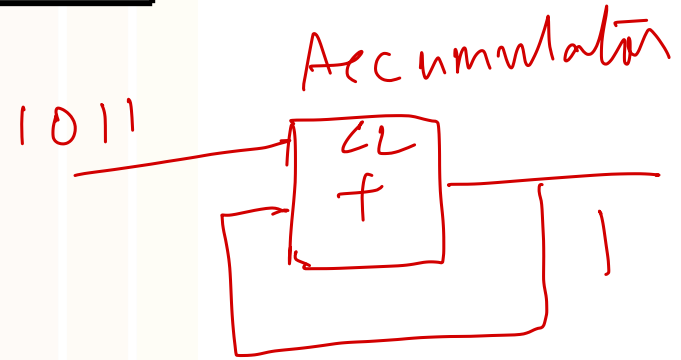
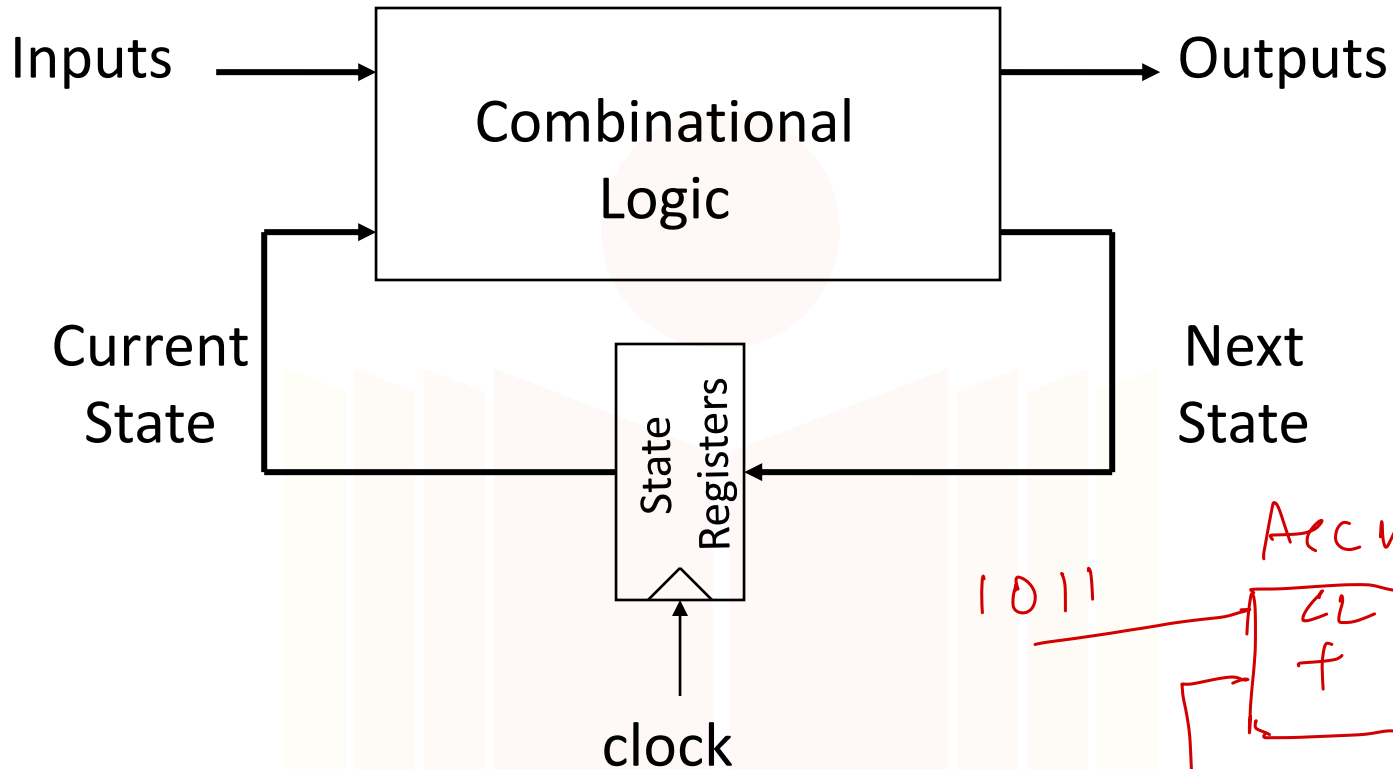


