Path Delay

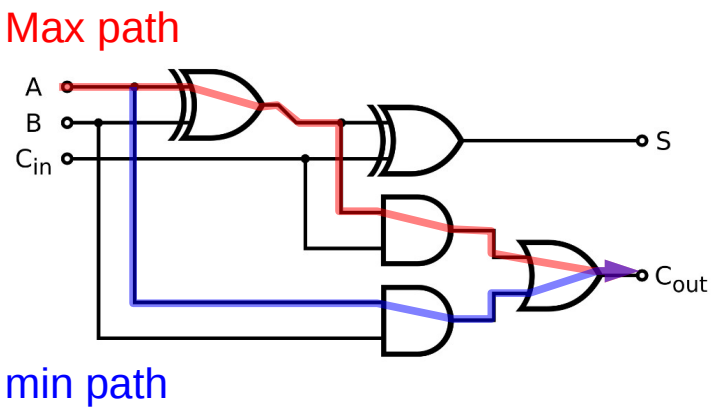
Please send corrections (or suggestions) to youngwlim@hotmail.com.

This document was produced by using OpenOffice and Octave.

Gate Delay

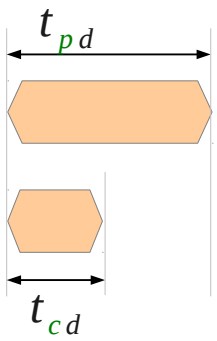
Fan out
Path Delay
Max-Path
Min-Path
Clock
Setup & Hold Time
Metastability
Synchronizer

