ROSE-HULMAN INSTITUTE OF TECHNOLOGY

ECE203 DC Circuits Spring 2016-2017

Homework Set #21
DUE Friday, May 5, 2017

1. Design an inverting summing amplifier so that

$$v_o = -(3v_a + 5v_b + 4v_c + 2v_d).$$

If the feedback resistor (R_f) is chosen to be 60 kΩ, draw a circuit diagram of the amplifier and specify the values of R_a, R_b, R_c, and R_d.

We want the following expression for the output voltage:

$$v_o = -(3v_a + 5v_b + 4v_c + 2v_d)$$

This is an inverting summing amplifier, so each input voltage is amplified by a gain that is the ratio of the feedback resistance to the resistance in the forward path for the input voltage:

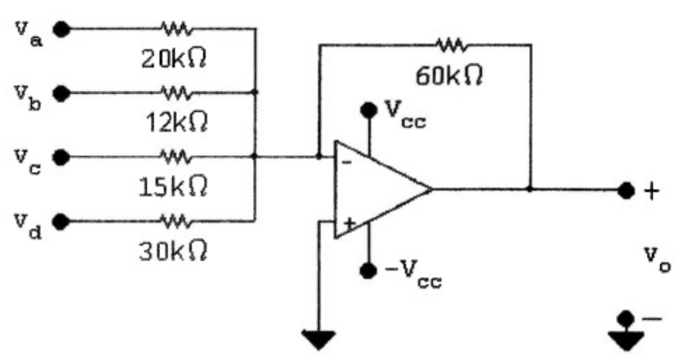
$$v_o = -\left[\frac{60\text{k}}{R_a}v_a + \frac{60\text{k}}{R_b}v_b + \frac{60\text{k}}{R_c}v_c + \frac{60\text{k}}{R_d}v_d\right]$$

Solve for each input resistance value to yield the desired gain:

$\therefore \quad R_a = 60{,}000/3 = 20\,\text{k}\Omega \qquad R_c = 60{,}000/4 = 15\,\text{k}\Omega$

$R_b = 60{,}000/5 = 12\,\text{k}\Omega \qquad R_d = 60{,}000/2 = 30\,\text{k}\Omega$

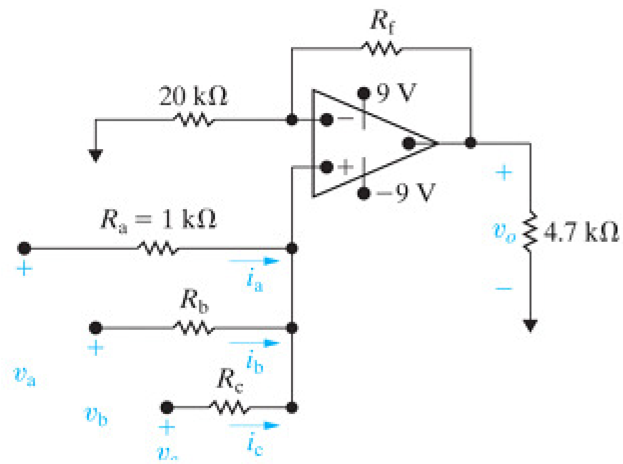
The final circuit is shown here:



2. The following circuit has to have an output voltage given by:

$V_0 = 4v_a + v_b + 2v_c$

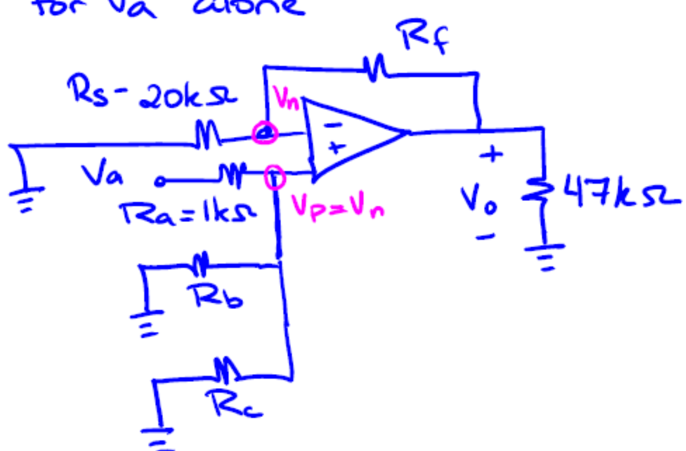
a. Specify the numerical values of R_b, R_c, and R_f.
b. Using the values found in part (a) for R_f, R_b, and R_c, calculate (in microamperes) i_a, i_b, and i_c when v_a = 0.75 V, v_b=1.0 V, and v_c = 1.5 V.



(HINT: Use superposition to get an expression for V_O in terms of the unknown resistors. This gives you the ratios and R_a is known.)

analysis: using superposition

for Va alone



KCL Vn)
$$\frac{V_n}{R_s} + \frac{V_n - V_o}{R_f} = 0$$

$$\Rightarrow V_n = \frac{V_o}{R_f}\left(\frac{1}{R_s} + \frac{1}{R_f}\right)^{-1}$$

$$= \frac{V_o}{R_f} \frac{R_s R_f}{(R_s + R_f)}$$

KCL Vp)
$$\frac{V_p - V_a}{R_a} + \frac{V_p}{R_b} + \frac{V_p}{R_c} = 0$$

$$\Rightarrow V_p = \frac{V_a}{R_a}\left(\frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c}\right)^{-1}$$

let $R_{eq} = R_a \| R_b \| R_c$

set $V_n = V_b$

$$V_o \left(\frac{R_s}{R_s + R_f} \right) = \frac{V_a}{R_a} R_{eq}$$

$$V_o = \left(1 + \frac{R_f}{R_s} \right) \frac{R_{eq}}{R_a} V_a$$

using superposition

$$V_o = \left(1 + \frac{R_f}{R_s} \right) R_{eq} \left(\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} \right)$$

Design eqns

① $$4 = \left(1 + \frac{R_f}{R_s} \right) \frac{R_{eq}}{R_a}$$

② $$1 = \left(1 + \frac{R_f}{R_s} \right) \frac{R_{eq}}{R_b}$$

③ $$2 = \left(1 + \frac{R_f}{R_s} \right) \frac{R_{eq}}{R_c}$$

①-③ $4 R_a = R_b = 2 R_c$

$R_a = 1k\Omega$

$R_b = 4k\Omega$

$R_c = 2k\Omega$

$R_{eq} = R_a \| R_b \| R_c = 571.4\,\Omega$

$R_s = 20k\Omega$