DOGGO 151/251A SP2022 Discussion 8

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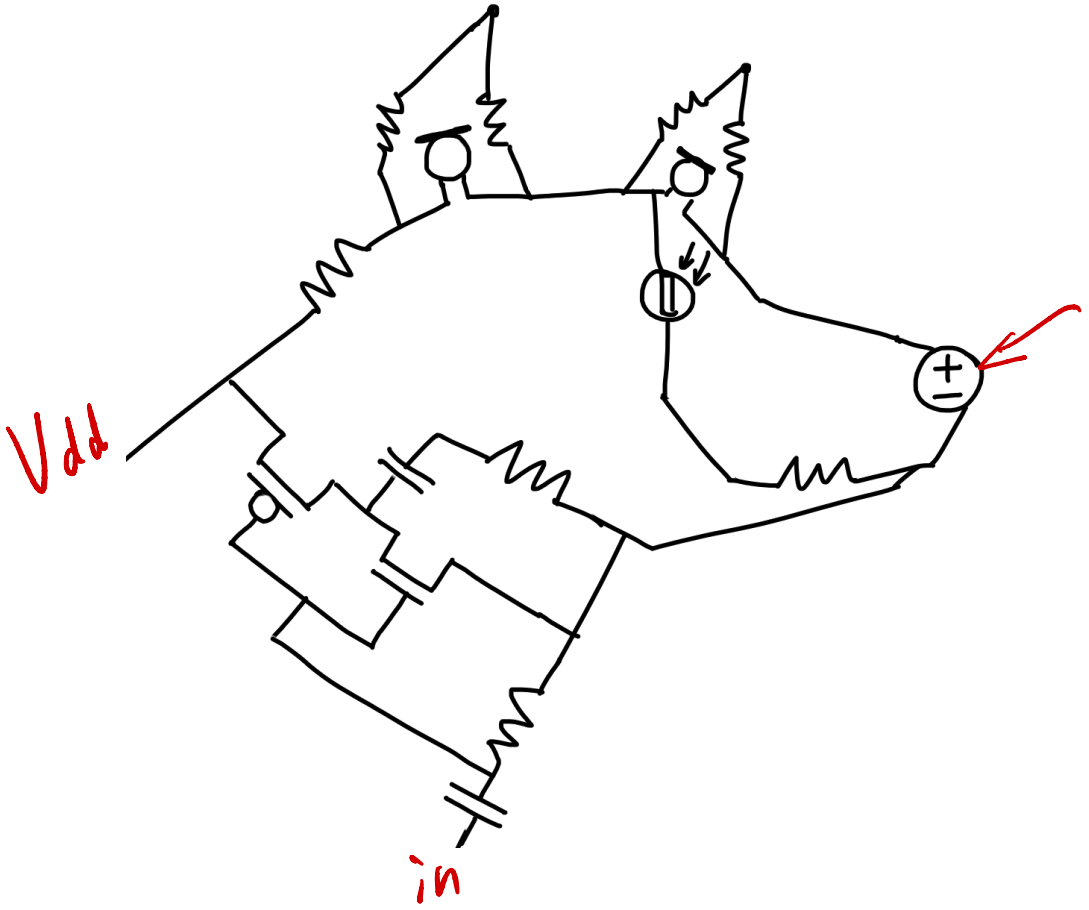
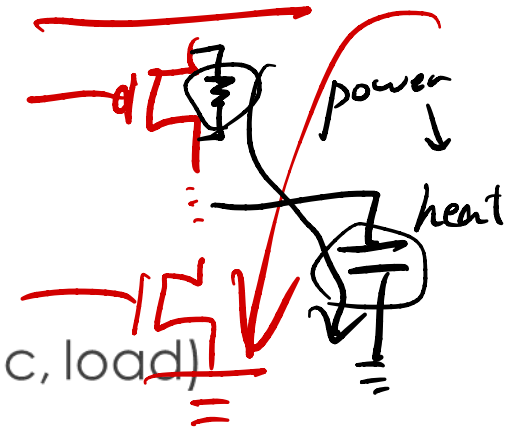
Agenda

