ENGR-4300

Electronic Instrumentation

Quiz 1

Spring 2012

Name ___________________________

Section ___

Question I (20 points) ____________

Question II (16 points) ____________

Question III (16 points) ____________

Question IV (16 points) ____________

Question V (16 points) ____________

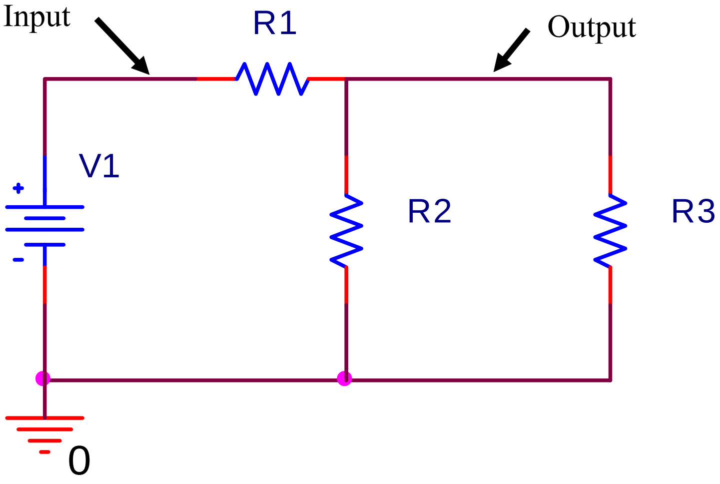
Question VI (16 points) ____________

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. Voltage Dividers (20 points)

This question consists of 10 short problems involving the voltage divider circuit shown below. In each case, V1=42V, but, R1, R2 & R3 are different for each problem.



1) R1=1kΩ, R2=R3→∞ (open circuit) (2 pts)

V_{output} = *42 Volts. Since R2 and R3 are open, there is no current through R1 so no voltage drop across R1.*

2) R1=1kΩ, R2→∞ (open circuit), R3=10MΩ (input impedance of smaller Mobile Studio voltage range). (2 pts)

V_{output} = *42 Volts. Since R2 is open and R3 is so large, the output is* $(R2/(R1+R3))V1 = (10^7/(10^7+10^3))42=42$ *Volts*

3) R1=1kΩ, R2→∞ (open circuit), R3=6kΩ (input impedance of larger Mobile Studio voltage range). (2 pts)

V_{output} = *(6/7)42=36 Volts because the circuit is just a voltage divider consisting of a 1k & a 6k resistor, with the output across the 6k.*

4) R1=1kΩ, R2→∞ (open circuit), R3=0 (short circuit). (2 pts)

V_{output} = *0 Volt because the voltage is always zero across a short circuit.*

5) R1=R2=1kΩ, R3→∞ (open circuit). (2 pts)

V_{output} = *(1/(1+1))42=21 Volts. This is the ideal voltage divider built with two 1k resistors.*

6) R1=R2=1kΩ, R3=10MΩ (input impedance of smaller Mobile Studio voltage range). (2 pts)

V_{output} = *21 Volts. This is practically the same as question 5 because 10MΩ is so much greater than 1kΩ.*

7) R1=R2=1kΩ, R3=6kΩ (input impedance of larger Mobile Studio voltage range). (2 pts)

V_{output} = *19.4 Volts. This is the only part of question 1 that is a little more complicated. The 6k in parallel with 1k is now the net bottom resistor of the voltage divider. That parallel combo is (6/7)kΩ. Thus the output is 42((6/7)/(1+6/7))=42(6/13)=19.4 Volts.*

8) R1=R2=1kΩ, R3=0 (short circuit). (2 pts)

