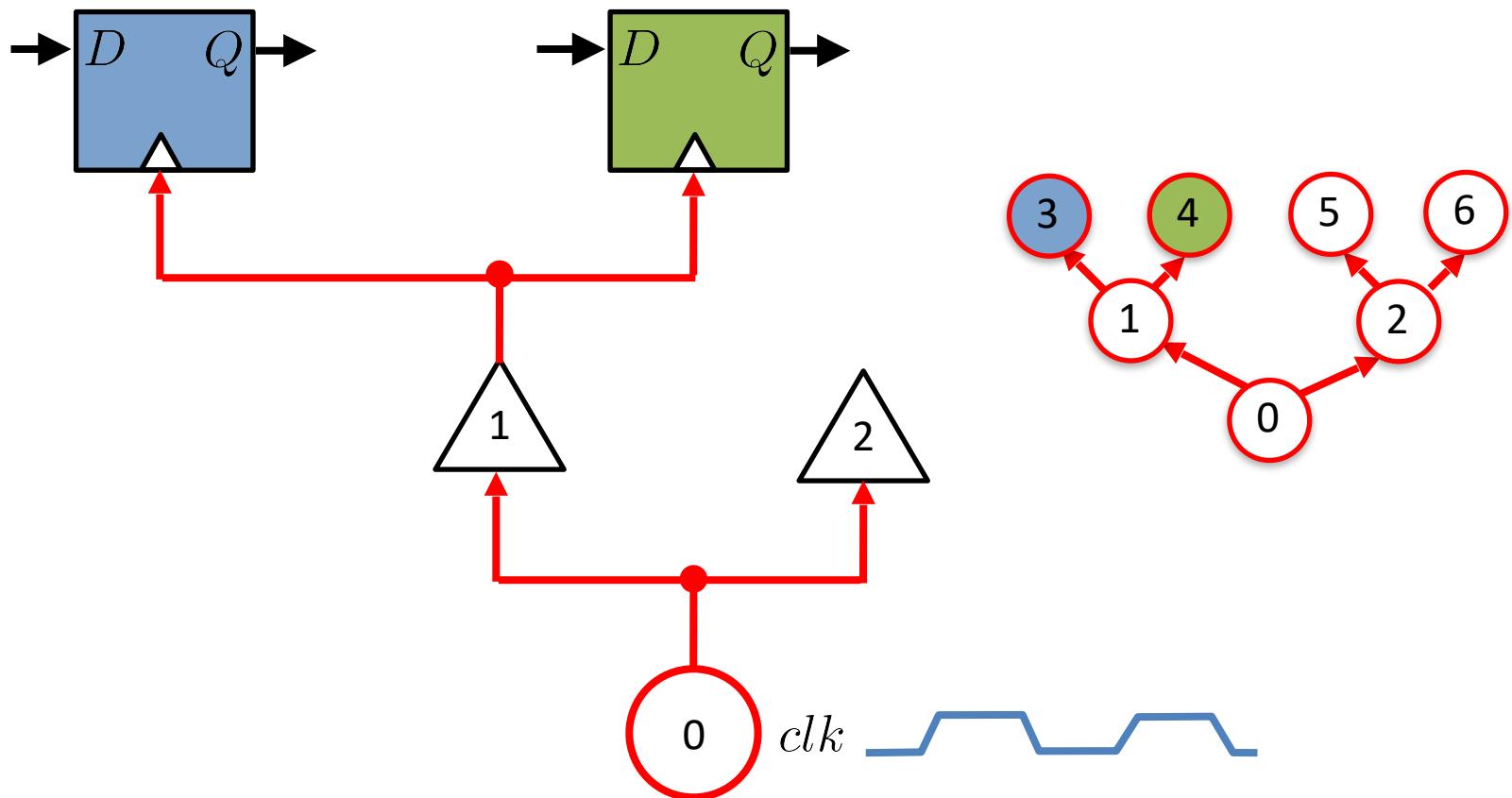


Chapter 11

Low-degree clock distribution networks

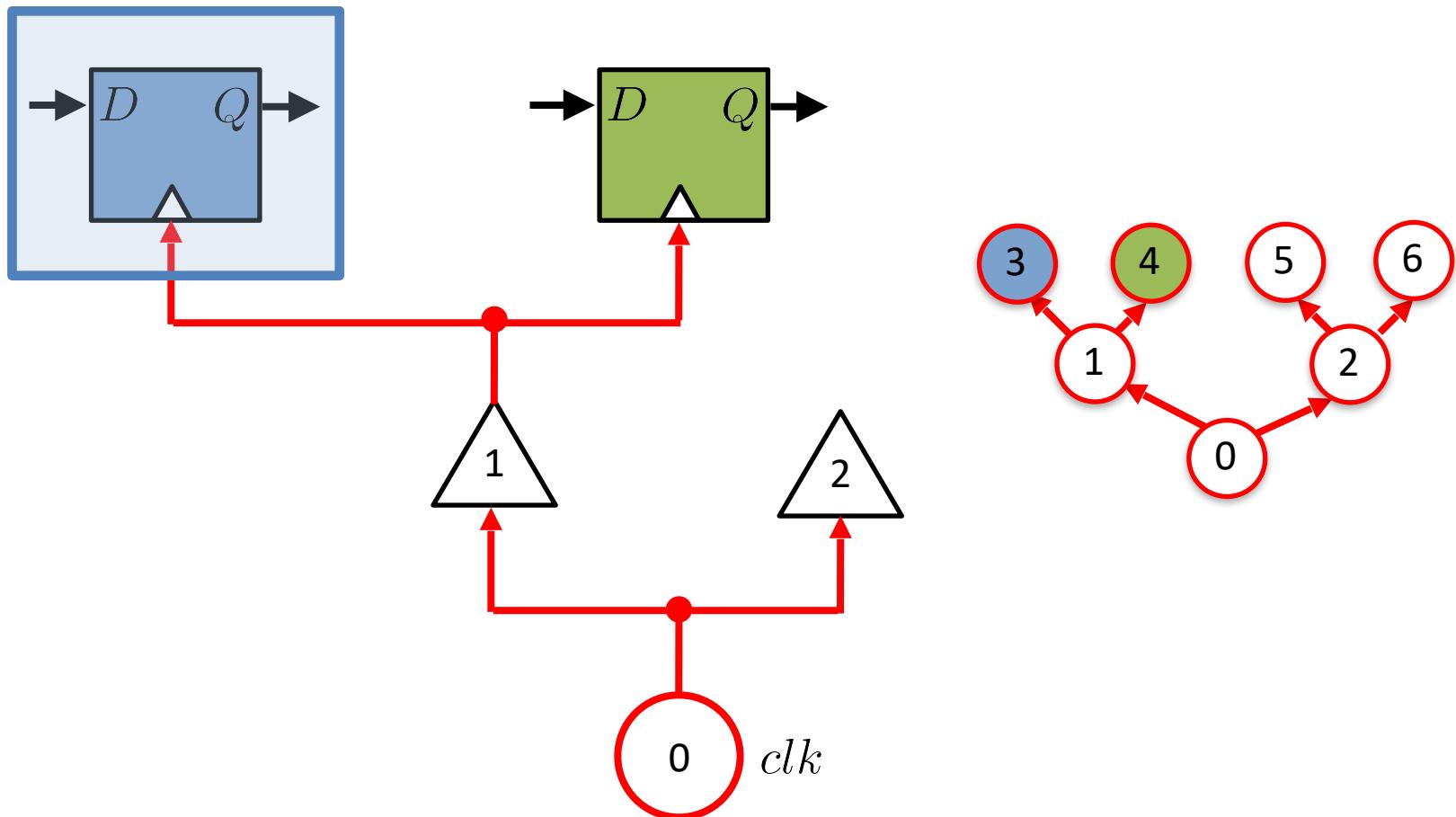
Matthias Fuegger and Christoph Lenzen

Clock distribution network

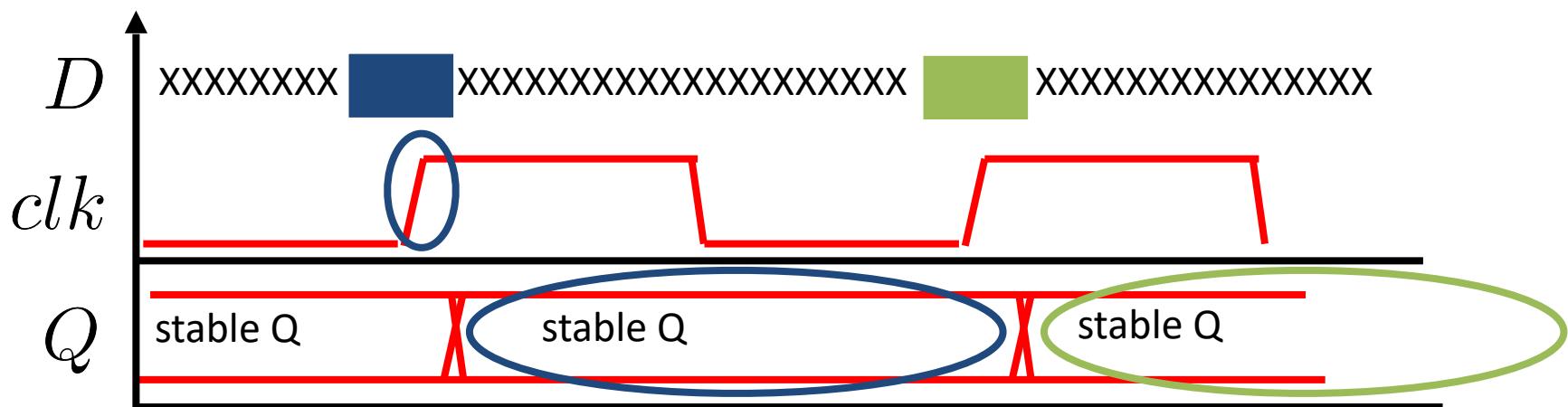
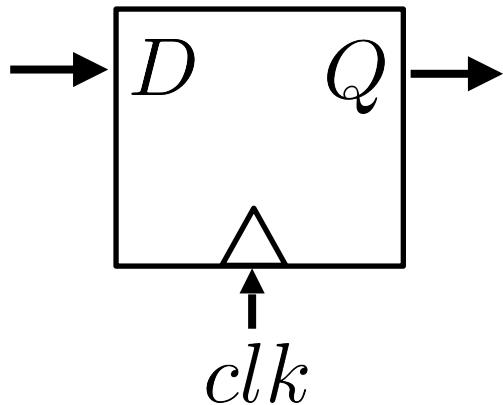


Quick summary...

