

ENGR-2300

Electronic Instrumentation

Quiz 1

Spring 2013

Name _____

Section ____



Question I (25 points) _____

Question II (25 points) _____

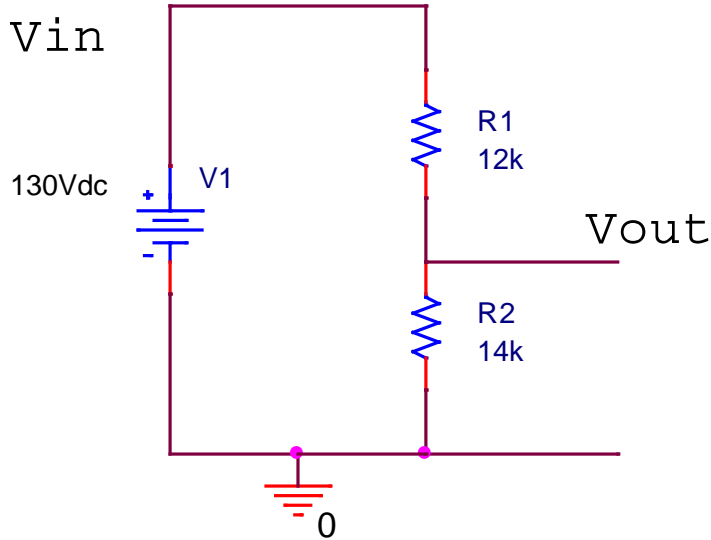
Question III (25 points) _____

Question IV (25 points) _____

Total (100 points) _____

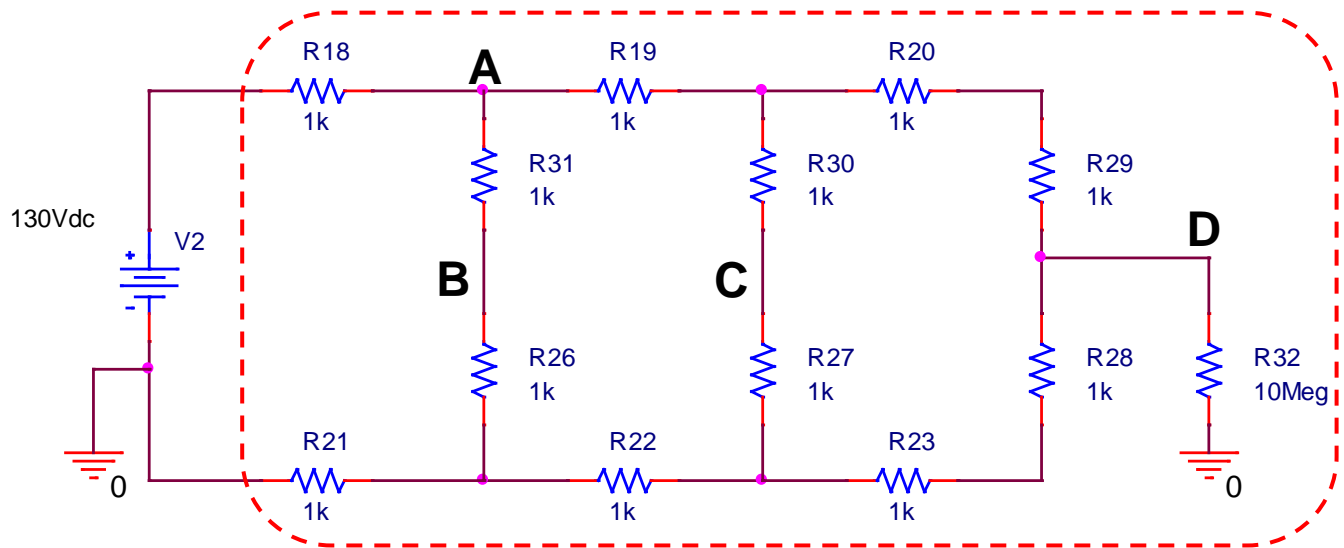
On all questions: **SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS.** No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

I. Resistive circuits (25 points)



a) Find the voltage V_{out} in the circuit above. (4 pts)

$$V_{out} = V_{in} \left(\frac{R2}{R1 + R2} \right) = 130 \frac{14}{26} = 70V$$



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)

Combined R at C is $R_C = \frac{(4k)(2k)}{6k} = 1.333k$ & R at B is $R_B = \frac{(3.333k)(2k)}{5.333k} = 1.25k$ so that

$R_{IN} = 2k + 1.25k = 3.25k$ is the resistance seen from the voltage source.

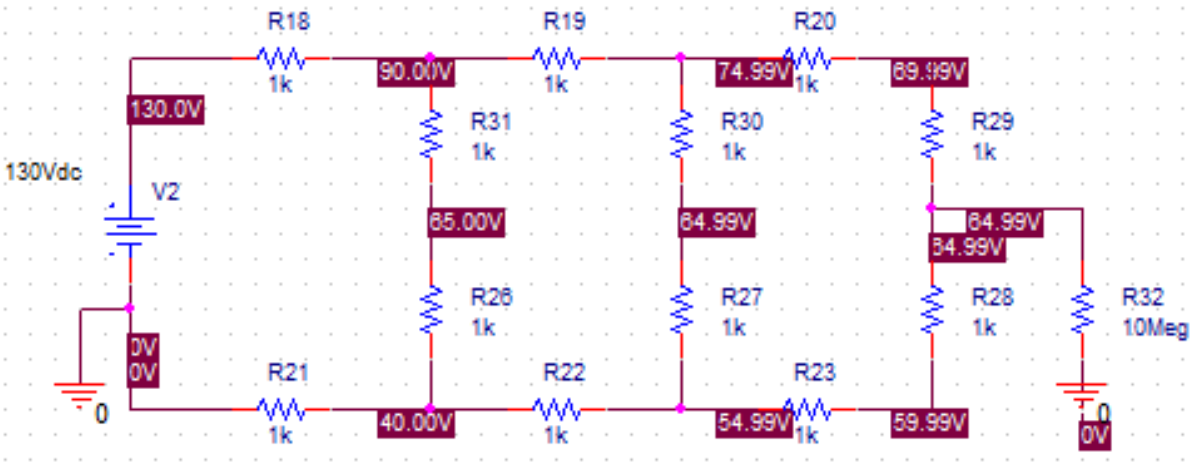
c) Find the voltages at the points A, B, C and D. (8 pts)

The voltage at A is $V_A = \frac{2250}{3250}130 = 90V$

The voltage at B is $V_B = 130/2 = 65V$

The voltage at C is $V_C = 130/2 = 65V$

The voltage at D is $V_D = 130/2 = 65V$



d) Find the current drawn from the 130V DC voltage source. (2 pts)

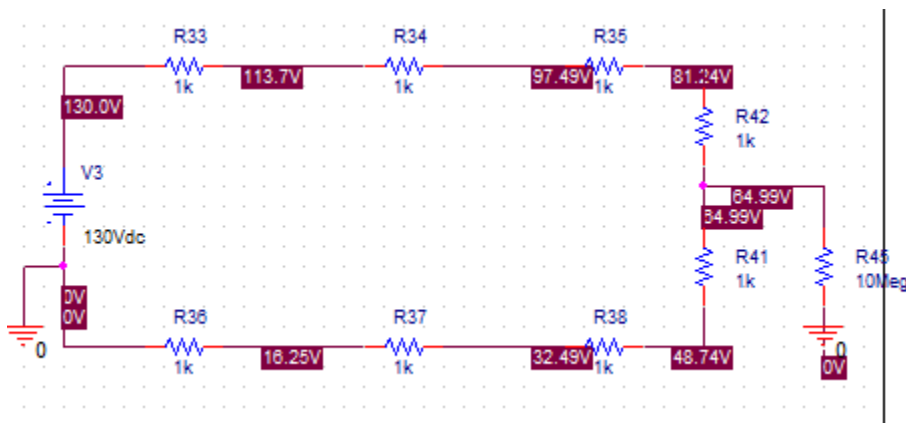
$$I_{source} = 130/3.25k = 40mA$$

The previous circuit is modified by removing the connections between resistors R31 and R26 and between resistors R30 and R27. That is, the circuit becomes open at points B and C.

