Lecture 7 - Module 2

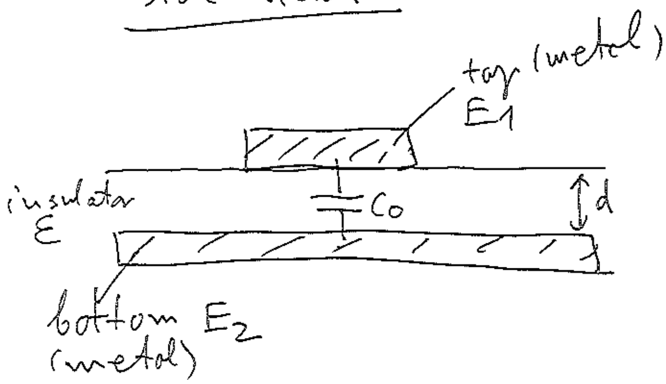
EE16A

Today:

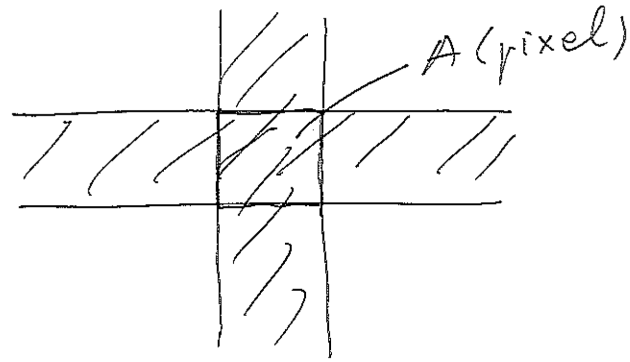
Note 17

* 2D touch screen (capacitive)
  * sensing capacitor
  * capacitance measurement circuit
  * comparator (op-amp)

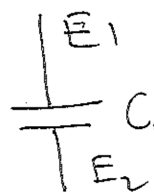
Side view:



Top view:

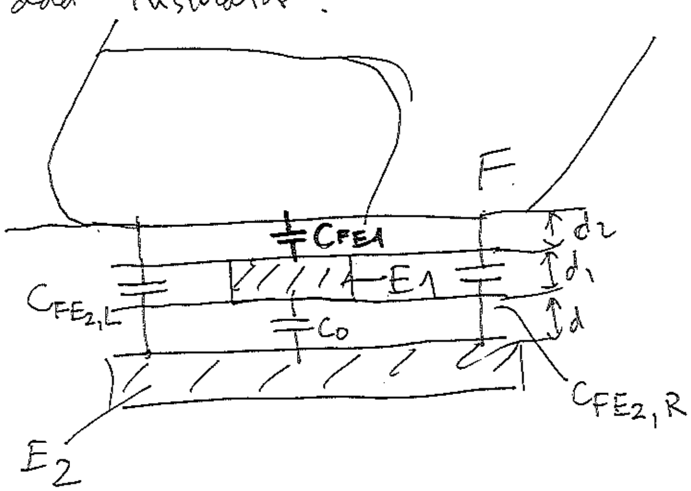


Model w/o touch:

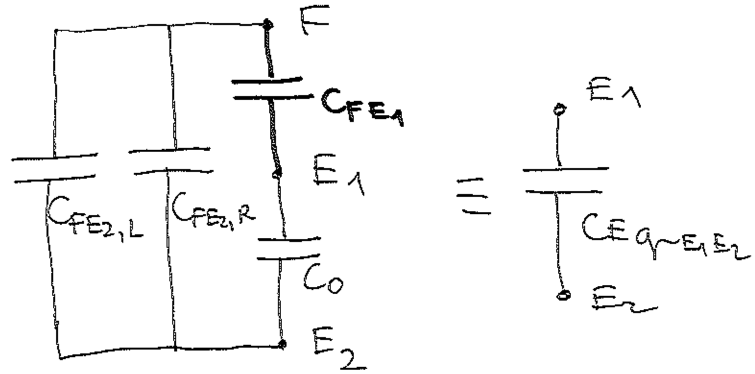


$$C_0 = \varepsilon \cdot \frac{A}{d}$$

add insulator:

