ENGR-4300

Electronic Instrumentation

Quiz 2

Spring 2011

Name ________________________

Section ___

Question I (20 points) ___________

Question II (20 points) ___________

Question III (20 points) ___________

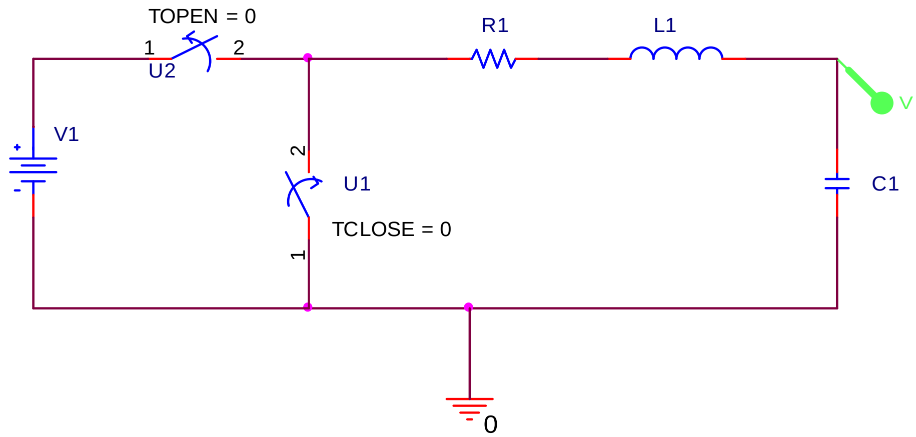
Question IV (20 points) ___________

Question V (20 points) ___________

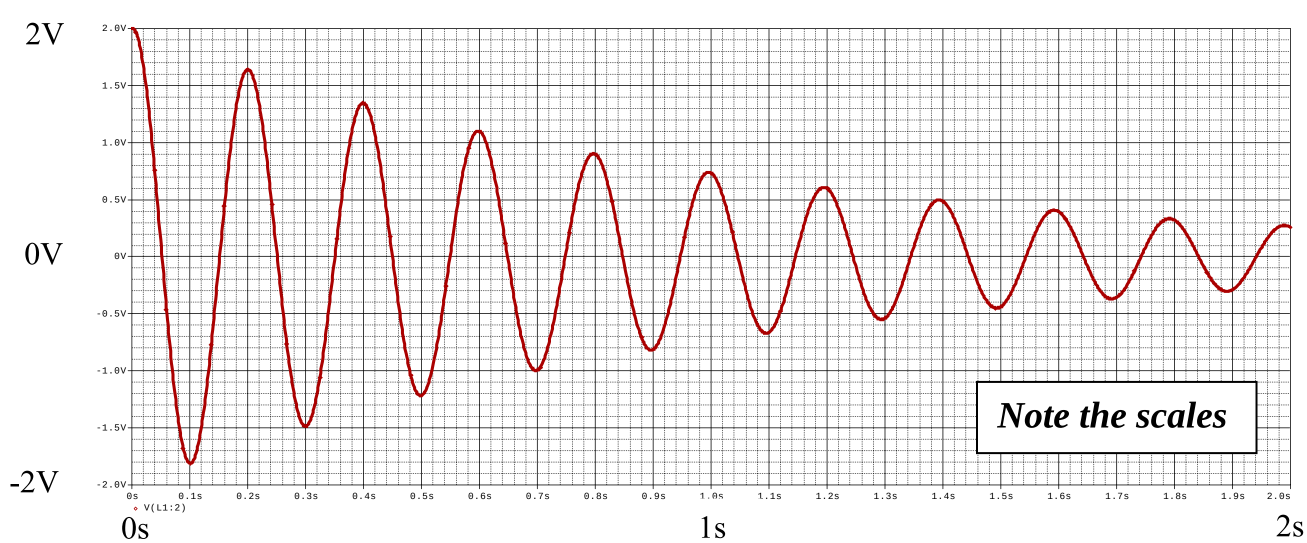
Total (100 points) ______________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification.

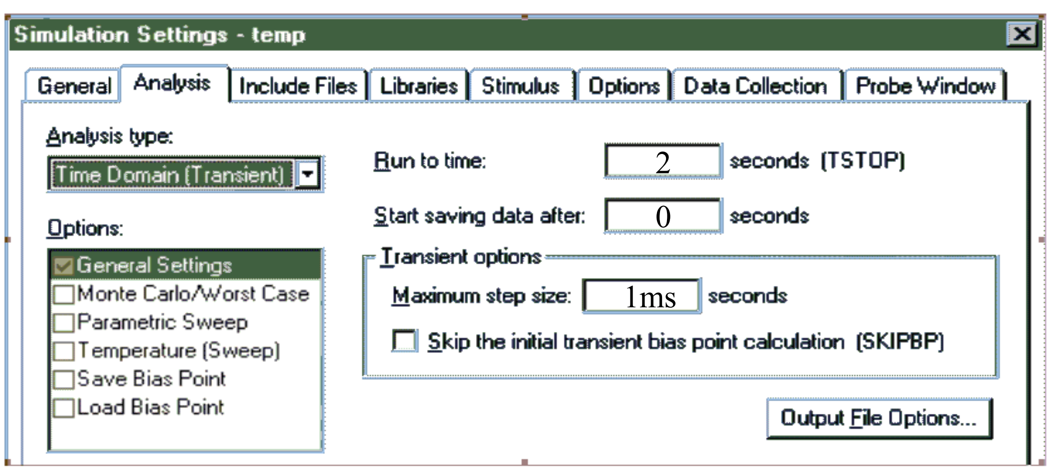
1) Damped Sinusoids (20 points)



You wire the circuit above in PSpice and run a simulation obtaining the following output:



a) How would you set up the PSpice simulation screen below, to get the output above? (3 pts)



The max step size just needs to be small

b) Using the output pictured, determine the damping constant, α, of the circuit. (3 points)

$0.3 = 2e^{-\alpha 2}$ *or* $\ln\left(\frac{0.3}{2}\right) = -2\alpha$ *or* $\alpha = .95 \approx 1$ *(The actual number is 1)*

c) What is the resonant frequency of the circuit in Hertz? Is this frequency similar to any you have observed in class? (3 points)

There are 10 cycles in 2 seconds or f=5Hz

d) Write an expression in the form $v(t) = Ae^{-\alpha t}\cos(\omega_0 t)$ for the output signal. (2 points)

