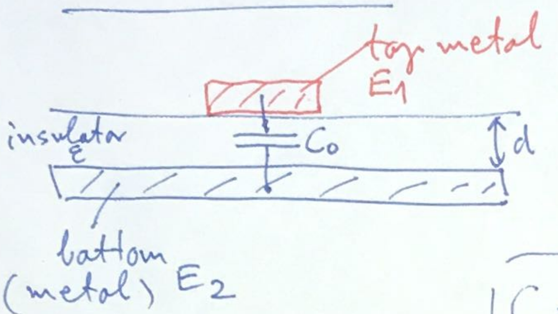
EE16A

Lecture 7 - Module 2

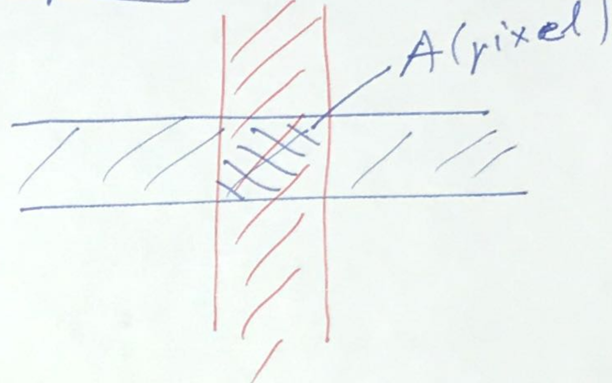
Today:
Note 17

* 2D touchscreen (capacitive)
  * sensing capacitor
  * capacitive measurement circuit
  * comparator (op-amp)

Side view:

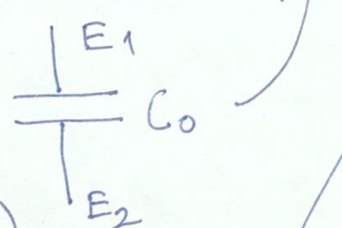


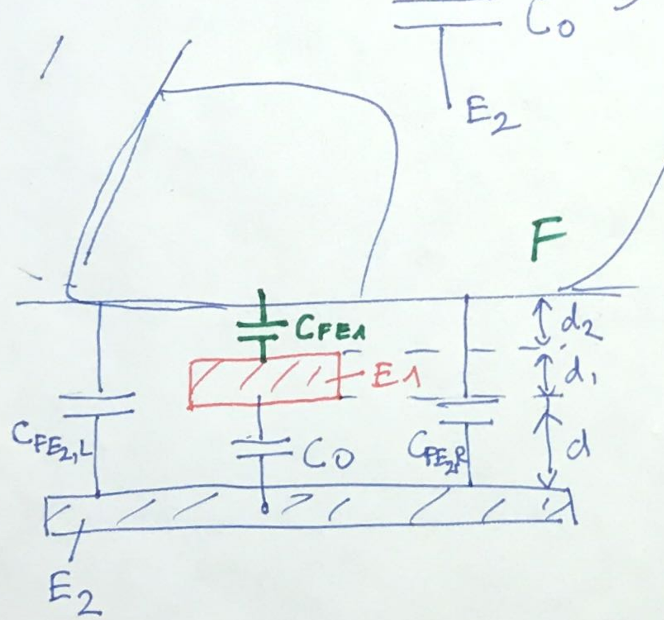
Top view:



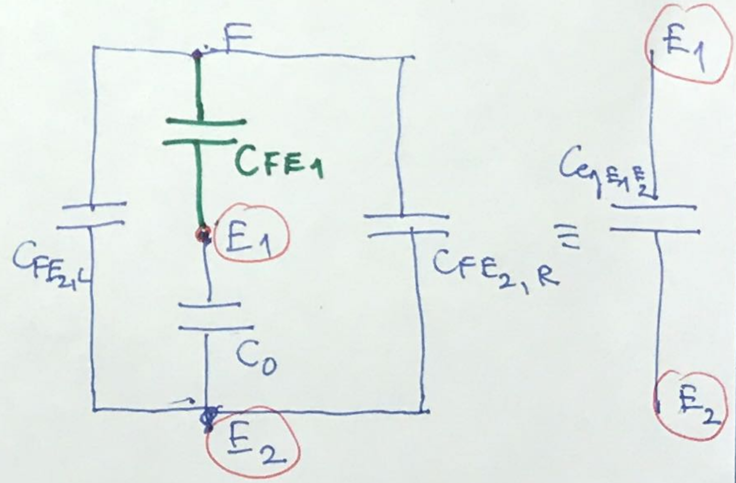
$$C_0 = \varepsilon \frac{A}{d}$$

Model w/o touch:

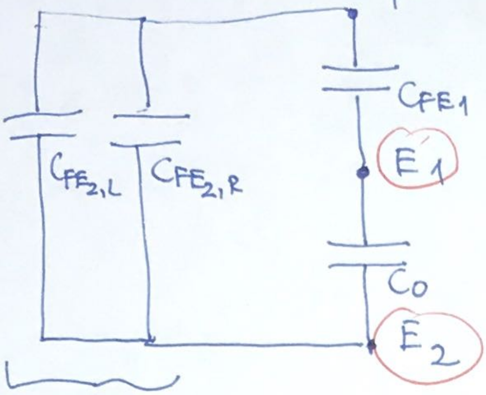




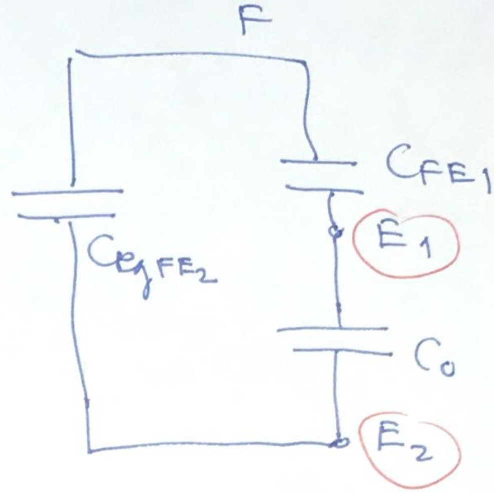
Model with touch:



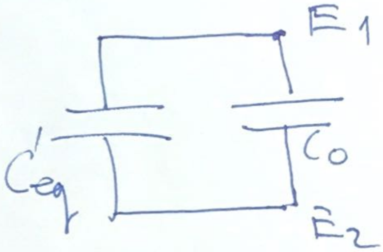
$$C_{eq\,E_1E_2} = C_0 + C_{FE1} \,||\, (C_{FE2,L} + C_{FE2,R})$$

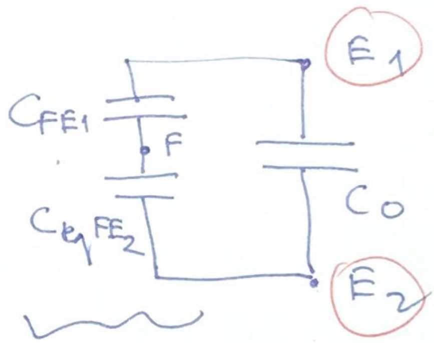


$\simeq$



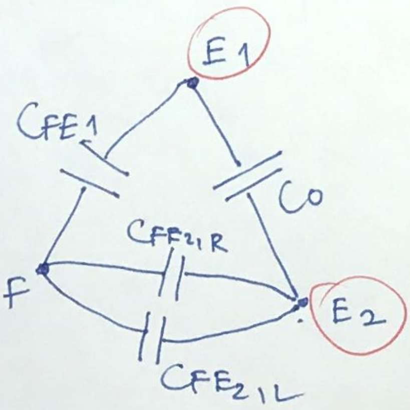
$$C_{eq\,FE_2} = C_{FE_{2,L}} + C_{FE_{2,R}}$$