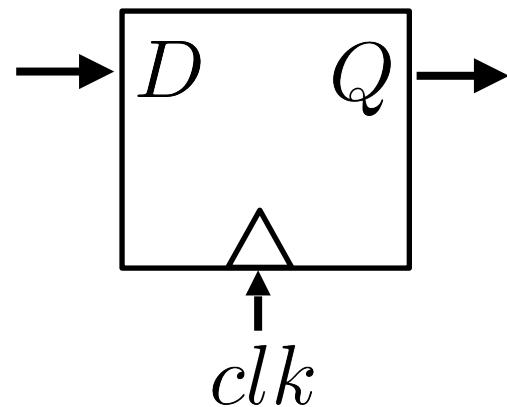
Clock distribution network



Flip-flop = edge triggered copy

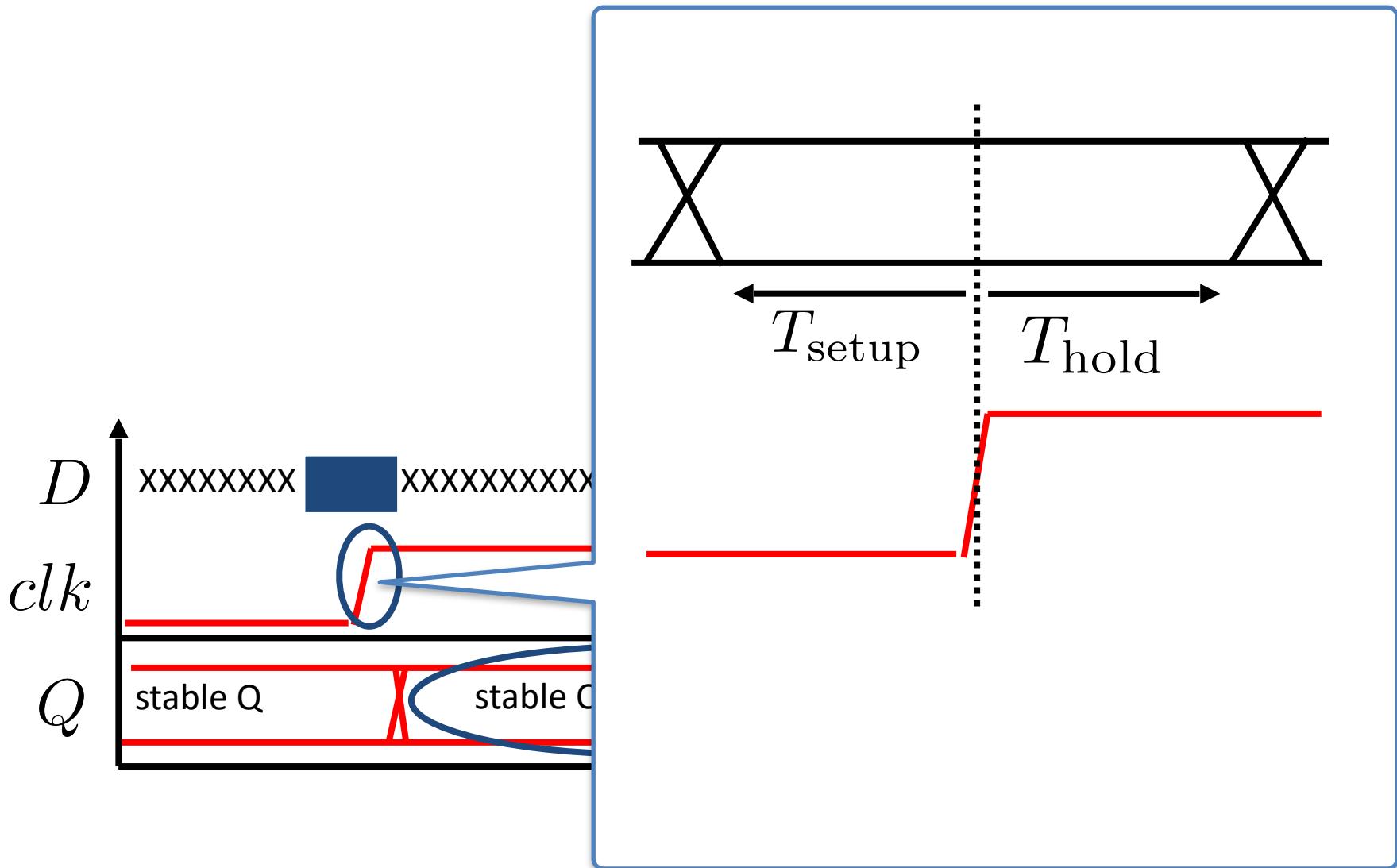


Flip-flop = edge triggered copy

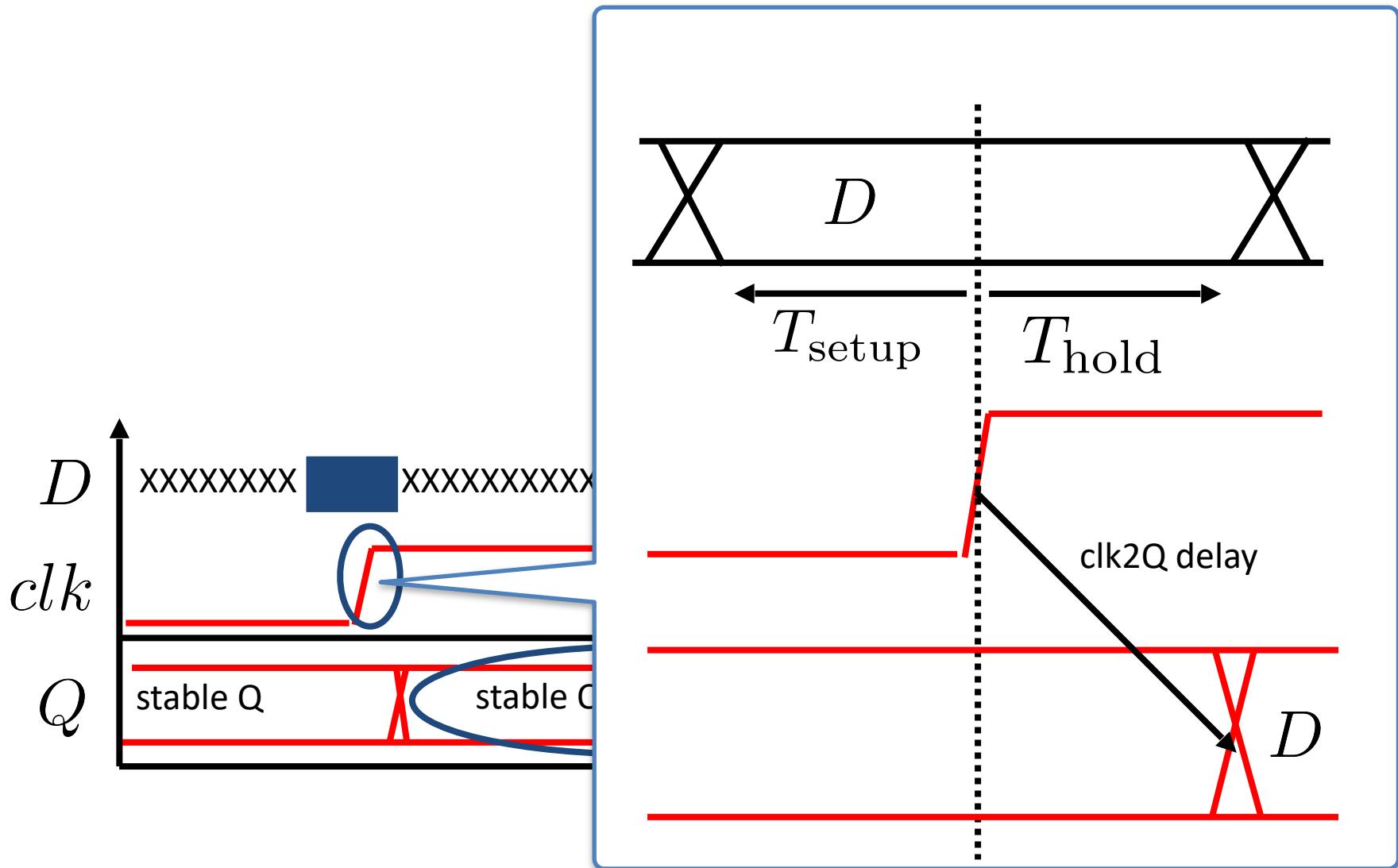


```
-- FF
FF: process (clk, D)
begin
    if (clk'event and clk = '1') then
        Q <= D;
    end if;
end process FF;
```

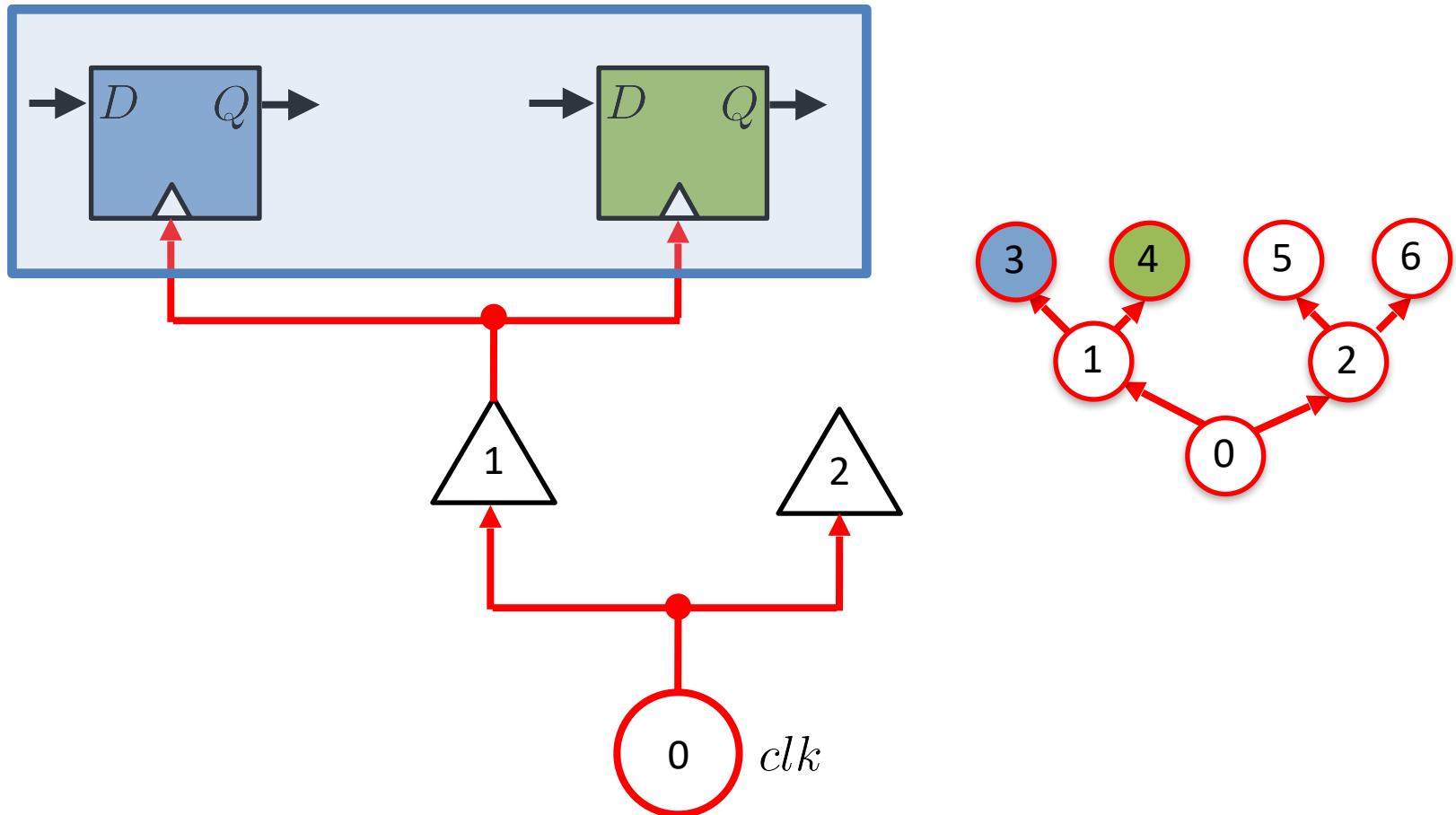
Timing: constraints



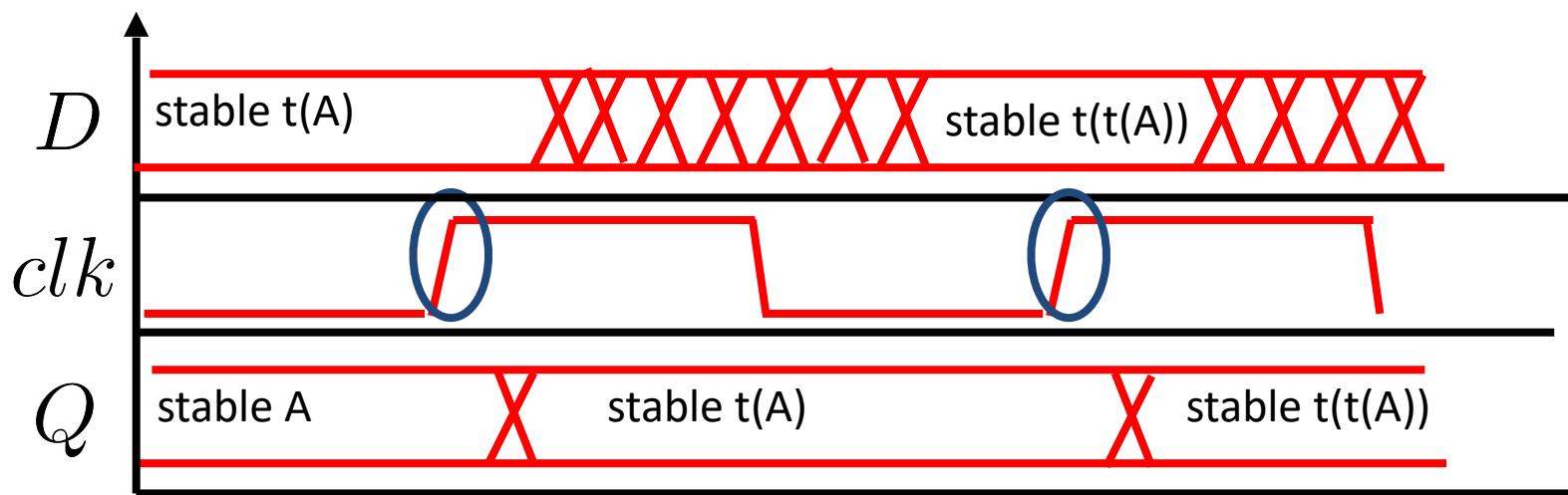
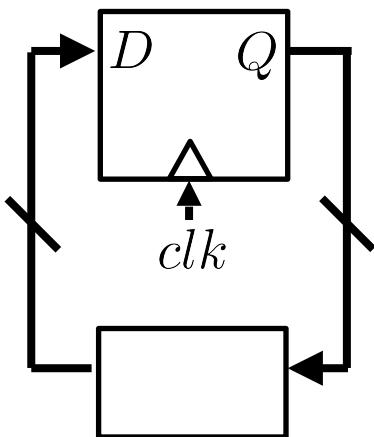
Timing: guarantees

