ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2012

Name ________________________

Section ___

Question I (25 points) ___________

Question II (25 points) ___________

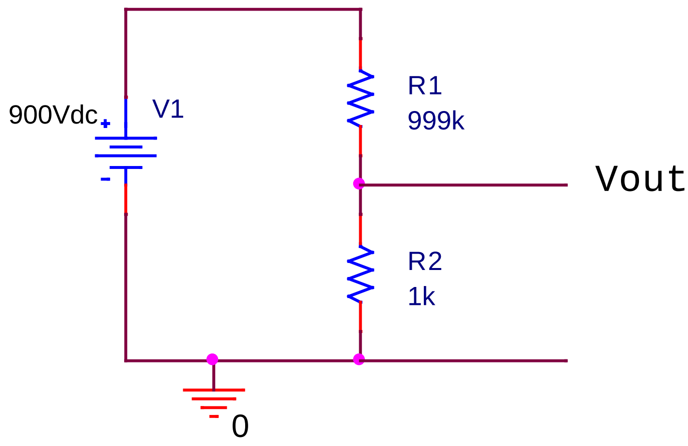
Question III (25 points) ___________

Question IV (25 points) ___________

Total (100 points) ______________

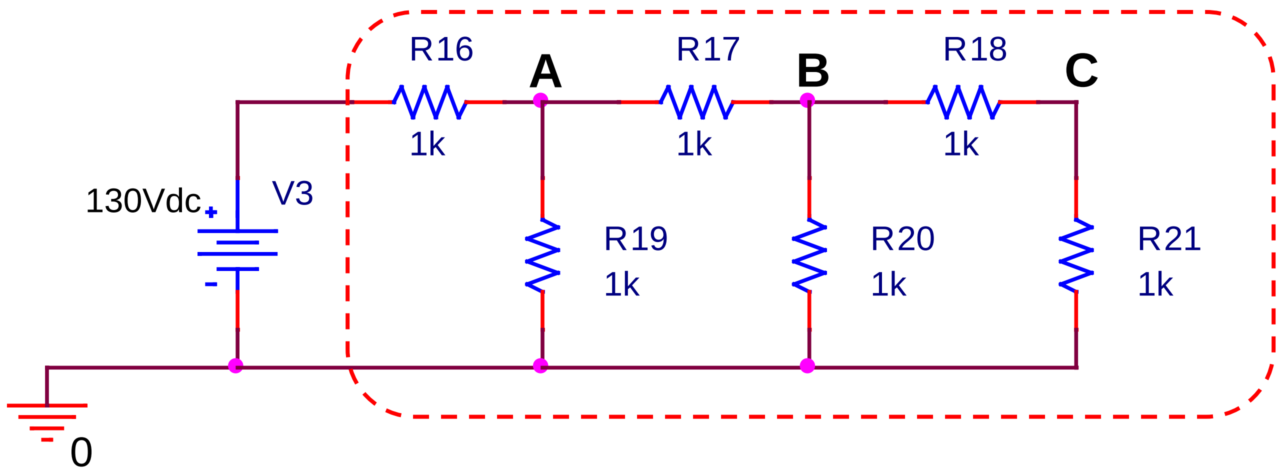
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

I. Resistive circuits (25 points)



a) Find the voltage Vout in the circuit above. (4 pts)

$$Vout = \frac{R2}{R1+R2} Vin = \frac{1}{1000} 900 = .9V \ \ (PSpice\ gives\ 900mV)$$



b) Find the total resistance of the circuit above, seen from the 130V voltage source. (i.e. all resistors inside the dashed region) (5 pts)

$$R_{total} = 1k + 1k \,||\, (1k + 1k \,||\, 2k) = 1k + 1k \,||\, (1k + 2/3k) = 1k + \frac{\frac{5}{3}k}{1+\frac{5}{3}} = \frac{13}{8}k$$

$$R_a = (2/3)k\,;\ R_b = 1k \,||\, (1k + 2/3k) = \frac{5}{3}k\,;$$

c) Find the voltages at the points A, B and C. (6 pts)

$V_A = 50V \ V_B = 20V \ V_C = 10V$

From the answer to d, the voltage drop across R16 is 1k times 80mA or 80V so that $V_A = 130 - 80 = 50V$

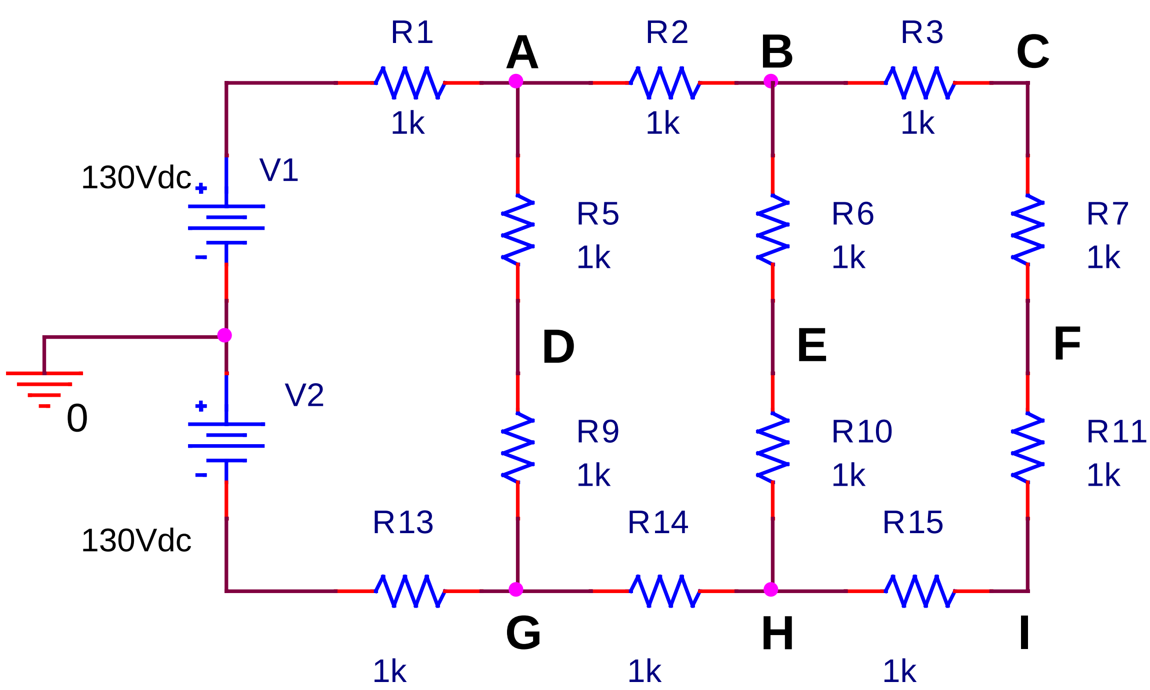
$V_C = V_B/2$ *from the voltage divider.* V_B *is also determined from a voltage divider. Thus,*

