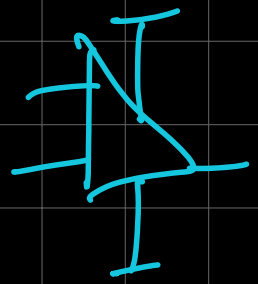
Lecture 7B

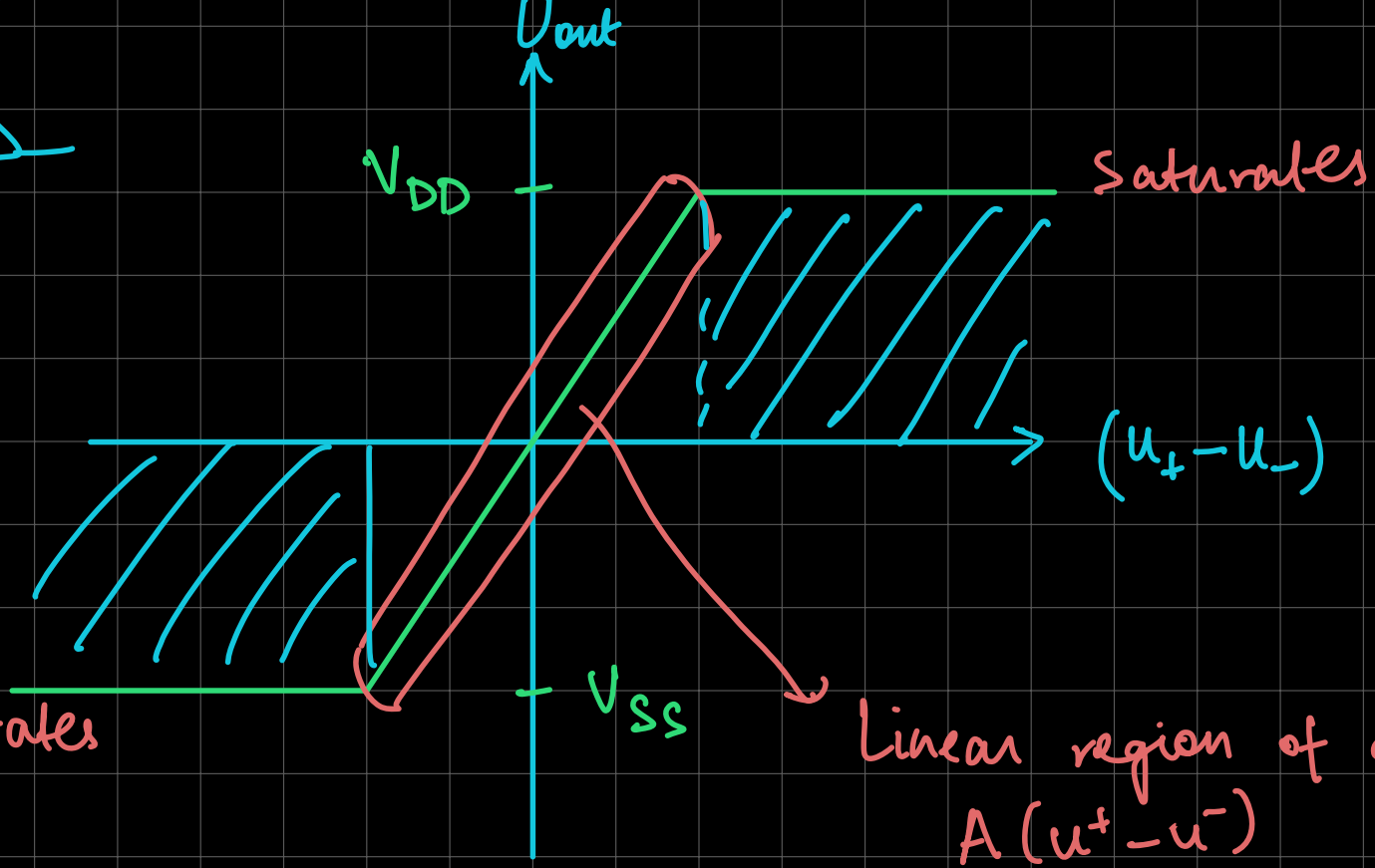
Agenda:

- → Op Amps and Comparators
- → Op Amp Circuit Analysis
- → Circuit Design
- → Capacitors and Charge Sharing
- → Superposition
- → Eigenstuff / Least Squares

