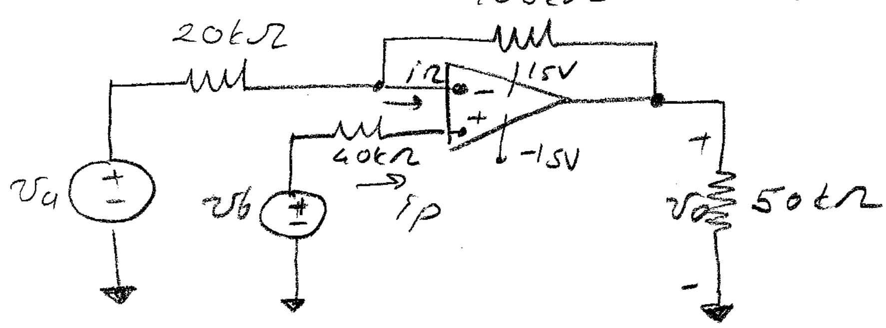
EE 210 Chapter 5 Solutions

5.2



a) For an ideal opamp $i_p = i_n = 0$, which implies that $v_b = v_p$, also for an ideal opamp $v_p = v_n$, thus $v_b = v_n$, thus

$$\frac{v_b - v_a}{20} + \frac{v_b - v_o}{100} = 0 \Rightarrow 5(v_b - v_a) + v_b - v_o = 0$$

$$v_o = 6v_b - 5v_a$$

(a) $v_a = 4V$, $v_b = 0V$, $v_o = -15V$ (sat)