$$C'_{eq} = C_{FE_1} \parallel (C_{FE_{2,L}} + C_{FE_{2,R}})$$

$$C_{eq\,E_1E_2} = C'_{eq} + C_0$$



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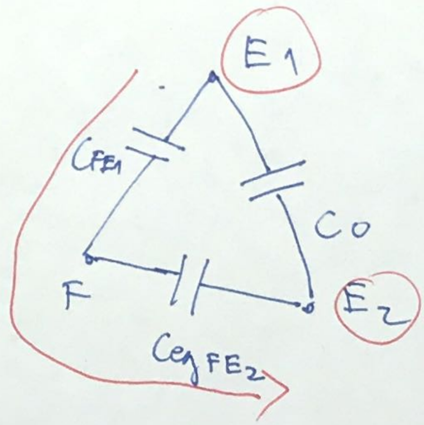

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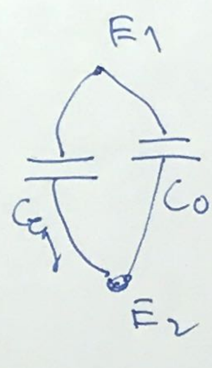
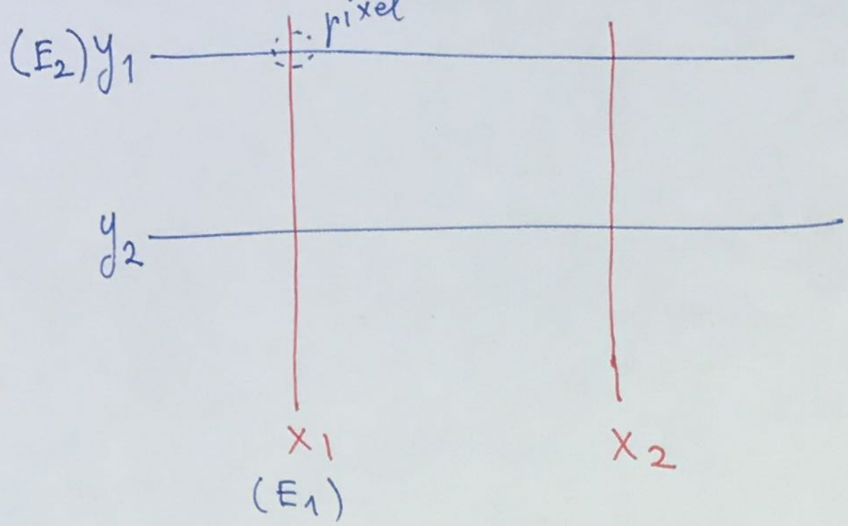


<u>Touch</u>:

$$C_{eq\,E_1E_2} = C_0 + \Delta C$$

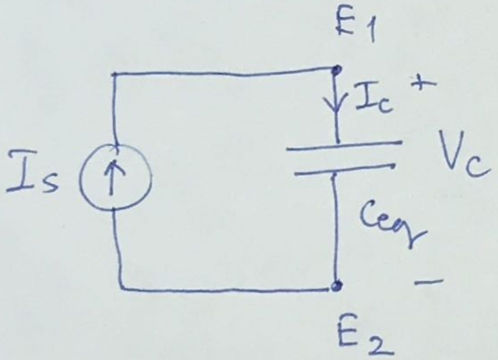
$$\Delta C = C_{FE_1} \parallel C_{FE_2\,eq} > 0$$

(l3) 2D view:



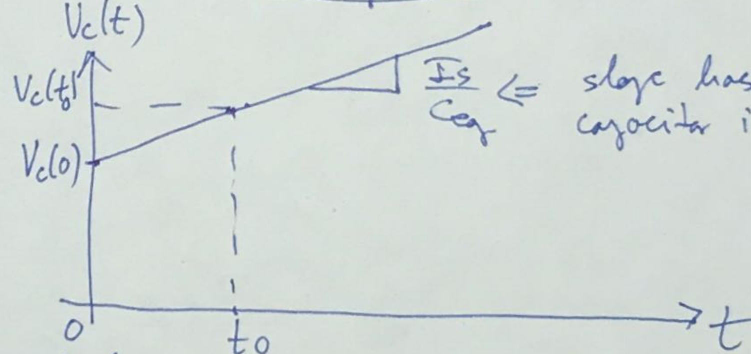
How do we **measure** the capacitance? → turn into voltage or current

Attempt 1: Want to convert capacitance value to voltage.



$$I_c = C_{eq} \cdot \frac{dV_c}{dt}$$

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



$\frac{I_s}{C_{eq}} \Leftarrow$ slope has capacitor info!

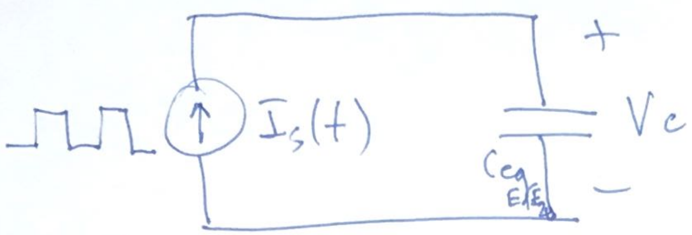
$V_c(t)$ grows indefinitely $\Rightarrow$ problem for potential implementation

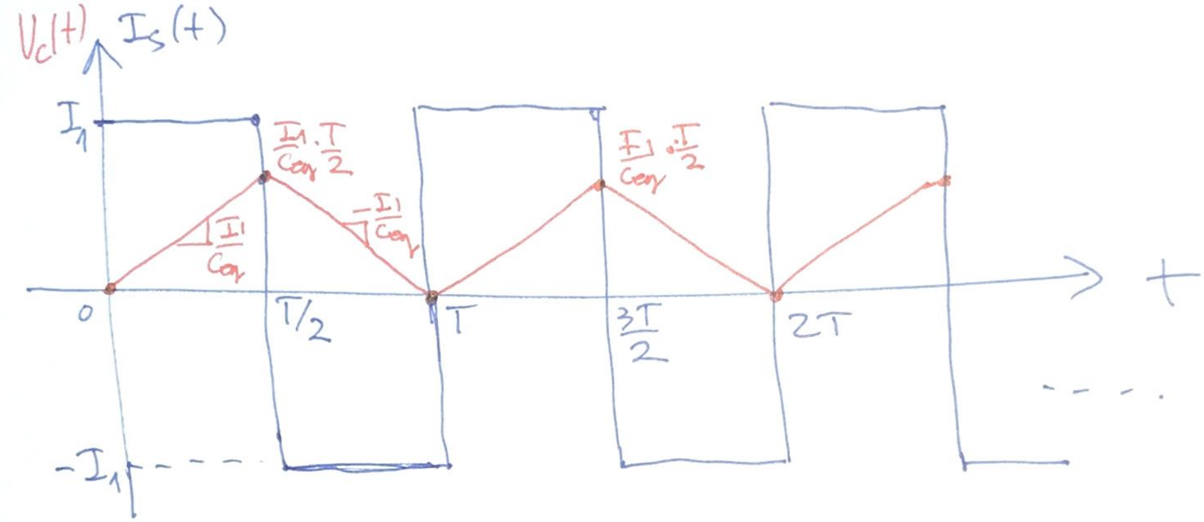
In general, for constant I_s from t_0 to t

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

(L4)

