ENGR-2300

Electronic Instrumentation

Quiz 2

Fall 2012

Name ***Solution***______________________

Section ___

Question I (25 points) ___________

Question II (25 points) ___________

Question III (25 points) ___________

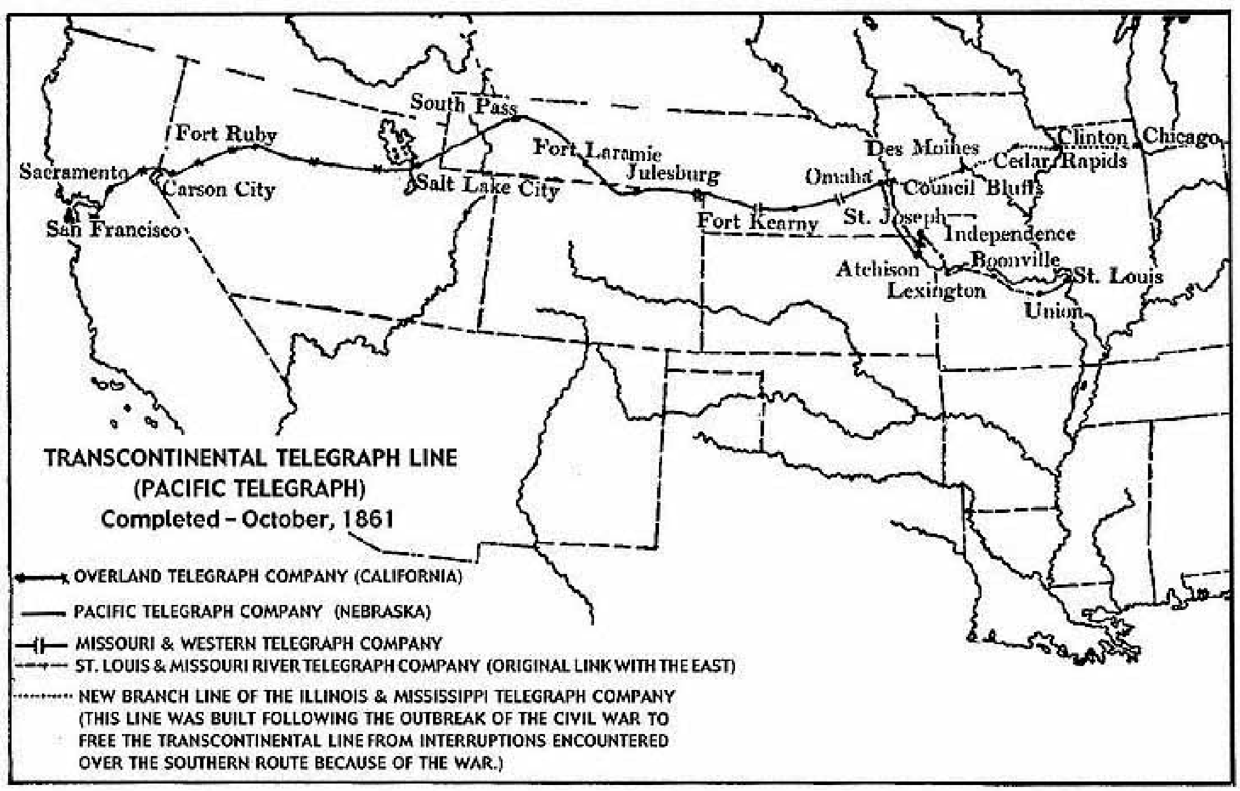
Question IV (25 points) ___________

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. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

24 October

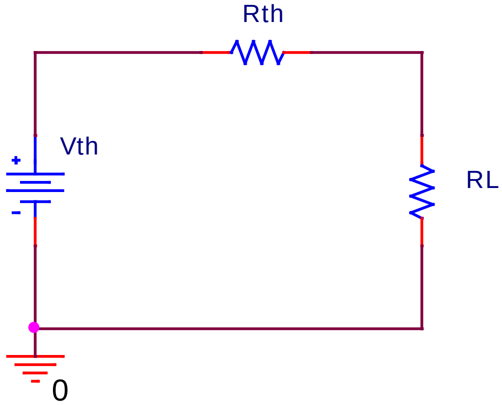
On this day in 1861, workers of the Western Union Telegraph Company linked the eastern and western telegraph networks of the nation at Salt Lake City, Utah, completing a transcontinental line that for the first time allows instantaneous communication between Washington, D.C., and San Francisco. Stephen J. Field, chief justice of California, sent the first transcontinental telegram to President Abraham Lincoln, predicting that the new communication link would help ensure the loyalty of the western states to the Union during the Civil War. (from History.com)



