ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2013

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.

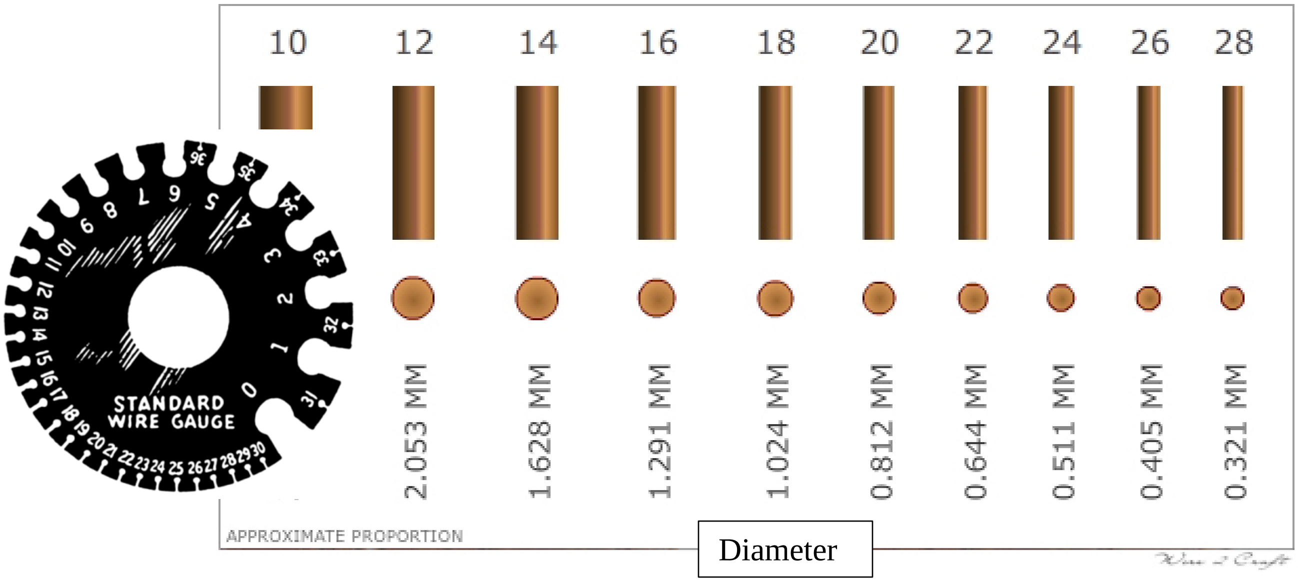
This Day in History – 1957

1957 is one of my favorite years. I was in 6th grade and had one of my very best elementary school teachers (the only one who is still alive). The highlight in Wisconsin, where I grew up, was the Milwaukee Braves beating the Yankees in the World Series. We also had some major tragedies in our family including a barn on the family farm burning down. The International Geophysical Year put a focus on science that has as much to do with the career path I chose as the launching of Sputnik on October 4th. During the next few years, top students in Madison (at least top male students) were encouraged to pursue careers in science & engineering, with many new opportunities for accelerated education. On the 25th of September, a little more than a week before Sputnik, the big news was political, not scientific. (KC)

"On Sept. 24, 1957, President Dwight D. Eisenhower ordered units of U.S. Army's 101st Airborne Division to escort nine Black students, nicknamed the 'Little Rock Nine,' into the previously all-white Central High School in Little Rock, Arkansas. In the weeks before, the students were refused entry by the Arkansas National Guard and mobs of segregationists gathered to block the doors, abusing the Black teens with obscenities and death threats. The "Little Rock Nine" attended their first full day of class on **Sept. 25, 1957**, and to ensure their safety, the federal officers were ordered to escort them to classes throughout the school year. Two of the students, Jefferson Thomas and Thelma Mothershed, earned their diploma from Central High School in 1960. A third member, Carlotta Walls, earned hers through correspondence classes. The remaining six students completed their high school educations at other schools."

