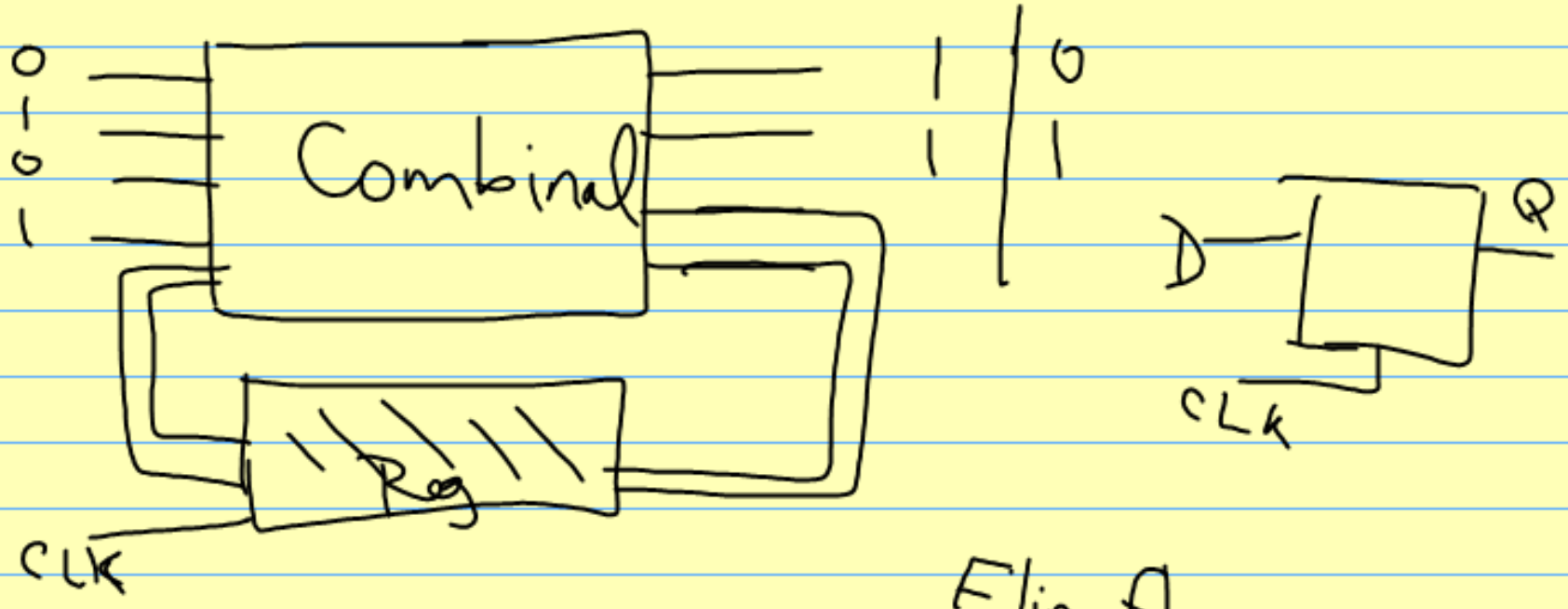
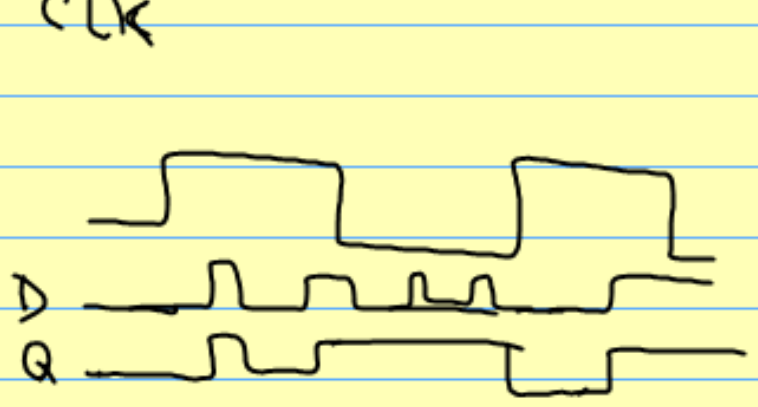
Sequential Logic





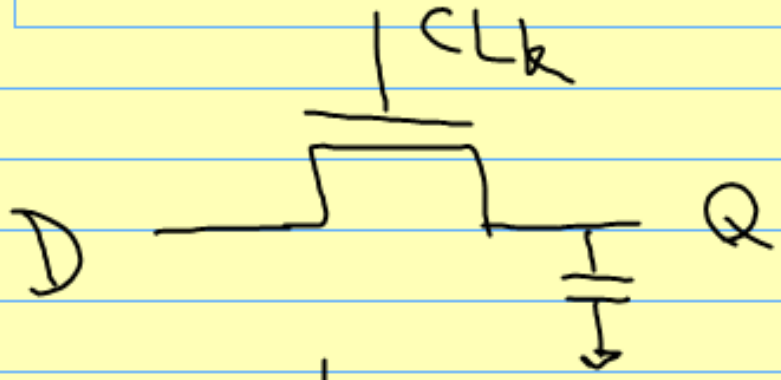
Flip-flop

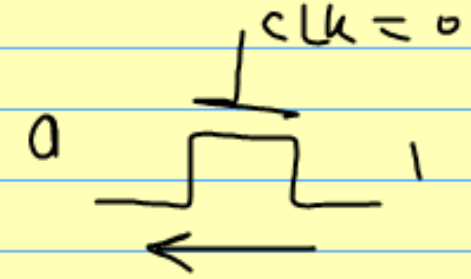
Latch

Reg

clock edge

Memory Cell





\+ simple

\+ area

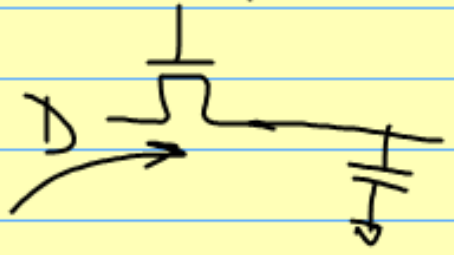
fast?