- Power/Energy
- Adders

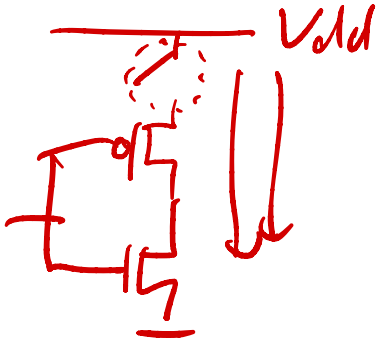


Energy

Power/Energy in Digital Circuits



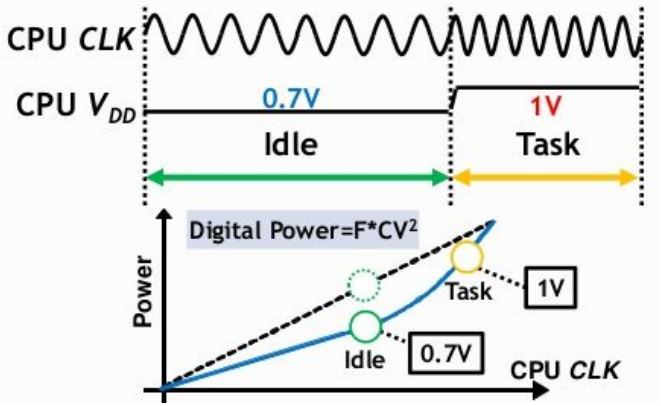
- Fundamentally, charging/discharging capacitors (gate, parasitic, load) through resistances (PMOS, NMOS, wires)
  - Capacitors draw CV^2 joules from supply over 1 charge/discharge cycle
    - $\frac{1}{2}CV^2$ dissipated in PMOS as heat when charging
    - $\frac{1}{2}CV^2$ stored on capacitor, then dissipated in NMOS when discharging



- Dynamic power = $P_{switching} = \alpha CV^2 f$, $\alpha \in [0, 1]$
  - How to minimize each term?
  - Minimizing which terms reduces total energy consumed?
- Static power = leakage → wasted energy!

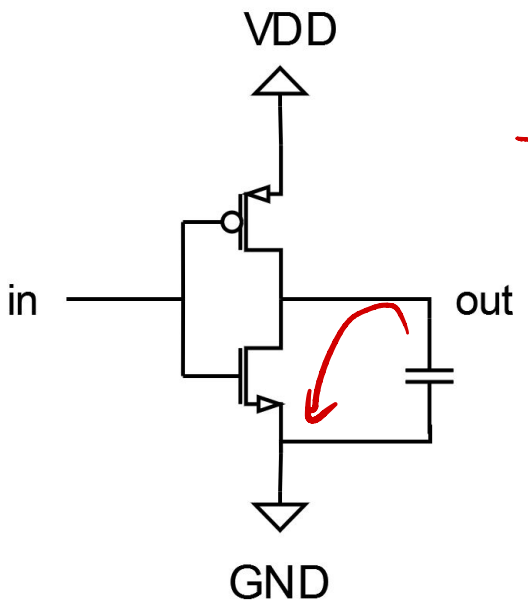
freq ↑ → V ↓ → slower clk

Dynamic Voltage and Frequency Scaling (DVFS)