Op Amps and Comparators

$-V_{DD} = V_{SS}$





Linear region of operation

$A(u^+ - u^-)$

↳ gain

$(A \to \infty)$

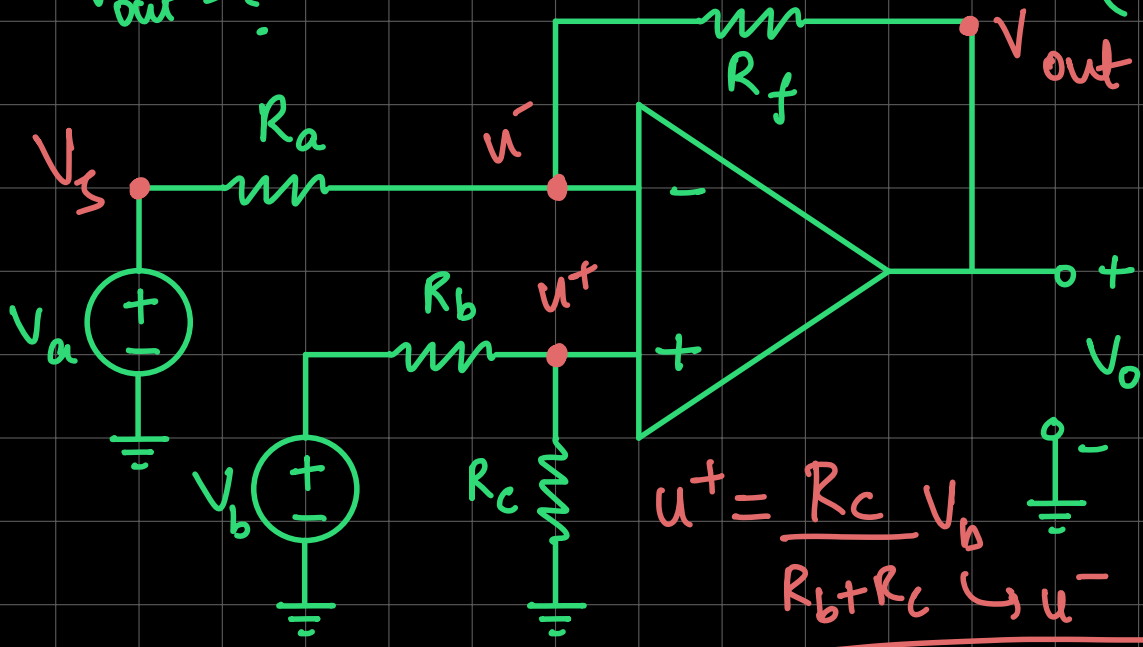
NFB → $(u_+ - u_-)$

Golden Rules → $I^+ = I^- = 0$

Ideal Op Amp $u^+ = u^-$ in NFB

Op Amp Circuit Analysis

$V_{out} = ?$ (SP19 MT2)



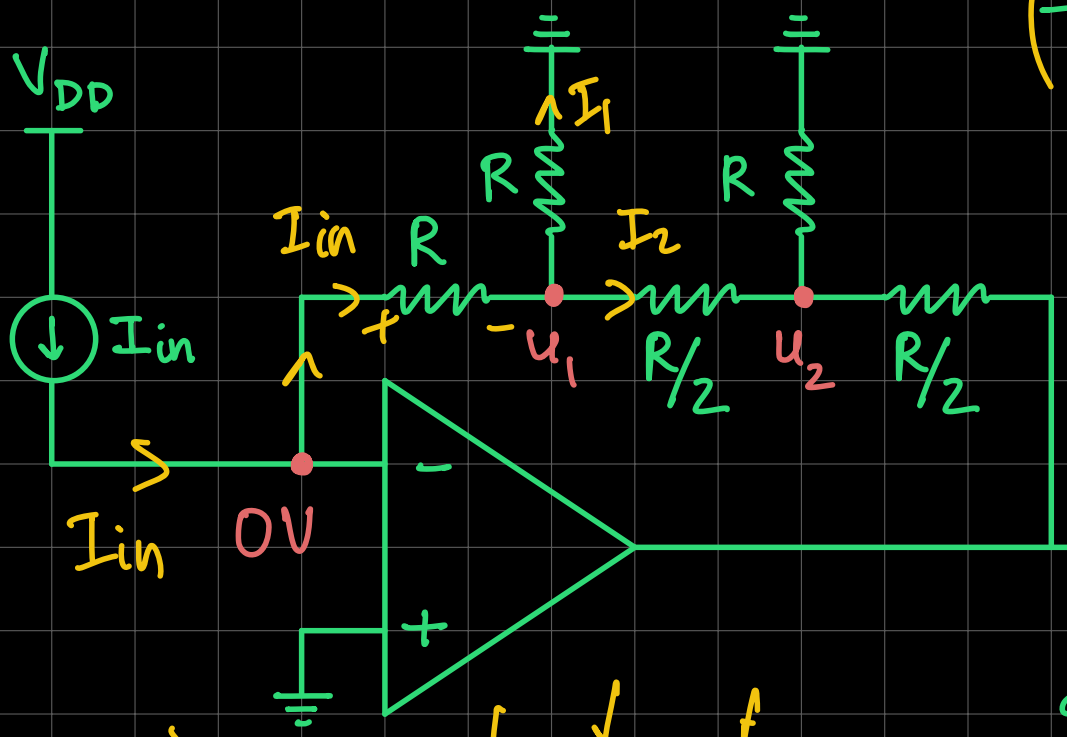
$$\frac{u^- - V_s}{R_a} + \frac{u^- - V_{out}}{R_f} = 0$$

$$u^+ = \frac{R_c}{R_b + R_c} V_b \quad (u^+ \hookrightarrow u^-)$$

$$u^- \left(\frac{1}{R_a} + \frac{1}{R_f}\right) - \frac{V_a}{R_a} = \frac{V_{out}}{R_f}$$

$$\boxed{R_f \left(\left(\frac{V_b R_c}{R_b + R_c} \right) \left(\frac{1}{R_a} + \frac{1}{R_f} \right) - \frac{V_a}{R_a} \right) = V_{out}}$$

Op Amp Circuit Analysis (SU20 MT2)