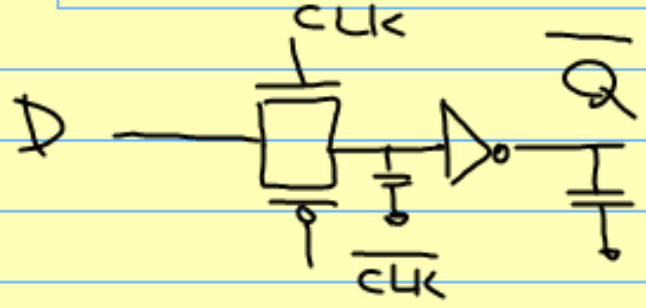
— charge leaks

— Float ⇒ noise

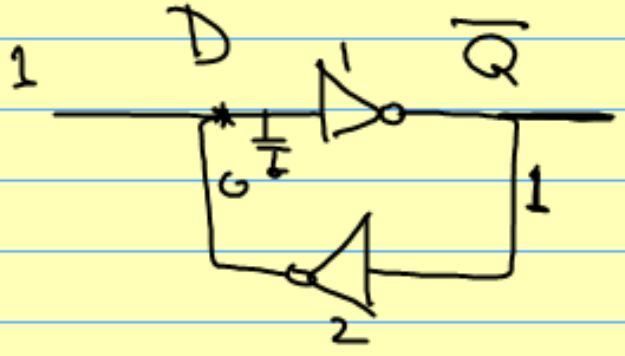
— Diffusion

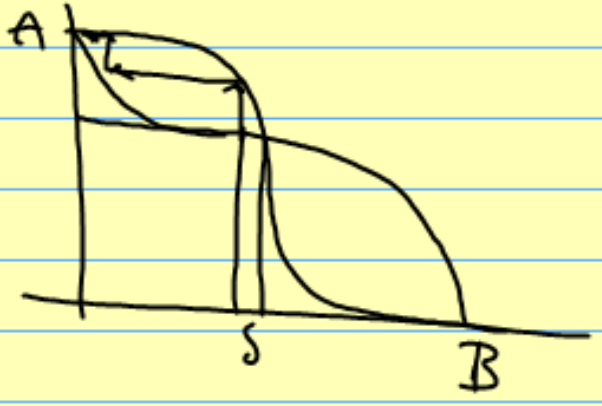
— V_t drop



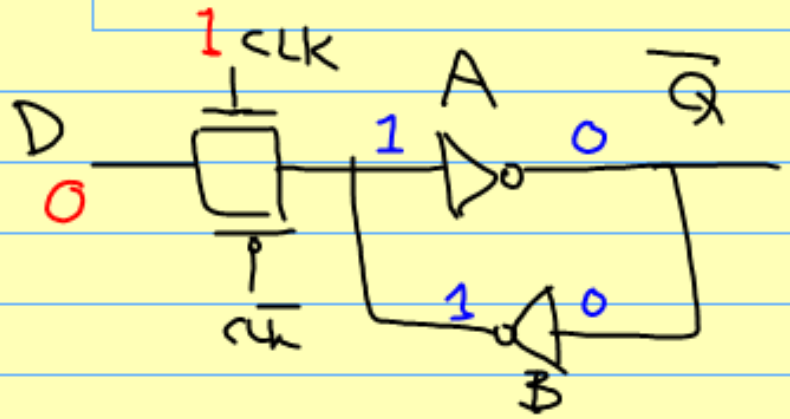


+ Restore weak D
+ Capacitive Coup D
– noise





SRAM cell α-release!



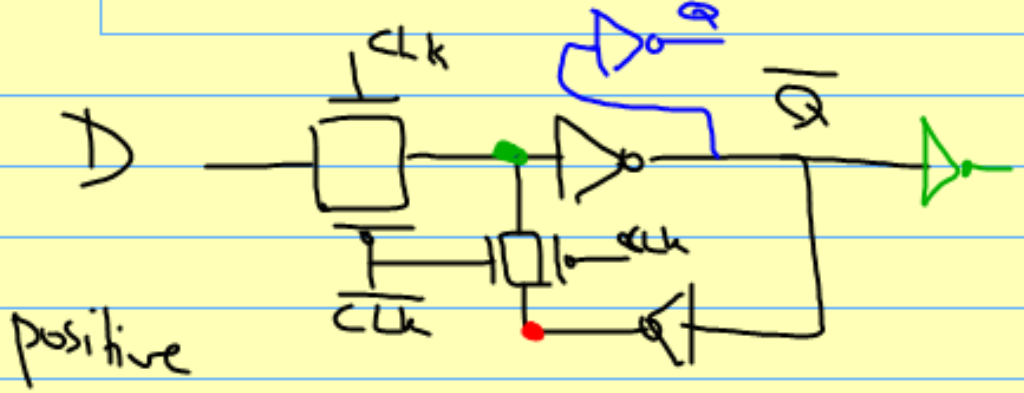
Read: $\overline{Q}$

Write: D ← value

CLK ← 1

- Careful sizing (gate B's pmos, nmos vs D)
  - ⇒ clock period
- Delay
- \+ robust

SRAM Cell (Mux-based Latch)