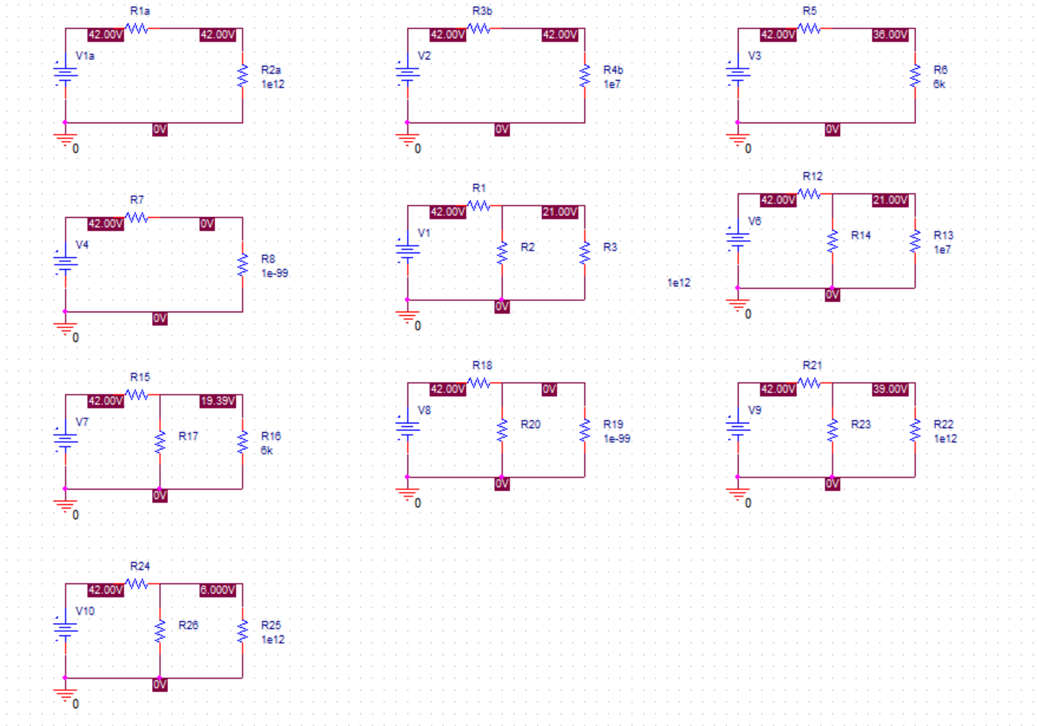
V_{output} = *0 Volt. Same as part 4.*

9) R1=1kΩ, R2=13kΩ, R3→∞ (open circuit). (2 pts)

V_{output} = *(13/14)42=39 Volts*

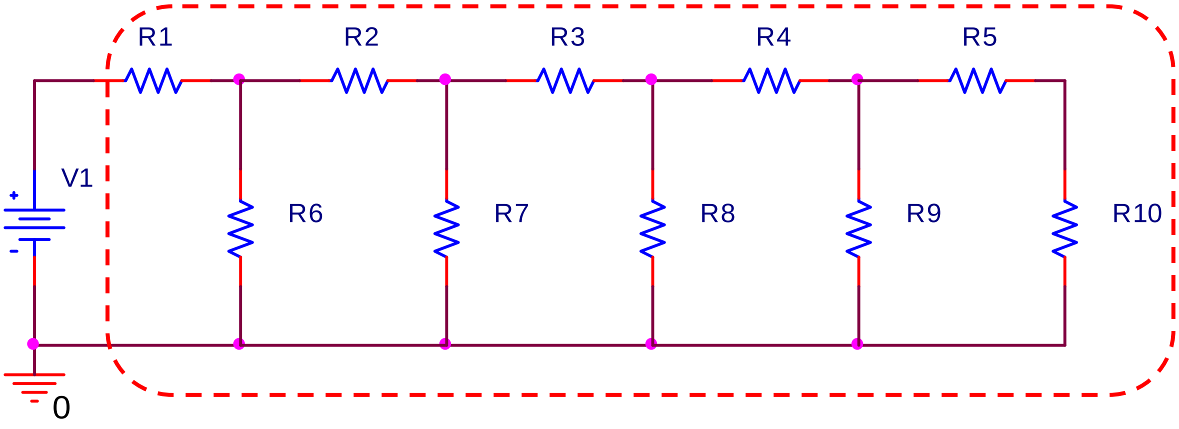
10) R1=1kΩ, R2=167Ω, R3→∞ (open circuit). (2 pts)

V_{output} = *(167/1167)42=6 Volts*



Question II. Resistive circuits (16 points)

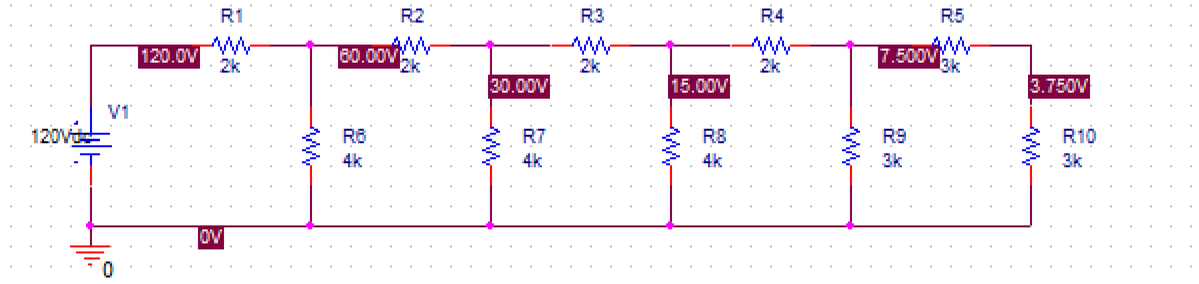
V1=120V, R6=R7=R8=4kΩ, R1=R2=R3=R4=2kΩ, R5=R9=R10=3kΩ



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

*R5+R10=6k, R9||(R5+R10)=((6)(3)/9)k=2k, R8||(R4+2k)=((4)(4)/8)k=2k, R7||(R3+2k)=2k, R6||R2+2k=2k, R1+2k=4k so the total is 4k*Ω