$\frac{2/3}{5/3} 50 = 20V$ *and* $V_C = 20/2 = 10V$.

d) Find the current drawn from the 130V DC voltage source. (4 pts)

$$I_{IN} = 130 / \left(13k/8\right) = 80mA$$

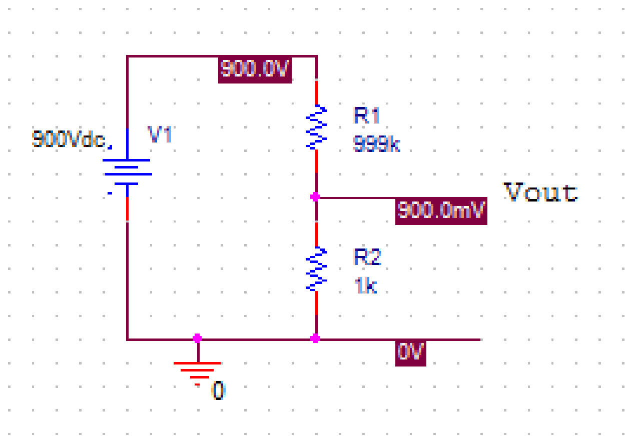
The previous circuit is modified as shown below.

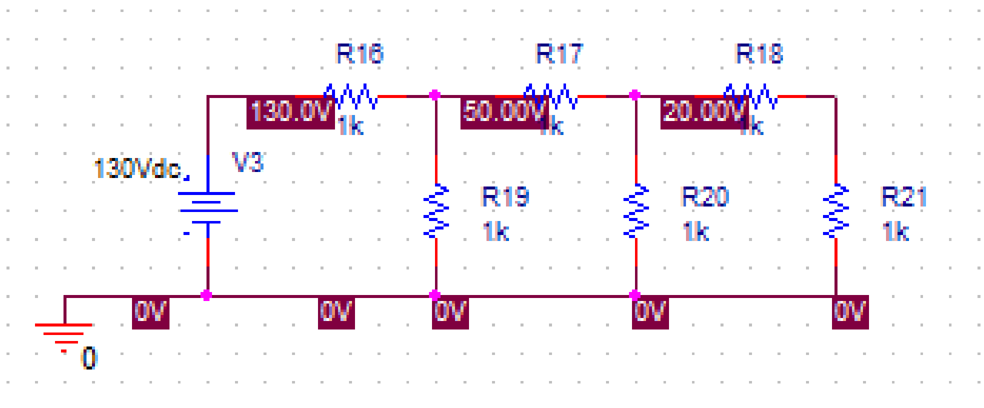


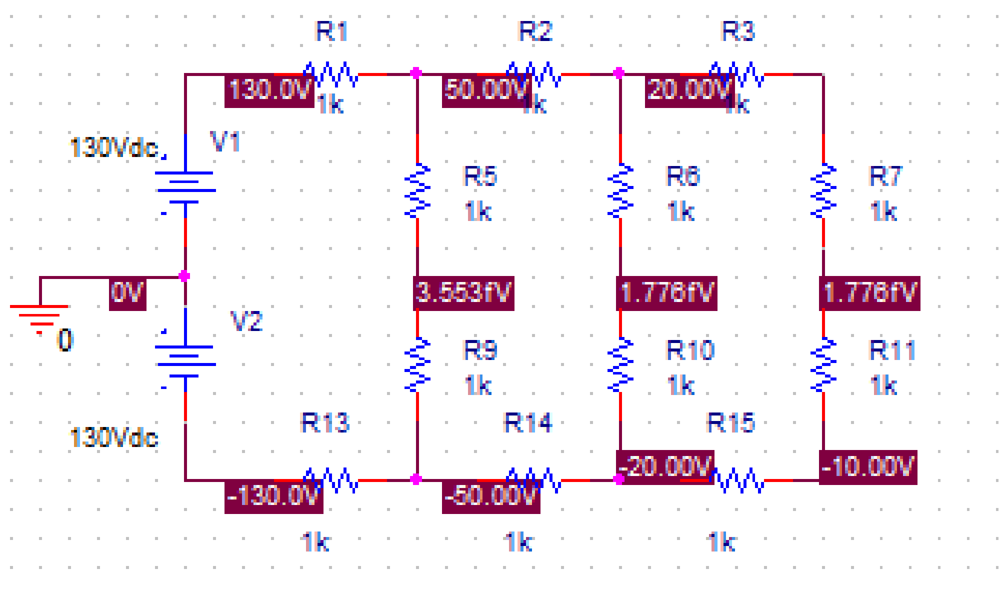
e) Find the voltages at the points A, B, C, D, E, F, G, H, I. (6 pts)

Note that this circuit is symmetric so that A, B, C are the same as before; D, E, F are all zero; G, H, I are the negative of A, B, C.