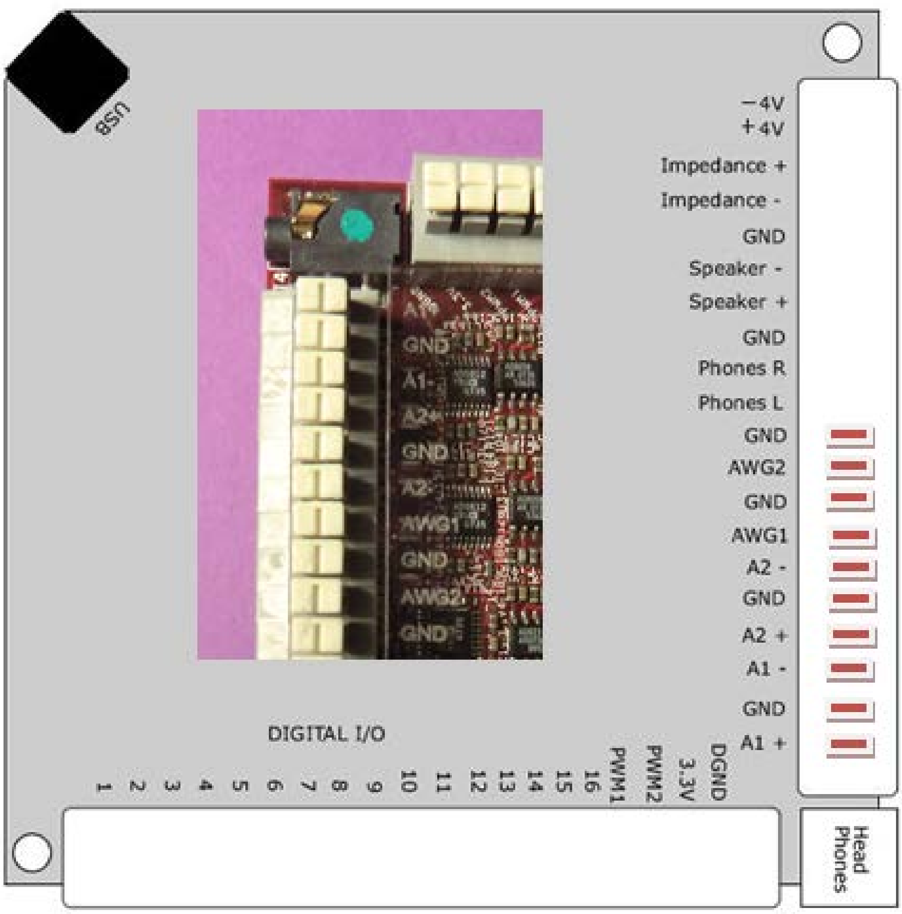
BET National News (Photo: Lloyd Dinkins/Commercial Appeal /Landov)