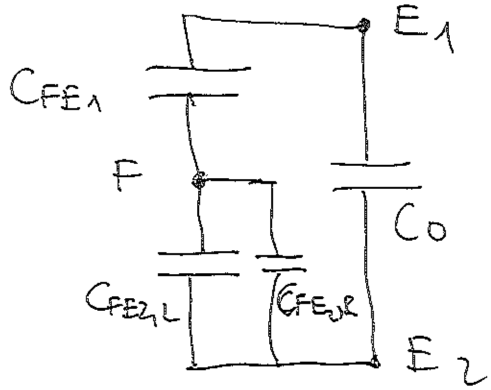


Model with touch:

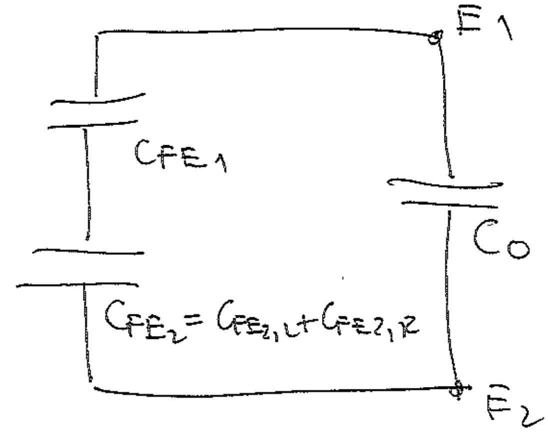


$$C_{eq_{E_1E_2}} = C_0 + C_{FE_1} \,||\, (C_{FE_{2,L}} + C_{FE_{2,R}})$$

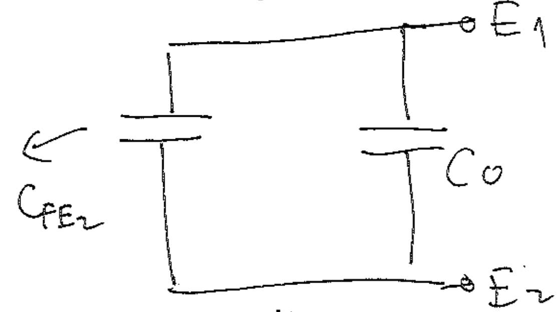
(l2)