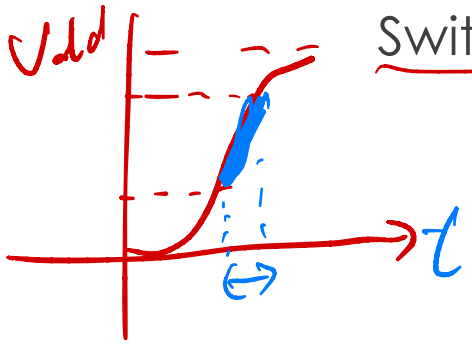
Power/Energy in Digital Circuits Causes

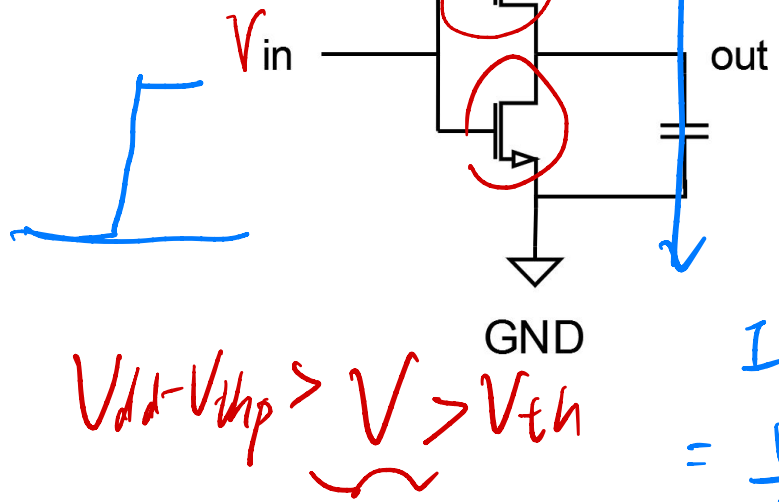
Dynamic Power



$\frac{1}{2} C V^2$

Switching Power

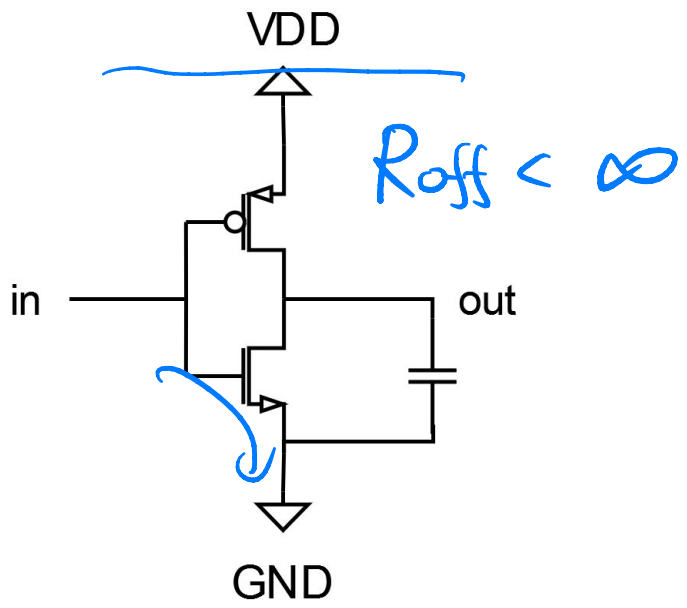




$V_{dd} - V_{thp} > V > V_{th}$

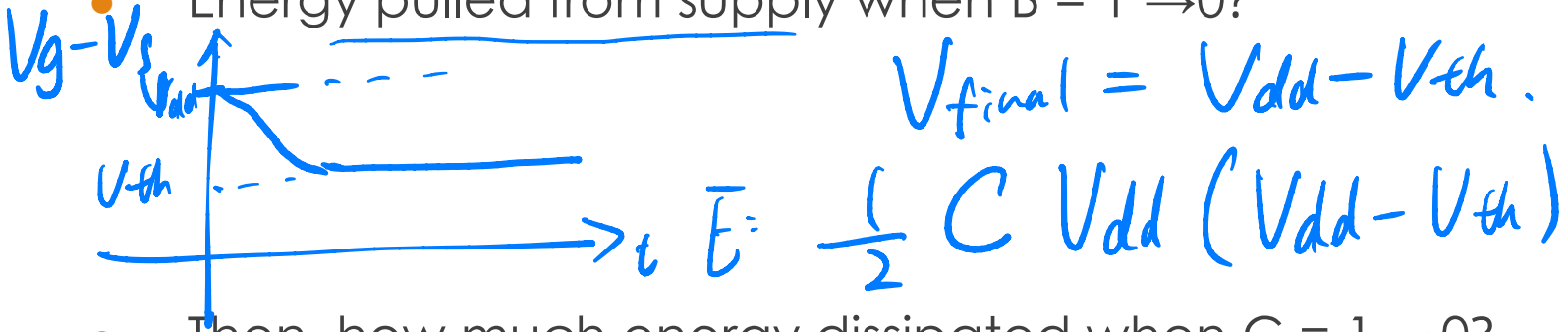
$IV = \frac{V^2}{R}$

Leakage Power



Energy Example

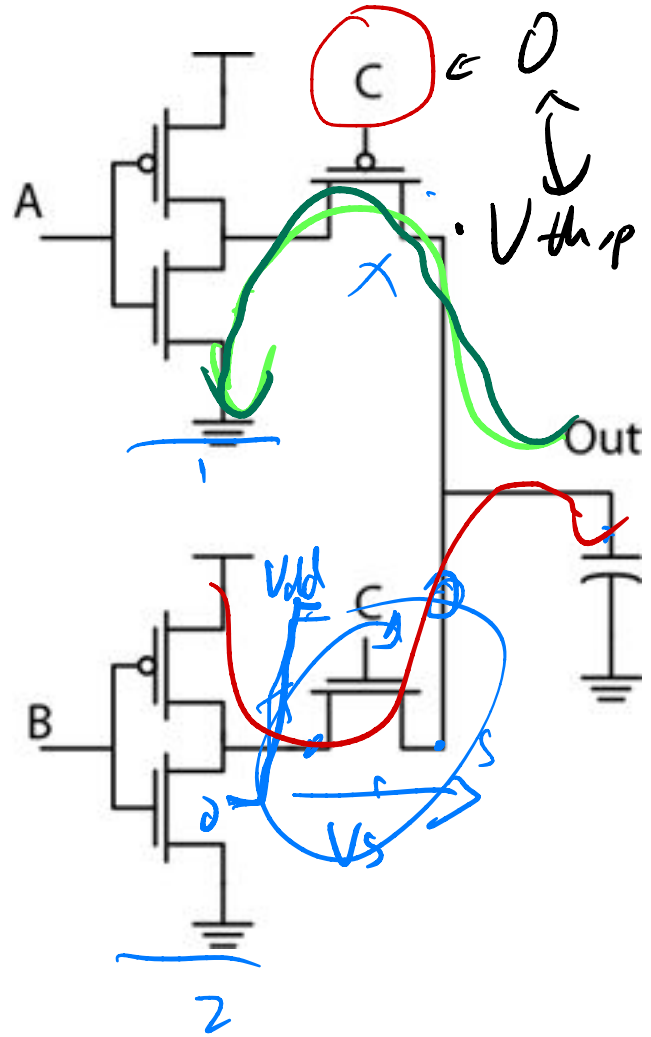
- Initially: A = 1, C = 1, Out = 0
- Energy pulled from supply when B = 1 →0?



