ENGR-4300

Electronic Instrumentation

Quiz 1

Fall 2011

Name ________________________

Section ___

Question I (20 points) ___________

Question II (20 points) ___________

Question III (20 points) ___________

Question IV (20 points) ___________

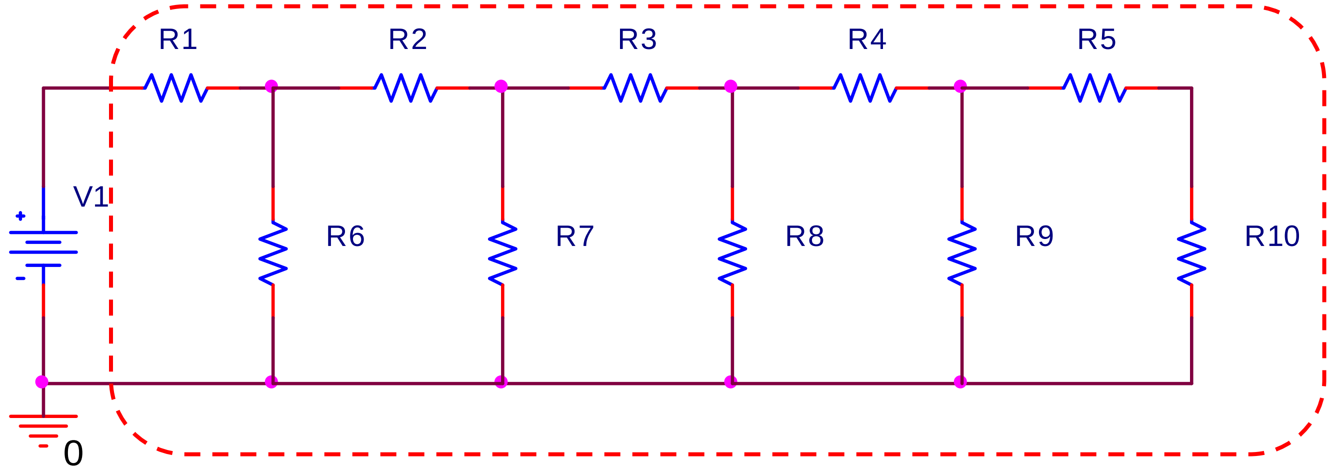
Question V (20 points) ___________

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

Question I. Resistive circuits (20 points)

V1=64V, R6=R7=R8=R9=2kΩ, R1=R2=R3=R4=R5=R10=1kΩ



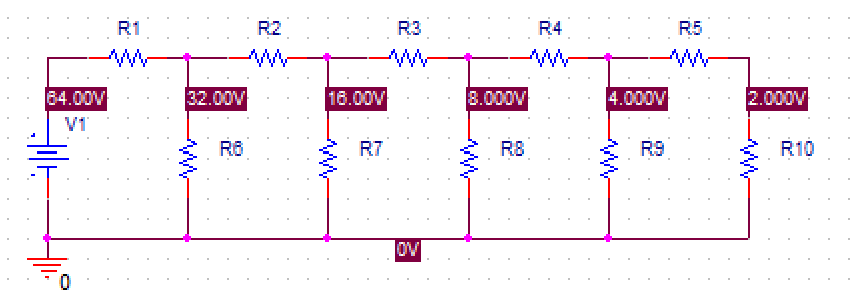
1) Find the total resistance of the circuit, seen from the voltage source. (i.e. all resistors inside the dashed region) (6 pts)

Ra=R5+R10=2k, Rb=R9||Ra=1k, Rc=R4+Rb=2k, Rd=R8||Rc=1k, Re=R3+Rd=2k, Rf=R7||Re=1k, Rg=R2+Rf=2k, Rh=R6||Rg=1k, <u>*Rtotal=R1+Rh=2k*</u>

2) Find the voltages across R3 and R4. (8 pts)

I thru R3 = I thru R7 = 8mA so V for R3 is 1k x 8mA = 8V

I thru R4 = I thru R8 = 4mA so V for R4 is 1k x 4mA = 4V



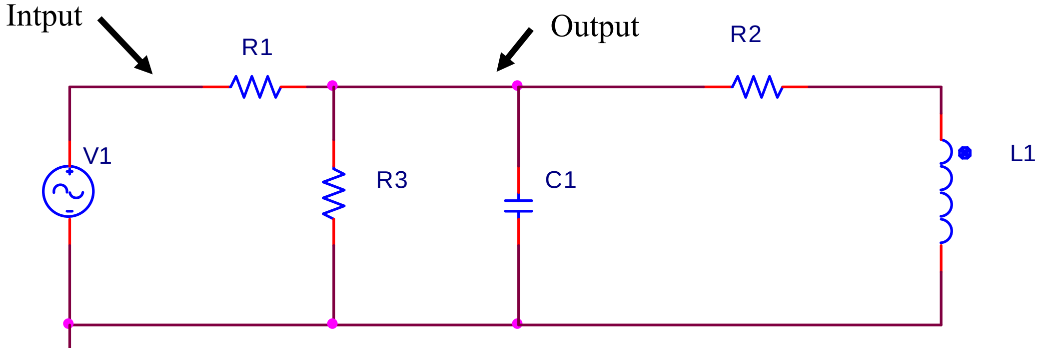
3) Find the currents through R10 and R6. (6 pts)

Note that the current splits equally at every node. The total current is Itotal=64/2k=32mA