$\Rightarrow$

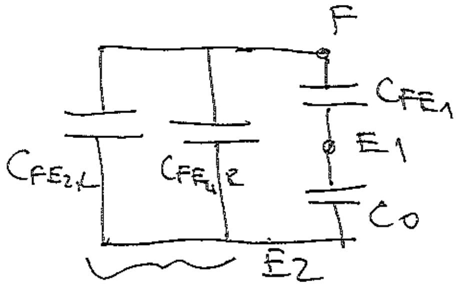


$\Downarrow$

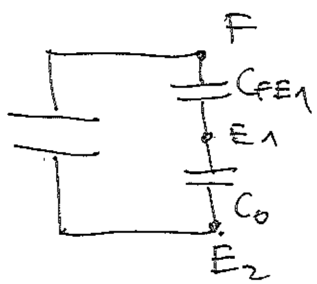


$\Downarrow$

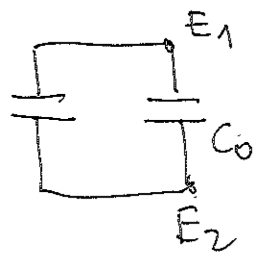
$C_0 + C_{FE1} \| C_{FE2}$



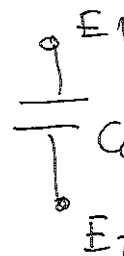
$C_{FE2} = C_{FE2,L} + C_{FE2,R}$



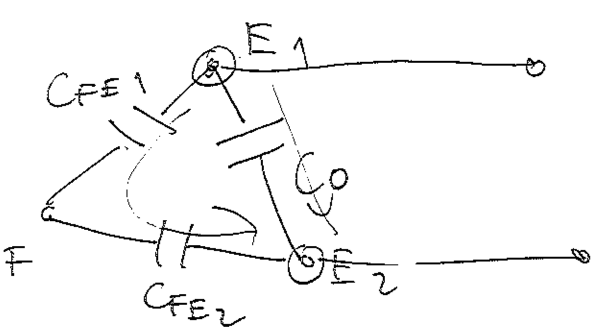
$C_{FE1} \| C_{FE2}$



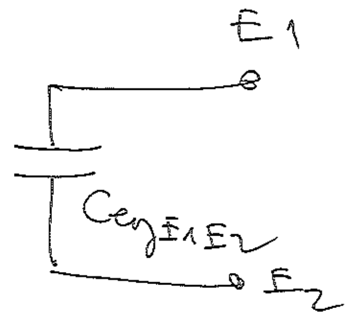
$=$



$C_{eq\,E_1E_2} = C_0 + C_{FE1} \| C_{FE2}$



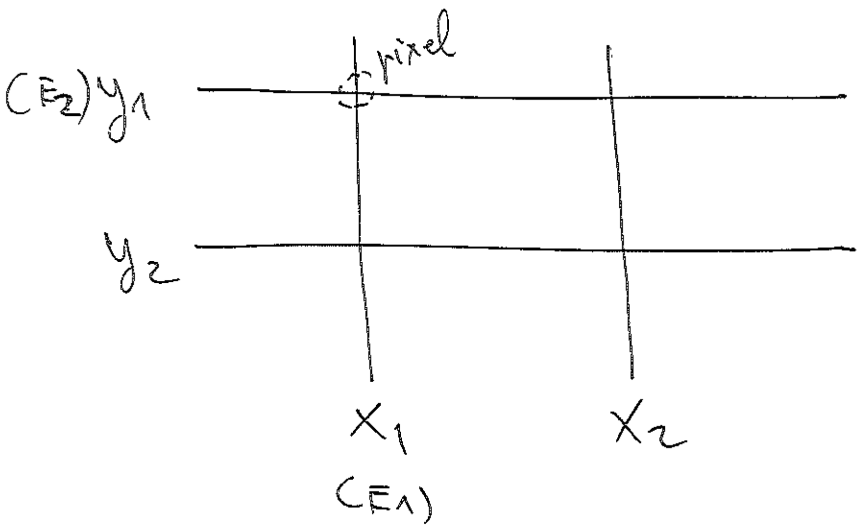
$=$



Touch:

$$C_{eq\,E_1E_2} = C_0 + \underbrace{\Delta C}_{C_{FE1} \| C_{FE2} > 0}$$

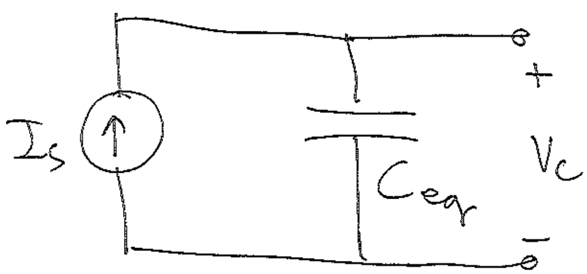
2D view:



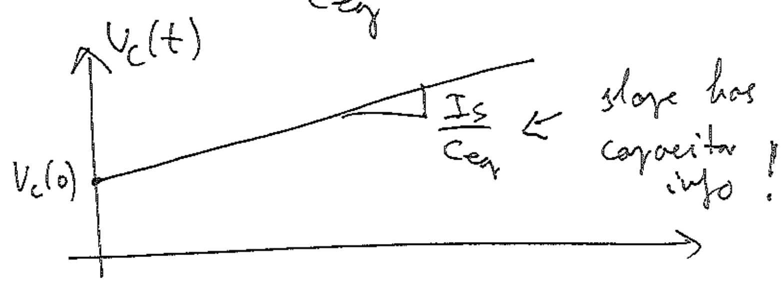
upper left $(x_1\, y_1)$
⋮

How do we measure the capacitance?