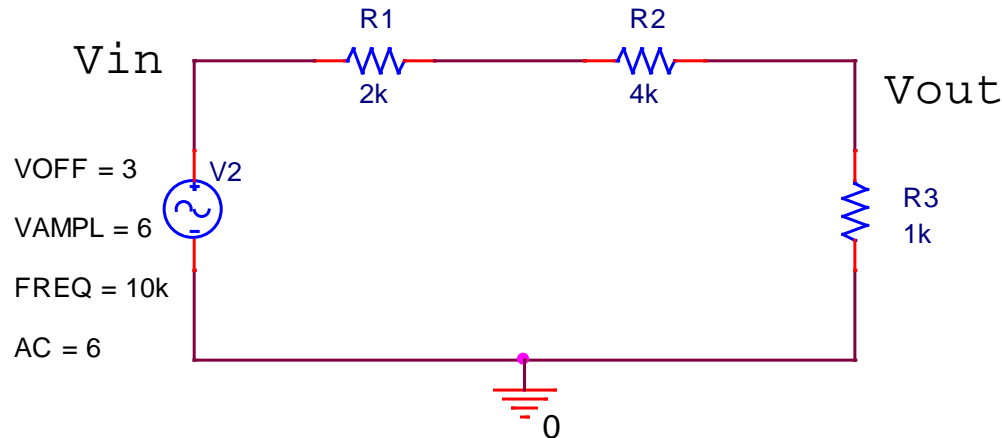
The circuit becomes a series combination of eight 1k resistors.

e) Find the voltages at points A and D and the total current from the source. (6 pts)

The voltage at D is still half of 130V or 65V & The voltage at A is $V_A = \frac{7000}{8000}130 = 113.75V$



II. Filters & Transfer Functions (25 points)



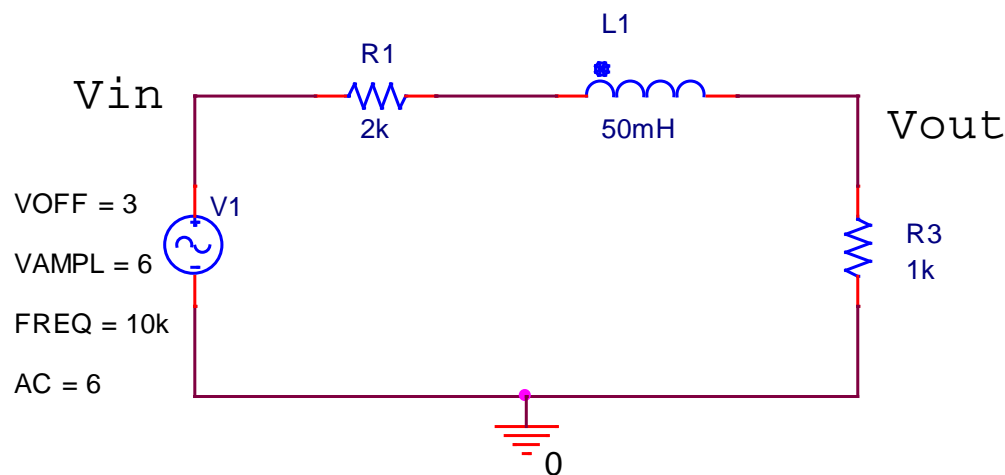
a) Find the transfer function V_{out}/V_{in} for the resistive circuit shown above. Note that output is measured across $R3$. (2 pts)

$$V_{out} = V_{in} \left(\frac{R3}{R1 + R2 + R3} \right) = 0.1429$$

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

$$V_{out} = (3 + 6 \sin \omega t) V_{in} = 0.4286 + 0.8571 \sin \omega t \quad \& \quad \omega = 2\pi 10000 = 20000\pi = 62832$$

The previous circuit is modified by replacing the second resistor with and inductor.



c) Find the transfer function V_{out}/V_{in} for the new circuit. Write it first in general form $H(j\omega)$ in terms of ω , $R1$, $R3$, and $L1$ and then plug in the given numerical values. (4 pts)

$$\frac{V_{out}}{V_{in}} = \frac{R3}{R1 + j\omega L1 + R3} = \frac{1k}{3k + j\omega 0.05} = \frac{1000}{3000 + j3141.6} = \frac{1}{3 + j\pi} \frac{3 - j\pi}{3 - j\pi} = \frac{3 - j\pi}{9 + \pi^2} = 2.33 - j2.44$$

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

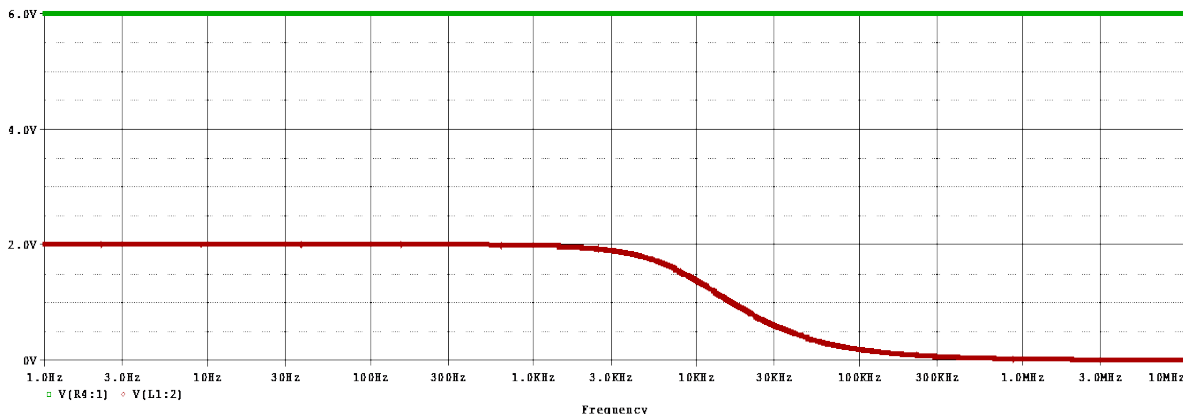
$$H_{low}(j\omega) = ? = \frac{V_{out}}{V_{in}} = \frac{R3}{R1 + j\omega L1 + R3} = \frac{1k}{3k + j\omega 0.05} \approx \frac{1}{3} = 0.33333$$

$$H_{high}(j\omega) = ? = \frac{V_{out}}{V_{in}} = \frac{R3}{R1 + j\omega L1 + R3} = \frac{1k}{3k + j\omega 0.05} \approx \frac{20000}{j\omega}$$

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

At low frequencies, the inductor approaches a short and the circuit is a two resistor divider.

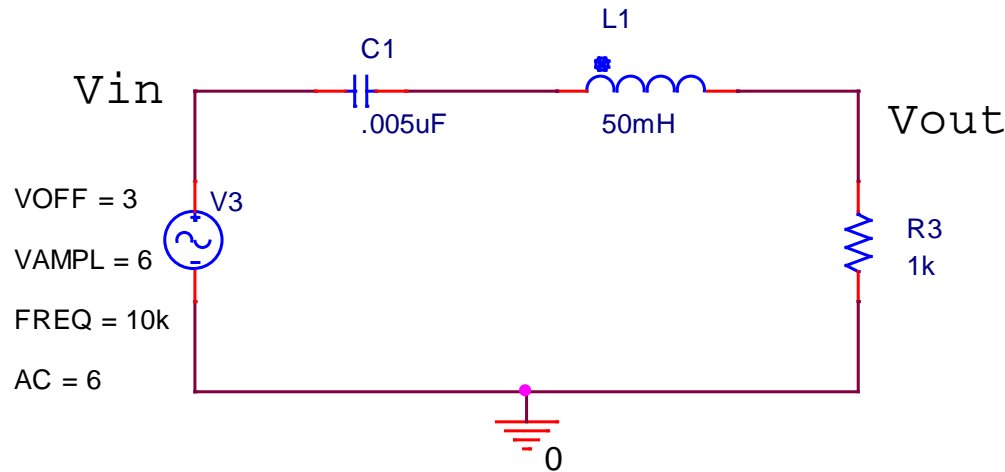


f) What kind of filter response would best represent this circuit if the positions of the inductor and resistor $R3$ are reversed? (Please circle one.) (2 pts) *Hint: Sketch the new circuit diagram.*

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

At high frequencies, the inductor approaches an open circuit. With no current through the resistors, the voltage drop across them is zero.