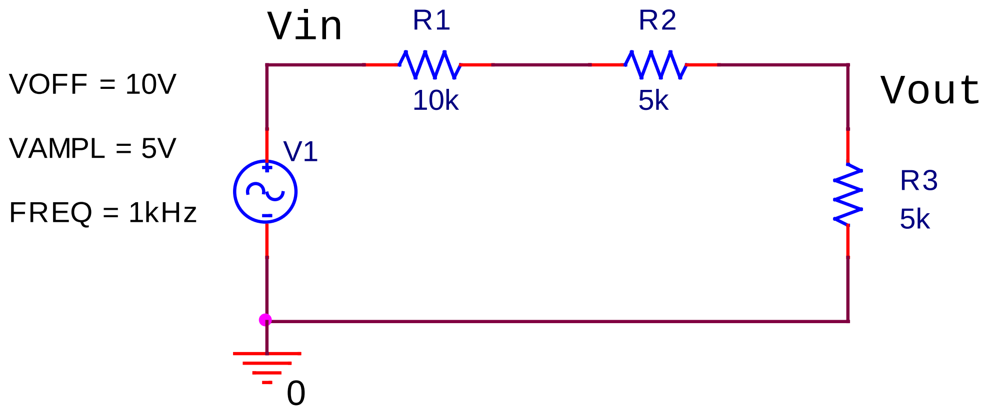
PSpice Solutions:







II. Filters & Transfer Functions (25 points)



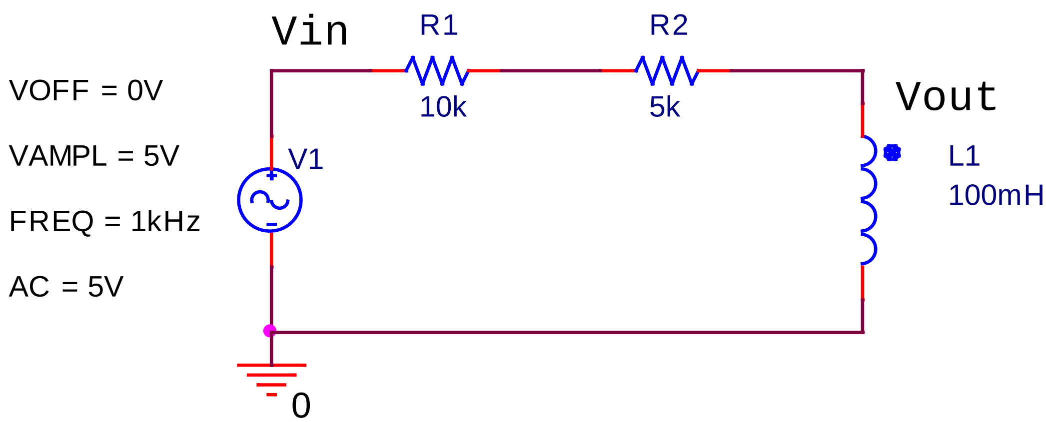
a) Find the transfer function $Vout/Vin$ for the resistive circuit shown above. Note that output is measured across R3. (2 pts)

$Vout = Vin(5/20) = Vin/4$

b) Write the input voltage *Vin* and the output voltage *Vout* as sinusoidal functions with offsets for the given operating conditions. That is write the voltages in the form $Vin = A + B\sin\omega t$ and $Vout = C + D\sin\omega t$ (2 pts)

$Vin = 10 + 5\sin\omega t \qquad Vout = 2.5 + 1.25\sin\omega t$

The previous circuit is modified by replacing the third resistor with and inductor. For simplicity, the offset voltage has also been set to zero.



c) Find the transfer function $Vout/Vin$ for the new circuit. Write it first in general form *H(jω)* in terms of ω, *R1*, *R2*, and *L1* and then plug in the given numerical values. (4 pts)

$$H(j\omega) = j\omega L1 / (R1 + R2 + j\omega L1) = j\omega 0.1 / (15k + j\omega 0.1)$$

Can also replace $\omega = 2\pi f = 2000\pi$

d) Simplify the transfer function for low frequencies and for high frequencies. (4 pts)

$$H_{low}(j\omega) = j\omega L1 / (R1 + R2)$$

$$H_{high}(j\omega) = j\omega L1 / (j\omega L1) = 1$$

e) What kind of filter response would best represent this circuit? (Please circle one.) (2 pts)

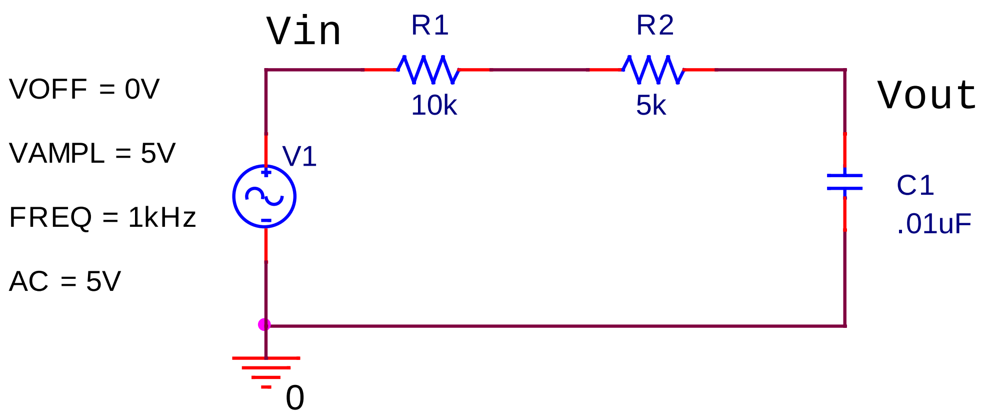
i) Low Pass ii) Band Pass iii) High Pass iv) Band Reject

f) What kind of filter response would best represent this circuit if the positions of the inductor and resistor R2 are reversed? (Please circle one.) (2 pts) *Hint: Sketch the new circuit diagram.*

i) Low Pass ii) Band Pass iii) High Pass iv) Band Reject

There is also some attenuation at low frequencies, but high frequencies are rejected.

