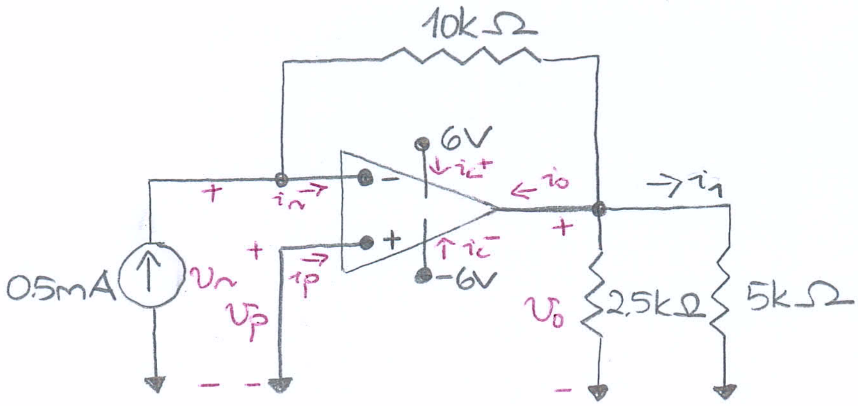
Selected Problems – I

Problem 1) Find i_1 in the circuit shown as



(Assume that the opamp is ideal.)

Solution. We have

$$v_p = 0 = v_n$$

$$i_p = i_n = 0$$

Applying KCL at non-inverting node gives

$$-0.5 \cdot 10^{-3} + \underbrace{i_n}_{0} + \frac{0 - v_o}{10k} = 0 \quad \Rightarrow \quad -0.5 \cdot 10^{-3} = \frac{v_o}{10k}$$

$$\Rightarrow \quad v_o = -5V$$

and KCL at output node yields

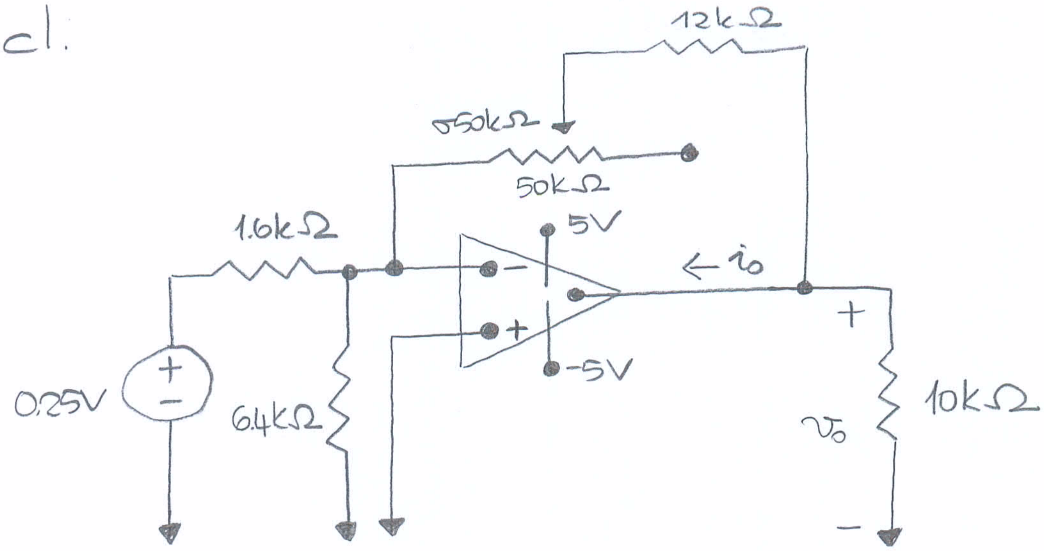
$$i_o + \frac{-5-0}{10k} + \frac{(-5)}{2.5k} + \frac{(-5)}{5k} = 0$$

$$\Rightarrow \quad i_o - 0.5 \cdot 10^{-3} - 2 \cdot 10^{-3} - 1 \cdot 10^{-3} = 0 \quad \Rightarrow \quad i_o = 3.5\ mA$$

and

$$i_1 = \frac{-5}{5k} = -1\ mA$$

Problem 2) The op amp in the following circuit is ideal.



a. Find the range of values for σ in which the op amp does not saturate.

b. Find i_o (in microamperes) when $\sigma = 0.272$

Solution. We have

a.

$$v_n = v_p = 0\,V$$
$$i_n = i_p = 0\,A$$

KCL at inverting terminal gives

$$\frac{0-0.25}{1.6k} + \cancel{\frac{0}{6.4k}}^{\,0} + \frac{0-v_o}{(\sigma 50+12)k} + \cancel{i_n}^{\,0} = 0$$

$$\Rightarrow \frac{v_o}{50\sigma+12} = -\frac{0.25}{1.6} \Rightarrow v_o = -\frac{0.25(50\sigma+12)}{1.6}$$

