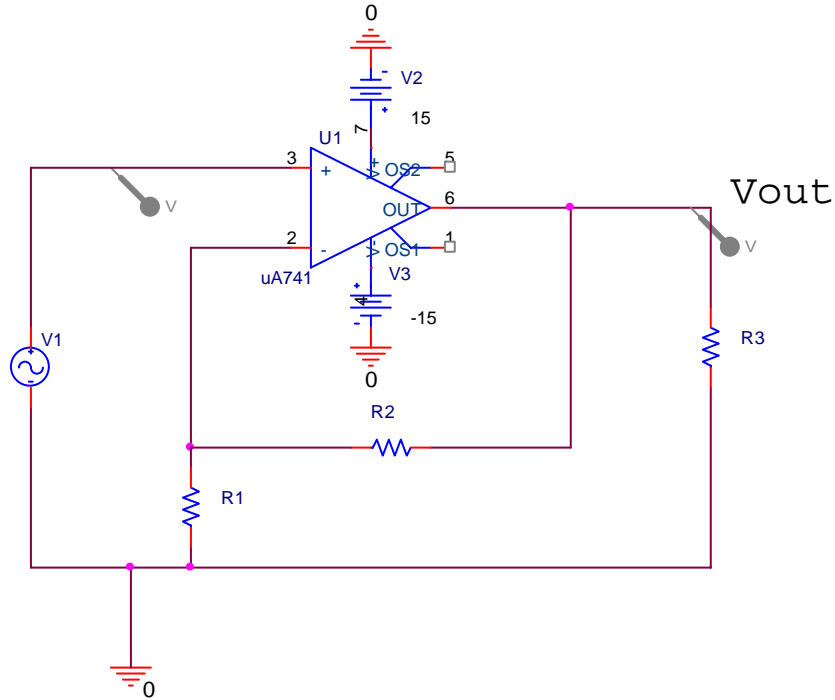Questions about Op Amp Analysis (Also see test for Spring 2005)

Spring 2004

Below is a Capture schematic of an op-amp amplifier circuit that you should recognize.

1. What kind of amplifier is it? (2 points)

2. What are the two "golden rules: of op-amp analysis? (2 points)

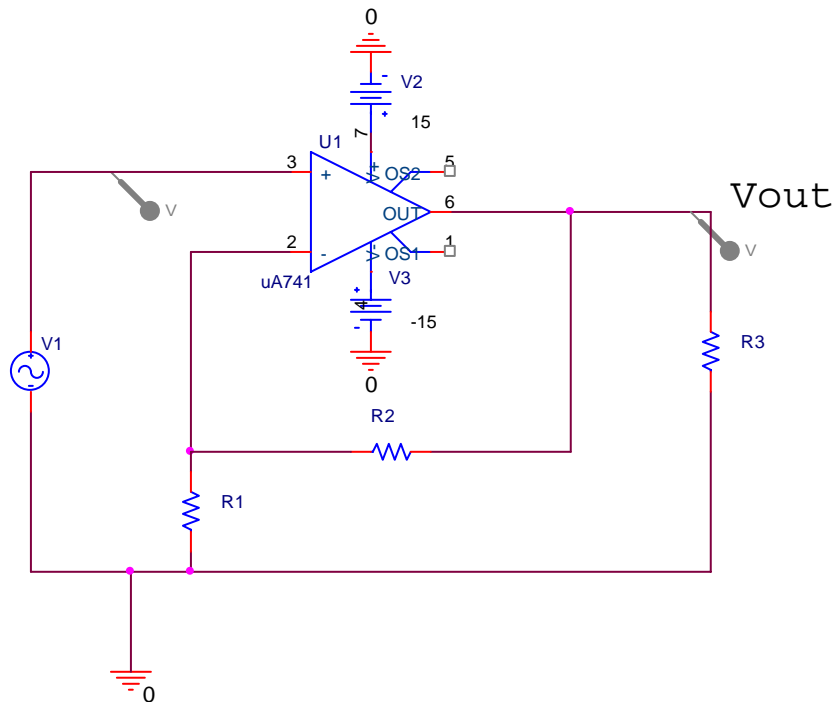3. Use these rules to derive an expression for Vout in terms of R1, R2 and V1. (8 points)

4. If V1=500mV, R1=1K and R2=4K, what is Vout? (4 points)

5. Find the current through the load resistor, R3, assuming the component values in part 4 and R3= 2K ohms. (4 points)

Question 4 – Op Amps (20 points)

Below is a Capture schematic of an op-amp amplifier circuit that you should recognize.