Introduction to VLSI Design

Lecture 20 – Sequential circuits

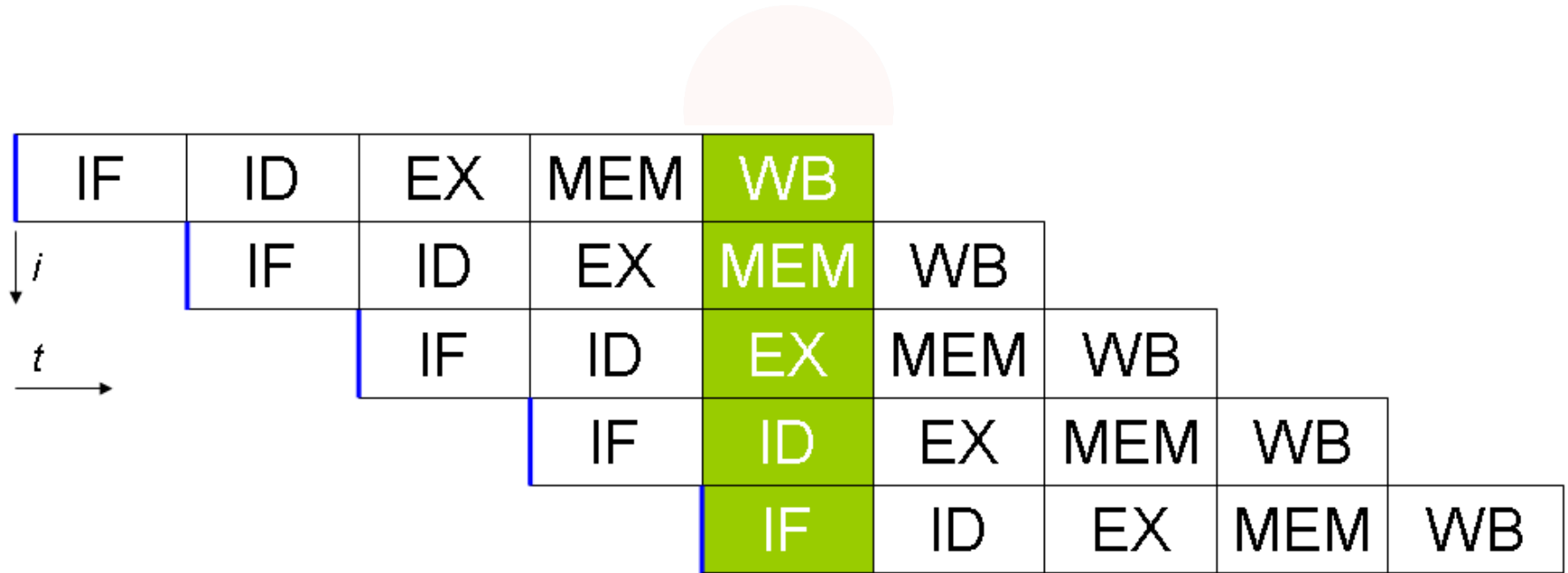
Material primarily from textbook and lecture slides for Rabaey et. al.
Digital Integrated Circuits, 2nd Edition (2002) and other online resources

