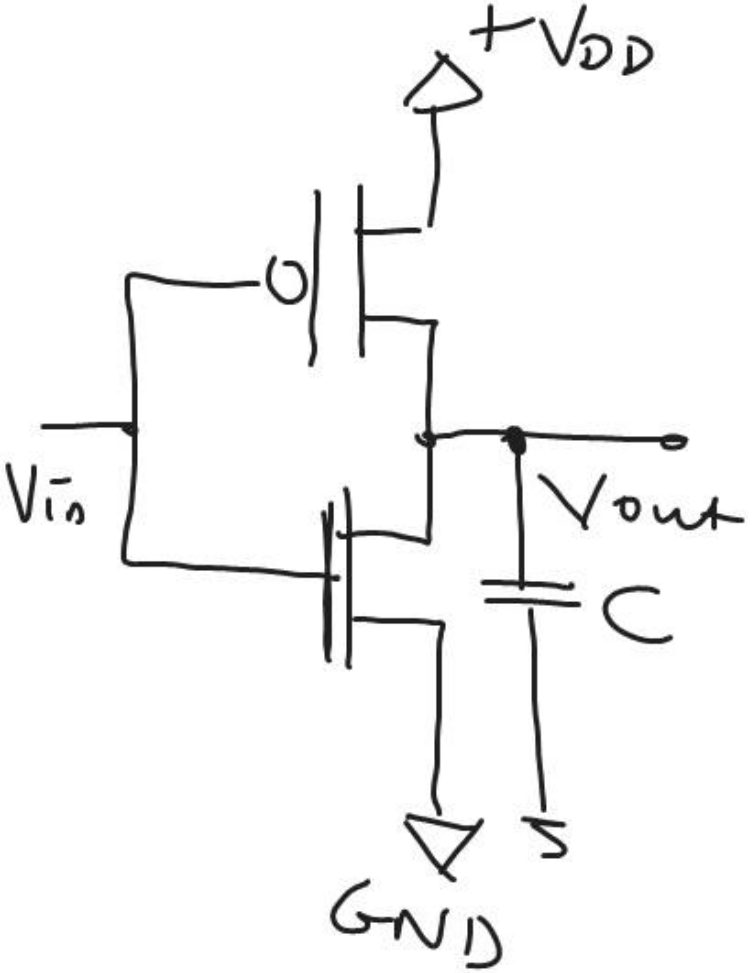
POWER

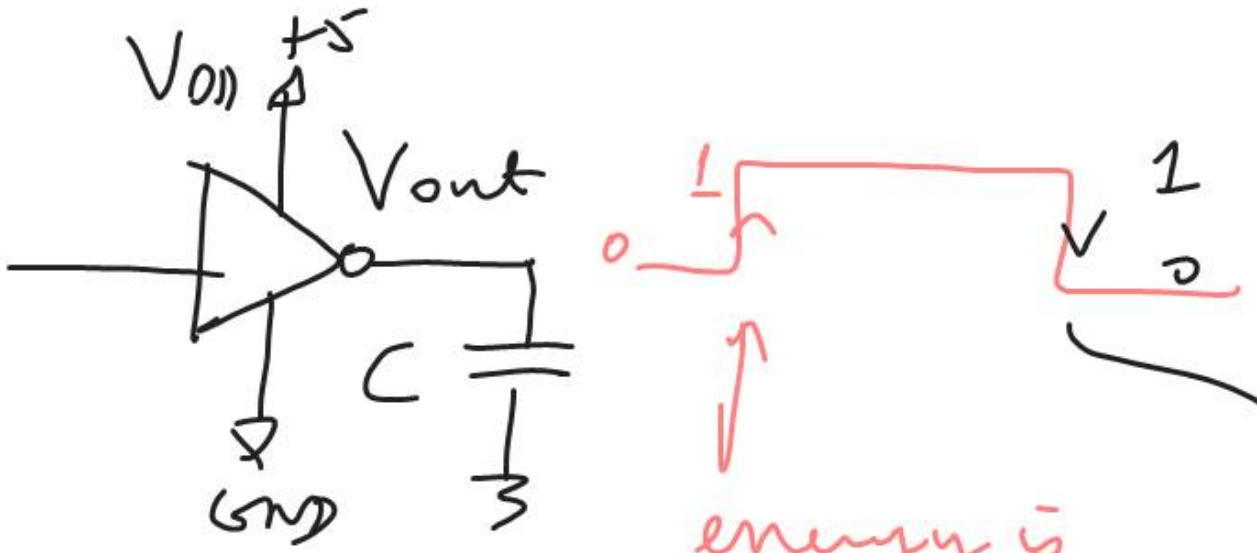
07.01.2011



We have limited energy in battery (for mobile devices) we should consume the lowest amount of power.

Power is the rate of use of energy.