Additional Reference Info



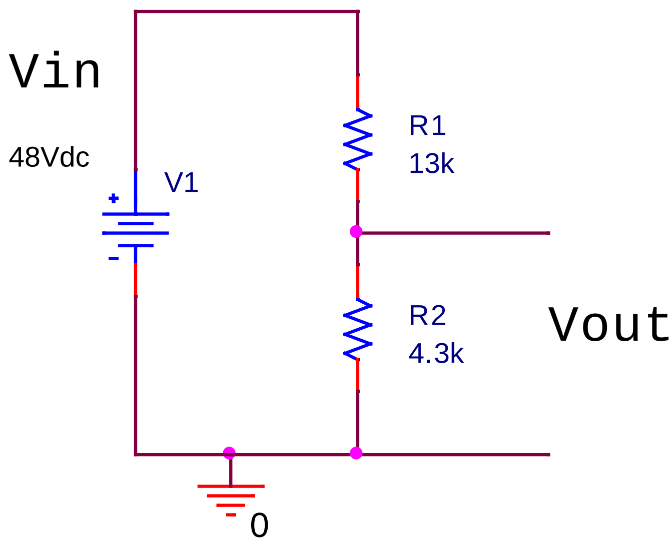
Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Standard Capacitor Values (±10%)						
10pF	100pF	1000pF	.010µF	.10µF	1.0µF	10µF
12pF	120pF	1200pF	.012µF	.12µF	1.2µF	
15pF	150pF	1500pF	.015µF	.15µF	1.5µF	
18pF	180pF	1800pF	.018µF	.18µF	1.8µF	
22pF	220pF	2200pF	.022µF	.22µF	2.2µF	22µF
27pF	270pF	2700pF	.027µF	.27µF	2.7µF	
33pF	330pF	3300pF	.033µF	.33µF	3.3µF	33µF
39pF	390pF	3900pF	.039µF	.39µF	3.9µF	
47pF	470pF	4700pF	.047µF	.47µF	4.7µF	47uF
56pF	560pF	5600pF	.056µF	.56µF	5.6µF	
68pF	680pF	6800pF	.068µF	.68µF	6.8µF	
82pF	820pF	8200pF	.082µF	.82µF	8.2µF	



Shown above is the pinout diagram for the Mobile Studio including the 10 input/output connections we have used. The insert is a photo of the relevant part of the Mobile Studio.

I. Resistive circuits (25 points)

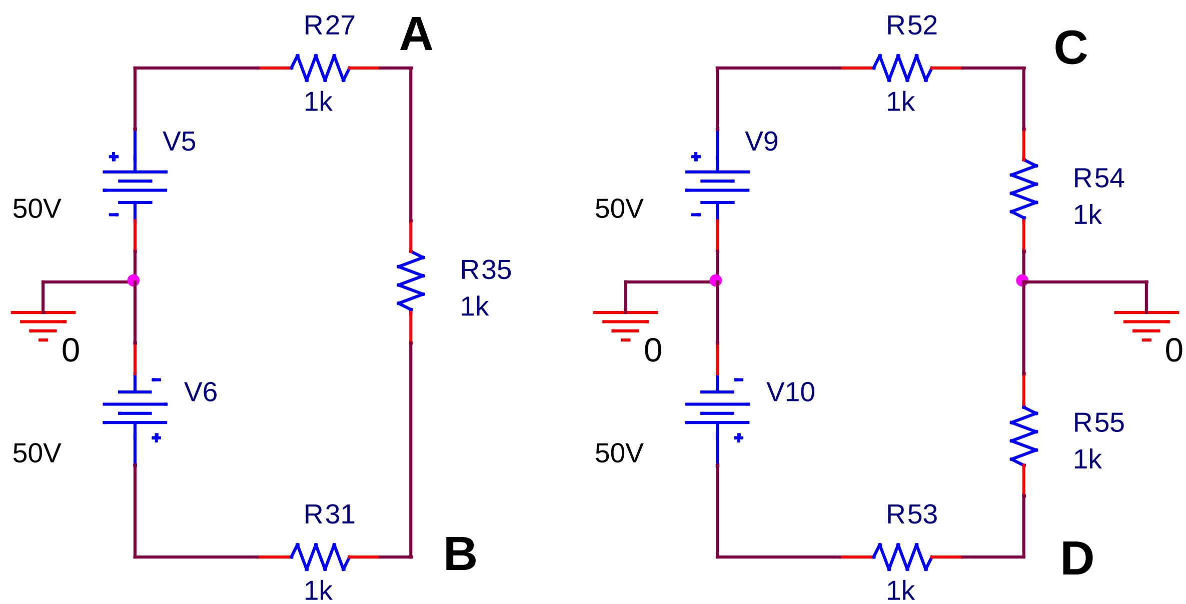


Voltage divider:

$$V_{OUT} = V_{IN}\left(R1/\left(R1+R2\right)\right)$$

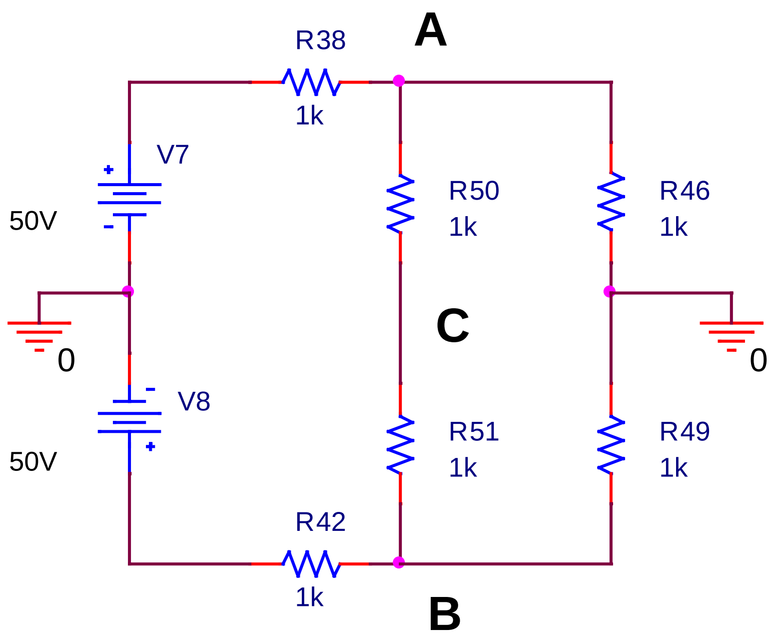
$$V_{OUT} = 48\left(4.3/\left(17.3\right)\right) = 12 Volts$$

a) Find the voltage Vout in the circuit above. (5 pts)



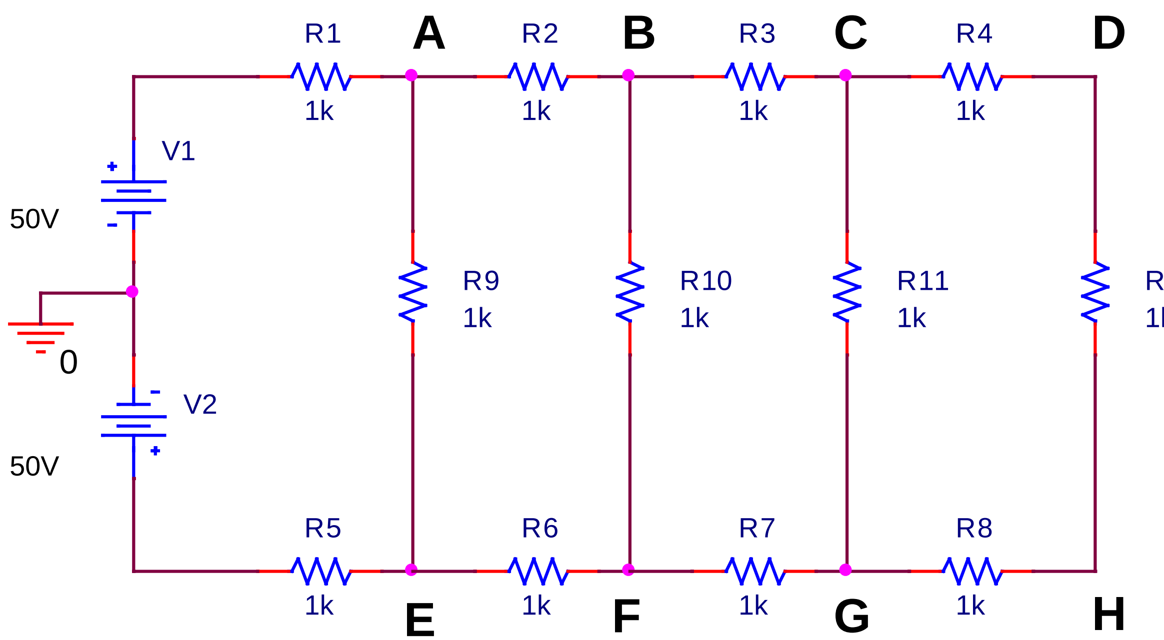
For the left circuit, there is no current through any of the resistors because the voltage = 50V at the upper left and lower right corners. Thus, V_A=50=V_B. For the right circuit, the top and bottom are symmetric, so they can be treated separately. Each looks like a simple voltage divider. Thus the voltages at C and D are both 25V.