Sequential Circuits



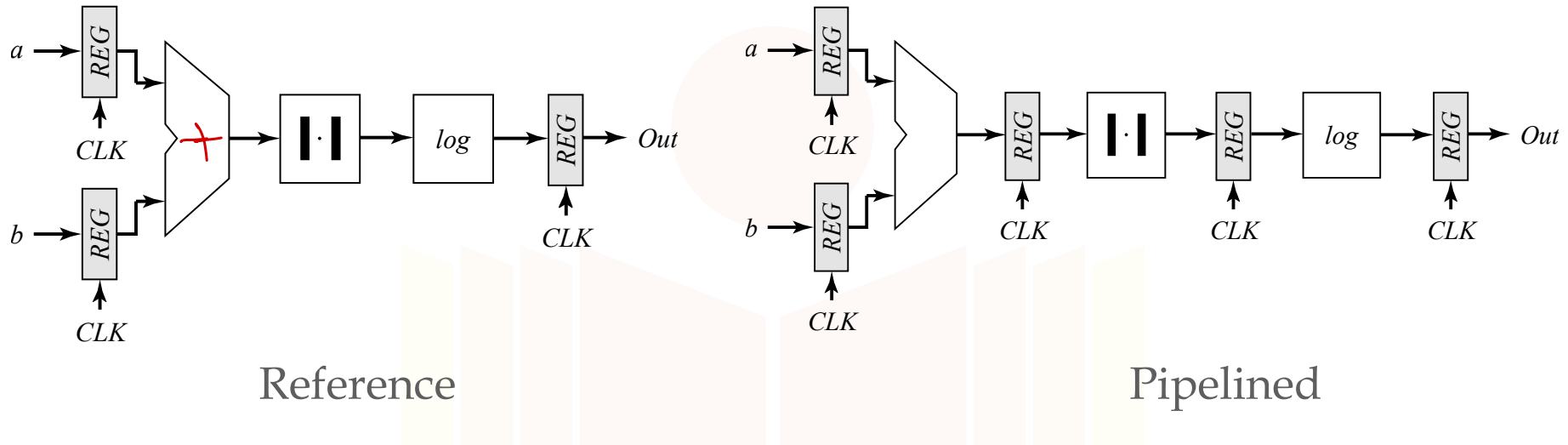
- Output state is dependent on inputs and current state
- Why do we need registers in feedback loop?
 - Know when output is ready, and next input can be applied
 - Avoid race conditions

Why Sequential Logic?



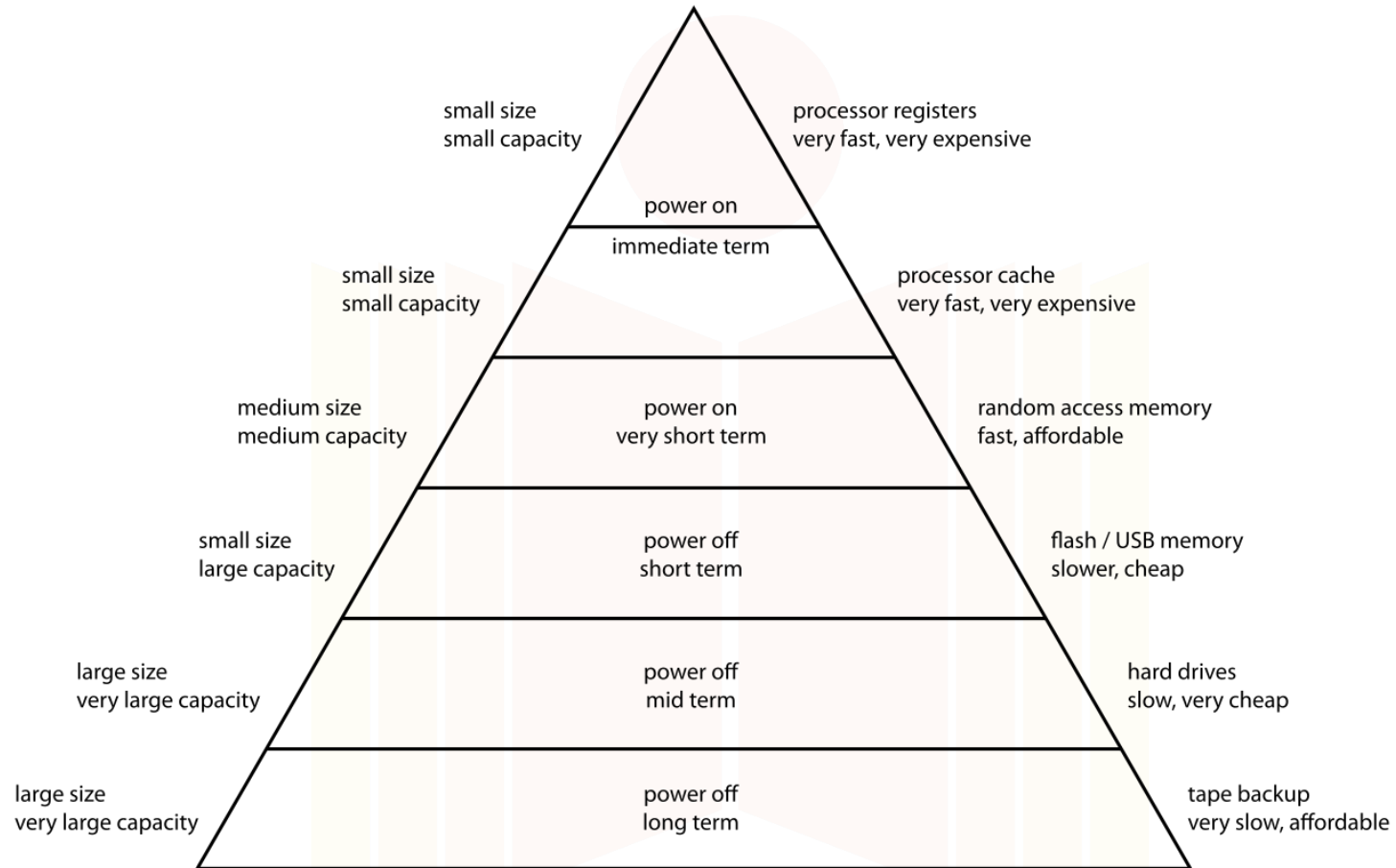
Basic five-stage pipeline in a RISC machine (IF = Instruction Fetch, ID = Instruction Decode, EX = Execute, MEM = Memory access, WB = Register write back).