I thru R6 = 16mA, I through R7=8mA, I thru R8=4mA, I thru R9=2mA, I thru R5 and R10 =1mA

Thus, I thru R10 = 1mA and I thru R6 = 16mA

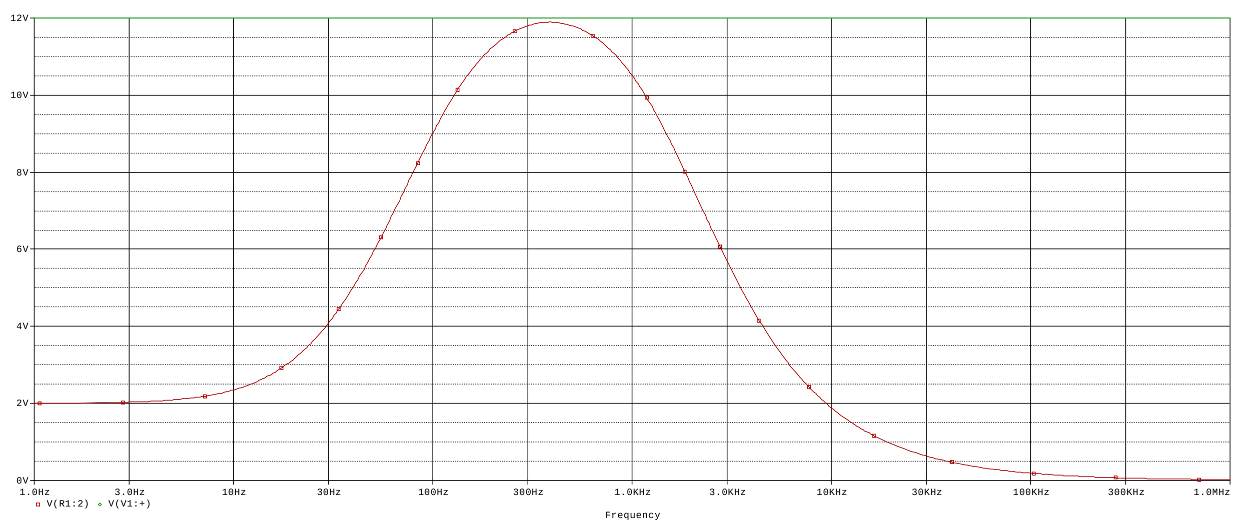
Question II. Filters (20 points)



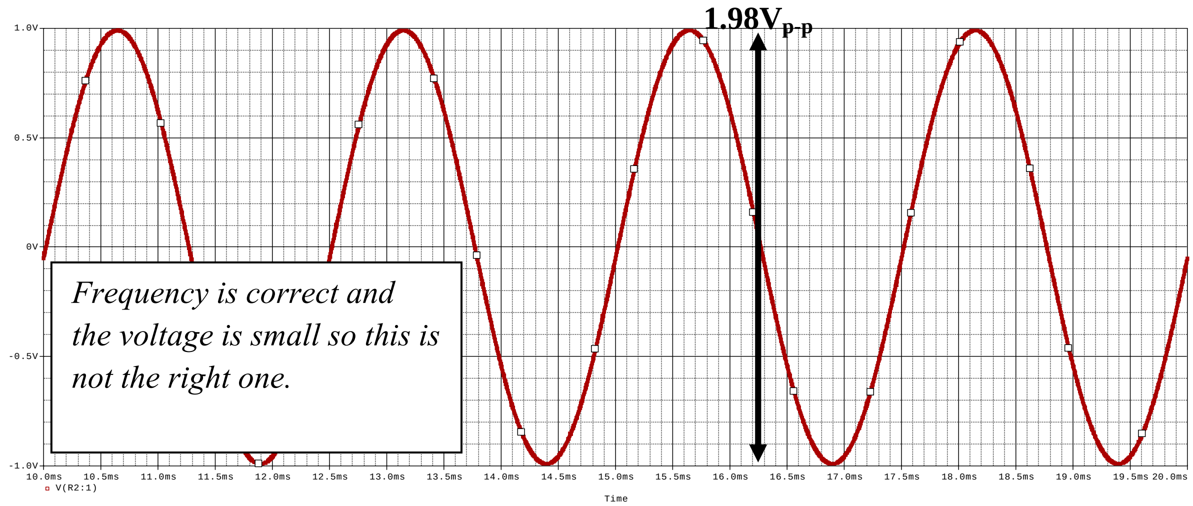
For the circuit above, R1=1Ω, R2=0.2 Ω, R3=1MegΩ, L1=2mH and C1=100µF.