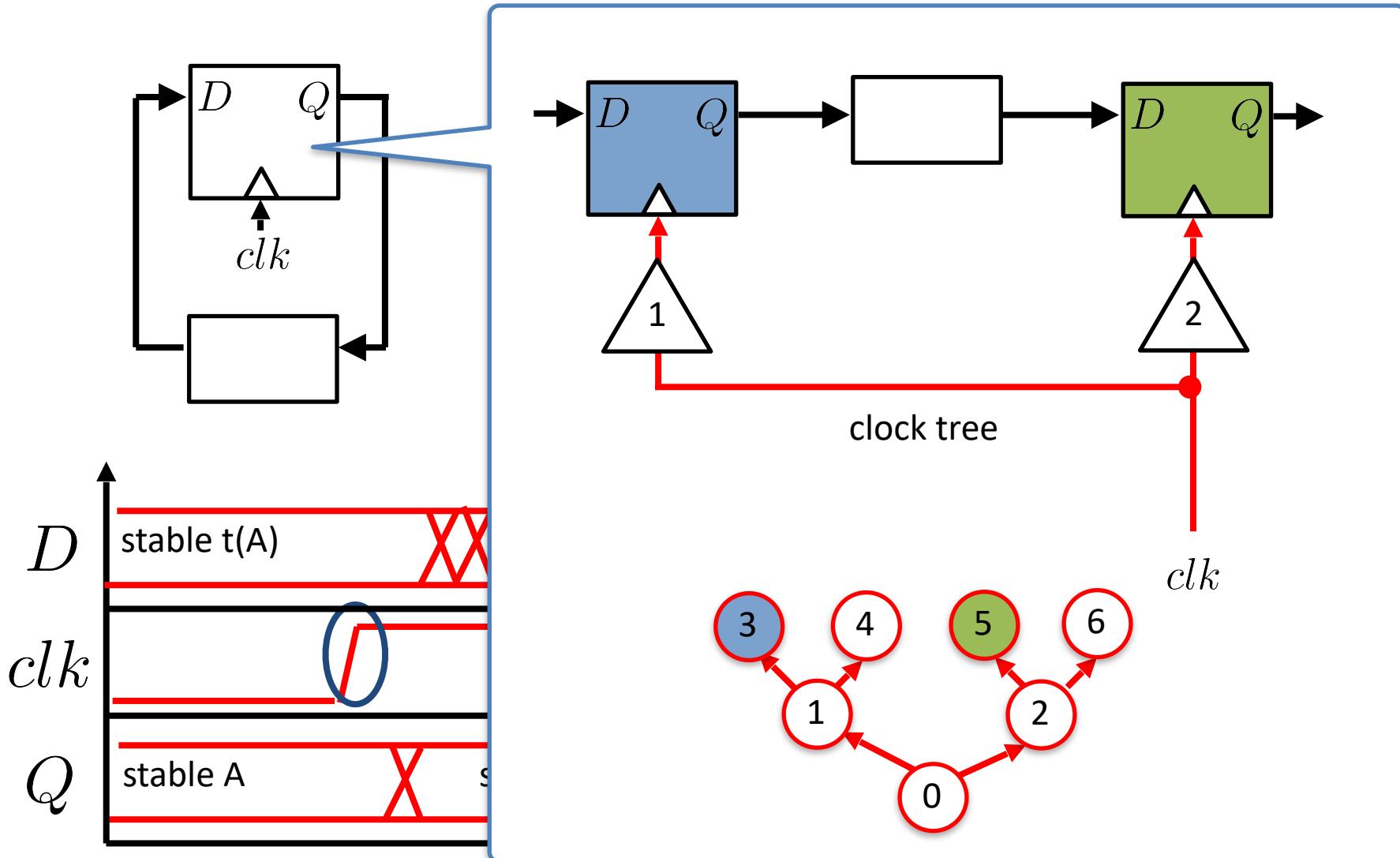


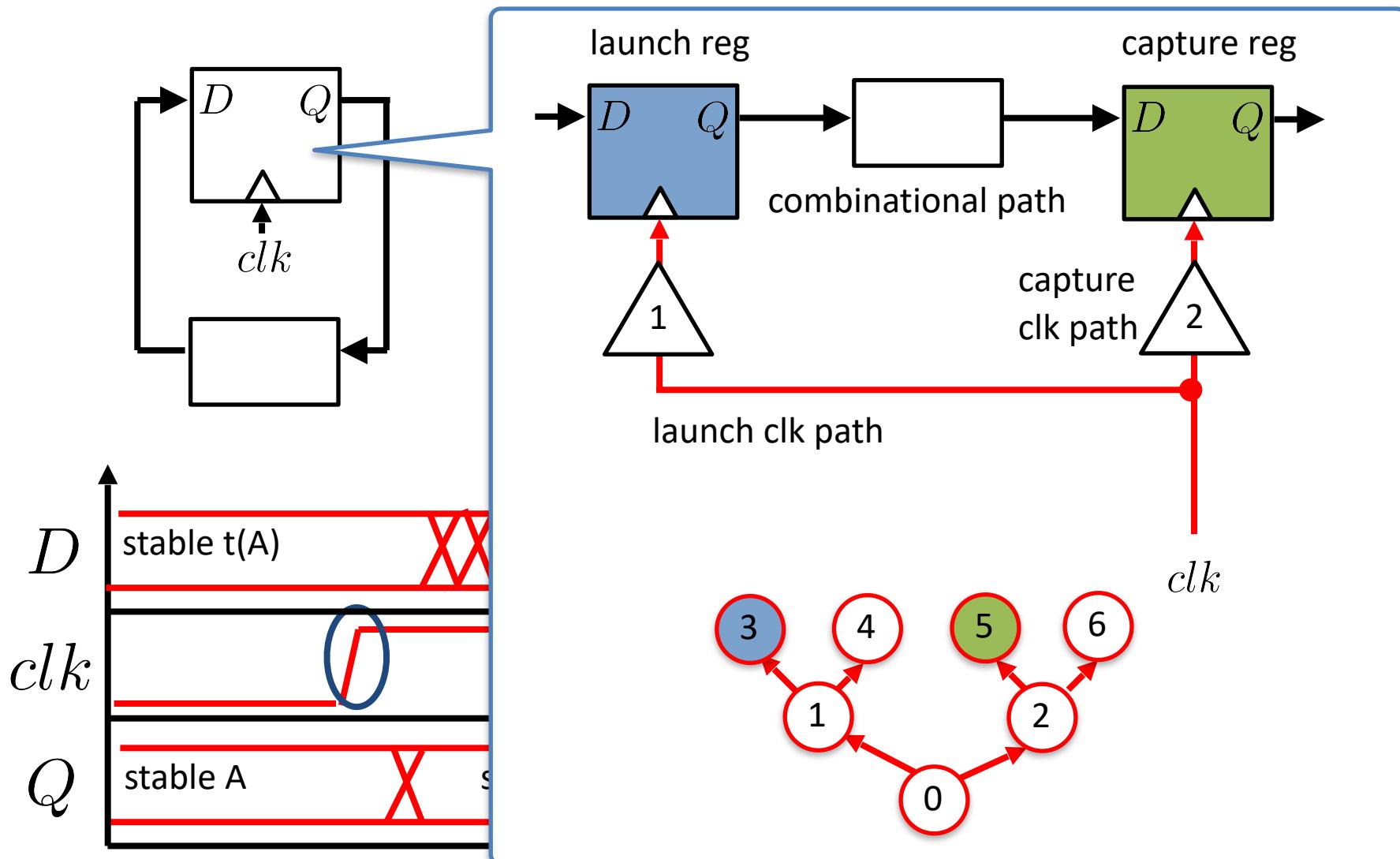
Goal: small skew

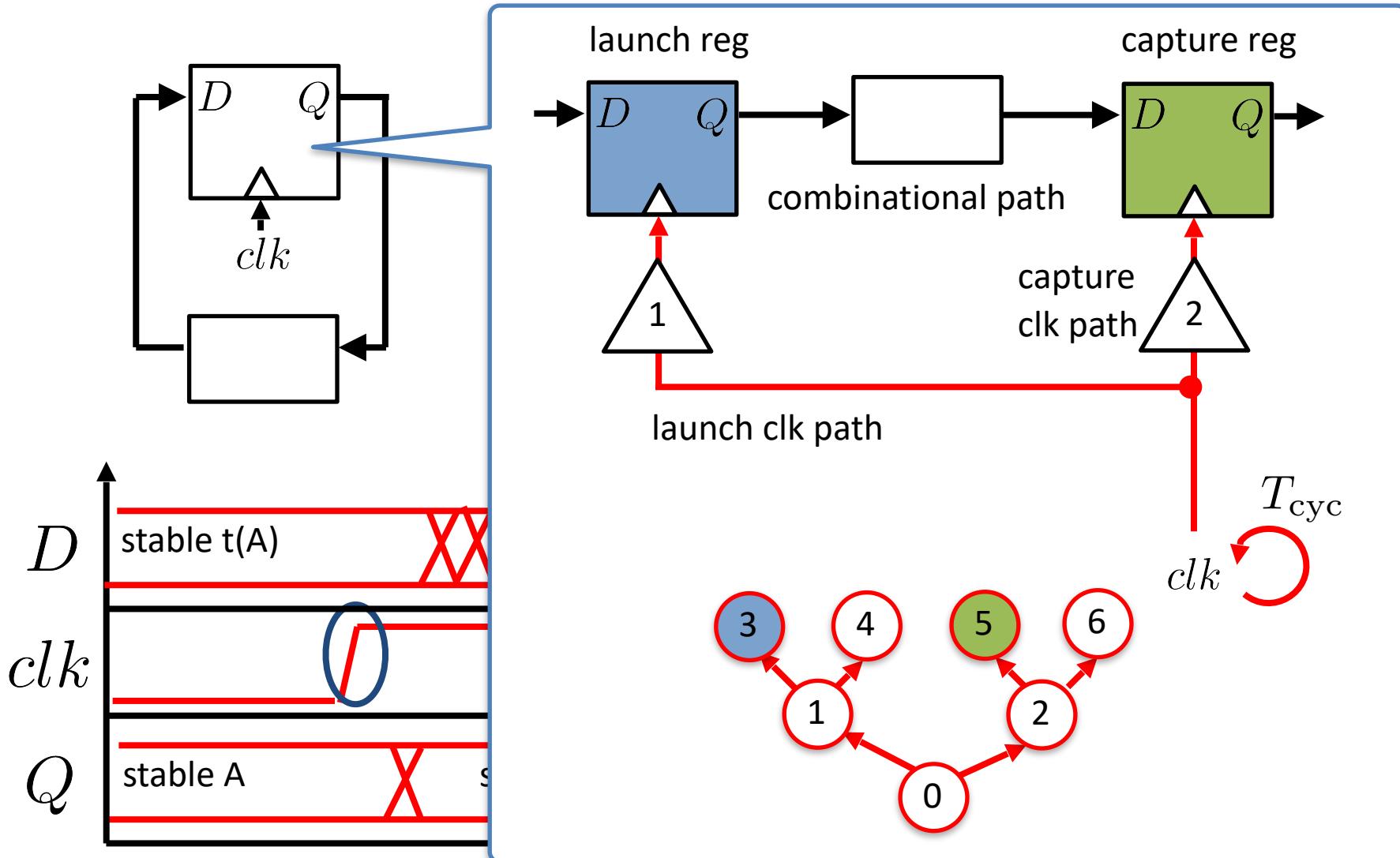


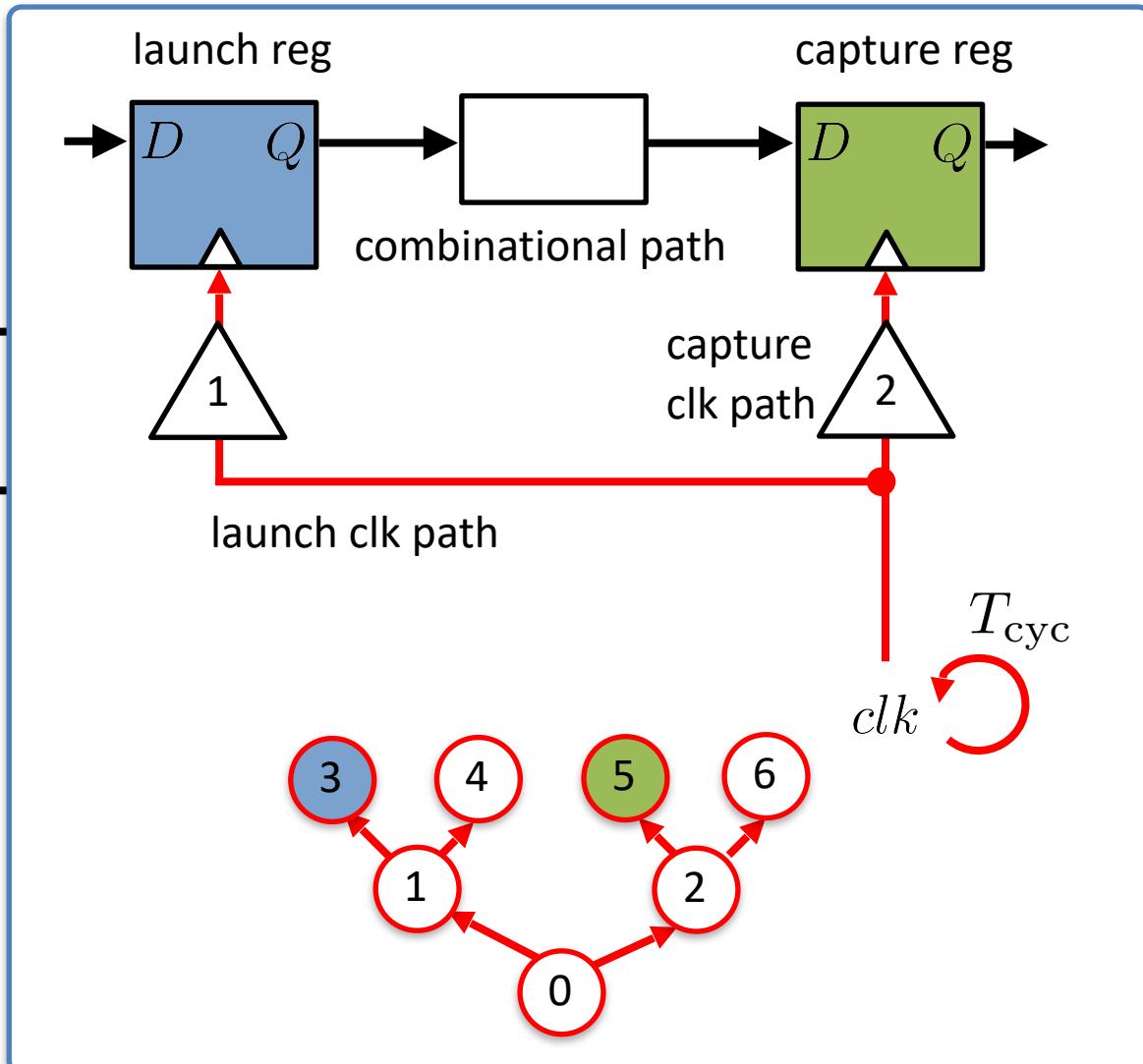