1. What kind of amplifier is it? (2 points)

   non-inverting amplifier

2. What are the two "golden rules: of op-amp analysis? (2 points)

   1) The current at both of the op-amp inputs is zero. $I_+ = I_- = 0$
   2) The op-amp attempts to make the voltages at the two inputs equal. $V_+ = V_-$

3. Use these rules to derive an expression for Vout in terms of R1, R2 and V1. (8 points)

   1) Remove the op-amp from the circuit
   2) Draw a circuit for each input:
       +: V1 o----------o V+
       - : Vout o------[R2]-----o-------[R1]-------o GND
                             V-
   3) Simplify and solve for Vout/Vin:
       V+=V-=V1
       V- = Vout(R1)/(R1+R2)
       V1=Vout(R1)/(R1+R2)
       Vout/V1 = (R1+R2)/R1

   Vout = [1 + (R2/R1)]V1

The following is for Test A:

4A. If V1=500mV, R1=1K and R2=4K, what is Vout? (4 points)

$Vout = [1+(4K/1K)](500mV) = 2500mV$ **Vout=2.5V**

5A. Find the current through the load resistor, R3, assuming the component values in part 4 and R3= 2K ohms. (4 points)

$I = V/R = 2.5V/2K = 1.25mA$ **I=1.25mA**

The following is for Test B:

4B. If V1=300mV, R1=2K and R2=8K, what is Vout? (4 points)

$Vout = [1+(8K/2K)](300mV) = 1500mV$ **Vout=1.5V**
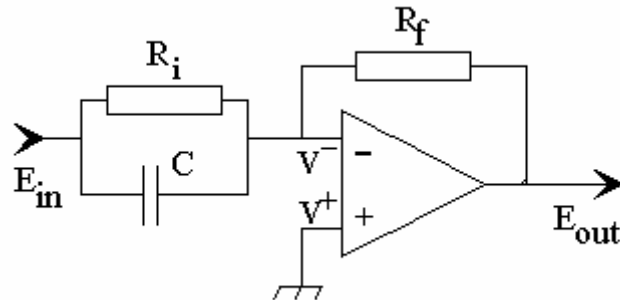
5B. Find the current through the load resistor, R3, assuming the component values in part 4 and R3= 5K ohms. (4 points)

$I = V/R = 1.5V/5K = 0.3mA$ **I=0.3mA**

4. Op-amp Analysis (20 points)

The circuit below shows an op-amp differentiator which has been modified by the addition of a resistor in parallel with the input capacitor.

a) What are the two rules for op-amp analysis (2 pnts)?

b) Using these two rules you have stated above, find the transfer function for the above circuit $H(j\omega) = Eout/Ein$. You must show your work! (10 pnts)

c) Use the transfer function from b) to find how the circuit behaves at low frequencies. Give the function in terms of ω (2 pnts), the magnitude (1 pnt) and the phase (1 pnt).

d) Use the transfer function from b) to find how the circuit behaves at high frequencies. Give the function in terms of ω (2 pnts), the magnitude (1 pnt) and the phase (1 pnt).

Extra credit (1 pnt): Is this a good differentiator? Why or why not?

4. Op-amp Analysis (20 points)

The circuit below shows an op-amp differentiator which has been modified by the addition of a resistor in parallel with the input capacitor.
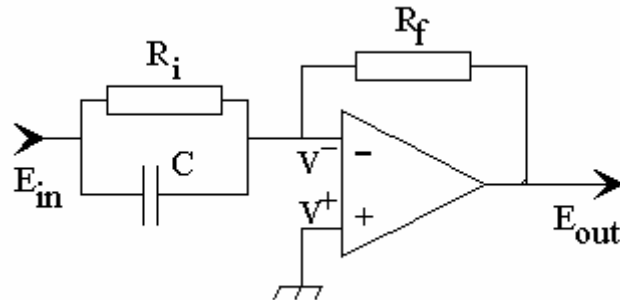
a) What are the two rules for op-amp analysis (2 pnts)?

$$1) \ V^+ = V^- \qquad 2) \ I^+ = I^- = 0$$

b) Using these two rules you have stated above, find the transfer function for the above circuit $H(j\omega) = E_{out}/E_{in}$. You must show your work! (10 pnts)

$$Zin = \frac{R_i\left(\frac{1}{j\omega C}\right)}{R_i + \left(\frac{1}{j\omega C}\right)} = \frac{R_i}{j\omega R_i C + 1} \qquad I = \frac{E_{in} - V^-}{Zin} = \frac{V^- - E_{out}}{R_f} \qquad V^- = V^+ = 0 \qquad \frac{E_{in}}{Zin} = \frac{-E_{out}}{R_f}$$

$$\frac{E_{out}}{E_{in}} = -\frac{R_f}{Zin} = -\frac{R_f(j\omega R_i C + 1)}{R_i} \qquad H(j\omega) = -\frac{j\omega R_i R_f C + R_f}{R_i}$$

c) Use the transfer function from b) to find how the circuit behaves at low frequencies. Give the function in terms of ω (2 pnts), the magnitude (1 pnt) and the phase (1 pnt).

$$H_{LO} = -\frac{R_f}{R_i} \qquad |H_{LO}| = \frac{R_f}{R_i} \qquad \angle H_{LO} = \pi \ or \ -\pi \quad (probably \ -\pi)$$

d) Use the transfer function from b) to find how the circuit behaves at high frequencies. Give the function in terms of ω (2 pnts), the magnitude (1 pnt) and the phase (1 pnt).

$$H_{HI} = -\frac{j\omega R_i R_f C}{R_i} = -j\omega R_f C \qquad |H_{HI}| = \infty \qquad \angle H_{HI} = -\frac{\pi}{2}$$

Extra credit (1 pnt): Is this a good differentiator? Why or why not?

This is not a good differentiator because according to its transfer function, it is supposed to differentiate at high frequencies. However, at high frequencies, the output approaches infinity. Therefore, it would only differentiate when its magnitude was approaching infinity, which is somewhat useless. It would also likely saturate the op-amp before it did anything useful.