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





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

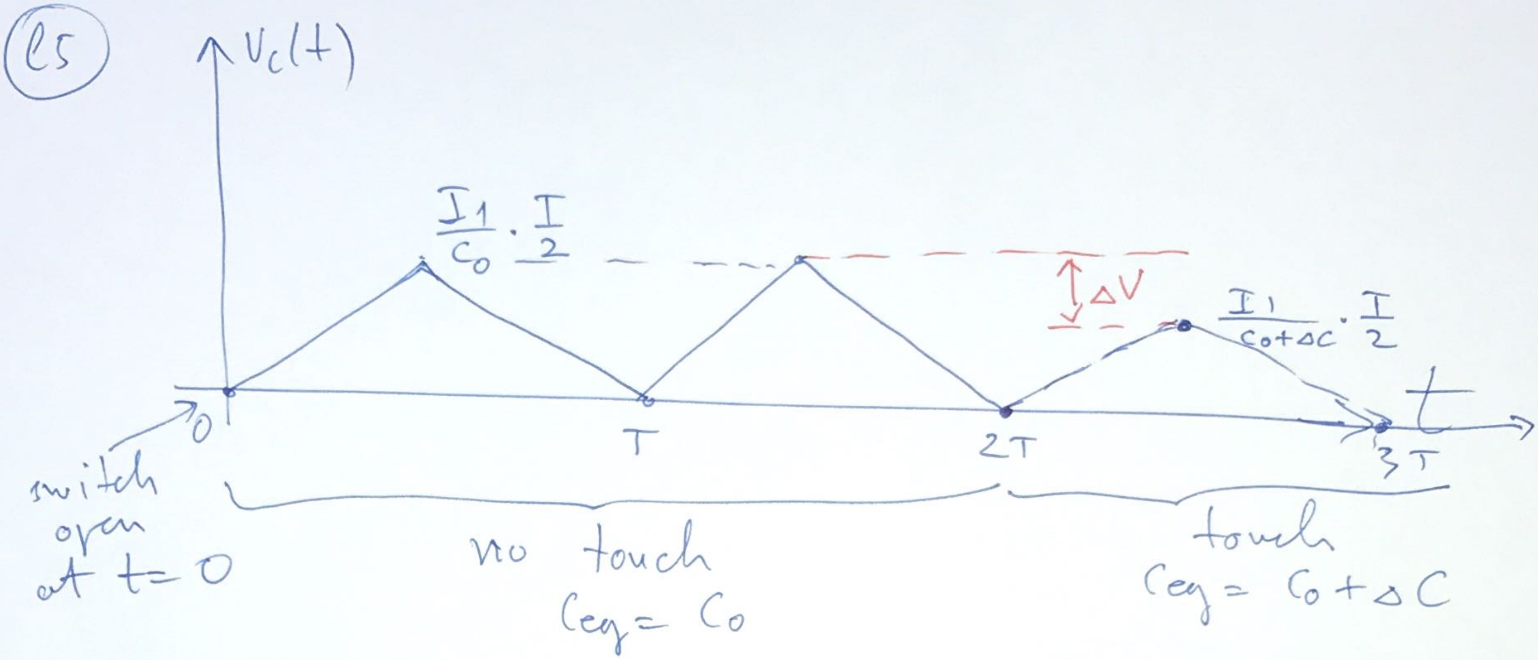
$t \in [\frac{T}{2}, T]$: $I_s(t) = -I_1 \Rightarrow V_c(t) = -\frac{I_1}{C_{eq}} \cdot (t - \frac{T}{2}) + V_c(\frac{T}{2})$

($\frac{T}{2}$ = t_0)