The resistor R1 is now replaced by a capacitor.



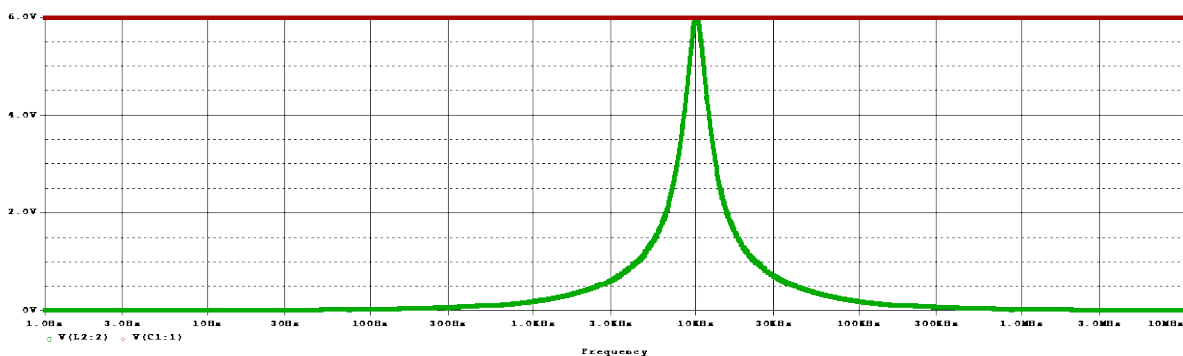
g) Find the transfer function V_{out}/V_{in} for the new circuit. Write it first in general form $H(j\omega)$ in terms of ω , $R3$, $L1$, and $C1$ and then plug in the given numerical values. (4 pts)

$$V_{out}/V_{in} = \frac{R3}{1/j\omega C1 + j\omega L1 + R3} = \frac{1k}{1/j\omega 5nF + j\omega 0.05 + 1k}$$

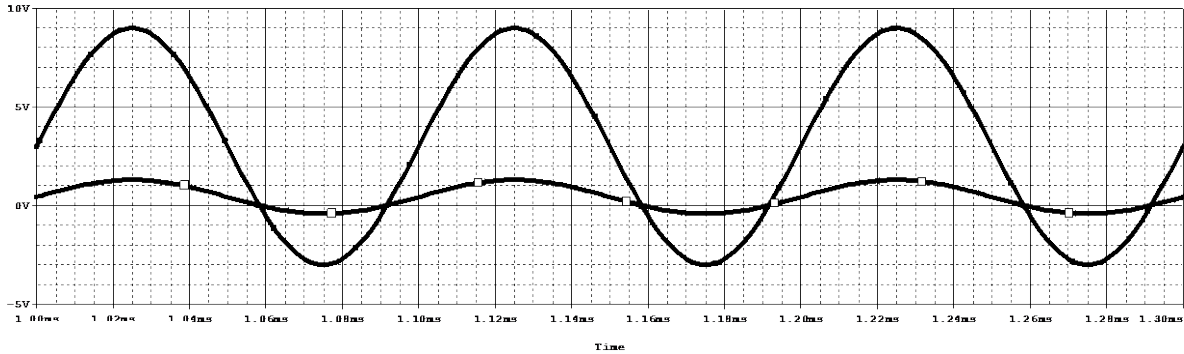
h) Determine the corner frequency f_c for the circuit with the inductor and resonant frequency f_r for the circuit with the inductor and capacitor. Find the numerical values, not just the general expression. (2 pts)

Inductor f_c : 9.55kHz (this checks with the AC sweep shown above)

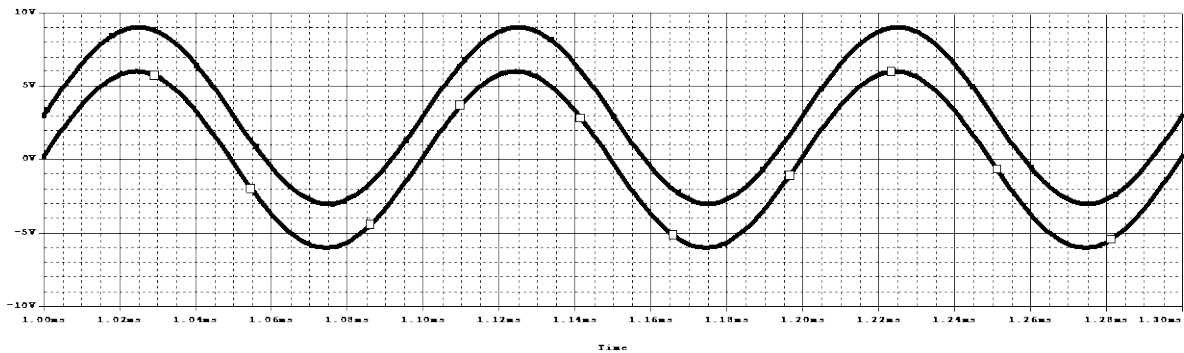
Inductor/Capacitor f_r : 10kHz (this checks with the AC sweep shown below)



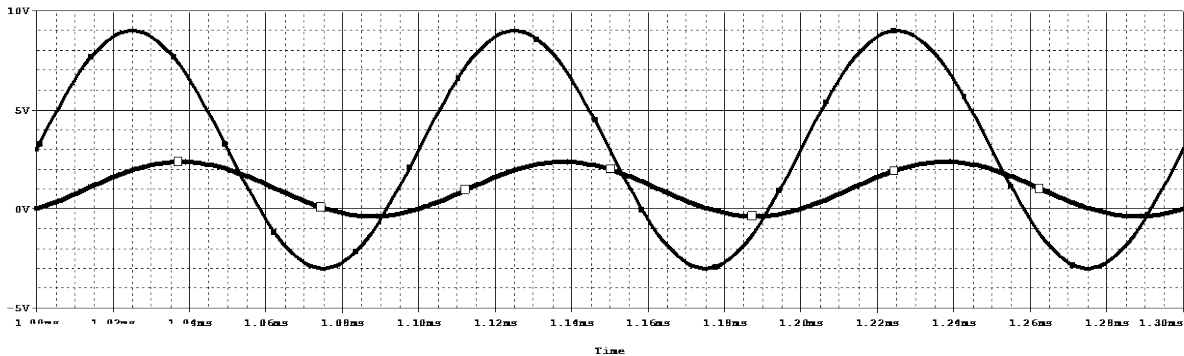
h) On this page are the input and output voltages for the three circuit configurations considered in this problem ($3R$, $2R+L$, $R+L+C$). Label which plot goes with which circuit and explain your answer. (3 pts)



This is the $3R$ circuit because V_{in} and V_{out} are in phase and both have offsets.

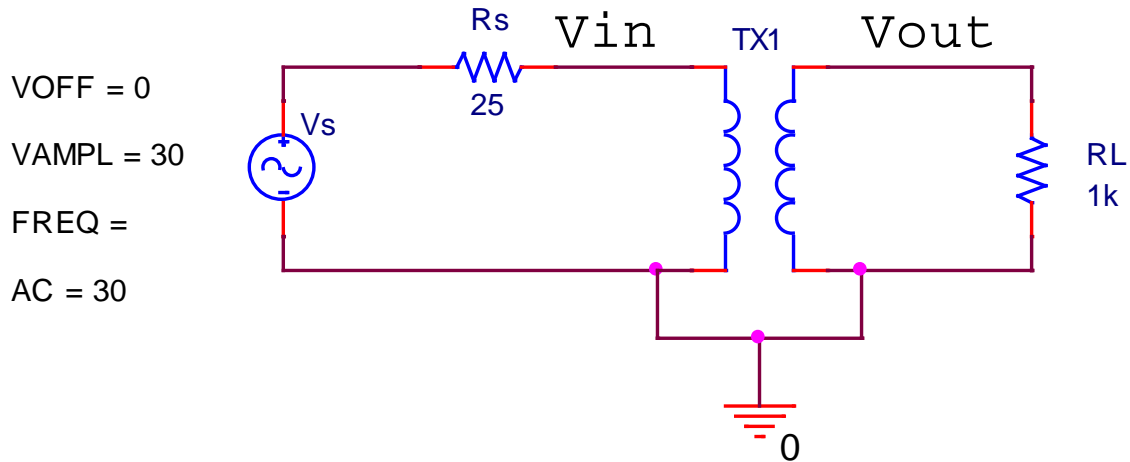


This is the $R+L+C$ circuit because the peak-to-peak output is the same size as the input without the offset. The C and L do not allow the offset to pass to the output.