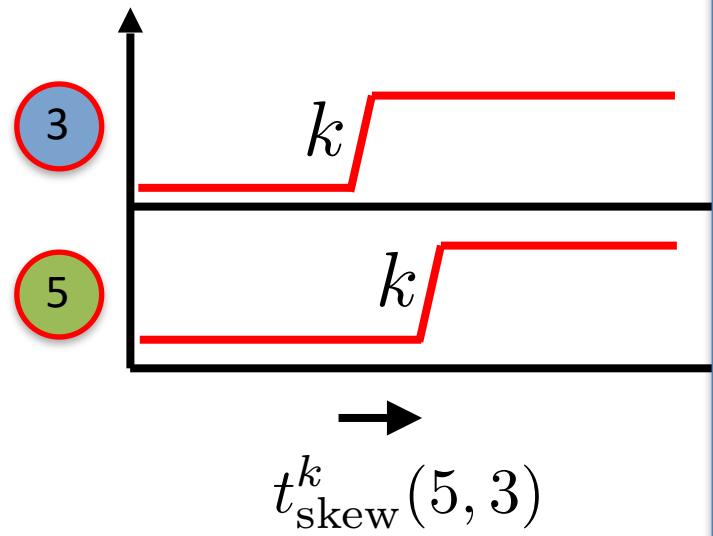
Clocked Design

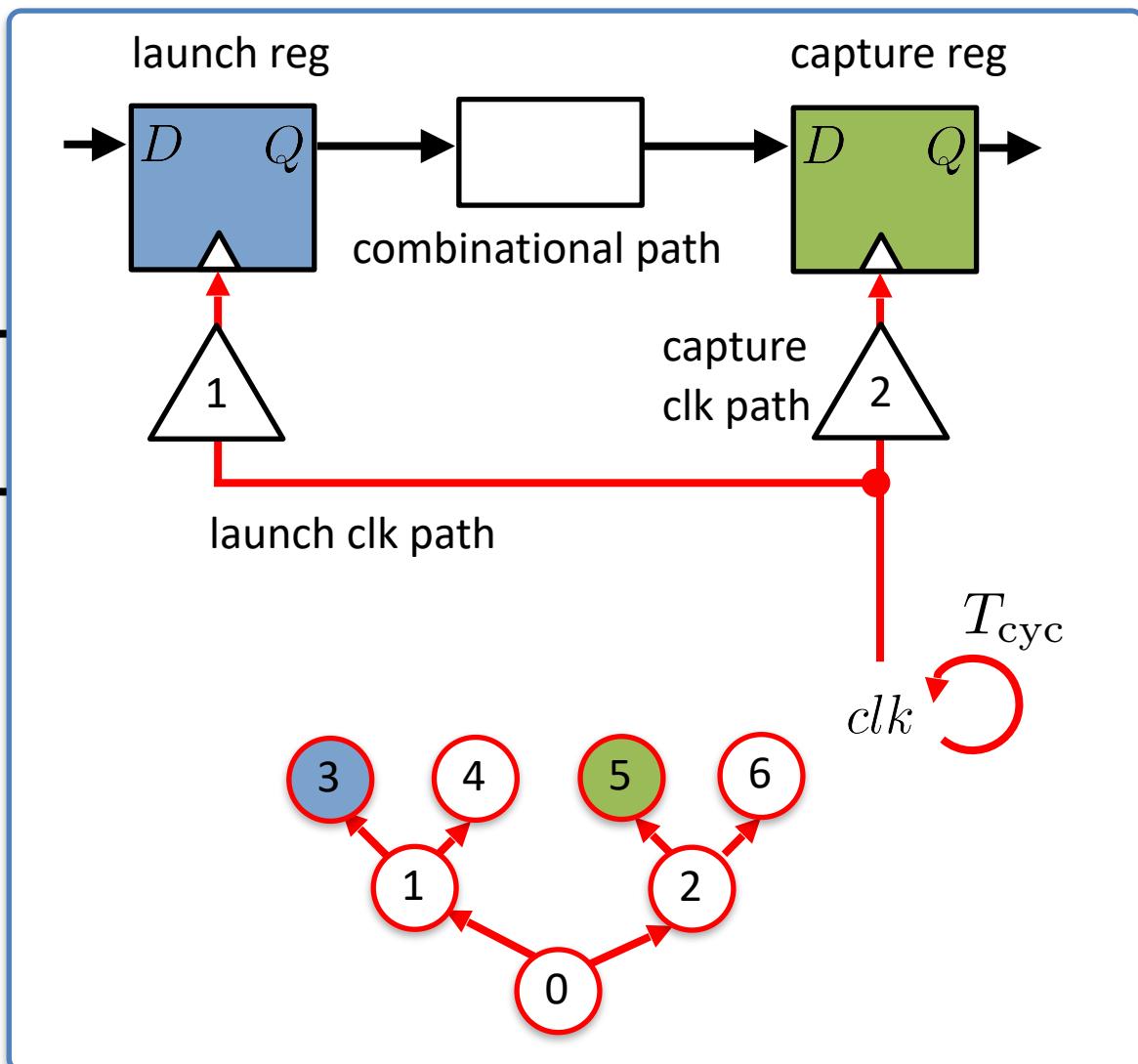
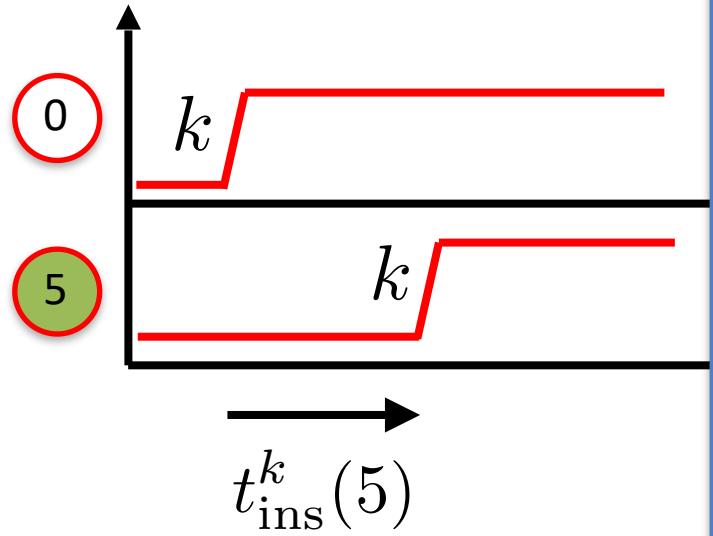


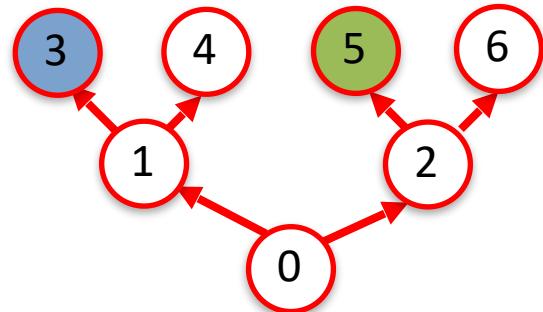
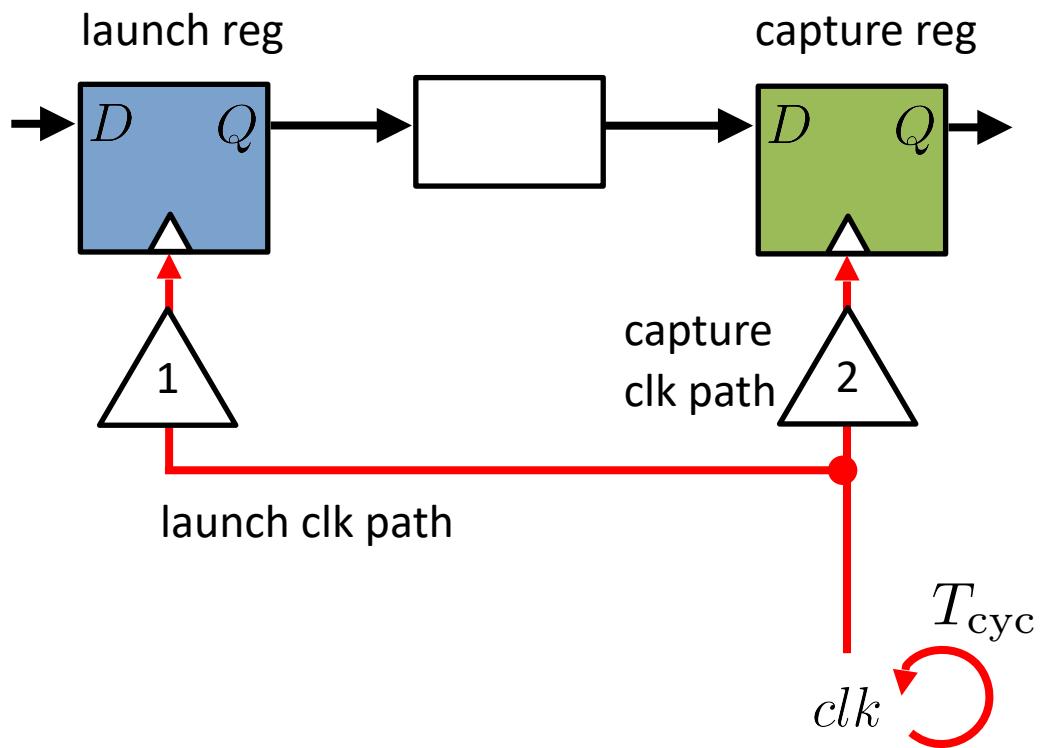




