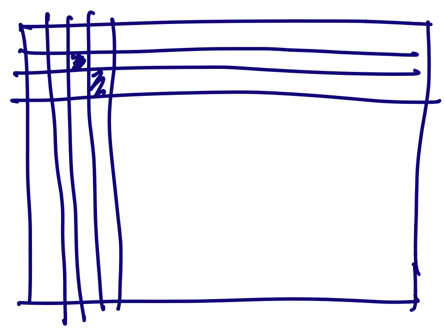
EECS 16A

Logistics

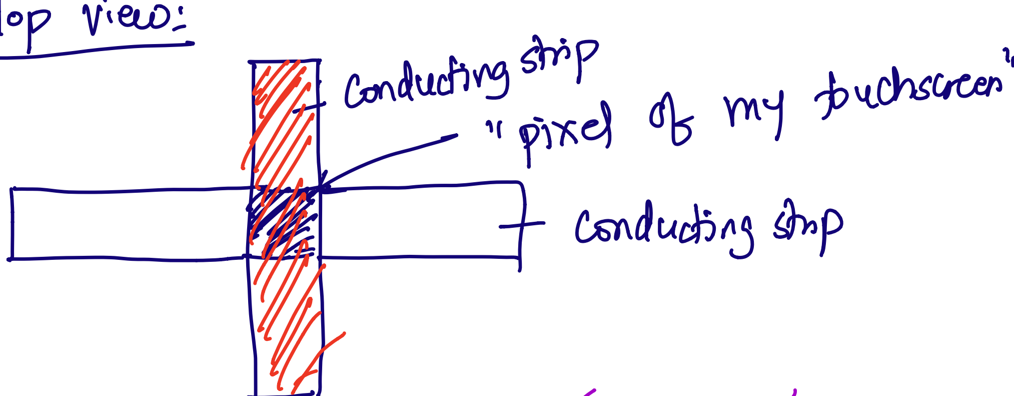
- MT2 coming
- Power outage + fires.
- Circuit review – moved to Friday.
- 16B.

Today:

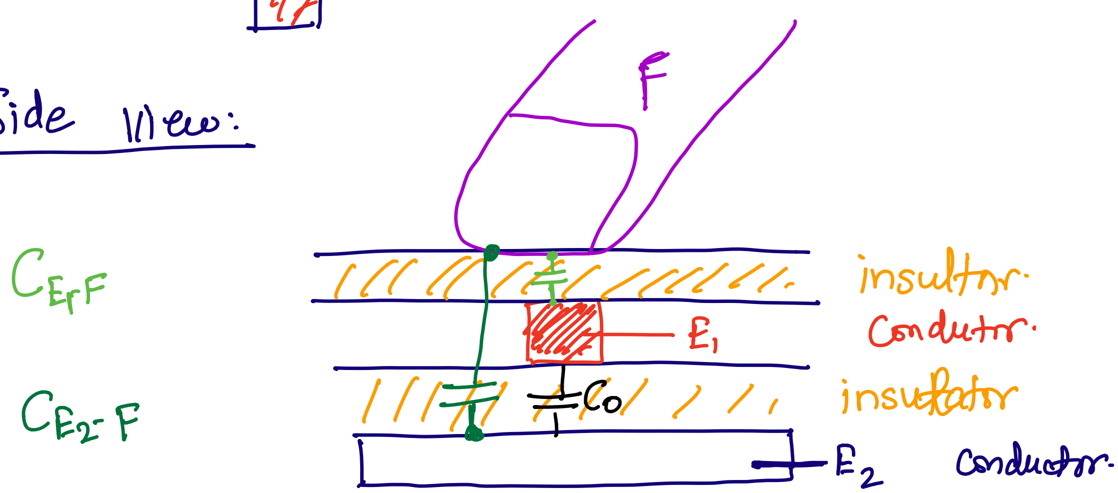
- Capacitive touchscreen
- Charge-Sharing.



Top view:

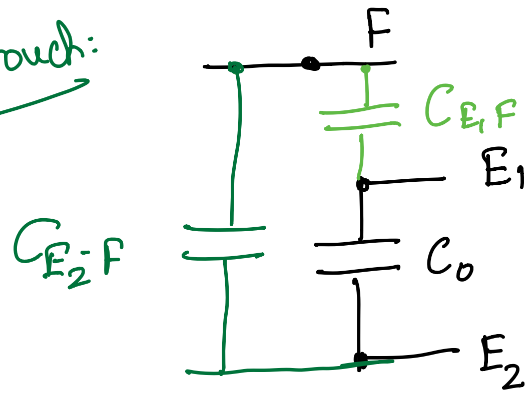


Side view:



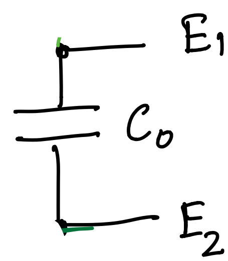
Capacitor between E_1 and E_2 : we call C_0

Circuit-touch:



When finger is touchin

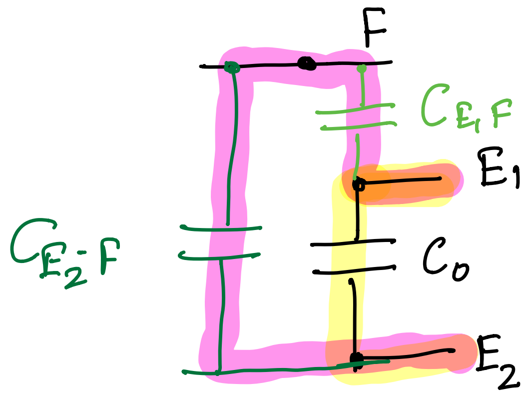
Circuit Notouch:

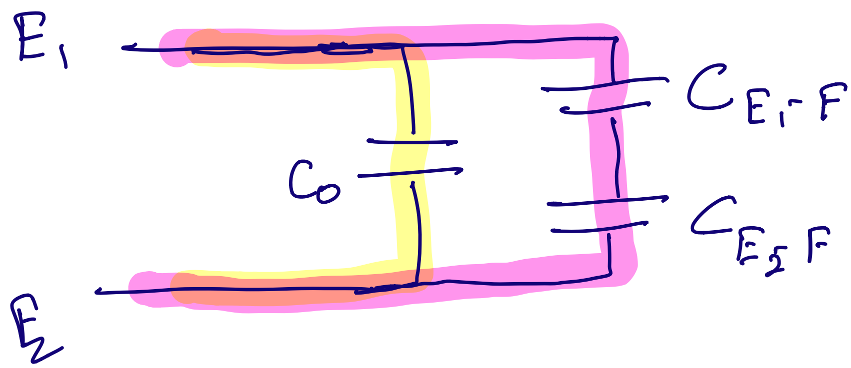


No finger touching

Reliably: E_1, E_2 will always be there

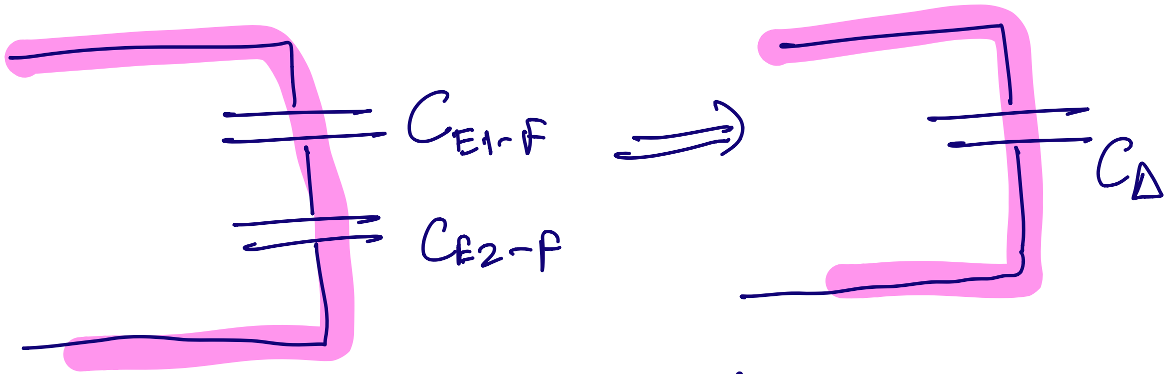
Redraw circuit looking in from $E_1 - E_2$:





If no finger, no pink path!

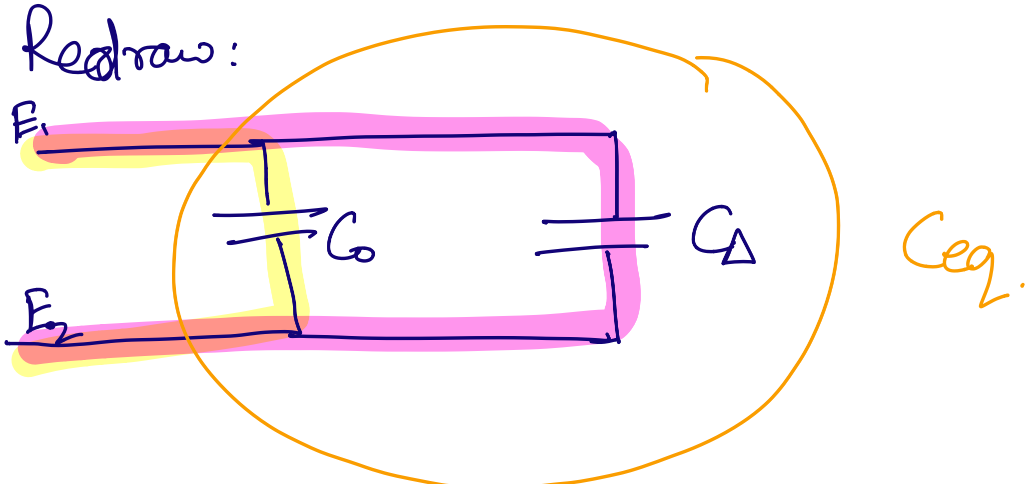
$\Rightarrow$ Equivalent capacitance between $E_1 - E_2$ changes based of if we touch!