Attempt 1: Want to convert capacitance value to voltage:



$$V_c(t) = \frac{I_s}{C_{eq}} \cdot t + V_c(0)$$

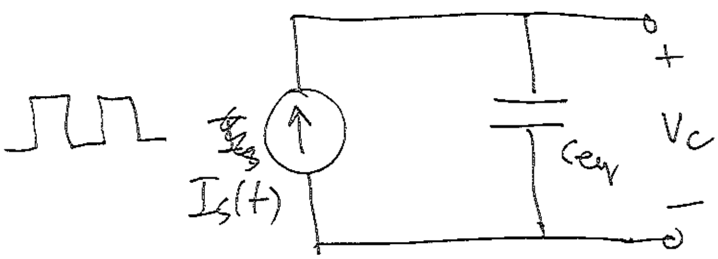


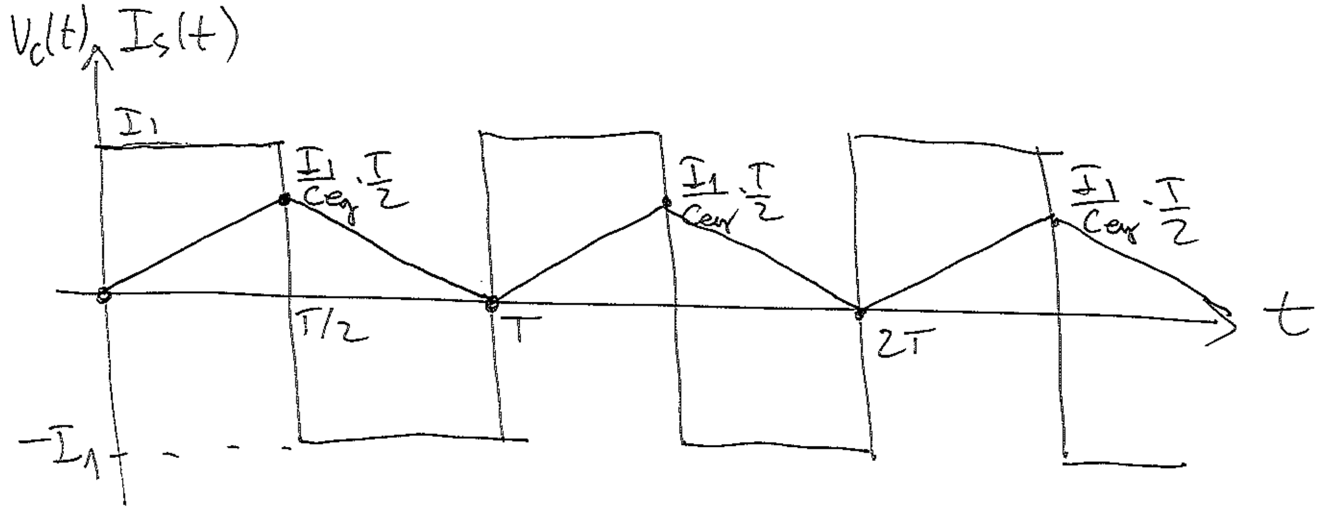
$V_c(t)$ grows indefinitely $\Rightarrow$ problem for practical implementation.

In general, for constant I_s from t_0 to t

$$V_c(t) = \frac{I_s}{C_{eq}} \cdot (t - t_0) + V_c(t_0)$$

Attempt #2: Make current source periodic to limit $V_c(t)$





$$t \in \left[0, \tfrac{T}{2}\right]: \quad I_s(t) = I_1 \Rightarrow V_c(t) = \frac{I_1}{C_{eq}} \cdot t + \cancel{V_c(0)}^{\,0}$$

$$t \in \left[\tfrac{T}{2}, T\right]: \quad I_s(t) = -I_1 \Rightarrow V_c(t) = -\frac{I_1}{C_{eq}} \cdot \left(t - \frac{T}{2}\right) + V_c\left(\frac{T}{2}\right)$$