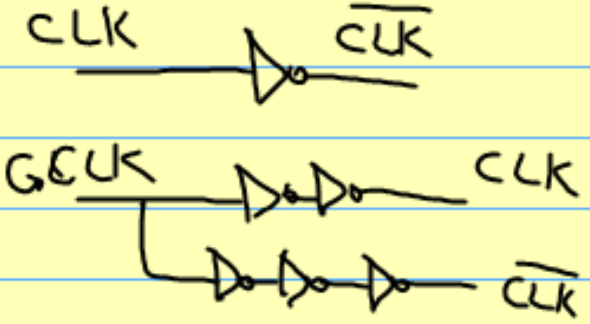
optional path

+ Robust++

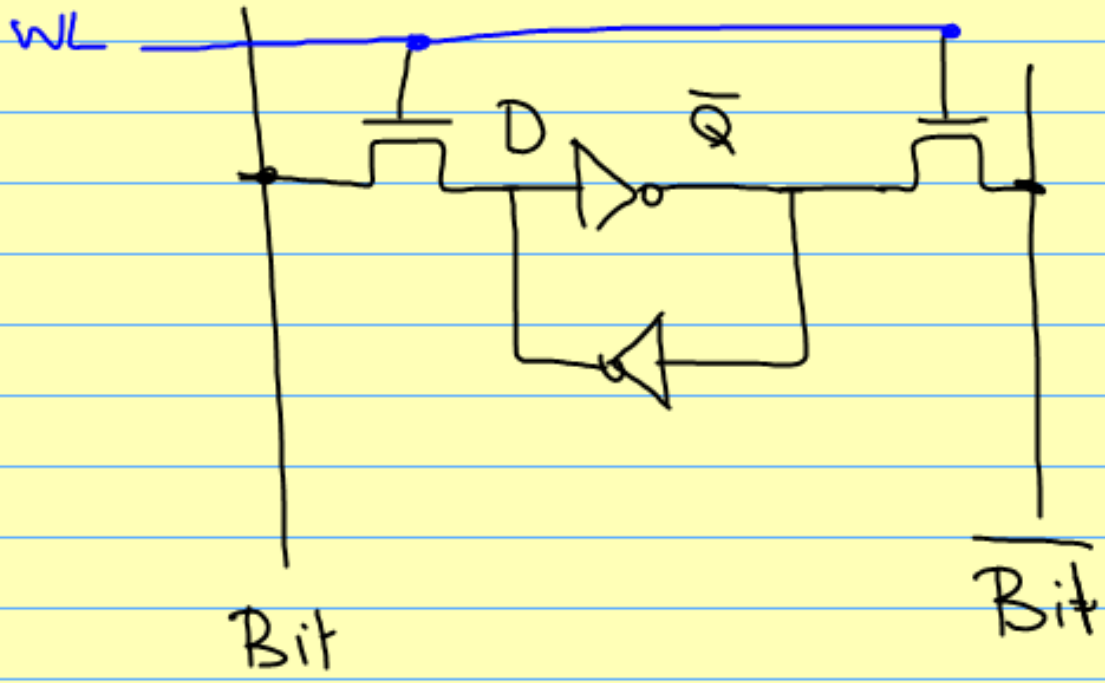
+ popular

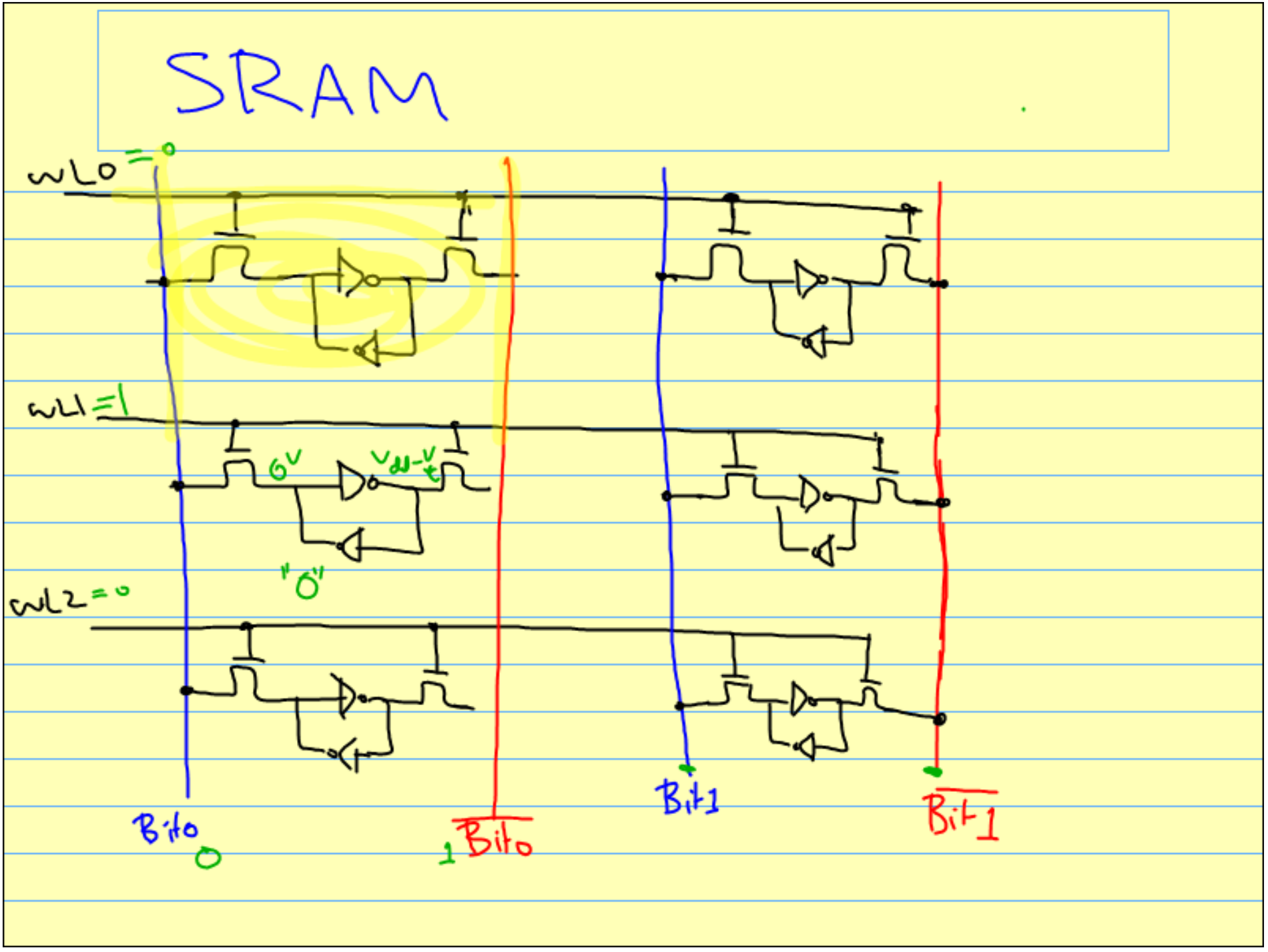
– area

– more load on CLK

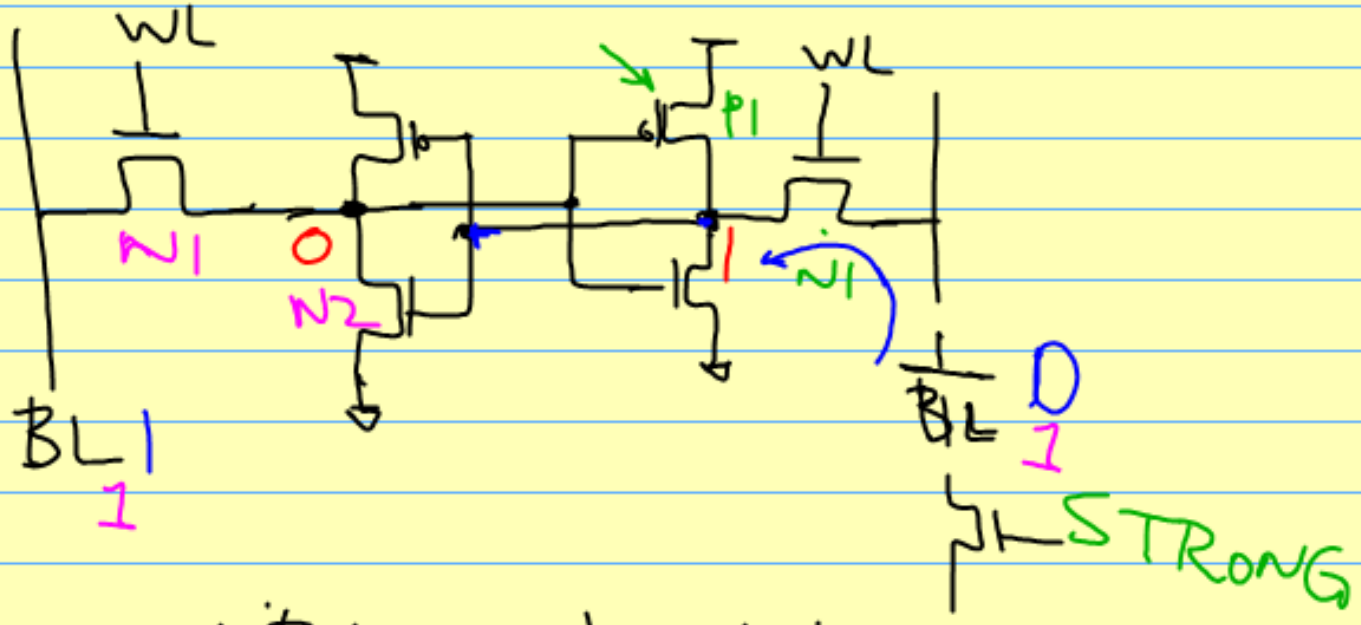


SRAM




SRAM
WL0 = 0