$V_c(\frac{T}{2}) = \frac{I_1}{C_{eq}} \cdot \frac{T}{2}$ — max voltage

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

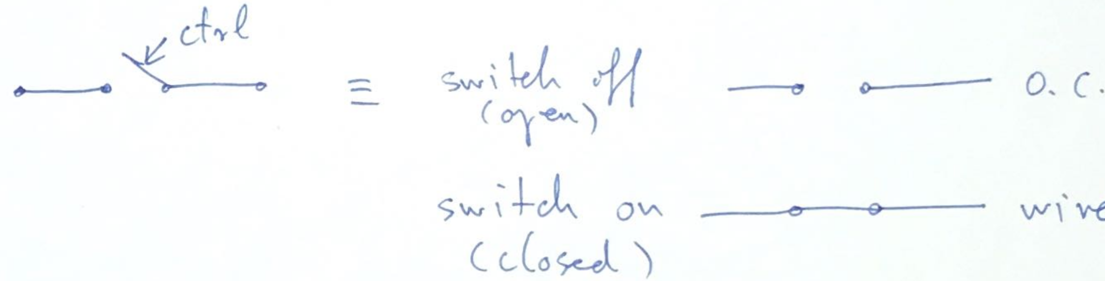
$V_c(T) = 0$

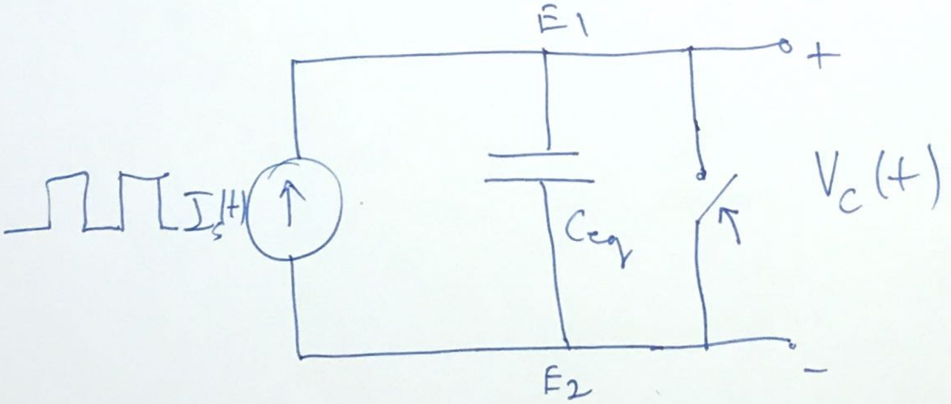


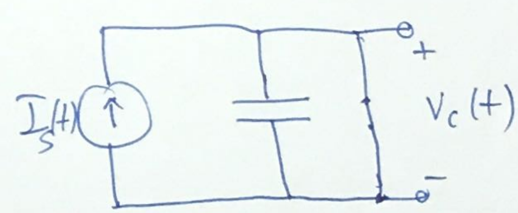
small change:

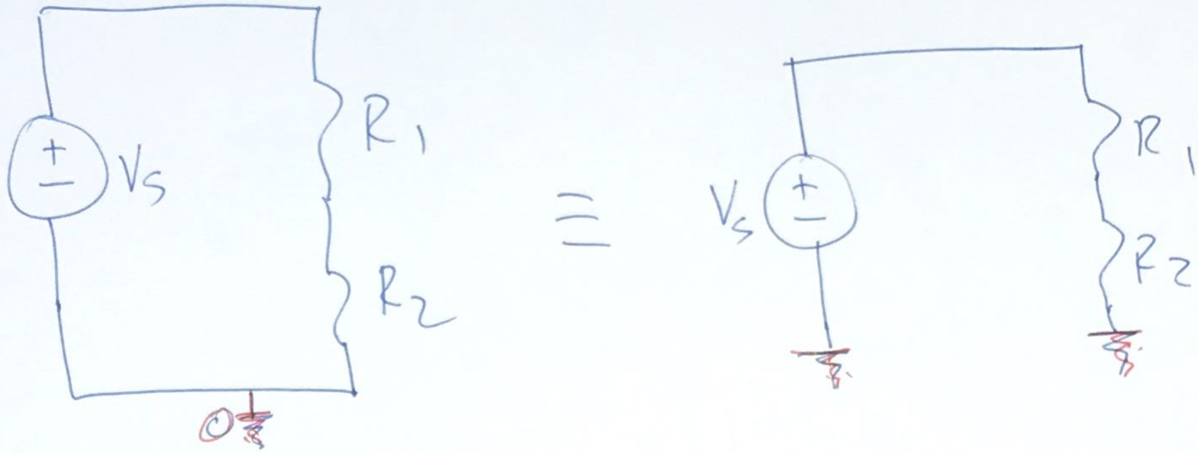
$$\Delta V = \left(\frac{I_1}{C_0} - \frac{I_1}{C_0+\Delta C}\right)\cdot\frac{T}{2}$$