$-4.5 I_{in}R$

$\left(-\frac{9}{2} I_{in}R\right)$, 0 ✗

$$\frac{0-U_1}{R} = I_{in}$$

$$\boxed{U_1 = -I_{in}R}$$

U_1 → $I_{in} = \frac{U_1}{R} + \frac{U_1-U_2}{R/2}$

$$\frac{U_2-0}{R} + \frac{U_2-U_1}{R/2} + \frac{U_2-V_{out}}{R/2} = 0$$

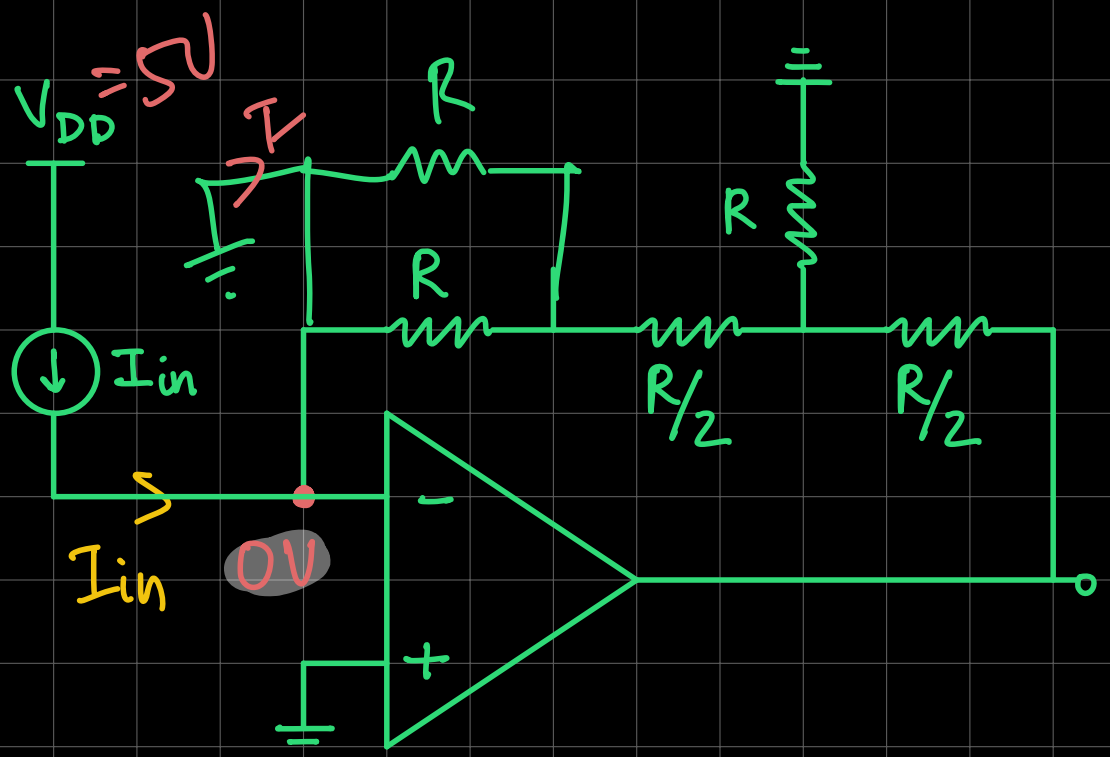
$$I_{in} = -\frac{I_{in}R}{R} + \frac{-I_{in}R}{R/2} - \frac{U_2}{R/2}$$

$$4I_{in} = -\frac{U_2}{R/2}$$

$$\boxed{U_2 = -2 I_{in}R}$$

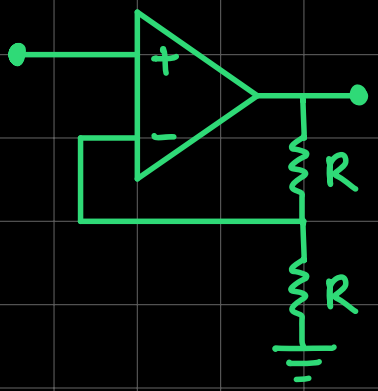
$$-2I_{in} - 4I_{in} + 2I_{in} - 4I_{in} = 2\frac{V_{out}}{R}$$

$$\Rightarrow \boxed{V_{out} = -4 I_{in}R}$$


$V_{DD} = 5V$
I
R
R
R
I_{in}
$R/2$
$R/2$
I_{in}
0V
−
+

Circuit Design (SU20 Final Q14)

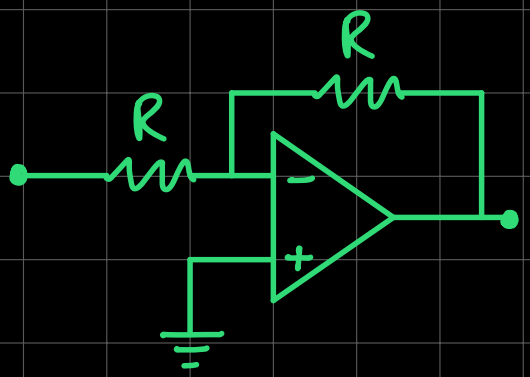
(A)



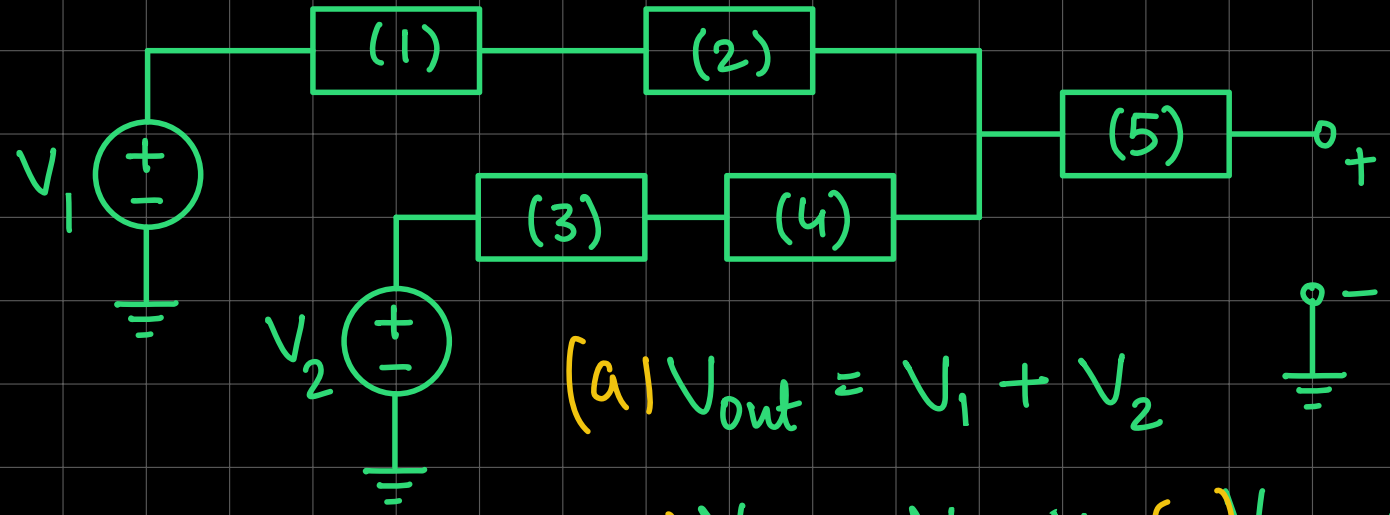
(B)