WL1 = 1
0V
$V_{dd}-V_t$
"0"
WL2 = 0
Bit0
0
1
$\overline{Bit_0}$
Bit1
$\overline{Bit_1}$

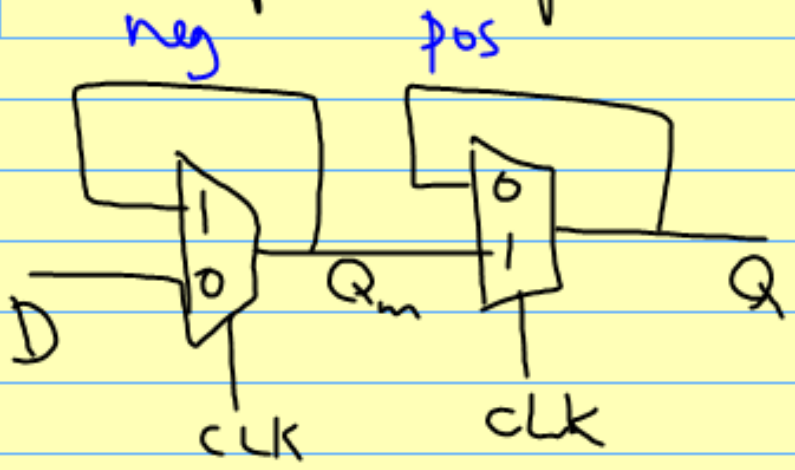
Sizing SRAM Cell



Proper write: N1 has to be stronger than P1

proper read: N_2 ~ ~ ~ N_1

Flip-Flops (Edge Triggered)