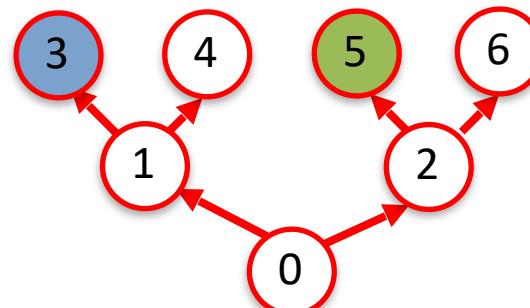
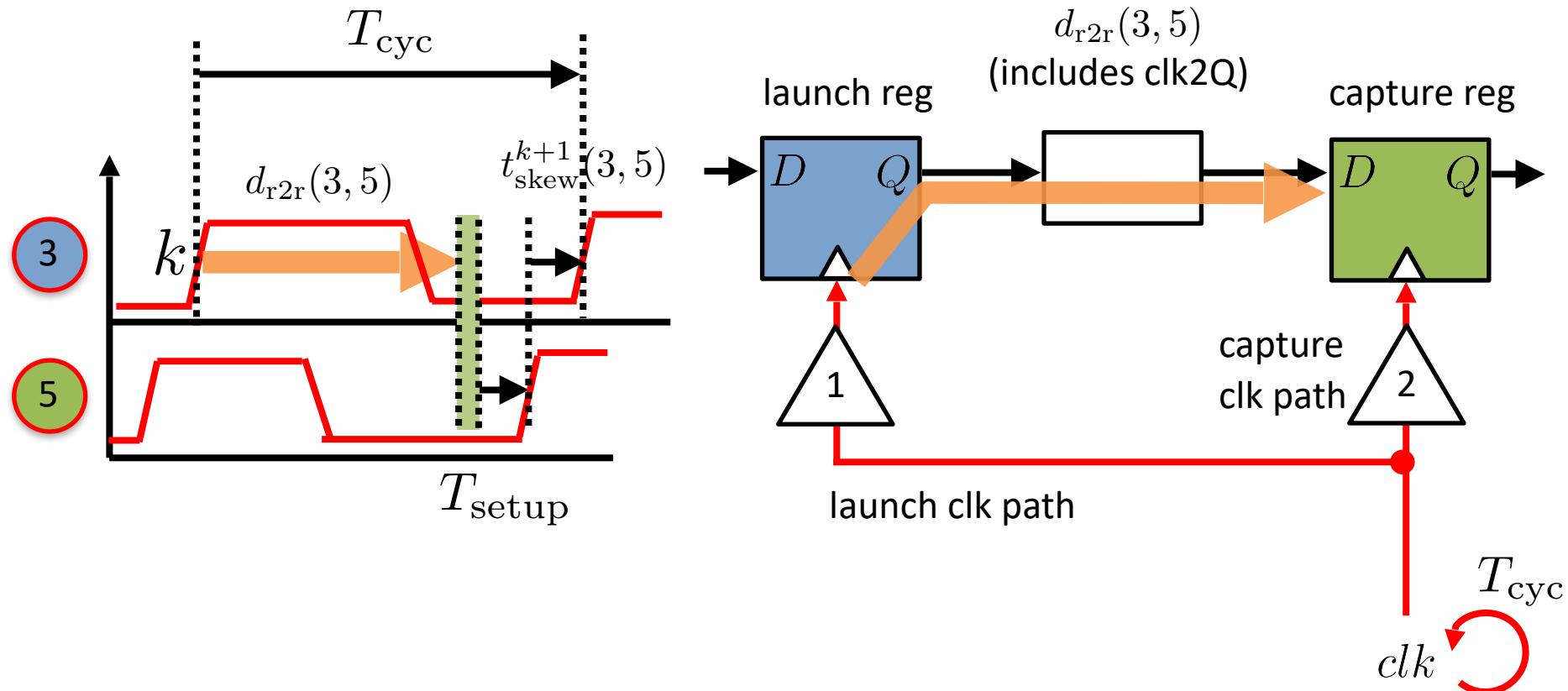




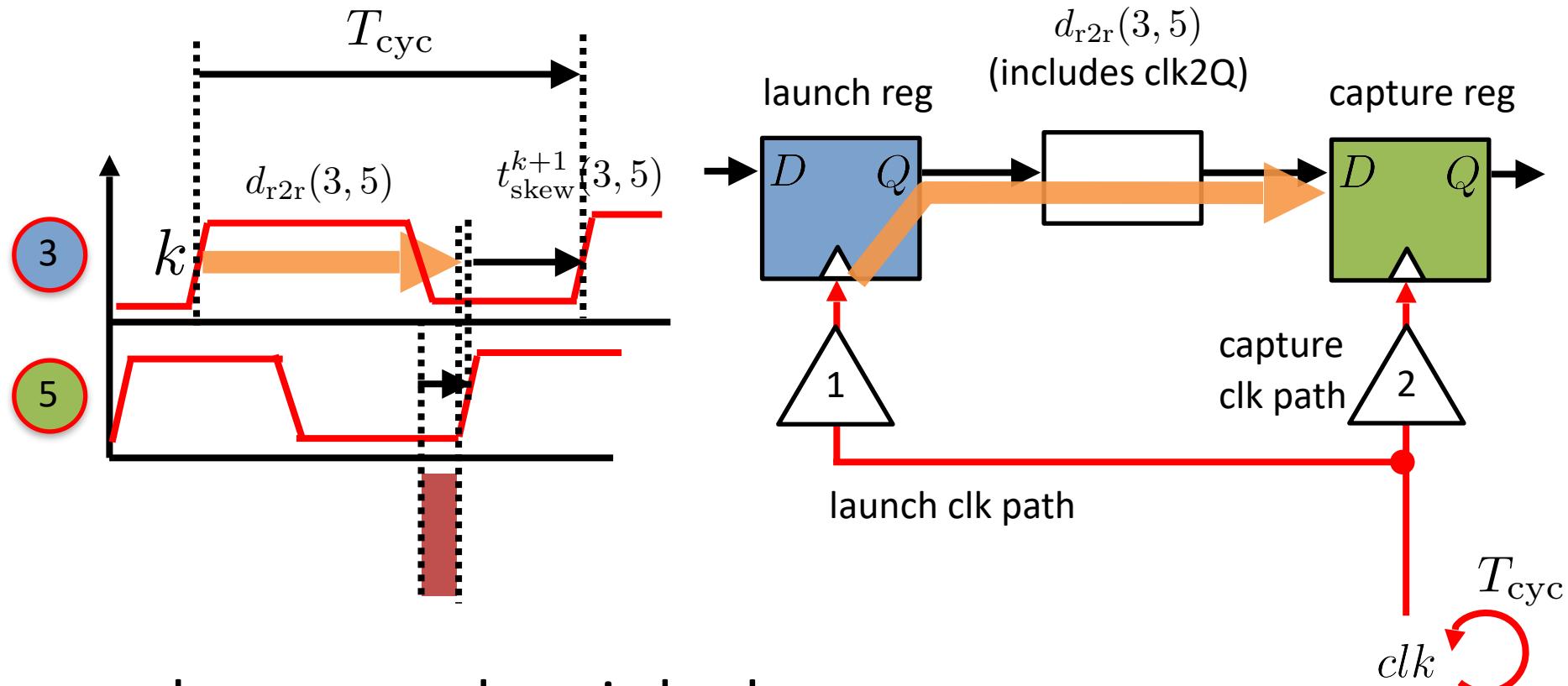




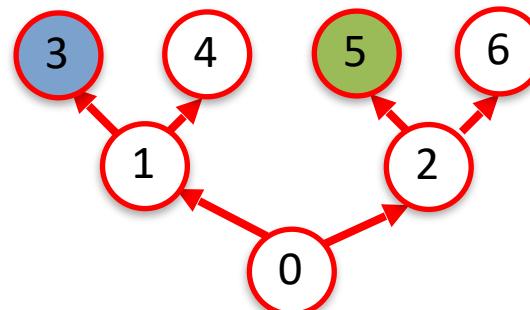
The setup constraint



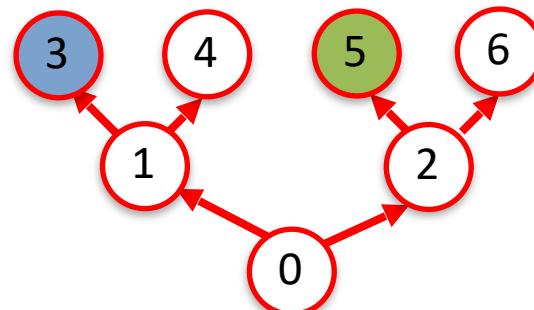
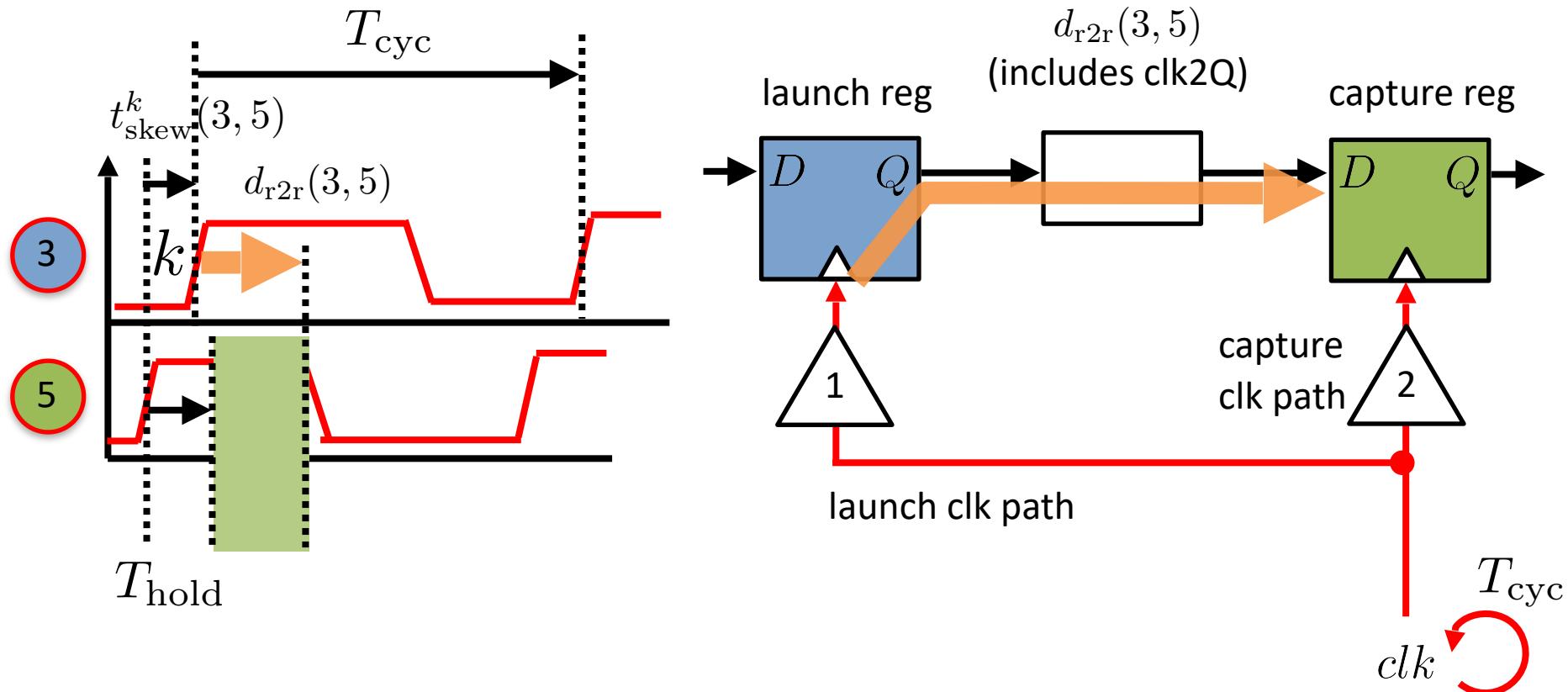
The setup constraint