The inductor is now replaced by a capacitor.



g) Find the transfer function $Vout/Vin$ for the new circuit. Write it first in general form *H(jω)* in terms of ω, *R1*, *R2*, and *C1* and then plug in the given numerical values. (4 pts)

$$H(j\omega) = \frac{\frac{1}{j\omega C1}}{\left(R1 + R2 + \frac{1}{j\omega C1}\right)} = 1/(1 + j\omega C1(R1 + R2)) = 1/(1 + j\omega(1.5x10^{-6}))$$

h) Determine the corner frequencies f_c for both the circuit with the inductor (at the output) and the circuit with the capacitor. Find the numerical values, not just the general expression. (2 pts)

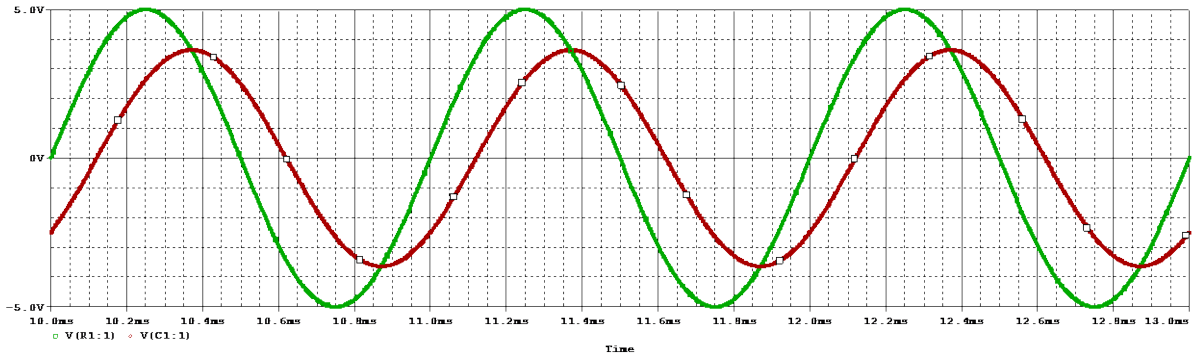
Inductor f_c: $R/2\pi L = 23{,}873Hz$

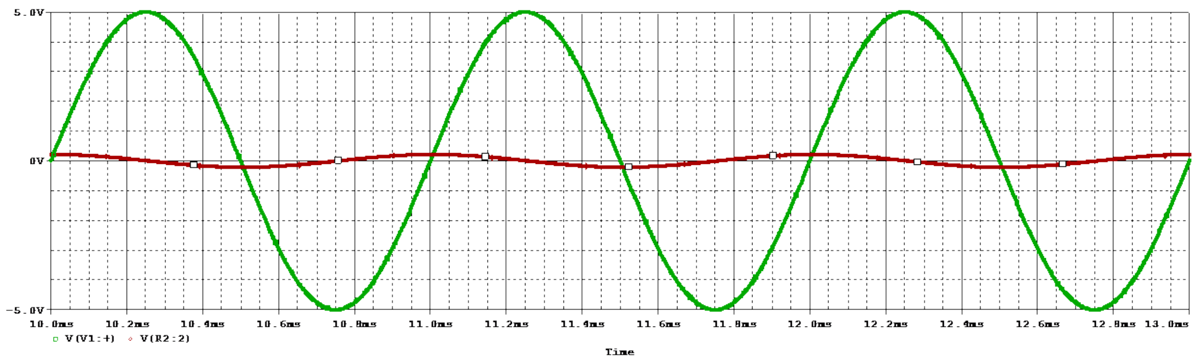
Capacitor f_c: $1/2\pi RC = 1061Hz$

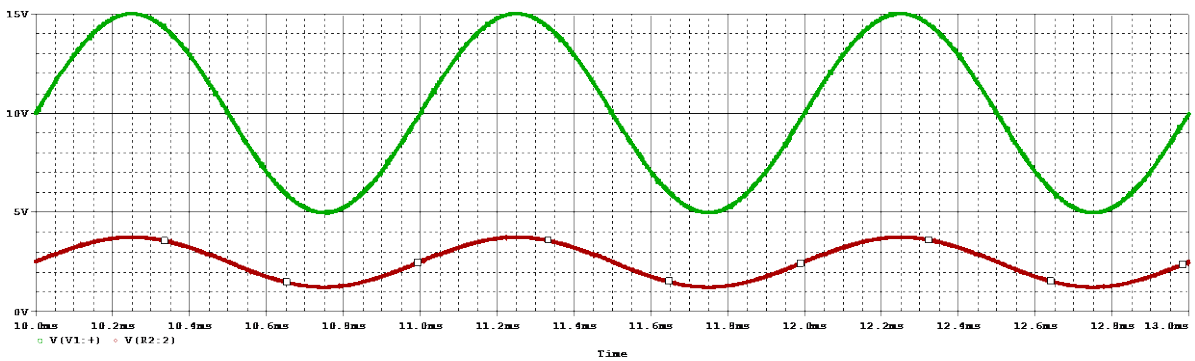
Thus, 1kHz is near the corner for RC and way below the corner for RL

h) On the following page are the input and output voltages for the three circuit configurations considered in this problem (output across resistor, output across inductor and output across capacitor). Label which plot goes with which circuit and explain your answer. (3 pts)