$$= -\frac{125\sigma+30}{16}$$

-in order to avoid saturation, we need to guarantee

$$-5 \leq -\frac{125\sigma+30}{16} \leq 5$$

$$\Rightarrow -80 \leq 125\sigma + 30 \leq 80$$

$$\Rightarrow -110 \leq 125\sigma \leq 50$$

$$\Rightarrow -0.88 \leq \sigma \leq 0.4$$

a. KCL at output node yields

$$i_o + \frac{v_o}{10k} + \frac{v_o - 0}{(50\sigma+12)k} = 0$$

- it follows from part a that when $\sigma = 0.272$

$$v_o = -\frac{125 \cdot 0.272 + 30}{16}$$

$$= 4V$$

- then

$$i_o = -\frac{4}{10k} - \frac{4}{50 \cdot 0.272 + 12}$$

$$= -0.4 - 0.1563$$

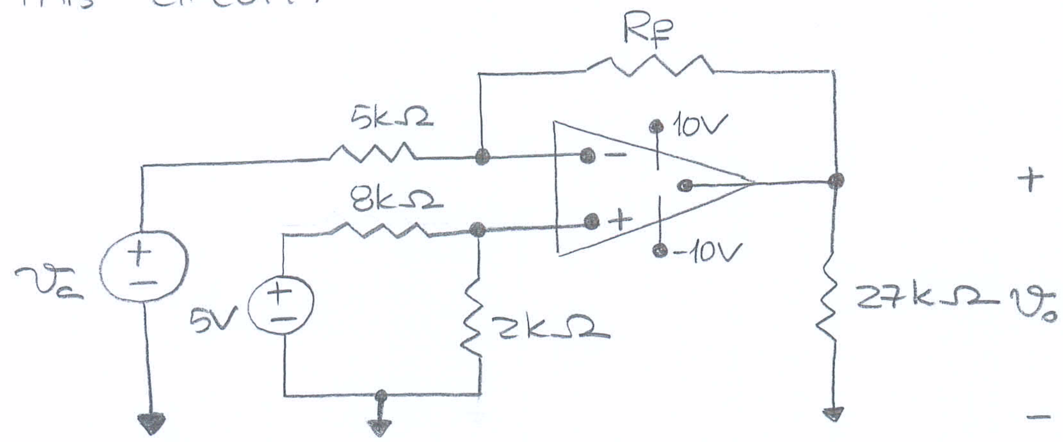
$$= -0.2438 mA$$

$$= -243.8 \mu A$$

Problem 3) The op amp in the following circuit is ideal. What value of R_F will give the equation

$$v_o = 5 - 4v_a$$

for this circuit?



Solution. We have

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

KCL at non-inverting terminal gives

$$\frac{v_p - 5}{8k} + \frac{v_p}{2k} + 0 = 0 \Rightarrow 5v_p - 5 = 0 \Rightarrow 5v_p = 5$$

(4)

$$\Rightarrow v_p = 1V = v_n$$

KCL at inverting node yields

$$\frac{1 - v_a}{5k} + \frac{1 - v_o}{R_f} + 0 = 0$$

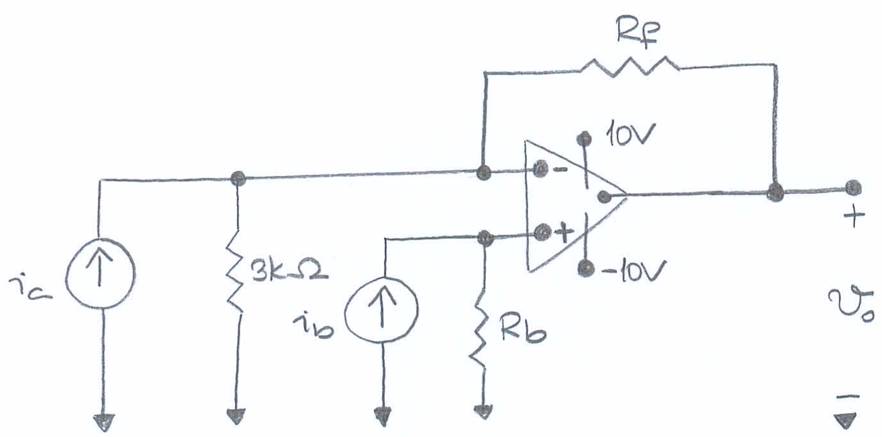
$$\Rightarrow \frac{1 - v_a}{5k} + \frac{1 - 5 + 4v_a}{R_f} = 0$$

$$\Rightarrow \frac{1 - v_a}{5k} - 4\frac{(1 - v_a)}{R_f} = 0$$

$$\Rightarrow (1 - v_a)\left(\frac{1}{5k} - \frac{4}{R_f}\right) = 0$$

$$\Rightarrow \frac{1}{5k} - \frac{4}{R_f} = 0 \Rightarrow R_f = 4 \cdot 5k = 20k\Omega$$

Problem 4) Select the values of R_b and R_f in the following circuit so that



$$v_o = 2000(i_b - i_a)$$

The op amp is ideal.

Solution. $v_p = v_n$, $i_p = i_n = 0$

KCL at non-inverting terminal :

$$-i_b + \frac{v_p}{R_b} + 0 = 0 \Rightarrow v_p = i_b R_b$$

KCL at inverting terminal :

$$-i_c + \frac{v_n}{3k} + \frac{v_n - v_o}{R_f} = 0$$

$$\Rightarrow -i_c + \frac{i_b R_b}{3k} + \frac{i_b R_b - 2000(i_b - i_c)}{R_f} = 0$$

-let R_b and R_f are in $k\Omega$'s

$$\Rightarrow -i_c + \frac{i_b R_b}{3} + \frac{i_b R_b - 2(i_b - i_c)}{R_f}$$

$$\Rightarrow -3R_f i_c + R_b R_f i_b + 3 R_b i_b - 6 i_b + 6 i_c = 0$$

$$\Rightarrow \underbrace{(-3R_f + 6)}_{=0} i_c + \underbrace{(R_b R_f + 3R_b - 6)}_{=0} i_b = 0$$

$$\Rightarrow -3R_f + 6 = 0 \Rightarrow R_f = 2\,k\Omega$$

$$\Rightarrow 2R_b + 3R_b - 6 = 0 \Rightarrow 5R_b = 6 \Rightarrow R_b = 1.2\,k\Omega$$