*This can also be confirmed using PSpice. Since the voltage between R1 and R2 is 80V, the resistance of everything to the right of R1 must be equal to R1 or the total is 4k*Ω



2) Find the voltage across R6. (5 pts)

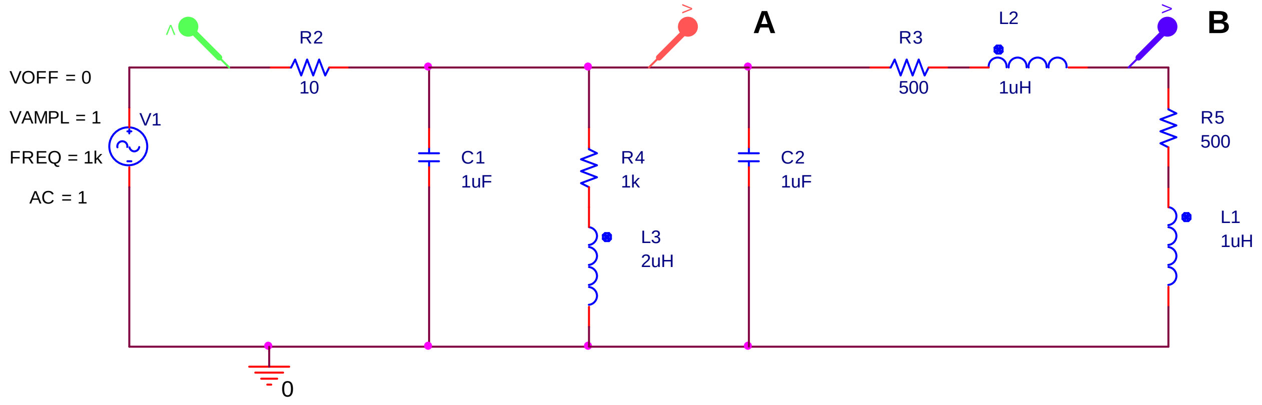
From PSpice the voltage is 60 Volts. To confirm this result, the resistance of everything to the right of R1 is 2k, so the voltage to the left of R2 is 60V (half of 120V).

3) Find the current through R5. (5 pts)

To find the current in R5, we need the rest of the voltages shown in the PSpice result. The resistances to the right of R3 and R4 are also 2k, so the voltage drops by half each time. Thus the voltage to the right of R4 is 7.5V. This voltage drops across two identical 3k resistors so that the voltage to the right of R5 is 3.75V. The current through R5 is thus (7.5-3.75)/3k or 3.75/3mA or ***1.25mA****. This is also confirmed by PSpice.*

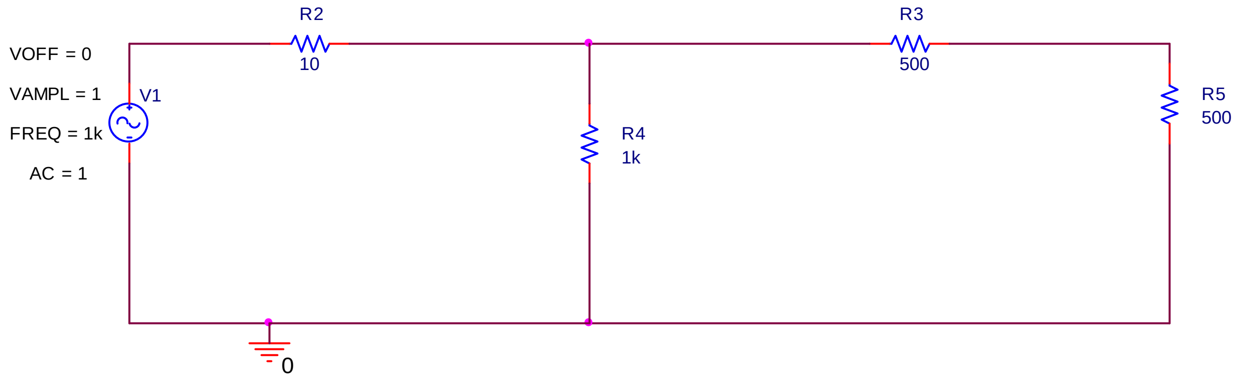
Question III. Filters (16 points)

You are given the following circuit. The input at V1 has the following properties: VAMPL = 1V, Freq = 1kHz, Voff=0V



A. The behavior of this circuit at low frequencies

1) Redraw the circuit at zero (DC) frequency (2 points)



2) What is the amplitude of the voltage at point A at DC? (2 points)