(C)

(D)



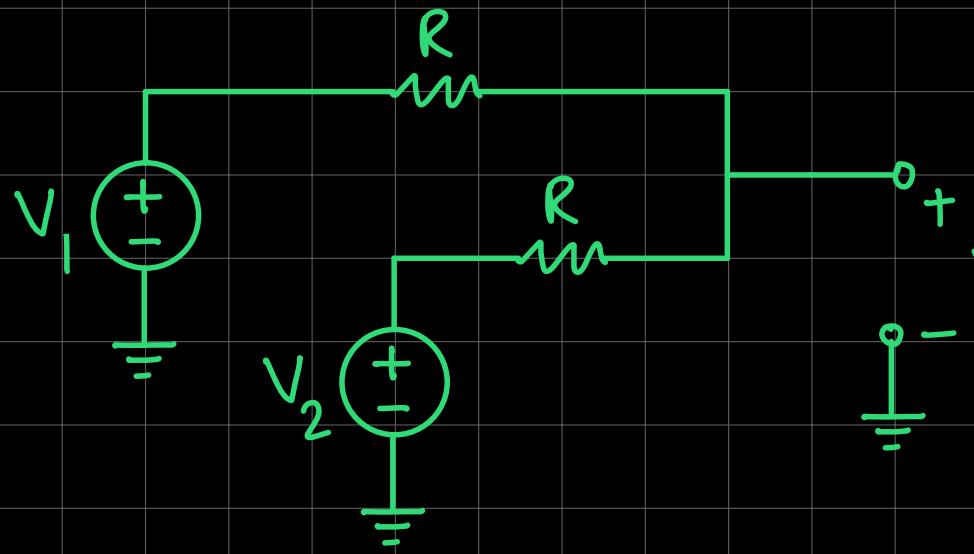
Outline



(a) $V_{out} = V_1 + V_2$

(b) $V_{out} = V_1 - V_2$ (c) $V_{out} = \frac{2}{3}V_1 + \frac{4}{3}V_2$

Example:



$$V_{out} = \frac{1}{2}V_1 + \frac{1}{2}V_2$$

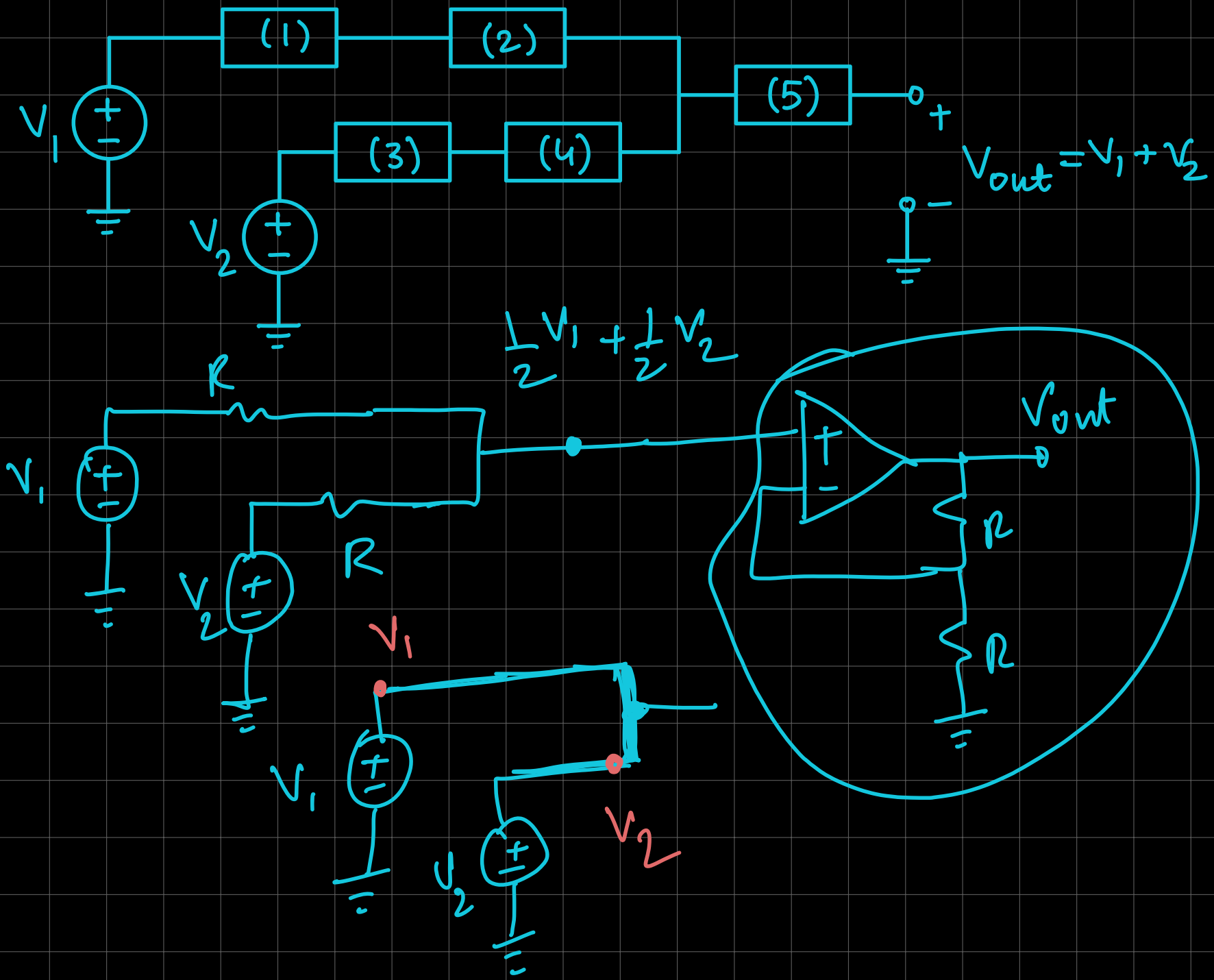
Design a circuit using ABCD & the outline such that:

(a) $V_{out} = V_1 + V_2$

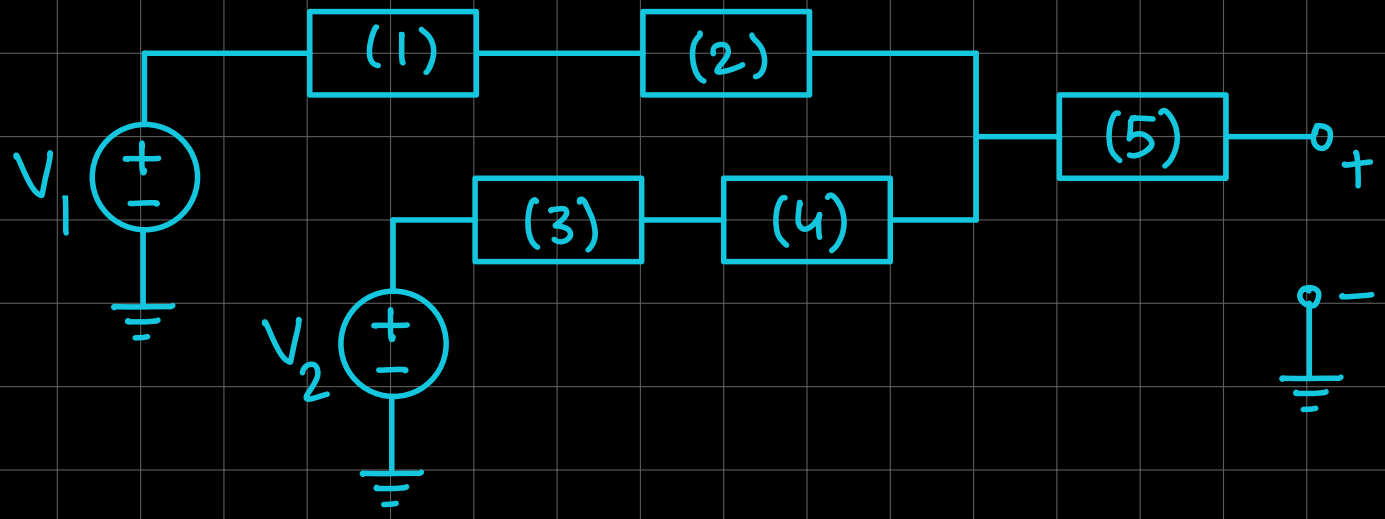
(b) $V_{out} = V_1 - V_2$

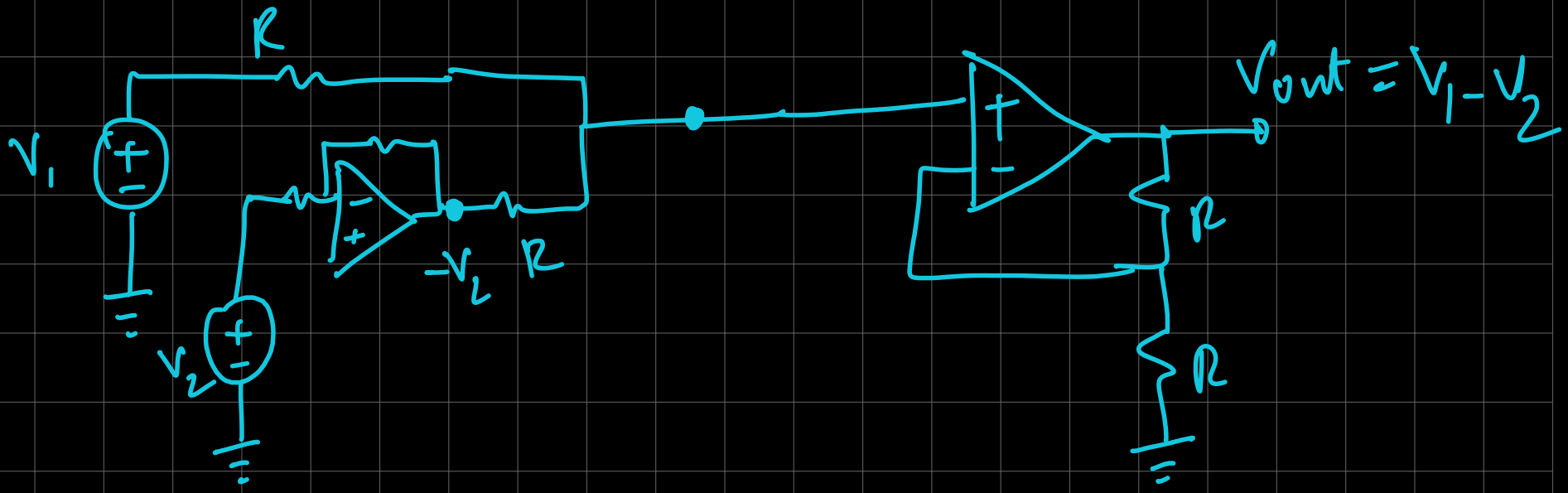
(c) $V_{out} = \frac{2}{3}V_1 + \frac{4}{3}V_2$