- Then, how much energy dissipated when C = 1 →0?

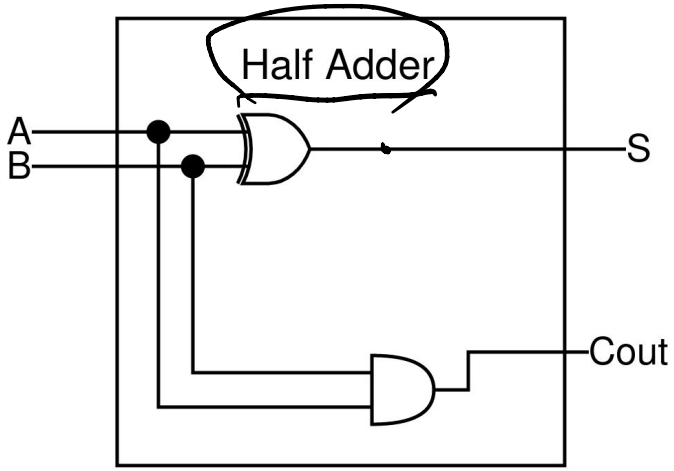
V_{cap} : $V_{dd} - V_{th,n} \rightarrow V_{th,p}$

$E = \frac{1}{2} C (V_{dd} - V_{th,n})^2 - \frac{1}{2} C V_{th,p}^2$



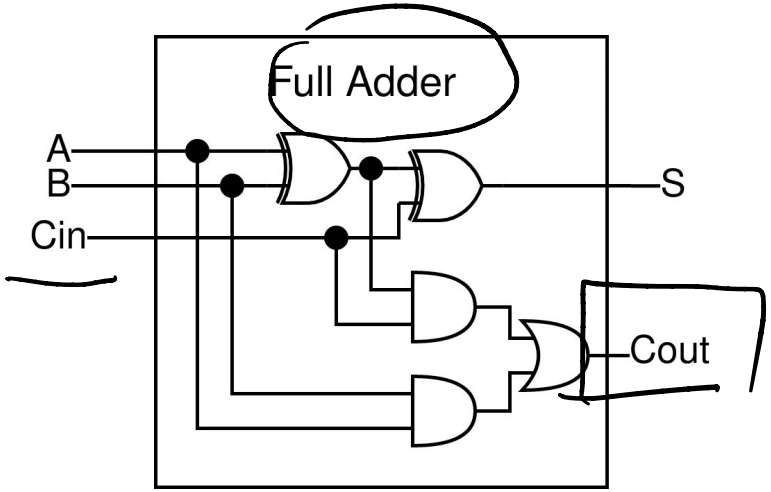
Adders

Adder Components



