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**ECE 301**
**Fall Semester, 2006**
**HW Set #12**

Due: November 30, 2006 Name wlg
wlg Print(last, first)

circle: 2:10 section 3:40 section

Use Engineering Paper. Work only on one side of the paper. Use this sheet as your cover sheet, placed on top of your work and stapled in the top left-hand corner. Number the problems at the top of the page, in the center of the sheet. **Do neat work. Underline your answers. Show how you got your equations. Be sure to show how you got your answers.** Each problem counts 15 points.

(1) You are given the configuration shown in Figure 1(a). The input voltage is 2 volts. You want to design an op amp circuit so that the output voltage is 10 volts. There are two purposed circuit layouts that you are to use. These are described in Figures 1(b) and 1(c). Your assignment here is to complete the task.

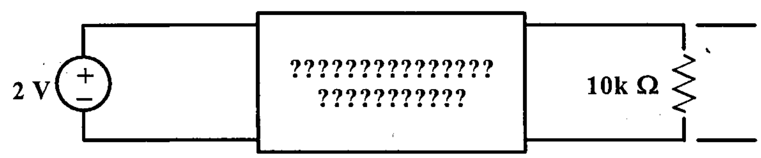


Figure 1(a): Basic layout for problem 1.

(a) Use the following configuration to achieve the requirements stated above. Give your values of $R_1$, $R_2$, $R_3$, and $R_4$. Give the development of your work that leads to your final answer.

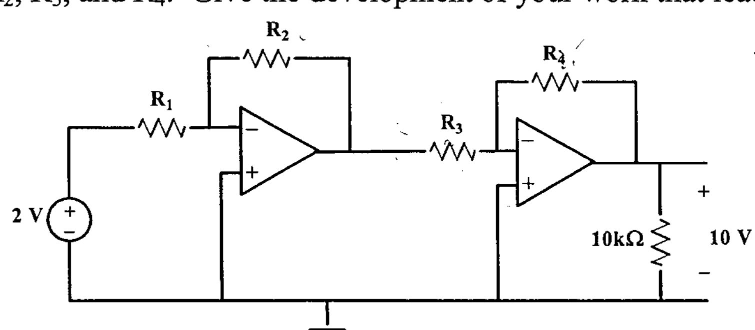


Figure 1(b): Purposed circuit for satisfying design specs.

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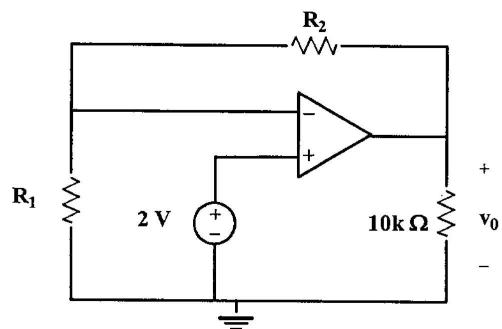
(b) Use the following configuration to achieve the requirements stated above. Give your values of $R_1$ and $R_2$. Again, show the development of your work that leads to your final answer.




$V_O = 2\left(1 + \frac{R_2}{R_1}\right)$

Figure 1(c): Purposed circuit for satisfying design specs.

(2) Find $i_o$ in the op amp circuit of Figure 2. Ans: $i_0 = 0.12$ mA.

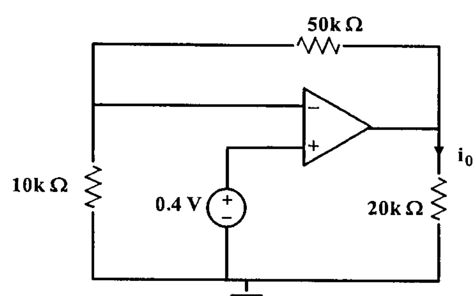



Figure 2: Circuit for problem 2.

(3) You are given the op amp circuit of Figure 3. Find $v_0/v_{in}$. Ans: $R_2/R_1$

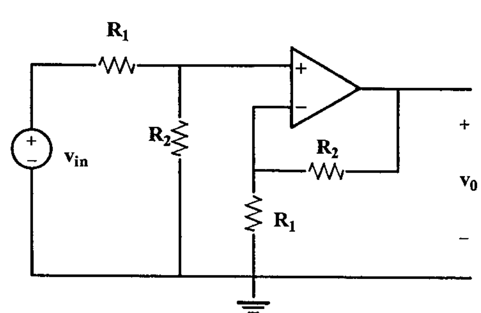



Figure 3: Circuit for problem 3.