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} = \text{Energy} \times \text{Frequency}$$



energy is drawn from the battery during a 0-1 transition

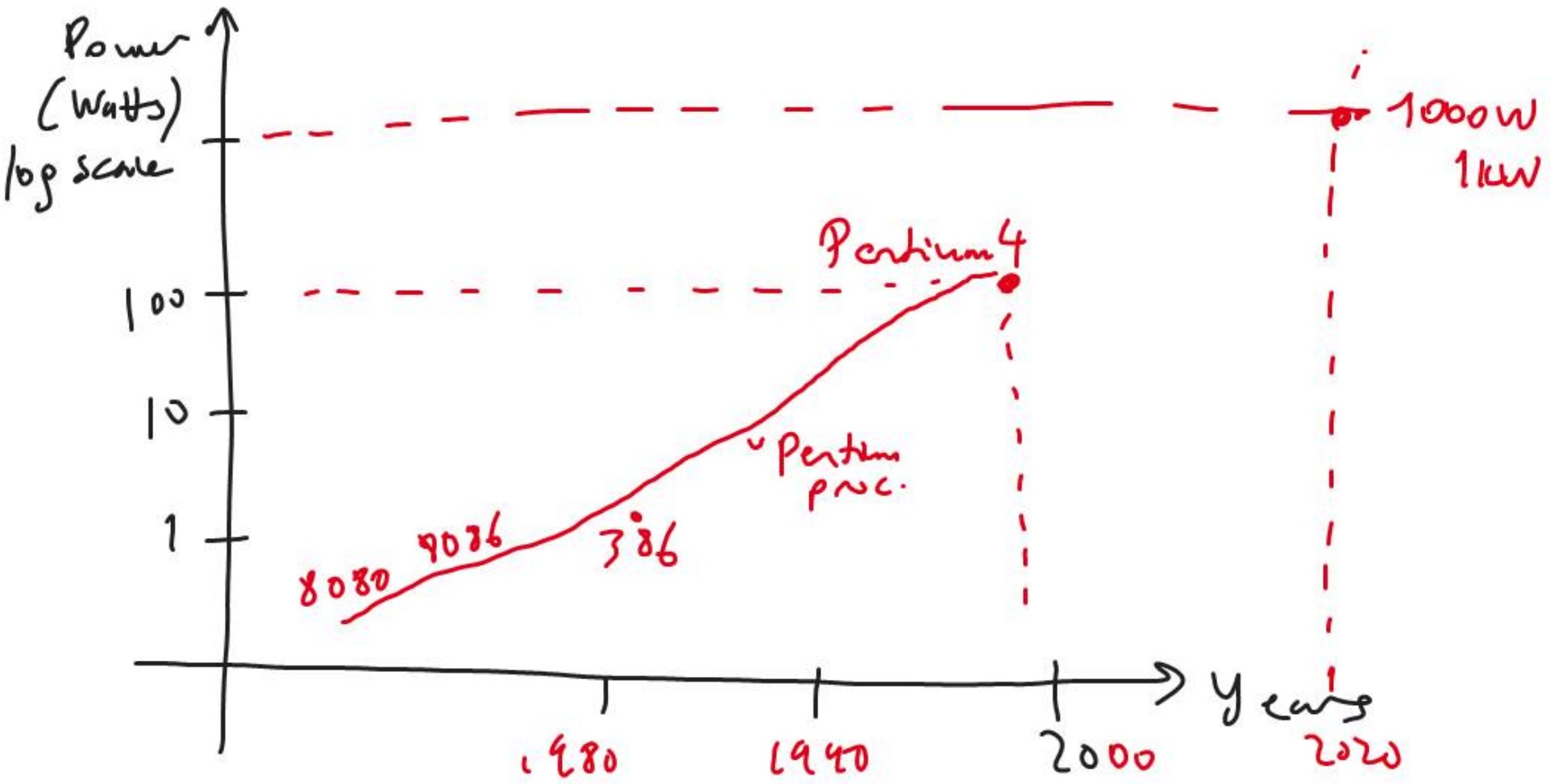
$$E = CV_{DD}^2$$

The stored energy in the Capacitor is consumed as heat on the pull-down transistor.

$\frac{1}{2}CV_{DD}^2$

$E_{consumed} = \frac{1}{2}CV_{DD}^2$ as heat in charging

$\frac{1}{2}CV_{DD}^2$ is stored in the C



Internet data center has ~ 8000 servers ⇒ 2 MW

25% Power added to cool (take the heat out) the devices.

ENVIRONMENTAL CONCERN!

In 2010 ~ 2 Billion PCs

2×10^9 PCs $\times$ 100 W/PC $= 200 \times 10^9$ W $= 200$ GW

1 Hoover Dam in Las Vegas $\rightarrow$ 2.5 GW

For only PCs This much of power is needed.

A very big ENVIRONMENTAL ISSUE !