b) Find the voltages at the four points in the two circuits above. (4 pts)



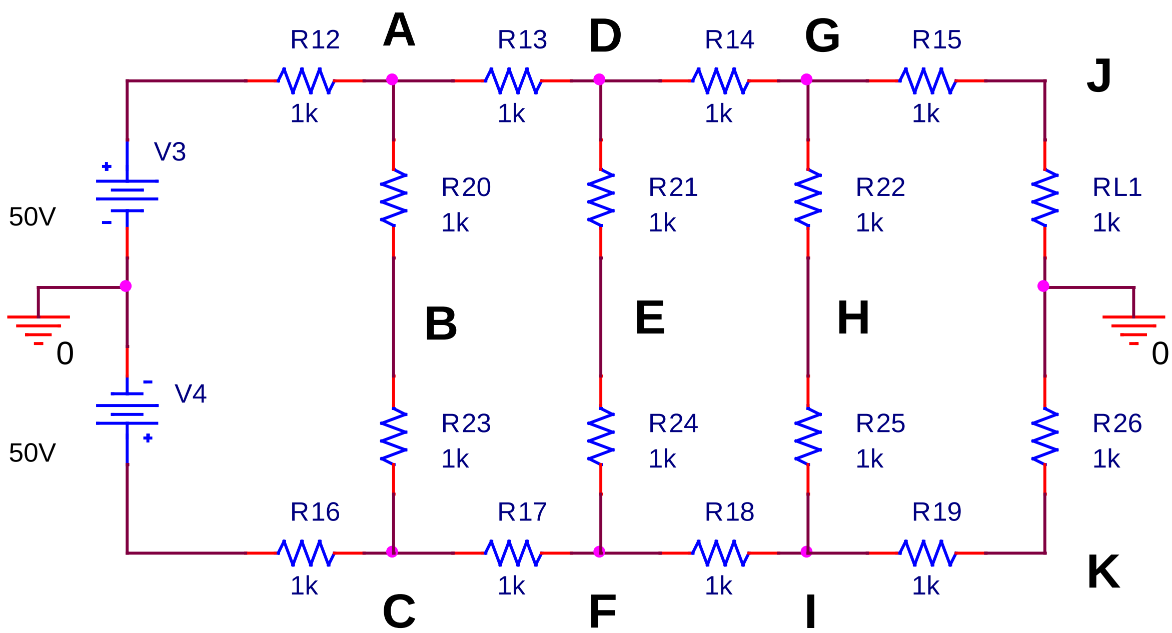
Again, symmetry says that the voltage at A is the same as the voltage at B, just as in the circuit at the right above. Thus, there is no current in R50 or R51 and all three voltages are 25V.

c) Find the voltages at the points A, B & C in the circuit above. (6 pts)



This is just a more elaborate version of the left circuit in part b. $V_A=V_E$, $V_B=V_F$, $V_C=V_G$, $V_D=V_H$ so <u>there is no current in any of the resistors</u> and all voltages are 50V.