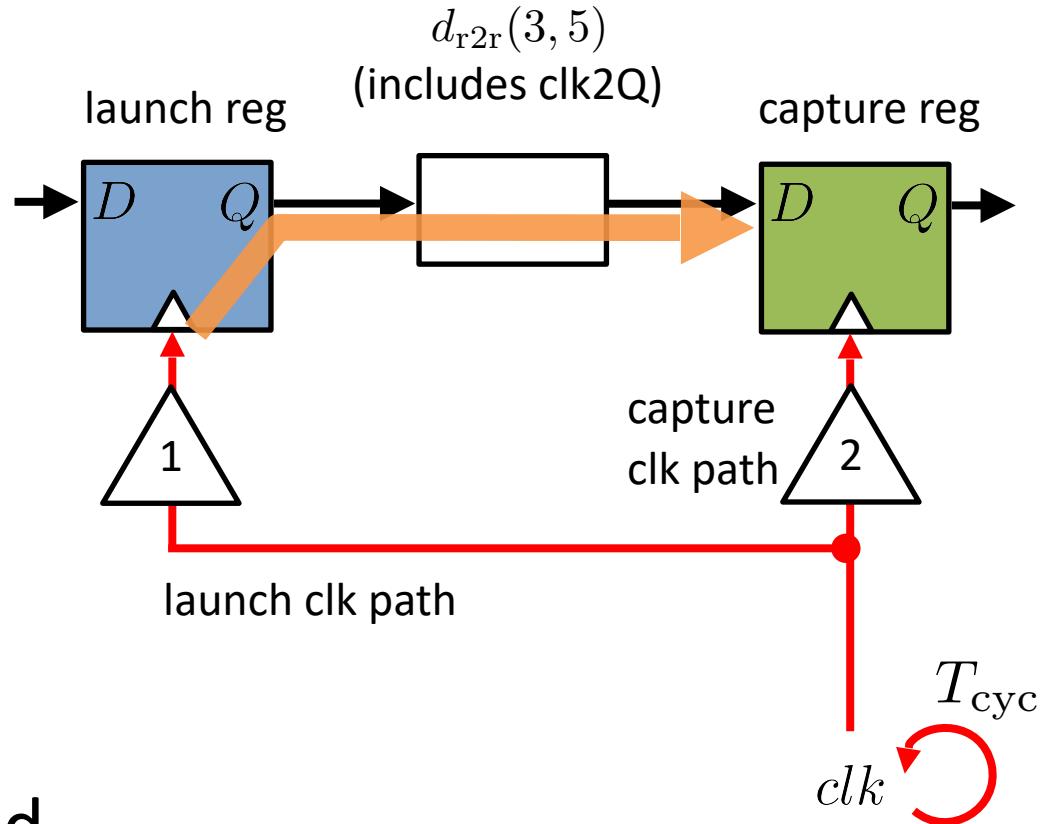
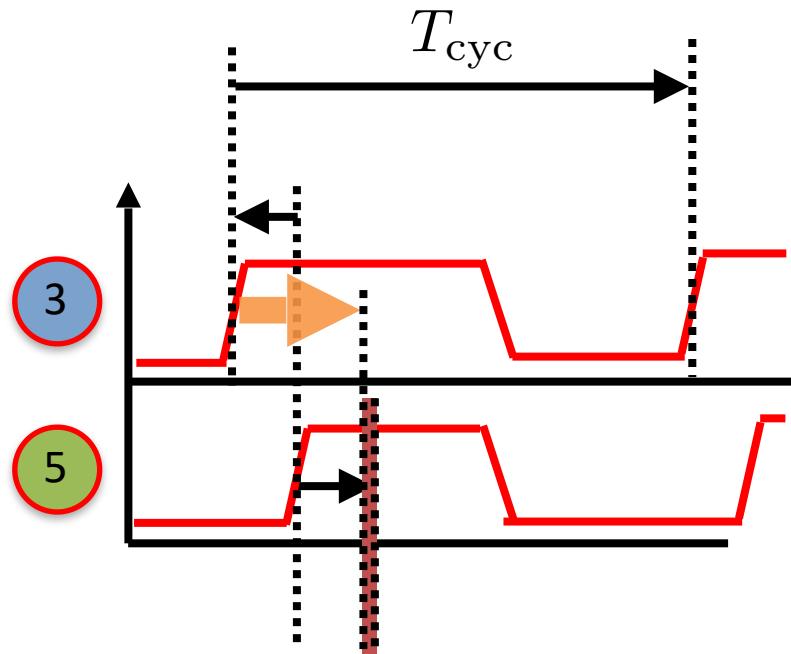
large pos. skew is bad