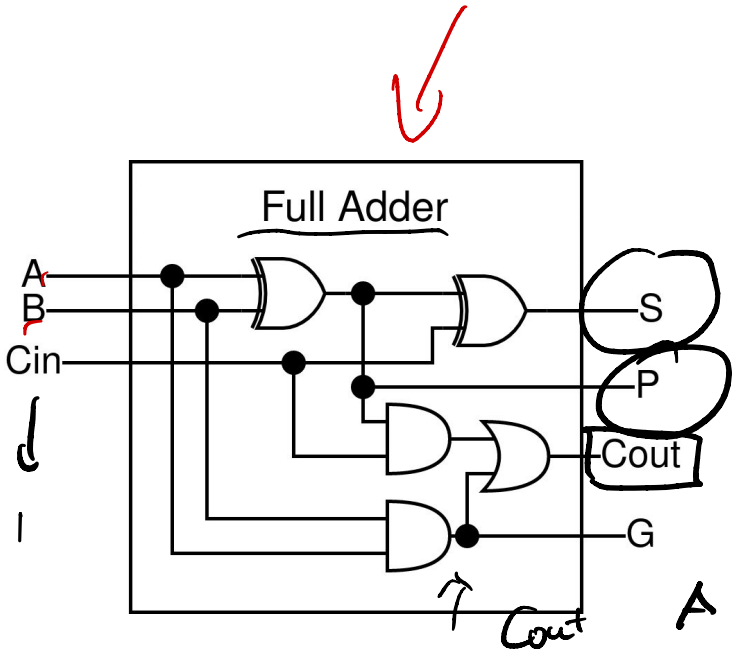
$$S = A \oplus B$$

$$C_o = A\,B$$



$$S = A \oplus B \oplus Ci$$

$$C_o = A\,B + B\,Ci + A\,Ci$$



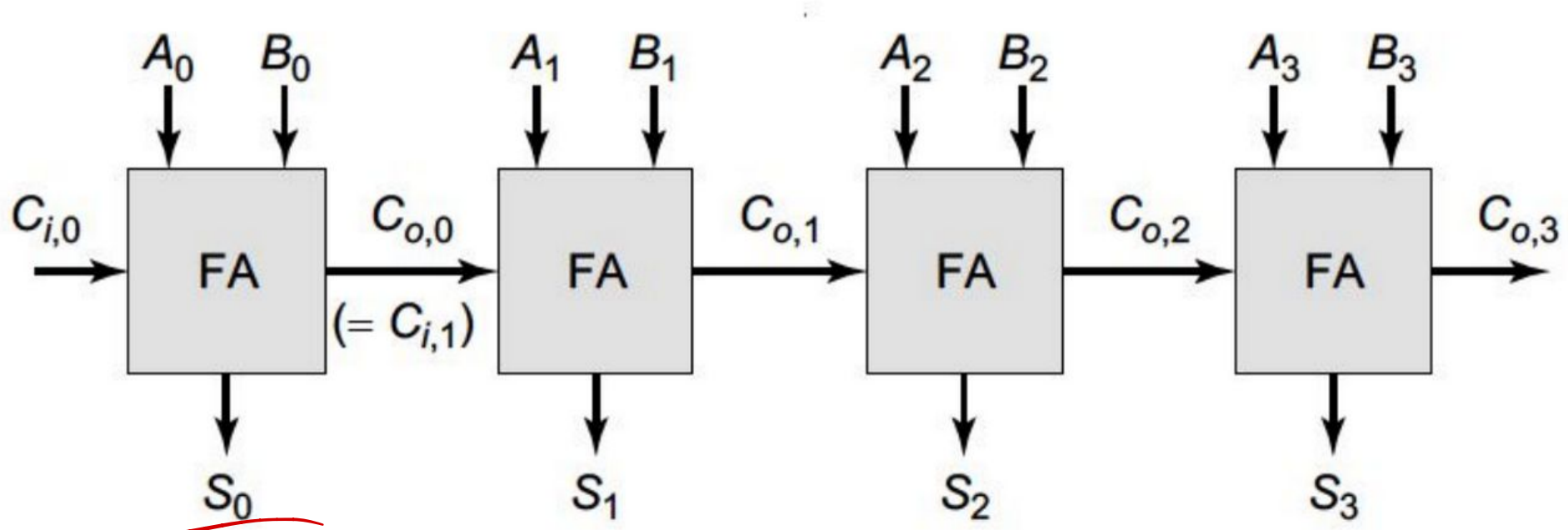
propagate

$$P = A \oplus B$$

$$G = A\,B$$

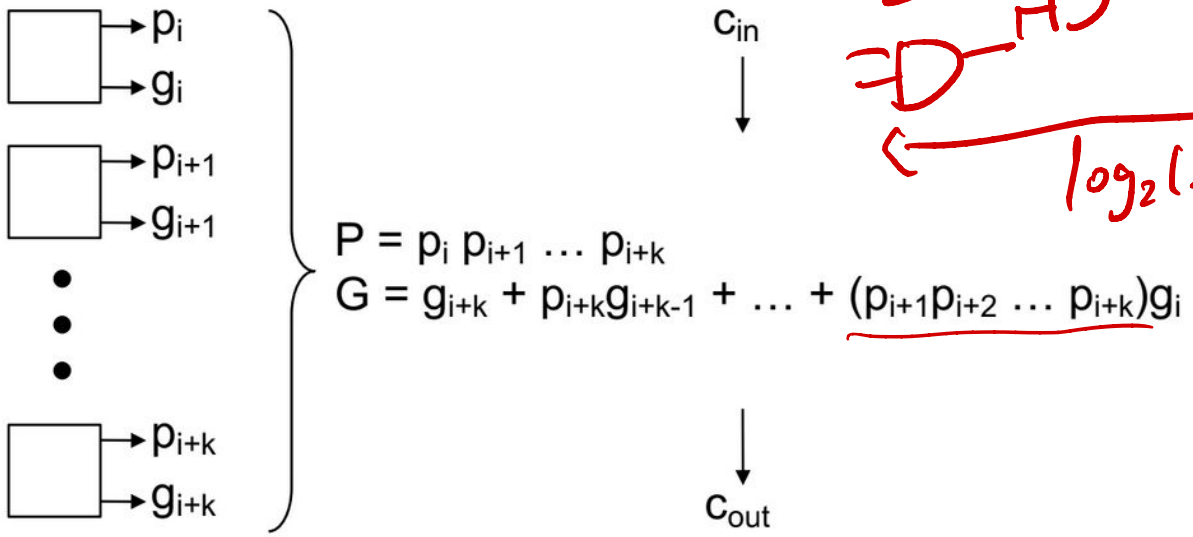
generate.