This is the $2R+L$ circuit because of the phase shift and the offset. It is also the only one left after the first two were identified.

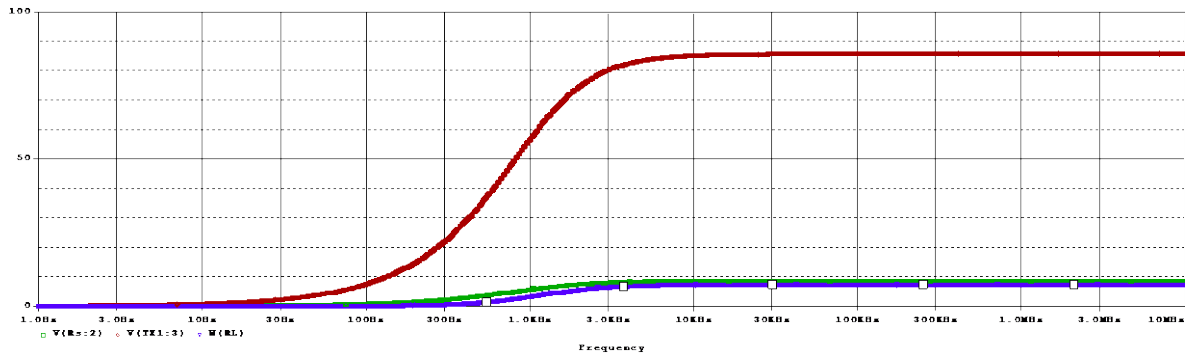
III – Signals, Transformers and Inductors (25 points)



- a) Given the circuit above, assume an ideal transformer with full coupling. With $R_s = 25\Omega$, $R_L = 1k\Omega$, $L_1 = 1mH$, and $L_2 = 100mH$, find V_{in} , V_{out} , and the power in R_L . (6 pts)

$$a = \sqrt{\frac{L_2}{L_1}} = 10 \quad Z_{IN} = \frac{R_L}{a^2} = \frac{1000}{100} = 10 \quad V_{IN} = \frac{Z_{IN}}{R_s + Z_{IN}} 30 = \frac{10}{35} 30 = 8.57V$$

$$V_{out} = 10V_{IN} = 85.7V \text{ and the power in } R_L \text{ is } P_L = \frac{V_{out}^2}{R_L} = \frac{85.7^2}{1000} = 7.35W$$



- b) For which of the following frequencies will the transformer work for the given component values? Explain your answer. (4 pts)

10Hz 30Hz 100Hz 300Hz 1kHz 3kHz 10kHz 30kHz 100kHz 300kHz

From the PSpice plot we can see that we get reasonable transformer action from about 10kHz

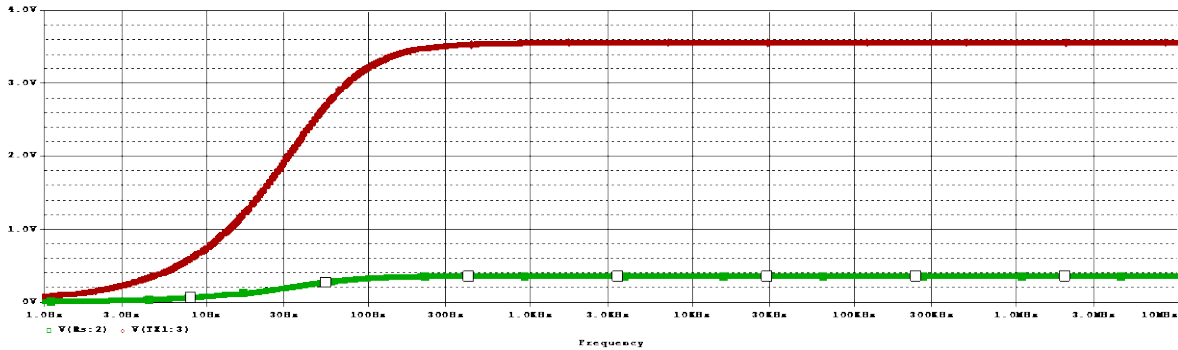
up. To calculate this, we need $f \gg \frac{R}{2\pi L} = \frac{1000}{2\pi \cdot 0.1} = 1592Hz$ so 10kHz will work. If 5% error is

the condition or 20 times is the rule, then 30kHz. Your answer must state your condition.

- c) What is the largest load impedance that permits the transformer to work at 300Hz?
Explain your answer. (4 pts)

.1Ω 3Ω 1Ω 3Ω 10Ω 30Ω 100Ω 300Ω 1kΩ 3kΩ 10kΩ

Again, the answer depends on the requirement. If \gg means 20 times, the condition is quite stringent. It is not necessary to go so high, but if you state your condition, and it is reasonable, then your answer will be what it is.

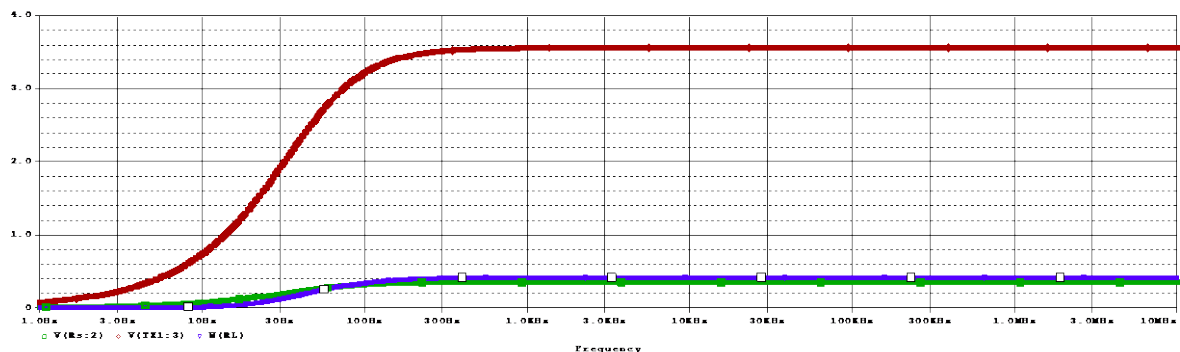


From the graph above, 300ohms is fine. From calculations, $R \ll 2\pi(300)(0.1) = 189$ so R is 6 times smaller at 300ohms, so that is OK.

- d) For this load resistance and frequency, what are the new values for V_{in} , V_{out} , and the power in RL? (6 pts)

$$e) a = \sqrt{\frac{L_2}{L_1}} = 10 \quad Z_{IN} = \frac{RL}{a^2} = \frac{30}{100} = .3 \quad V_{IN} = \frac{Z_{IN}}{R_S + Z_{IN}} 30 = \frac{.3}{25.3} 30 = .356V$$

$$V_{out} = 10V_{IN} = 3.56V \text{ and the power in RL is } P_L = \frac{V_{out}^2}{RL} = \frac{3.56^2}{30} = 422mW$$



- f) You decide to build this transformer by winding 24 gauge wire, in a single layer, on a long cylinder with a 5cm radius. This wire has a diameter of 0.51mm. Using the ideal long solenoid inductance formula, determine how many turns you will need for both the primary and secondary. $\mu_o = 4\pi \times 10^{-7}$ S/m. How many turns will be required and approximately how long must the solenoid be? (5 pts)

Using the ideal formula, $L = \frac{\mu_o N^2 r_c}{d}$, determine the properties of the larger inductor, since it will dominate the design. The length of the inductor $d = Nd_w$ where d_w is the wire diameter.