$v(t) = 2e^{-t}\cos(10\pi t)$

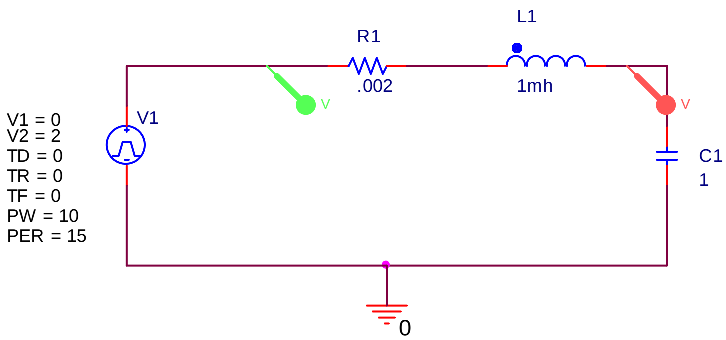
e) The data shown exhibits the characteristics of a damped harmonic oscillator, because that is what it is. From your knowledge of other systems that behave in this manner, is this an under damped system, a critically damped system or an over damped system? (3 points)

It is under damped because there is an oscillation. Neither critical nor over damped would show any oscillatory behavior.

f) The differential equation that governs the behavior of a damped sinusoid is given by $\frac{d^2V}{dt^2} + 2\alpha\frac{dV}{dt} + \omega_0^2 V = 0$. In a simple RLC circuit like the one in this question, the angular resonant frequency of the circuit, ω_0, is given by $\omega_0 = \frac{1}{\sqrt{LC}}$ and the decay constant, α, is given by $\alpha = \frac{R}{2L}$. In the circuit in this question, the value of the resistor, R1, is 2mΩ. What are the values of the capacitor, C1, and the inductor, L1? (4 points)

Since α=1, L=1mH. The frequency gives us C. $C = \frac{1}{(10\pi)^2 L} = 1F$

This seems like a really big capacitance, and it is. However, ultra caps (used for energy storage in hybrid cars) can be much larger. We have several samples here that are the size of matchbooks and are 8F. Note that to simulate this circuit, we cannot use the standard PSpice switch model because it assumes an on resistance that is too large. Thus, in this case, we used a pulsed source as shown below. We also started the simulation at 10 seconds.

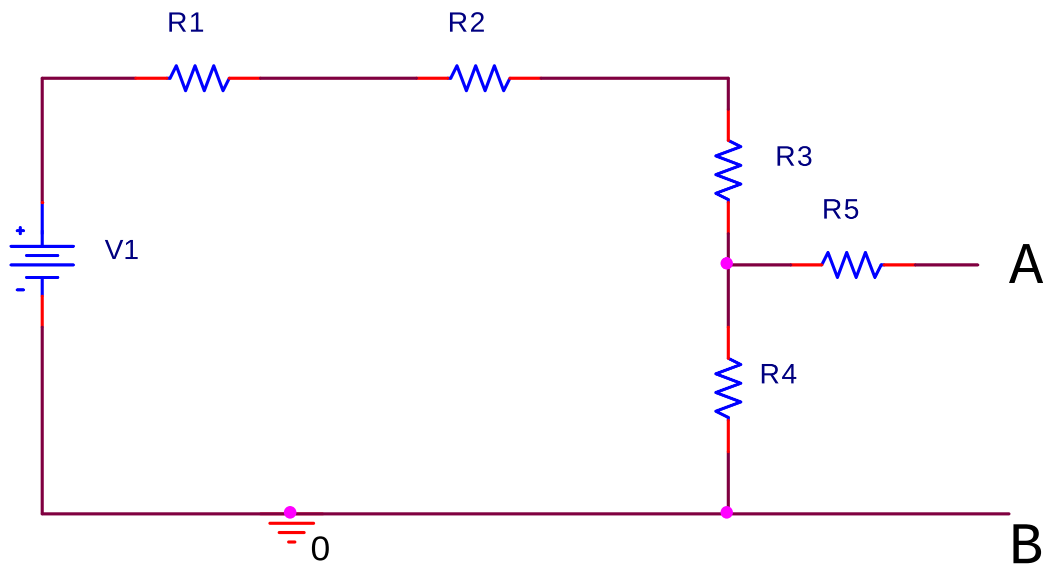


g) You want the damping constant of the circuit to be half of what it is now. What value of L1 would make this occur? (2 points)

It should double because L is in the denominator.

2) Thevenin Equivalent Sources (20 points)

You build the circuit pictured below



Given: R1=100Ω, R2=3kΩ, R3 = 3kΩ, R4=3kΩ and R5=3kΩ. V1=12V

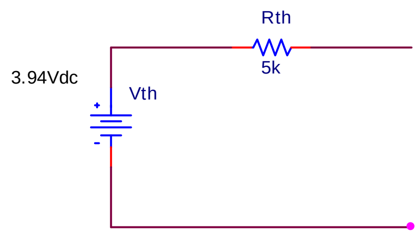
a) Find the Thevenin Equivalent voltage, Vth, of this circuit between point A and point B. (6pts)

Since all resistors are the same size, the voltage across R4 is one third of the source or 4V. There is no current through R5 for an open circuit so Vth = 4V. There is a small error in this because we have ignored the 100Ω resistor, so the voltage will be a little less than 4V.

b) Find the Thevenin Equivalent Resistance, Rth, of this circuit between point A and point B. (6pts)

Rth will be R5 plus the parallel combo of (R1+R2+R3) and R4 or $Rth = \frac{3k(6.1k)}{9.1k} + 3k = 5k$

c) Redraw the Thevenin equivalent model of the circuit (2pts).