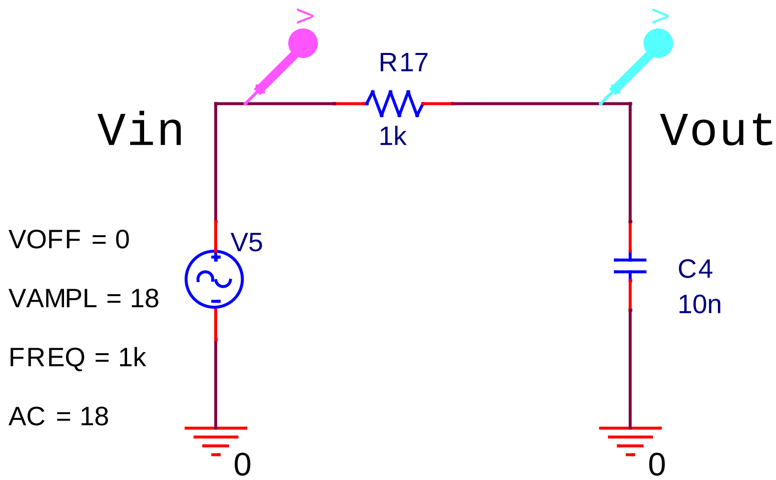
d) Find the voltages at the points A, B, C, D, E, F, G & H above. Also determine the current in resistor R4. (4 pts)



This is just a more elaborate version of part c. The $V_A=V_C$, $V_D=V_F$, $V_G=V_I$. Thus, the circuit can be analyzed by ignoring the six resistors in the middle. Again we have simple voltage dividers and the voltages are 40, 30, 20 and 10 along the top or the bottom. For example $V_A=V_C=V_B=40V$ & $V_J=V_K=10V$. The current in R15 is 50V/5k= 10mA.

e) Find the voltages at the points A, B, C, D, E, F, G, H, I, J & K above. Also determine the current in resistor R15. (6 pts)

II. Filters & Transfer Functions (25 points)



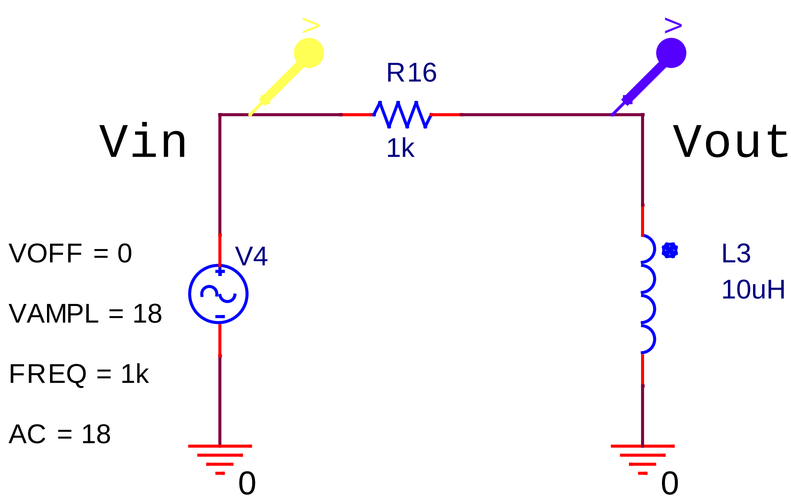
$$V_{out} = V_{in}\left(\frac{1/j\omega C}{R + 1/j\omega C}\right) = V_{in}\left(\frac{1}{1 + j\omega RC}\right)$$

$V_{out} = V_{in}$ at low f

$V_{out} = V_{in}\left(\frac{1}{j\omega RC}\right)$ at high f

$$f_{corner} = 1/(2\pi RC) = 15.9kHz$$

a) Find the transfer function $Vout/Vin$ for the RC circuit shown above. Note that output is measured across C4. Simplify the expression for both low frequencies and high frequencies. Determine the corner frequency. (6 pts)