(a)

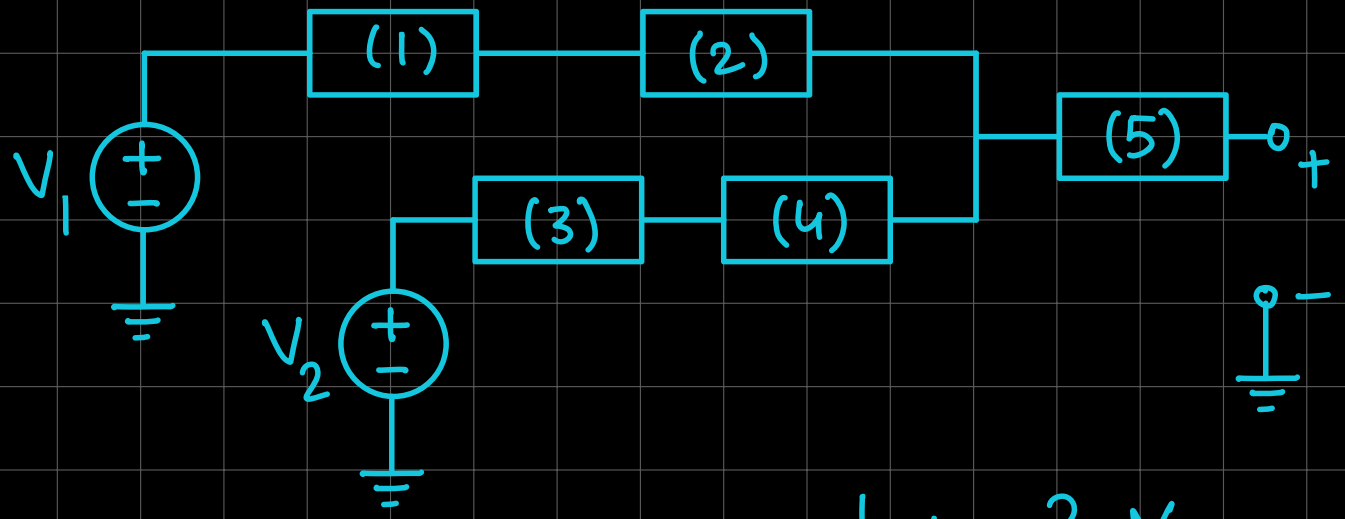

(1)
(2)
(3)
(4)
(5)
V_1
V_2
+
−
$V_{out} = V_1 + V_2$
$\frac{1}{2}V_1 + \frac{1}{2}V_2$
R
R
R
R
V_{out}
V_1
V_2
V_1
V_1
V_2
V_2

(b)