$$V_c\left(\frac{T}{2}\right) = \frac{I_1}{C_{eq}} \cdot \frac{T}{2}$$

$$\Downarrow$$

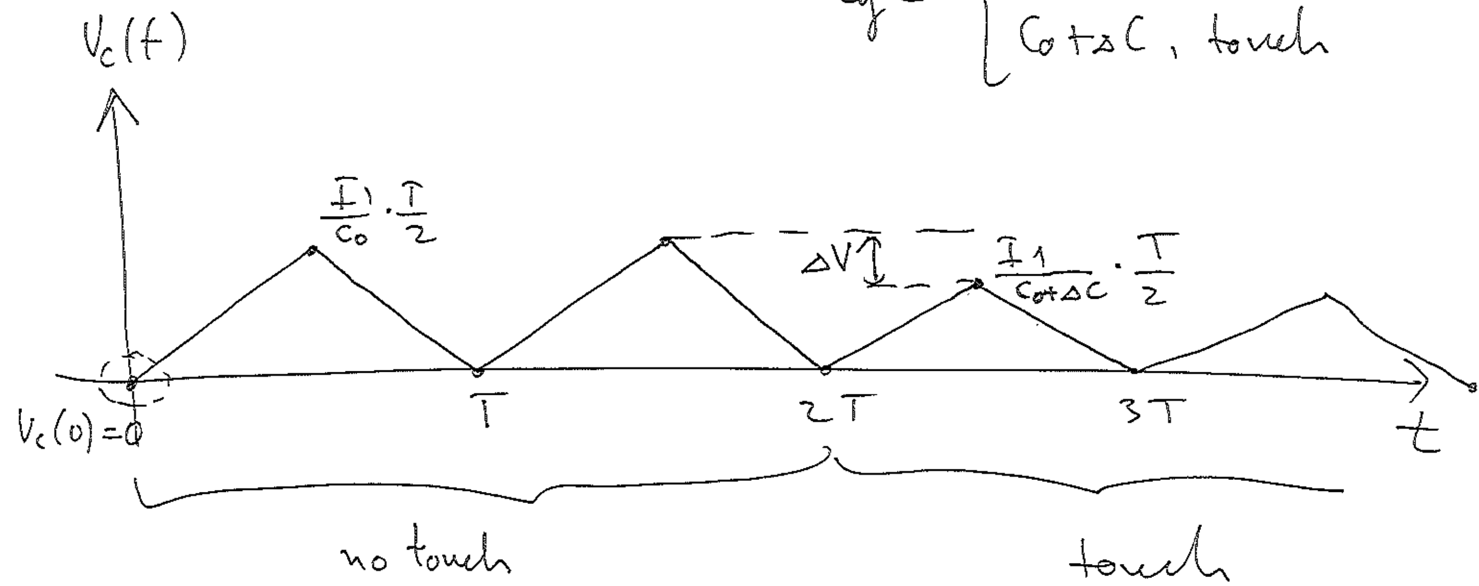
$$V_c(t) = -\frac{I_1}{C_{eq}} \cdot \left(t - \frac{T}{2}\right) + \frac{I_1}{C_{eq}} \frac{T}{2}$$

$$V_c(T) = 0$$

$$\boxed{\max\left(V_c(t)\right) = \frac{I_1}{C_{eq}} \cdot \frac{T}{2}} \Leftarrow C_{eq} \text{ info.}$$

(25)

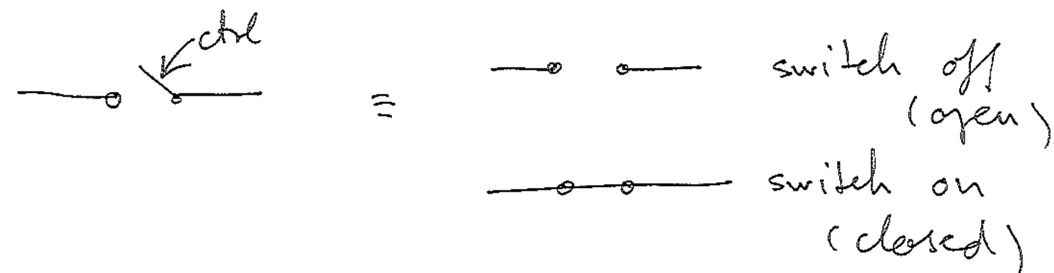
$$C_{eq} = \begin{cases} C_0, & \text{no touch} \\ C_0+\Delta C, & \text{touch} \end{cases}$$