(b) $v_a = 2V$, $v_b = 0V$, $v_o = -10V$

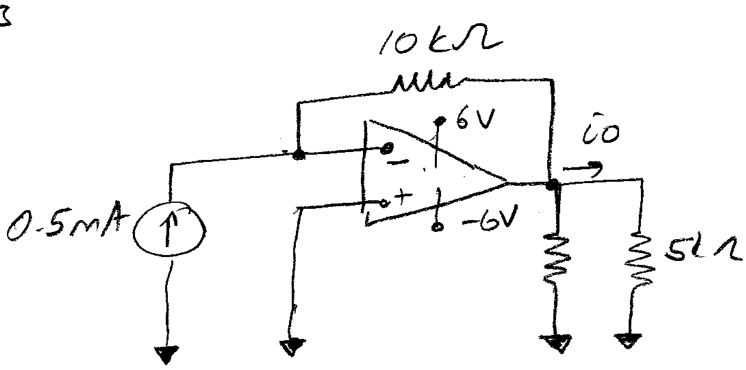
(c) $v_a = 2V$, $v_b = 1V$, $v_o = -4V$

(d) $v_a = 1V$, $v_b = 2V$, $v_o = 7V$

(e) If $v_b = 1.6V$, $v_o = 9.6 - 5v_a = \pm 15$

$\therefore -1.08 \leq v_a \leq 4.92V$

5.3

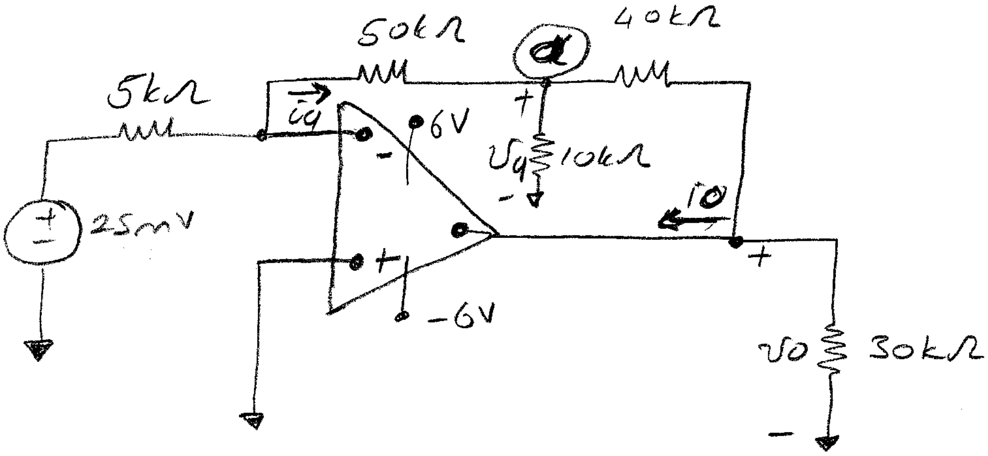


Node equation at the inverting input $-0.5 + \frac{v_n - v_o}{10} = 0$ (I)

But $v_p = 0$ and for an ideal opamp $v_p = v_n$, thus v_n is also zero. Equation (I) becomes $-0.5 = \frac{v_o}{10} \Rightarrow v_o = -5V$

$$i_o = -\frac{5V}{5k\Omega} = -1mA$$

5.5



a) as $i_p = i_n =$ the current in the 5kΩ resistor equals to the current in the 50kΩ resistor, thus

$$i_a = \frac{25mV}{5k\Omega} = 5\mu A$$

The inverting input is at zero volts thus, the voltage from the inverting input to node ⓐ equals to v_a

$$v_a = -50\times10^3 i_a = -250mV$$

(b) We write the node equation at node ⓐ.

$$\frac{v_a}{50} + \frac{v_a}{10} + \frac{v_a - v_o}{40} = 0$$

$$4v_a + 20v_a + 5(v_a - v_o) = 0$$

$$29v_a = 5v_o \qquad v_o = 5.8v_a = \underline{\underline{-1.45V}}$$

(c) $i_a = 5\mu A$

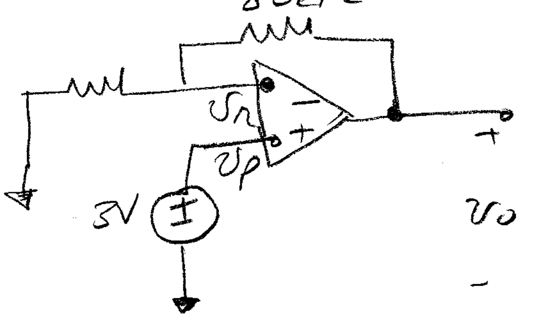
(d) We write the node equation at the output terminal

$$\frac{v_o - v_a}{40} + \frac{v_o}{30} + i_o = 0$$

$$i_o = \frac{-v_o}{30} - \frac{v_o}{40} + \frac{v_a}{40}$$

$$i_o = \frac{+1.45}{30} + \frac{1.45}{40} - \frac{0.25}{40} = 0.0783 mA = 78.33\mu A$$

5.7



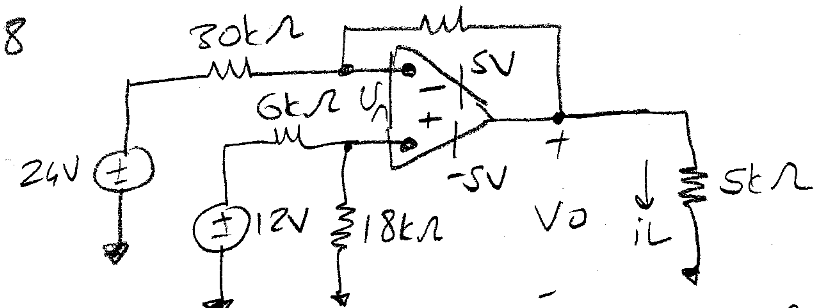
$$v_p = v_n = 3V$$

$$\frac{3-0}{40} + \frac{3-v_o}{80} = 0$$

$$6 + 3 - v_o = 0$$

$$v_o = 9V$$

5.8



If we can find v_o, we can find i_L

$$\text{I} \quad \frac{v_n-24}{30} + \frac{v_n-v_o}{20} = 0 \qquad \text{II} \quad \frac{v_p-12}{6} + \frac{v_p}{18} = 0$$