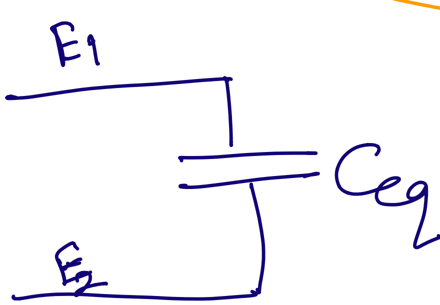


$$C_\Delta = C_{E1\text{-}F} \parallel C_{E2\text{-}F}$$

$$= \frac{C_{E1F} \cdot C_{E2F}}{C_{E1\text{-}F} + C_{E2\text{-}F}}$$

Redraw:





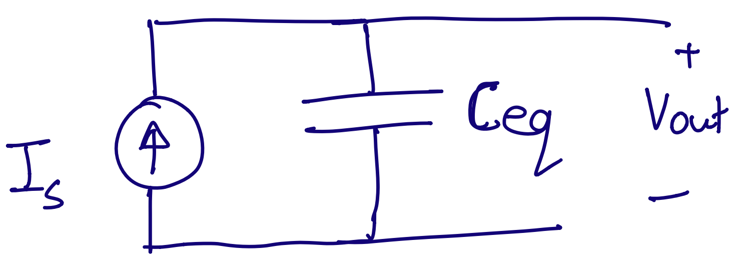
If No touch:
$C_{eq} = C_0$

If touch:
$C_{eq} = C_0 + C_\Delta$

Summary: Touch changes equivalent capacitance between $E_1 - E_2$.

Question: How to detect this change?

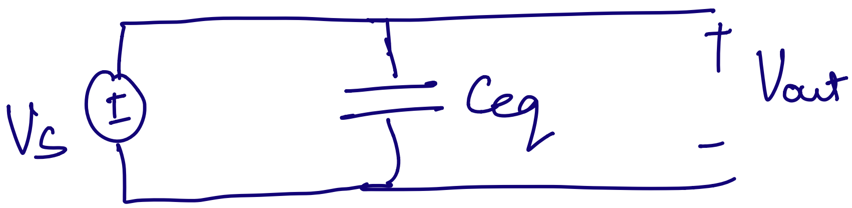
Attempt I: Use a current source



$$I_s = \frac{C \cdot dV_c}{dt}, \quad V_c = \int_0^t \frac{I_s}{C_{eq}} dt = \frac{I_s \cdot t}{C_{eq}}$$

Assuming $V_{out}(0) = 0$

Attempt 2:

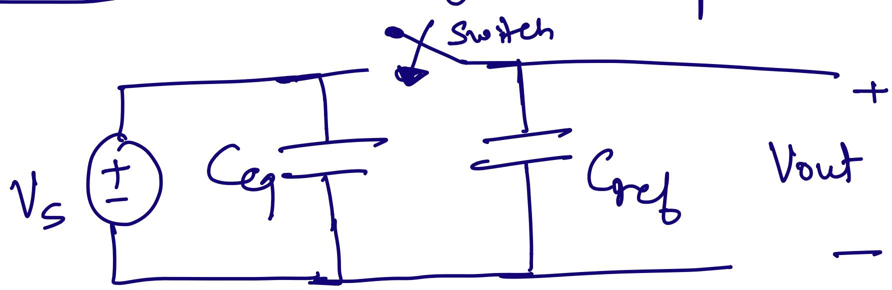


V_{out} (touch) $= V_s$

V_{out} (no touch) $= V_s$

Fails because V_{out} does not change based on touch v/s no touch.