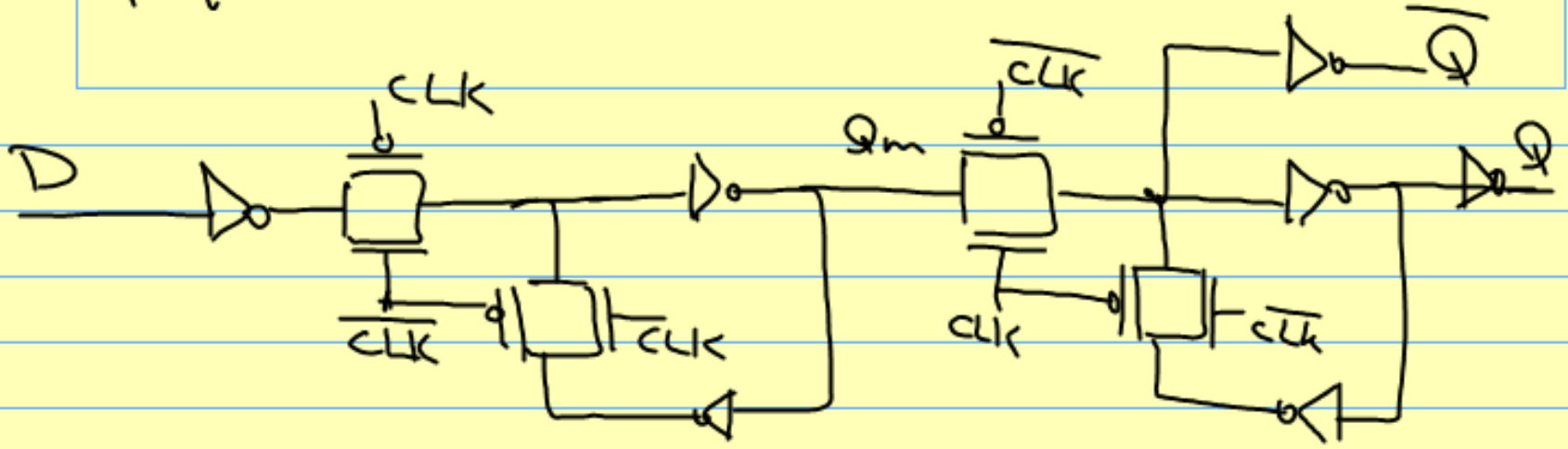


pos pos

CLK $\overline{CLK}$

CLK : 0		D → Qm	Q hold
CLK	↑	DX	Qm hold	Qm → Q
CLK	1	Dx	Q hold	Q follows Qm ⇒ Q hold