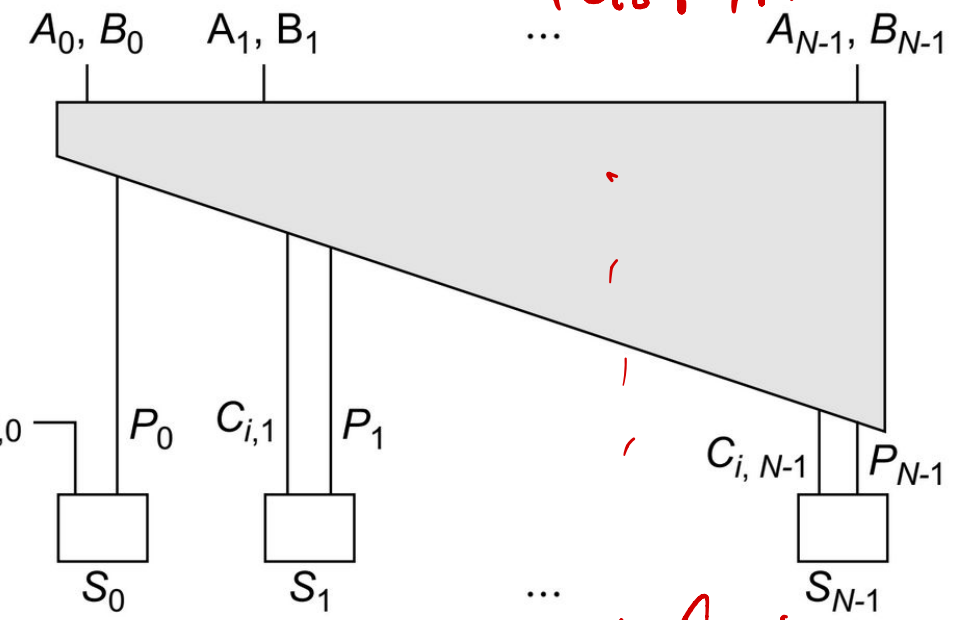
Ripple-Carry Adder



- Time Complexity? O(N)
- Area Complexity? O(N)

Carry-Lookahead Adder





$$C_{o,k} = f(A_k, B_k, C_{o,k-1}) = G_k + P_k C_{o,k-1}$$

- Time Complexity?
- Area Complexity?

Carry-Lookahead Tree Adder

- Time Complexity?

$O(\log_2 N)$

- Area Complexity?