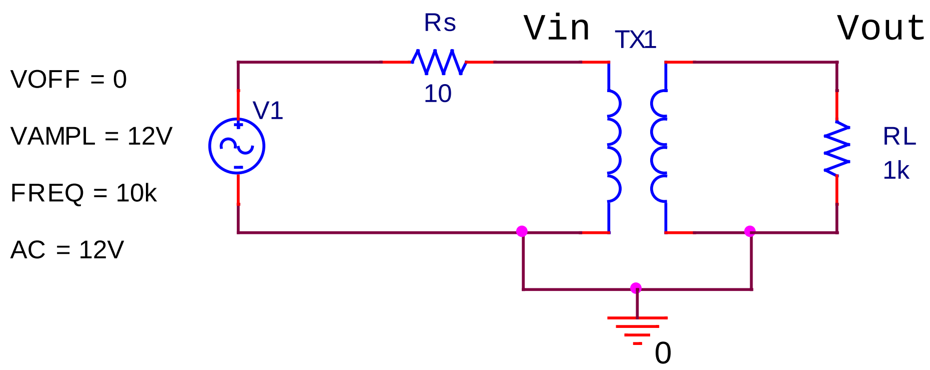
The resistor case is obvious because of the offsets. The RC case has the largest output voltage because 1kHz is near the corner. The RL case has the very small output voltage because the source frequency is so much less than the corner.


5.0V
0V
-5.0V
10.0ms 10.2ms 10.4ms 10.6ms 10.8ms 11.0ms 11.2ms 11.4ms 11.6ms 11.8ms 12.0ms 12.2ms 12.4ms 12.6ms 12.8ms 13.0ms
V(R1:1) V(C1:1)
Time


5.0V
0V
-5.0V
10.0ms 10.2ms 10.4ms 10.6ms 10.8ms 11.0ms 11.2ms 11.4ms 11.6ms 11.8ms 12.0ms 12.2ms 12.4ms 12.6ms 12.8ms 13.0ms
V(V1:+) V(R2:2)
Time


15V
10V
5V
0V
10.0ms 10.2ms 10.4ms 10.6ms 10.8ms 11.0ms 11.2ms 11.4ms 11.6ms 11.8ms 12.0ms 12.2ms 12.4ms 12.6ms 12.8ms 13.0ms
V(V1:+) V(R2:2)
Time

III – Signals, Transformers and Inductors (25 points)



a) Given the circuit above, assume an ideal transformer with full coupling. With Rs = 10Ω and RL = 1kΩ and L2/L1=100, find Vin, Vout, and the power in RL. (6 pts)

$Z_{IN} = RL/a^2 = 1k/100 = 10$ *thus Vin will be half of VAML or 6V. Vout will be 10X larger than Vin or 60V. The power in RL is* $Vout^2/RL = 60^2/1000 = 3.6W$ *which should be the same as the power delivered to the transformer input =* $6^2/10=3.6W$. *(While this is not mentioned in the solutions to previous semesters' quizzes, the answer is actually ½ of this value because the RMS voltage is supposed to be used instead of the amplitude. However, for a ballpark number, this approach is fine.)*

b) For which of the following choices for L2 will the transformer work at the given frequency, but not a 100Hz? (4 pts)

1μH 10μH 100μH 1mH 10mH 100mH 1H

The primary and the secondary legs of the circuit must be dominated by inductance to work as a transformer. Thus $\omega L >> R$ $L > R/(2\pi f) = 1000/(2\pi 10000) = .016$ *so for the given values, only 100mH and 1H are large enough. 100mH will not work at 100Hz. 1H will be marginal.*
$L > R/(2\pi f) = 1000/(2\pi 100) = 1.6$

c) If L1 is set equal to L2 (everything else remains as in 1), what are the new values for Vin, Vout, and the power in RL? (6 pts)

$Z_{IN} = RL/a^2 = 1k/1 = 1000$ *thus Vin will be most of VAML or ~12V. Vout will be the same. The power in RL is* $Vout^2/RL = 12^2/1000 = 144mW$.

d) If L2 = L1 = 1H, for which of the following frequencies will the transformer work? (4 pts)

60Hz 100Hz 1kHz 10kHz 30kHz 100kHz

$f >> R/(2\pi L) = 1000/2\pi = 167Hz$

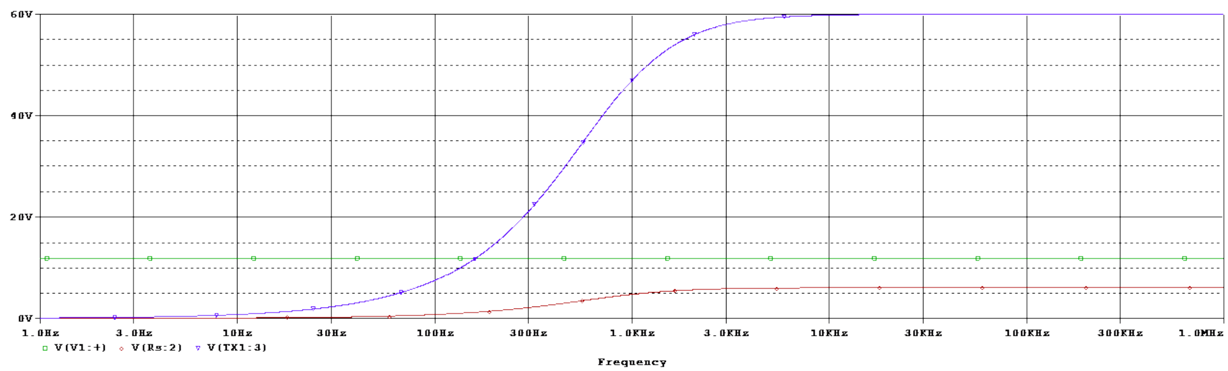
e) Out of curiosity, you decide to build a 1H inductor by winding wires on a 4m long, hollow cardboard cylinder with a radius of 10cm. Assuming the ideal formula gives a reasonably accurate result for this geometry, how many turns of wire will you need if $\mu = \mu_o = 4\pi \times 10^{-7}$ H/m? (4 pts)

$$L = \mu N^2 \pi r^2 / d = (4\pi x 10^{-7}) N^2 \pi (0.1)^2 / 4 \; or\; N=10000$$