FF



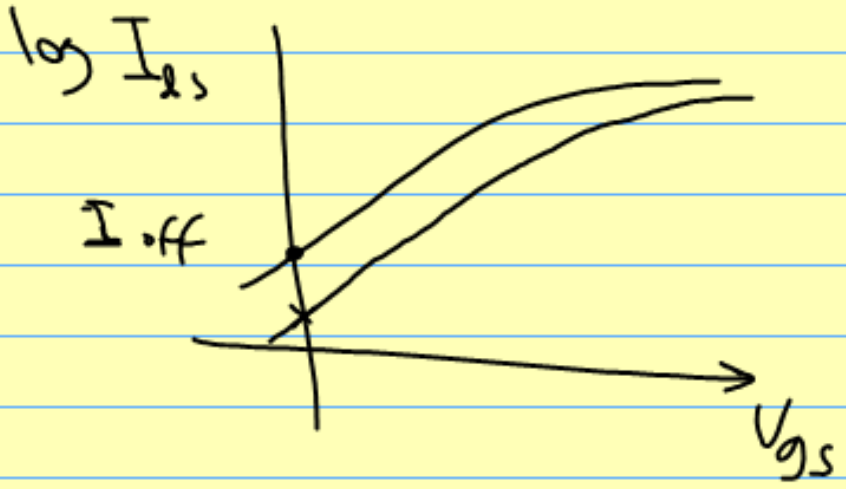
Timing Properties

7.2.4 Low Voltage Static Latches

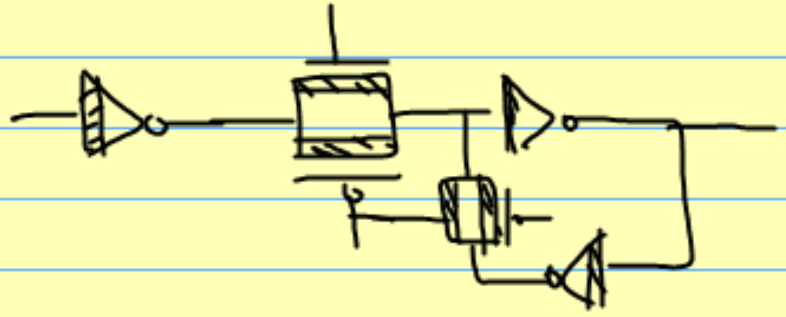
Dual / multiple Vt process

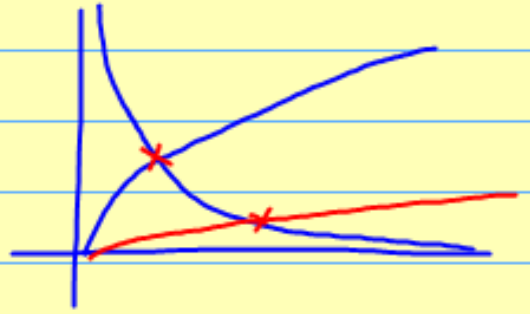
$V_{dd} = 1V$ $V_{t\text{-}low} = 0.2V$

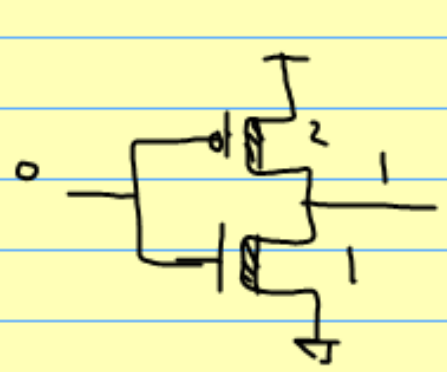
$V_{t\text{-}high} = 0.4V$

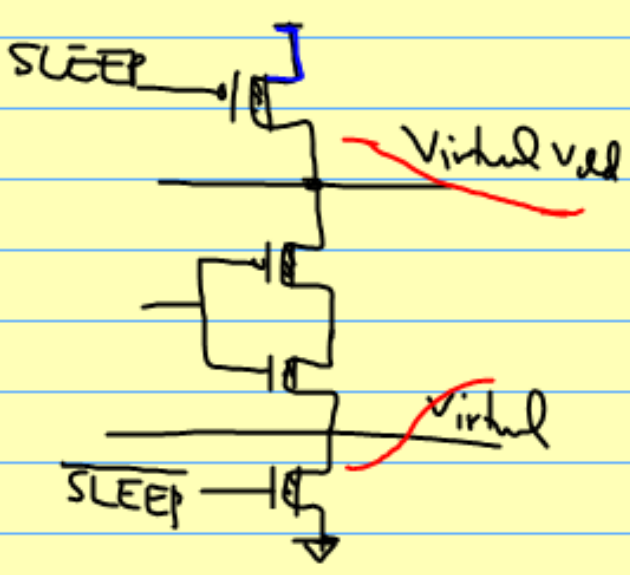


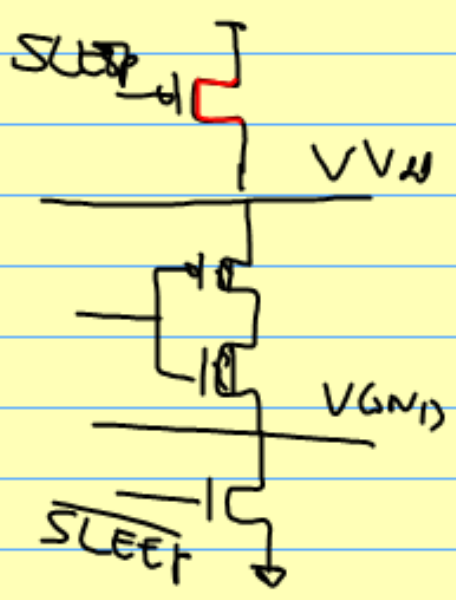
Purely low-Vt



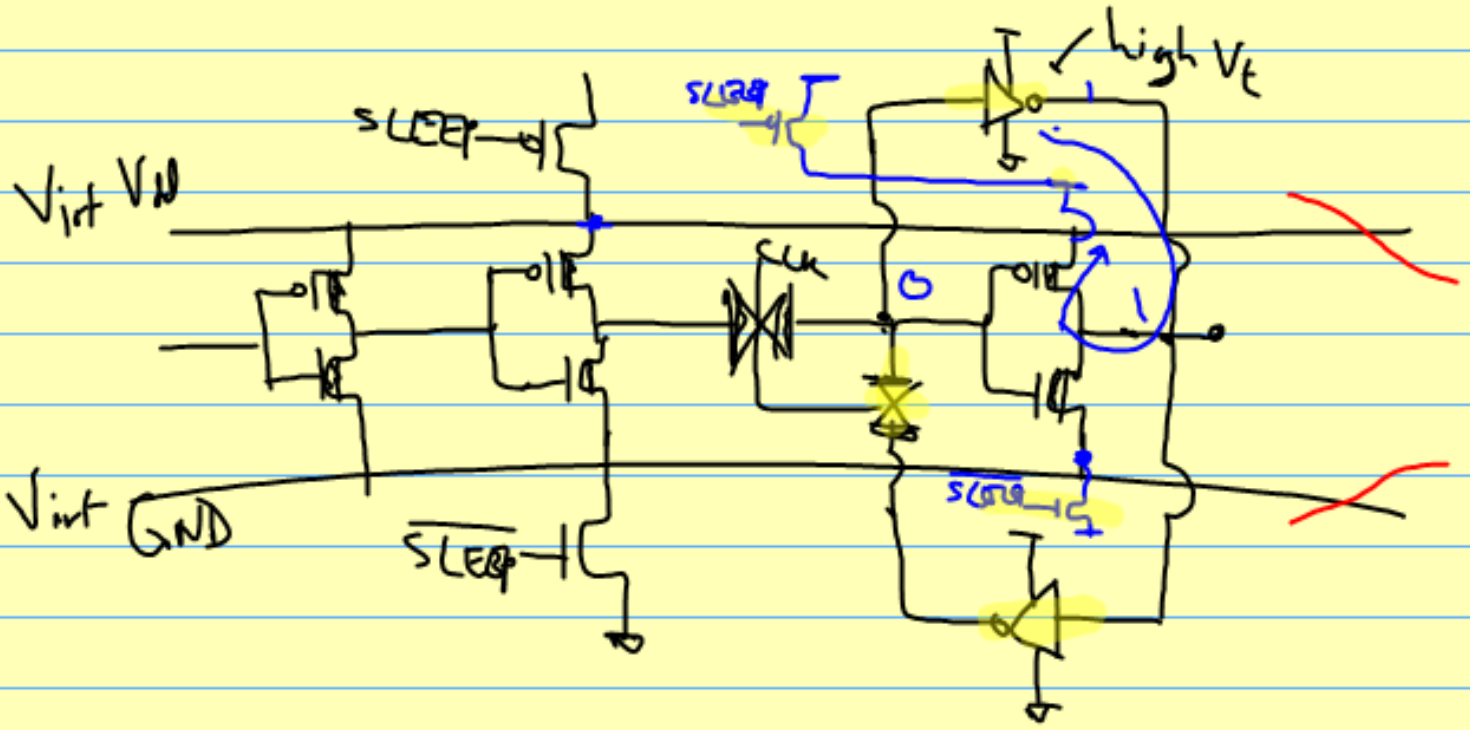




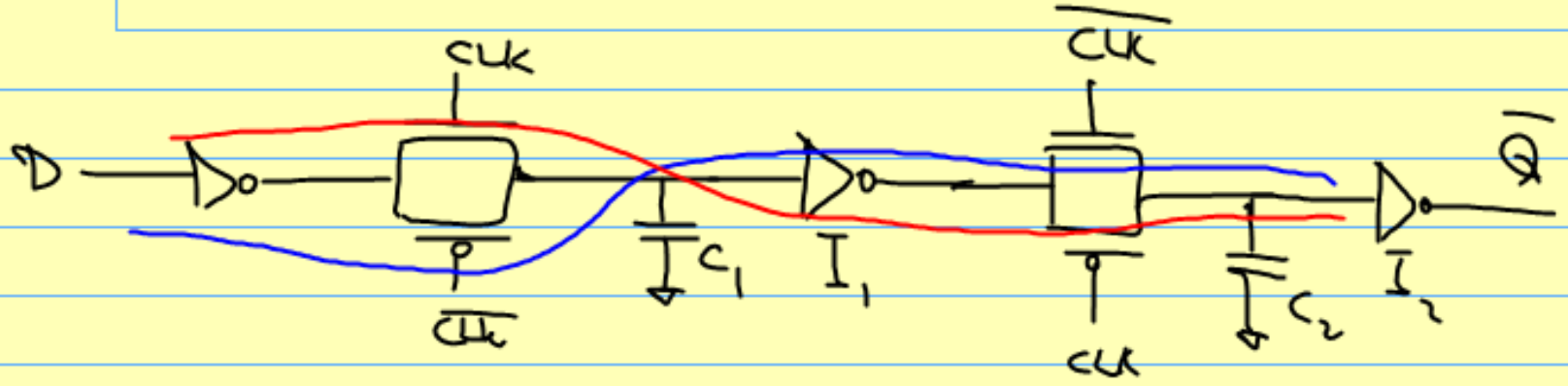