$$\text{Thus, } L = \frac{\mu_o N^2 r_c}{Nd_w} = \frac{\mu_o N r_c}{d_w} \text{ or } N = \frac{d_w L}{\mu_o r_c} = \frac{(0.00051)(.1)}{\mu_o (0.05)} = 5,167 \text{ and}$$

$d = \text{length} = (5167)(.00051) = 2.64m$ which is, indeed, long. Checking the answer,

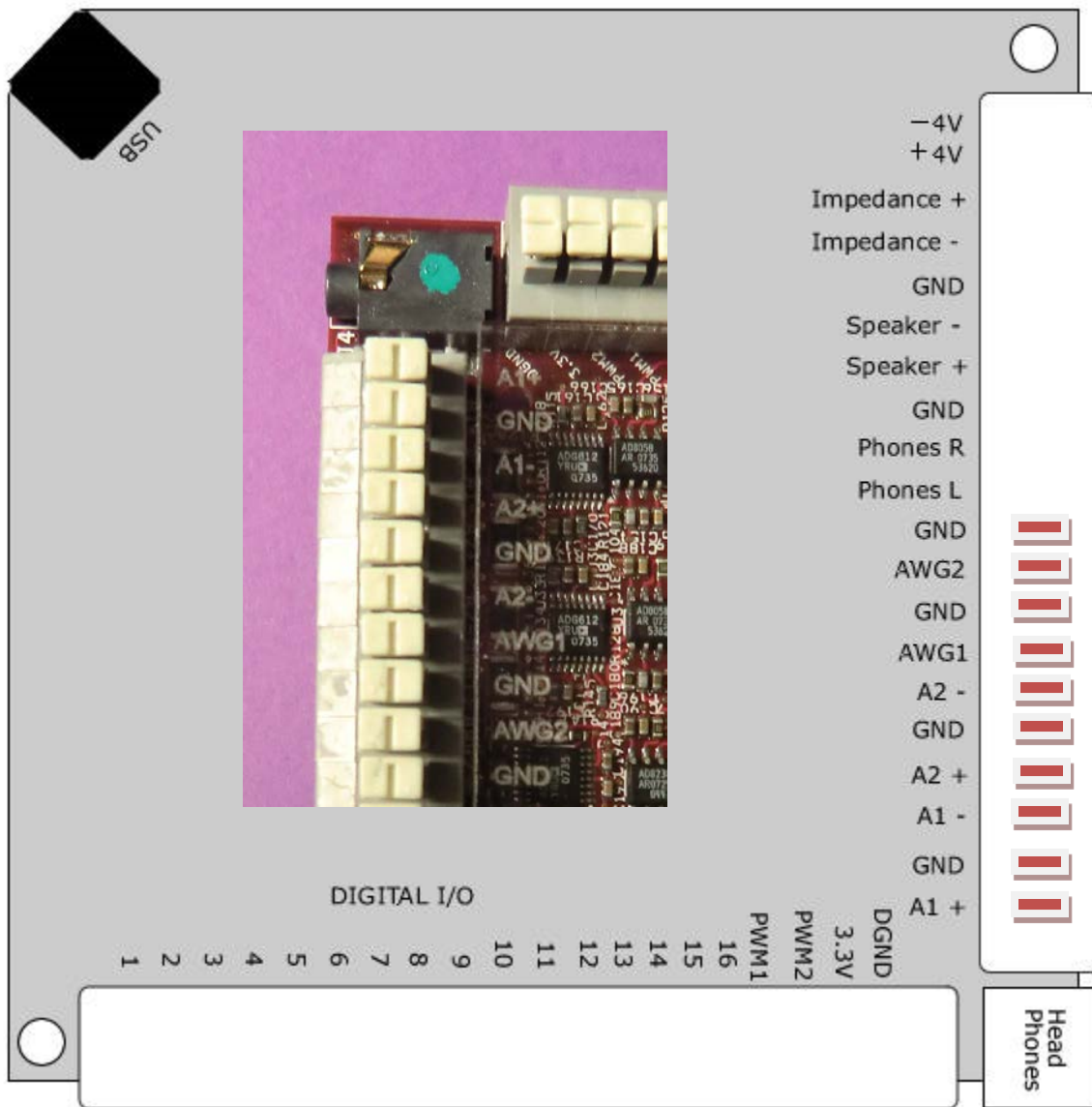
$$L = \frac{\mu_o N^2 r_c}{d} = \frac{\mu_o (5167)^2 (0.05)}{2.64} = 0.1H = 100mH$$

Note that in this problem, the assumption is that the two windings must have the same length d which means that the primary winding must be loosely wound rather than tightly wound. The question on the length refers to the shortest possible length d , which is the tightly wound winding with the largest number of terms. The assumption that the length of the windings must be the same to use the PSpice formula is not stated in the problem, so we are flexible in the answers we will accept for the length.

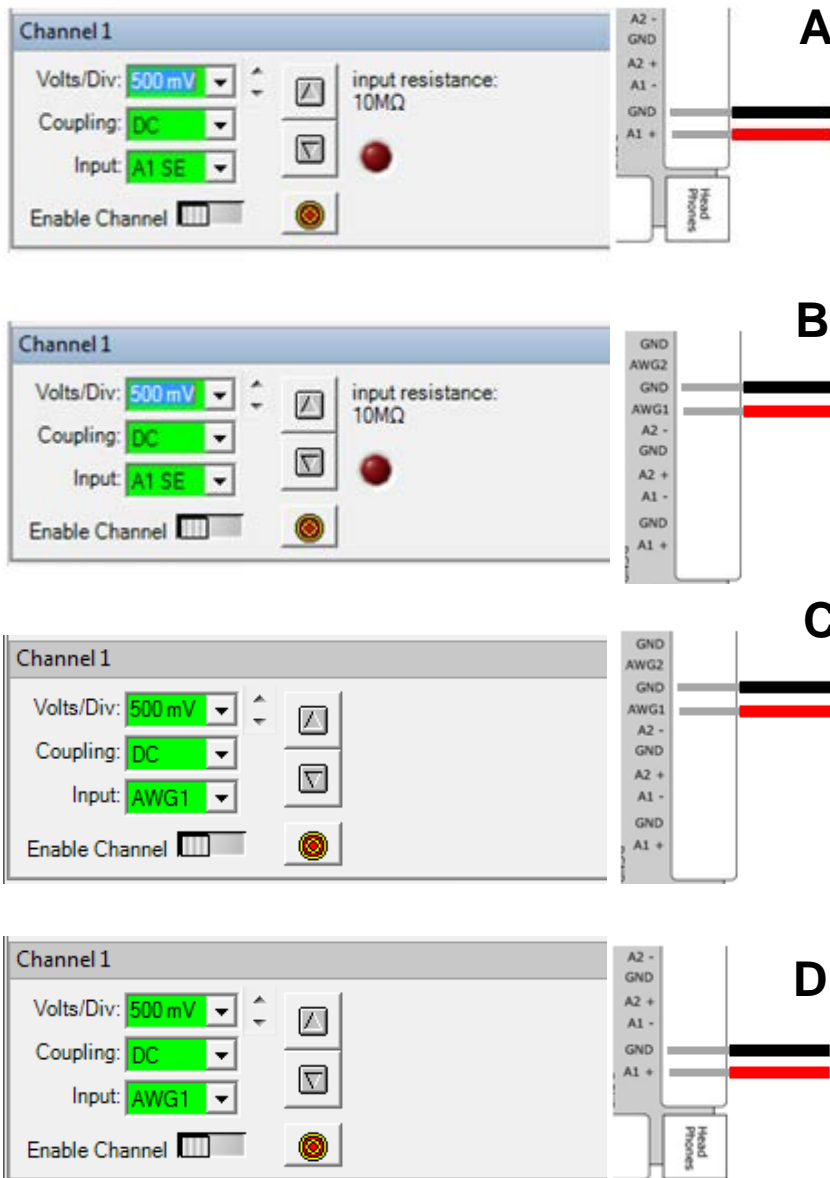
Extra (not included in the problem, but added here for completeness):

To see if the transformer still works, we have to see what the resistance of the coil is. Using the resistance formula, we find that R is about 1320ohms. This means that the frequency cannot be as low as 300Hz because the coil resistance is too high.