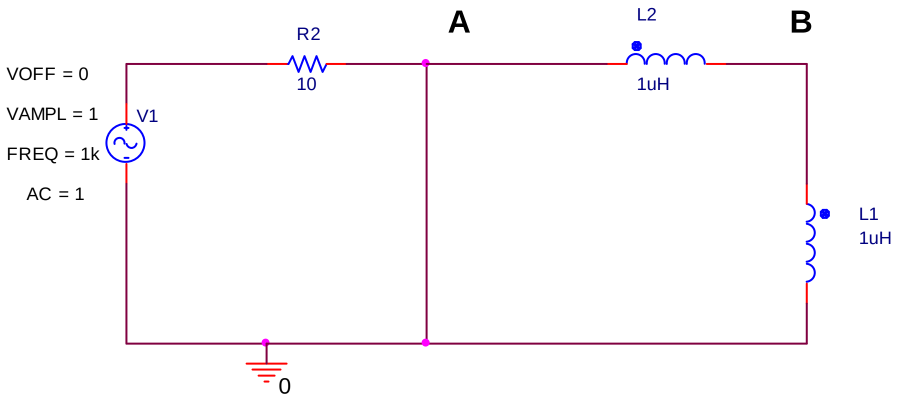
The combination of R4, R3 and R5 is 500Ω so the voltage is almost 1V (0.98V)

3) What is the amplitude of the voltage at point B at DC? (2 points)

Because of the two 500Ω resistors, the voltage will divide equally, so about 0.5V

B. The behavior of the circuit at very, very high ($f \rightarrow \infty$) frequencies

1) Redraw the circuit at infinite frequencies (2 points)



or the voltage at A is shorted to ground and the voltage at B is connected through the infinite but equal inductive impedances. Note that at ∞ frequencies, it is still necessary to keep the inductors in the circuit since voltage division can still take place. Otherwise the voltage at B is undetermined rather than zero as it is here. This is a subtle point that is probably beyond the scope of this course, but asking the question allows us to determine if anyone has a more advanced level of understanding.

2) What is the amplitude of the voltage at point A at infinite frequencies? (2 points)

0V

3) What is the amplitude of the voltage at point B at infinite frequencies? (2 points)

Also 0V because it will be half of A.

C. Is this a filter?

1) What type of filter could this be at point A (circle one)? (2 points)

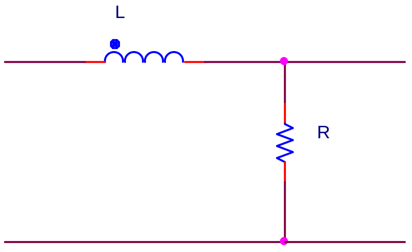
[✓ Low Pass] High Pass Neither

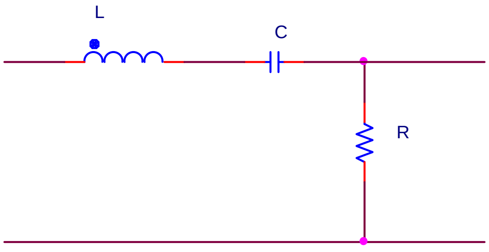
2) What type of filter could this be at point B (circle one)? (2 points)

[✓ Low Pass] High Pass Neither

This connection at A makes a better filter.

Question IV – Transfer Functions (16 points)





Circuit A Circuit B

A. Transfer Functions

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

$$H_A(j\omega) = \frac{R}{R + j\omega L}$$

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

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

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

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

$$H_{BLO}(j\omega) = \frac{j\omega RC}{1 + j\omega RC - \omega^2 LC} \approx \frac{j\omega RC}{1} = j\omega RC$$

$$\left|H_{BLO}(j\omega)\right| \approx \left|j\omega RC\right| = \omega RC$$

$$\angle H_{BLO}(j\omega) \approx \angle j\omega RC = \frac{\pi}{2}$$

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

$$H_{BHI}(j\omega) = \frac{j\omega RC}{1 + j\omega RC - \omega^2 LC} \approx \frac{j\omega RC}{-\omega^2 LC} = \frac{R}{j\omega L} = -j\frac{R}{\omega L}$$

$$\left|H_{BHI}(j\omega)\right| \approx \left|-j\frac{R}{\omega L}\right| = \frac{R}{\omega L}$$

$$\angle H_{BHI}(j\omega) \approx \angle\left(-j\frac{R}{\omega L}\right) = -\frac{\pi}{2}$$

3) What type of filter is circuit B? *Explain your answer.* (2 point)

Band pass. The output is very small (approaching zero at both high and low frequencies. At the resonant frequency, $H_B(j\omega) = \frac{j\omega RC}{1 + j\omega RC - \omega^2 LC} = \frac{j\omega RC}{j\omega RC} = 1$ *so the input is reproduced at the output.*

C. If L=1mH and R=100Ω, what are the magnitude and phase of the transfer function of circuit A at its corner frequency? (2 points)