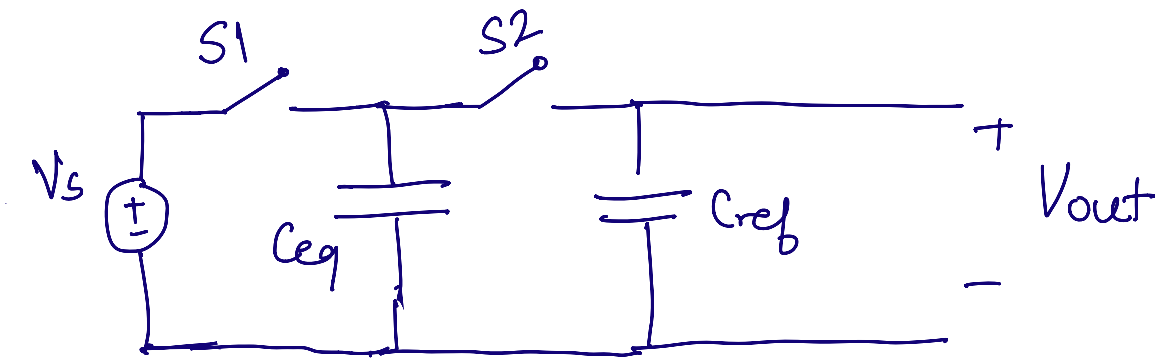
Attempt 3: Use a reference capacitor



V_{out} (when swith is open) = 0

V_{out} (— " — — " — closed) = V_s

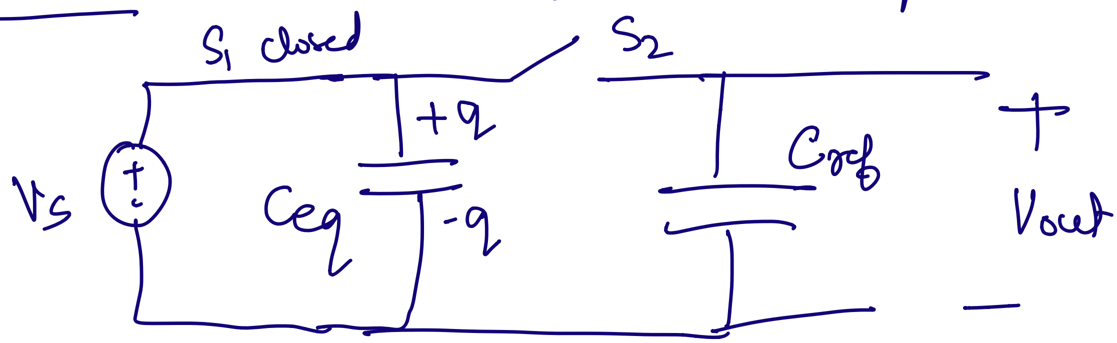
Attempt 4:



Question: is it helpful to close both S1 and S2 at the same time?

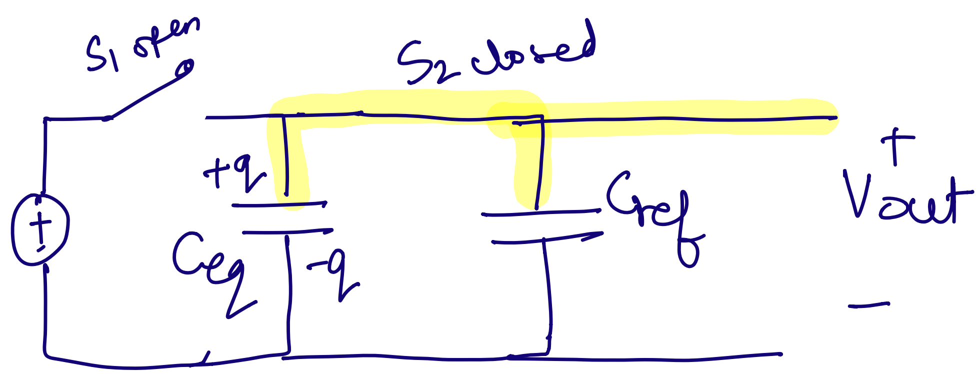
Ans: No: $V_{out} = V_s$ in this case.

Phase 1: Close S_1, S_2 is open.