switch:





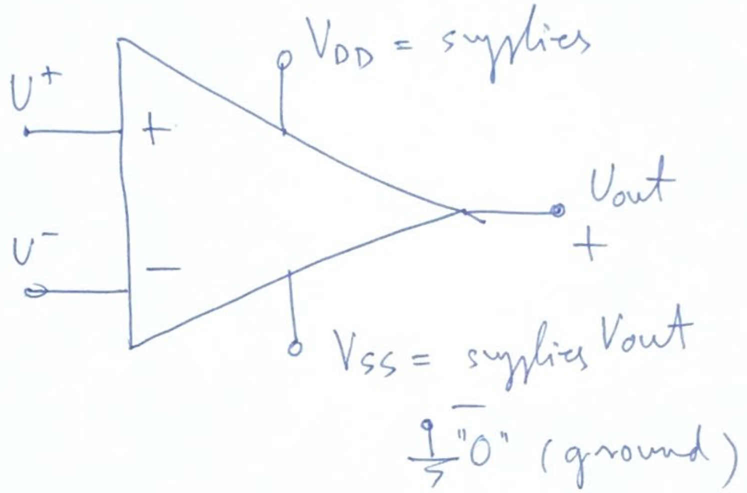



Vs
R1
R2
≡
Vs
R1
R2

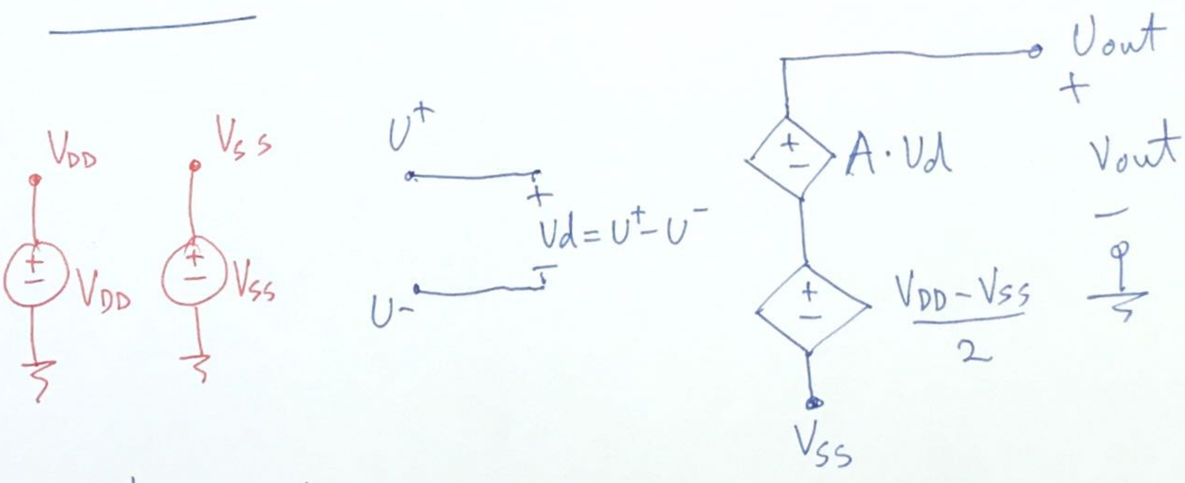
New element: Op-amps

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

Symbol:



Model:



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

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