The corner frequency is $\omega = \frac{R}{L}$. *The transfer function for A is*

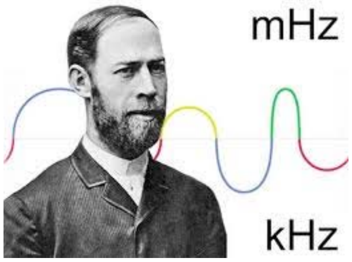
$H_A(j\omega) = \frac{R}{R + j\omega L} = \frac{R}{R + jR} = \frac{1}{1+j} = \frac{1}{1+j}\frac{1-j}{1-j} = \frac{1-j}{2}$ *so it does not matter what the values of R or L actually are. The magnitude is* $\left|H_A(j\omega)\right| = \left|\frac{1-j}{2}\right| = .707$ *and the phase angle is*

$$\angle H_A(j\omega) = \angle\frac{1-j}{2} = -\frac{\pi}{4}$$

D. Extra Credit (2 points)

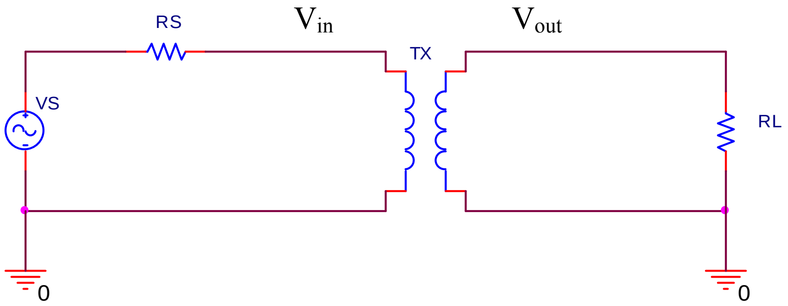
Today is the birthday of a famous German scientist. Google has noted his birth date on its search engine page (see image below). Hint: we have named the units of frequency after him.

Heinrich Rudolf Hertz



Question V – Signals, Transformers and Inductors (16 points)

Two different configurations are to be compared. Both have the same source with amplitude VS = 600V, frequency = 1kHz, RS = 10Ω. The transformer is ideal with full coupling.



1) With RL = 90Ω and L2/L1=9, find Vin, Vout, and the power in RL. (6 pts)

$$a = \frac{V_2}{V_1} = \frac{I_1}{I_2} = \sqrt{\frac{L_2}{L_1}} = \sqrt{9} = 3 \quad Z_{in} = \frac{Z_L}{a^2} = \frac{Z_L}{9} = \frac{90}{9} = 10\Omega$$

V_S is divided by the combination of R_S & Z_{in} so that V_{in} is half V_S or 300V.

$V_{out} = aV_{in} = 900V$ *The power delivered to the load is* $P_L = \frac{V_L^{\,2}}{R_L} = \frac{900^2}{90} = 9000W$ *Note that since there is no power delivered to the transformer, one can also calculate the power to the load by finding the power delivered to Z_{in}.* $P_L = \frac{V_{in}^{\,2}}{Z_{in}} = \frac{300^2}{10} = 9000W$

2) With RL = 10Ω and L2/L1 = 1, what are the new values for Vin, Vout, and the power in RL? (6 pts)

$$a = \frac{V_2}{V_1} = \frac{I_1}{I_2} = \sqrt{\frac{L_2}{L_1}} = \sqrt{1} = 1 \quad Z_{in} = \frac{Z_L}{a^2} = \frac{Z_L}{1} = \frac{10}{1} = 10\Omega$$

V_S is divided by the combination of R_S & Z_{in} so that V_{in} is half V_S or 300V.

$V_{out} = aV_{in} = 300V$ *The power delivered to the load is* $P_L = \frac{V_L^{\,2}}{R_L} = \frac{300^2}{10} = 9000W$ *Note that since there is no power delivered to the transformer, one can also calculate the power to the load by finding the power delivered to Z_{in}.* $P_L = \frac{V_{in}^{\,2}}{Z_{in}} = \frac{300^2}{10} = 9000W$

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 1kHz? (4 pts)

a) 1μH

b) 10μH

c) 100μH

b) 1mH

[✓ c) 10mH]