(from The Omaha Project)

1931.466 Henry F. Farny, ***The Song of the Talking Wire,*** 1904, oil on canvas, (56 x 101.6cm., 22 1/8 x 40 in.), Bequest of Charles Phelps and Anna Sinton Taft, Taft Museum of Art, Cincinnati, Ohio

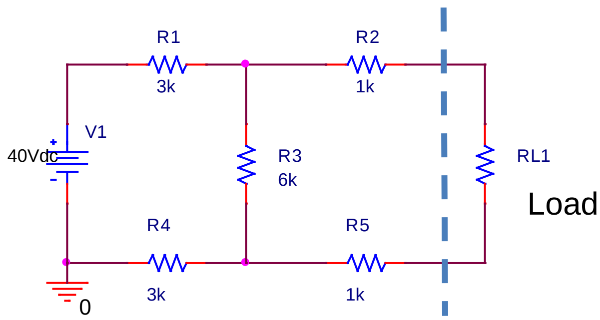
I. Thevenin Equivalent Voltage Source



The Thevenin equivalent circuit consists of a voltage source in series with a resistor, which provides a very simple replacement for much more complex circuits. If we have this simple source, analyzing changing loads becomes quite easy.

In this problem, you are to find the Thevenin voltage and resistance for three circuits. The load is to the right of the dashed line in the first two circuits.

Circuit 1: (This is the simplest of the three problems.) {15 pts}

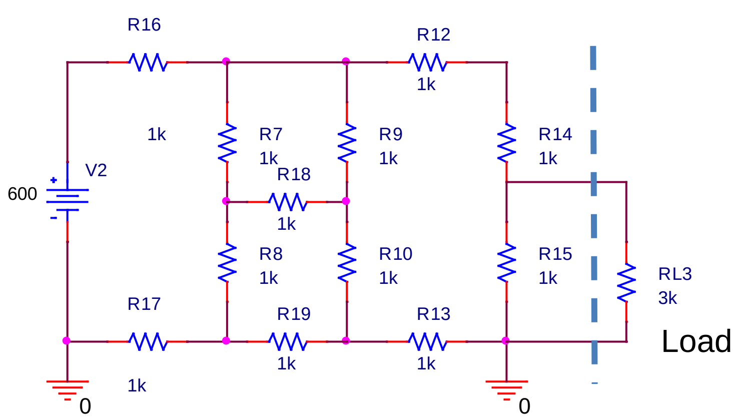


Vth = $V_{open\ circuit}$ = (6/12)40 = 20V

For Rth, short out the voltage source and then

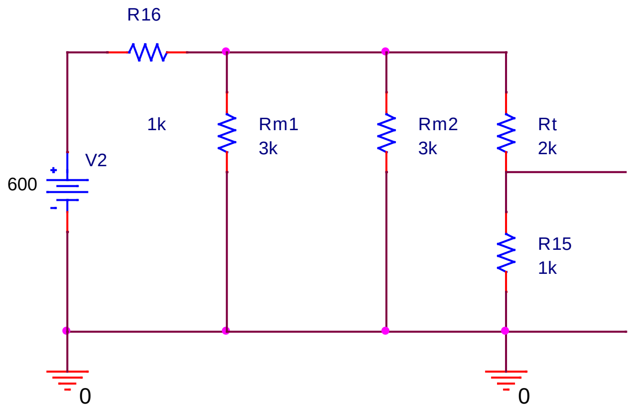
Rth = 6k||6k + 2k = 5k

Circuit 2: (This one requires a good deal more insight to solve, so it is not required. Rather, up to 5 points of extra credit can be earned if solved correctly.) {5 pts}



There is a way to simplify this problem before fully analyzing it. The resistors in the center (R7, R8, R9, R10, R13, R17, R18, R19) form two identical paths to ground. Thus, there will be no current thru R18 & R19, so these resistors can be removed from the circuit. The two parallel paths each becomes a 3k resistor from the node between R16 & R12 and ground.

One can also combine R12 & R14 into a single 2k resistor. The simplified circuit is below.