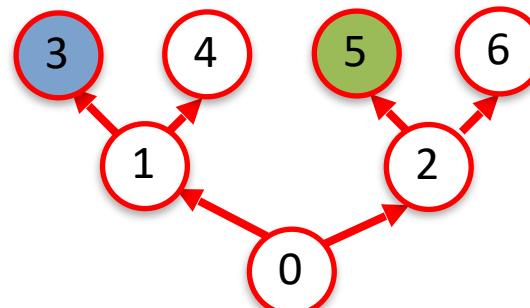
The hold constraint



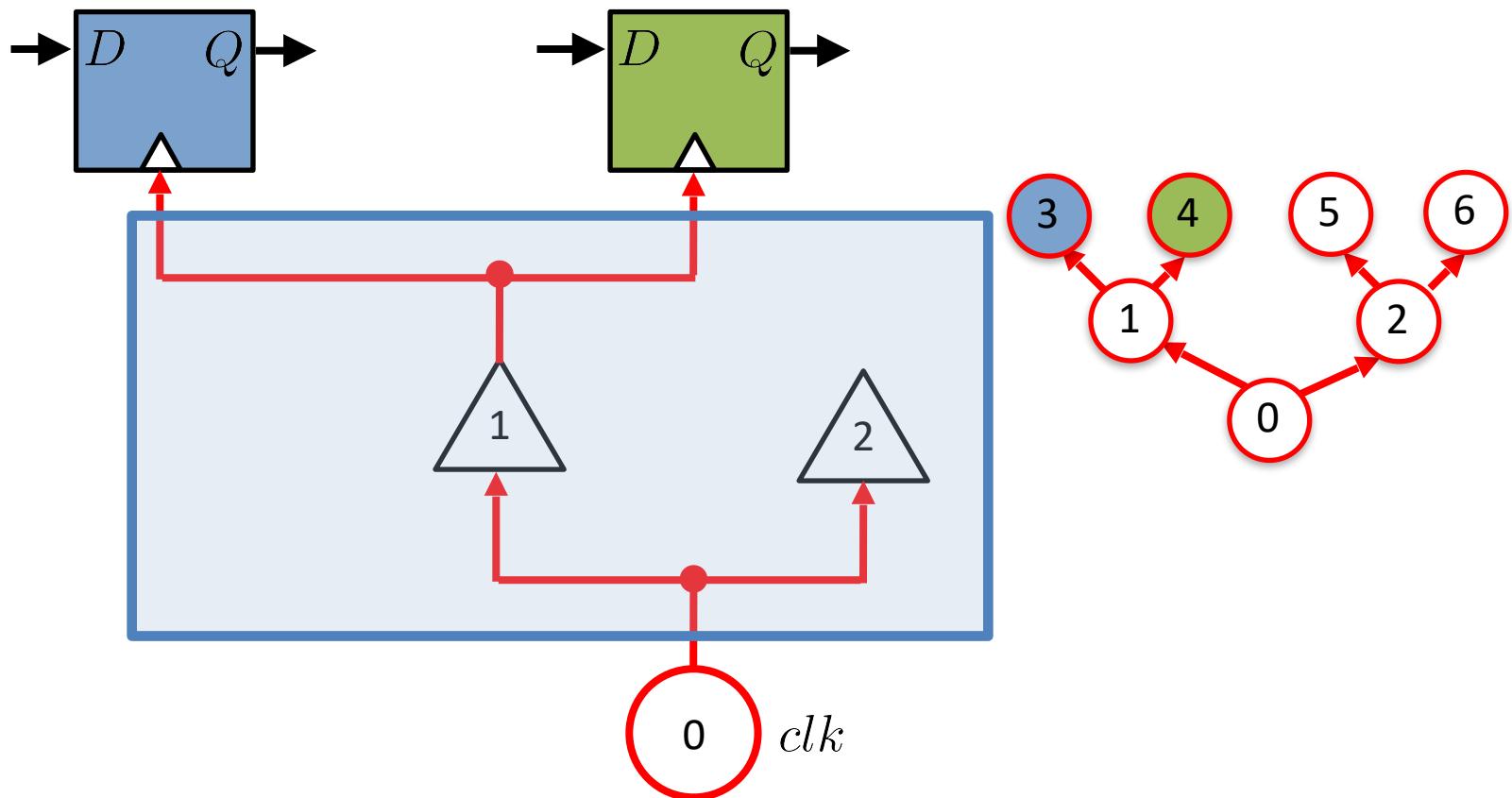
The hold constraint



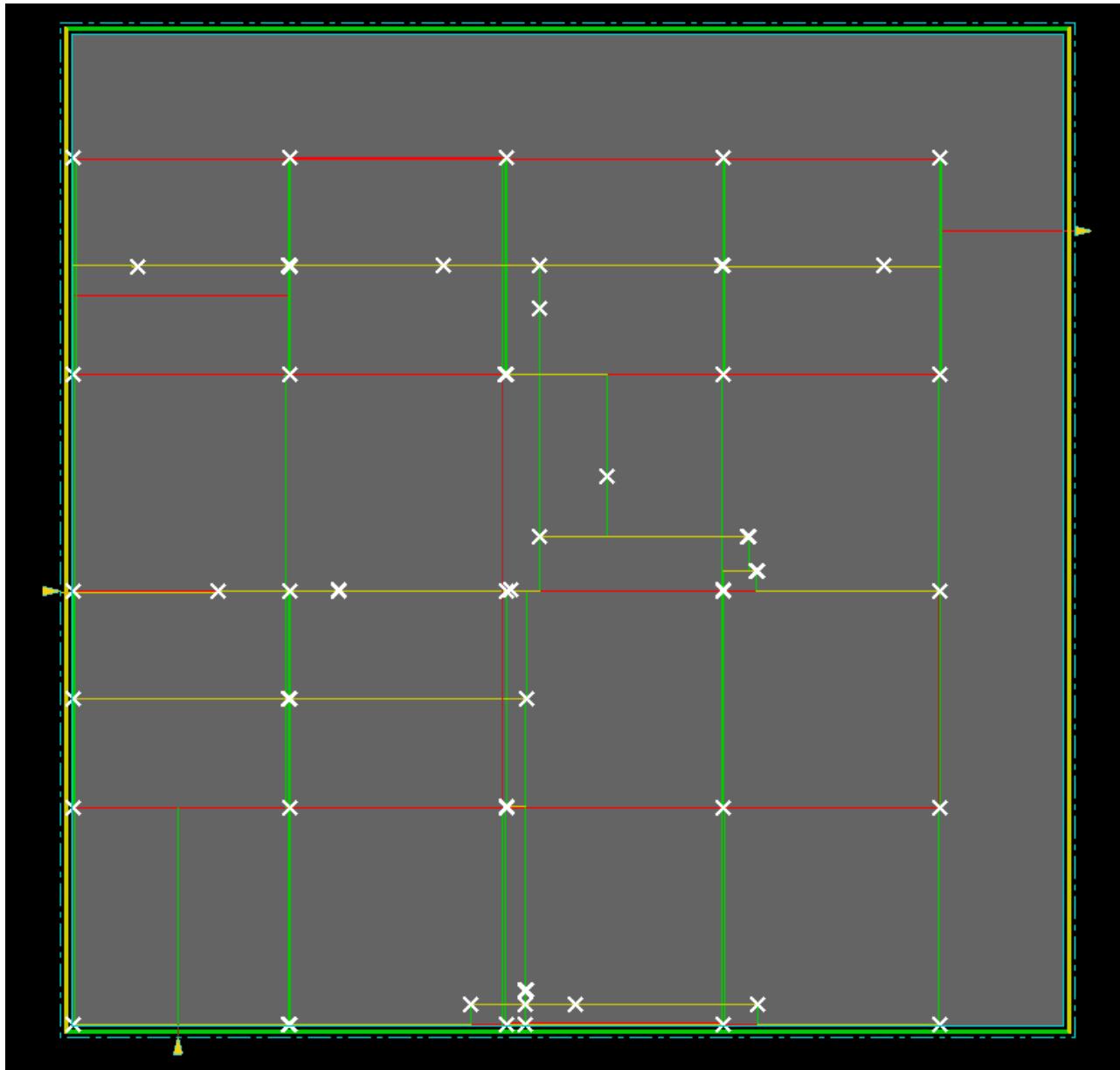
large neg. skew is bad



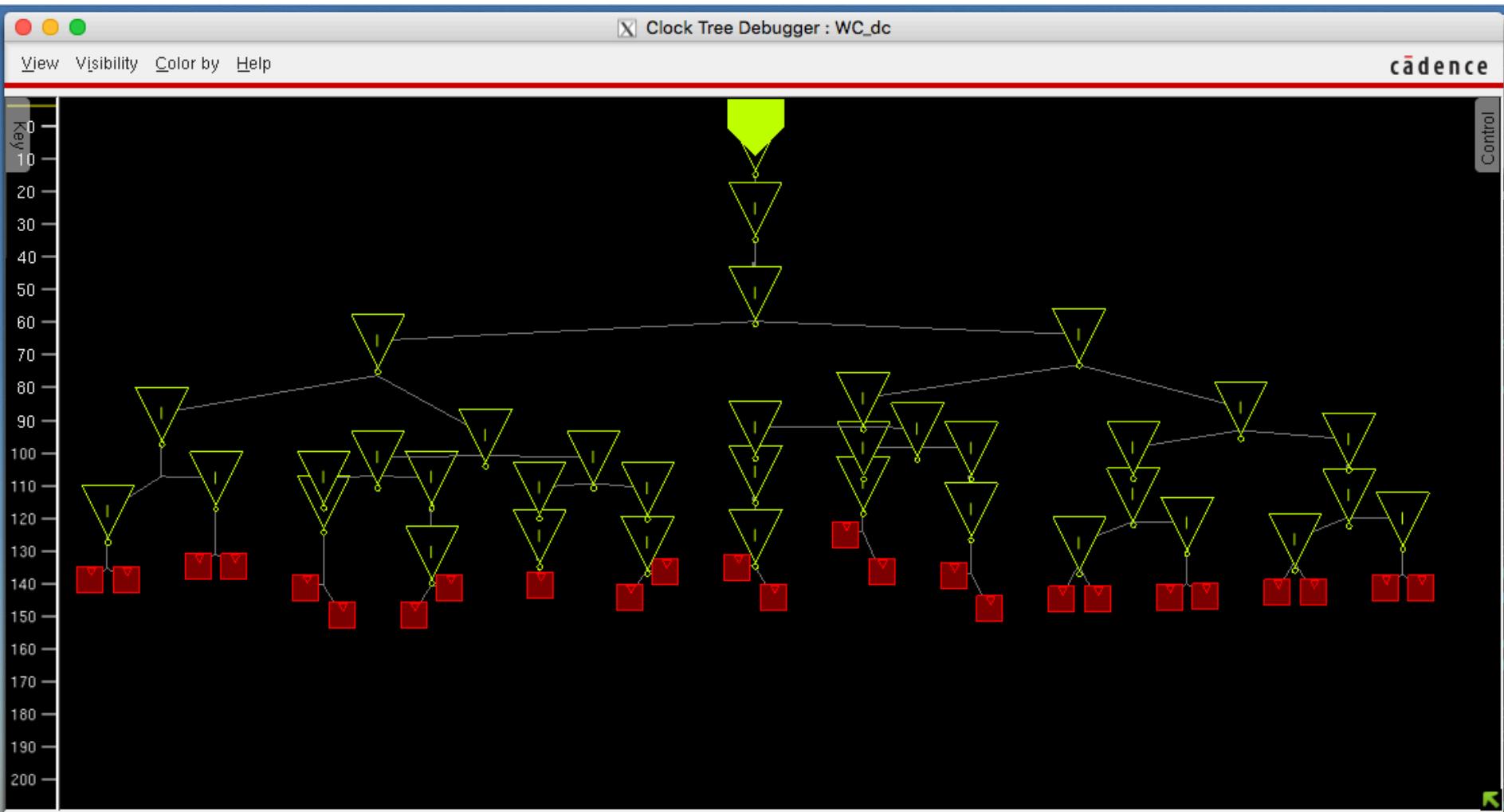
Clock distribution network



The clock



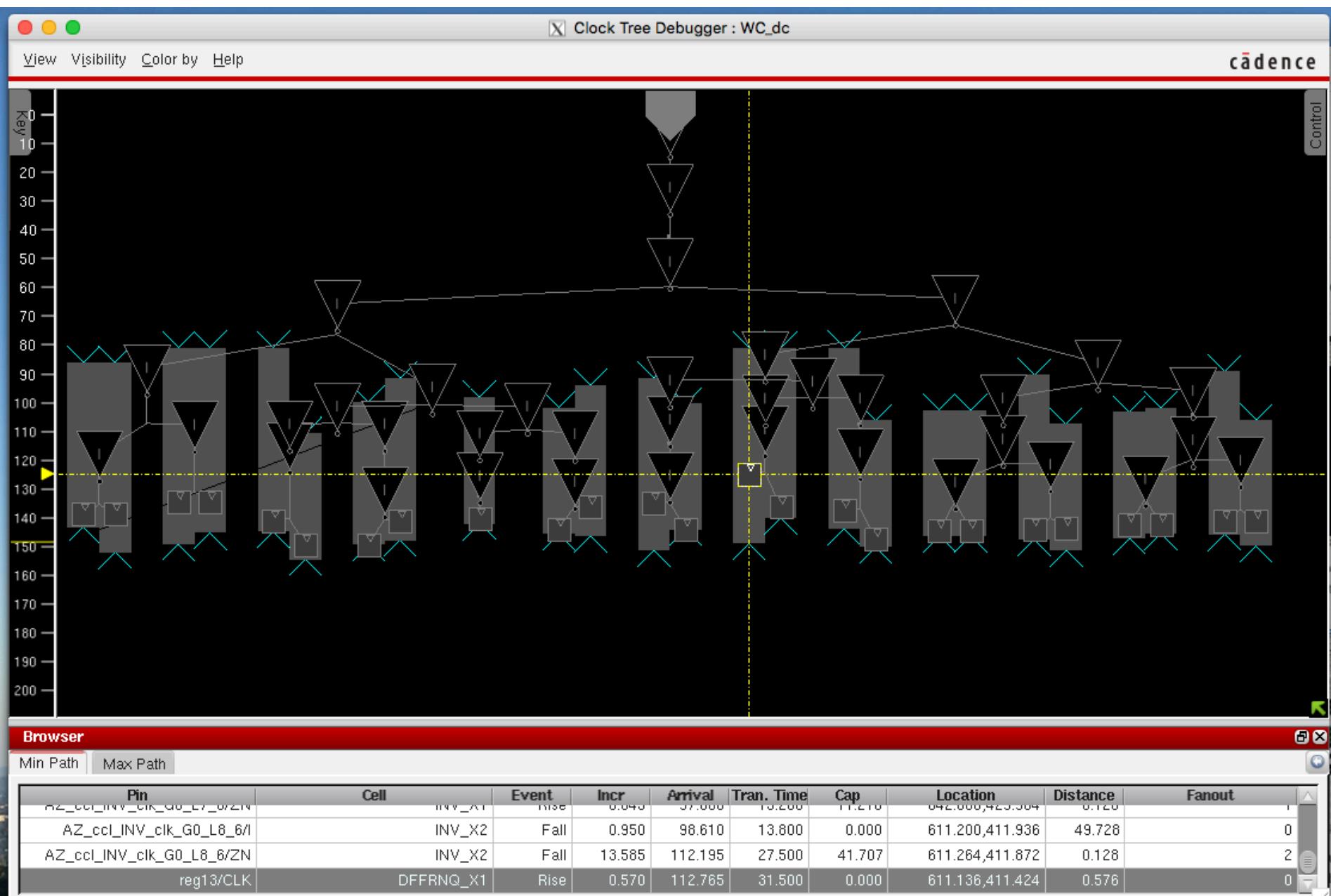
Its skew



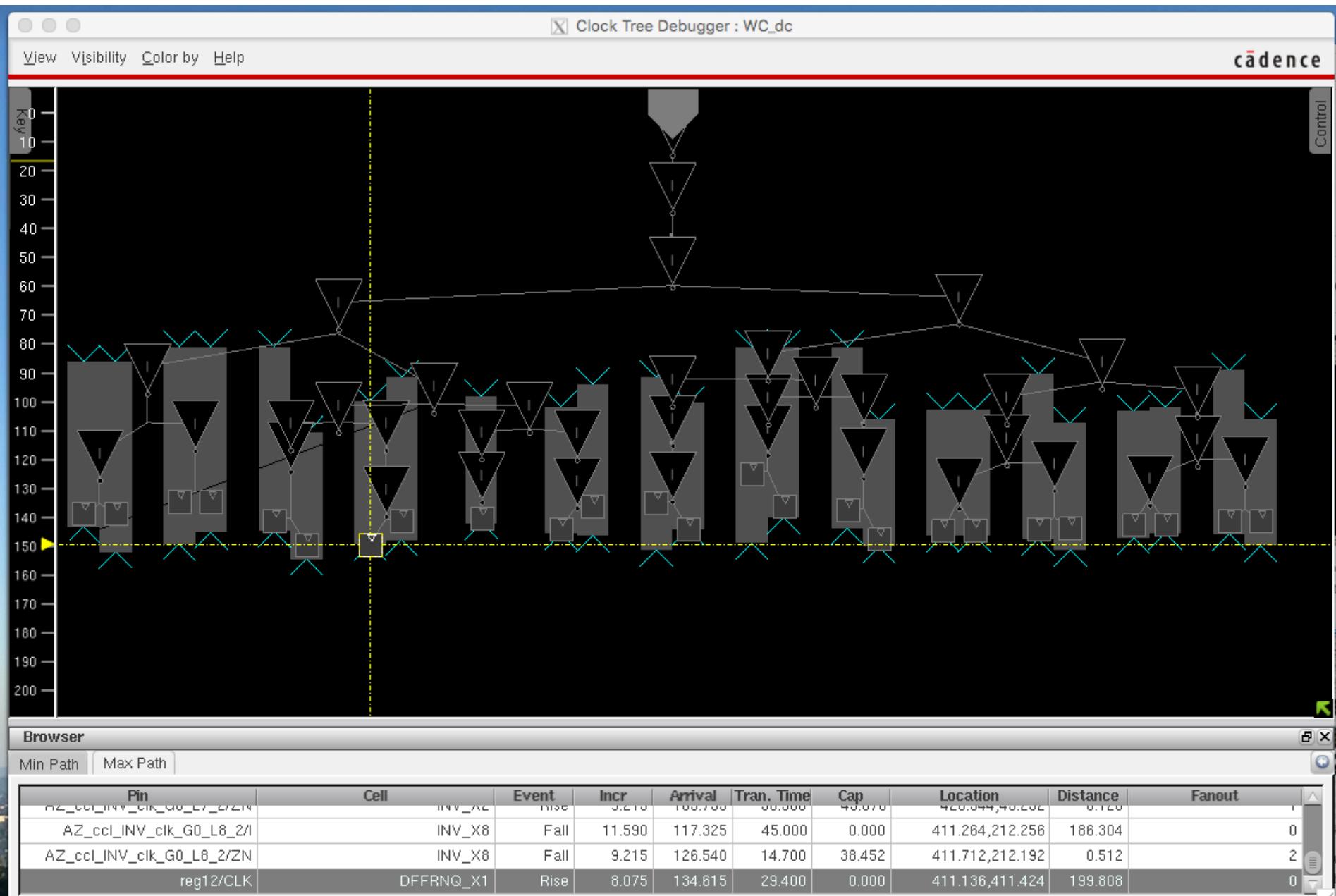
Browser

Analysis View	Skew Group	Skew	Min Delay	Max Delay	Min Pin	MinPath Level	Max Pin	MaxPath Level
WC_dc:hold.early	clk/CM	21.850	112.765	134.615	reg13/CLK	10	reg12/CLK	10
WC_dc:hold.late	clk/CM	24.675	124.530	149.205	reg13/CLK	10	reg12/CLK	10
WC_dc:setup.early	clk/CM	21.850	112.765	134.615	reg13/CLK	10	reg12/CLK	10
WC_dc:setup.late	clk/CM	24.675	124.530	149.205	reg13/CLK	10	reg12/CLK	10