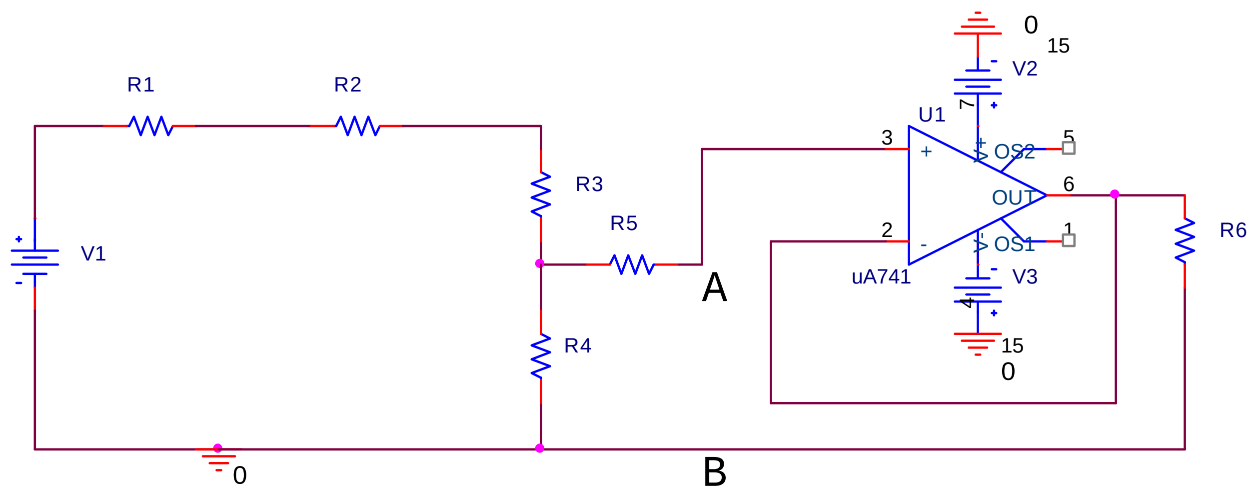


Approximately

d) If you place a 3kΩ load on the circuit, what will the output voltage be between A and B? (3pts)

Approximately 4(3/8)=1.5V

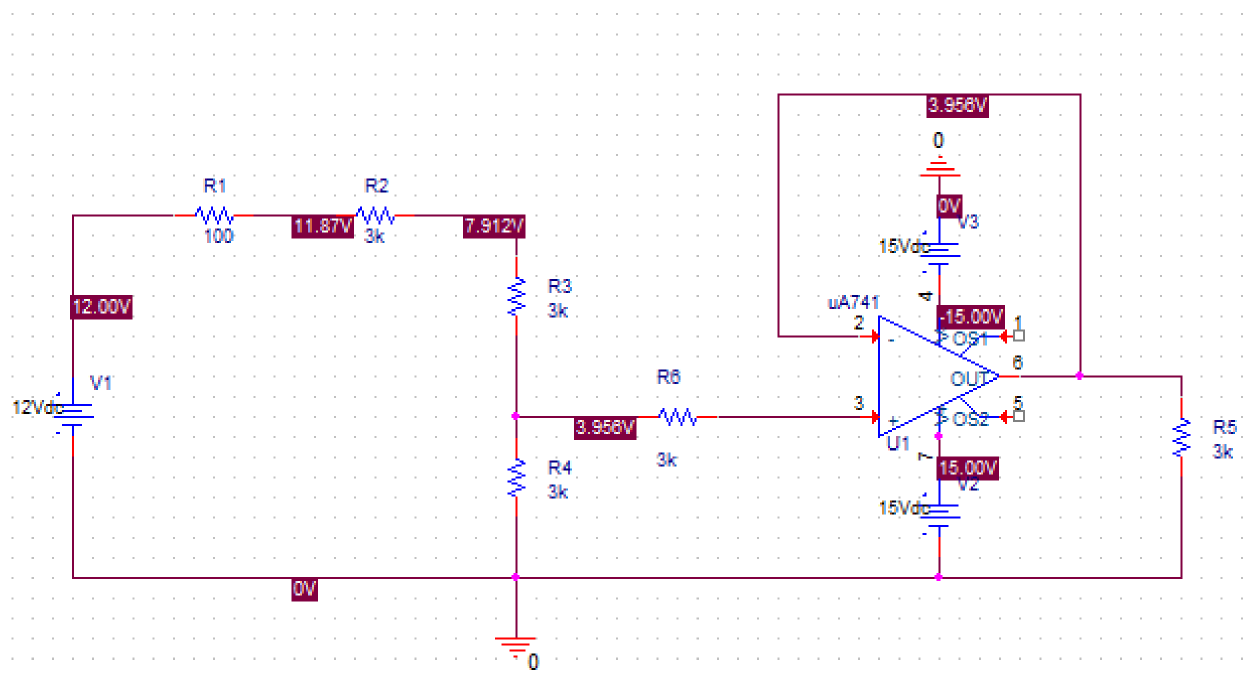
You place a voltage follower into this circuit between A and B, as pictured below.



Given: R1=100Ω, R2=3kΩ, R3 = 3kΩ, R4=3kΩ and R5=3kΩ. V1=12V, R6 is the load of 3kΩ

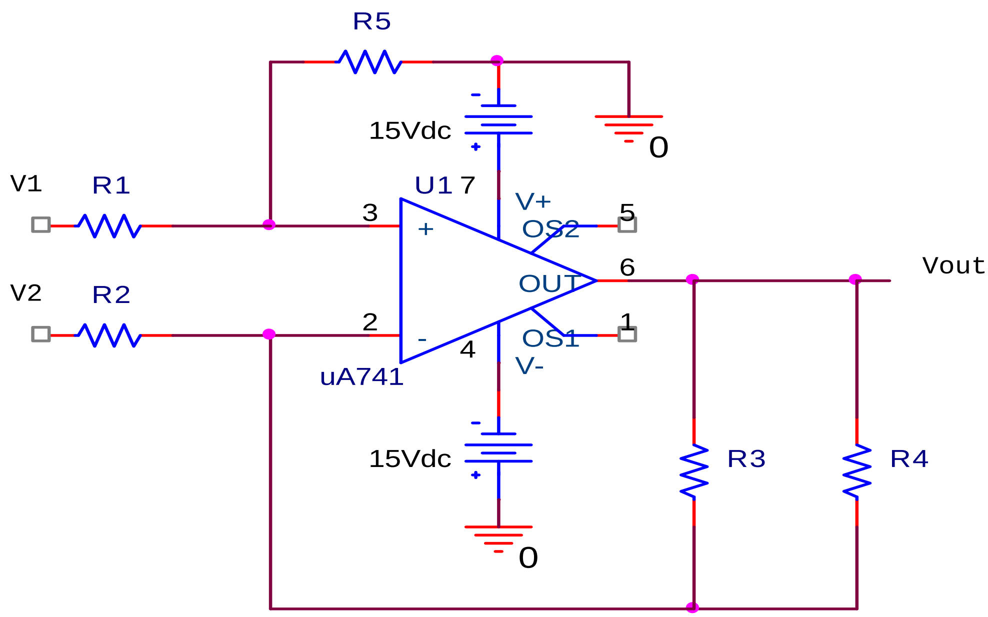
e) What is the voltage output between A and B for this circuit now? (3 points)

It will be Vth since there is now no load on the divider. See next page for PSpice analysis.