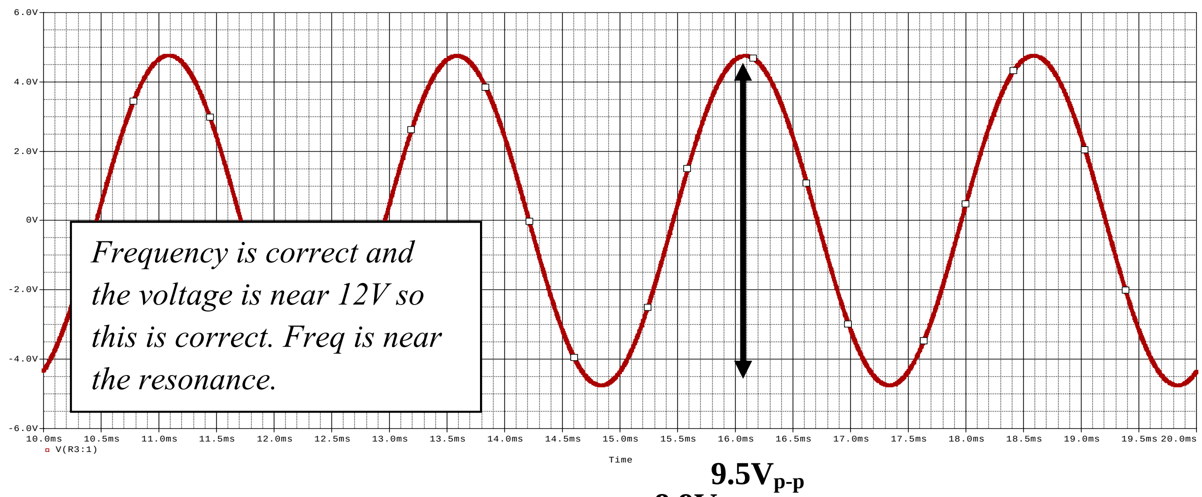
For this circuit, note that R3 is very large, so it can be ignored except at very low frequencies and it can be removed from the circuit. At very low frequencies, C1 is open and L1 is a short, so the only component left is R2. The voltage at low frequencies should be V1 times R2/(R1+R2) or V1/6. At high frequencies, C1 is a short and the output voltage is zero. The resonant frequency is given by $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(10^{-4})(2x10^{-3})}} = 356Hz$ *or* $\omega = 2240$

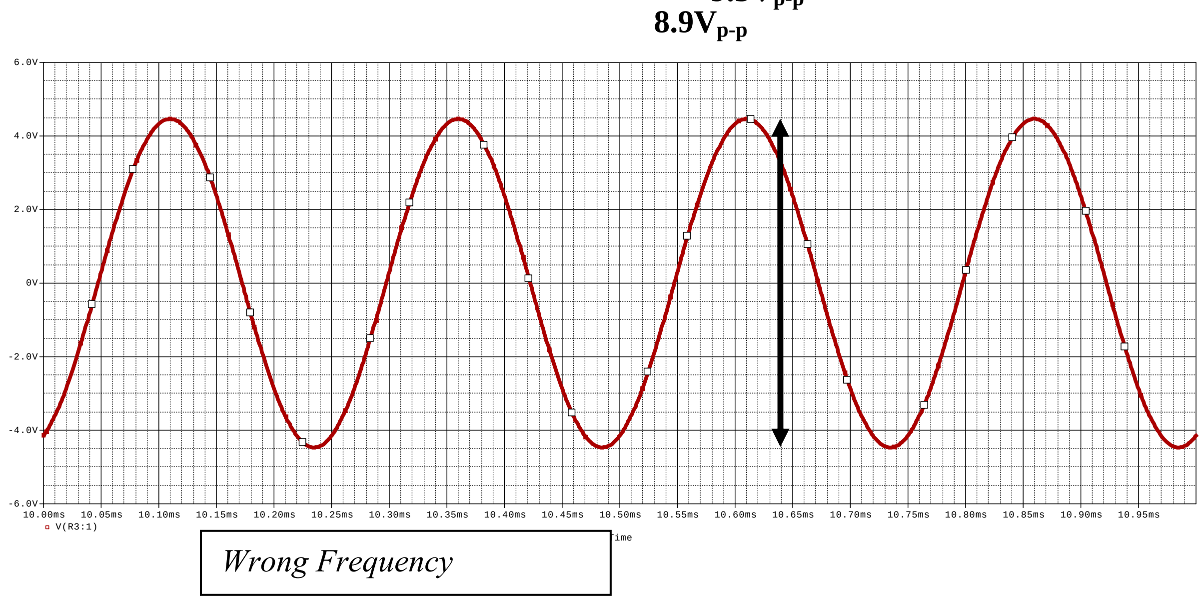
At this frequency, the impedance of the section to the right of the output marker is the parallel combination of C1 and (R2+L1). The impedance of C1 is $\frac{1}{j\omega C} = \frac{1}{j(2240)(10^{-4})} = -j4.47$ *and the impedance of L1 is* $j\omega L = j4.47$. *The parallel combo of C1 and (R2+L1) =*
$\frac{-j4.47(.2+j4.47)}{.2} = -j4.47 + 100 \approx 100$ *so nearly all of the voltage is across the impedance or it should be about 12V which agrees with the PSpice plot below.*



1) Which of the 3 graphs below would best represent the output seen across capacitor C1; where Vin = 12V cos(2πft), with **f = 400Hz**? (8 pts)







2) What kind of filter response would best represent this circuit? (Please circle one.) (4 pts)

a) Low Pass – *Since there is some signal at low f, this is not totally unreasonable (3pts)*

b) Band Pass –*This is the best answer, even though it does pass some signal at low f (4pts)*

c) High Pass

d) Band Reject

3) What kind of filter response would best represent this circuit if the inductor and resistor R2 were removed, leaving the capacitor and two resistors? (Please circle one.) (4 pts) *Hint: Sketch the new circuit diagram.*

a) Low Pass – *The cap shorts out the signal at high f*

b) Band Pass

c) High Pass

d) Band Reject

4) What kind of filter response would best represent the original circuit if the capacitor were removed leaving the inductor and three resistors, with the output measured across L1? (Please circle one.) (4 pts) *Hint: Sketch the new circuit diagram.*