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



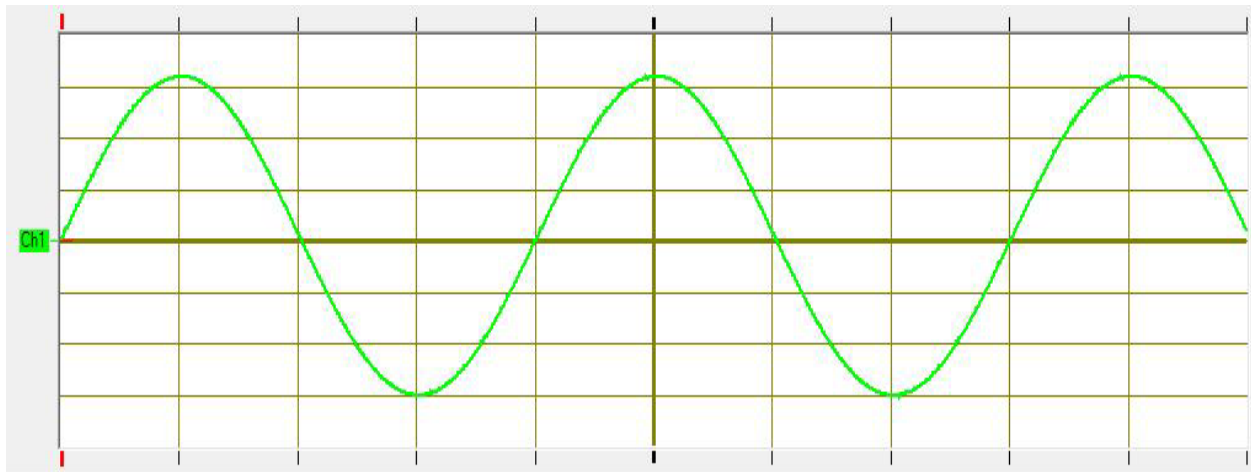
Shown above is the pinout diagram for the Mobile Studio. Shown also at the right are the 10 input/output connections we have used so far in the course. The insert in the figure is a photo of the relevant part of the Mobile Studio board.



- a) 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. (4 pts)

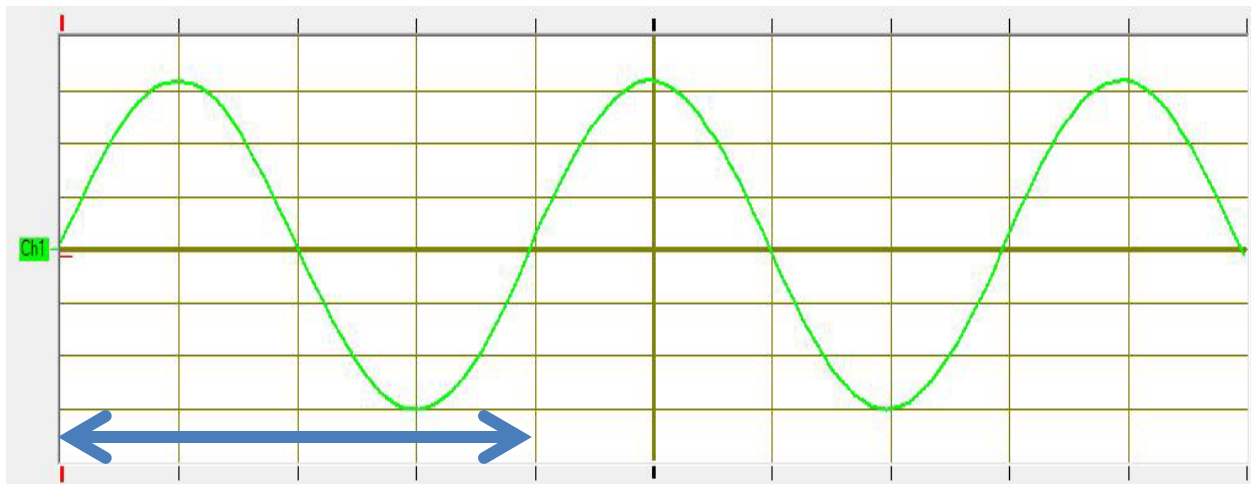
A because we need to connect to the proper input connections (A1+ and GND) and tell Mobile Studio to display the signal from A1+ (A1 SE)

- b) Shown below are two Mobile Studio measurements of sine waves. Which of the two waves has a frequency of 25kHz? Label the correct plot and explain your answer. (4 pts)



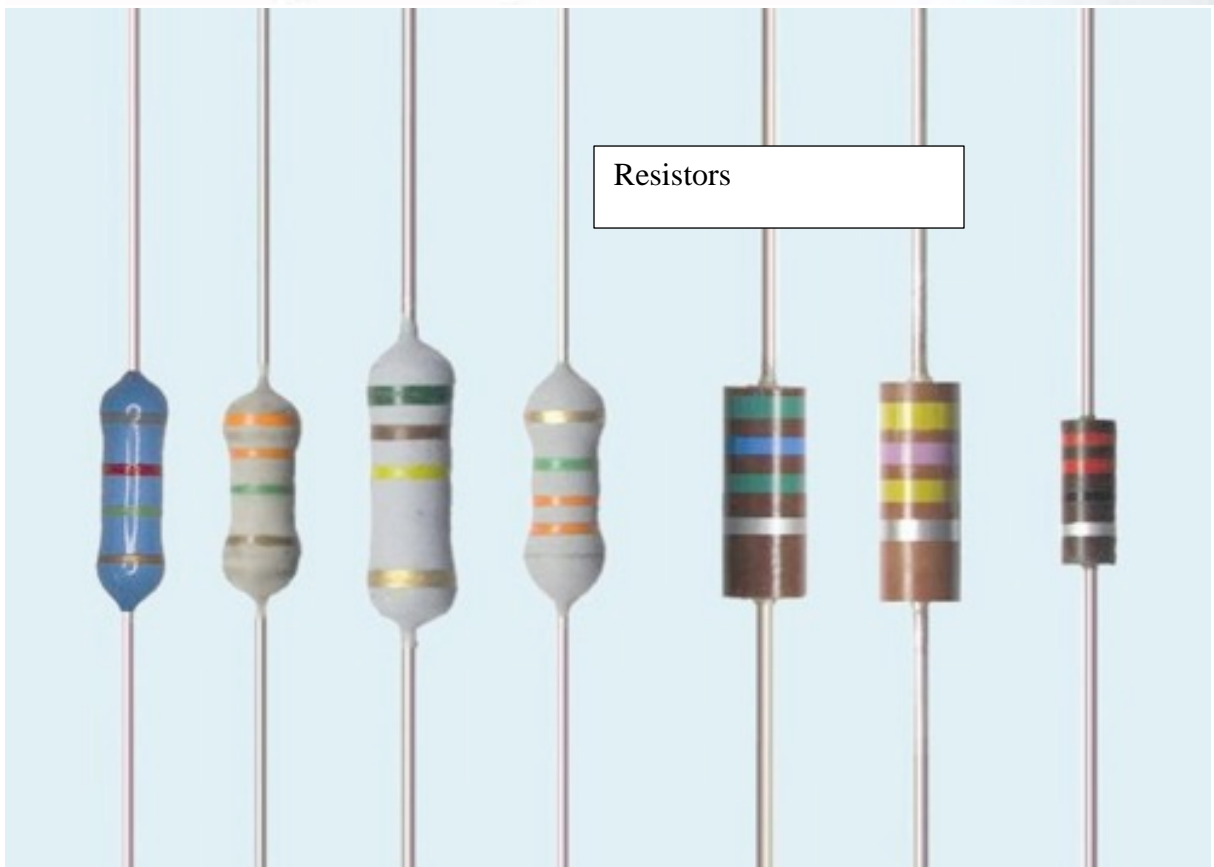
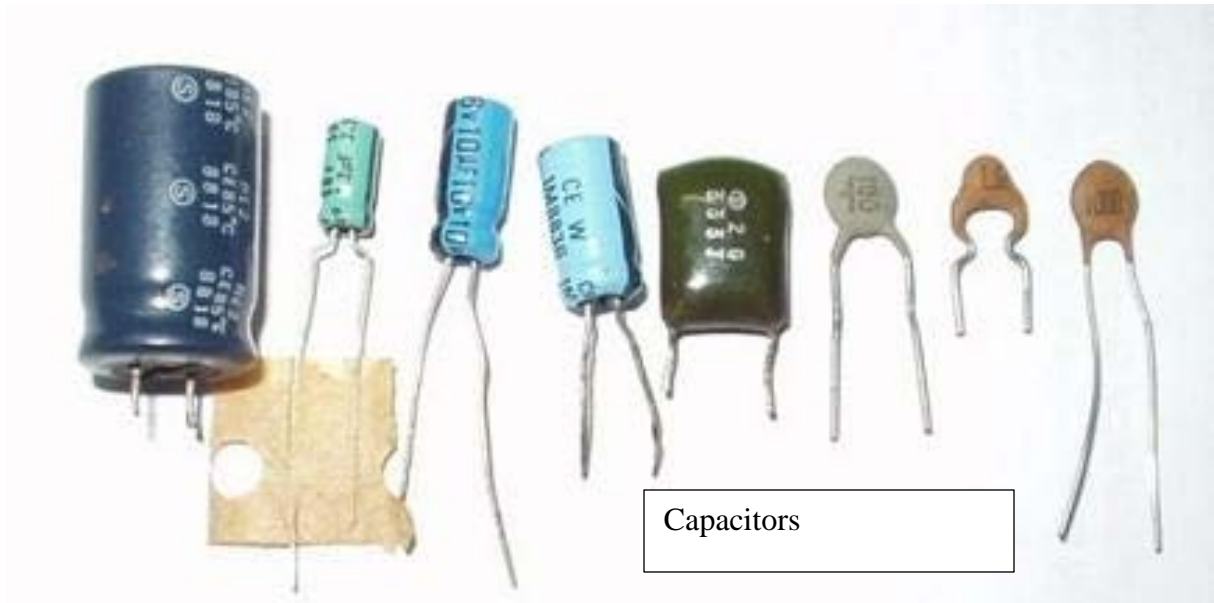
Horizontal: 100 μ s/Div
 Channel 1: Vertical: 500 mV/Div
 Coupling: DC
 Input: AWG1

