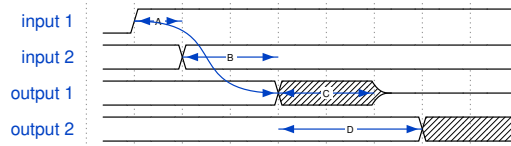


## Timing Analysis

### 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?

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

**Exercise 3:** Is  $t_{\text{SU}}$  a requirement or a guaranteed response? How about  $t_{\text{H}}$ ?

**Exercise 4:**

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

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

**Exercise 5:** For a particular circuit  $f_{\text{clock}}$  is 50 MHz,  $t_{\text{CO}}$  is 2 ns (maximum), the worst-case (maximum)  $t_{\text{PD}}$  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?

**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?