(4) For the op amp configuration of Figure 4, Ffind $v_0/v_{in}$. Ans: $-R_{FB}/R_A$

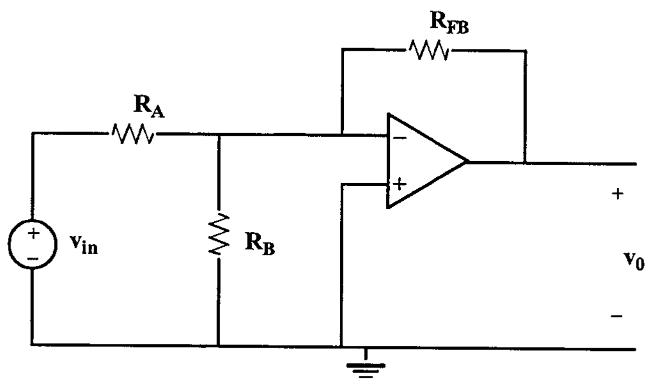



Figure 4: Circuit for problem 4.

(5) Find the output voltage $v_0$ in terms of the input voltage $v_{in}$ for the op amp circuit of Figure 5.
Ans: $v_0 = -6v_{in}$

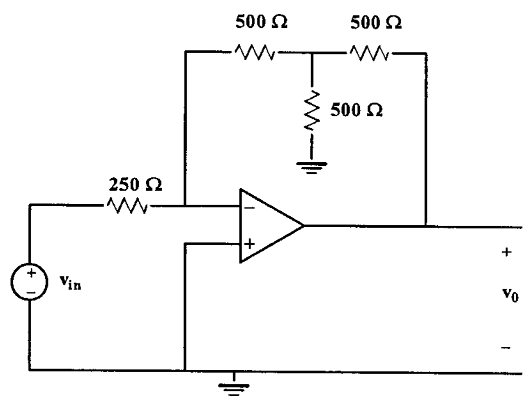



Figure 5: Circuit for problem 5.

(6) You are given the op amp circuit of Figure 6. Show that $v_0 = -(2/3)v_S$.

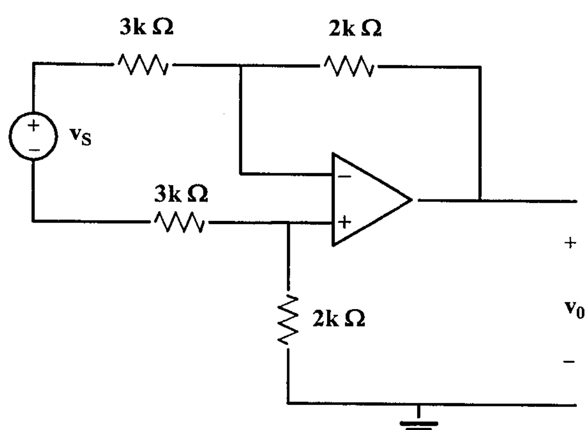



Figure 6: Circuit for problem 6.

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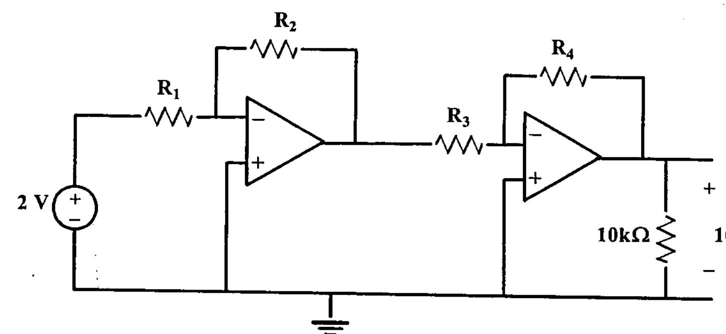
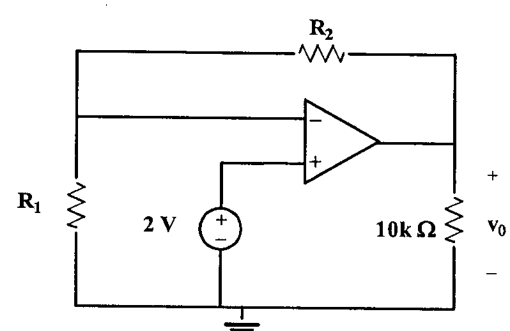
H.W. #12
ECE 301
Fall term '06

(1)
Want an op amp design that will give 10V out for 2V in. Input +, output positive.




(a)
With the above configuration, make $R_2 = 10k$, $R_1 = 2k$; you get a gain of 5. Then make $R_4 = R_3$, say 2k each to change the sign back to +.