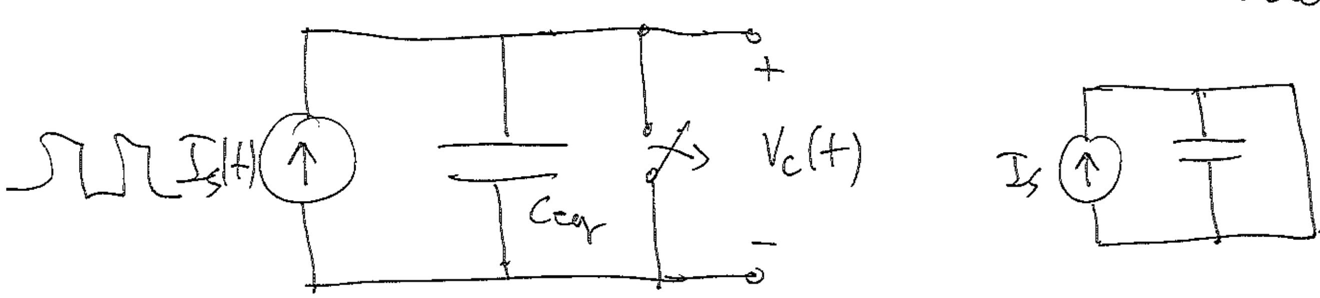


small change in $(V_c(t))_{max} = \left(\frac{I_1}{C_0} - \frac{I_1}{C_0+\Delta C}\right)\frac{T}{2}$

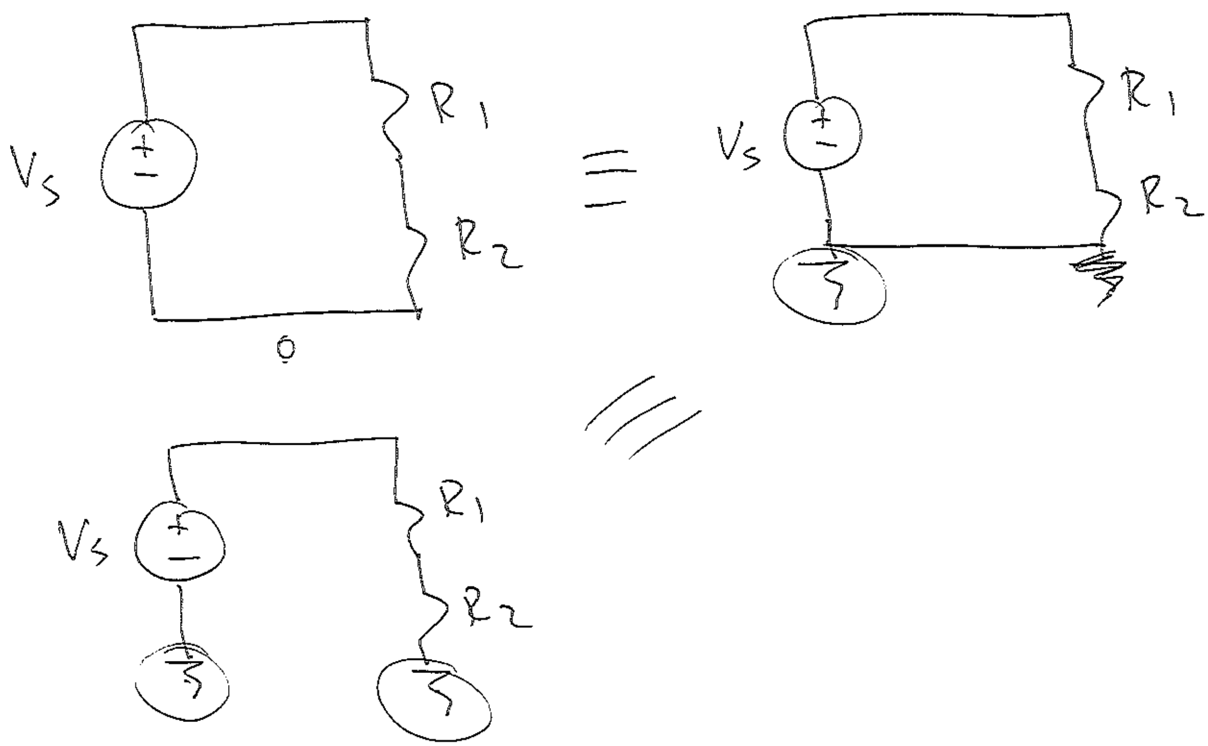
How do we get a bigger change in voltage?