3.956V
0
0V
V3
15Vdc
R1
100
R2
3k
11.87V
7.912V
R3
3k
12.00V
uA741
2
-15.00V
1
OS1
6
OUT
V1
12Vdc
R6
3k
3.956V
3
U1
OS2
5
R4
3k
15.00V
V2
15Vdc
R5
3k
0V
0

3) Op-Amp Analysis (20 points)

Part A Given the op-amp circuit below:



R1 = R2 = 1kΩ, R3 = R4 = 8kΩ, R5 = 4kΩ

a. What op-amp circuit given on your crib sheet does this circuit most closely represent? (2pts)

Differential amplifier

b. What are the golden rules of op-amp analysis? (2pts)

I. The output attempts to do whatever is necessary to make the voltage difference between the inputs zero.

II. The inputs draw no current.

c. Find an expression for Vout in terms of V1, V2 and resistor values R1, R2, R3, R4, and R5 (do not substitute actual resistor values) (8 points)

From the voltage divider relations

$$V_+ = V_1 \frac{R5}{R5+R1} \;\; and \;\; V_- = V_2 + (V_{out} - V_2)\frac{R2}{R2 + R3||R4} \;\; \& \;\; R3||R4 = \frac{R3R4}{R3+R4}$$

We then set these to be equal to one another and simplify

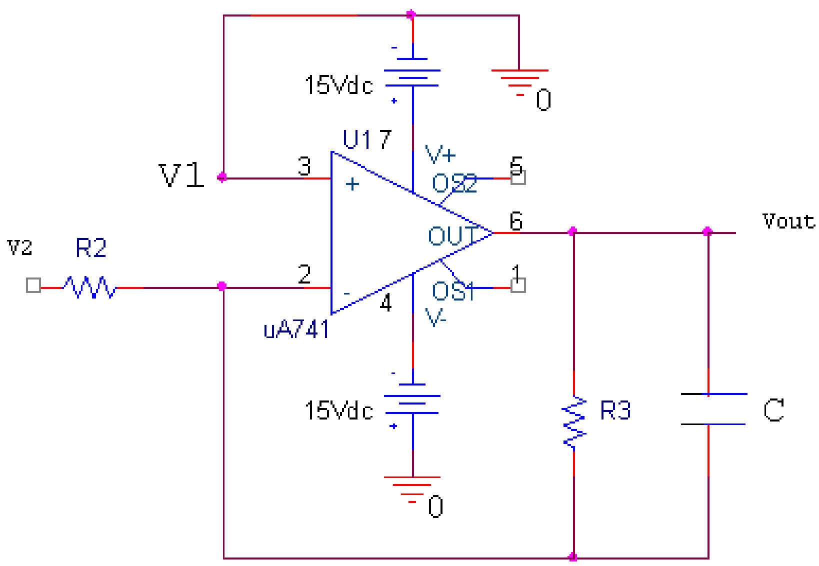
$$V_{out} = \frac{R2 + R3||R4}{R2}\left(V1\frac{R5}{R5+R1} - V2\frac{R3||R4}{R2+R3||R4}\right)$$

d. Substitute resistor values in this equation and write the equation for Vout in terms of V1 and V2 input signals. (2 points)

Note that R3 and R4 combine to form the same value as R5

$$V_{out} = (V_2 - V_1)\frac{4k}{1k} = 4(V_2 - V_1)$$

Part B What if R4 is replaced by a 10uF capacitor and V1 is grounded, as shown below?



a. What function is this circuit designed to perform? (2pts)

Integrator (this is the Miller integrator configuration)

b. Write the transfer function Vout/V2 for this circuit (2pts)

The transfer function has to include the resistor in the feedback impedance Z_f

$$\frac{Vout}{V2} = -\frac{Z_f}{R2} \text{ and } Z_f = \frac{R3\left(\frac{1}{j\omega C}\right)}{R3 + \frac{1}{j\omega C}}$$

c. Over about what frequency range is the desired function of the circuit reliably performed? [You can assume that the operation is being performed even when the output amplitude is very small.] (2pts)

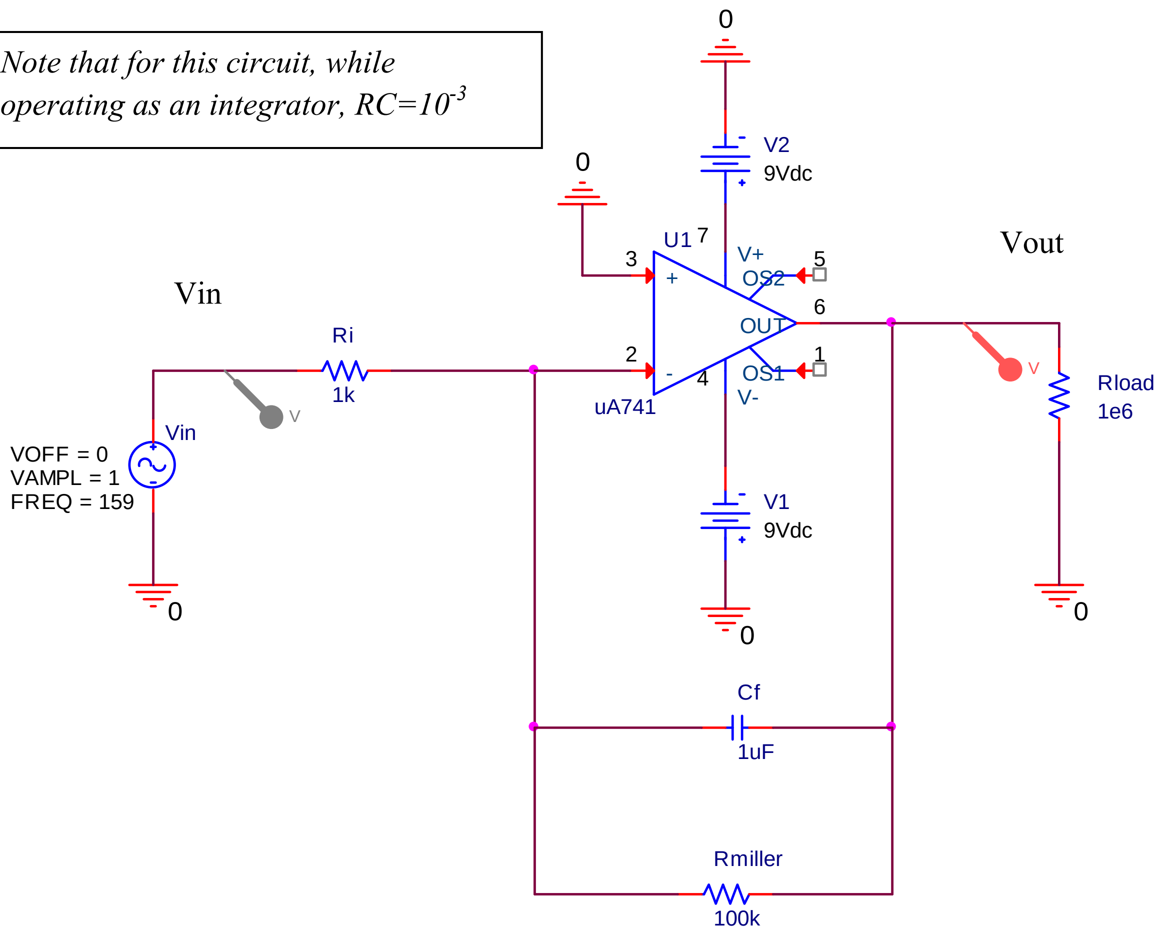
This is when the capacitor dominates the feedback, or for large frequencies since the two components are in parallel so the smaller one dominates.