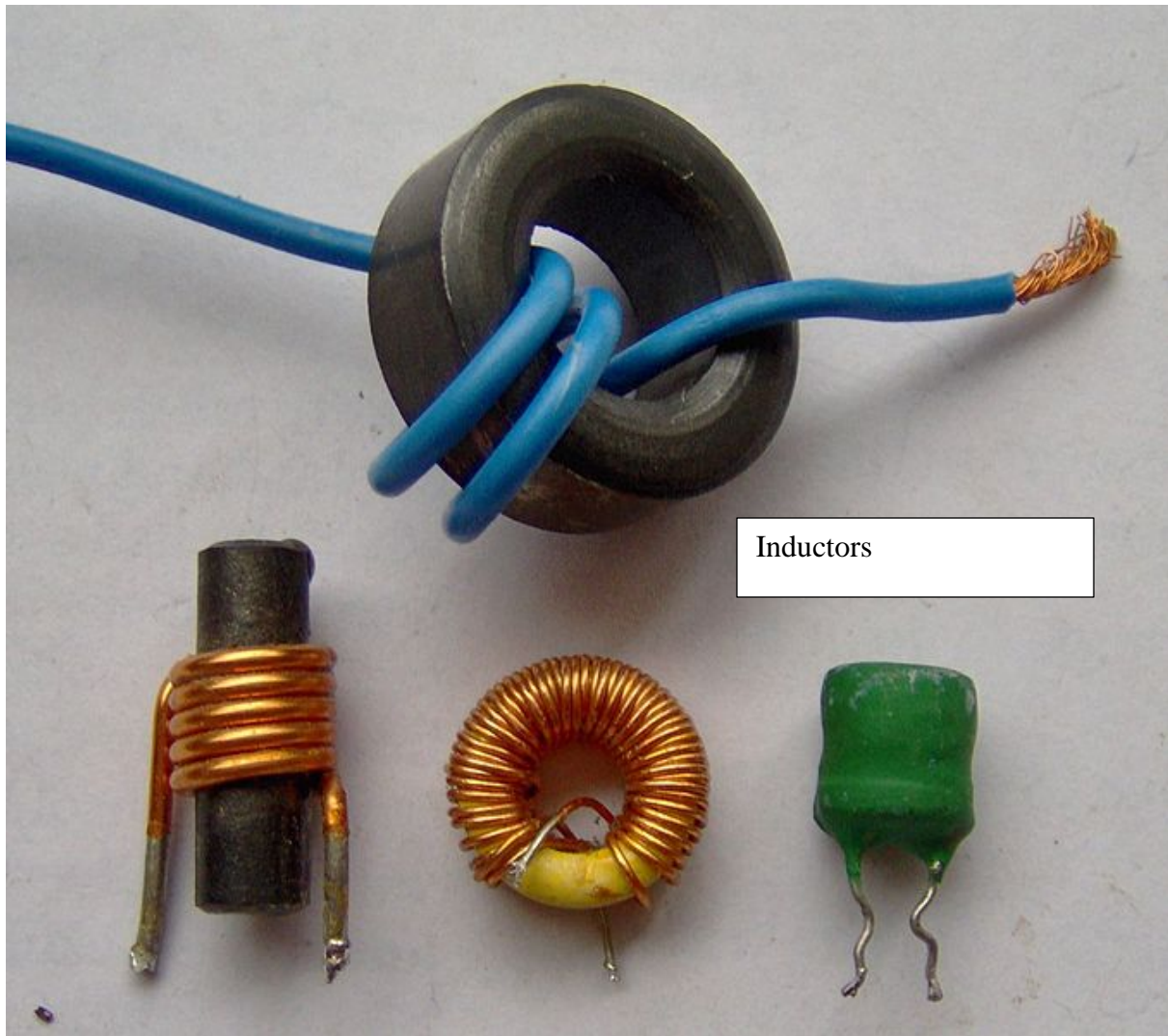
The period for 25kHz is $1/25000 = 40\mu$ s so the correct plot is the one below, where the period is shown by the arrow.



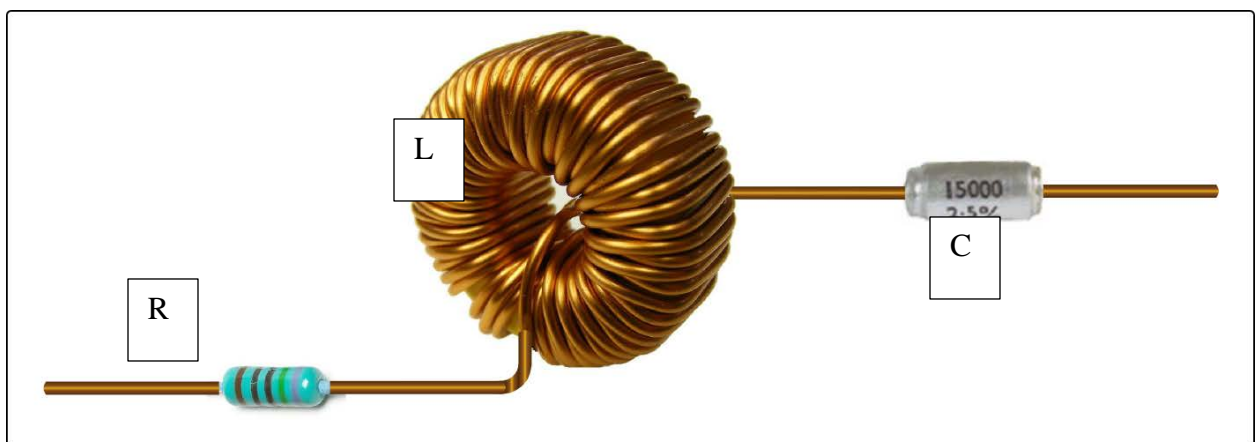
Horizontal: 10.0 μ s/Div
 Channel 1: Vertical: 500 mV/Div
 Coupling: DC
 Input: AWG1

