Electric Circuits
Lecture 8 Energy and Power

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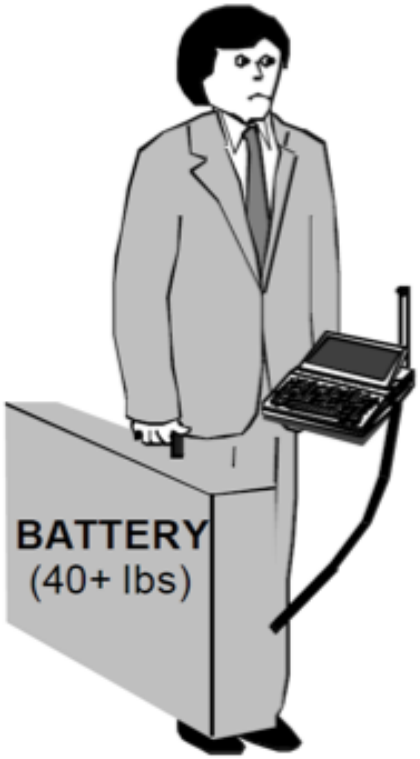
Why Worry about Energy?

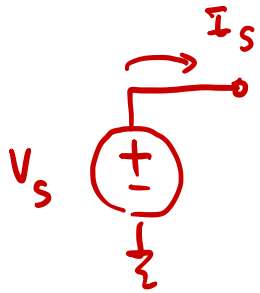
- Portable devices

- How long will the battery last?
  - In standby mode
  - In active mode
- Will the chip overheat and self-destruct?



Static and Dynamic Power

- Static power: power loss due to static current drawn from the power supply.

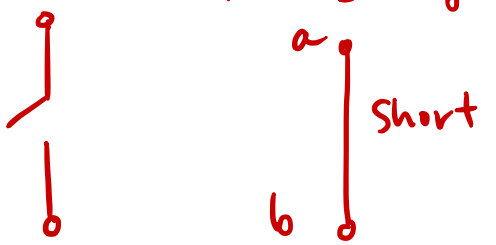


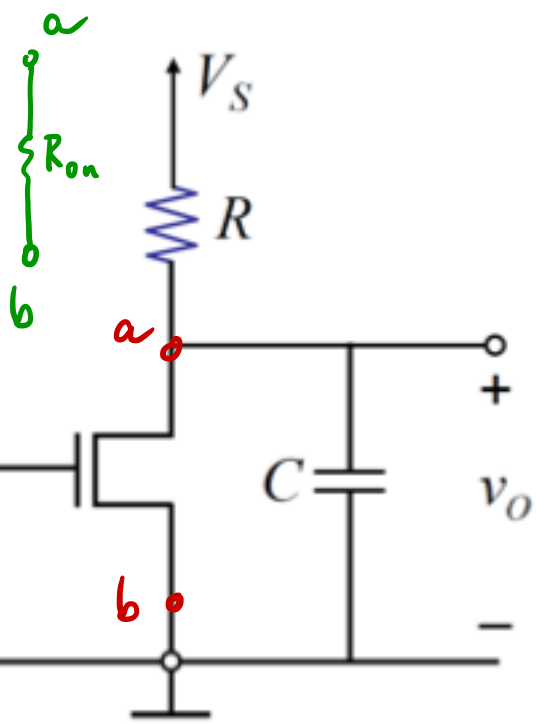
$$P_S = V_S \cdot I_S$$

- Dynamic power: power loss due to the switching current required to charge and discharge capacitors.