(b)

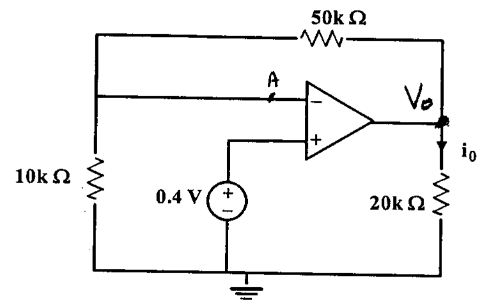



For the above configuration we have shown

$$V_0 = \left(1 + \frac{R_2}{R_1}\right)2$$ to get 10V out

make $\frac{R_2}{R_1} = 4$, say $R_2 = 8\,k\Omega$, $R_1 = 2\,k\Omega$

(2) Find $i_o$ in the op amp circuit of Figure 2. Ans: $i_0 = 0.12$ mA.




At "A" we writ the node equation

$$\frac{0.4}{10k} + \frac{.4 - V_o}{50k} = 0$$

OR

$$2 + .4 - V_o = 0$$

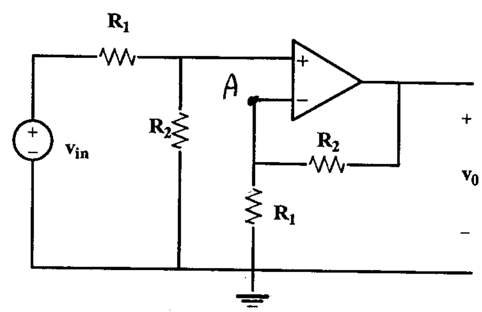
$$V_o = 2.4\ V$$

Now,

$$i_o = \frac{V_o}{20k} = \frac{2.4}{20k}$$

$$\boxed{i_o = 0.12\ mA}$$

(3) You are given the op amp circuit of Figure 3. Find $v_0/v_{in}$. Ans: $R_2/R_1$




The voltage at "A" is

$$V_A = \frac{V_{in} \times R_2}{R_1 + R_2} \qquad (1)$$

Also, the voltage at "A" is

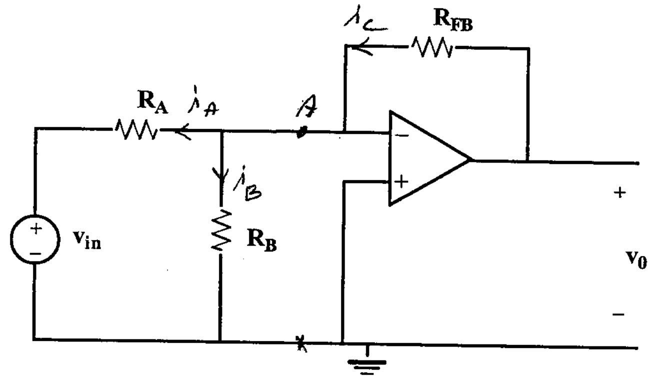
$$V_A = \frac{V_o \times R_1}{R_1 + R_2} \qquad (2)$$

Equate (1) to (2)

$$\frac{V_o \times R_1}{R_1 + R_2} = \frac{V_{in}\, R_2}{R_1 + R_2}$$

$$\frac{V_o}{V_{in}} = \frac{R_2}{R_1}$$

(4) For the op amp configuration of Figure 4, Ffnd $v_0/v_{in}$. Ans: $-R_{FB}/R_A$




$i_C = i_B + i_A$

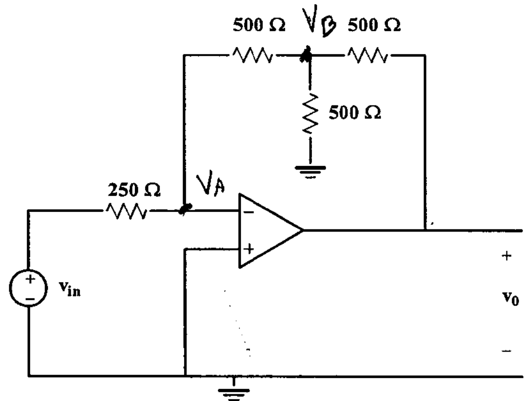
but $i_B = 0$ because the voltage at "A" = 0

so,

$$\frac{V_o}{R_{FB}} = \frac{0 - V_{IN}}{R_A}$$

$$\frac{V_o}{V_{in}} = -\frac{R_{FB}}{R_A}$$

(5) Find the output voltage $v_0$ in terms of the input voltage $v_{in}$ for the op amp circuit of Figure 5.
Ans: $v_0 = -6v_{in}$




