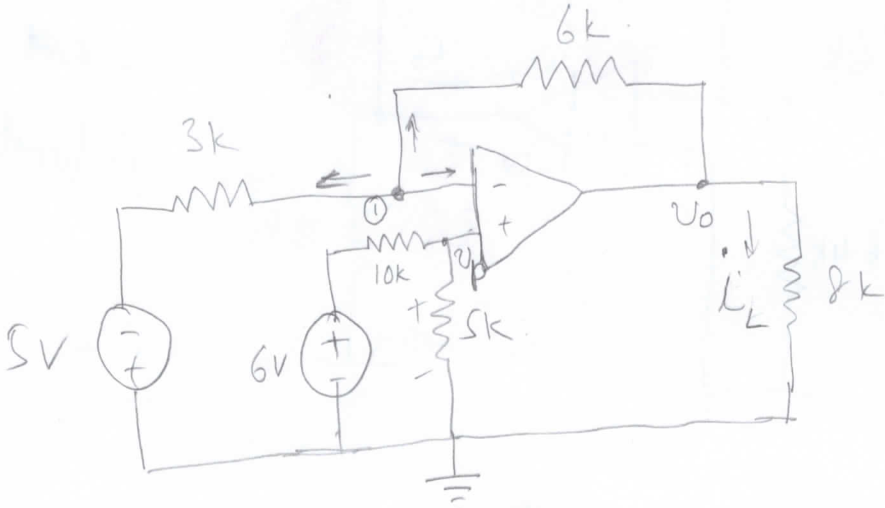
Ch 5 - Solved Problems

Op Amps

Pr 5.6

Find i_L.



We first need to find v_o, the output voltage.

Since the Op Amp is ideal:

$$v_p = v_n ; \quad i_p = i_n = 0$$

Also, $v_n = v_p = \left(\frac{5k}{5k+10k}\right) 6 = 2$ volts. (Not zero!)

Writing KCL at node 1:

$$\frac{v_n + 5}{3k} + \frac{v_n - v_o}{6} + i_n = 0$$

or $\frac{v_n - v_o}{6k} + \frac{v_n + 5}{3k} = 0$, since $i_n = 0$

i.e. $\frac{2 - v_o}{6} + \frac{7}{3} = 0$

$2 - v_o + 14 = 0$

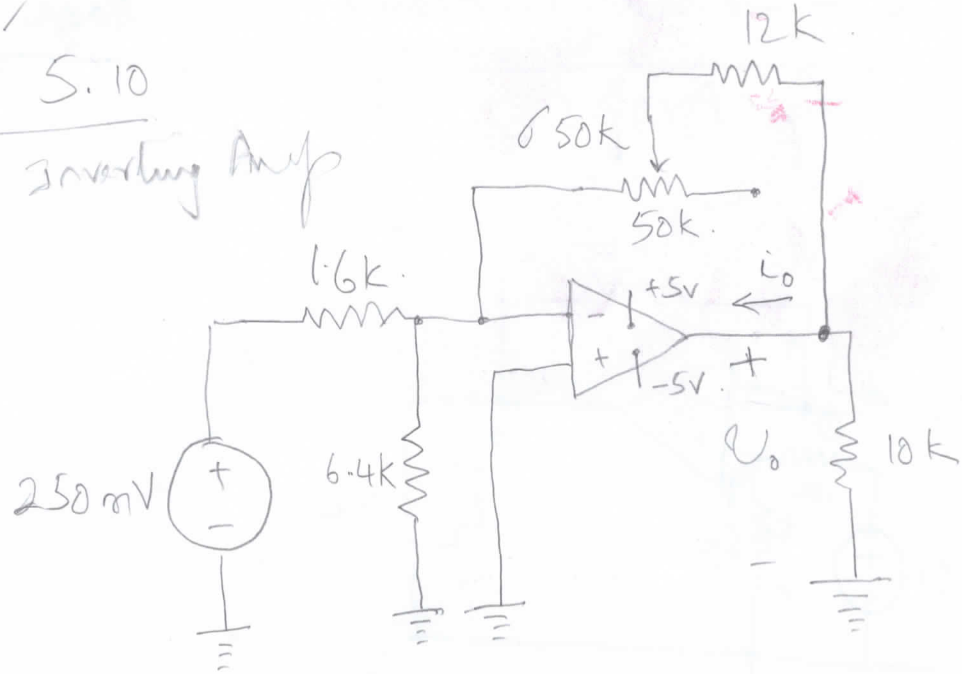
Vo = 16V

Hence, $i_L = \frac{v_o}{R} = \frac{16}{8k}$

$= 2$ mAmps

Pr 5.10

Inverting Amp



a) find σ so no saturation

b) find i_o at σ=0.272

Let us solve part b) first

b). Find v_o & i_o when $\sigma = 0.272$.

when $\sigma = 0.272$, the feedback resistance

value is $12k + (0.272 * 50k) = 25.6 k\Omega$.

