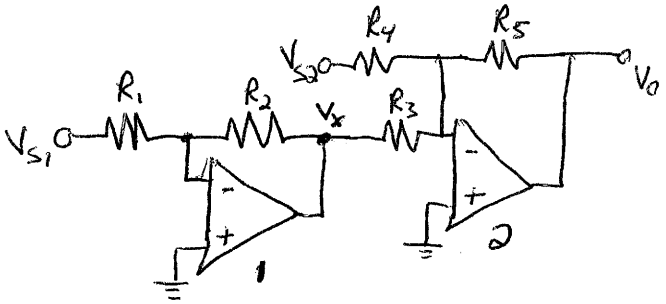
ENGR 210 HW 8 Solutions Spring '05

#1 $V_{p_1} = V_{n_1} = 0 \qquad V_{p_2} = V_{n_2} = 0$



KCL @ V_{n_1}: $\frac{V_{s1}}{R_1} = \frac{-V_x}{R_2} \Rightarrow V_x = -\frac{R_2}{R_1} V_{s1}$

KCL @ V_{n_2}: $\frac{V_x}{R_3} + \frac{V_{s2}}{R_4} = \frac{-V_o}{R_5}$

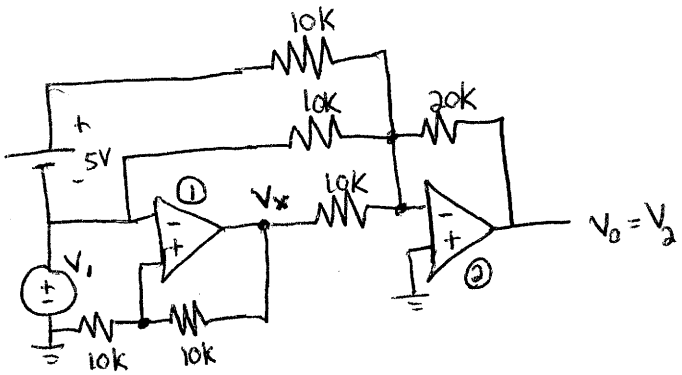
$$V_o = -\frac{R_5}{R_3}\left(-\frac{R_2}{R_1}\right)V_{s1} - \frac{R_5}{R_4} V_{s2}$$

$$\boxed{V_o = \frac{R_2}{R_1}\frac{R_5}{R_3} V_{s1} - \frac{R_5}{R_4} V_{s2}}$$

#2 $V_{p_1} = \frac{10k}{10k+10k} V_x = \frac{V_x}{2} = V_{n_1} = V_1$

$V_{n_2} = V_{p_2} = 0$

KCL @ V_{n_2}: $\frac{V_x}{10k} + \frac{V_1}{10k} + \frac{V_1+5}{10k} = \frac{-V_o}{20k}$



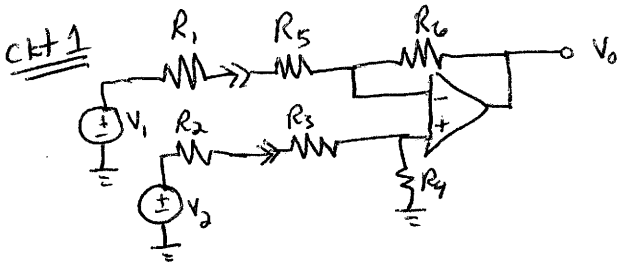
$$V_o = -2V_x - 2V_1 - 2V_1 - 5(2) = V_2$$

$$= -2(2V_1) - 2V_1 - 2V_1 - 10$$

$$\boxed{V_o = -8V_1 - 10}$$

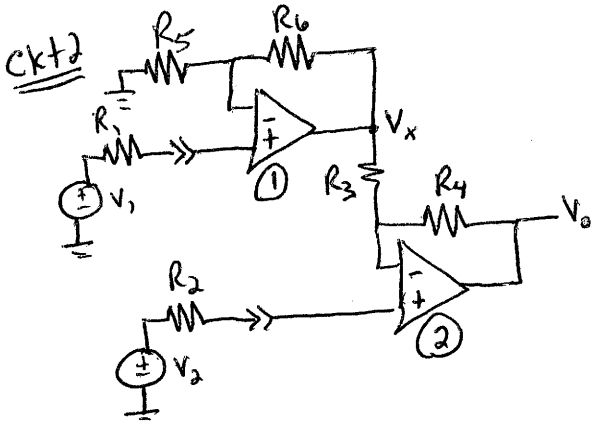
#3 $V_o = K_2 V_2 + K_1 V_1$

(a) Same Ckt as on last HW



$$V_o = \frac{\left(1 + \frac{R_6}{R_5+R_1}\right)}{\left(1 + \frac{R_2+R_3}{R_4}\right)} V_2 - \left(\frac{R_6}{R_5+R_1}\right) V_1$$

$$\boxed{K_2 = \frac{\left(1 + \frac{R_6}{R_5+R_1}\right)}{\left(1 + \frac{R_2+R_3}{R_4}\right)} \qquad K_1 = -\left(\frac{R_6}{R_5+R_1}\right)}$$



#3 cont...