Max Path / Min Path



Max delay

min delay

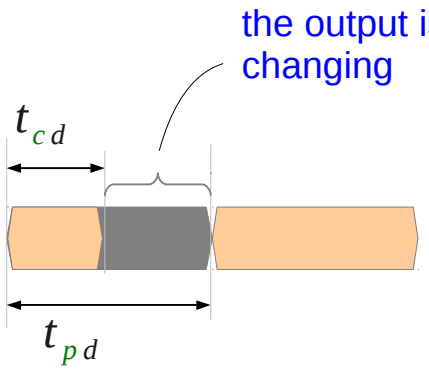


contamination delay

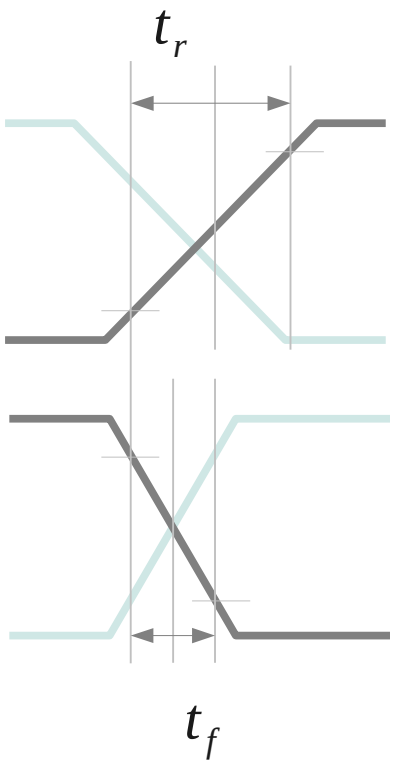
propagation delay

$$t_{cd} \leq t_{delay} \leq t_{pd}$$

min delay Max delay

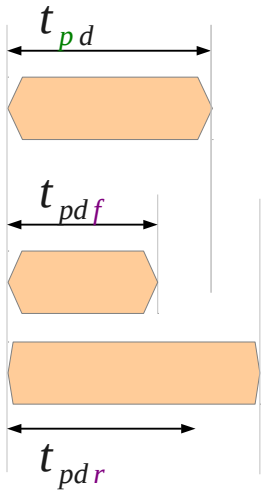


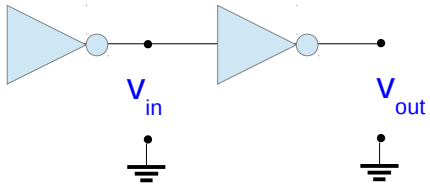
Rise / Fall Times



Max delay

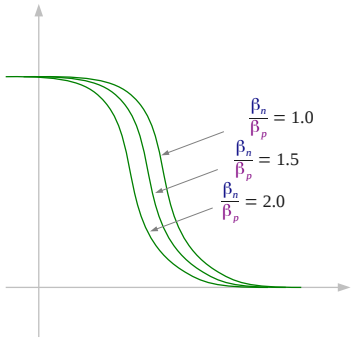
min delay

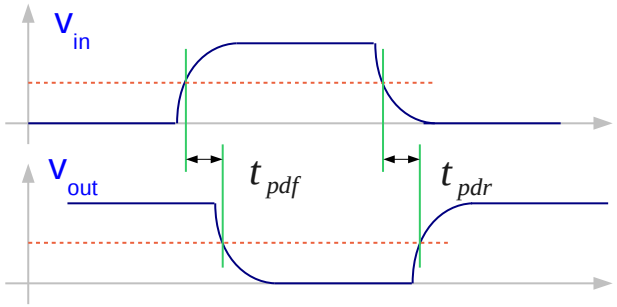




$$\frac{\beta_n}{\beta_p} > 1 \qquad \frac{R_n}{R_p} < 1$$

$$\frac{t_f}{t_r} = \frac{2.2\,\tau_n}{2.2\,\tau_p} \qquad \frac{\tau_n}{\tau_p} = \frac{R_n C_{out}}{R_p C_{out}} = \frac{R_n}{R_p} < 1$$