The three 3k resistors in parallel combine to a single 1k resistor. Thus, the voltage to the right of R16 is 600(1/2) = 300V. Then the voltage divider for the output is 300(1/3) = 100V = Vth.

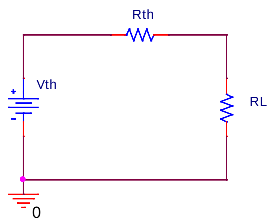
Again, using the simplified circuit, short out the voltage source to find Rth. Then

Rth = 1k||(2k+3k||3k||1k)= .72k

Circuit 3 Solution:

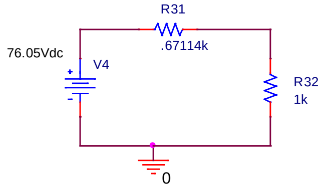
Vth is very simple to obtain. In the top circuit, the load is essentially open because it is 100MΩ. Thus, Vth = 76.05V

For Rth, we use the bottom circuit. If we replace the complex circuit with its Thevenin equivalent (see below), with Vth = 76.05 and RL = 1k, we can use the standard voltage divider expression to find Rth.



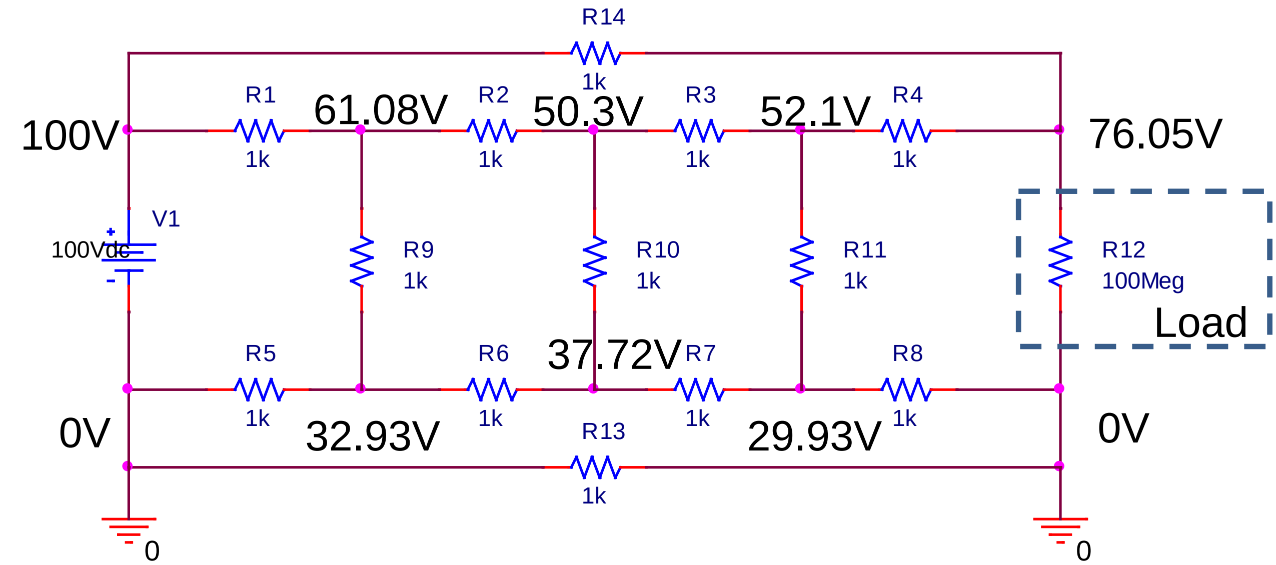
Vload = Vth (RL/(RL + Rth)) or 45.52 = 76.05(1k/(1k+Rth))