d) 100mH

e) 1H

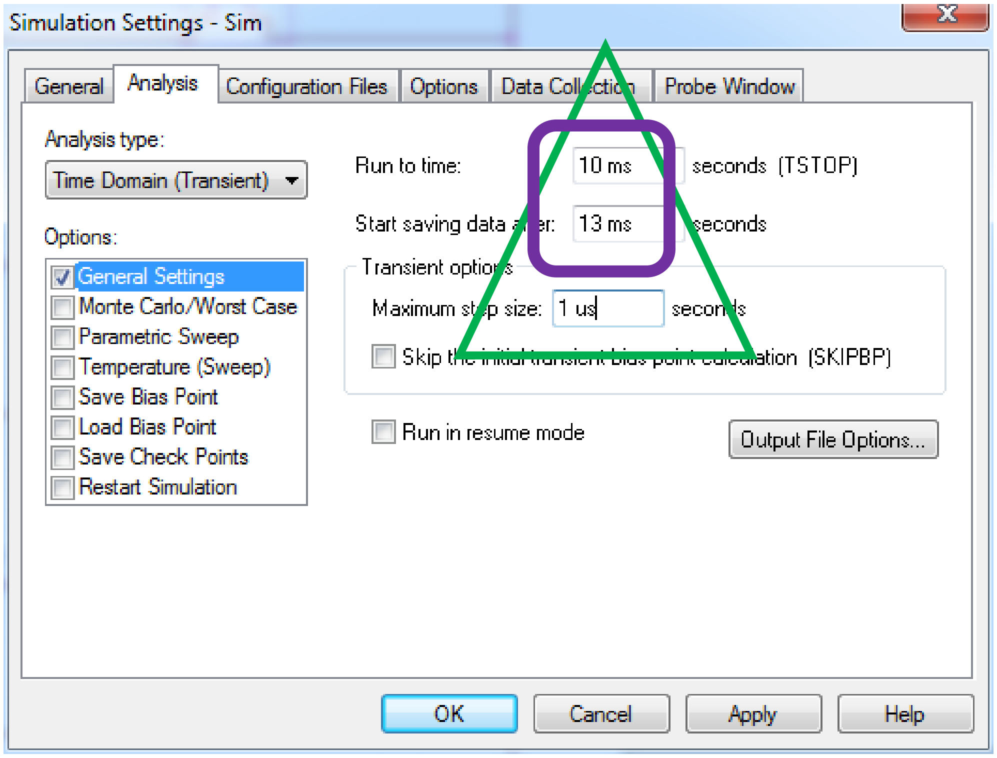
f) 10H

g) 500H

To function as a transformer, the inductive impedance must be significantly larger than the resistive impedance. Thus,
$L >> \frac{R}{\omega} = \frac{10}{2\pi 1000} = \frac{10}{2\pi}$ *mH so 10mH is a good choice.100mH is also not totally unreasonable, so 3 points for that answer.*

Question VI – Instrumentation, PSpice and components (16 points)

1) Identify the two errors in the simulation profile shown below. (4 pts)



Analysis type: Time Domain (Transient)

Run to time: 10 ms seconds (TSTOP)

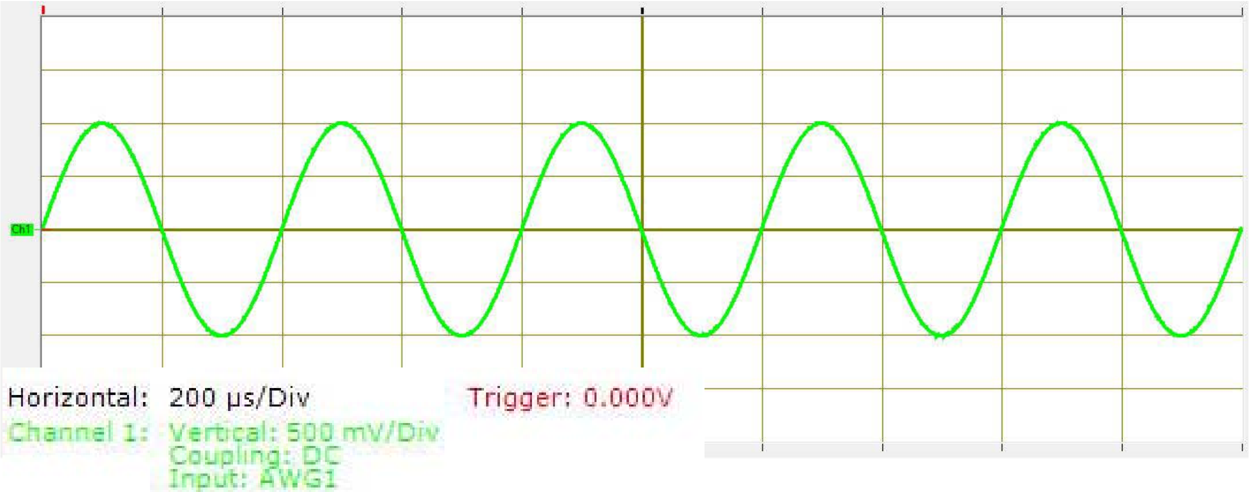
Start saving data after: 13 ms seconds

Maximum step size: 1 us seconds

One: there is a space between the number and the units.

Two: the start saving time is after the run to time so nothing will be done.