Pipelining



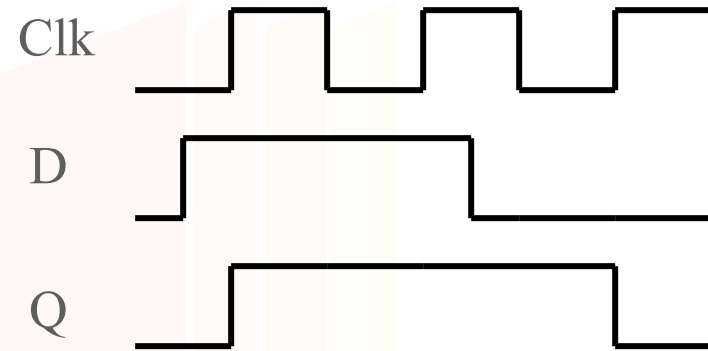
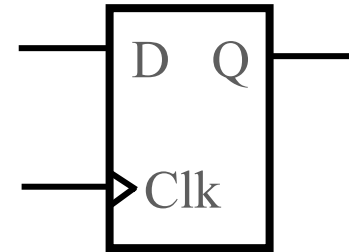
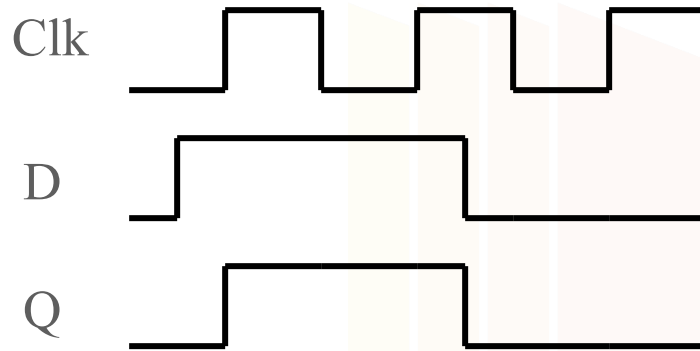
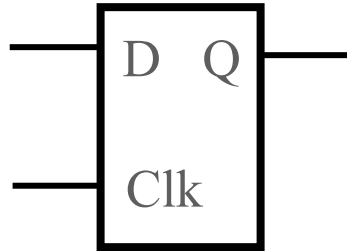
Clock Period	Adder	Absolute Value	Logarithm
1	$a_1 + b_1$		
2	$a_2 + b_2$	$ a_1 + b_1 $	
3	$a_3 + b_3$	$ a_2 + b_2 $	$\log(a_1 + b_1)$
4	$a_4 + b_4$	$ a_3 + b_3 $	$\log(a_2 + b_2)$
5	$a_5 + b_5$	$ a_4 + b_4 $	$\log(a_3 + b_3)$

