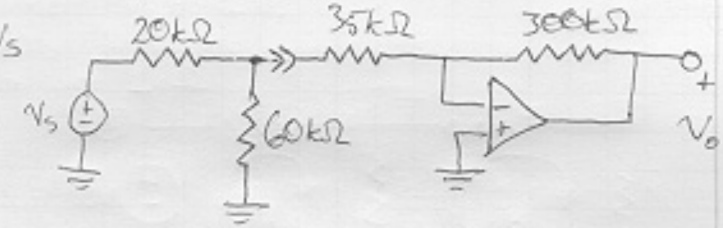
Homework V | Ch. 4: 21, 24, 28, 29, 31, 32, 35, 38, 45, 54

P.4.21 find v_o in terms of v_s



$v_p = v_n = 0$

$i_n = i_p = 0$

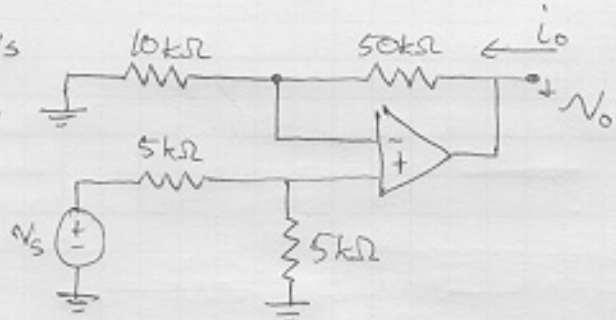
current through 35kΩ resistor = - current through 300kΩ resistor

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

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

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

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 10kΩ = current in 50kΩ

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

~~$= \frac{1}{20} v_s$ mA~~

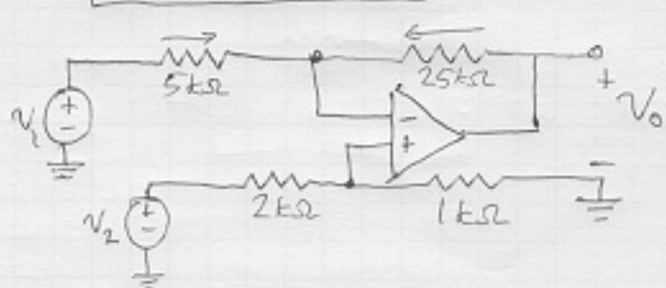
$$v_o = i_o(50k\Omega) + \frac{1}{2} v_s$$

$$\boxed{v_o = 3 v_s}$$

if $v_s = 2V$

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

P.4.28 find v_o in terms of v_1 & v_2



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

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

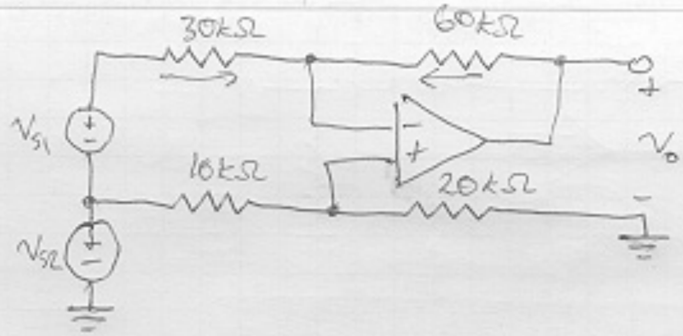
$$v_o = i_{25k\Omega}(25k\Omega) + \frac{1}{3} v_2$$

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

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

$$\boxed{v_o = 2 v_2 - 5 v_1}$$

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 30kΩ

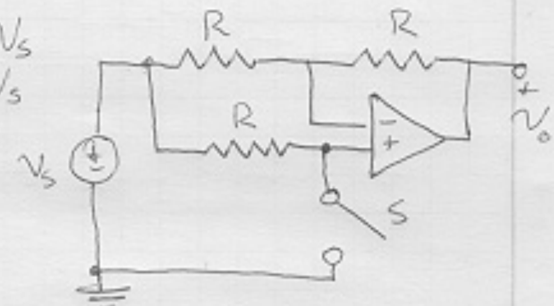
$$i = \frac{(v_{s1} + v_{s2}) - \frac{2}{3} v_{s2}}{30k\Omega}$$

$$v_o - \frac{2}{3} v_{s2} = -i\,(60k\Omega)$$

$$v_o = -2v_{s1} - 2v_{s2} + \frac{4}{3} v_{s2} + \frac{2}{3} v_{s2}$$

$$\boxed{v_o = -2v_{s1}}$$

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



__switch open__

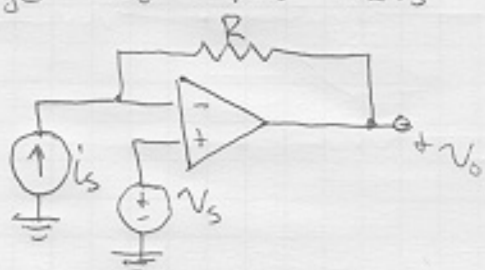
$v_n = v_p = v_s$

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 $v_o = K_1 v_s + K_2 i_s$
find constants K_1 & K_2



