

Homework V

Ch. 4: 21, 24, 28, 29, 31, 32, 35, 38, 45, 54

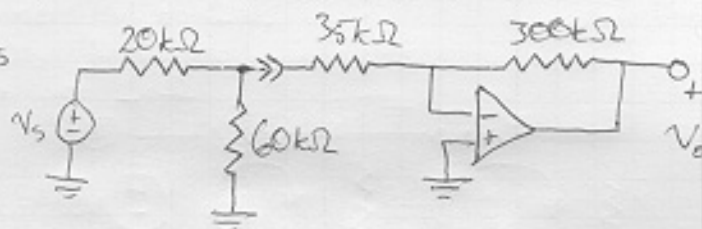
P. 4.21 find v_o in terms of v_s

$v_p = v_n = 0$
 $i_n = i_p = 0$
 current through $35k\Omega$ resistor =
 - current through $300k\Omega$ resistor

$$i = \frac{\frac{1}{35}}{\frac{1}{20} + \frac{1}{60} + \frac{1}{35}} \left(\frac{v_s}{20k\Omega} \right) = \frac{3}{200} v_s \text{ mA}$$

$$v_o = -i(300k\Omega)$$

$$v_o = -\frac{9}{2} v_s = -4.5 v_s$$



P. 4.24 a) find v_o in terms of v_s

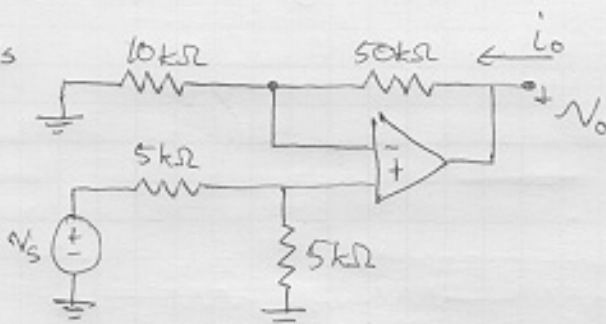
b) find i_o for $v_s = 2V$
 $i_n = i_p = 0$
 $v_p = v_n = \frac{5}{5+5} v_s = \frac{1}{2} v_s$

current in $10k\Omega$ = current in $50k\Omega$

$$i = \frac{v_s}{10k\Omega} = \frac{1}{20} v_s \text{ mA} = i_o$$

$$v_o = i_o(50k\Omega) + \frac{1}{2} v_s$$

$$v_o = 3 v_s$$



if $v_s = 2V$

$$i_o = 0.1 \text{ mA}$$

P. 4.28 find v_o in terms of v_1 & v_2

$$v_n = v_p = \frac{1}{3} v_2$$

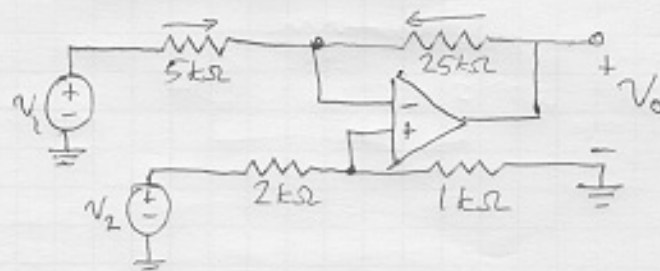
$$i_{5k\Omega} = \frac{(v_1 - \frac{1}{3} v_2)}{5k\Omega} = -i_{25k\Omega}$$