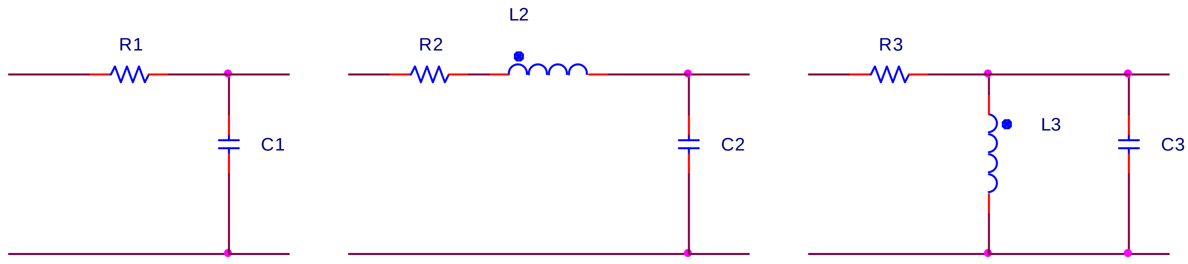
a) Low Pass

b) Band Pass

c) High Pass -- *The cap is gone and the inductor is open, so no current through the resistor.*

d) Band Reject

Question III – Transfer Functions (30 points)



Circuit A Circuit B Circuit C

A. Transfer Functions

1) What is the transfer function for circuit A? You must simplify. (3 points)

$$H_A(j\omega) = \frac{1/j\omega C}{R + 1/j\omega C} = \frac{1}{j\omega RC + 1}$$

2) What is the transfer function for circuit B? You must simplify. (4 points)

$$H_B(j\omega) = \frac{1/j\omega C}{j\omega L + R + 1/j\omega C} = \frac{1}{-\omega^2 LC + j\omega RC + 1}$$

3) What is the transfer function for circuit C? You must simplify. (5 points)

Total impedance is $R + \dfrac{\left(\dfrac{1}{j\omega C}\right) j\omega L}{\left(\dfrac{1}{j\omega C}\right) + j\omega L} = R + \dfrac{j\omega L}{1-\omega^2 LC} = \dfrac{R + j\omega L - \omega^2 RLC}{1-\omega^2 LC}$ *and impedance of load is* $\dfrac{\left(\dfrac{1}{j\omega C}\right) j\omega L}{\left(\dfrac{1}{j\omega C}\right) + j\omega L} = \dfrac{j\omega L}{1-\omega^2 LC}$.

$$H_C(j\omega) = \frac{\dfrac{j\omega L}{1-\omega^2 LC}}{\dfrac{R + j\omega L - \omega^2 RLC}{1-\omega^2 LC}} = \frac{j\omega L}{R + j\omega L - \omega^2 RLC}$$

B. We want to determine what type of filter circuit C is

1) What are the simplified transfer function, the magnitude, and the phase of circuit **C** at low frequencies? (3 points) *Hint: Remember that the frequency is not zero, just small.*

$H_{BLO}(j\omega) = \frac{j\omega L}{R}$

$|H_{BLO}| = \frac{\omega L}{R}$

$\angle H_{BLO}$ = *90 degrees or π/2*

2) What are the simplified transfer function, the magnitude, and the phase of circuit **C** at high frequencies? (3 points)

$H_{BHI}(j\omega) = \frac{j}{\omega RC}$

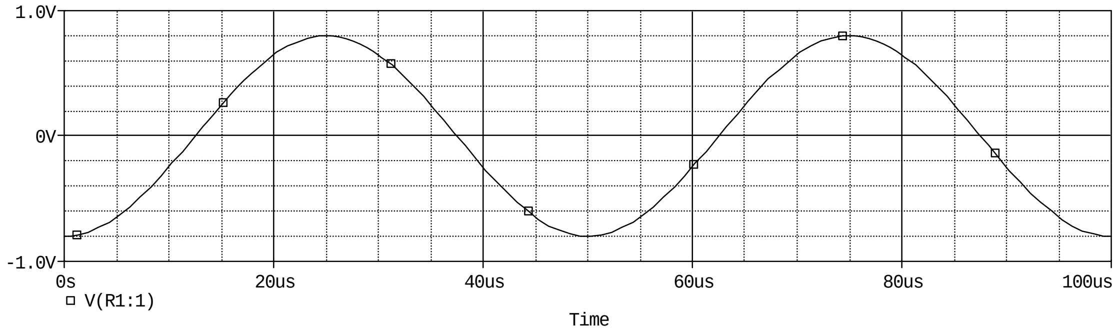
$|H_{BHI}| = \frac{1}{\omega RC}$

$\angle H_{BHI}$ = *90 degrees or π/2*

3) What type of filter is circuit **C**? (1 point)

Band Pass

C. We want to know what the output of circuit A will look like for the input shown below. If you cannot read the time scale markers, the fill width of the plot is 100µs.