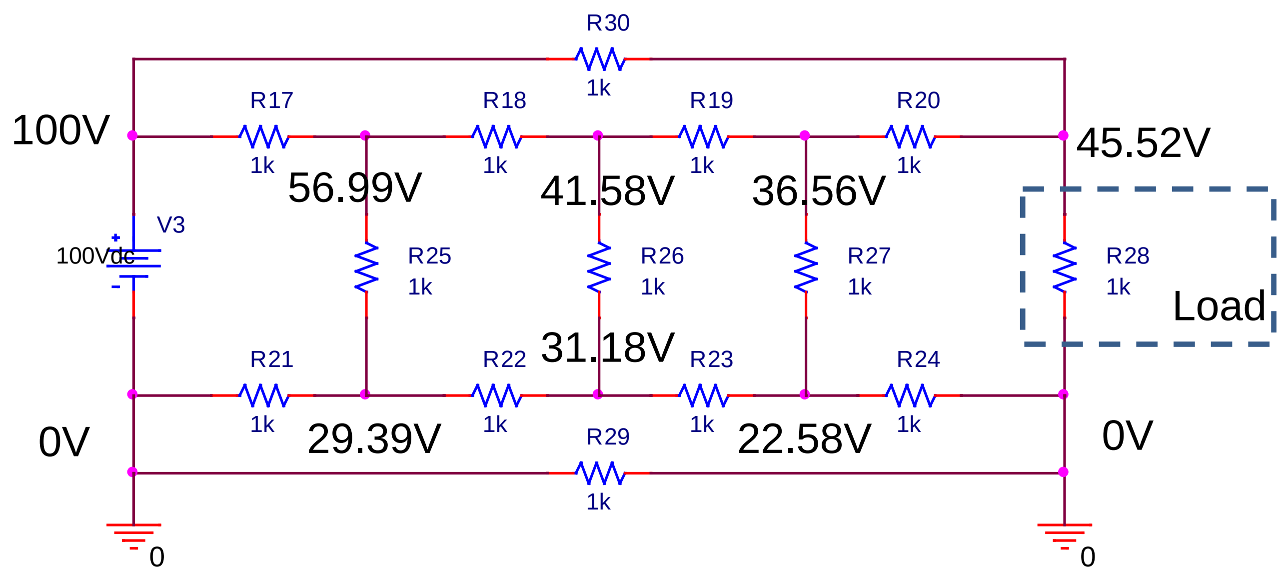
1k + Rth = (76.05/45.52)k = 1.67k or Rth = .67k



Circuit 3:

The 3rd circuit is significantly more complicated than the other two. Rather than analyze it from first principles, we will use the results from a PSpice simulation.



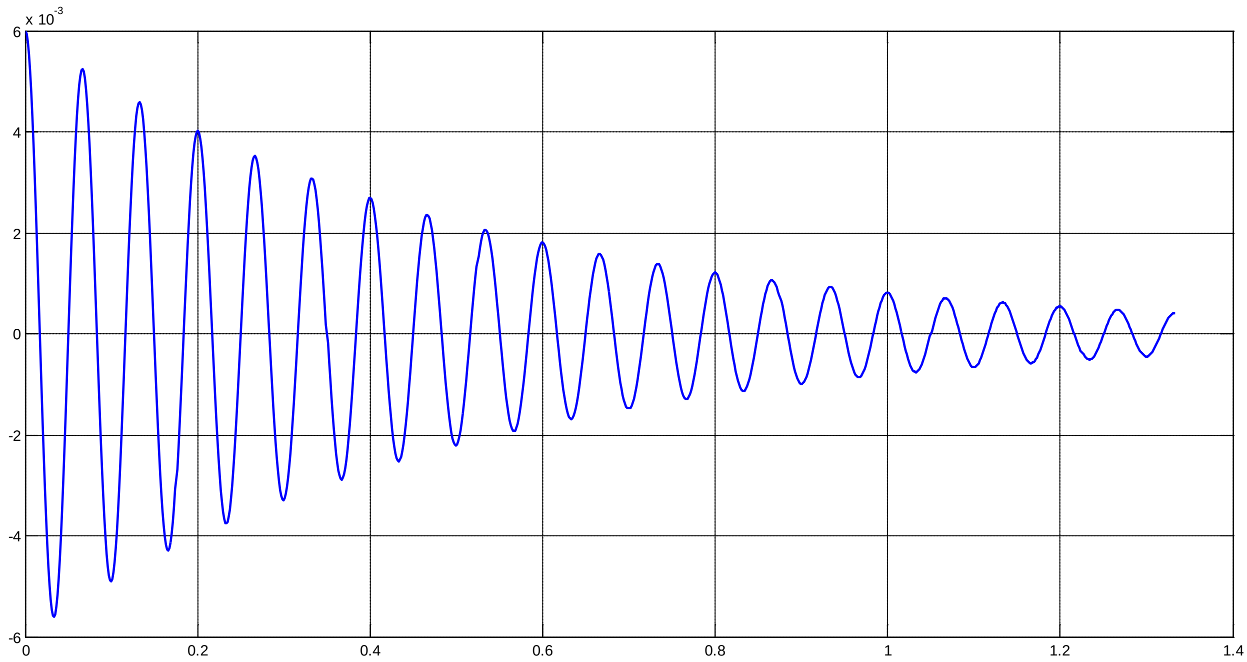


Using the given voltages at each of the nodes for an open circuit load (R12 is the load in the top version) and for a 1kΩ load (R28 is the load in the bottom version), determine Vth and Rth. {10 pts}

See previous page.