- c) You are to build a circuit using resistors, inductors and capacitors. Which of the following figures shows a collection of resistors? Which shows capacitors? Which shows inductors? Label each one. (3 pts)





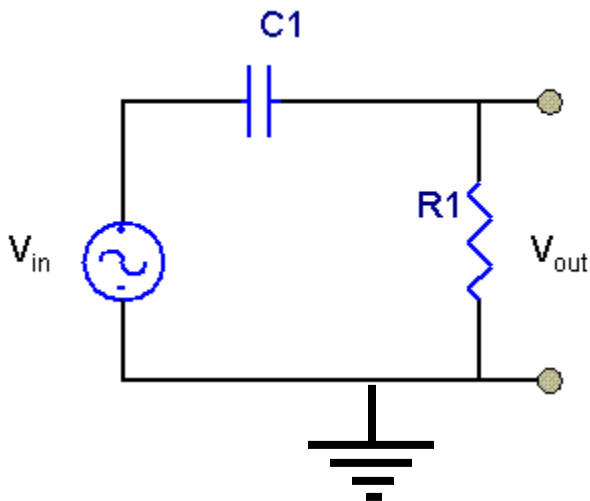
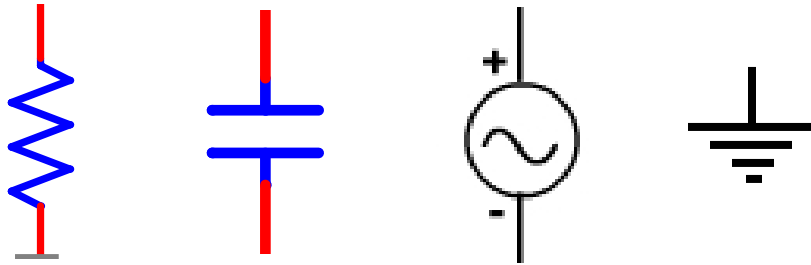
The following diagram shows a circuit made with one each of the three types of components. Label the capacitor, the resistor and the inductor. (2 pts)



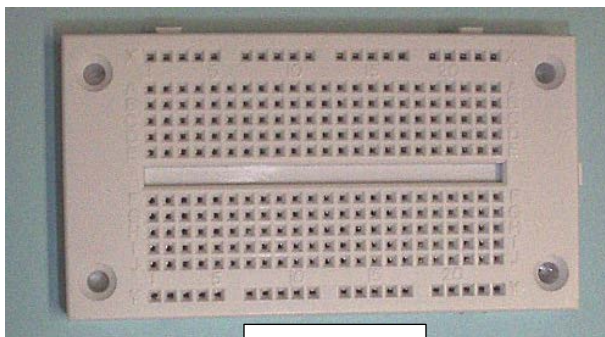
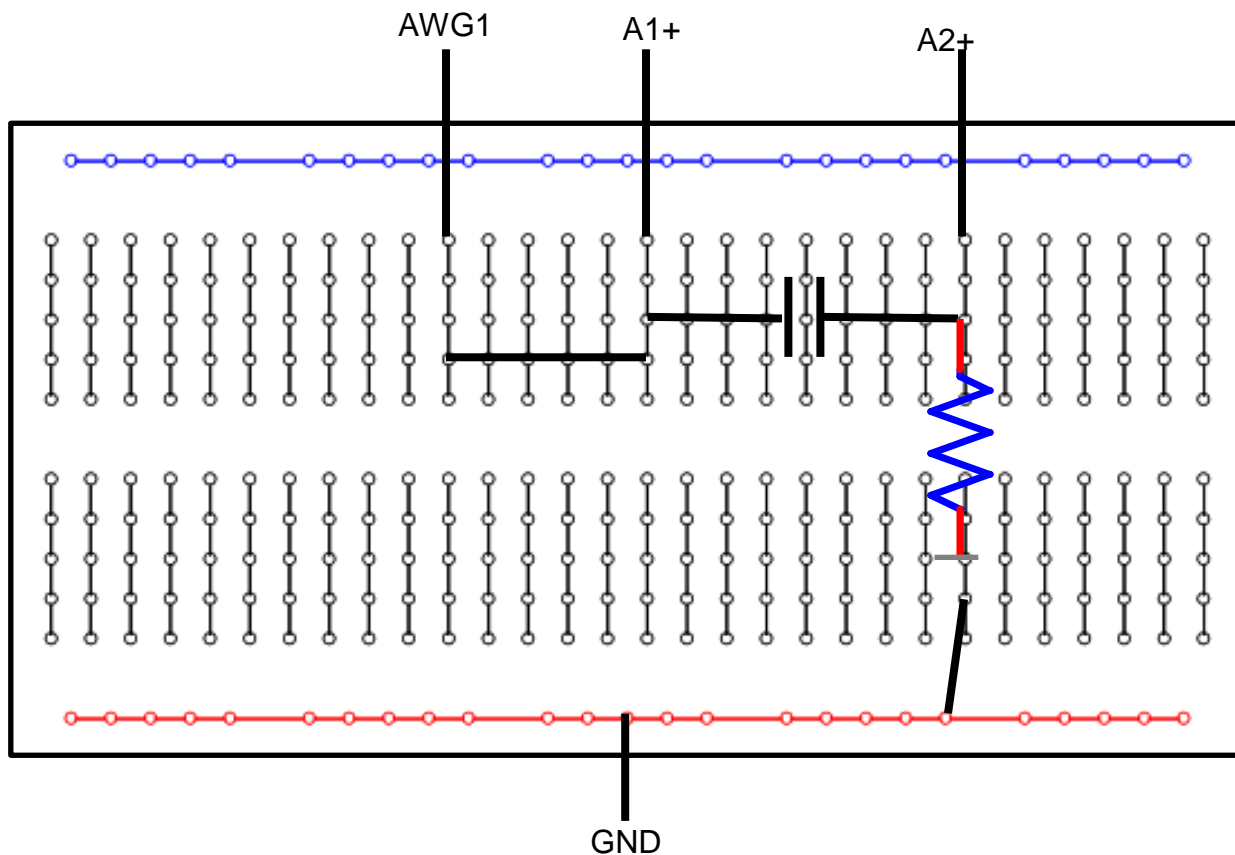
- d) When does a real physical inductor behave like a resistor? When does it behave like an inductor? (2 pts)

It behaves like a resistor when the frequency is sufficiently low that $R \gg \omega L$ and it behaves like an inductor when $R \ll \omega L$ or when the frequency is sufficiently high.

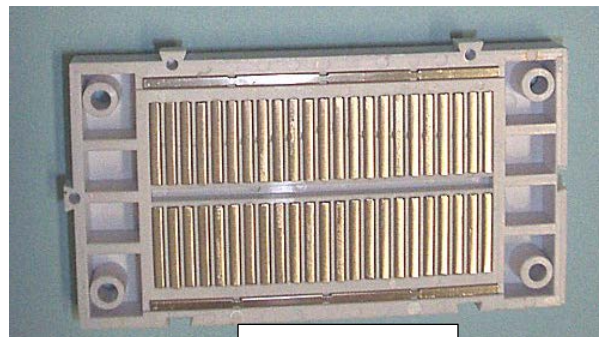
- e) You are given a resistor, a capacitor, a proto-board, some wires and the Mobile Studio board. You are to use these components to build a high-pass filter. Draw the circuit diagram using the four symbols below. Be sure you properly connect all components and the ground and label the input voltage and the output voltage. Draw your circuit carefully so it is easy to read. (5 pts)



- f) Configure your RC filter on the protoboard below. For clarity, the capacitor has been drawn showing where it is connected, as has the connection to the Mobile Studio ground. Add the resistor and all other connections to the Mobile Studio board so that, through measurements, it is possible to demonstrate that your filter is working. Note that, like your circuit diagram, your protoboard diagram must be easy to read. Your connections to the Mobile Studio should be drawn like the ground, with a short, straight line terminated in the label of the connection. The connections labels are shown at the beginning of this problem. Also, photos of the top and bottom view of a protoboard are shown at the bottom of this page. Explain how you will make the measurement. (5 pts) *Input A1+ and output A2+.*



Top View



Bottom View