1) Write an equation in the form $V_{in}(t) = A_{in} \sin(\omega t + \phi_{in})$ which describes the input signal shown. (3 points) *Two cycles in 100* µs *so period is half that and f=20kHz*

$V_{in}(t) = 800mV \sin(40K\pi t - \pi/2)$

2) If C=0.01µF, L=10µH, and R=10K, what are the magnitude and phase of the transfer function of circuit A? (4 points)

$|H_A|$ = ***0.079***

$$|H_A| = \left|\frac{1}{j\omega RC + 1}\right| = \left|\frac{1}{j(40k\pi)(10k)(0.01\mu) + 1}\right| = \left|\frac{1}{j(12.57) + 1}\right|$$

$$|H_A| = \frac{1}{\sqrt{12.57^2 + 1^2}} = 0.079$$

$\angle H_A$ = ***-1.49 radians***

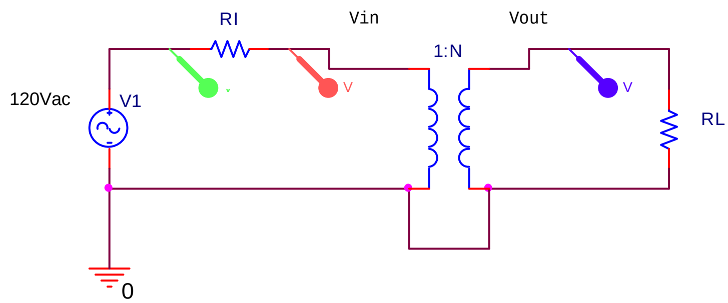
$\angle(1) - \angle(1+j(12.57)) = 0 - \tan^{-1}(12.57) = 0 - 1.49 = -1.49$

3) What are the amplitude and phase of the output of circuit **A**, when the input signal from part C-1 is applied to the circuit? (4 points)

A_{out} = (0.079)(800m) = ***63.2mV***

ϕ_{out} = -1.571 – 1.49 = ***-3.06 radians***

Question IV – Signals, Transformers and Inductors (20 points)



1) Given the circuit above, assume an ideal transformer with full coupling. With RI = 50Ω and RL = 100Ω and L2/L1=10, find Vin, Vout, and the power in RL. (6 pts)

$a = \sqrt{\frac{L_2}{L_1}} = \sqrt{10} = 3.16 \quad Z_{IN} = \frac{Z_L}{a^2} = \frac{100}{10} = 10$ *so Vin can be found from the voltage divider formula for the input impedance and R1 or Vin=20V, Vout=N(Vin)=63.2V, the power is*

$$P = \frac{V^2}{R} = \frac{(63.2)^2}{100} = 40W$$

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

$a = \sqrt{\frac{L_2}{L_1}} = 1 \quad Z_{IN} = \frac{Z_L}{a^2} = 100$ *so Vin can be found from the voltage divider formula for the input impedance and R1 or Vin=80V, Vout=N(Vin)=80V, the power is* $P = \frac{V^2}{R} = \frac{(80)^2}{100} = 64W$

3) Knowing that a real transformer's behavior deviates from that of an ideal, what would be an appropriate minimum value for the inductance on the primary of the transformer in 1), given the source's frequency of 60Hz? (4 pts)