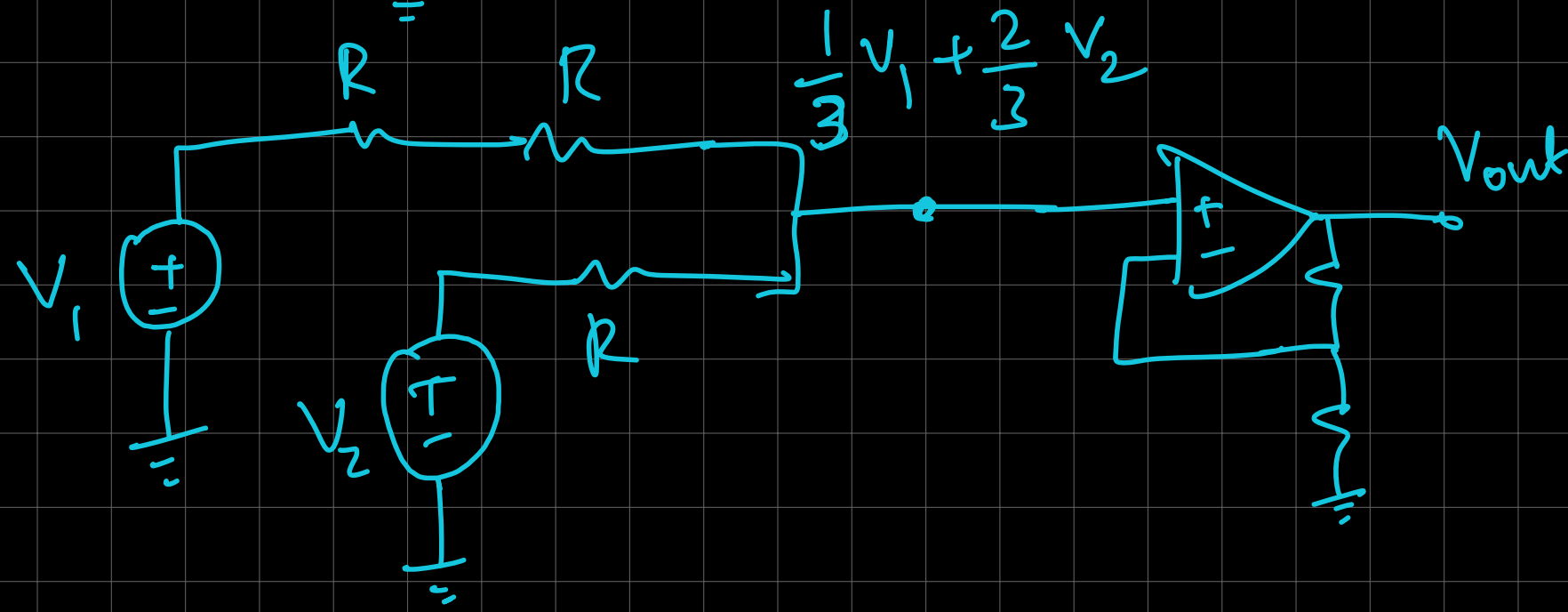




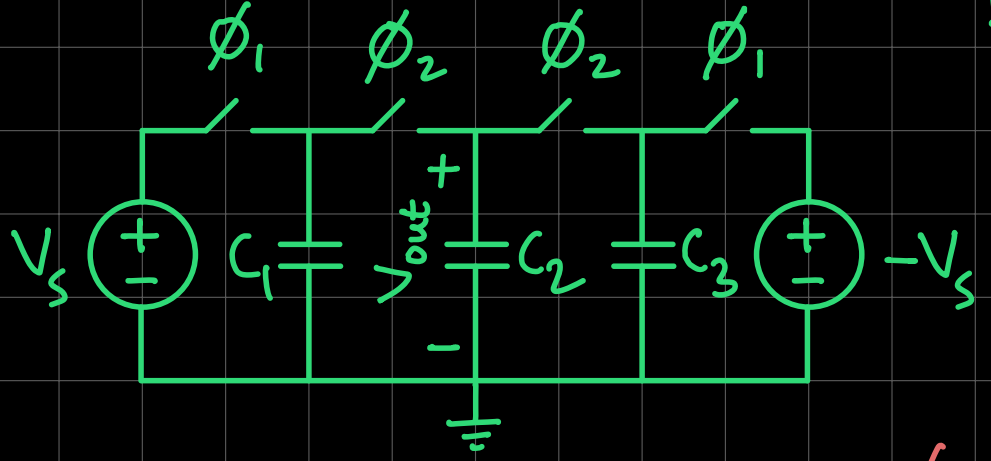
(c)



$$V_{out} = \frac{2}{3}V_1 + \frac{1}{3}V_2$$



Capacitors and Charge Sharing (FA19 Final Q9)



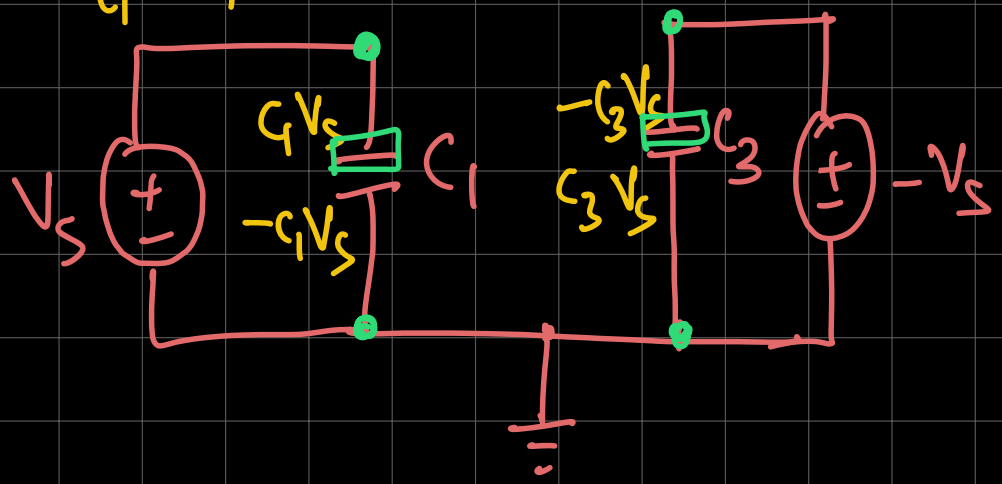
Find V_{out} after ϕ_1 & ϕ_2.

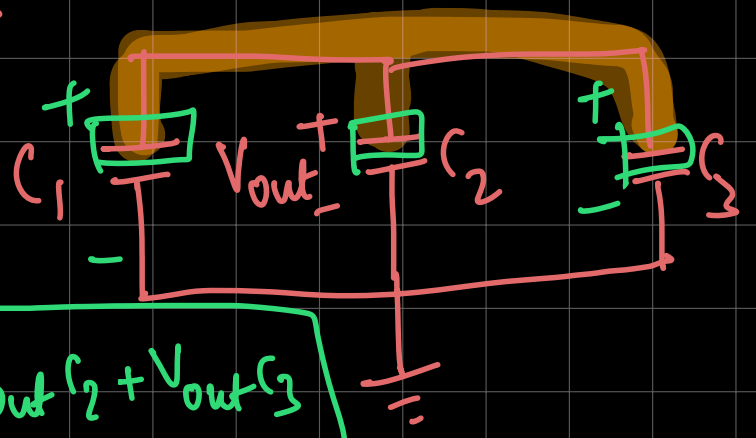
$\phi_1 \rightarrow 0$

$\phi_2 \rightarrow V_s \dfrac{(C_1 - C_3)}{C_1 + C_2 + C_3}$

$\phi_2 \rightarrow \dfrac{V_s(C_1 - C_2)}{C_1 + C_2 + C_3}$ $\phi_1 \rightarrow V_{out} = 0$