Memory Hierarchy



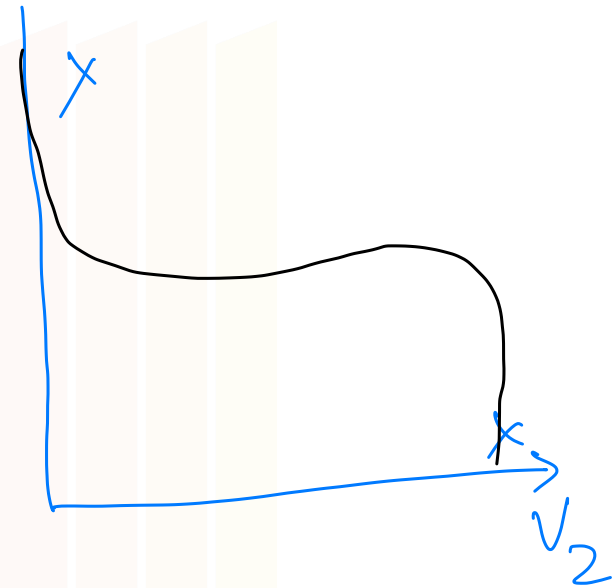
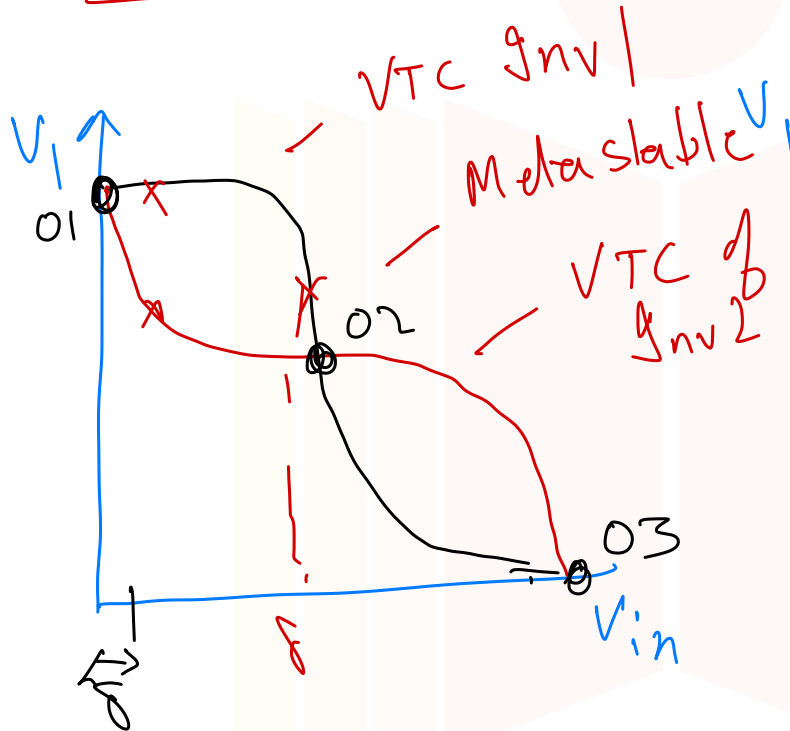
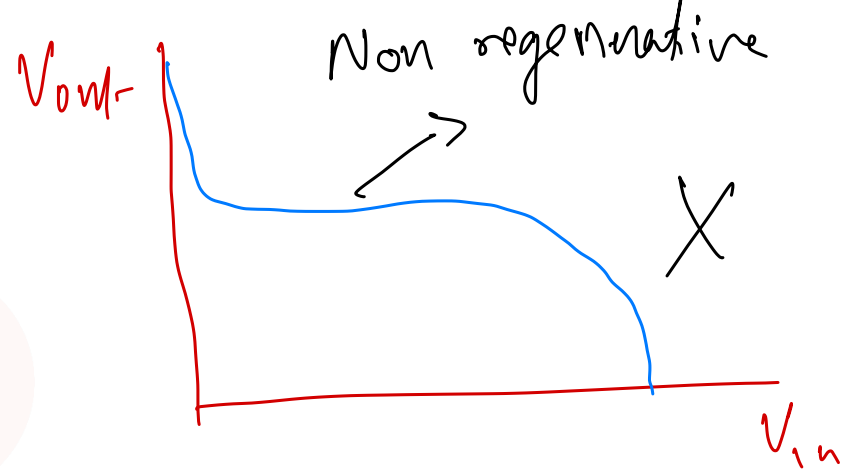
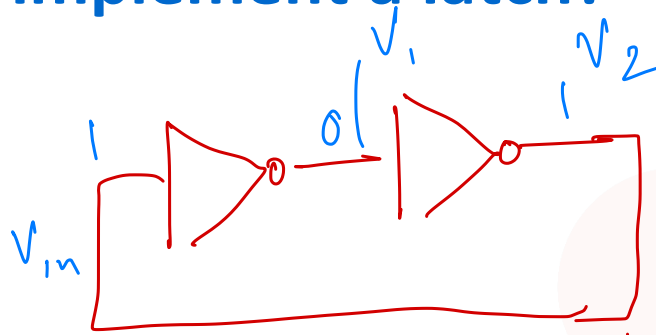
https://en.wikipedia.org/wiki/Memory_hierarchy