Energy Dissipation in MOSFET Gates

switch v_I = high

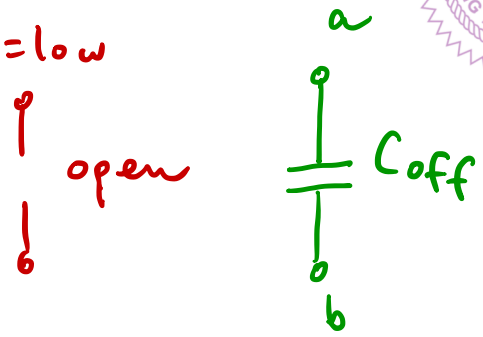




ideally, $R_{on} \to 0$

R_{on}: on resistance

v_I = low



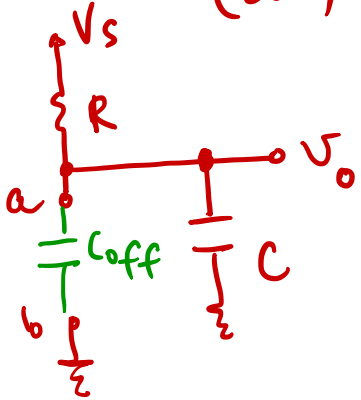
ideally $C_{off} \to 0$

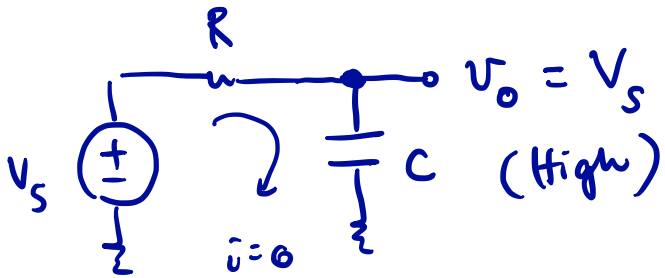
2) when $v_I = V_S$ (High)

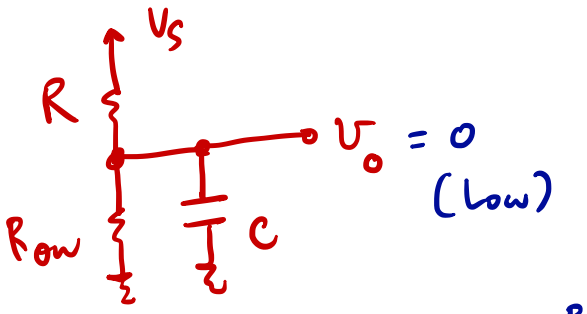
($v_I \geq V_{TH}$ 0.3 v ~ 1v

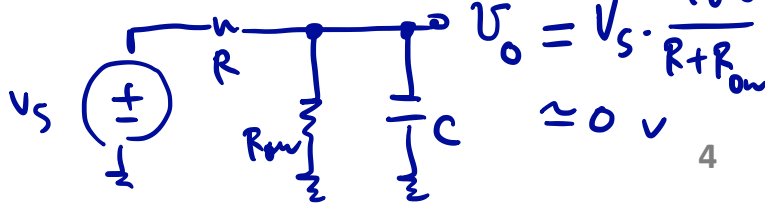
V_{TH}: threshold voltage)

1) when $v_I = 0$ (Low)