II. Harmonic Oscillators

The position measured for an oscillating cantilever beam is shown in graphical form as:



where the horizontal scale is time (0.2 sec per division) and the vertical scale is position (2 mm per division).

a. Find the decay constant α and the angular frequency ω for this function. {6 pts}

The amplitude at zero is 0.006m = 6mm. At t=.2, the position is 0.004m = 4mm. Thus, 6exp(-α0.2) = 4 or ln(1.5) = α0.2 or α = 2. The frequency is 3/.2 = 15 so the angular frequency is ω = 30π.

b. Write the mathematical expression for the position in the form $x(t) = Ae^{-\alpha t}\cos\omega t$. Use real values for the constants and provide units where appropriate. {4 pts}

$$x(t) = Ae^{-\alpha t}\cos\omega t = 0.006e^{-2t}\cos 30\pi t \text{ Meters}$$

c. Find the velocity *v(t)* and the acceleration *a(t)* of the beam from your answer to part b. Again, use real values for the constants and provide units where appropriate. {6 pts}

$$x(t) = 0.006e^{-2t}\cos 30\pi t$$

$$v(t) = \dot{x}(t) = (-2)\left(0.006e^{-2t}\cos 30\pi t\right) - 30\pi\left(0.006e^{-2t}\sin 30\pi t\right)$$

$$a(t) = \dot{v}(t) = (4)\left(0.006e^{-2t}\cos 30\pi t\right) + 60\pi\left(0.006e^{-2t}\sin 30\pi t\right) +$$

$$60\pi\left(0.006e^{-2t}\sin 30\pi t\right) + (30\pi)(30\pi)\left(0.006e^{-2t}\cos 30\pi t\right)$$

d. As you may have surmised, we get a lot of our circuit components from Analog Devices, a world leader in electronics whose main design and manufacturing facilities are in the Boston area. Analog developed the first practical accelerometer chip for applications like auto airbags and laptop hard drive protection. They have suggested that we use a new accelerometer – the ADXL327 – in our cantilever beam experiments, mainly because it is cheaper, more sensitive, requires lower power and is a fully three axis device. It is sufficiently low power that it can be run directly off an Arduino (with inexpensive printed circuit boards available from Adafruit or Sparkfun). Assuming that the position data shown above is typical for our experiments and that the operating range of the ADXL327 is ±2g, can we use this new accelerometer in place of our present device, the ADXL250? {4 pts}

The dominant term in the acceleration expression has amplitude $(30\pi)(30\pi)(0.006)=53.3(m/s^2) = 5.4g$ which is beyond the range of the new accelerometer, so it cannot be used. The actual value is a little smaller but still larger than 5g.

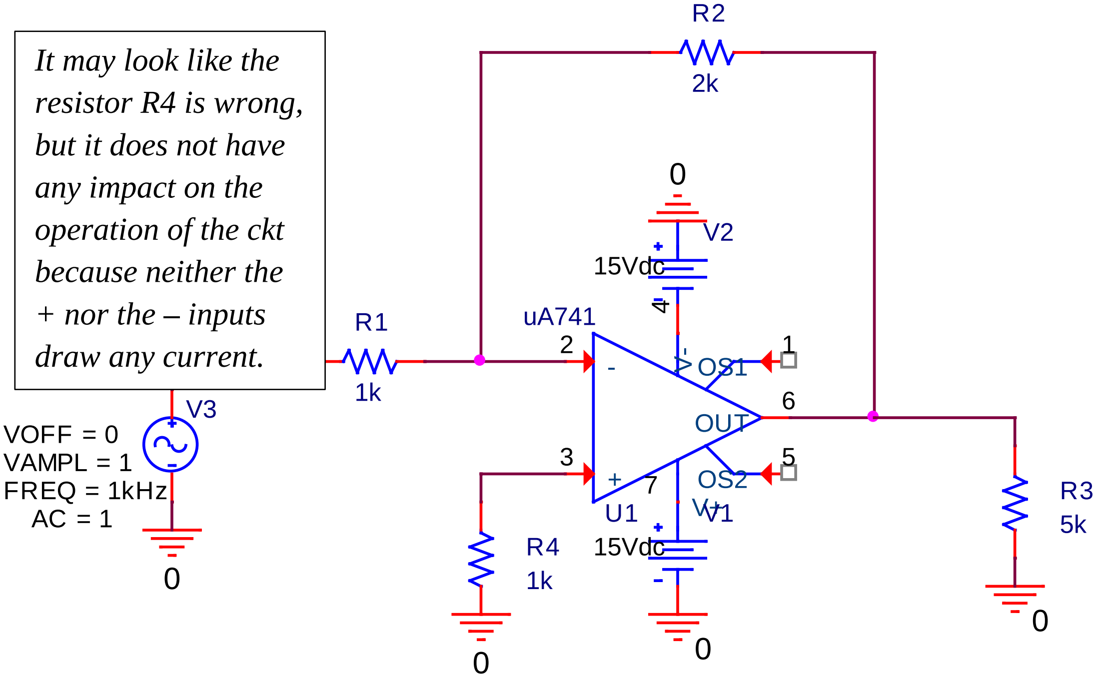
e. Of all the types of candy made available to you in the classroom, what is your favorite? {5 pts … really!}