$$v_o = i_{25k\Omega} (25k\Omega) + \frac{1}{3} v_2$$

$$= - (25k\Omega) \frac{(v_1 - \frac{1}{3} v_2)}{5k\Omega} + \frac{1}{3} v_2$$

$$v_o = -5 v_1 + \frac{5}{3} v_2 + \frac{1}{3} v_2$$

$$v_o = 2 v_2 - 5 v_1$$



P.4.29 find V_o in terms of V_{s1} & V_{s2}

$$i_p = i_n = 0$$

$$V_n = V_p = \frac{2}{3} V_{s2}$$

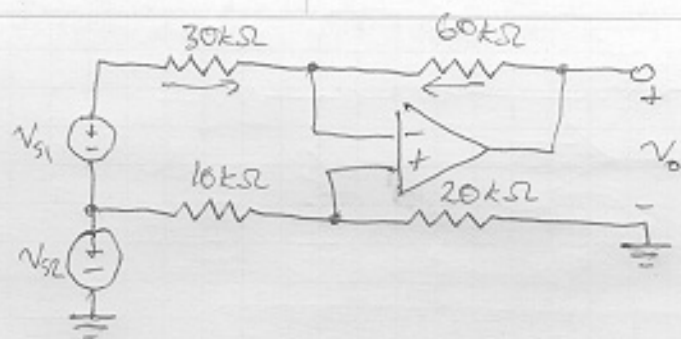
Current through $30k\Omega$

$$i = \frac{(V_{s1} + V_{s2}) - \frac{2}{3} V_{s2}}{30k\Omega}$$

$$V_o - \frac{2}{3} V_{s2} = -i (60k\Omega)$$

$$V_o = -2V_{s1} - 2V_{s2} + \frac{4}{3} V_{s2} + \frac{2}{3} V_{s2}$$

$$\boxed{V_o = -2V_{s1}}$$



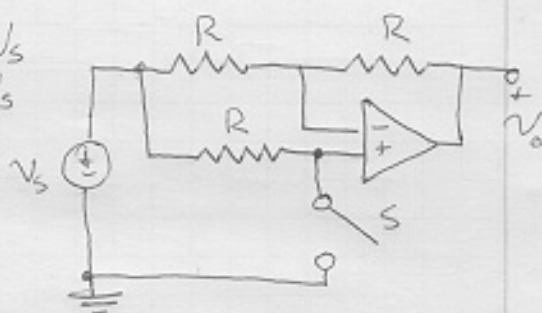
P.4.31 Claim: Switch open $V_o = -V_s$
 Switch closed $V_o = V_s$
 Prove or disprove this claim.

Switch open

$$V_n = V_p = V_s$$

because $i_p = 0 = i_n$
 all current is zero
 $\therefore V_o = V_s$

DISPROVED



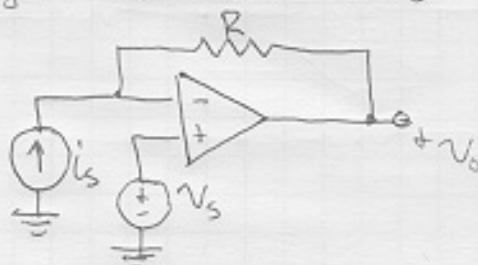
P.4.32 When OP-AMP is in linear range find constants K_1 & K_2 $V_o = K_1 V_s + K_2 i_s$

$$V_n = V_p = V_s$$

$$V_o - V_s = -i_s R$$

$$V_o = V_s - R i_s$$

$$\boxed{\begin{matrix} K_1 = 1 \\ K_2 = -R \end{matrix}}$$



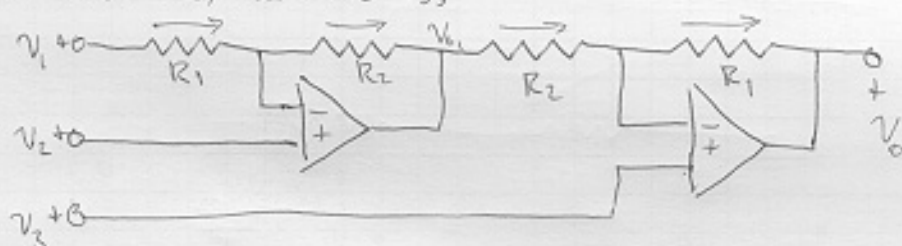
P.4.35 find v_o in terms of v_{s1} , v_{s2} and v_{s3}