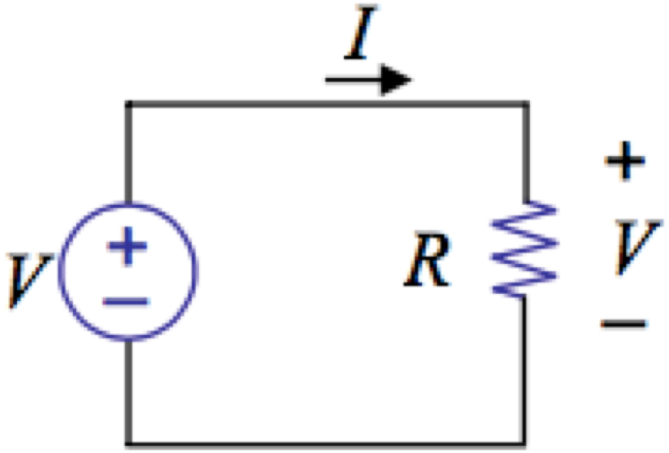


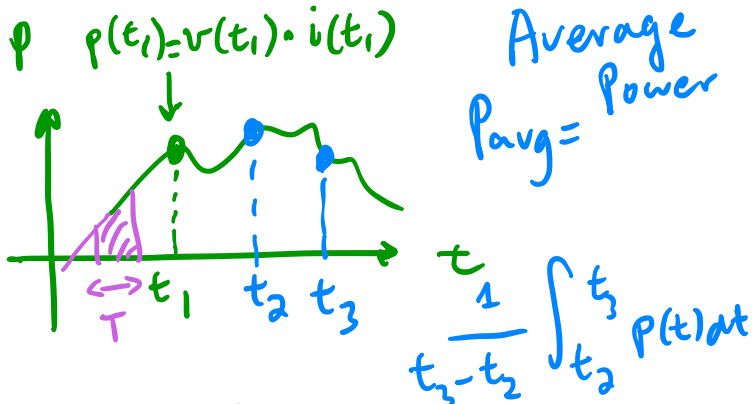


First Example

- The power consumed by R

$$p = v \cdot i = V \cdot \frac{V}{R} = I^2 \cdot R \quad (W)$$





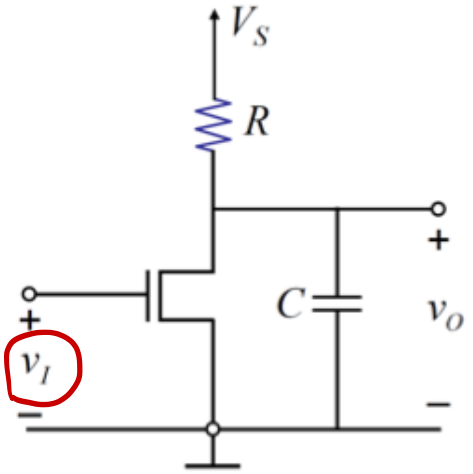
- The energy dissipated during time interval T