$$\frac{1}{j\omega C} << R3 \text{ or } \omega >> \frac{1}{R3C}$$

4) Op-Amp Circuit (20 points)

Shown below is a circuit that we studied extensively in class.

Note that for this circuit, while operating as an integrator, $RC=10^{-3}$



a. Evaluate the following mathematical expressions? (6pts)

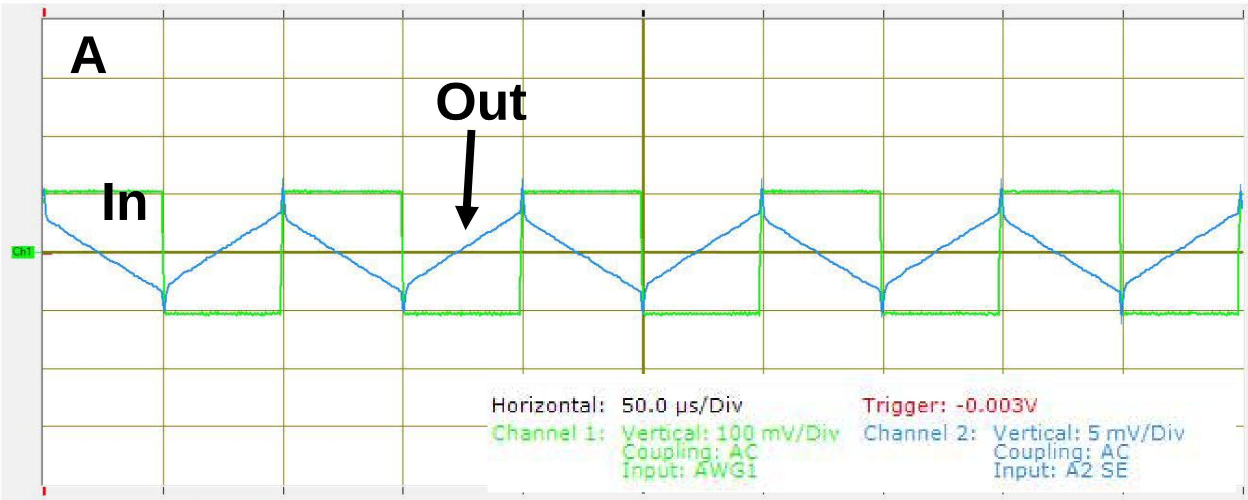
$$\frac{d}{dt}(a\sin\omega t) = \omega a\cos\omega t \qquad \int(a\sin\omega t)dt = -\frac{a\cos\omega t}{\omega}$$

$$\frac{d}{dt}(at) = a \qquad \int(at)dt = \frac{at^2}{2}$$

$$\frac{d}{dt}(a) = 0 \qquad \int(a)dt = at$$

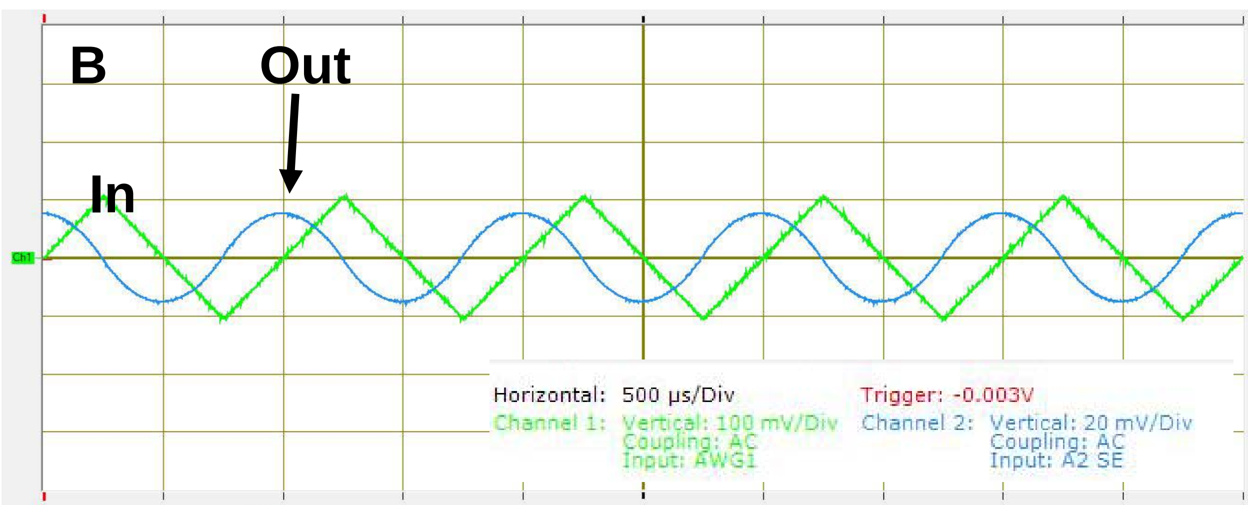
The constants should also be included in the integrals, but are not necessary here.

b. On the next 3 pages are shown input and output voltages obtained with this circuit using the Mobile Studio IOBoard. For each plot, label the input and output voltages and the signal frequency. Explain your answer in each case. (12pts)