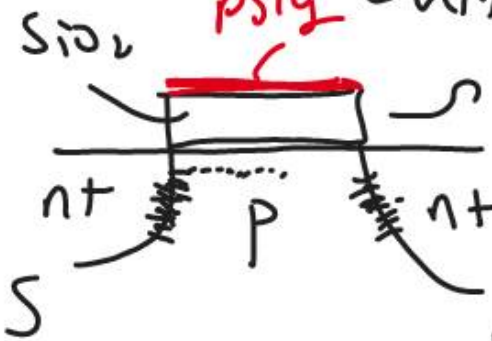
We should reduce the Power Consumption ***

Power Dissipation

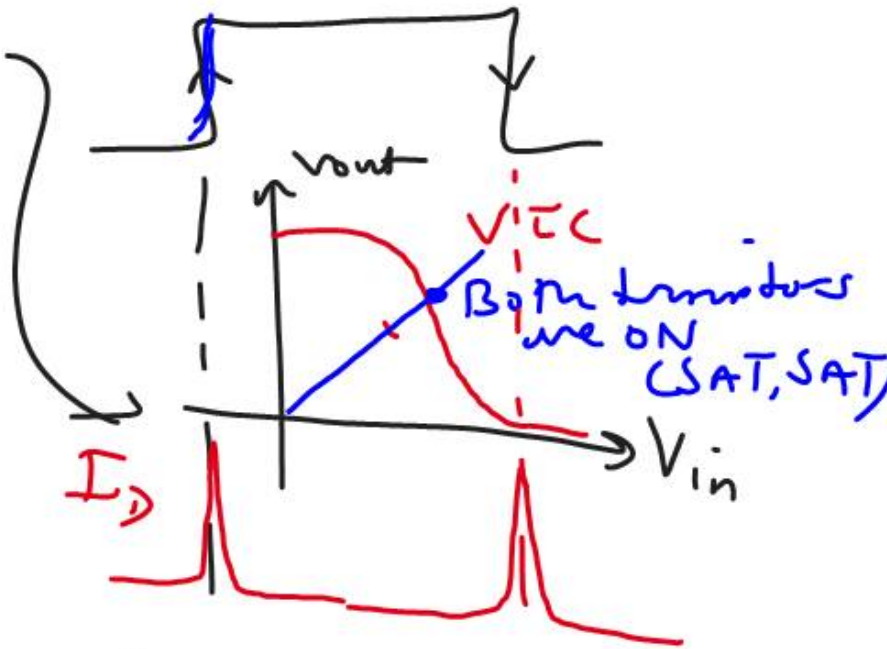
1. Charging & discharging the capacitor during switching ($\frac{1}{2}CV^2$)