$$E = \int_T p\,dt = P \cdot T \quad (J)$$

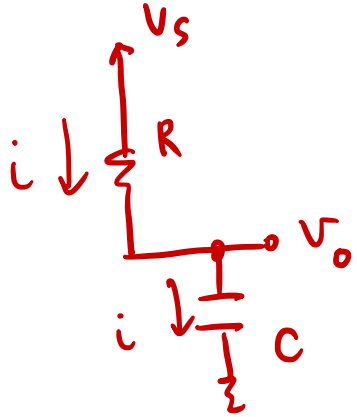
$$\text{Energy} = \int_T p(t)\,dt$$

Apply to Our Gate for Steady-State Static Power

- When the gate is not switching



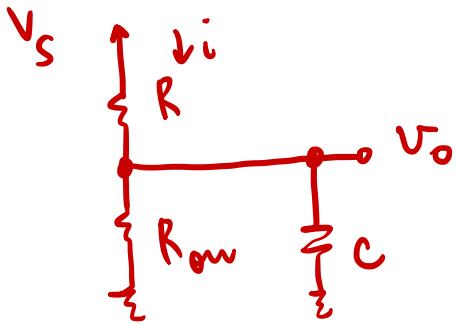
1) when v_I = low



$i = 0$

$P = V_S \cdot i = V_S \cdot 0 = 0$ W

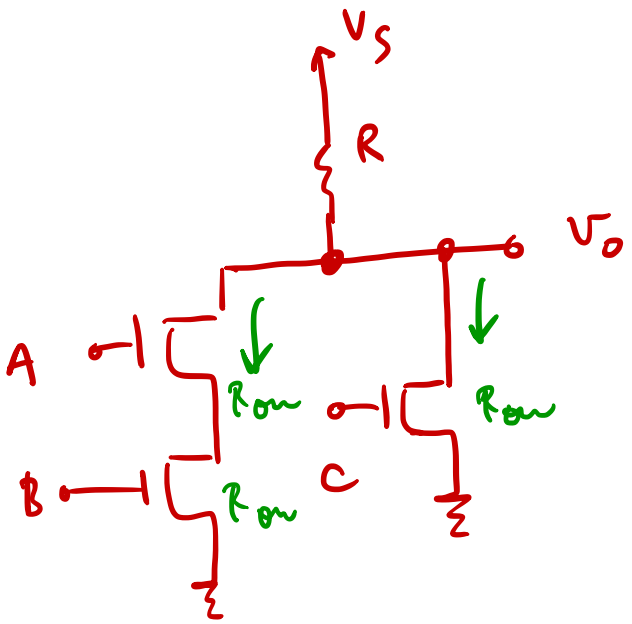
2) when v_I = high



$$P = V_S \cdot i = V_S \cdot \frac{V_S}{R + R_{on}} = \frac{V_S^2}{R + R_{on}} \quad W$$

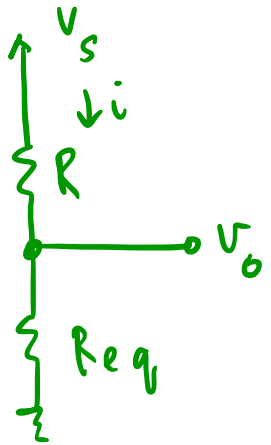
Example

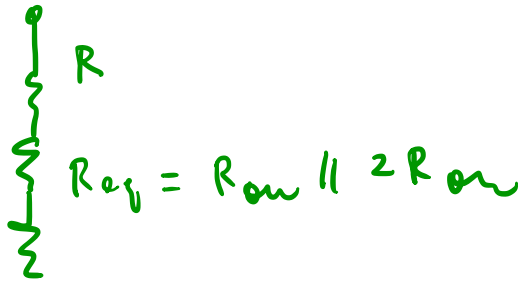
Find the max. static power.



$$P_{static} = V_S \cdot i = V_S \cdot \frac{V_S}{R + R_{eq}} = V_S \cdot \frac{V_S}{R + \frac{2}{3} R_{on}}$$

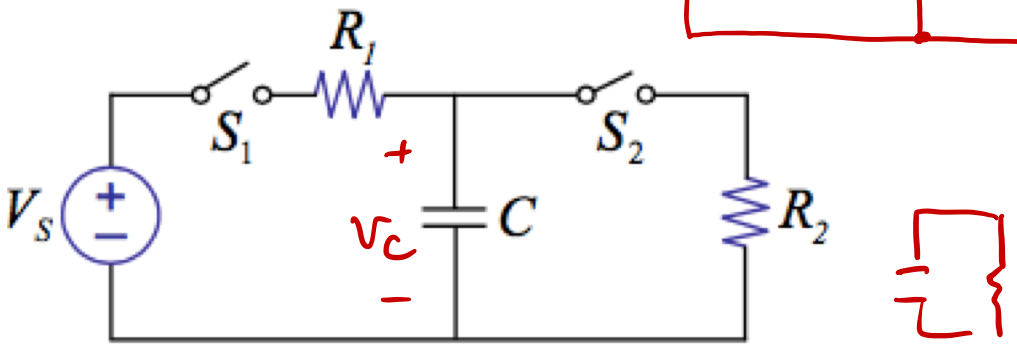
$\Rightarrow$ min. R_{eq}. A, B, C = High