Latch Vs Flipflop/Register

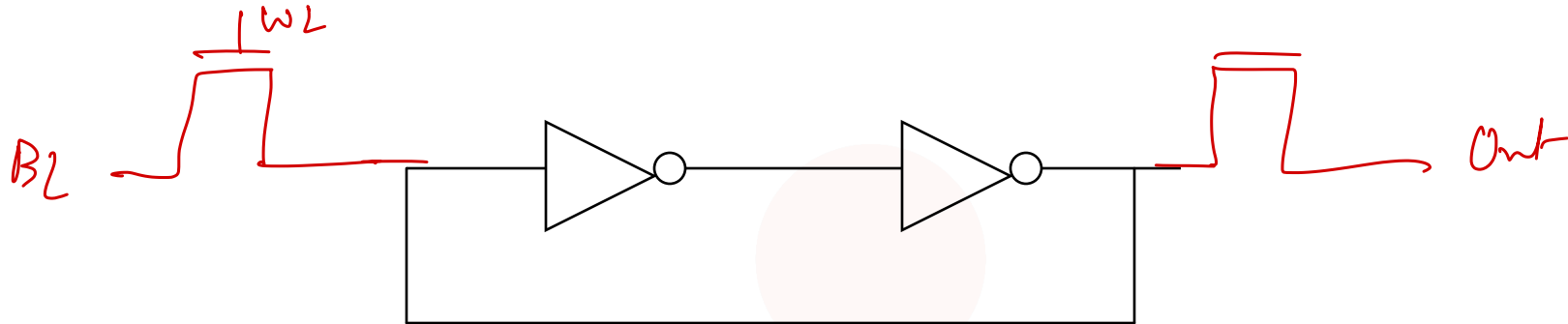


- Latch – level sensitive
 - Transparent/Hold when CLK is high/Low
- Flipflop – edge triggered
 - Samples input only when edge occurs

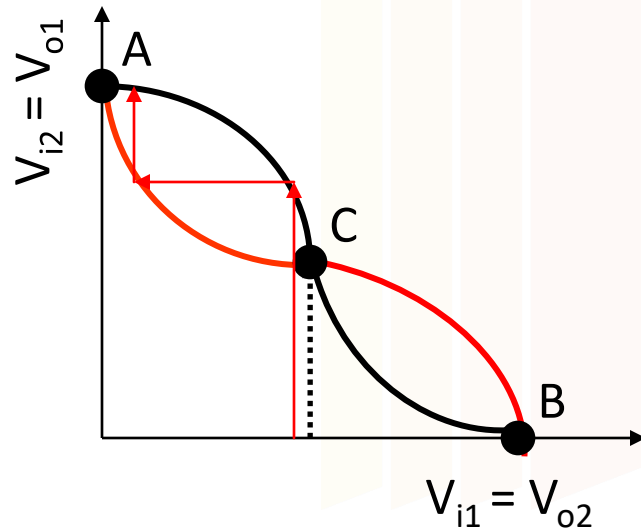
How to implement a latch?



How to implement a latch?