$4 + 2 + 1$

$= 2^3 - 1$

$= 2^{\log_2 8} - 1$

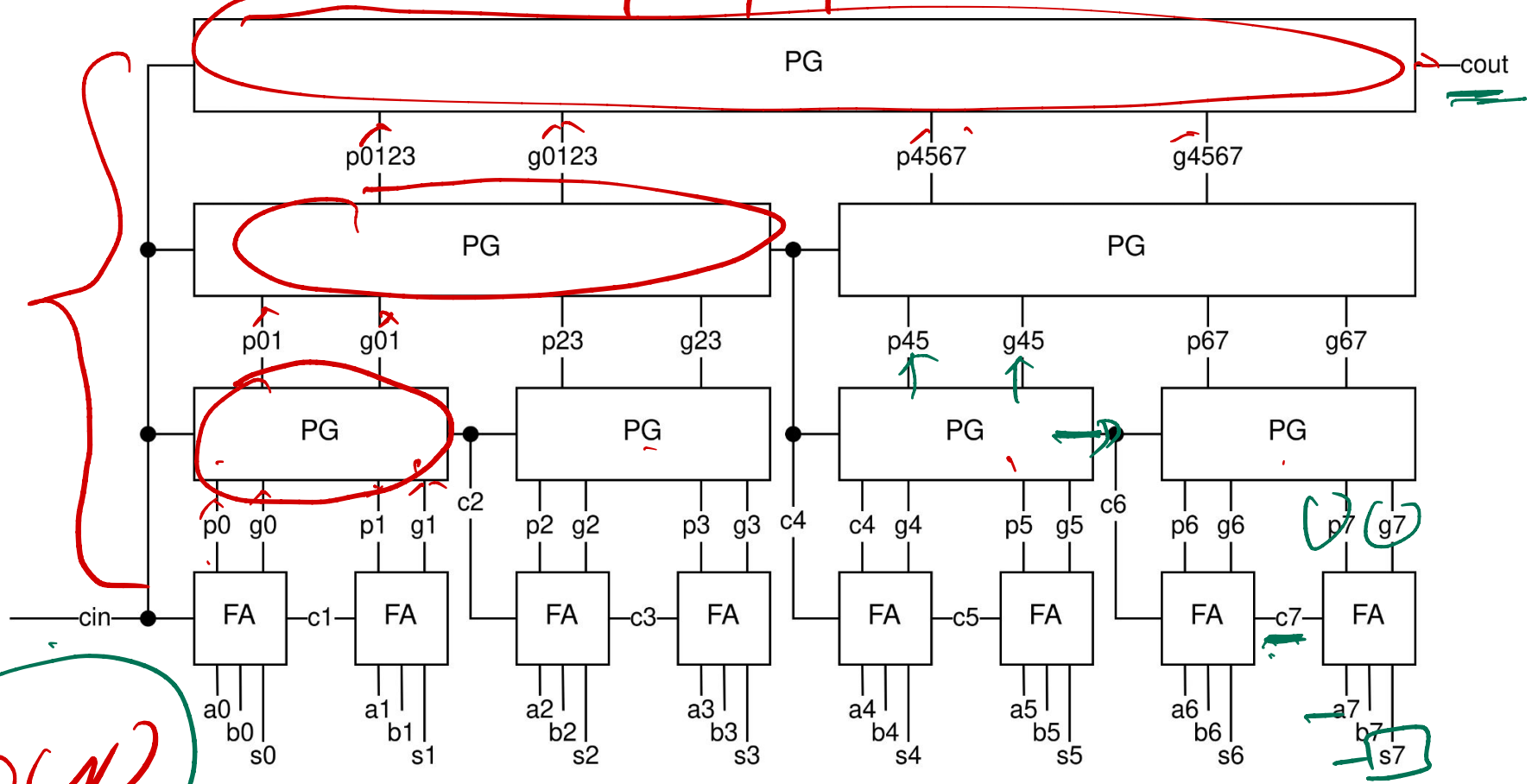
$= 8 - 1 \Rightarrow O(N)$

Group Gen ; Group Prop.

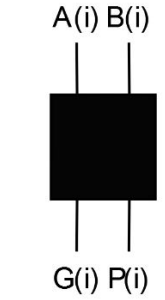
$P_{1:0} = \prod P_i$

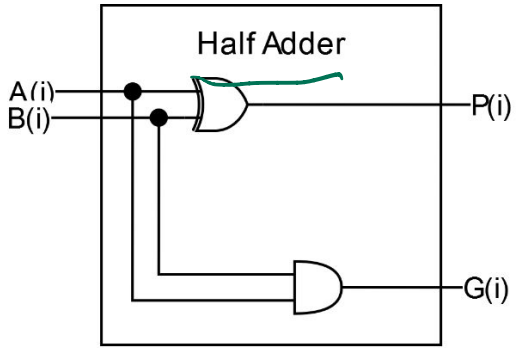
$C_{out6} = G_{6:0} + P_{6:0} C_{0,in}$

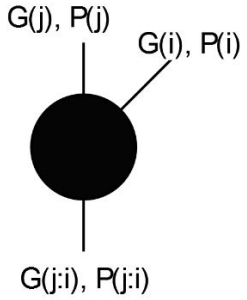
$P_{1:0} = P_1 \cdot P_0,\ G_{1:0} = G_1 + P_1 \cdot G_0, \rightarrow C_{out1} = G_{1:0} + P_{1:0} \cdot C_{0,in}$

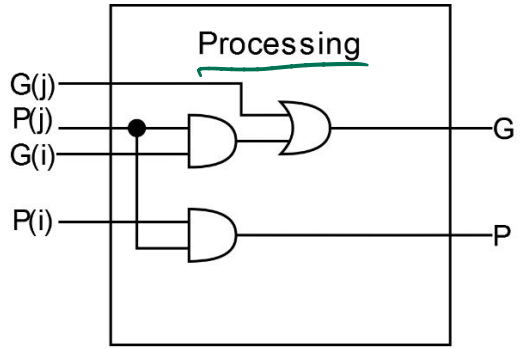


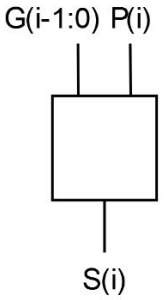
Kogge-Stone Tree Adder (Components)