FF w/ Sleep Transistors (dual Vt)



Dynamic Latches



clk = 0 — Master hold — Slave Transparent

clk = V_{dd} — Trans — hold

$t_{setup} = t_{inv} + t_{tx}$

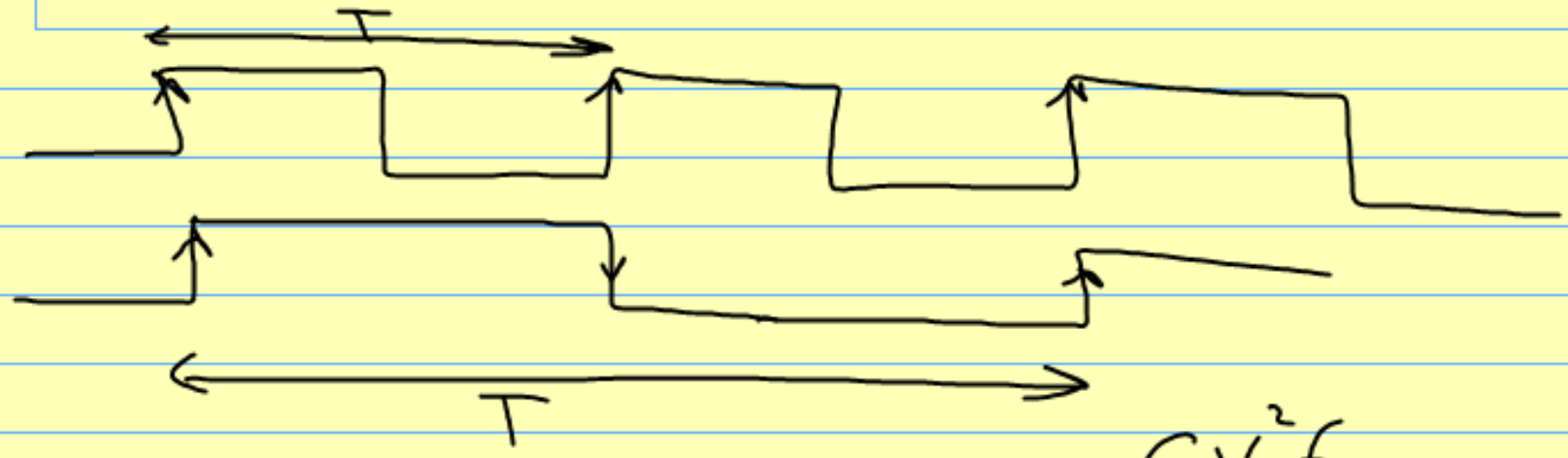
$t_{c-q} = t_{inv} + t_{tx}$

$t_{hold} < 0$

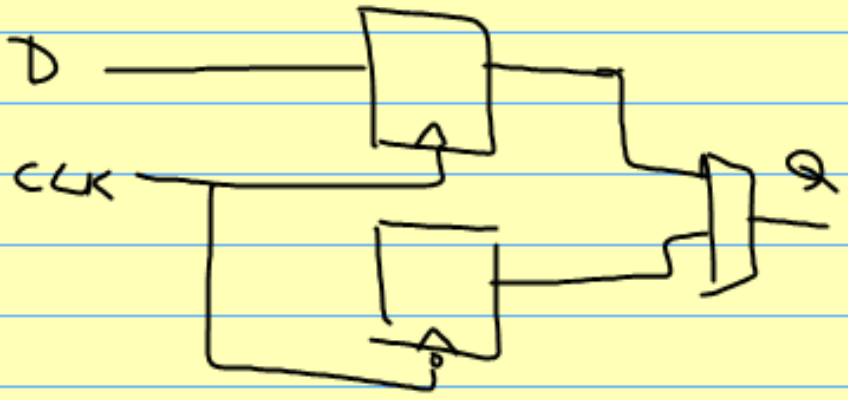
0–0 overlap

1–1 overlap $t_{11overlap} < 2t_x + 2t_{inv}$

Dual Edge-triggered Registers



$\subseteq V^2 f$



+ global clk freq $\times \frac{1}{2}$

− clk load 2x

− area increase (register area)