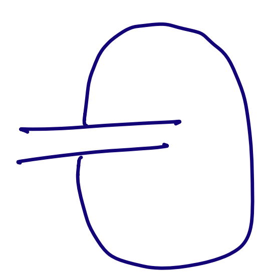
$$q = C \cdot V = C_{eq} \cdot V_s$$

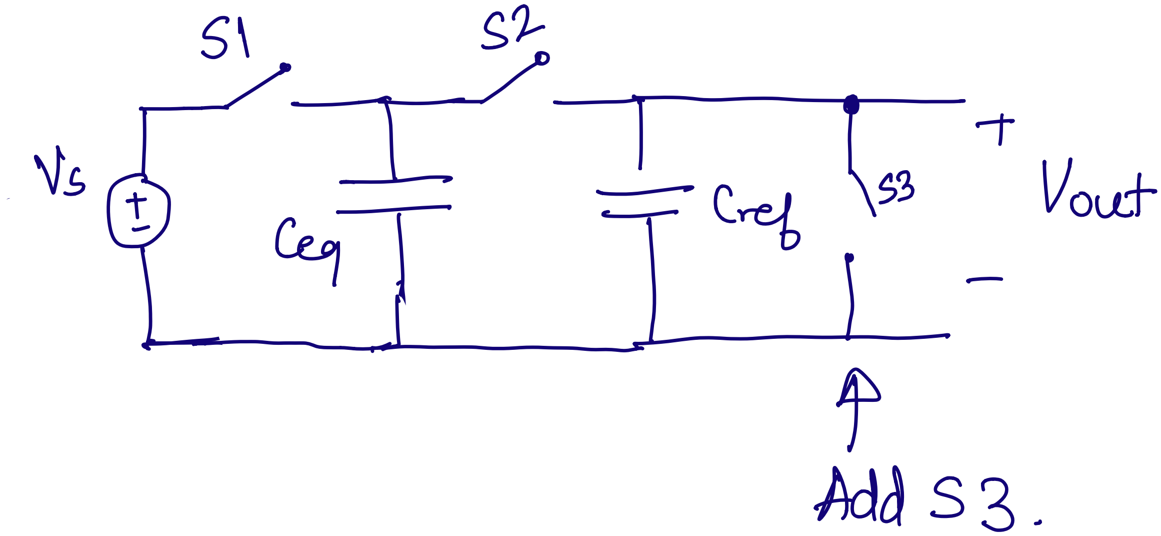
Phase 2: Close S_2, open S_1



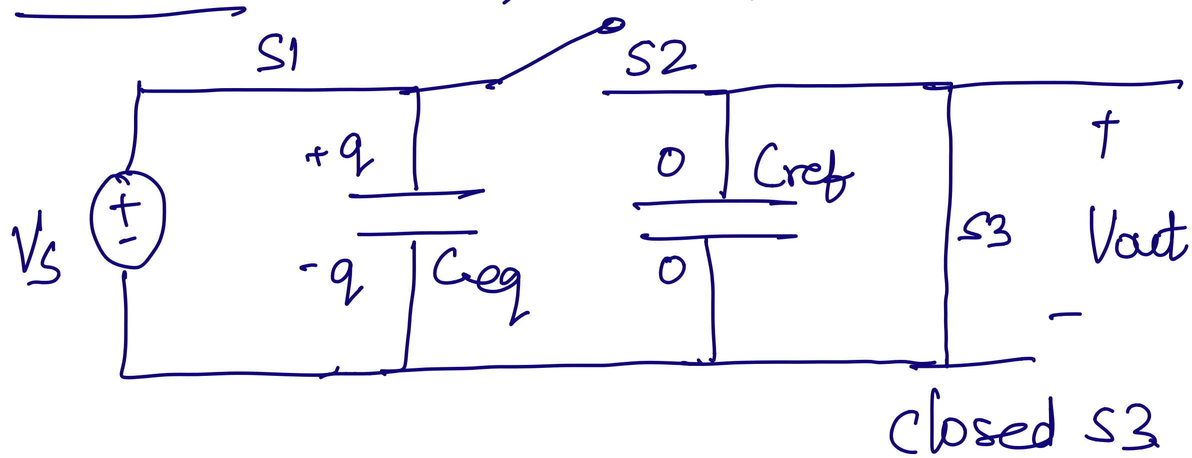
Issue: Don't know if inital charge on $C_{ref} = 0$

Attempt 5:





Phase 1: S3 ON, S1 ON, S2 OFF



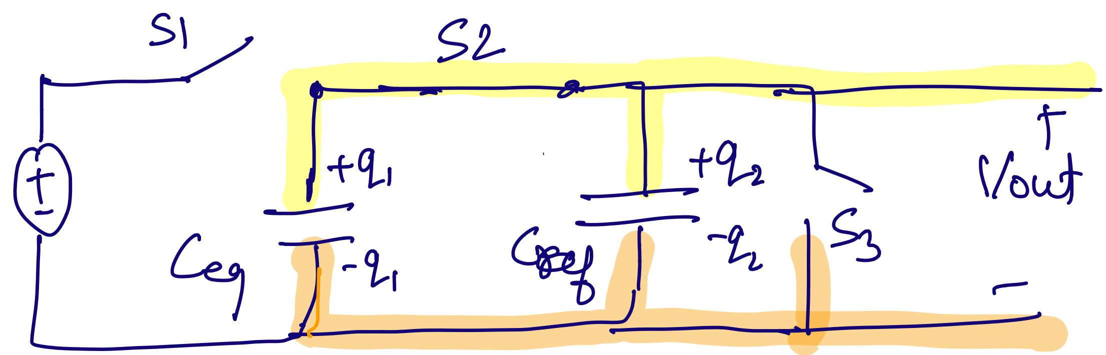
Voltage across C_{ref} : 0

Charge on C_{ref} : $q = C \cdot V = 0$

Voltage across C_{eq} : V_s

Charge on C_{eq} : $q = C_{eq} V_s$

Phase 2: S1 OFF, S3 OFF, S2 ON



Voltage across C_{eq}: V_{out}

Voltage across C_{ref}: V_{out}

Charge across C_{eq}: $\boxed{C_{eq} \cdot V_{out}}$

Charge across C_{ref}: $\boxed{C_{ref} \cdot V_{out}}$

Total charge is conserved at yellow node.

Phase 1 charge : $\boxed{C_{eq} \cdot V_s}$.

Phase 2 charge = $\boxed{C_{eq} \cdot V_{out} + C_{ref} \cdot V_{out}}$

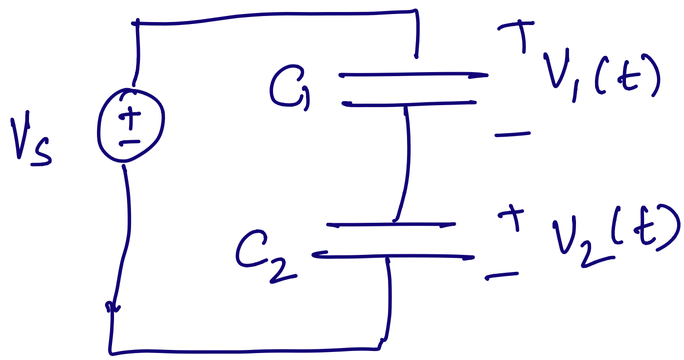
$$C_{eq} V_s = C_{eq} \cdot V_{out} + C_{ref} \cdot V_{out}$$

$$\boxed{V_{out} = \frac{C_{eq} \cdot V_s}{C_{ref} + C_{eq}}}$$

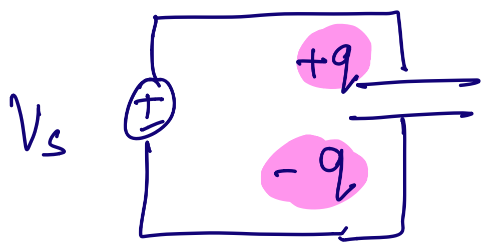
<u>If touch:</u> $V_{out} = \dfrac{(C_0 + C_\Delta) \cdot V_s}{C_{ref} + C_0 + C_\Delta}$

<u>If no touch:</u> $V_{out} = \dfrac{C_0 \cdot V_s}{C_{ref} + C_0}$

Capacitor trick 1:

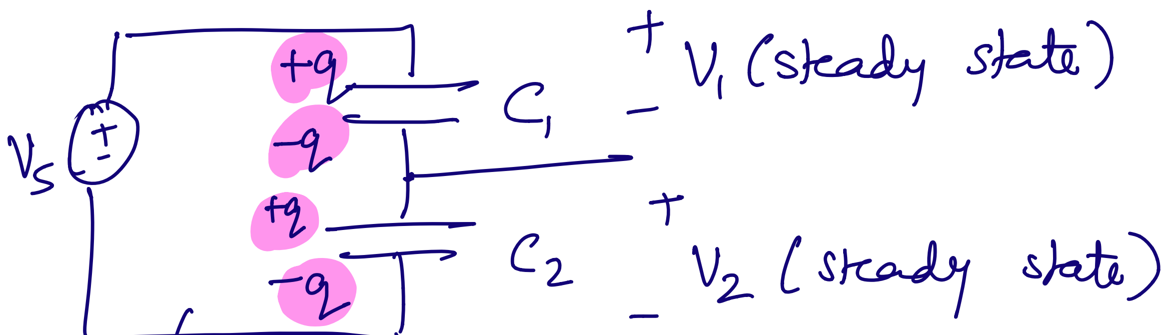


$$V_1(0) = 0$$
$$V_2(0) = 0$$



$$C_{eq} = C_1 \parallel C_2$$

$$\Longrightarrow q = C_{eq} \cdot V_s .$$



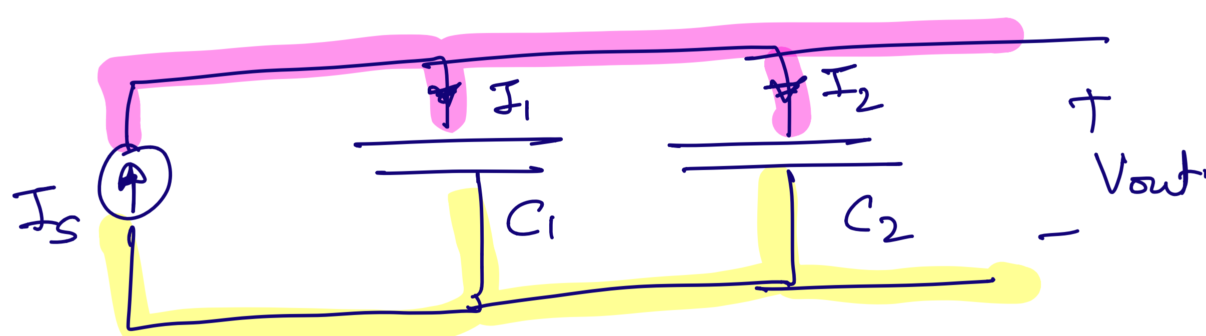
$$q = C_{eq} \cdot V_s .$$

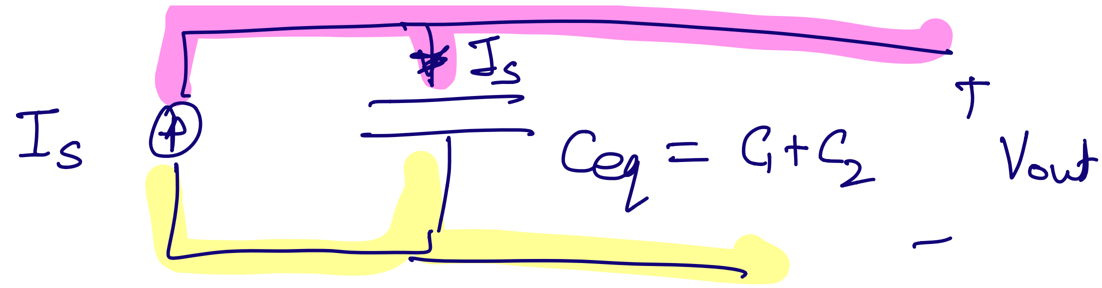
$$q = V_1 C_1$$

$$\Rightarrow V_1 C_1 = V_S \cdot C_{eq}$$

$$\boxed{\Rightarrow V_1 = \frac{C_{eq}}{C_1} \cdot V_S}$$

<u>Similarly</u>: $V_2 = \frac{C_{eq}}{C_2} \cdot V_S$





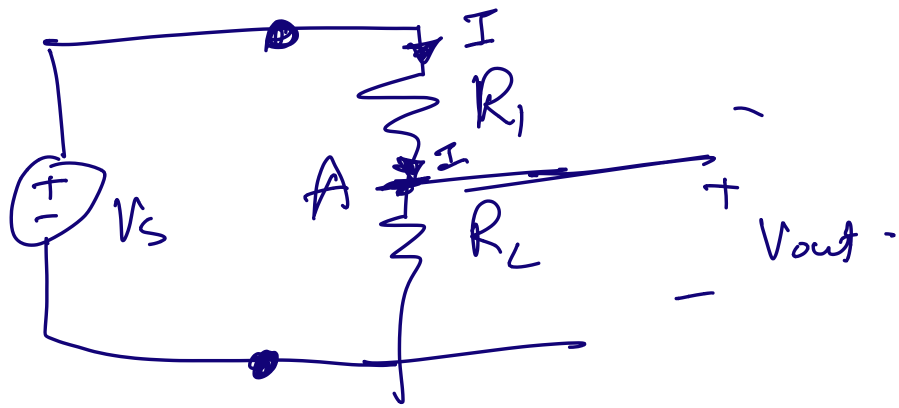
$$C_{eq} = C_1 + C_2$$

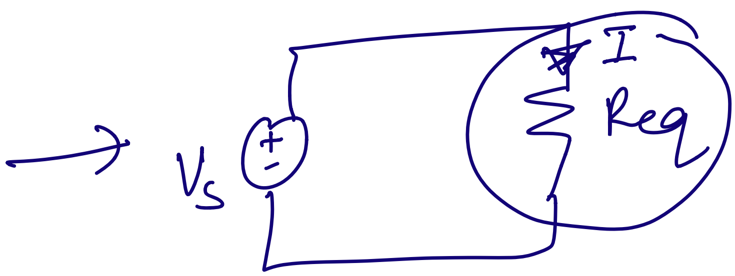
$$C_{eq}\frac{dV_{out}}{dt} = I_s \rightarrow \boxed{\frac{dV_{out}}{dt} = \frac{I_s}{C_{eq}}}$$