2. Short circuit current

3. Gate tunneling current

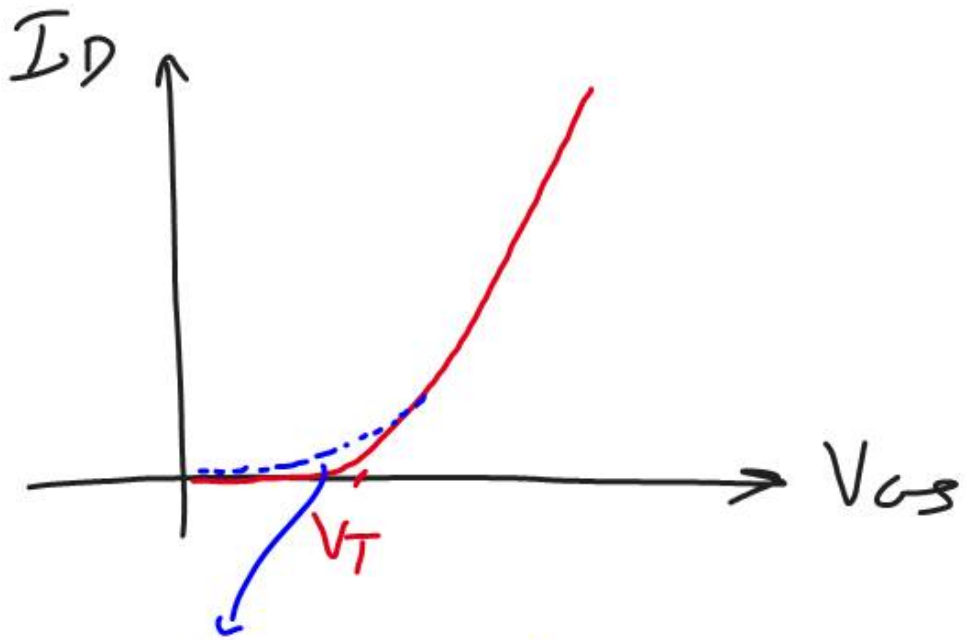


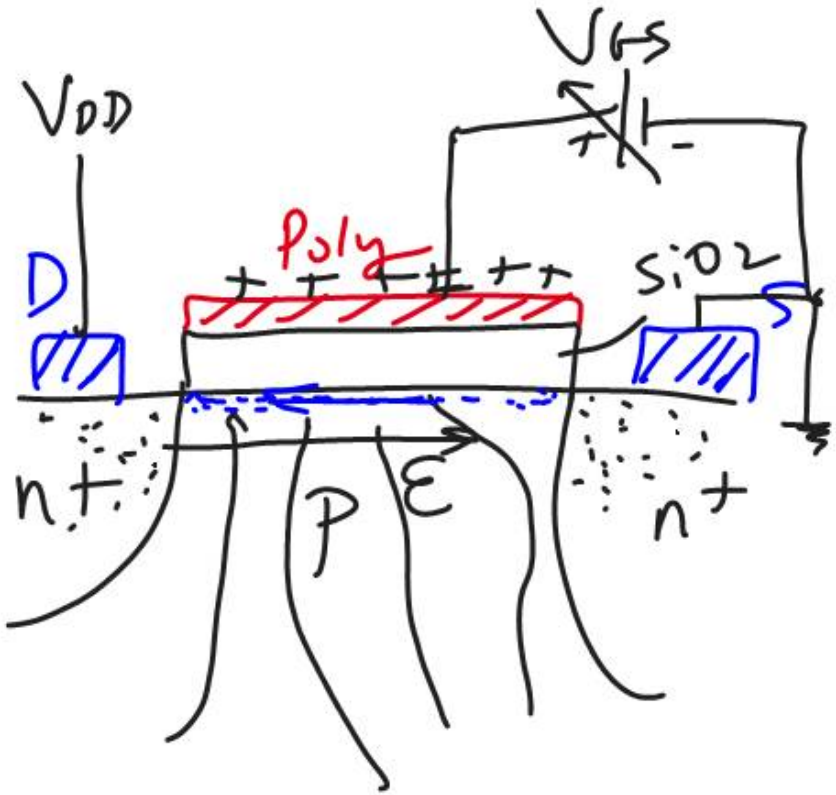
Current tunneling occurs



4. Drain and Source Reverse Diode Leakages

5. Subthreshold (V_T) Leakage


I_D
V_{GS}
V_T
Subthreshold leakage of I_D with V_{GS}


V_{GS}
V_{DD}
Poly
D
SiO2
S
n+
P
E
n+

SWITCHING POWER

$$\text{Power} = \text{Activity} \times \text{frequency} \times \left(\frac{1}{2} C V_{DD}^2 + V_{DD} I_{SC}\right) + V_{DD} I_{subthreshold} + V_{DD} I_{diode} + V_{DD} I_{tunneling\ gate}$$

Activity is the # of circuits switched out that frequency

$$\text{Power} \cong \text{ACTIVITY} \times \frac{1}{2} C V^2 \times \text{Frequency}$$

To minimize the power dissipation:

1 – reduce ACTIVITY

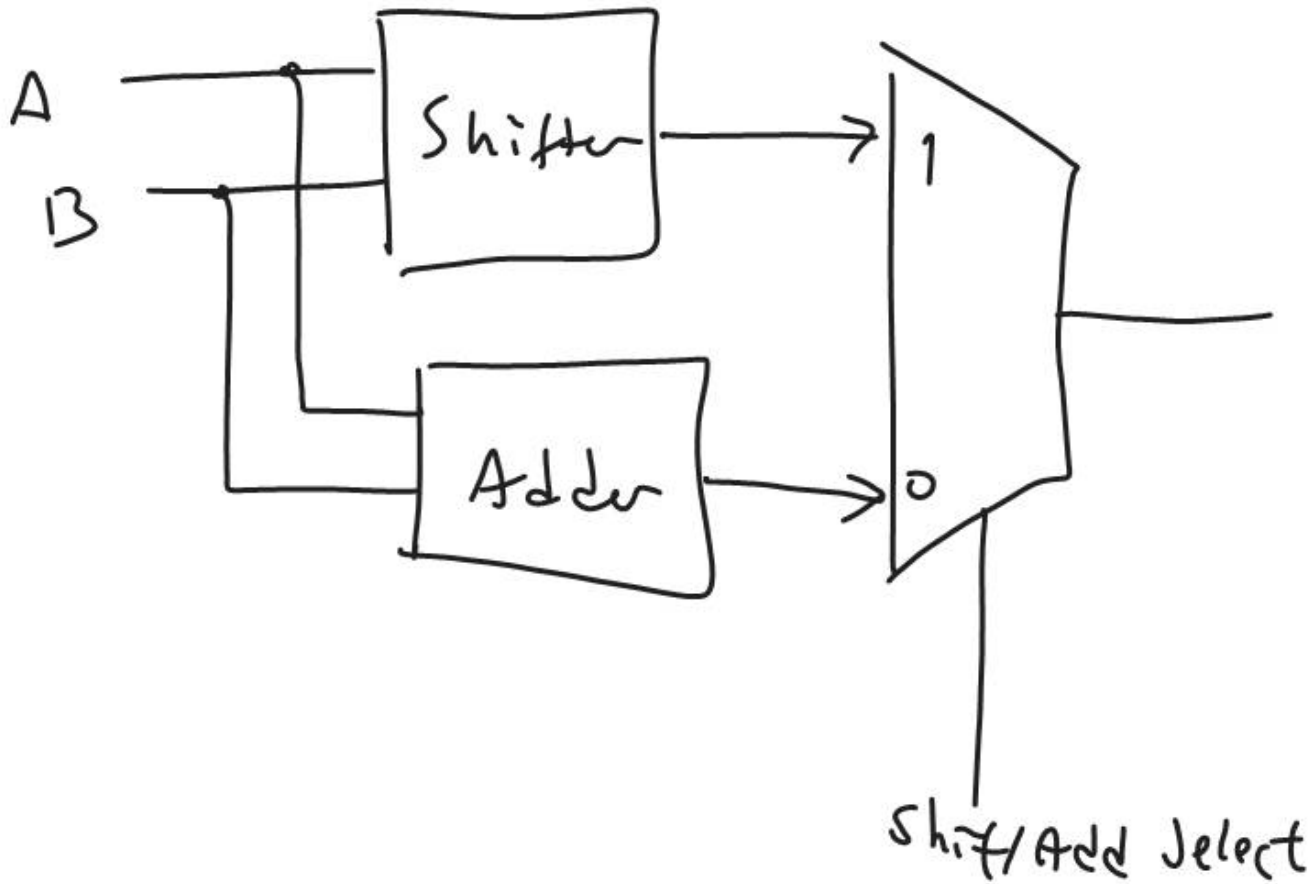
2 – reduce switching capacitance C

3 – reduce supply voltage (V_{DD})