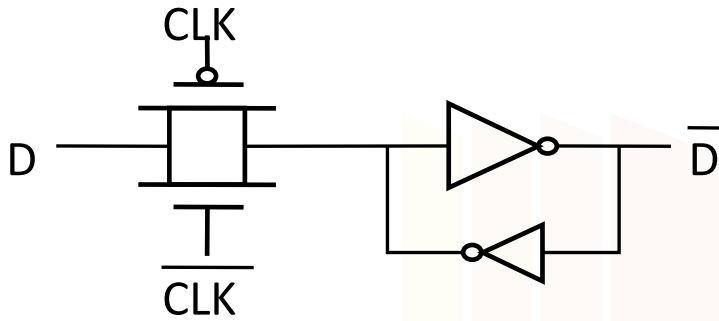
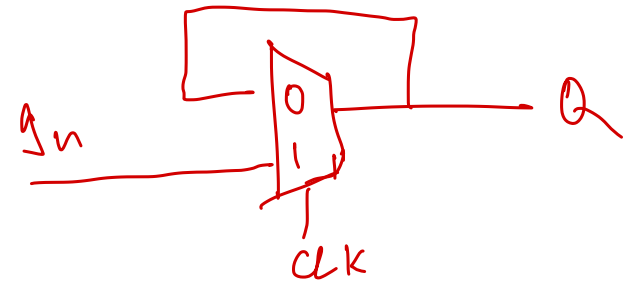


cascaded inverters

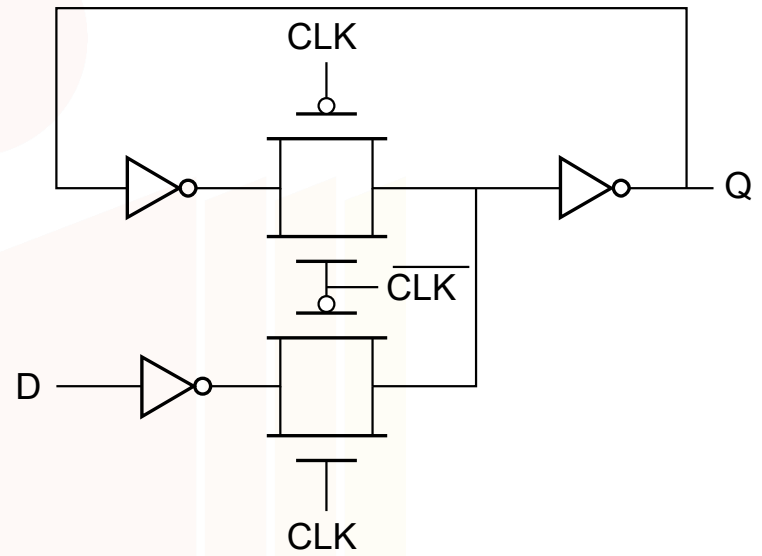


Two cascaded inverters show **bistable** operation. If the gain in the transient region is larger than 1, only **A and B are stable operation points**. **C is a metastable operation point**.

Implementations of a latch



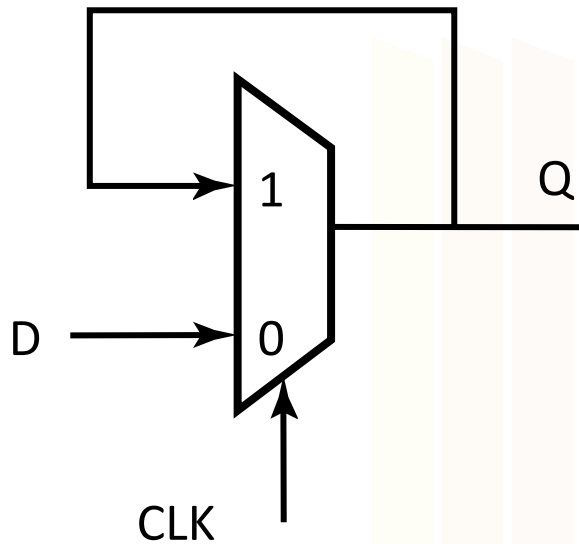
Forcing a state



Converting a MUX into a latch

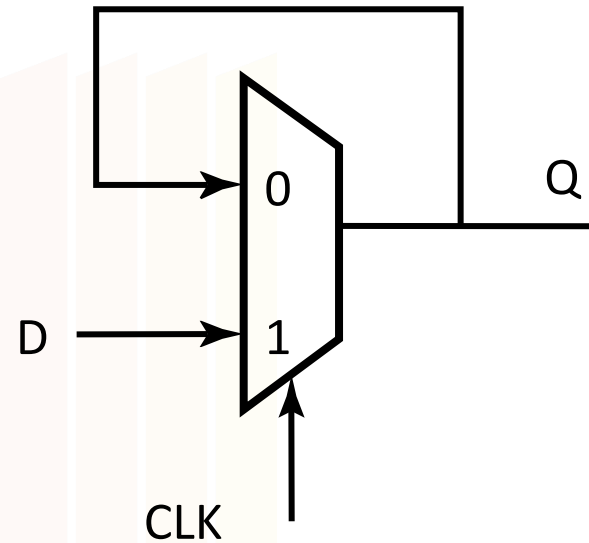
Mux based Latches

Negative latch
(transparent when CLK= 0)