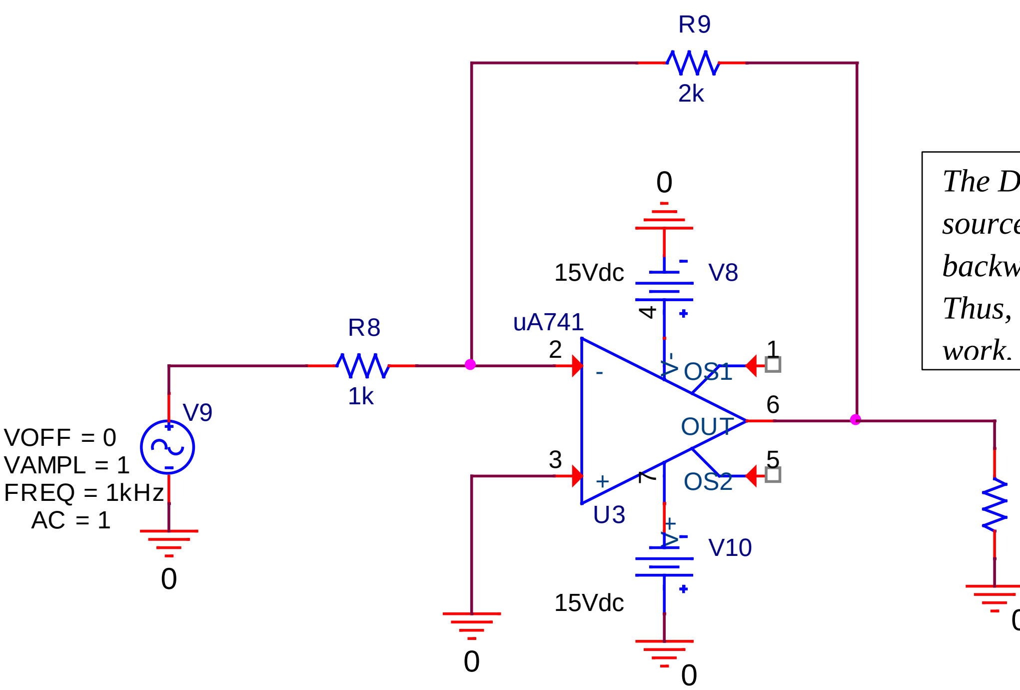
Any answer is fine.

III. Op-Amps

a. Only one of the two op-amp configurations shown will work. Which one is it? Explain your answer and be careful when you look at the two diagrams. {5 pts}