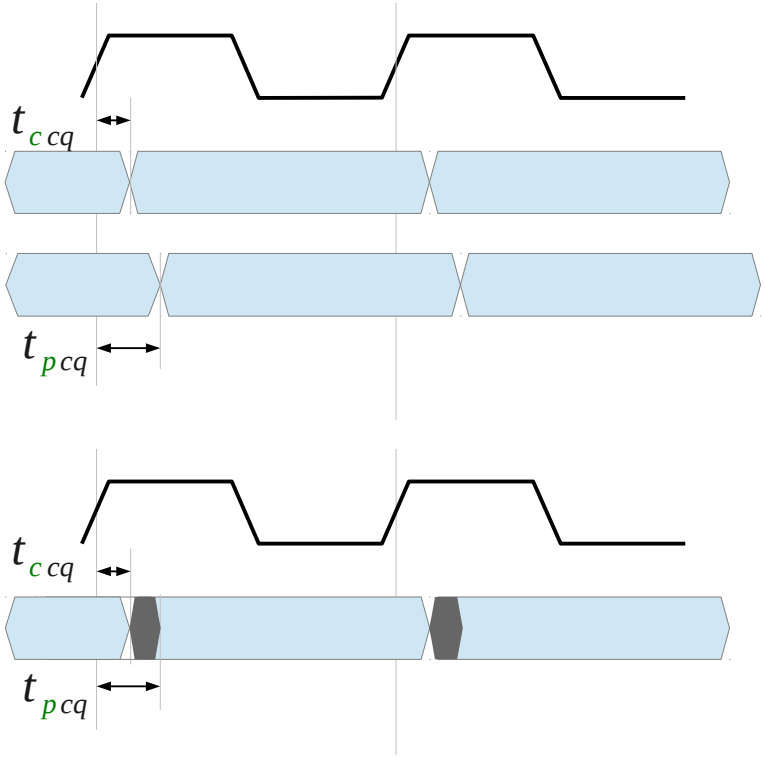


PVT Variation

- Process
- Voltage
- Temperature

High temperature	Max delay
Low temperature	min delay

FF Output Delay



contamination delay

propagation delay

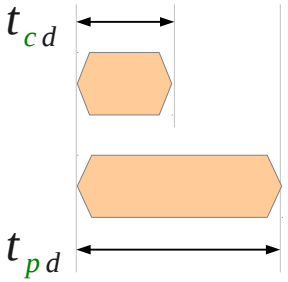
flipflop clock-to-q

$$t_{c\,cq} \leq t_{delay} \leq t_{p\,cq}$$

min delay

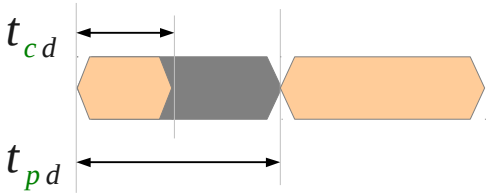
Max delay

Path Delay



contamination delay

propagation delay



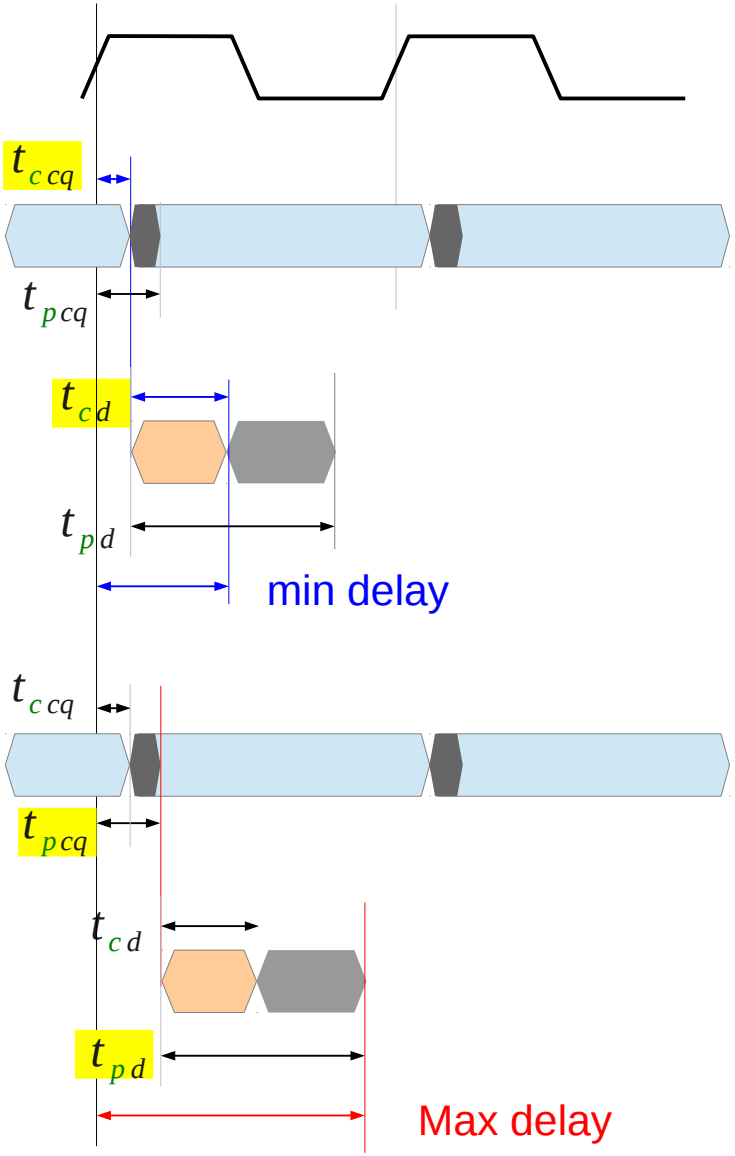
combinational logic delay

$$t_{cd} \leq t_{delay} \leq t_{pd}$$

min delay

Max delay

Reg-to-Reg Delay (1)