(a) cont... $V_{p_1} = V_{n_1} = V_1$ $\quad V_{p_2} = V_{n_2} = V_2$

KCL @ V_{n_1}: $\frac{0 - V_1}{R_5} = \frac{V_1 - V_x}{R_6}$

$V_x = V_1\left(1 + \frac{R_6}{R_5}\right)$

KCL @ V_{n_2}: $\frac{V_x - V_2}{R_3} = \frac{V_2 - V_o}{R_4}$

$V_o = R_4\left(\frac{V_2}{R_4} + \frac{V_2}{R_3} - \frac{V_x}{R_3}\right)$

$V_o = V_2\left(1 + \frac{R_4}{R_3}\right) - \left(\frac{R_4}{R_3}\right)\left(1 + \frac{R_6}{R_5}\right)V_1$

$$K_2 = \left(1 + \frac{R_4}{R_3}\right) \qquad K_1 = -\left(\frac{R_4}{R_3}\right)\left(1 + \frac{R_6}{R_5}\right)$$

(b) $R_1 = R_2 = 1k \quad R_3 = R_5 = 10k$

$V_o = 5(V_2 - V_1)$

(c)

ckt 1

$K_1 = -5 = -\left(\frac{R_6}{R_5 + R_1}\right) \Rightarrow R_6 = 5(10k + 1k)$

$$R_6 = 55k$$

$K_2 = \frac{(1+5)}{1 + \frac{R_2 + R_3}{R_4}} = 5 \qquad 6 = 5 + \frac{5(R_2 + R_3)}{R_4}$

$\frac{1}{5} = \frac{R_2 + R_3}{R_4} \Rightarrow R_4 = 5(10k + 1k)$

$$R_4 = 55k$$

ckt 2

$K_1 = -5 = -\left(\frac{R_4}{R_3}\right)\left(1 + \frac{R_6}{R_5}\right)$

$K_2 = 5 = \left(1 + \frac{R_4}{R_3}\right)$

$$R_4 = 4R_3 = 40k$$

$5 = \left(\frac{40k}{10k}\right)\left(1 + \frac{R_6}{10k}\right) = 4 + \frac{4R_6}{10k}$

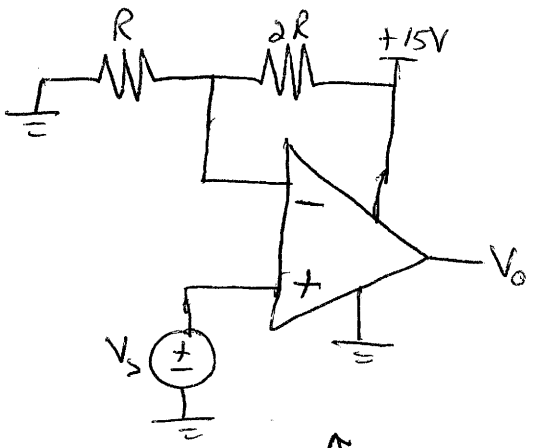
$$R_6 = \frac{10k}{4} = 2.5k$$

(d) + ckt 1 only uses one opamp versus two for ckt 2

however, sources v_1 and v_2 are loaded by R_5 and R_3 respectively in ckt 1.

+ These tradeoffs would have to be considered if placing these subtractor circuits into a design.

#4 $V_{OH} = 15V \quad V_{OL} = 0$



↑

Open Loop Comparator

No Feedback so $V_+ \neq V_-$

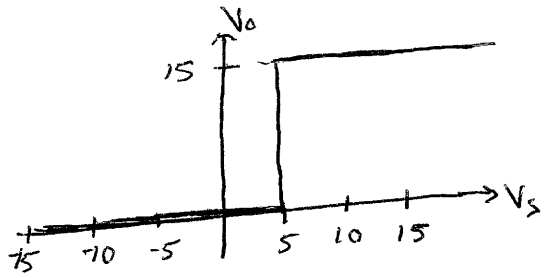
↓

(a) $V_- = \frac{R}{R+2R}(15) = 5$

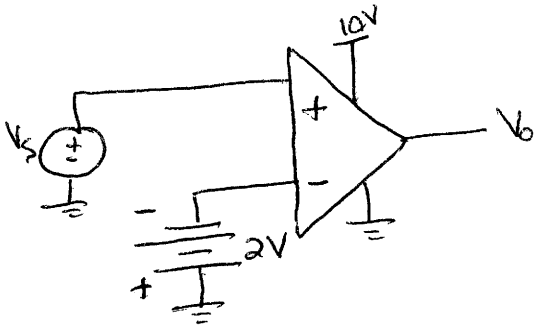
$V_o = V_{OH}$ if $V_s > 5V$

$V_o = V_{OL}$ if $V_s < 5V$

(b)



#5 $V_{OH} = 10V \quad V_{OL} = 0V$



(a) if $V_p > V_n \Rightarrow V_{OH}$

$V_s > -2 \quad V_o = V_{OH}$

if $V_p < V_n \Rightarrow V_{OL}$

$V_s < -2 \quad V_o = V_{OL}$

(b)