At $V_B$

$$\frac{V_B}{500} + \frac{V_B - V_0}{500} + \frac{V_B - 0}{500} = 0 \qquad (V_A = 0)$$

so

$$V_B + V_B - V_0 + V_B = 0$$

$$V_0 = 3 V_B \qquad (1)$$

At $V_A$

$$\frac{0 - V_{IN}}{250} + \frac{0 - V_B}{500} = 0$$

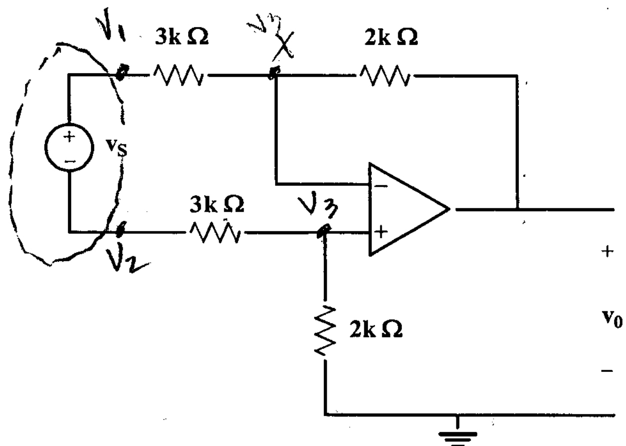
$$-2V_{IN} = V_B \qquad (2)$$

substitute (2) into (1)

$$V_0 = -6 V_{IN}$$

(6)

(6) You are given the op amp circuit of Figure 6. Show that $v_0 = -(2/3)v_S$.




At the super node:

$$\frac{V_1 - V_3}{3K} + \frac{V_2 - V_3}{3K} = 0$$

OR $\boxed{V_1 + V_2 - 2V_3 = 0}$ (1)

At $V_3$

$$\frac{V_3 - V_2}{3K} + \frac{V_3}{2K} = 0$$

OR

$$2V_3 - 2V_2 + 3V_3 = 0$$

$\boxed{-2V_2 + 5V_3 = 0}$ (2)

At $V_x$

$$\frac{V_3 - V_1}{3K} + \frac{V_3 - V_0}{2K} = 0$$

OR

$$2V_3 - 2V_1 + 3V_3 - 3V_0 = 0$$

$\boxed{-2V_1 + 5V_3 - 3V_0 = 0}$ (3)

(b) continued

Constraint Equation

$V_2 + V_s - V_1 = 0$

OR $\boxed{V_1 - V_2 = V_s}$ (4)

From (1), (2), (3), (4)

$$\begin{bmatrix} 1 & 1 & -3 & 0 \\ 0 & -2 & 5 & 0 \\ -2 & 0 & 5 & -3 \\ 1 & -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ V_s \end{bmatrix}$$

Since we only have one input entry, Let $V_s = 1$. Solve simultaneous equations

$$\boxed{V_0 = -\frac{2}{3} V_s}$$

$-\frac{2}{3}(1)$

Just for the exercise of it, and the fun of doing it, solve using the symbolic tool kit functions of MATLAB

(6) continued

Let

$$V = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_0 \end{bmatrix}$$

$$V = \begin{bmatrix} 1 & 1 & -3 & 0 \\ 0 & -2 & 5 & 0 \\ -2 & 0 & 5 & -3 \\ 1 & -1 & 0 & 0 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ V_S \end{bmatrix} = A * B$$

```
A = sym('[1 1 -3 0; 0 -2 5 0; -2 0 5 -3; 1 -1 0 0]')
B = sym('[0; 0; 0; Vs]')
V = symmul(inv(A), B)
```

The results are shown on the following pages

```
%  writing a program to illustrate the symbolic
%  solution of equtions.  W. Green Nov 26, 2006
%  call the program symbol_A.m

% Solving the equation;
%  V = [V1; V2; V3; Vo] = inv(A)*B
%  where

%  A = [1, 1, -3, 0;0, -2, 5, 0; -2, 0, 5, -3; 1, -1, 0, 0]
%  B = [0;0;0;Vs]

A = sym('[1, 1, -3, 0;0, -2, 5, 0; -2, 0, 5, -3; 1, -1, 0, 0]')
B = sym('[0;0;0;Vs]')

V = symmul(inv(A),B)

% V = [V1; V2; V3; V4] = [V(1); V(2); V(3); V(4)]

V1 = V(1)
V2 = V(2)
V3 = V(3)
Vo = V(4)
```

```
>> symbol_A

A =

[  1,  1, -3,  0]
[  0, -2,  5,  0]
[ -2,  0,  5, -3]
[  1, -1,  0,  0]


B =

[  0]
[  0]
[  0]
[ Vs]


V =

[ -1/4*Vs]
[ -5/4*Vs]
[ -1/2*Vs]
[ -2/3*Vs]


V1 =

-1/4*Vs


V2 =

-5/4*Vs


V3 =

-1/2*Vs


Vo =

-2/3*Vs

>>
```