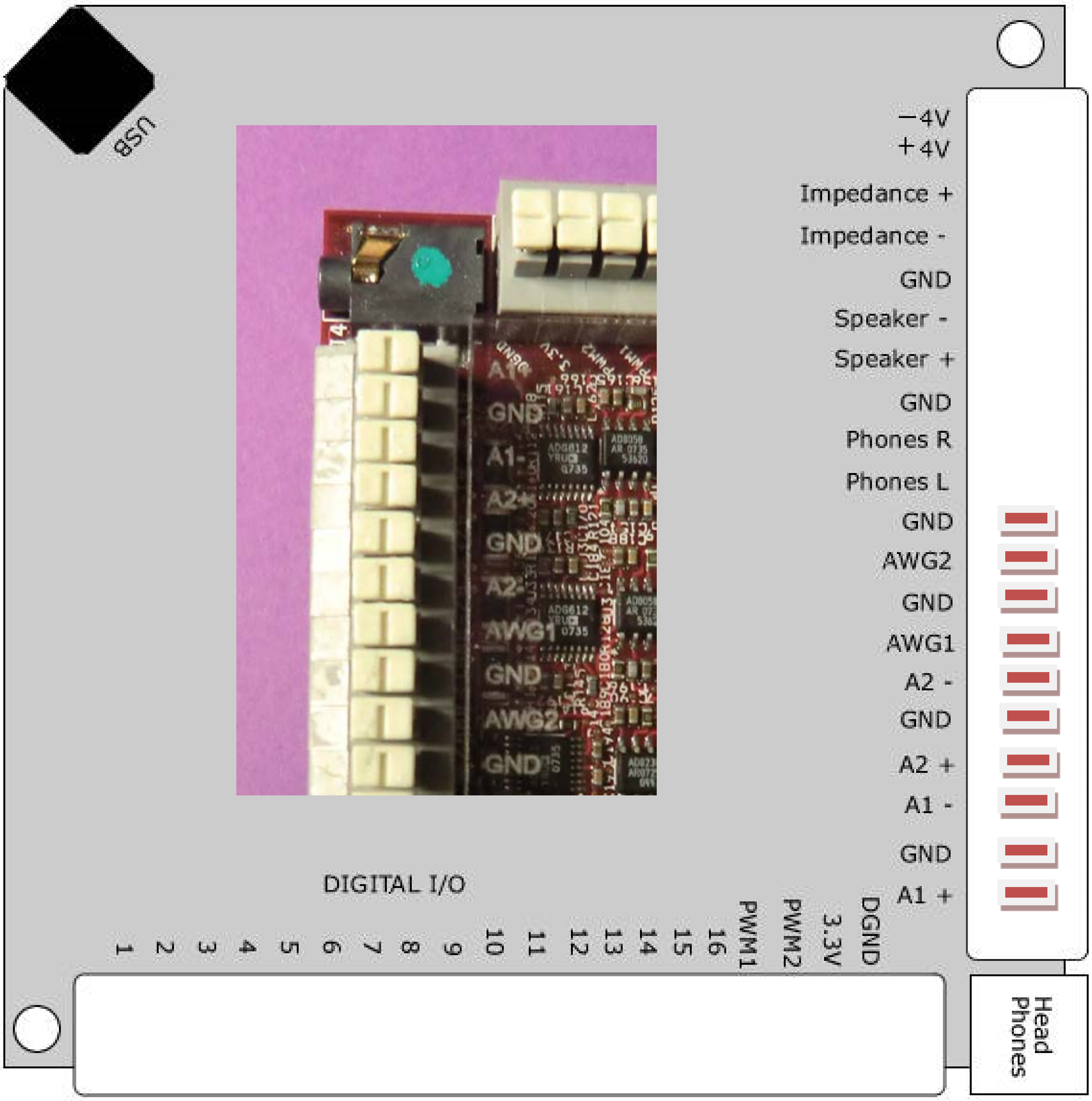
Assuming that you wind the coil with standard 12 gauge wire (diameter = 2mm), how much wire will you need? Note that this wire costs roughly $1 per meter. (1 pt)

2mm diameter means 2000 turns per layer or 5 total layers. Each of the turns has a circumference of 2π times 10cm or the total length is about 6300 meters.

PSpice Solution for Original Transformer Configuration:

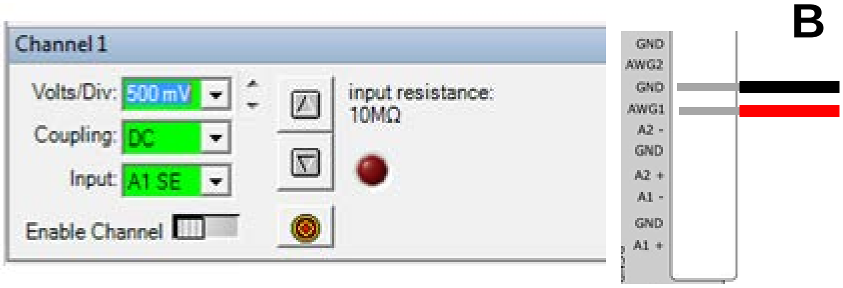


IV – Instrumentation, PSpice, Components, Troubleshooting & Concepts (25 points)



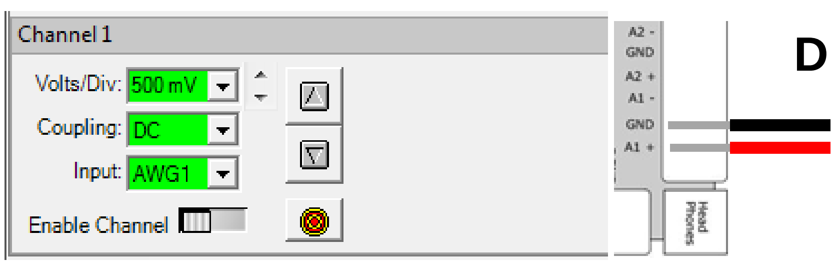
Shown above is the pinout diagram for the Mobile Studio. Shown also at the right are the 10 input/output connections we have used so far in the course. The insert in the figure is a photo of the relevant part of the Mobile Studio board.