$$t_{c\,cq} \le t_{FF} \le t_{p\,cq}$$

min delay Max delay

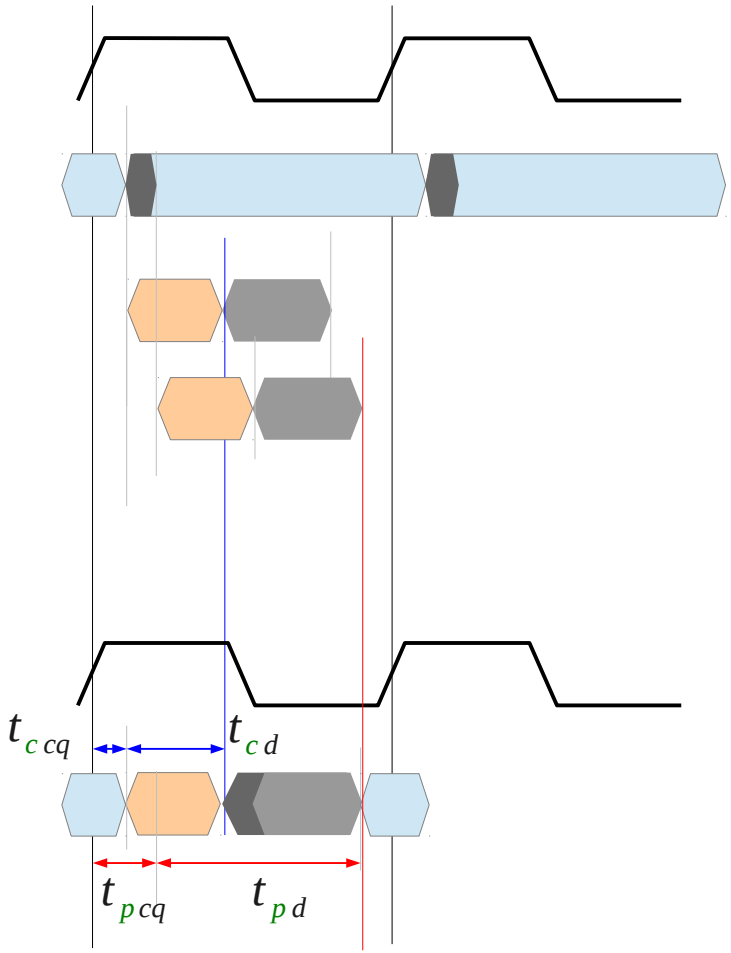
$$t_{c\,d} \le t_{comb} \le t_{p\,d}$$

min delay Max delay

$$t_{c\,cq} + t_{c\,d} \le t_{delay} \le t_{p\,cq} + t_{p\,d}$$

min delay Max delay

Reg-to-Reg Delay (2)



