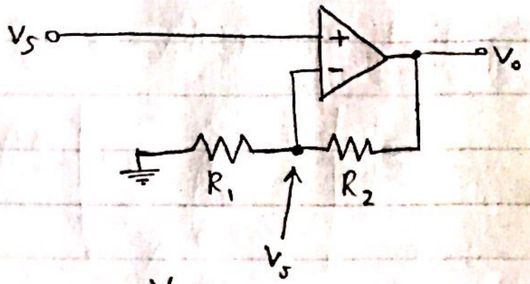
Vaibhav Bhat

EE16A hw 9

#1 Basic Amplifier Building Blocks

a)



Non-inverting b/c gain is ⊕.

$$V = IR$$

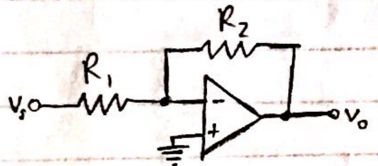
$$V_s - 0 = I(R_1)$$

$$I = V_s / R_1$$

$$V_{R_2} = IR_2 = \frac{V_s R_2}{R_1}$$

$$V_o = V_s + V_{R2} = \boxed{V_s\left(\frac{R_1+R_2}{R_1}\right)}$$

b)



$$V_+ = V_- = 0$$

Inverting b/c gain is ⊖

$$V_s - IR_1 = 0$$

$$I = \frac{V_s}{R_1}$$

$$V_o = 0 - IR_2 = -\left(\frac{R_2}{R_1}\right)V_s$$

$$\text{Gain} = \frac{V_o}{V_s} = \boxed{-\frac{R_2}{R_1}}$$

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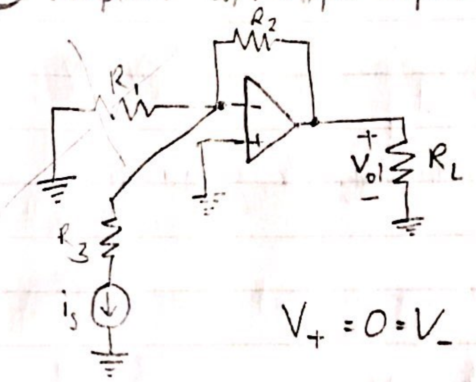
#2 Amplifier w/ Multiple Inputs

a)

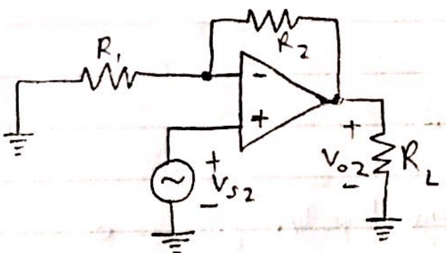


$V_+ = 0 = V_- \Rightarrow V_{R_1} = 0$

$V_{R_2} = i_s R_2$

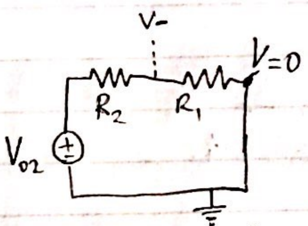
$V_{R_2} = \boxed{V_{o1} = i_s R_2}$

b)



$V_+ = V_{s2} = V_-$

R_1 & R_2 in series



Voltage divider!

$$V_{R_1} = V_{o2}\left(\frac{R_1}{R_1+R_2}\right)$$

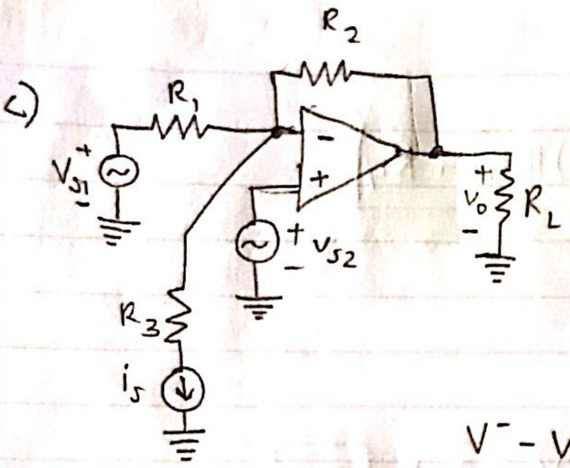
$V_- =$

& $V_- = V_{s2}$

so... $$V_{s2} = V_{o2}\left(\frac{R_1}{R_1+R_2}\right)$$

$$\boxed{V_{o2} = V_{s2}\left(\frac{R_2}{R_1}+1\right)}$$

c)