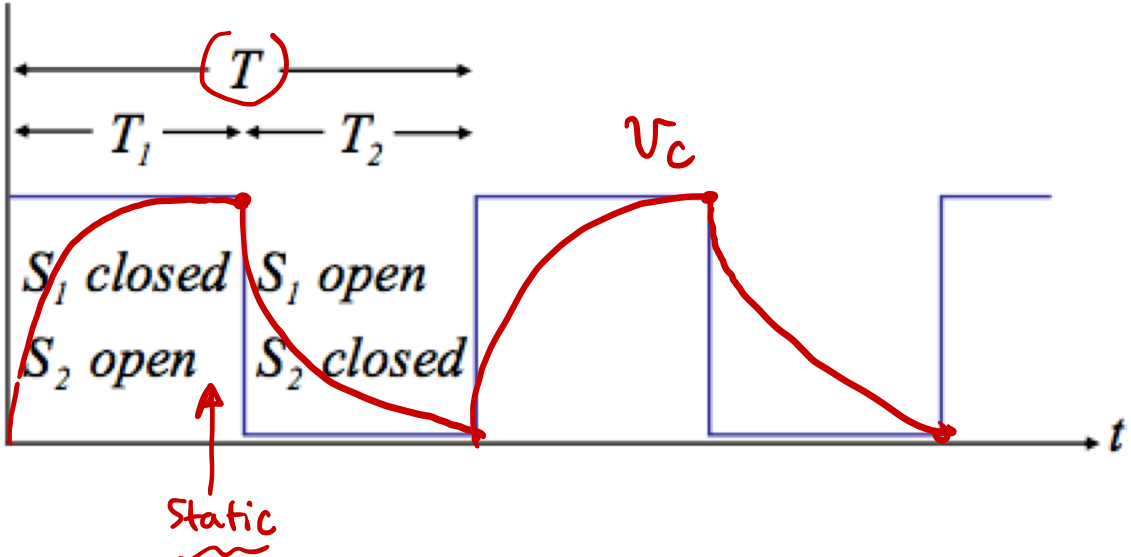




Second Example

- Consider

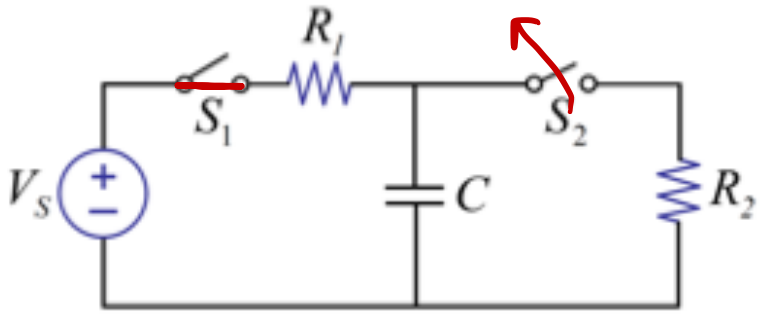


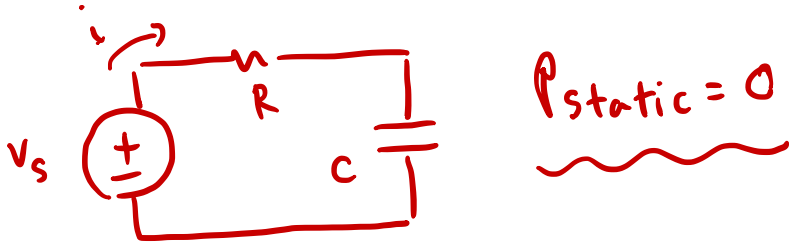


- Find energy dissipated in each cycle.
- Find average power.

Second Example

- During T_1 :
  S_1 is closed and S_2 is open.



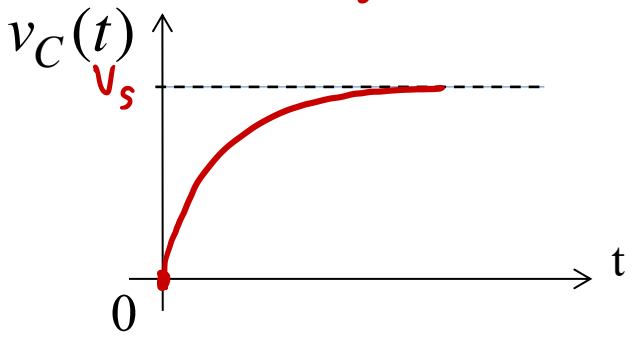


$P_{static} = 0$

$i_C = C \cdot \frac{dv}{dt} = \frac{v_R}{R}$

$= \frac{V_S - v_C}{R}$

$v_C = V_S \cdot (1 - e^{-t/RC})$



$i_C = \frac{V_S}{R_1} \cdot e^{-t/RC}$