a) 5µH

b) 50µH

c) 500µH

b) 5mH

c) 50mH

d) 500mH

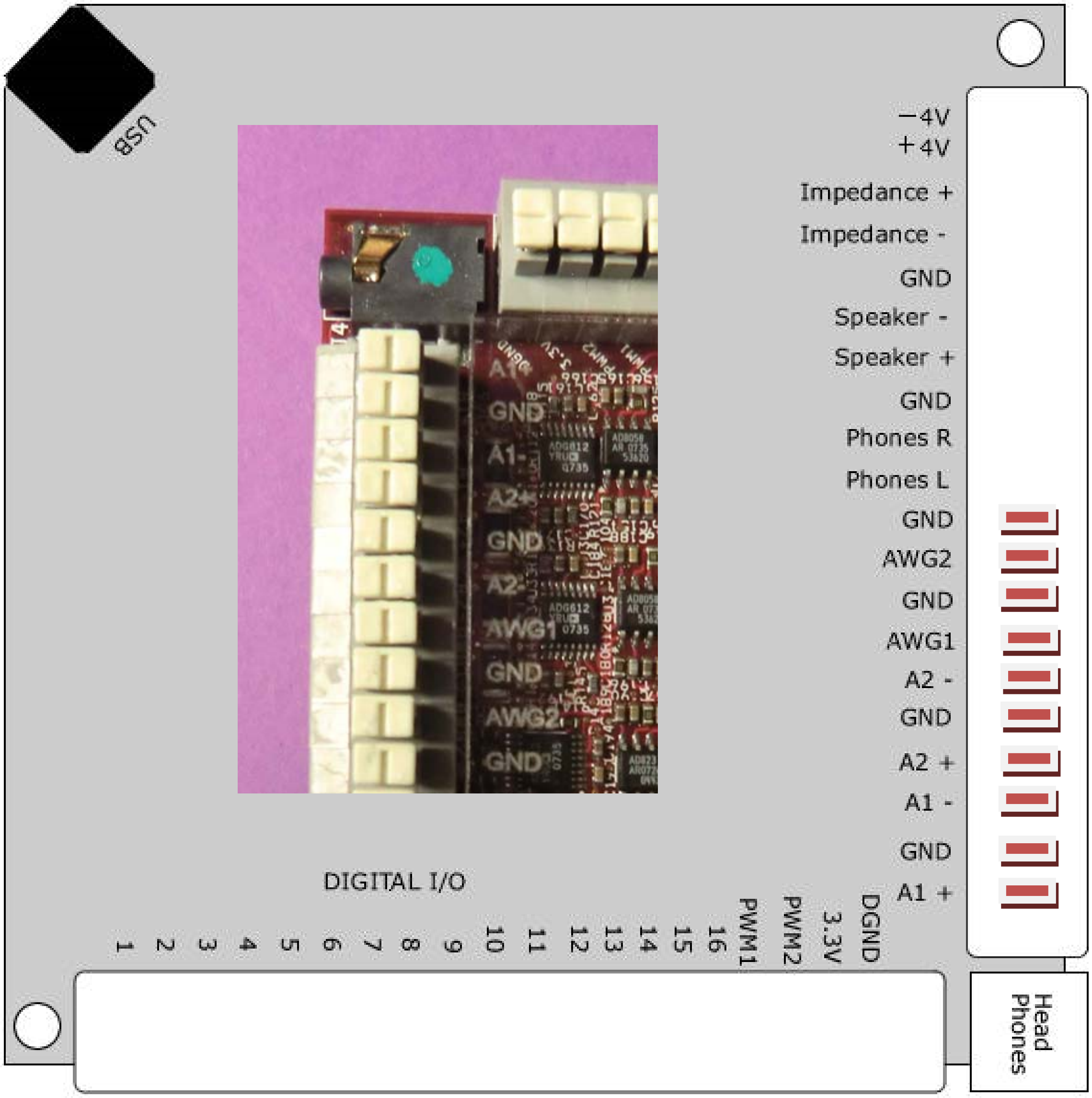
e) 5H

f) 50H

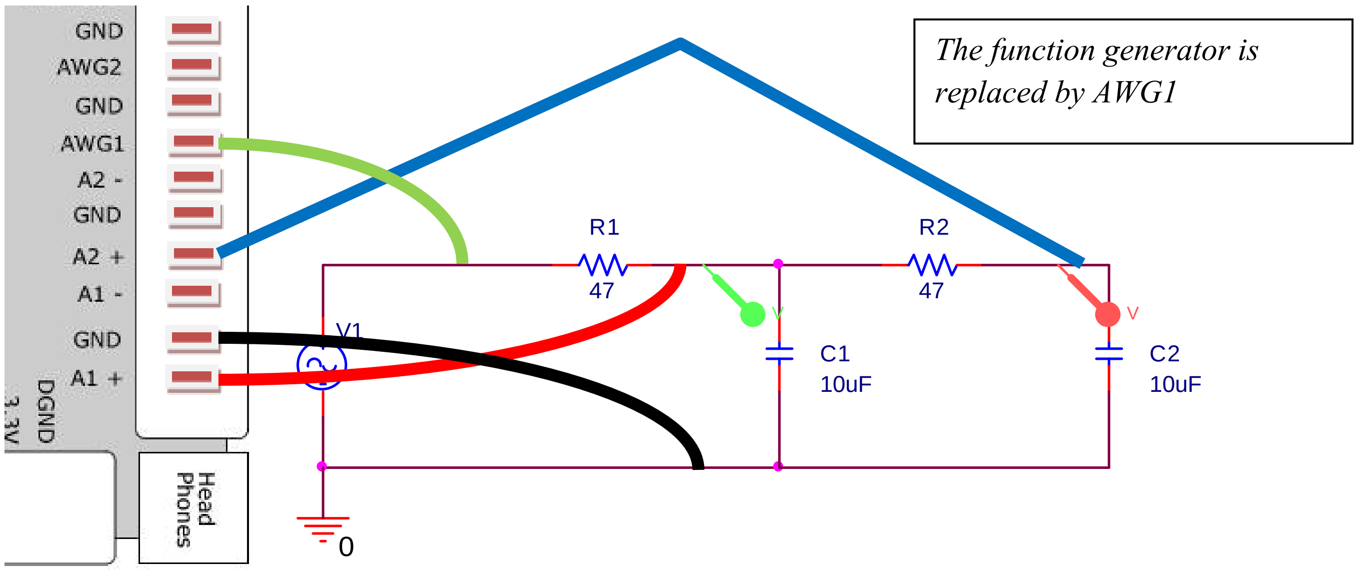
g) 500H

$\omega L >> R = 100$ or $L >> 100/377 = 320mH$ *but the next higher value is almost as good so is worth 3pts*

Question V – Instrumentation, PSpice and components (20 points)

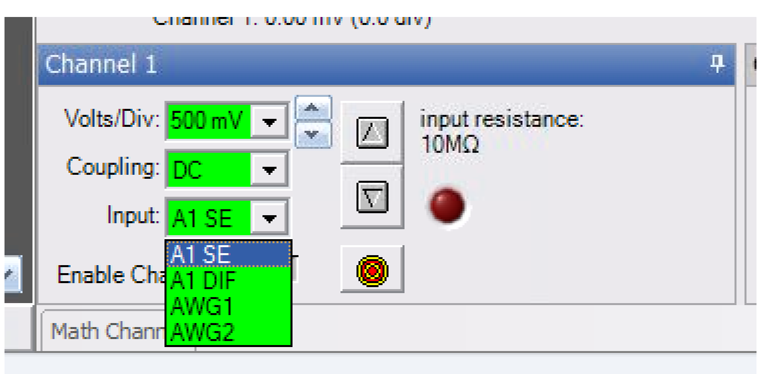


Shown above is the pinout diagram for the Mobile Studio. Shown also at the right are the 10 input/output connections we have used so far in the course. The insert in the figure is a photo of the relevant part of the Mobile Studio board. In the next few questions, you are asked to indicate how we connect the Mobile Studio board to a circuit, which you have now done several times in the classroom. In the following you should assume that all oscilloscope measurements are made single-ended. That is, when you select the display for the two channels, they are set at A1 SE and A2 SE and not AWG1, AWG2, A1 DIF, or A2 DIF.