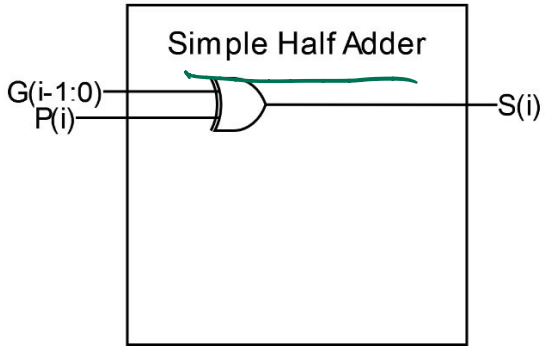


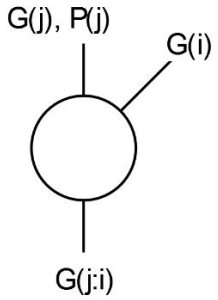


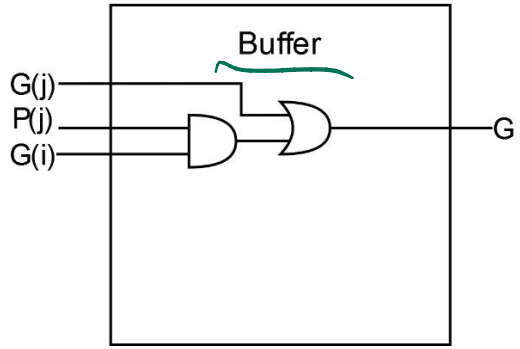




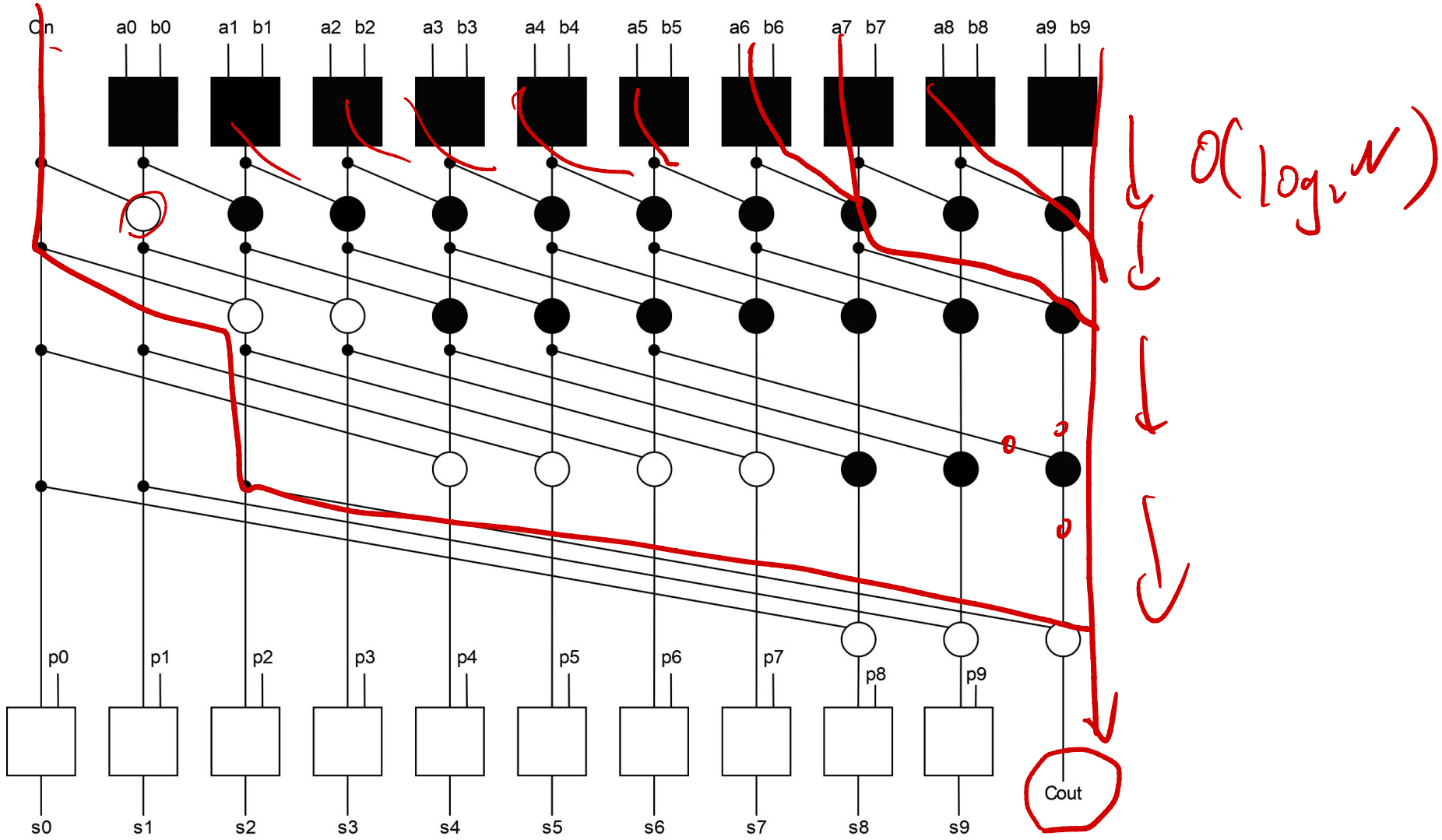








Kogge-Stone Tree Adder



Doggo Adder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Questions?