this circuit operate reliably? If not, what is the maximum clock frequency at which it will?

$$f_{\text{clock}} = 50 \text{ MHz} \rightarrow T_{\text{clock}} = \frac{1}{f_{\text{clock}}} = \frac{1}{50 \times 10^6} = 20 \text{ ns.}$$

$$t_{\text{su}}(\text{avail}) = T_{\text{clock}} - t_{\text{co}} - t_{\text{pd}}$$

$$= 20 - 2 - 15 = 3 \text{ ns.} \leftarrow$$

$$\text{slack} = t_{\text{su}}(\text{avail}) - t_{\text{su}}(\text{req'd})$$

$$= \underline{3} - 5 = -2 \text{ ns.}$$



Solve for T_{clock} :

$$t_{\text{su}}(\text{avail}) = 5 \text{ ns} = T_{\text{clock}} - t_{\text{co}} - t_{\text{pd}}$$

$$5 = T_{\text{clock}} - 2 - 15$$

$$T_{\text{clock}} = 5 + 2 + 15 = 22 \text{ ns}$$

$$f_{\text{clock}} = \frac{1}{22 \text{ ns}} \approx 45.5 \text{ MHz.}$$

Exercise 6: What is the maximum clock frequency for a counter using flip-flops with 200 ps setup times, 50 ps ~~hold~~ times and adder logic that has a 250 ps propagation delay? t_{co}

$$T_{\text{clock}} = ?$$

$$t_{\text{su}} = 200 \text{ ps}$$

$$t_{\text{co}} = 50 \text{ ps}$$

$$t_{\text{pd}} = 250 \text{ ps}$$

$$T_{\text{clock}} = t_{\text{su}} + t_{\text{co}} + t_{\text{pd}} = 500 \text{ ps}$$

$$2 \text{ GHz}$$