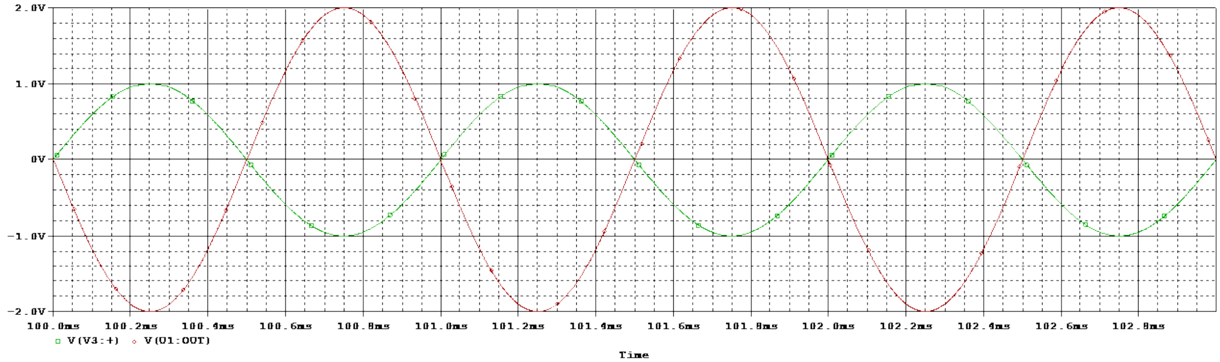
It may look like the resistor R4 is wrong, but it does not have any impact on the operation of the ckt because neither the + nor the – inputs draw any current.





The DC voltage sources are wired backwards in this case. Thus, this one will not work.

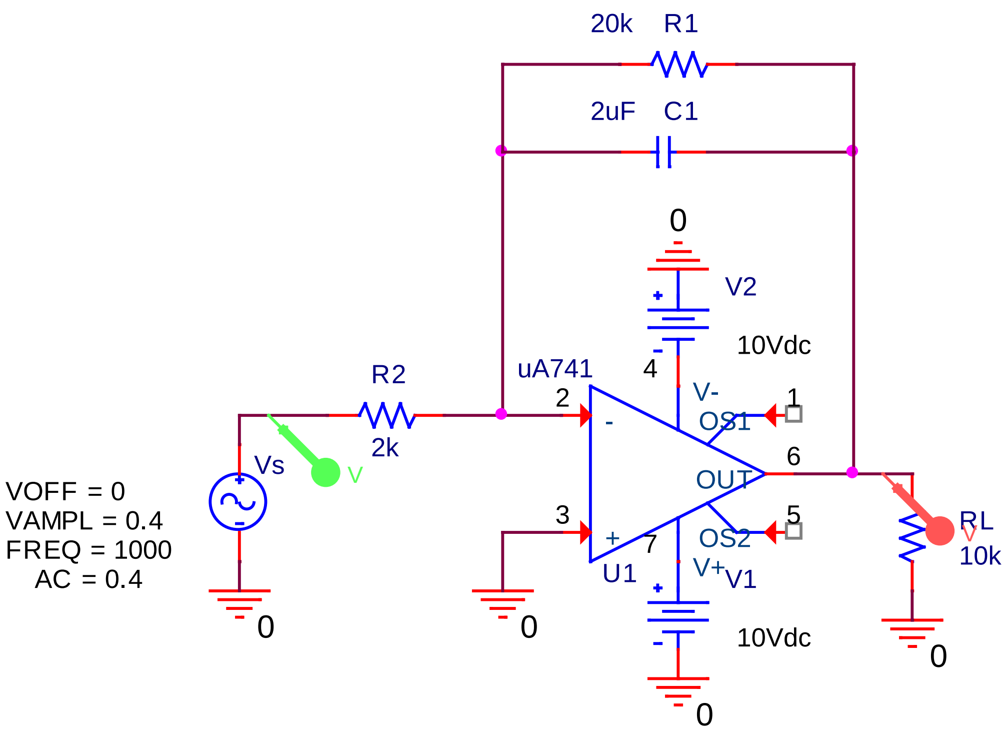
b. For the input voltage shown below, plot the output voltage as a function of time for the working circuit. {10 pts}



The gain is -2 so the output is flipped and twice the input.

The vertical scale goes from -3V to +3V and the horizontal scale from 100ms to 103ms.

c. Consider the following circuit, with a 1kHz input voltage with an amplitude of 0.4V. Determine the mathematical expression for the output voltage across the load resistance RL. Use real values, not just general constants and provide units where appropriate. {10 pts}