$$t_{c\,cq} \le t_{FF} \le t_{p\,cq}$$

min delay Max delay

$$t_{c\,d} \le t_{comb} \le t_{p\,d}$$

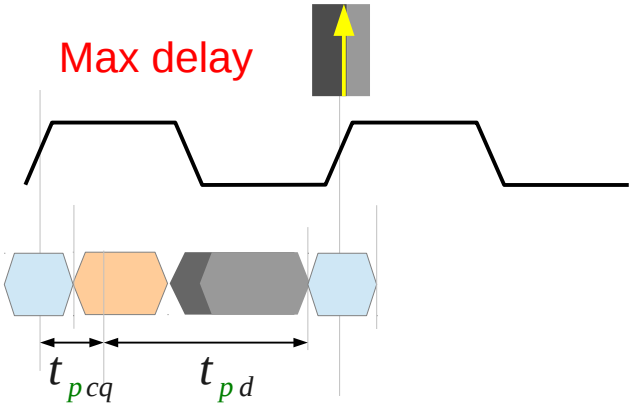
min delay Max delay

$$t_{c\,cq} + t_{c\,d} \le t_{delay} \le t_{p\,cq} + t_{p\,d}$$

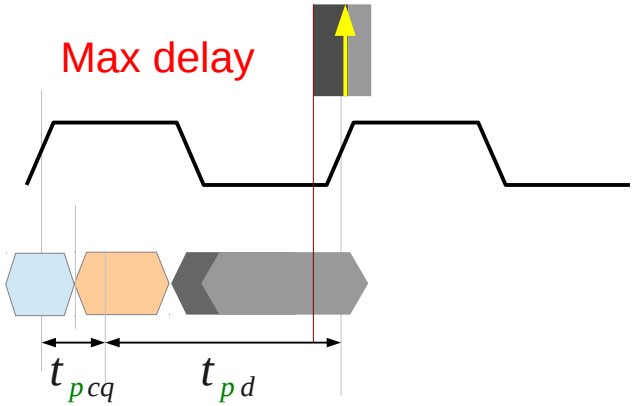
min delay Max delay

Setup Time / Hold Time

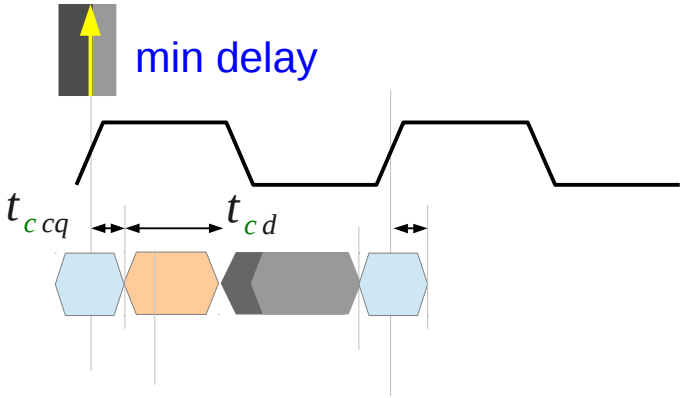
Setup Time OK



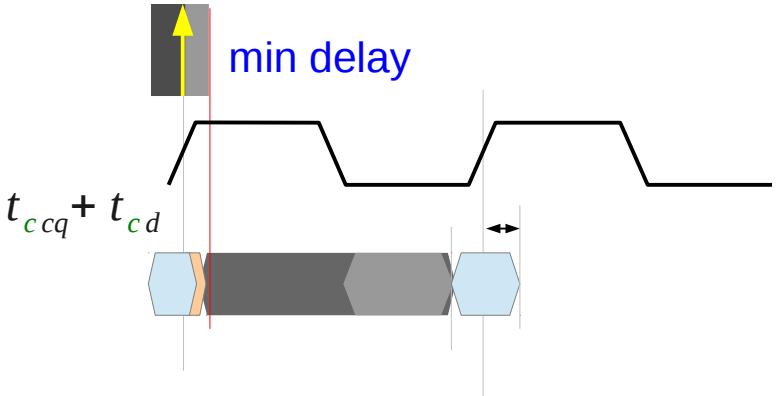
Setup Time Violation



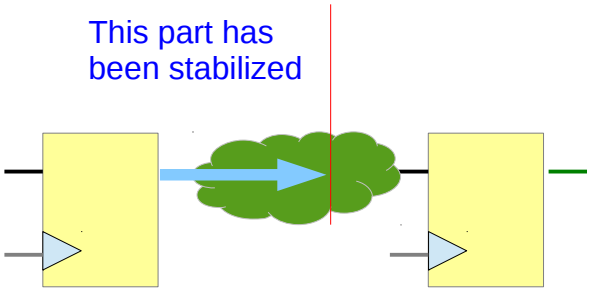
Hold Time OK



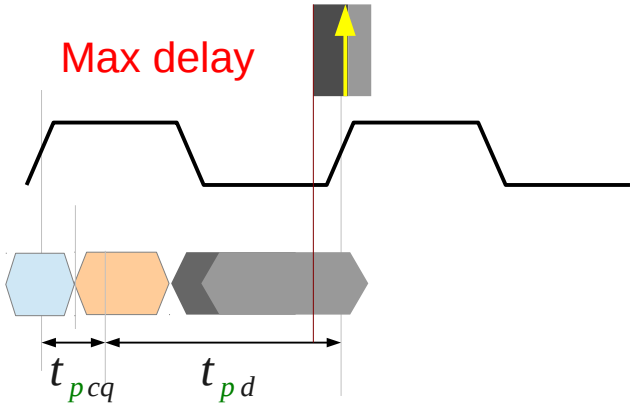
Hold Time Violation

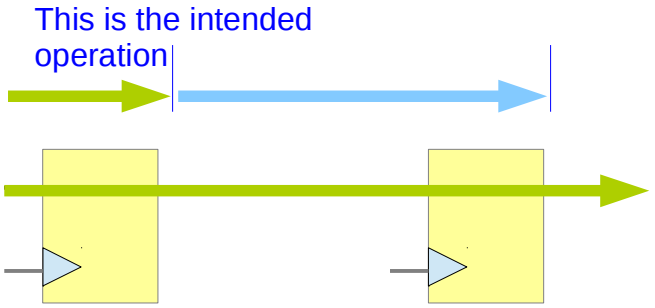


Setup Time / Hold Time



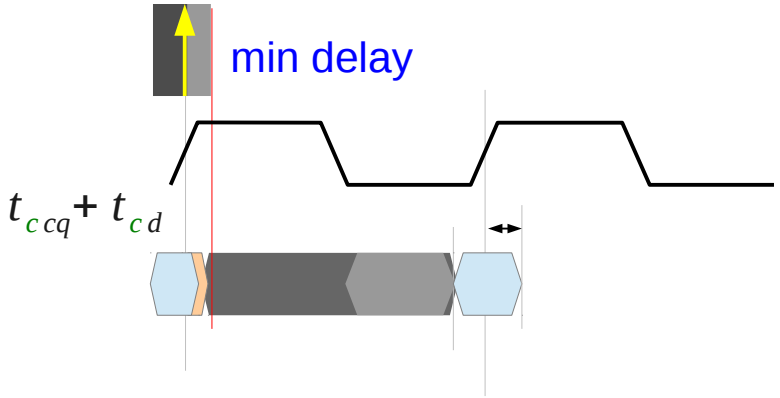
Setup Time Violation





Since the delay is too
small signal passes
through the 2nd FF

Hold Time Violation



References

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[4] N. Weste, D. Harris, “CMOS VLSI Design: A Circuits and Systems Perspective”
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[10] https://en.wikiversity.org/wiki/The_necessities_in_Computer_Organization