Dynamic Dual Gate Reg

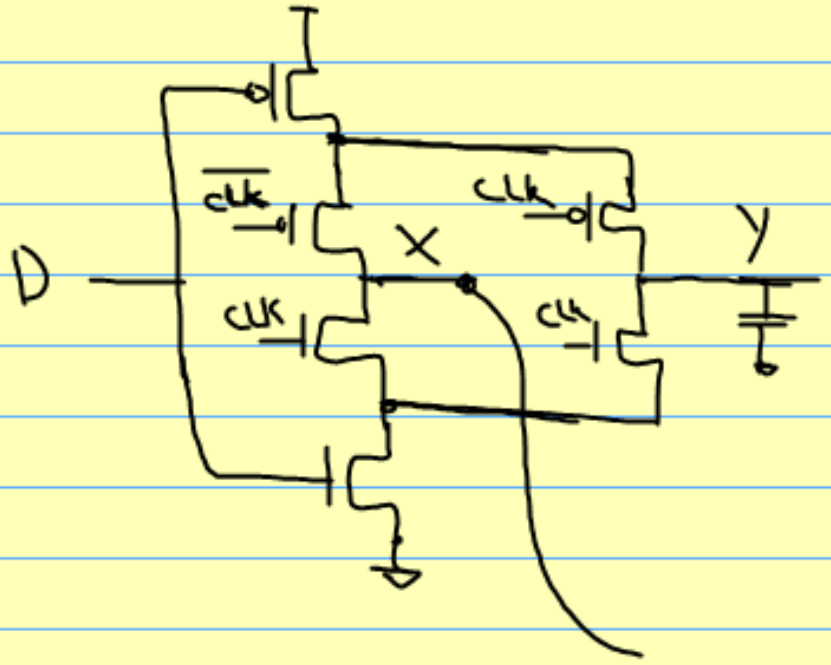
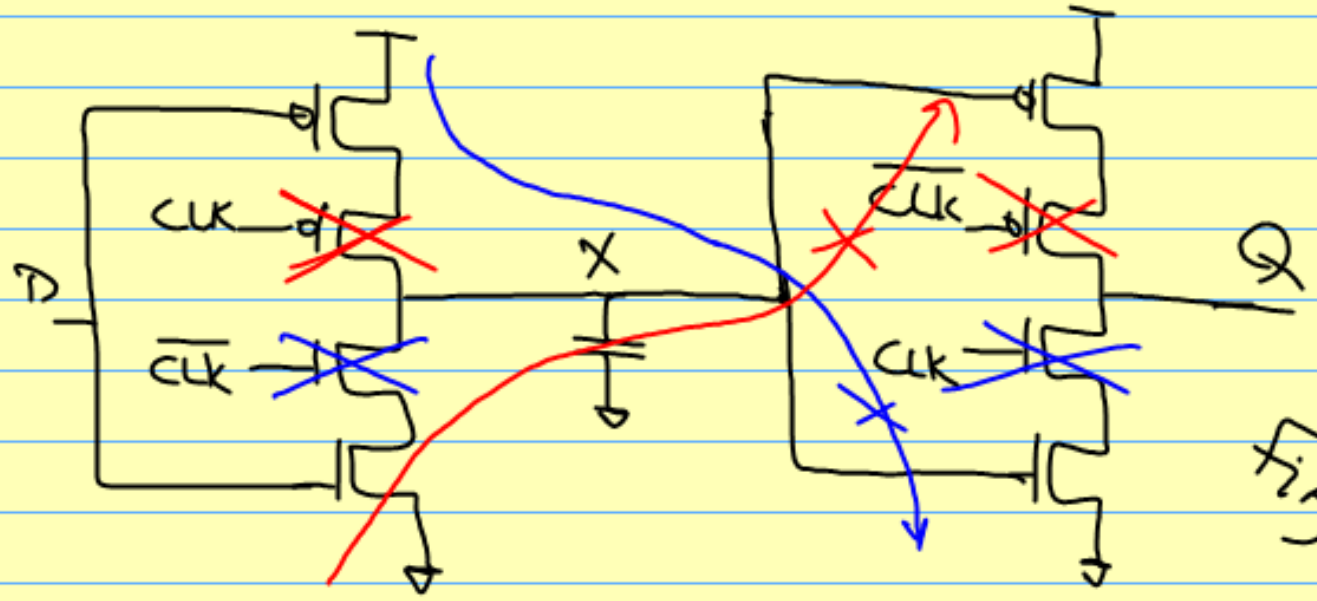


Fig 7-29

C^2MOS



Fig

V-26

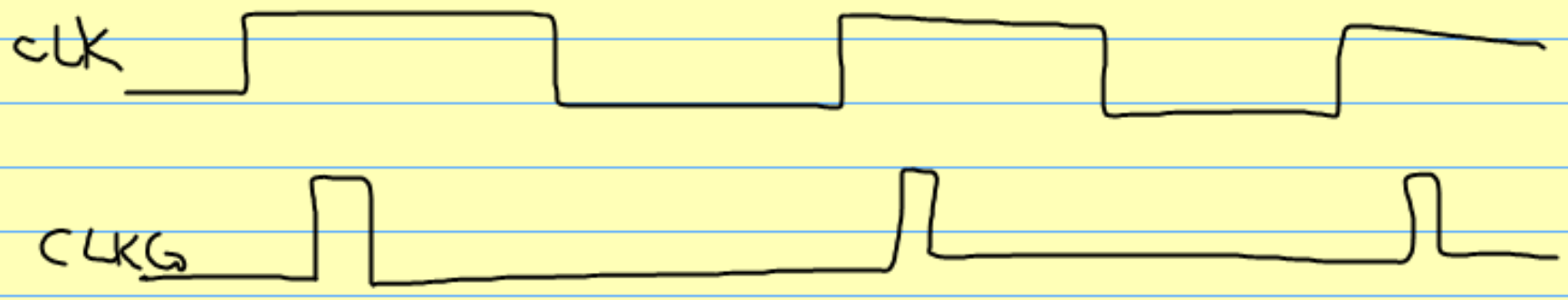
V-27

0-0 overlap $CLK = \overline{CLK} = 0$

1-1 overlap $CLK = \overline{CLK} = 1$

7.4.1 Pulsed Register

idea: get rid of $\overline{CLK}$ as global signal



+ use simple latch as register
+ no skew problems on $\overline{CLK}$
  ⇒ race conditions go away (D running over Q)
+ enables time borrowing