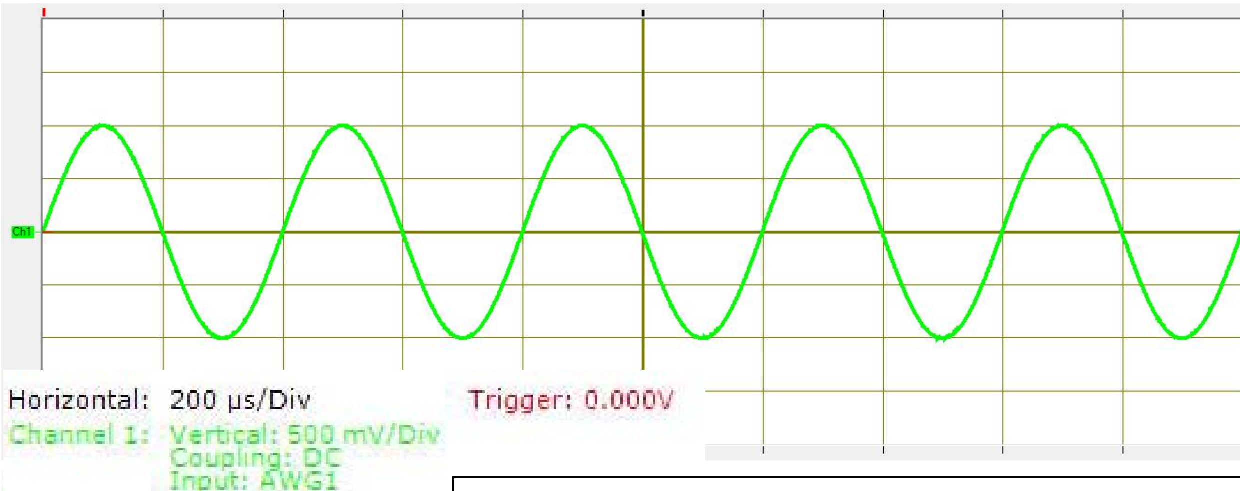


Very neatly draw in the connections required for the functions listed below.

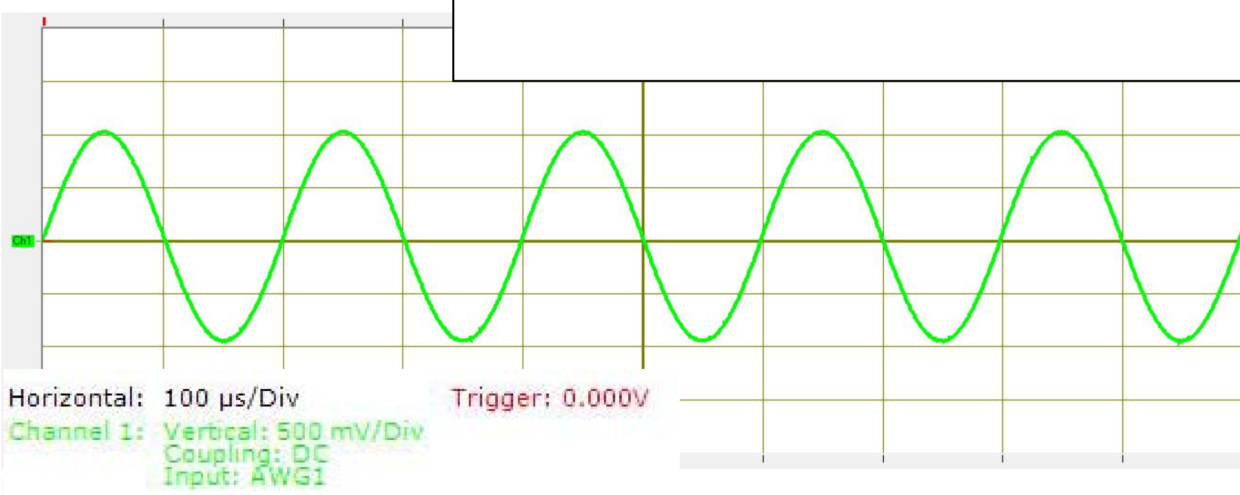
1) Display the voltage across capacitor C1 on the scope. (2pts)
2) Display the voltage across capacitor C2 on the scope. (2pts)
3) Connect the sinusoidal voltage source to the circuit. (2pts)
4) Based on your answer to question 3) and without rewiring your circuit, how would you display the input voltage V1 on channel 1 of the scope? That is, which of the following would you choose for the input: A1 SE, AWG1, AWG2, or A1 DIF. Circle your selection. The choices as seen on the Mobile Studio Desktop display are also shown below to remind you of what you see when doing the experiment. (2pts)