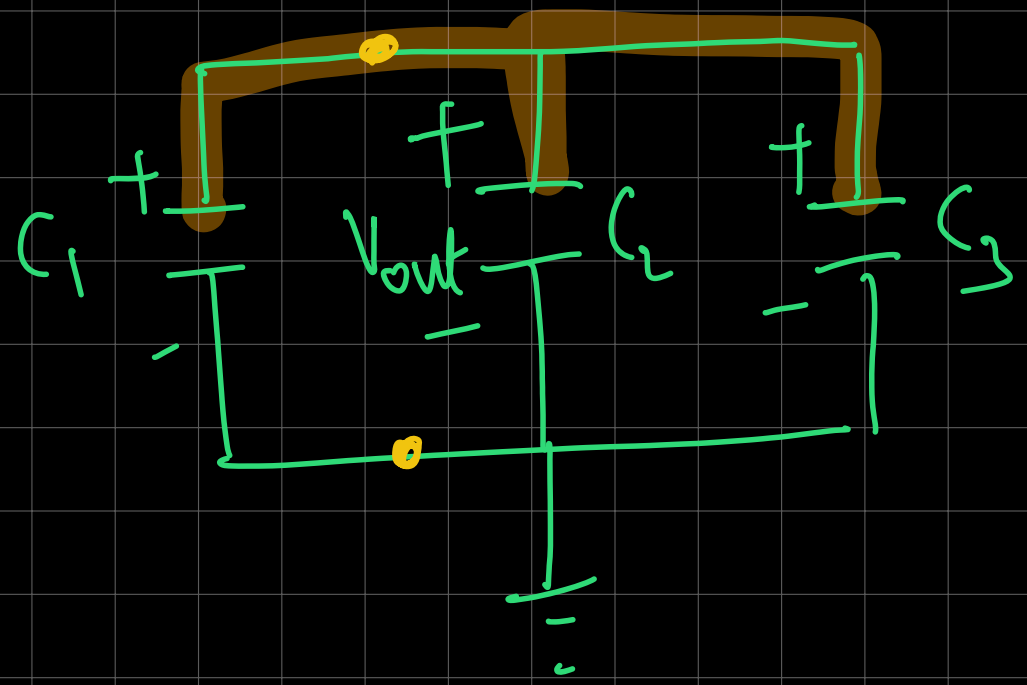
$q_1 = C_1 V_s$





$Q_{\phi_1} \rightarrow \boxed{C_1 V_s - C_3 V_s = V_{out} C_1 + V_{out} C_2 + V_{out} C_3}$

$$Q = C_2 V_{out}$$



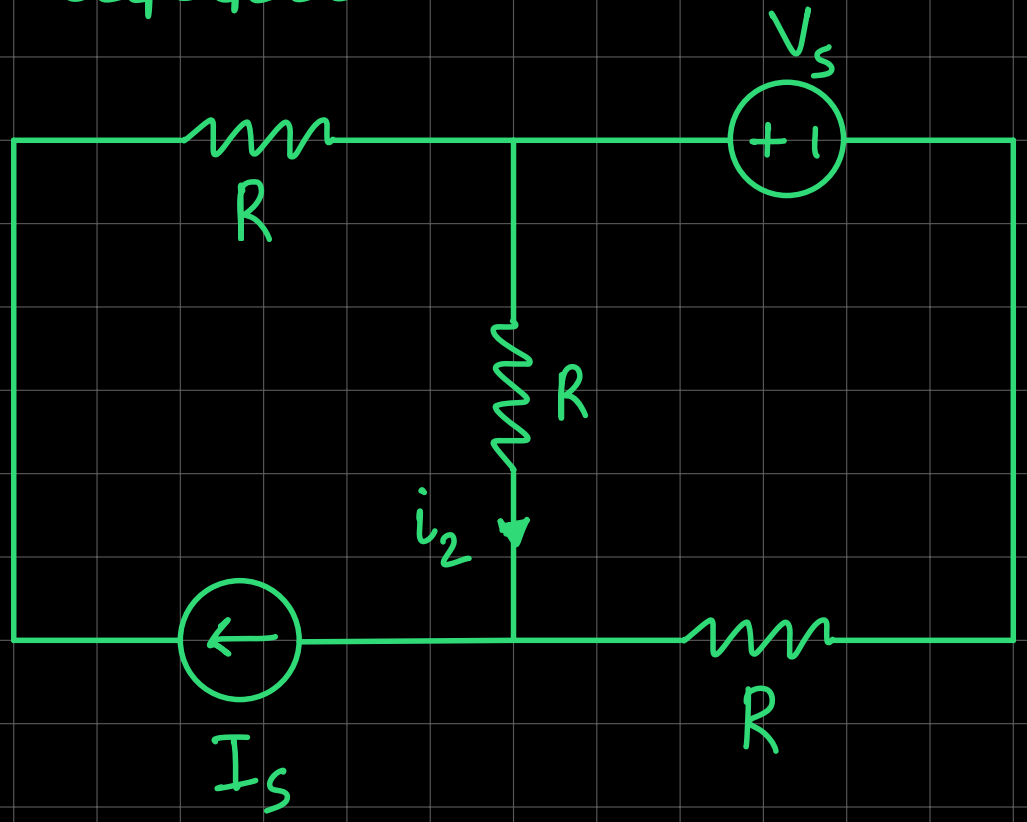
$$C_1 V_S - C_3 V_S = V_{out} C_1 + V_{out} C_2 + V_{out} C_3$$

ϕ_2

$$V_{out} = \frac{(C_1 - C_3) V_S}{C_1 + C_2 + C_3}$$

Superposition

(SP20 Final Q9)



Find i_2

Eigenstuff