A



B

C

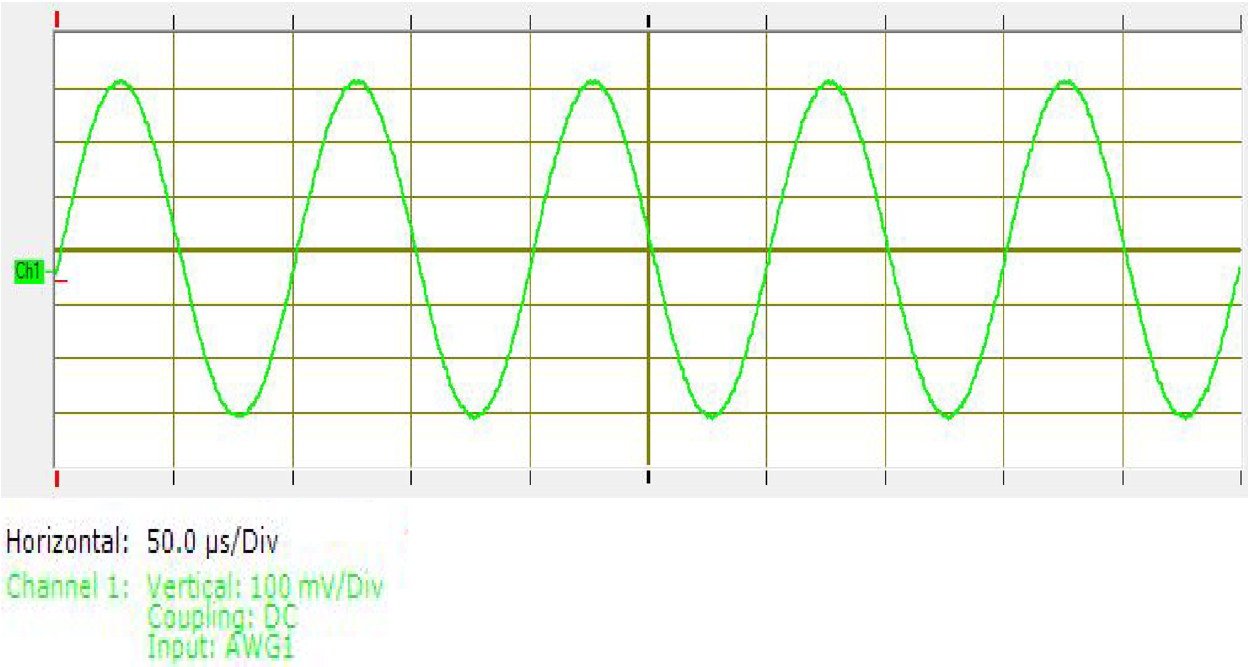


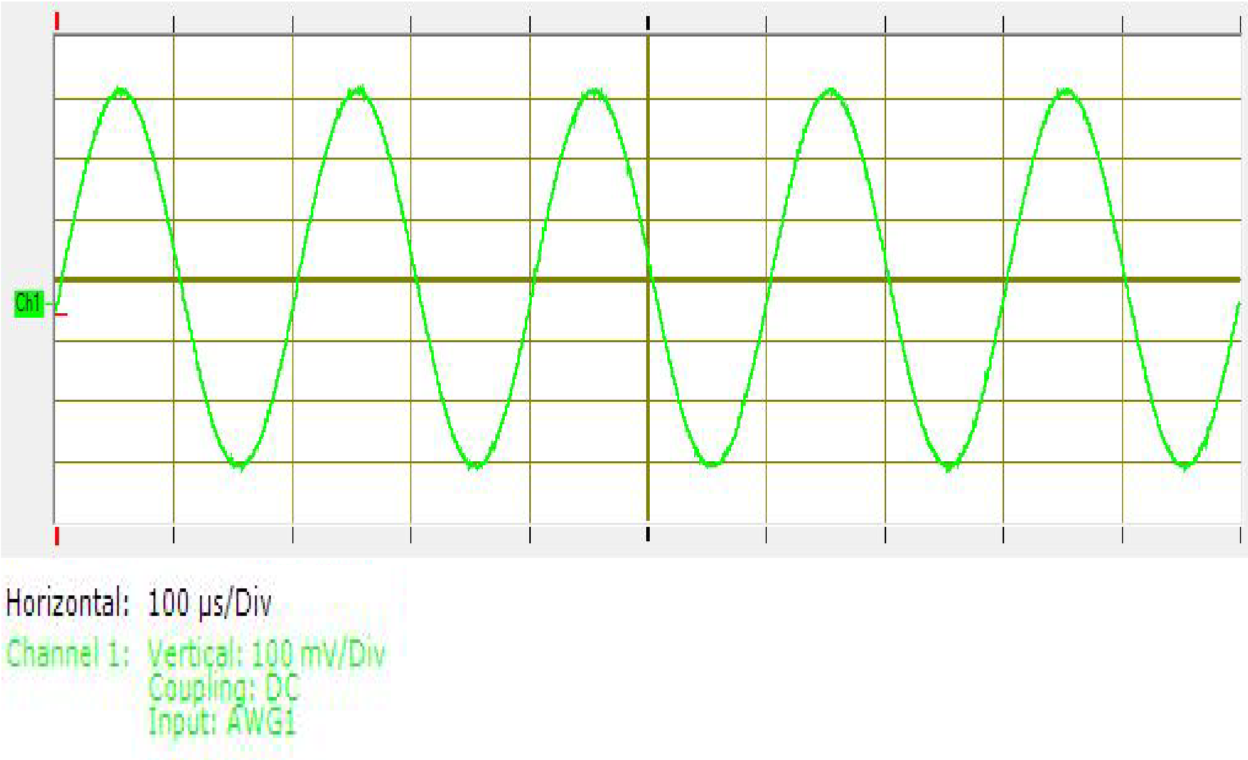
D

a) Shown above are four possible parameter selections for Channel 1 and wire connections. If you wish to measure a time varying voltage on Channel 1, using wires to connect to some points on your circuit, which of the 4 choices is correct? Explain your answer. (6 pts)

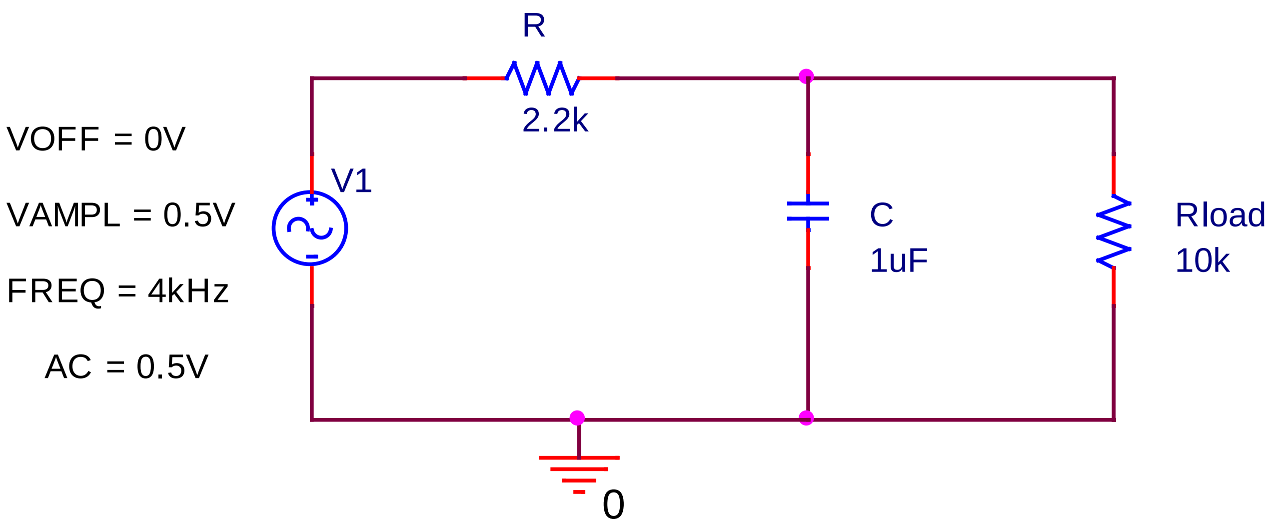
Setup A because we need to select the single ended measurement and connect A1+ and GND to the circuit being measured.

b) Shown below are two Mobile Studio measurements of sine waves. Which of the two waves has a frequency of 10kHz? Label the correct plot and explain your answer. (5 pts) *The first one has 5 cycles in .5ms so it will have 10 cycles in 1ms, which is 10kHz*

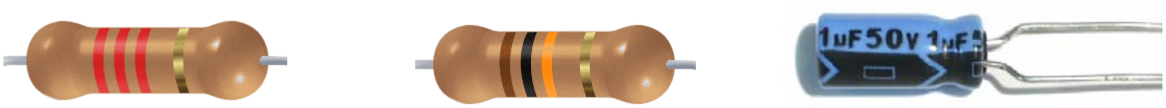




c) You are to build the following circuit that you have analyzed using PSpice and test it using the Mobile Studio. (4 pts)



i) Shown below are the components used to build the circuit. Label which one is R, Rload and C. While the figure is in black and white, there is still sufficient information to answer this question. *They are shown in the order they are used.*

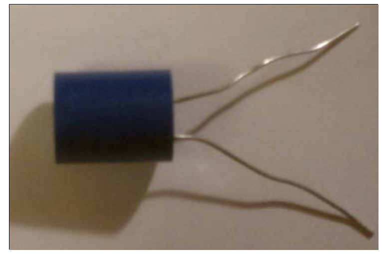


ii) The voltage source shown at the left is realized using the Mobile studio. Which of the two connections for the Mobile Studio must be used to provide the voltage source for this circuit?

AWG1 and GND or AWG2 and GND

In PSpice, you set up a circuit and perform a time domain simulation. You have carefully created all of the circuit components and correctly specified the simulation profile, but the simulation does not run. You get the following warning: *Your design does not contain a Ground (0) net. You may not be able to run analog simulation on this design.* You look at your circuit and cannot understand the warning because you have included a ground. What do you think could be wrong with your circuit? (4 pts)

The wrong ground was used. One needs the ground that specifies zero for PSpice.

d) Which of the three figures above shows an inductor? (3 pts)

All 3. The one on the left is a coil for Beakman's Motor. The one on the right is from our parts kit.

e) When does a real physical inductor behave like a resistor? When does it behave like an inductor? When does it behave like neither? (3 pts)

Inductor when $\omega L >> R$*, Resistor when* $R >> \omega L$*, neither when the two impedances are similar in size.*