Hence, $v_o = -\frac{R_f}{R_s} * v_s$.

$$= -\left(\frac{25.6}{1.6k \| 6.4k}\right) * \left(\frac{6.4k}{1.6k + 6.4k} * 250mV\right)$$

$$= \frac{-15.6k}{1.28k} * 0.2V$$

$$= -4 \text{ volts}.$$

To find i_o:

write KCL at the output node:

$$\frac{v_o}{10k} + \frac{v_o}{25.6k} + i_o = 0$$

$$i_o = -\left(\frac{-4}{10k}\right) - \left(\frac{-4}{25.6k}\right)$$

$$= 0.556 \text{ mA}$$

a) Now, let us solve for σ such that the op amp does NOT saturate.

i.e. $-5V \le v_o \le +5V$

Since v_s is fixed at $+250mV$, and the output v_o is inverted, we only have to check for saturation at the $-5V$ limit (negative).

At neg saturation;

$$v_o = -5 = -\frac{R_f}{R_s} v_{in}$$

(Define $R_\sigma = \sigma * 50k$)

$$= -\frac{12k + R_\sigma}{1.6k \| 6.4k} * \left(\frac{6.4k}{1.6k + 6.4k} * 250\,mV \right)$$

$$= -\frac{12k + R_\sigma}{1.28k} * 0.2$$

So, $-5 = -1.875 - 0.15625 \times 10^{-3} R_\sigma$

Hence, $R_\sigma = \dfrac{-3.125}{-0.15625 \times 10^{-3}}$

$= 20k\Omega$

i.e. $\sigma * 50k = 20k\Omega$

and so $\sigma = 0.4$

So the op Amp will not-re saturate for $0 \le \sigma \le 0.40$

i.e. the feedback resistance $12k \le R_f \le 32k$

Pr 5.12 Summing Amp

a) The circuit is an inverting summing amplifier.

b). $$v_0 = -\frac{220}{33}v_a - \frac{220}{22}v_b - \frac{220}{80}v_c$$

$$= -\frac{220}{33} \times 1.2 - \frac{220}{22} \times -1.5 - \frac{220}{80} \times 4$$

$$= -8 + 15 - 11$$

$$= -4 \text{ Volts.}$$

c). If v_b is unknown.

$$v_0 = -8 - 10v_b - 11$$

or $$v_0 = -19 - 10v_b.$$

At saturation, $v_0 = \pm V_{cc} = \pm 6$

when $v_0 = -6$, $v_b = \frac{-6+19}{-10} = -1.3V.$ ✓

$v_0 = +6$, $v_b = \frac{6+19}{-10} = -2.5V.$ ✓

So, the range for Vb is $\underline{-2.5V \leq Vb \leq -1.3V}$

Pr 5.15

Given $v_0 = -(8v_a + 4v_b + 10v_c + 6v_d)$.

So $\frac{R_f}{R_a} = 8$, and so on from the summing Amp equation.

Step 1 To pick a convenient R_f and get whole number R_a, R_b, R_c, R_d values, find the value of R_f that the other coeffiments are all a factor of (or the LCM).

Such a value is 120

So, pick $R_f = 120K$.

Step 2 then $R_a = \frac{R_f}{8} = \frac{120k}{8} = 15 k\Omega$.

$R_b = \frac{R_f}{4} = \frac{120k}{4} = 30 k\Omega$.

$R_c = \frac{R_f}{10} = \frac{120k}{10} = 12 k\Omega$.

$R_d = \frac{R_f}{6} = \frac{120k}{6} = 20 k\Omega$.