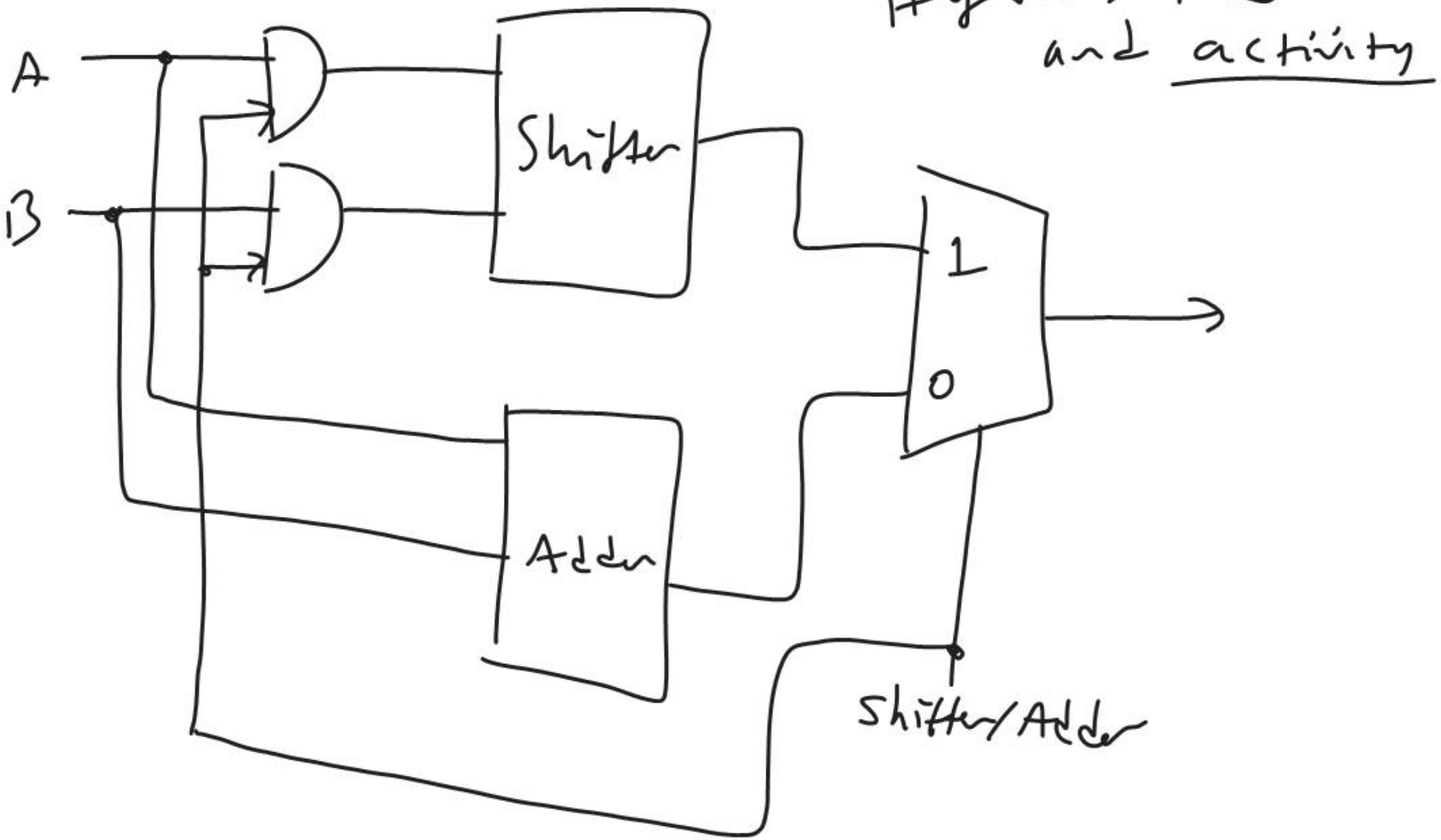
4 – reduce frequency

1- Reduce Activity

- Data Gating

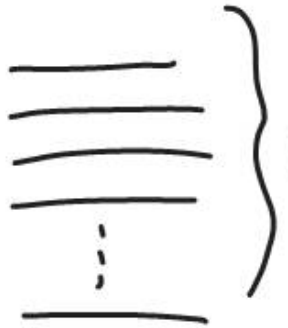


Gating reduces the # of transactions and activity



Other methods to reduce ACTIVITY:

- Bus encodings



parallel digital signal lines ⇒ a BUS

Gray code ⇒ reduces transactions (switching)