$$V_+ = V_- = V_{S2}$$

$$i_{R1} + i_{R3} + i_{R2} = 0$$

$$\downarrow$$

$$i_{R3} = i_s$$

$$\underbrace{\frac{V^- - V_{S1}}{R_1}}_{i_{R1}} + \underbrace{\frac{V^- - V_o}{R_2}}_{i_{R2}} + i_s = 0$$

$$V^- = V_{S2}$$

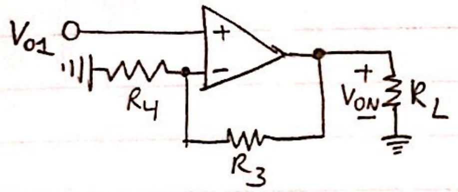
$$\frac{V_{S2} - V_{S1}}{R_1} + \frac{V_{S2} - V_o}{R_2} + i_s = 0$$

$$\boxed{V_o = V_{S2}\left(1 + \frac{R_2}{R_1}\right) + i_s R_2 - \left(\frac{R_2}{R_1}\right) V_{S1}}$$

d) No current flows in/out of op-amp, so voltages doesn't change from first part.

Output of part © = $V_{o1} = V_{S2}\left(1 + \frac{R_2}{R_1}\right) + i_s R_2 - \left(\frac{R_2}{R_1}\right) V_{S1}$

$$V_{ON} = V_{OUT-NEW}$$



$$V_+ = V_{o1} = V_-$$

Nodal analysis $\frac{V_- - \text{Ground}}{R_4} + \frac{V_- - V_{ON}}{R_3} = \emptyset$ $\$$ $V_- = V_{o1}$

$$\frac{V_{o1}}{R_4} = \frac{V_{ON} - V_{o1}}{R_3} \Longrightarrow \boxed{V_{ON} = \left(\frac{R_3 + R_4}{R_4}\right) V_{o1}}$$

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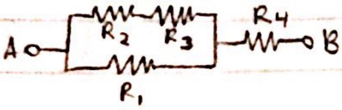
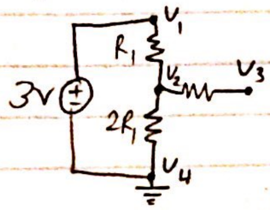
MT #3 Simplifying Resistor Networks



$$\boxed{R_{eq} = \left[(R_2+R_3) \,||\, R_1\right] + R_4}$$

MT#4 Capacitors

☆ Treat capacitors as open circuits



$V_{R_1} = \frac{1}{3} \times 3 = 1$

$\boxed{V_1 = 1V}$

$V_2 = 3 - 1 = \boxed{2V}$

MT#5 Ladder Nodal

Node A: $$\frac{V_A - V_B}{R_1} + \frac{V_A - V_1}{R_2} + \frac{V_A}{R_2} = \emptyset$$

Node B: $$\frac{V_B - V_2}{R_2} + \frac{V_B - V_A}{R_1} = \emptyset$$

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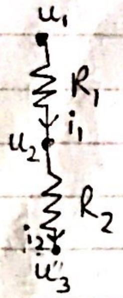
MT#6

a)



b)

$$F = \begin{array}{c|c} & \begin{matrix} u_1 & u_2 & u_3 \end{matrix} \\ \begin{matrix} i_1 \\ i_2 \end{matrix} & \begin{bmatrix} +1 & -1 & 0 \\ 0 & +1 & -1 \end{bmatrix} \end{array}$$

c) [for original circuit]

$$F^T \vec{i} = \begin{bmatrix} +1 & 0 \\ -1 & +1 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} i_1 \\ i_2 - i_1 \\ -i_2 \end{bmatrix} = \boxed{\begin{bmatrix} I_{s1} \\ I_{s2} \\ -I_{s1} - I_{s2} \end{bmatrix}}$$