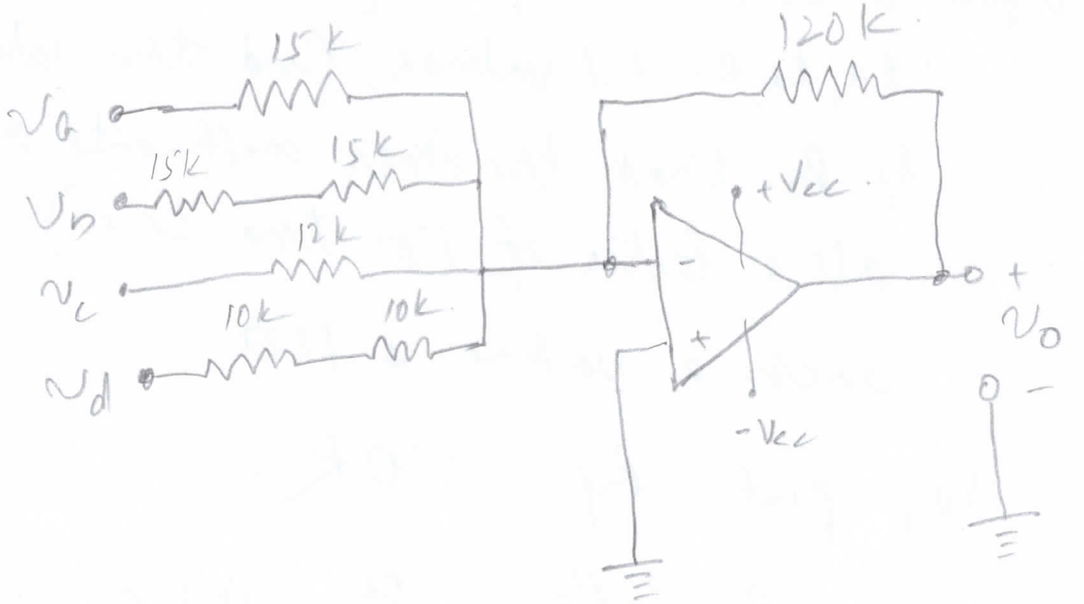
Step 3 Next, compare these values to the standard resistor values.

Only $R_b (30k)$ & $R_d (20k)$ are not standard

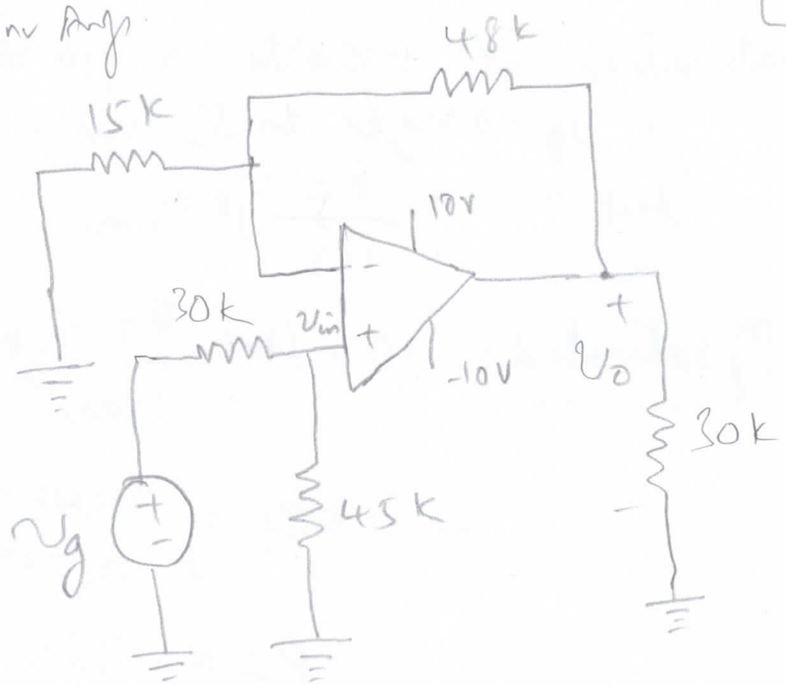
Step 4. $R_b = 30k = 15k + 15k$ (two 15k in series)

$R_d = 20k = 10k + 10k$.

Final circuit:



Pr 5.20 Non-Inv Ampl.



a). Standard Non-Inv amplifier equation is:

$$v_o = \left(1 + \frac{R_f}{R_s}\right) V_{in}$$

where Vin is signal voltage at the +ve terminal.