0 0 1
0 1 0 → 2 changes in 2 count
0 1 1
1 0 0
⋮

0 0 1 → 1_{10}
0 1 1 → 2_{10}
0 1 0 → 3_{10}
1 1 0 → 4_{10}

- Freeze Don't Cares

1, X, 1, 0, X, 0

↓

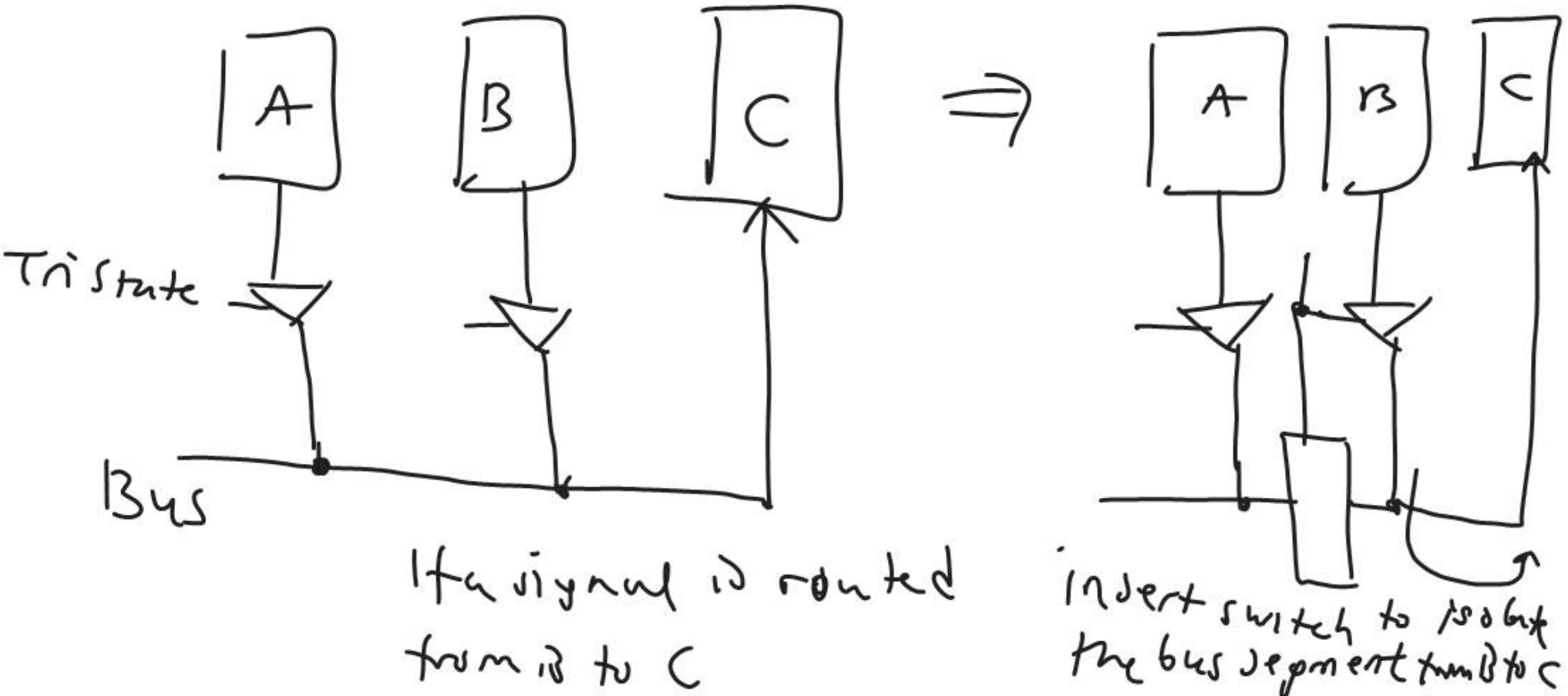
Don't care

1, X=1, 1, 0, X=0, 0

Freeze Don't cares

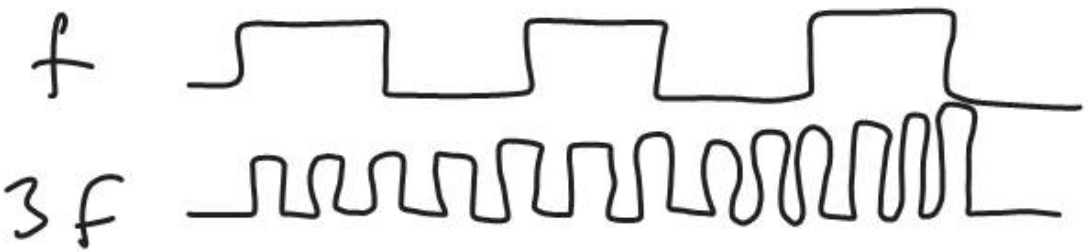
2 - Reduce CAPACITANCE

- careful transistor sizing
- Tighter layout (good floorplanning)
- Segmented structures



3- Reducing FREQUENCY

$$P \cong \text{ACTIVITY} \times \text{frequency} \times \left(\frac{1}{2} C V_{DD}^2\right)$$