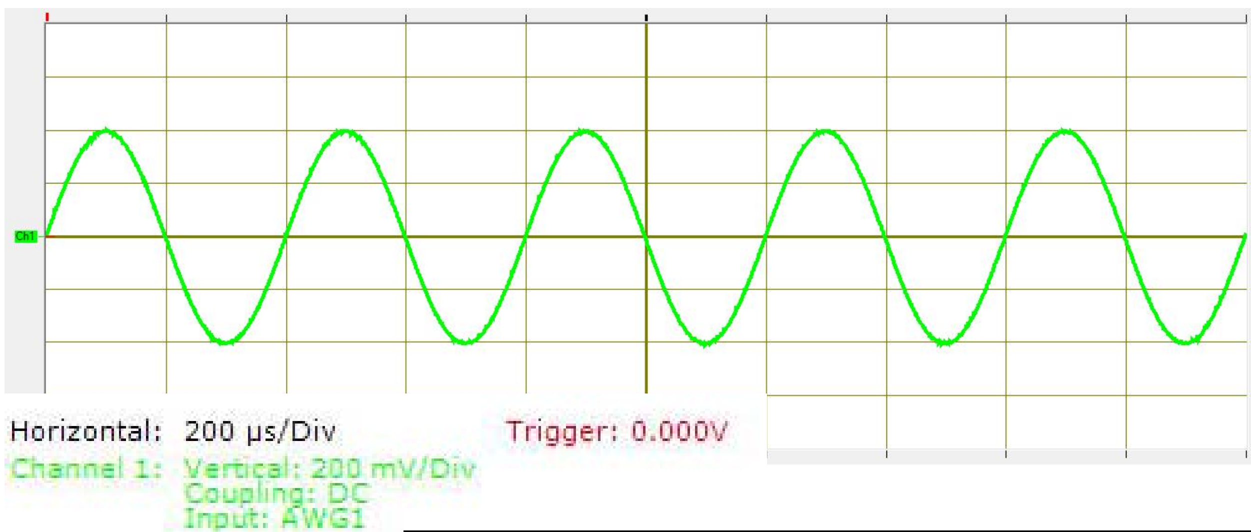


5) Assume that Function Generator 1 is used to generate a 2.5kHz sine wave with peak-to-peak amplitude of **0.8**V and it is connected to Channel 1 of the Oscilloscope. Which of the following four signals will be observed on Channel 1? Explain your choice. (4pts)



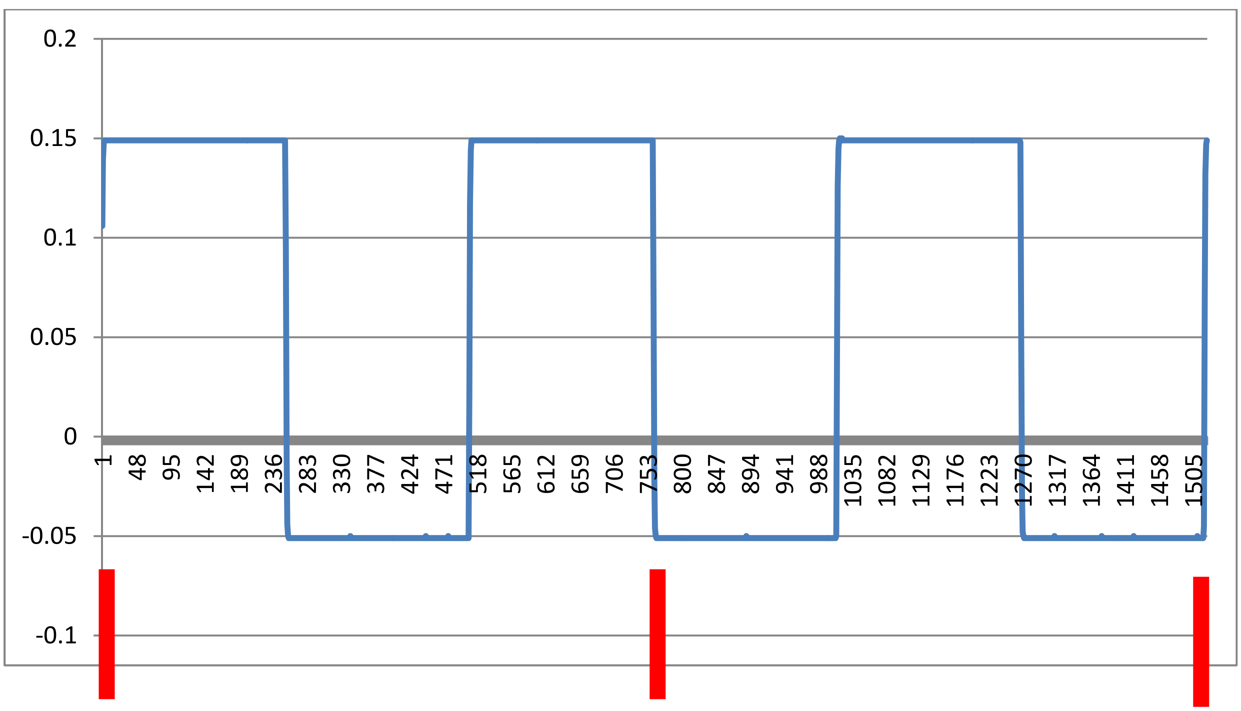
The period is 2ms/5 so f=2.5kHz the pk=pk amplitude is 4 times .5V or 2V





The period is 2ms/5 so f=2.5kHz the pk=pk amplitude is 4 times .2V or .8V

6) Function Generator 1 is modified so that it outputs the wave shown below as it is observed on oscilloscope channel 1, saved as a comma separated file, and then displayed in Excel. The frequency of this wave is 3kHz. The horizontal scale shown in the Excel plot is just the number of points so it does not really tell us anything about the wave. Label the plot with the correct time scale, assuming that t = 0sec occurs at the left end of the plot. Also, recalling that the function generator allows us to specific the phase, waveform, DC Offset and Pk-Pk amplitude (see below for an image of the Function Generator window from the Mobile Studio Desktop), what must be input selections be to obtain the waveform shown? That is, what must be chosen from each of the drop down menus for Waveform, DC Offset and Pk-Pk? Write your answers at the bottom of the page and also label the plot so that anyone looking just at the plot will easily be able to find this information. (8pts)



For a frequency of 3kHz, the period is 0.33ms or 3 cycles is 1ms

0ms 0.5ms 1ms