In the circuit, $R_f = 48k$, $R_s = 15k$; $v_g = 3V$.

$$V_{out} = \left(1 + \frac{48k}{15k}\right) * \underbrace{\frac{45k}{45k + 30k} \times 3 \text{ volts}}_{V_{in}}$$

$= (1 + 3.2) * 1.8V$

$= 7.56$ volts

b). (Gain) is $\frac{V_{out}}{v_g} = \frac{7.56}{3} = 2.52$. $v_g = \frac{v_{out}}{2.52}$

Vout is bound by $-10 \le v_o \le +10$

So v_g is $-3.97 \le v_g \le +3.97$

c). Saturation at +10volts is possible

If v_g changes to 5, $V_{in} = \frac{45}{45+30} * 5$ or 3 volts

$$V_{out} = \left(1 + \frac{R_f}{15k}\right) * V_{in}$$

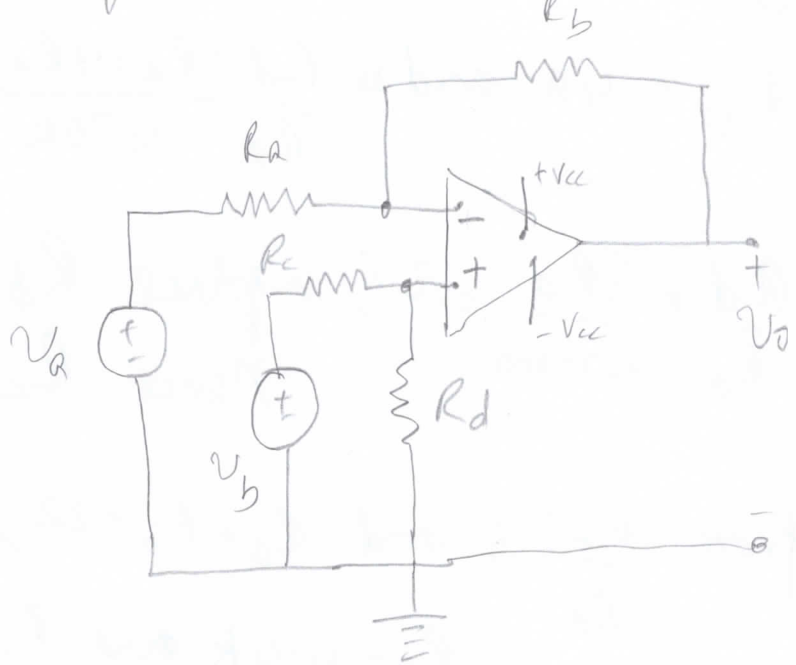
If saturated; $10 = \left(1 + \frac{R_f}{15000}\right) * 3$

So $3R_f = 150{,}000 - 45000$
$= 105{,}000$

$R_f = 35k$ ohms.

So an $R_f \geq 35k$ will cause saturation

Pr 5.28. Diff Amp



$$v_o = 3v_b - 4v_a \rightarrow (1)$$

the difference amplifier eq is:

$$v_o = \frac{R_d(R_a+R_b)}{R_a(R_c+R_d)} v_b - \frac{R_b v_b}{R_a}$$

Also, given that:

R_{in} for source v_b is 470k

i.e. $R_c + R_d = 470k$. (Since $i_p = i_n = 0$ for an ideal op Amp)

R_{in} for source v_a is 22k when v_o is 0

i.e. $R_a + R_b = 22k$.

(see figure)

Comparing (1) to the Difference Amp eq:

$\frac{R_b}{R_a} = 4$, $R_b = 4Ra$, and so $\frac{R_d}{R_a} \frac{(R_a + 4R_a)}{470k} = 3$.

$\Rightarrow \frac{R_d}{R_a} * \frac{5R_a}{470{,}000} = 3$; implies $R_d = 282\,k\Omega$

Hence $R_c = 188\,k\Omega$

Also: from $\frac{R_b}{R_a} = 4$ and $R_a + R_b = 22$, we get

$R_a = 4.4k$ and $R_b = 17.6\,k\Omega$

from Appendix A:

$R_d = 282k$, Use 270k.

$R_c = 188k$, Use 180k.

$R_b = 17.6k$, Use 12k + 5.6k

$R_a = 4.4k$, Use 2.2k + 2.2k