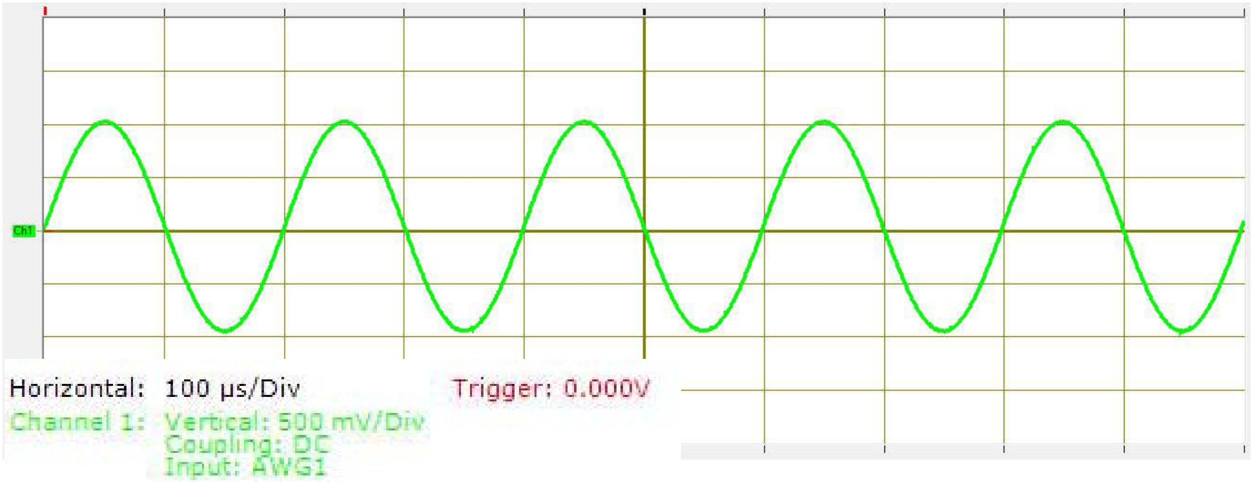
2) Assume that Function Generator 1 is used to generate a 2.5kHz sine wave with peak-to-peak amplitude of 0.8V and it is connected to Channel 1 of the Oscilloscope. Which of the following four signals will be observed on Channel 1? Explain your choice. (4pts)



Horizontal: 200 µs/Div

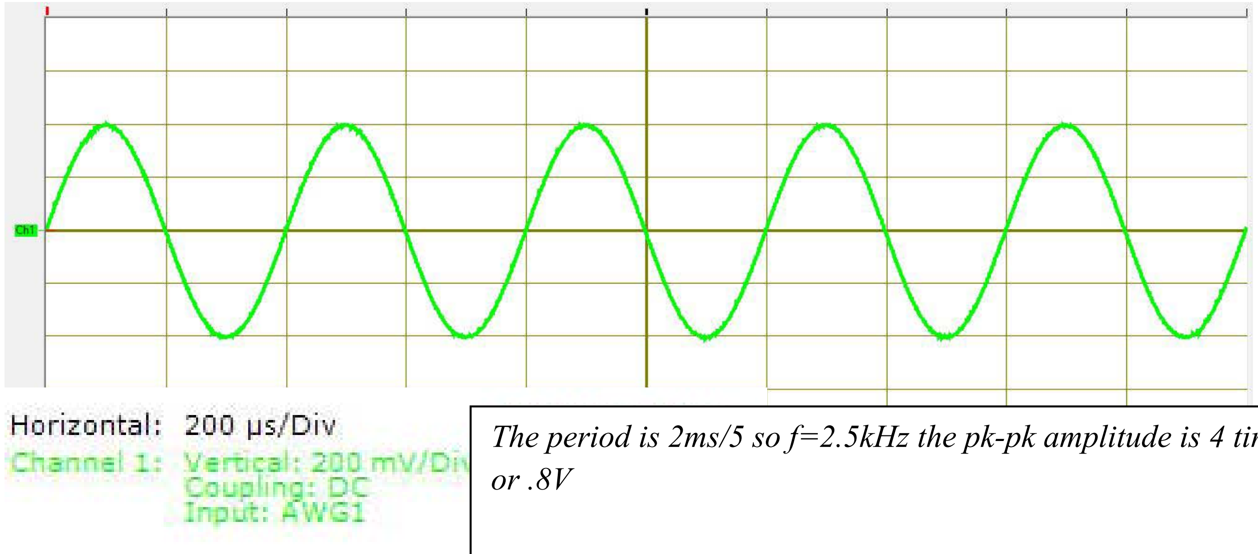
Trigger: 0.000V

Channel 1: Vertical: 500 mV/Div
Coupling: DC
Input: AWG1



Horizontal: 100 µs/Div Trigger: 0.000V
Channel 1: Vertical: 500 mV/Div
Coupling: DC
Input: AWG1