3×2 $\quad 2 \times 1$

$i_2 = I_{s1} + I_{s2}$

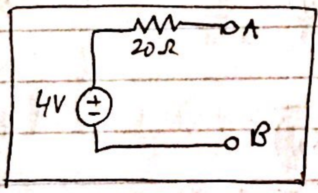
MT#7

a) $I_N = \frac{V_{Th}}{R_{Th}}$

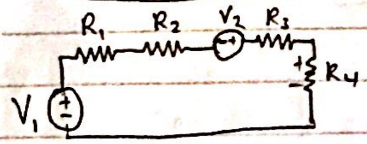
$\frac{1}{5} A = \frac{V_{Th}}{20\Omega}$

$\boxed{V_{Th} = 4V}$

$\boxed{R_{Th} = R_{No} = 20\Omega}$



b)

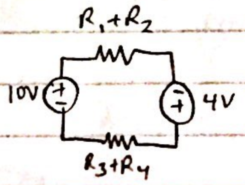


$V_{Th} = I_{No} R_{Th}$

$V_1 = \left(\frac{1}{3} A\right)(30\Omega) = \boxed{10V}$

$V_2 = \left(\frac{1}{5} A\right)(20\Omega) = \boxed{4V}$

c)



$10V - (40\Omega) I + 4V - (30\Omega) I = \emptyset$ KVL

$14V - (70\Omega) I = \emptyset$

$I = \frac{1}{5} A$

$V_{R4} = \left(\frac{1}{5} A\right)(10\Omega) = \boxed{2V}$

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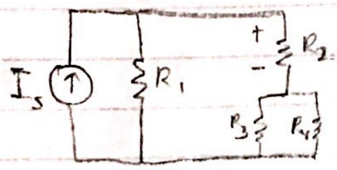
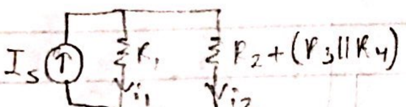
MT #8

1) V_{Th} over OC



V_{R_2}



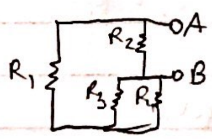
current divider!

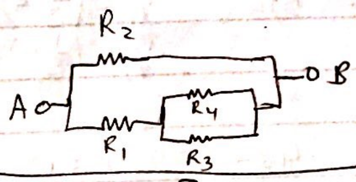
$$i_2 = I_s \frac{\frac{1}{R_2+(R_3||R_4)}}{\frac{1}{R_1}+\frac{1}{R_2+(R_3||R_4)}} = I_s \frac{1}{1+\frac{R_2+(R_3||R_4)}{R_1}}$$

$$i_2 = \frac{I_s R_1}{R_1+R_2+(R_3||R_4)}$$

$$V_{Th} = V_{R2} = i_2 R_2 = \boxed{\frac{I_s R_1 R_2}{R_1+R_2+(R_3||R_4)}}$$

2) R_{Th}





$$\boxed{R_{Th} = R_2 || [R_1 + (R_3||R_4)]}$$

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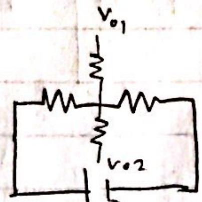
MT#9

a) $R_x = \frac{W}{A}(\rho_x)$ $\qquad R_y = \frac{L}{A}(\rho_y)$

b)



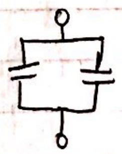
$\frac{1}{1+2} \times 3 = \boxed{1V}$

c) $V_{o2} = V_S\left(\frac{N+1-j}{N}\right)$

MT#10

a) $C = \varepsilon \frac{A}{d} = \varepsilon \frac{wx}{d}$

$\boxed{C = \varepsilon \frac{wx}{d}}$



parallel

$\boxed{\text{Net capacitance} = 2\varepsilon \frac{wx}{d}}$

b) $C_a V_S = (C_a + C_{ref}) V_{out}$

$\boxed{V_{out} = \frac{C_a V_S}{C_a + C_{ref}}}$

c) $\underbrace{V_S C_a + V_{out}[k-1] C_{ref}}_{\phi_1} = \underbrace{V_{out}[k] (C_a + C_{ref})}_{\phi_2}$

$\boxed{V_{out}[k] = \frac{V_S C_a + V_{out}[k-1] C_{ref}}{C_a + C_{ref}}}$

#11

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