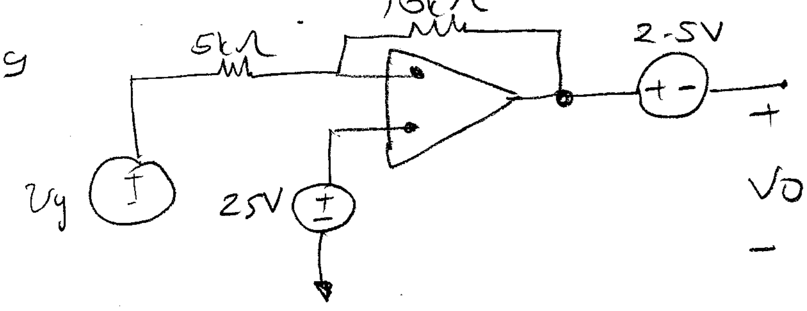
$$3v_p - 36 + v_p = 0 \qquad 4v_p = 36 \qquad v_p = 9V \qquad v_n = v_p = 9V$$

$$\frac{9-24}{30} + \frac{9-v_o}{20} = 0 \Rightarrow 2(9-24) + 3(9-v_o) = 0$$

$$18 - 48 + 27 - 3v_o = 0 \qquad -3v_o = 3V \qquad v_o = -1V$$

$$i_L = \frac{v_o}{5k\Omega} = \frac{-1V}{5k\Omega} = -0.200\,mA$$

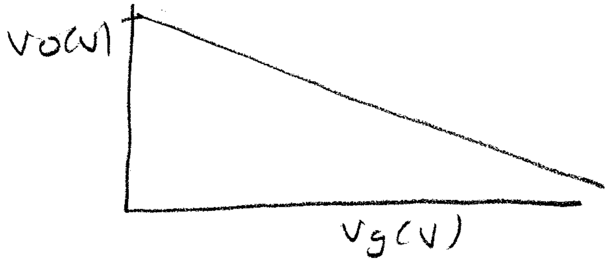
5.9



Let v_{o1} equal $v_p = v_n = 2.5V$ the voltage of the op-amp, then

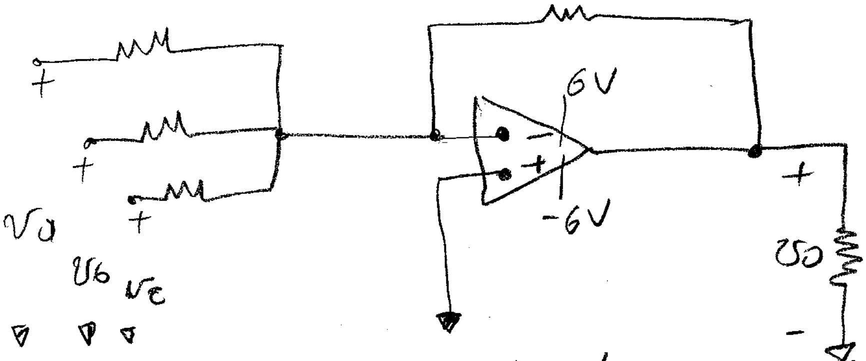
$$\frac{2.5 - v_g}{5000} + \frac{2.5 - v_{o1}}{10000} = 0 \qquad \therefore \quad v_{o1} = 7.5 - 2v_g$$

Also note that $v_{o1} - 2.5 = v_o \qquad \therefore \quad v_o = 5 - 2v_g.$



(b) Yes, the circuit designer is correct!