<u>Switch:</u>





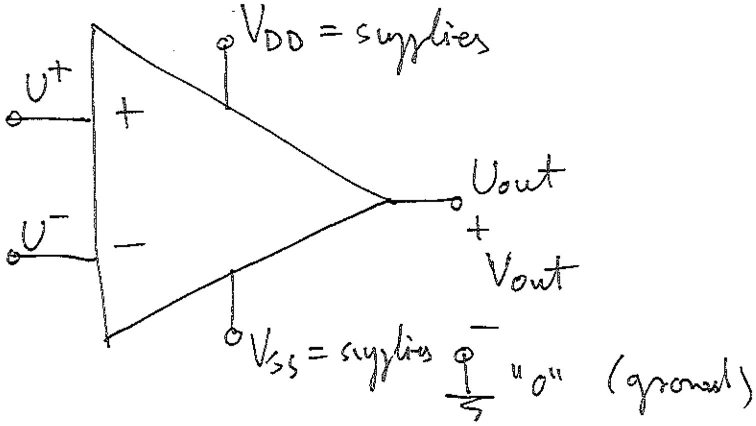
l6a



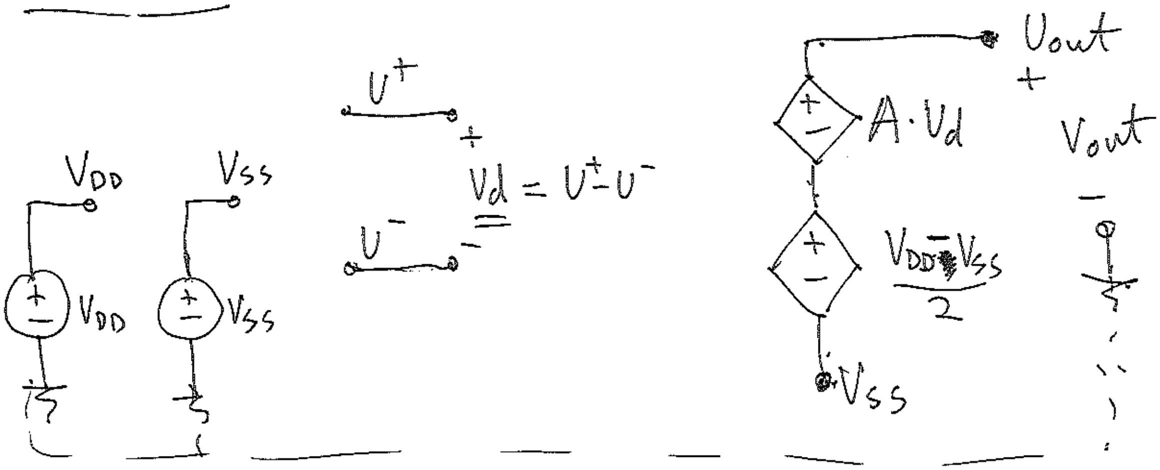
(26) New element: Op-amp

(can be used as a comparator – compare two potentials and determines which one is larger)

Symbol:



Model:



In ideal op-amp $A \to \infty$

KVL: $$V_{out} = \begin{cases} V_{DD}, & V^* > V_{DD} \\ V_{SS} + \frac{V_{DD} - V_{SS}}{2} + A \cdot V_d = V^*, & \text{when } V_{SS} \le \underbrace{\frac{V_{SS} + V_{DD}}{2} + A V_d}_{V^*} \le V_{DD} \\ V_{SS}, & V^* < V_{SS} \end{cases}$$