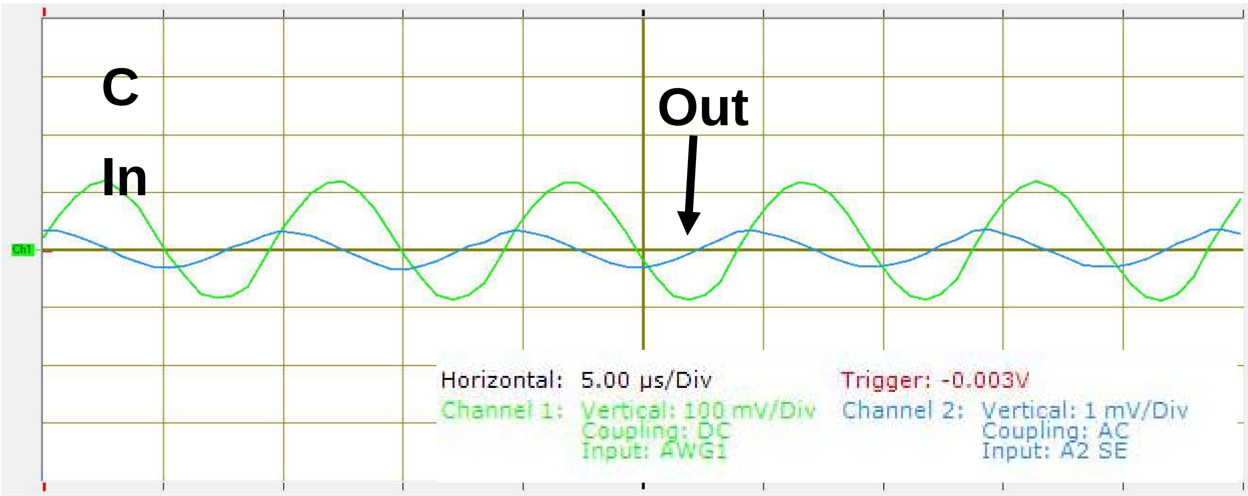
Frequency: one cycle is two divisions or T=100µs. The frequency is $1/T=10^4$Hz=10kHz

The integral of a square wave is a triangle wave (const integrates to linear increasing or decreasing with time). Also, the integrator is a low pass filter so the output will have less noise than the input.



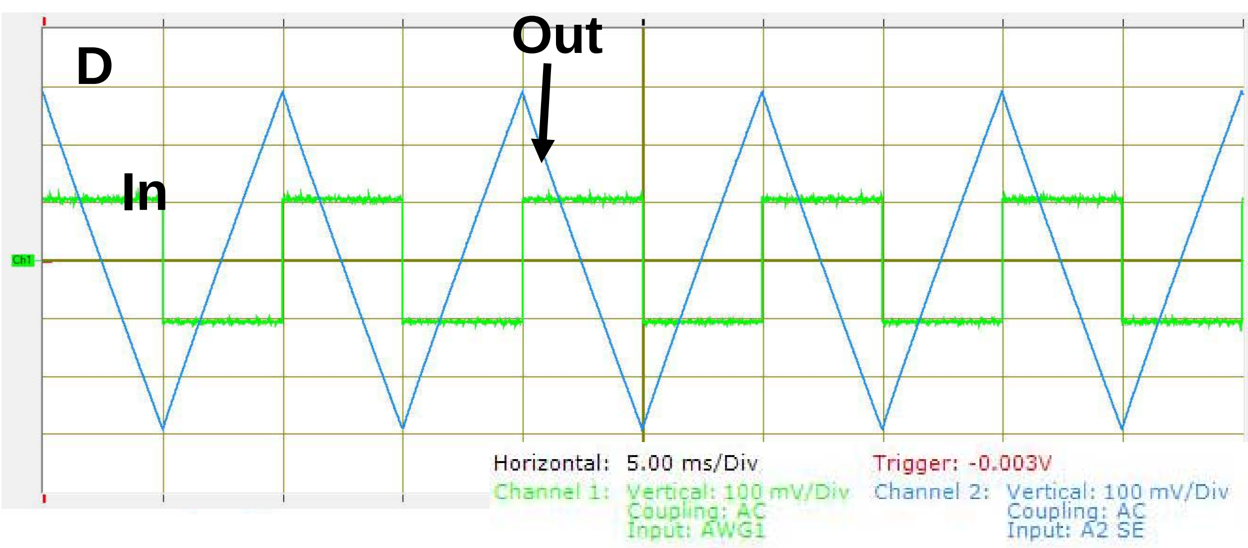
Frequency: one cycle is two divisions or T=1000µs. The frequency is $1/T=10^3$Hz=1kHz

The integral of a triangle wave is a series of parabolic pieces (linear function integrates to parabola). Also, the integrator is a low pass filter so the output will have less noise than the input.



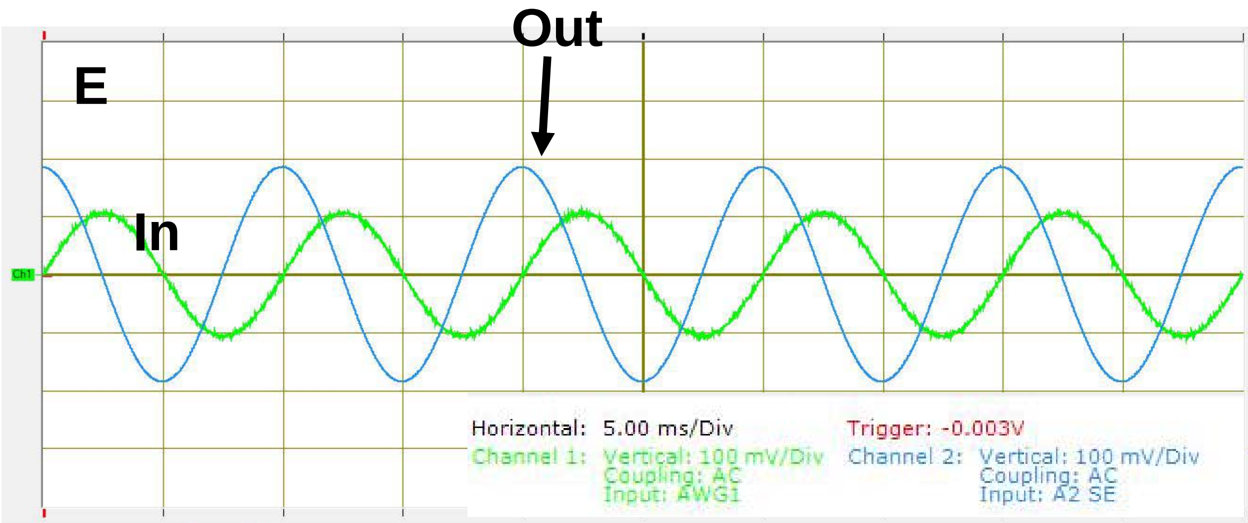
Frequency: one cycle is two divisions or T=10μs. The frequency is $1/T=10^5 Hz=100kH$