left OP-AMP

$$v_n = v_p = v_{s2}$$

$$i_{R1} = \frac{v_1 - v_2}{R_1}$$

$$\begin{aligned} v_{o1} &= v_{s2} - i_{R1} R_2 \\ &= v_{s2} - \frac{R_2}{R_1} (v_1 - v_2) \end{aligned}$$



right OP-AMP

$$v_n = v_p = v_3$$

$$i_{R2} = \frac{v_{o1} - v_3}{R_2} = \frac{v_{s2}}{R_2} - \frac{(v_{s1} - v_{s2})}{R_1} - \frac{v_{s3}}{R_2}$$

$$\begin{aligned} v_o &= v_{s3} - i_{R2} R_1 \\ &= v_{s3} - \frac{R_1}{R_2} v_{s2} + v_{s1} - v_{s2} + \frac{R_1}{R_2} v_{s3} \end{aligned}$$

$$v_o = v_{s1} - \left(1 + \frac{R_1}{R_2}\right) v_{s2} + \left(1 + \frac{R_1}{R_2}\right) v_{s3}$$

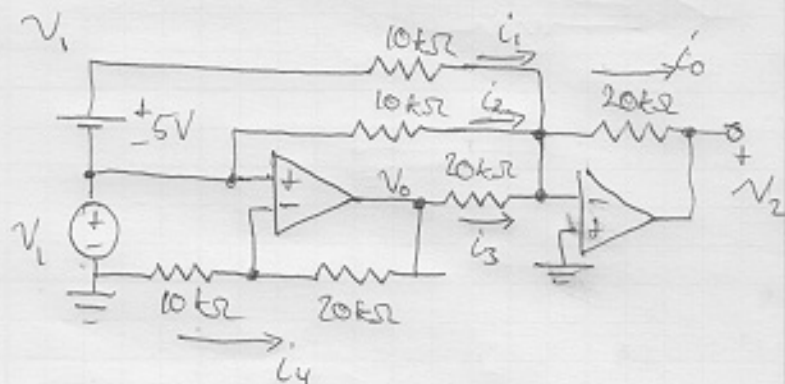
P.4.38 find v_2 in terms of v_1

right OP-AMP

$$v_p = v_n = 0$$

$$i_1 = \frac{v_1 + 5V}{10k\Omega}$$

$$i_2 = \frac{v_1}{10k\Omega}$$



left OP-AMP

$$v_n = v_p = v_1$$

$$i_4 = \frac{0 - v_1}{10k\Omega}$$

$$v_o = v_1 - \frac{i_4 (20k\Omega)}{20k\Omega}$$

$$i_3 = \frac{v_o}{20k\Omega}$$

$$v_o = v_1 - \frac{i_4 (20k\Omega)}{20k\Omega}$$

$$v_o = 3v_1$$

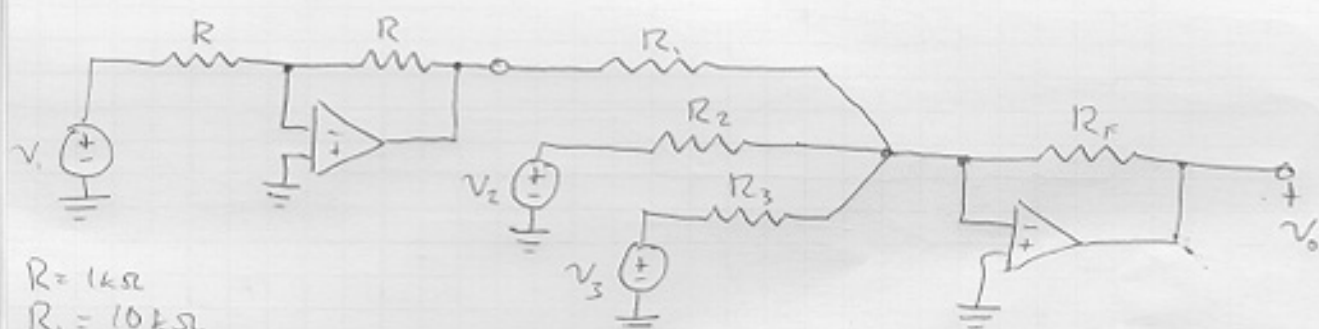
$$i_o = i_1 + i_2 + i_3 = \frac{v_1 + 5V}{10k} + \frac{v_1}{10k} + \frac{3v_1}{20k}$$