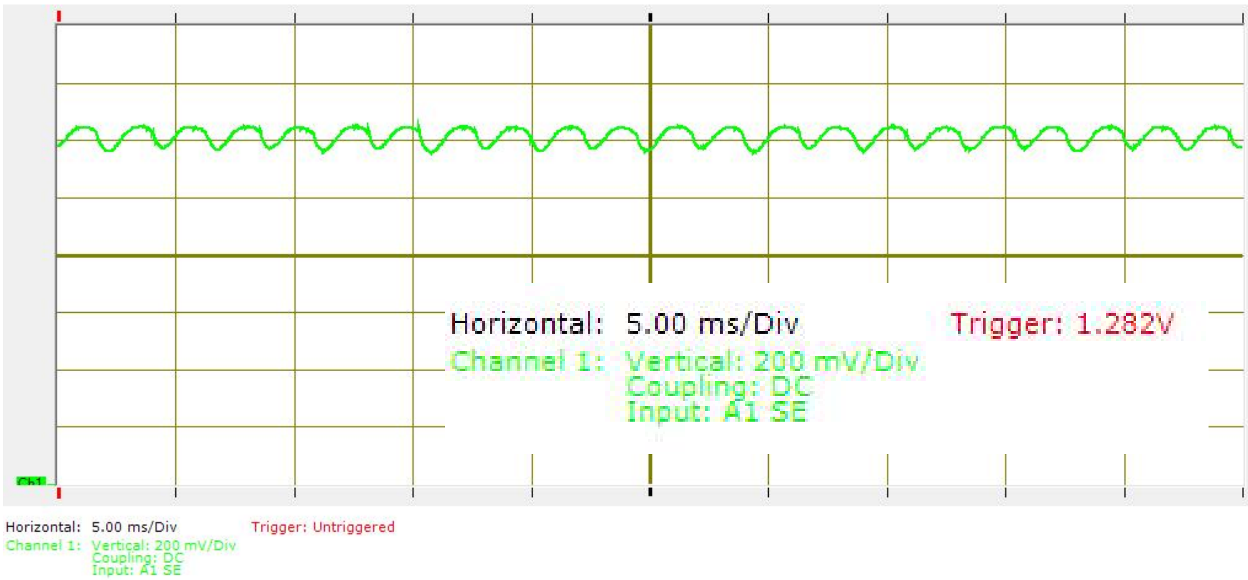


$$V_{out} = -\frac{1}{R2C1}\int V_s(t)dt \qquad V_s = 0.4\cos(2000\pi t)$$

$$V_{out} = -\frac{1}{(2E3)(2E-6)}\frac{1}{\pi 2E3}0.4\sin(2000\pi t) = -\frac{1}{20\pi}\sin(2000\pi t)$$

IV. Concepts, Troubleshooting, Data Analysis

a. As demonstrated in class, the voltage observed across the terminals of a small, DC motor from an electric razor looks like the figure below. Given that there are 3 coils in this motor so that connections are made 3 times per revolution, what is the approximate speed of this motor in RPM (revolutions per minute)? Note that the scale information found in the lower left-hand corner of the figure has been blown up to make it easier to read. These data were taken using a 1.5V AA battery. {5 pts}



There are 22 peaks in 10 times 5ms or 22/50 kHz = 440 Hz. There are three pulses per cycle so the actual speed is 440/3 = 147Hz. There are 60 sec per minute, so the RPM will be 8800.

Which of the following have been discovered while troubleshooting/debugging experimental and simulated circuits for some group in this class {1 pt each}? Circle all that are true. *All are true.*

b. 680kΩ resistors used instead of 680Ω resistors.

c. Connections to +4V and -4V reversed.

d. Large DC offset in signal not observed because the oscilloscope was set up for AC coupling rather than DC coupling.

e. Integrated circuit plugged in backwards.

f. No power to integrated circuit.

g. Identify and the following circuit component and give its value {4 pts} :

Capacitor

Value is $47 \times 10^{4} \times 10^{-12}$ *or* $.47\mu F$

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h. What are the golden rules of op-amps? {4 pts}

When there is negative feedback,

1. *An op-amp draws no current into either input.*
2. *An op-amp will do anything it can to its output to insure that its two inputs have the same voltage.*

i. Which of the following are true? {3 pts}
   - a. The input impedance of a voltage follower is very large.
   - b. The input impedance of a voltage follower is very small.
   - c. The input current of a voltage follower is very small.
   - d. The input current of a voltage follower is equal to the input voltage divided by the load resistance.
   - e. The output current of a voltage follower is very small.
   - f. The output current of a voltage follower is equal to the output voltage divided by the load resistance.

j. Which of the following scientists was born in Albany, NY and did fundamental work on electromagnets that helped lay the foundation for the telegraph? He was honored for this work by having the units for inductance named for him. {4 pts}
   - a. Michael Faraday
   - b. Joseph Henry
   - c. Georg Simon Ohm