The integral of a sine wave is negative cosine but this circuit also takes the negative of the integral and divides it by $RC\omega=10^{-3}2\pi 10^5=200\pi$ *so the output should be much smaller than the input. Also, the integrator is a low pass filter so the output will have less noise than the input. (Note that channel 1 was always the input for these plots and channel 2 the output.)*



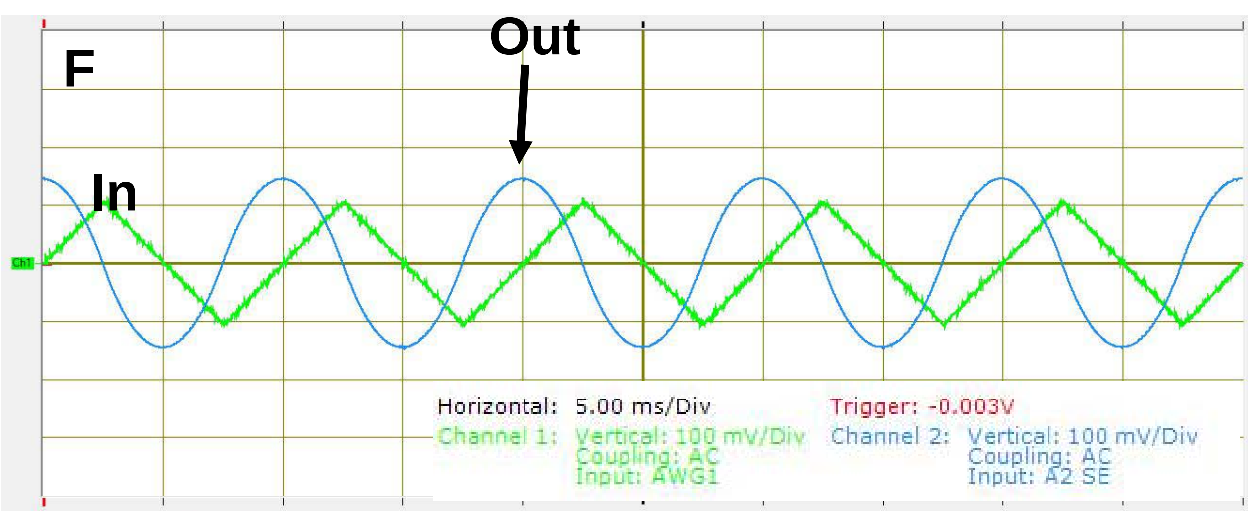
Frequency: one cycle is two divisions or T=10ms. The frequency is 1/T=100Hz

The integral of a square wave is a triangle wave (const integrates to linear increasing or decreasing with time). Also, the integrator is a low pass filter so the output will have less noise than the input.



Frequency: one cycle is two divisions or T=10ms. The frequency is 1/T=100Hz

The integral of a sine wave is negative cosine but this circuit also takes the negative of the integral and divides it by $RC\omega=10^{-3}2\pi100=.2\pi=.63$ so the output should be larger than the input. Also, the integrator is a low pass filter so the output will have less noise than the input.



Frequency: one cycle is two divisions or T=10ms. The frequency is 1/T=100Hz

The integral of a triangle wave is a series of parabolic pieces (linear function integrates to parabola). Also, the integrator is a low pass filter so the output will have less noise than the input.

c. For most of these plots, there are at least some non-ideal characteristics shown in either the input or output voltages. Identify any such non-ideal characteristics and explain your answers. (4pts)

One common issue is that there is noise on all of the input signals. This is not ideal.

For plot A there is a small blip at the point where the slope of the triangular wave changes. This is probably due to the response of the Mobile Studio.

It appears that there may be a small phase shift in the sine input cases C and E.

Points are given in this problem for any reasonable response.

5) Practical Questions (20 points)

The following contains several multiple choice questions that involve activities found in recent experiments and projects. More than one answer <u>may</u> be correct in each case. Circle all correct answers and explain your choice.

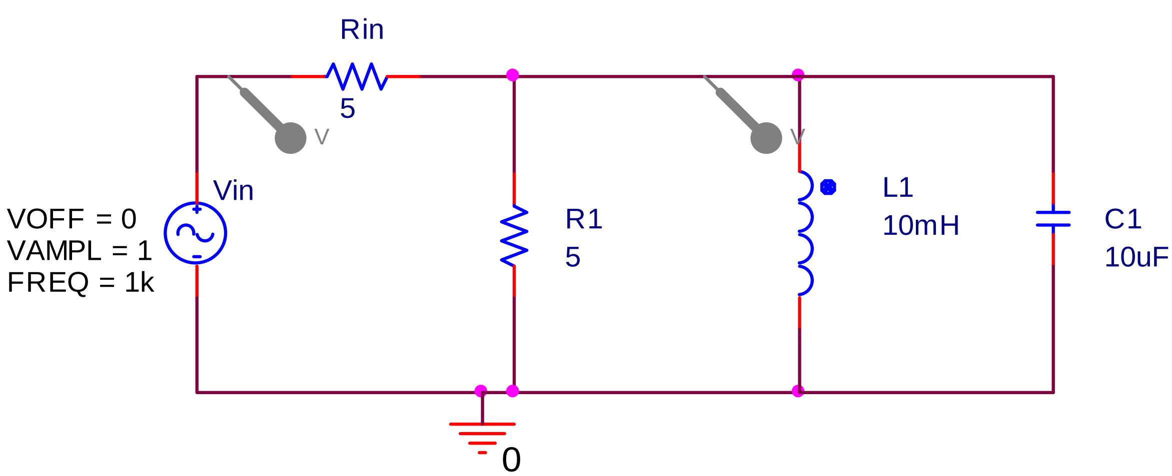
a. When building circuits on protoboards for the purpose of measuring their performance, (4pts)

- Have someone double check your circuit before applying power
- Be sure all wires are firmly connected
- Confirm that each sub-circuit works correctly before testing them together
- Insert the components neatly to better identify what you are building

b. When determining the response of a circuit with the Mobile Studio, it is essential to: (4pts)