5-16.



a) The circuit is an example of an inverting summing amplifier.

b) $v_p = v_n = 0 \Rightarrow -\frac{v_a}{33} - \frac{v_b}{22} - \frac{v_c}{80} - \frac{v_o}{220} = 0$

$v_o = 220 \times \left[-\frac{v_a}{33} - \frac{v_b}{22} - \frac{v_c}{80}\right] = -\frac{220 v_a}{33} - \frac{220}{22} v_b - \frac{220}{80} v_c =$

$-8 + 15 - 11 = -4V$

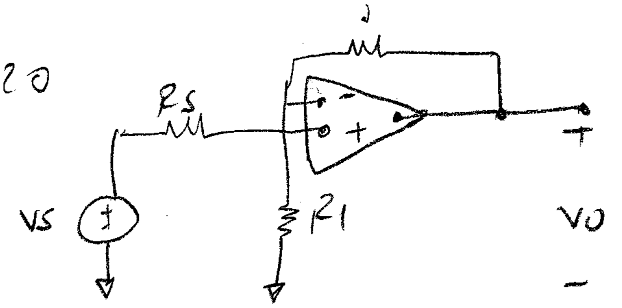
(c) $v_o = -\frac{220}{33} \times (1.2) - \frac{220}{80}(4) - \frac{220}{22} v_b = -19 - 10 v_b = \pm 6$

$\therefore$ $v_b = -1.3V$ when $v_o = -6V$;

$v_b = -2.5V$ when $v_o = 6V$

$-2.5V \le v_b \le -1.3V$

5-20



Node Equation at the inverting terminal:

I $\frac{v_n}{R_1} + \frac{v_n - v_o}{R_2} = 0$

Node Equation at the non-inverting terminal II $\frac{v_s - v_p}{R_s} = 0 \Rightarrow v_s = v_p$

As the op amp is ideal $v_p = v_n \therefore v_s = v_n$

substituting $v_s = v_n$ into the first node equation:

$$\frac{v_s}{R_1} + \frac{v_s - v_o}{R_2} = 0 \qquad v_s\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{v_o}{R_2}$$

$$v_s\left(\frac{R_2+R_1}{R_1R_2}\right) = \frac{v_o}{R_2} \Rightarrow \quad v_o = \frac{v_s(R_1+R_2)}{R_1}$$

or $$v_o = v_s\left[1 + \frac{R_2}{R_1}\right]$$

(b) $v_o = v_s$

(c) Because $v_o = v_s$, the output voltage follows the signal voltage.

5-32 $$v_p = \frac{v_b R_b}{R_a + R_b} = v_n$$

$$\frac{v_n - v_a}{4700} + \frac{v_n - v_o}{R_f} = 0$$

$$v_n\left(\frac{R_f}{4700} + 1\right) - \frac{v_a R_f}{4700} = v_o$$

$$\therefore \left(\frac{R_f}{4700} + 1\right)\frac{R_b}{R_a + R_b} v_b - \frac{R_f}{4700} v_a = v_o$$

$$\therefore \frac{R_f}{4700} = 10, \quad R_f = 47k\Omega$$

$$\therefore \frac{R_f}{4700} + 1 = 11 \quad \therefore \quad 11\left(\frac{R_b}{R_a + R_b}\right) = 10$$

$$11R_b = 10R_b + 10R_a \qquad R_b = 10R_a$$

$$R_a + R_b = 220k\Omega \Rightarrow 11R_a = 220k\Omega$$

$$R_a = 20k\Omega \quad R_b = 220 - 20 = 200k\Omega$$

5.33 $v_p = v_n = R_b i_b$

The node-equation at the inverting terminal.

$$\frac{R_b i_b - 3000 i_a}{3000} + \frac{R_b i_b - v_o}{R_f} = 0$$

$$\left(\frac{R_b}{3000} + \frac{R_b}{R_f}\right) i_b - i_a = \frac{v_o}{R_f}$$

$$v_o = \left[\frac{R_b R_f}{3000} + R_b\right] i_b - R_f i_a \quad \therefore R_f = 2000\,\Omega$$

$$\left(\frac{2}{3}\right) R_b + R_b = 2000 \quad \therefore R_b = 1200\,\Omega$$