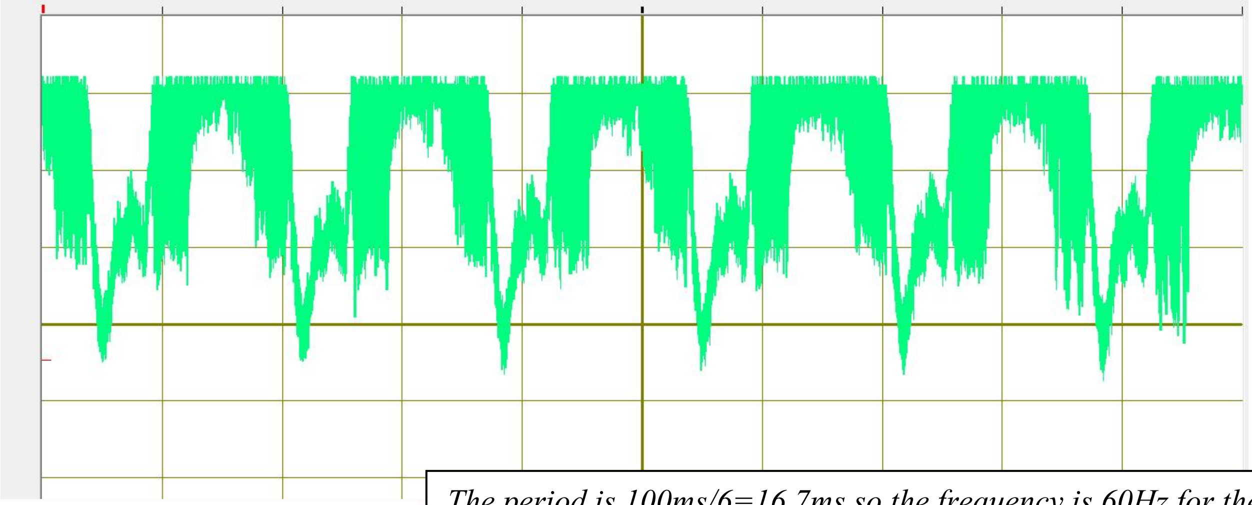
Horizontal: 100 µs/Div Trigger: 0.000V
Channel 1: Vertical: 500 mV/Div
Coupling: DC
Input: AWG1



Horizontal: 200 µs/Div
Channel 1: Vertical: 200 mV/Div
Coupling: DC
Input: AWG1

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

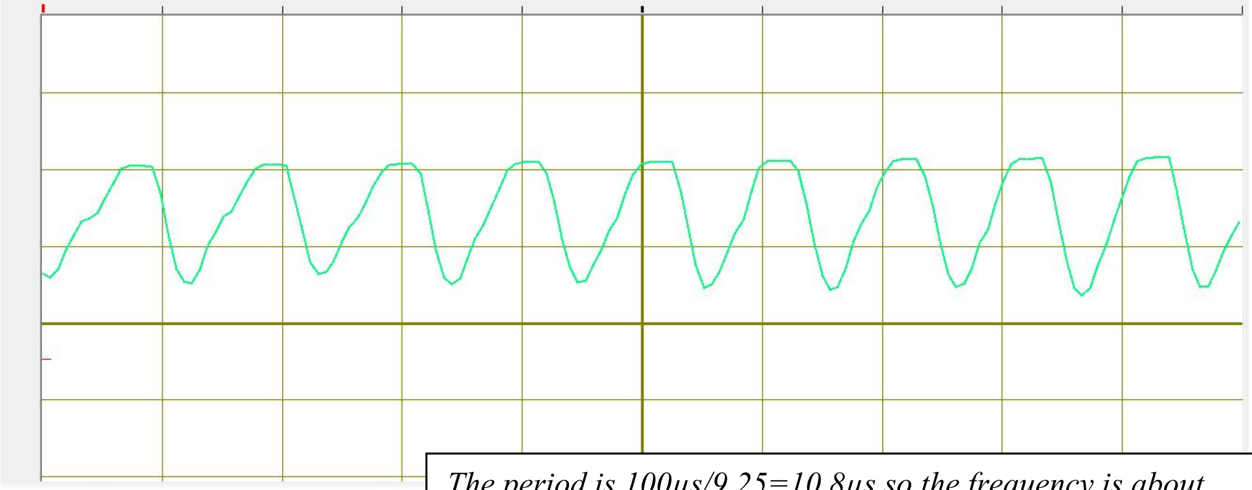
3) There is a problem with the circuit you have built and connected to your Mobile Studio IOBoard. Instead of seeing a nice 1kHz sine wave on channel 1 of the oscilloscope, you see the following signal instead. (4 pts)



Horizontal: 10.0 ms/Div
Channel 1: Vertical: 500 mV/Div
Coupling: DC
Input: A1 SE

The period is 100ms/6=16.7ms so the frequency is 60Hz for the main component. This is the power line frequency.

Because there seems to be both a low frequency and a high frequency component to this signal, you display it again with a different time scale.



Horizontal: 10.0 µs/Div
Channel 1: Vertical: 500 mV/Div
Coupling: DC
Input: A1 SE

The period is 100µs/9.25=10.8µs so the frequency is about 93kHz for the high frequency component.

What are the values of the two frequencies? Note that both signals are probably distorted somewhat but you should be able to identify the fundamental frequency in each case. Identify the source of the lower frequency.

See above.

4) What are the values of the following resistors? (4 pts)

Brown, Black, Red

*R=1k*Ω

Orange, Orange, Orange

*R=33k*Ω