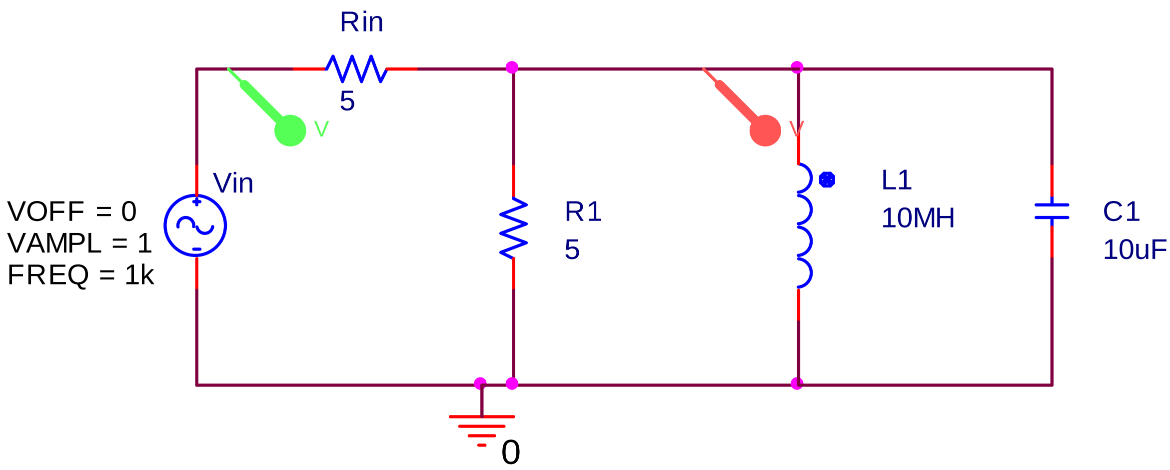
- Measure the output voltage but not the input voltage
- Measure both the output voltage and the input voltage *always measure both*
- First make your measurement using DC coupling before using AC coupling *AC coupling only removes the average so an off scale signal will look like a flat line*
- Calibrate your Mobile Studio Desktop software to achieve the highest quality results

c. When using PSpice to model the frequency response of the following circuit, (4pts)



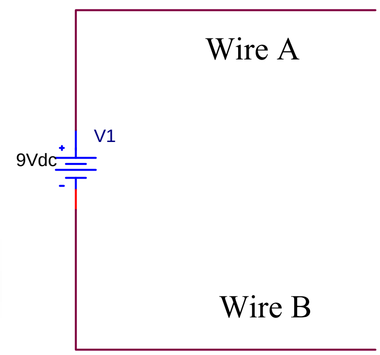
- The AC Sweep simulation will run with no changes to the default values found in the voltage source spreadsheet because the program uses the value you have specified for the source voltage
- The AC Sweep simulation will only run if you open the voltage source spreadsheet and input a value for the AC amplitude of the voltage source *the default is no entry in this cell*
- The lower case *m* stands for *milli-* and the lower case *u* stands for *micro-*

A small change is made in the circuit, as shown below.



- This circuit will produce exactly the same results as the first circuit *PSpice is not case sensitive*

d. Power Supplies (4pts)

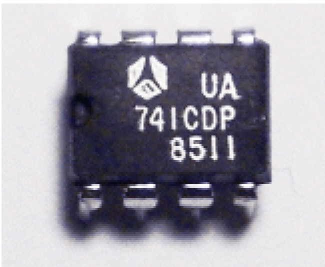


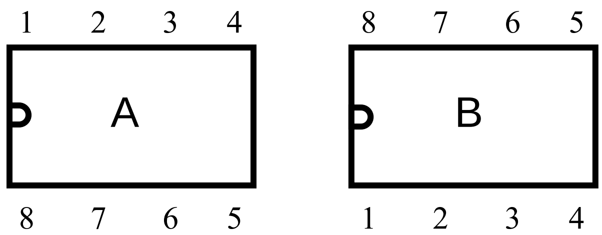
For a 9V battery connector (shown above) and the PSpice circuit diagram (above right)

- Wire A represents the red wire and Wire B represents the black wire
- Wire B represents the red wire and Wire A represents the black wire
- Wire A is connected to the circuit ground to provide +9V at some other point in a circuit
- Wire B is connected to the circuit ground to provide +9V at some other point in a circuit
- Wire A is connected to the circuit ground to provide -9V at some other point in a circuit
- Wire B is connected to the circuit ground to provide -9V at some other point in a circuit
- It is a bad idea to leave this connector attached to a battery when stored in your parts box *the wires can connect and drain the battery*
- At least one of our battery connectors has broken *any answer for this one*

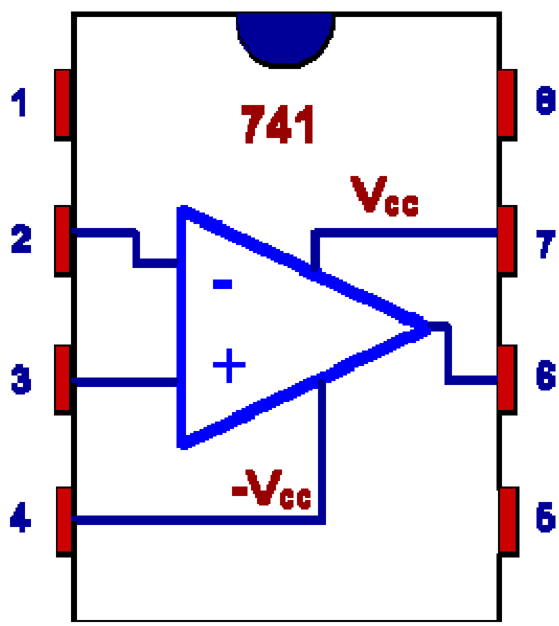
e. 741 Op-Amp (4pts)

Shown below is a photo of a 741 op-amp. The small dimple is at the left.





- The pins on the op-amp are numbered as shown in the figure labeled A
- The pins on the op-amp are numbered as shown in the figure labeled B
- The 741 requires a positive DC voltage (e.g. +9V) on pin 4 and a negative DC voltage (e.g. -9V) on pin 7 to operate
- The 741 requires a negative DC voltage (e.g. -9V) on pin 4 and a positive DC voltage (e.g. +9V) on pin 7 to operate
- The output signal is found on pin 6
- The output signal is found on pin 2
- The output signal is found on pin 3
- The input signal is connected to either pin 2 or pin 3



Extra Credit:

Describe up to five additional practical ideas you have learned in class that have helped you with the material and you think other students would benefit from knowing. Explain why they are valuable. There is no set number of points for this. The grade on this question is determined by the value of the ideas described, with roughly one point for each good idea. Do not spend a lot of time on this, however.