$$\begin{aligned} v_2 &= -i_o (20k\Omega) \\ &= -(2v_1 + 10V + 2v_1 + 3v_1) \end{aligned}$$

$$v_2 = -7v_1 - 10V$$

P.4.45 Using on more than two OP-AMPS, design a circuit that has inputs v_1, v_2, v_3 & output $v_o = 3v_1 - 2v_2 - 5v_3$

ex.



$$\begin{aligned} R &= 1k\Omega \\ R_1 &= 10k\Omega \\ R_2 &= 15k\Omega \\ R_3 &= 6k\Omega \\ R_4 &= 30k\Omega \end{aligned}$$

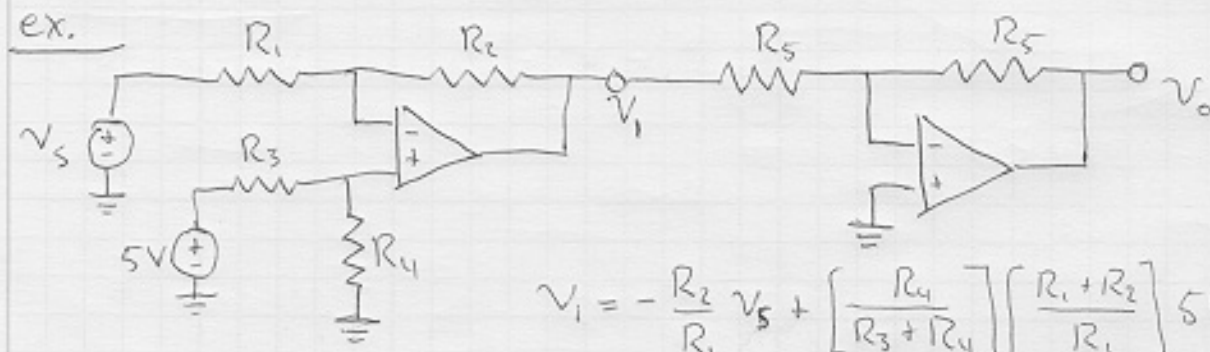
P.4.54 Given a temp. sensor that gives a voltage for a given temp., related by $v_s = (10T + 500)mV$, T in $^{\circ}C$, for a range of temps., $-40^{\circ}C$ to $110^{\circ}C$.

Design a circuit that translates this v_s into a range of $0V$ to $3V$. Can use a $5V$ source.

$$-40^{\circ}C \leq T \leq 110^{\circ}C$$

$$0.1V \leq v_s \leq 1.6V$$

want $0V \leq v_o \leq 3V$ $\Rightarrow v_o = 2v_s - 0.2$



$$v_1 = -\frac{R_2}{R_1} v_s + \left[\frac{R_4}{R_3 + R_4} \right] \left[\frac{R_1 + R_2}{R_1} \right] 5V$$

$$v_o = \frac{R_2}{R_1} v_s + \left[\frac{R_4}{R_3 + R_4} \right] \left[\frac{R_1 + R_2}{R_1} \right] 5V$$

$$R_1 = 1k\Omega, R_2 = 2k\Omega, R_3 = 14k\Omega, R_4 = 1k\Omega, R_5 = 1k\Omega$$