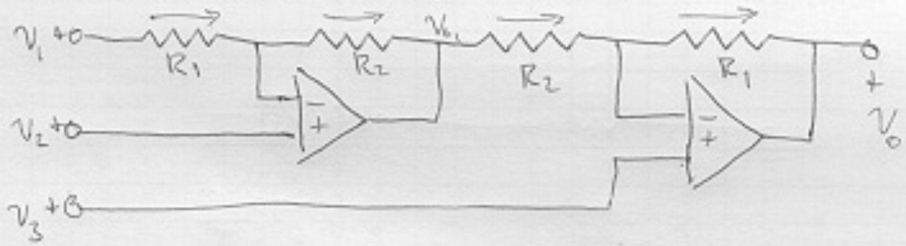
$v_n = v_p = v_s$

$v_o - v_s = -i_s R$

$v_o = v_s - R i_s$

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

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



left OP-AMP

$v_n = v_p = v_{s2}$

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

$$v_{o_1} = v_{s2} - i_{R_1} R_2$$

$$= v_{s2} - \frac{R_2}{R_1}(v_1 - v_2)$$

right OP-AMP

$v_n = v_p = v_3$

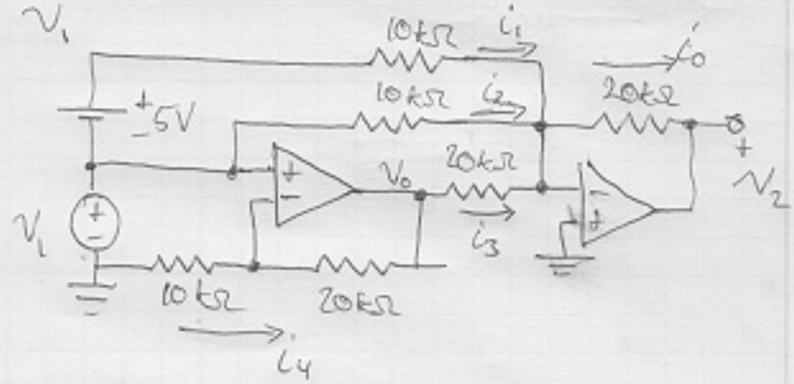
$$i_{R_2} = \frac{v_{o_1} - v_3}{R_2} = \frac{v_{s2}}{R_2} - \frac{(v_{s1} - v_{s2})}{R_1} - \frac{v_{s3}}{R_2}$$

$$v_o = v_{s3} - i_{R_2} R_1$$

$$= v_{s3} - \frac{R_1}{R_2} v_{s2} + v_{s1} - v_{s2} + \frac{R_1}{R_2} v_{s3}$$

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

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

$v_n = v_p = v_1$

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

~~$v_o = \ldots \frac{v_1}{20k\Omega}$~~

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

$v_o = 3v_1$

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

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

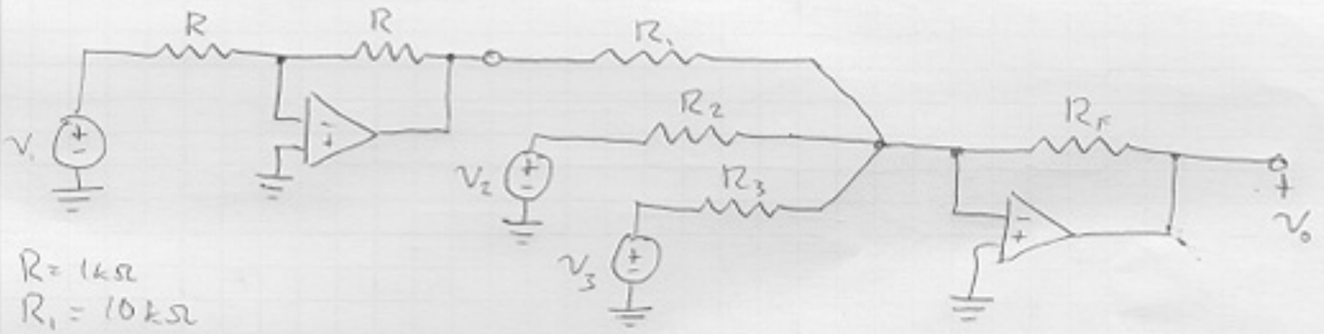
$$v_2 = -i_o (20k\Omega)$$

$$= -(2v_1 + 10V + 2v_1 + 3v_1)$$

$$\boxed{v_2 = -7v_1 - 10V}$$

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.



$R = 1k\Omega$
$R_1 = 10k\Omega$
$R_2 = 15k\Omega$
$R_3 = 6k\Omega$
$R_F = 30k\Omega$

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

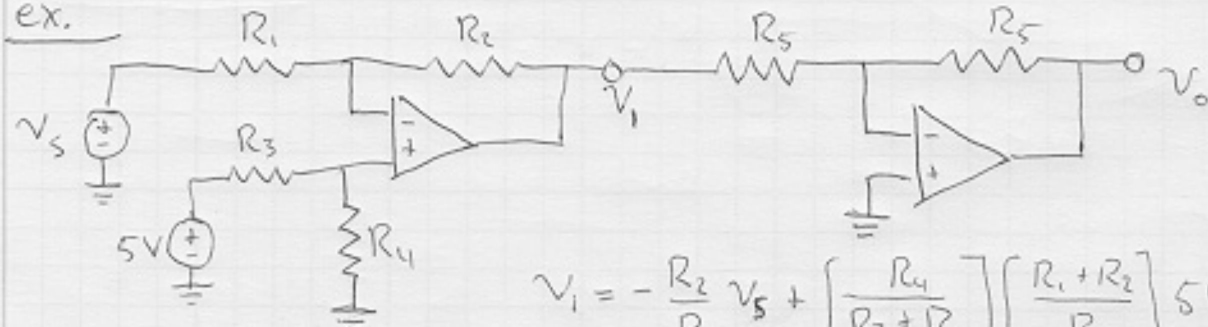
Design a ciruit that translates this v_s into a range of 0V to 3V. Can use a 5V source.

$-40°C \le T \le 110°C$

$0.1V \le v_s \le 1.6V$

want $0V \le v_o \le 3V$ $\quad > \quad v_o = 2v_s - 0.2$

ex.



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

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

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