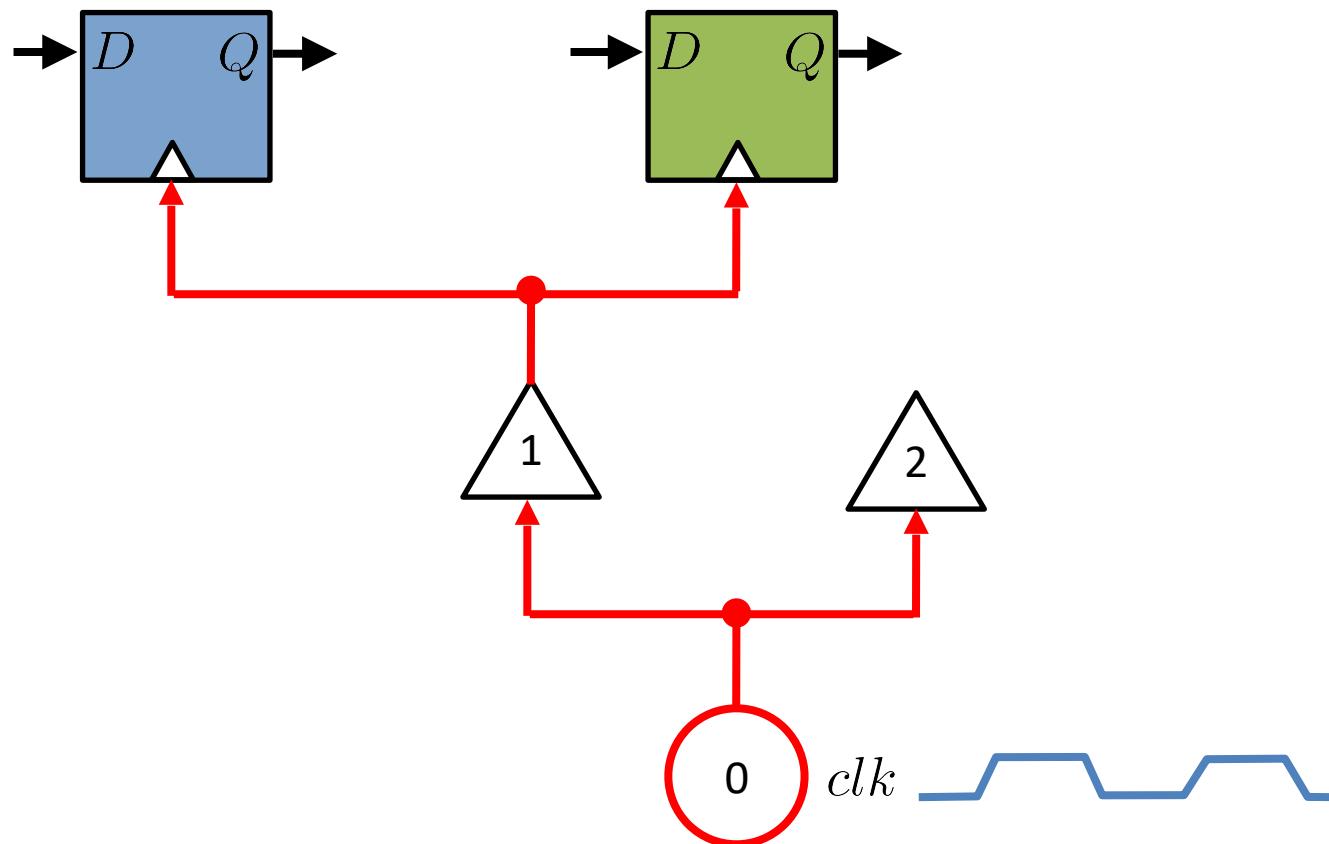
Minimum path



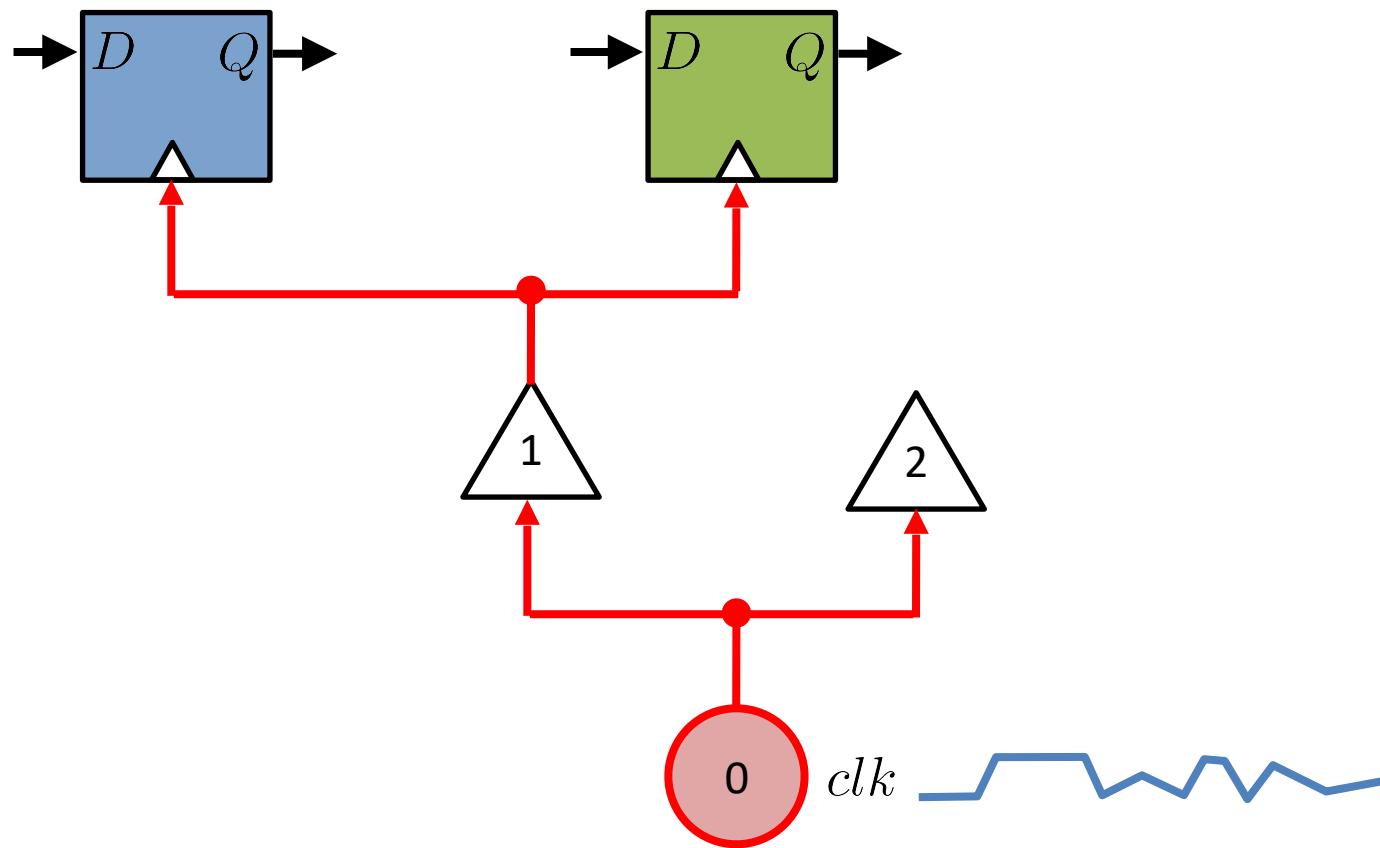
Maximum path



But ...

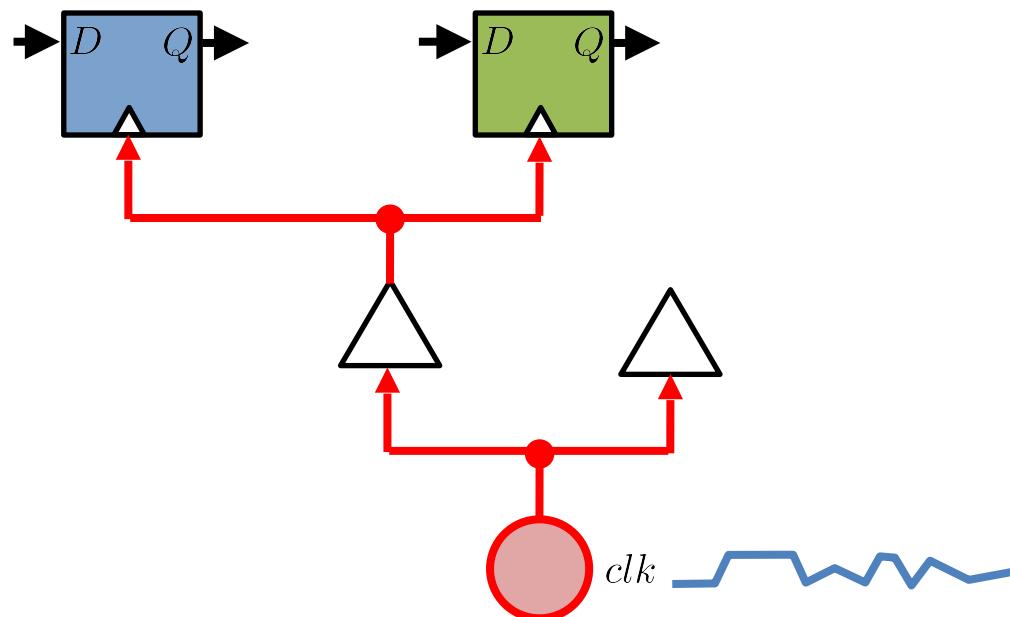


... faults



New requirements

Guarantee skew among some clock outputs despite faults



Pulse Synchronization

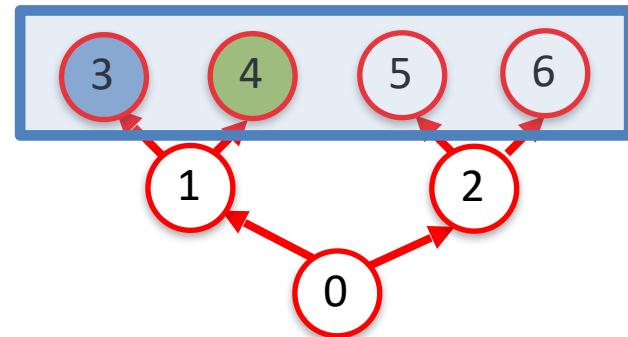
In pulse synchronization, for each $i \in \mathbb{N}$, every (correct) node $v \in V_g$ generates pulse i exactly once.

Let $p_{v,i}$ denote the time when v generates the i -th pulse. We require that there are $\mathcal{S}, P_{\max}, P_{\min} \in \mathbb{R}_{>0}$ satisfying

1. skew: $\sup_{i \in \mathbb{N}, u, w \in V_g} \{|p_{v,i} - p_{w,i}| \} = \mathcal{S}$

2. per-1: $\inf_{i \in \mathbb{N}} \left\{ \min_{v \in V_g} p_{v,i+1} - \max_{v \in V_g} p_{v,i} \right\} \geq P_{\min}$

3. per-2: $\sup_{i \in \mathbb{N}} \left\{ \max_{v \in V_g} p_{v,i+1} - \min_{v \in V_g} p_{v,i} \right\} \leq P_{\max}$



Lower bounds

Number of faults f . Then necessarily:

Global: $n > 3f$

Local: degree $> 2f$

Ideas?