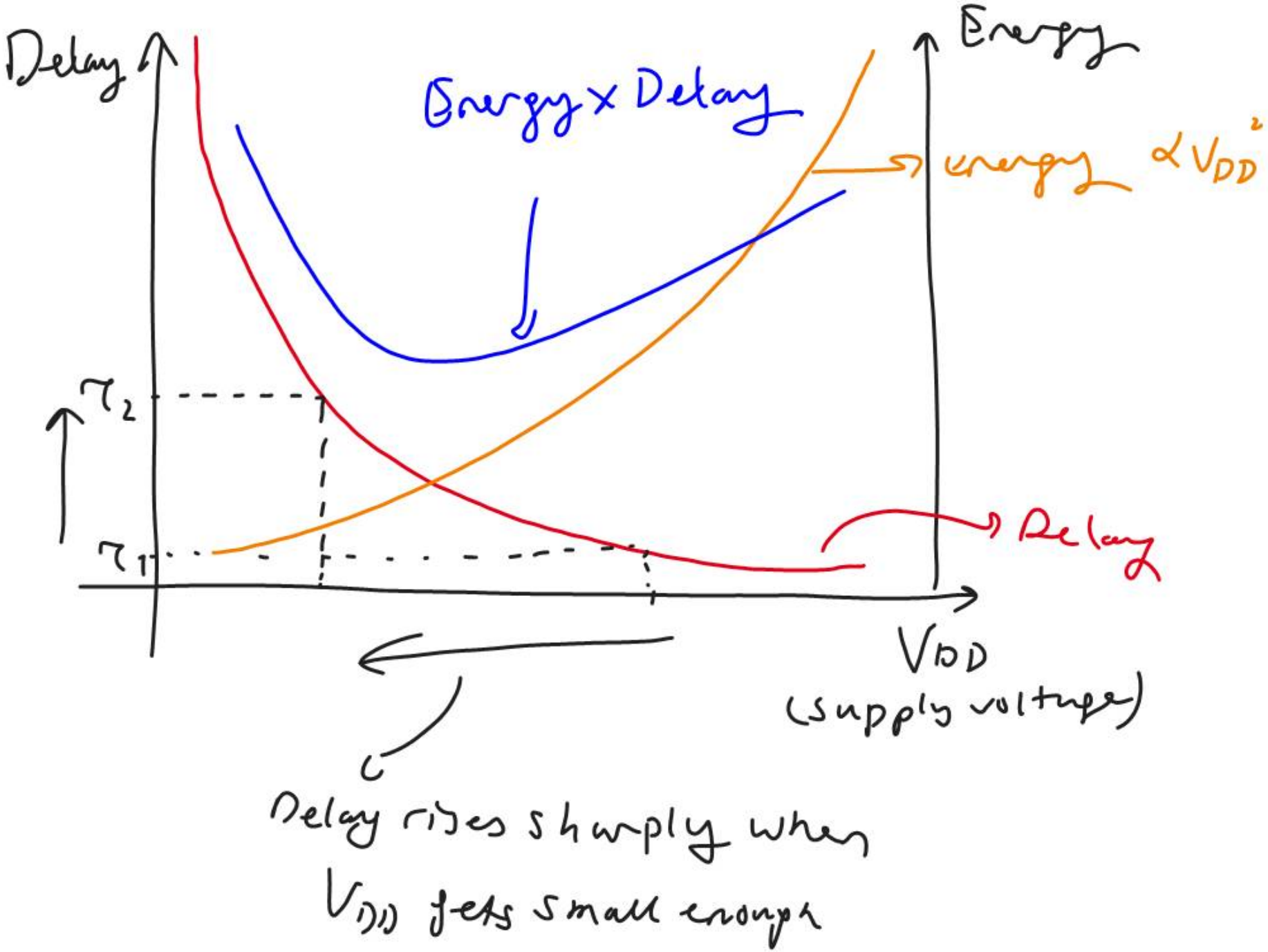


→ 3 times more Power consumption

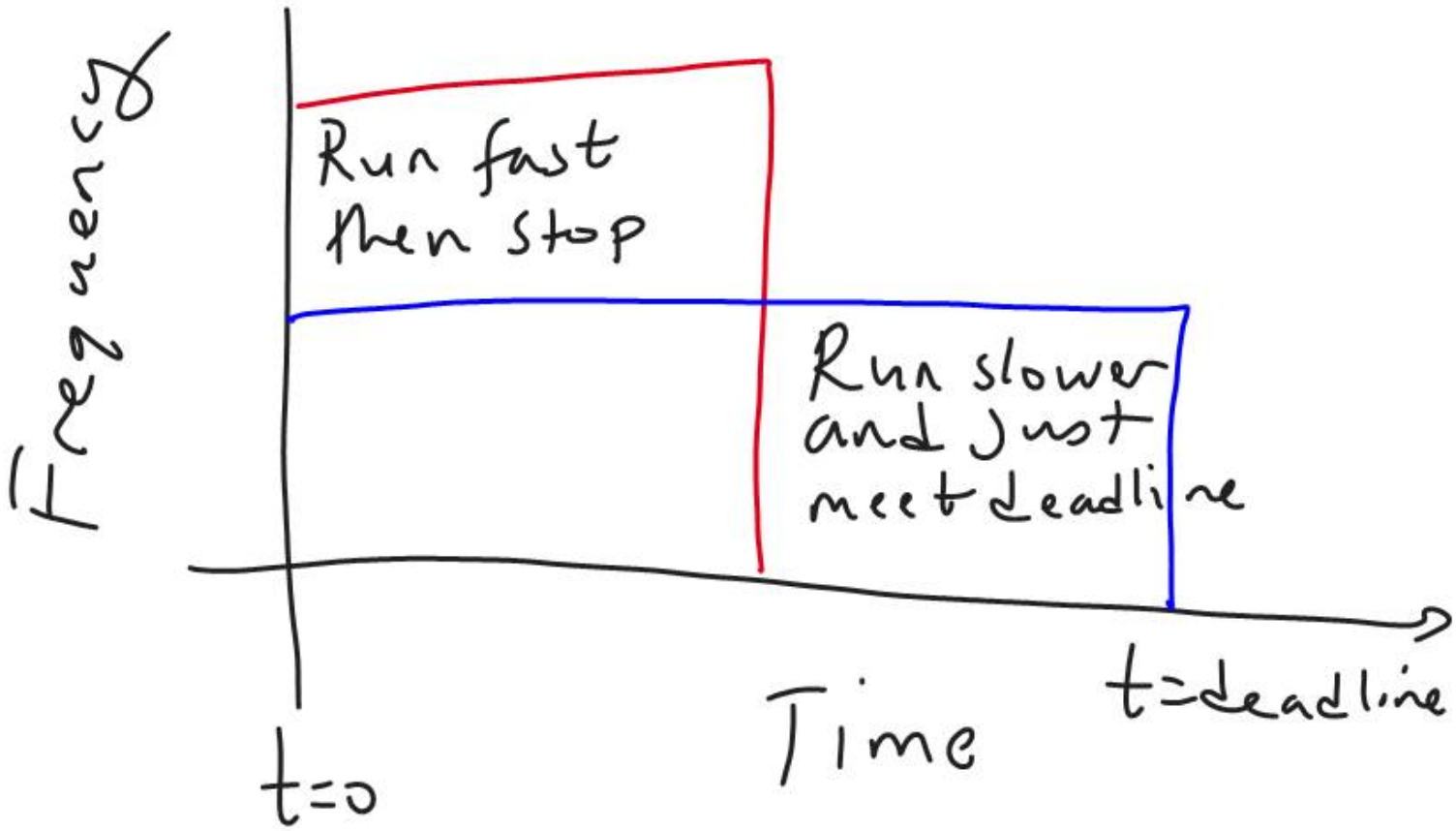
4- Reducing the Supply Voltage (V_{DD})

Reducing V_{DD} → will affect Power α V_{DD}^2

However reducing V_{DD} should make increasing the delay time a must.


Delay
Energy
Energy × Delay
Energy ∝ V_{DD}^2
τ_2
τ_1
Delay
V_{DD}
(supply voltage)
Delay rises sharply when
V_{DD} gets small enough

"Just Enough" performance:



Save Energy by reducing frequency and voltage to minimum necessary

Energy versus delay