$$\boxed{I_1 = \frac{dV_{out}}{dt} \cdot C_1}$$

$$\boxed{I_1 = \frac{I_s}{C_{eq}} \cdot C_1 = \frac{I_s}{C_1 + C_2} C_1}$$

Office Hours



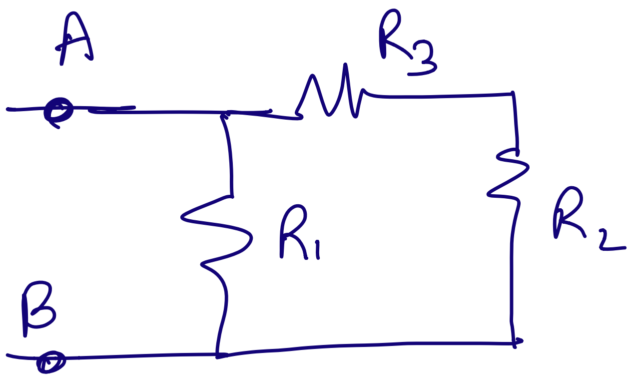


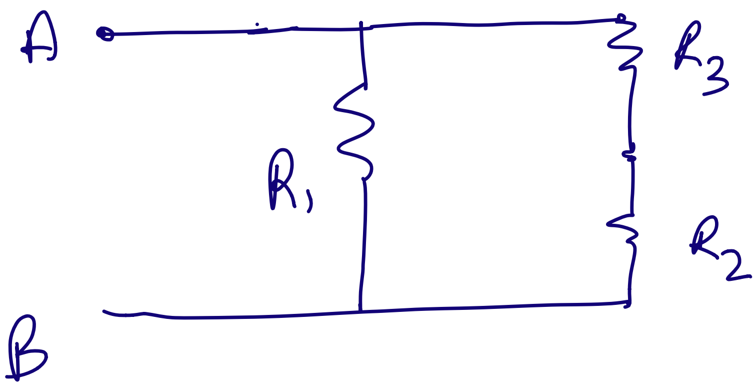
$I\,R_{eq} = V_s$

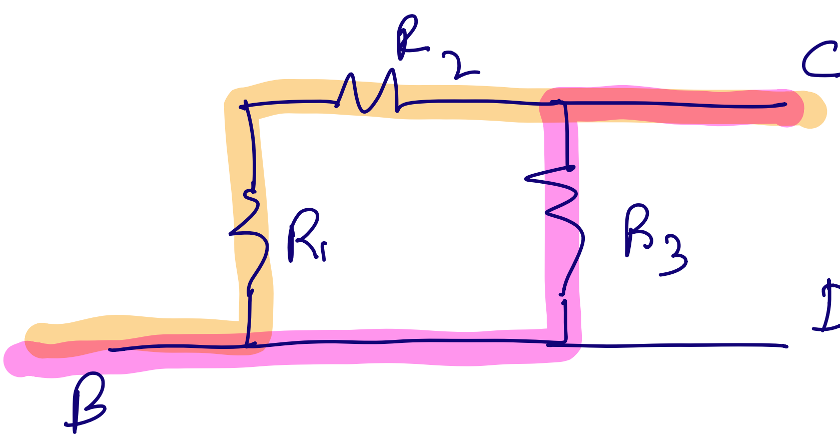
$I = \frac{V_s}{R_{eq}}$

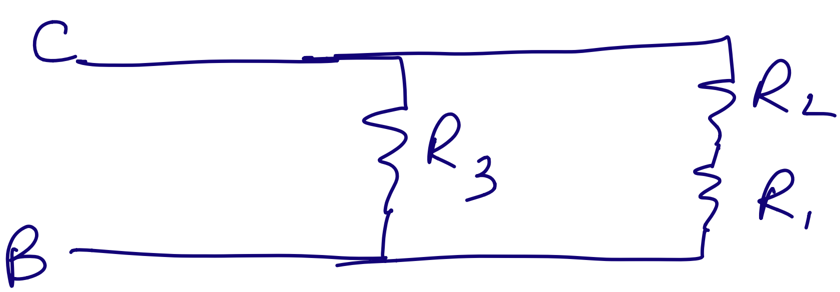
$$V_{out} = I \cdot R_2$$

$$= \frac{V_s}{R_{eq}} \cdot R_2 = \frac{V_s \cdot R_2}{R_1 + R_2}$$


A
R3
R1
R2
B


A
R3
R1
R2
B


R2
C
R1
R3
D
B


C
R2
R3
R1
B