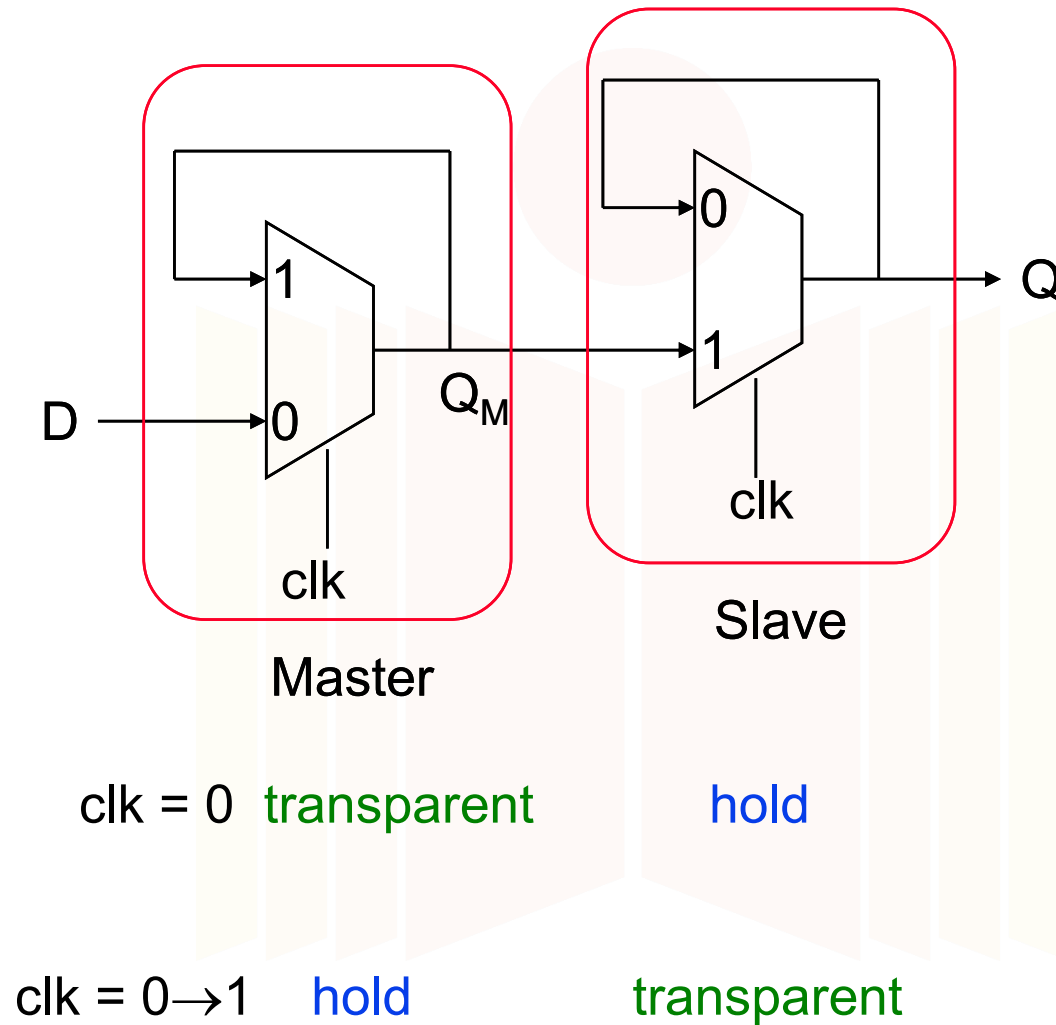
$$Q = \overline{Clk} \cdot Q + Clk \cdot In$$

Positive latch
(transparent when CLK= 1)



$$Q = Clk \cdot Q + \overline{Clk} \cdot In$$

Edge triggered Flipflop



Master Slave Flipflop Implementation