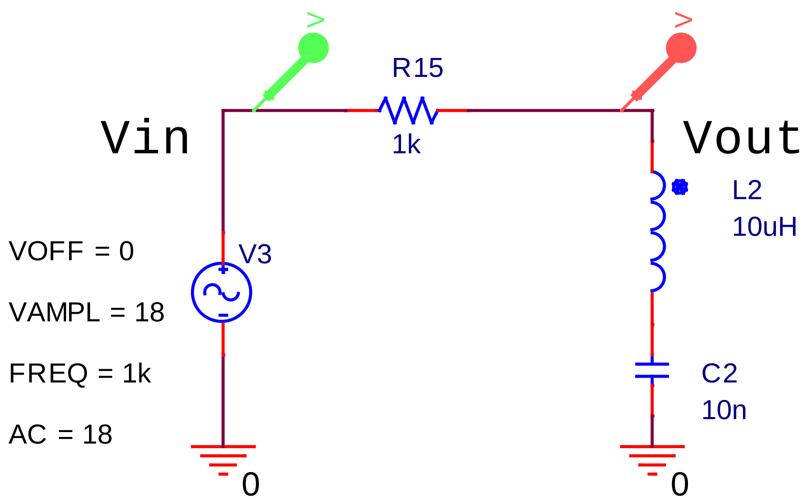
$$V_{out} = V_{in}\left(\frac{j\omega L}{R + j\omega L}\right)$$

$V_{out} = V_{in}\left(\frac{j\omega L}{R}\right)$ at low f

$V_{out} = V_{in}$ at high f

$$f_{corner} = R/(2\pi L) = 15.9MHz$$

b) Find the transfer function $Vout/Vin$ for the RL circuit shown above. Note that output is measured across L3. Simplify the expression for both low frequencies and high frequencies. Determine the corner frequency. (6 pts)



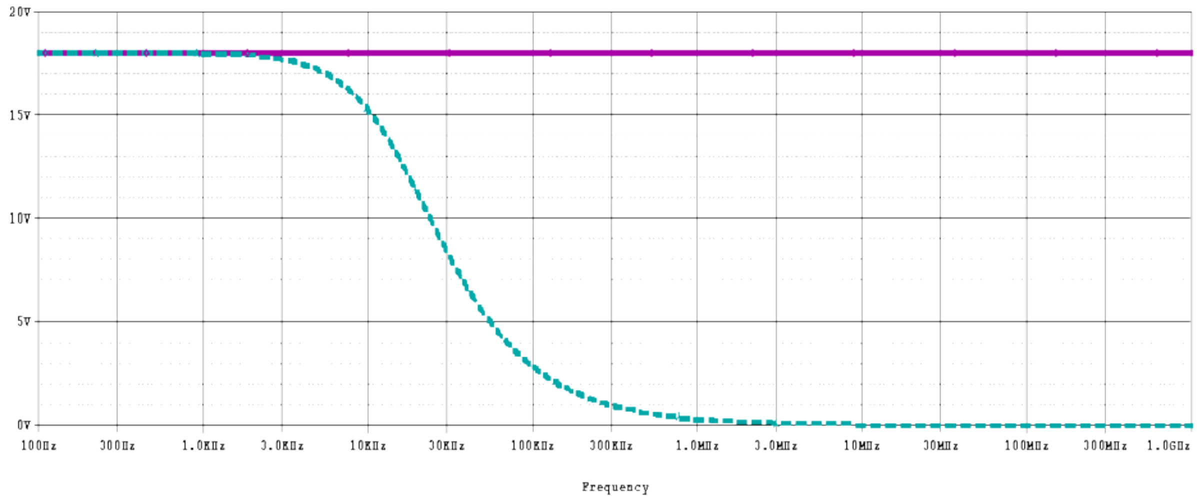
c) Find the transfer function $Vout/Vin$ for the RLC circuit shown above. Note that output is measured across L2 & C2. Simplify the expression for both low frequencies and high frequencies. Determine the resonant frequency and the transfer function at the resonant frequency. (8 pts)

$$V_{out}/V_{in} = \left(\frac{j\omega L + \frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}} \right) = \left(\frac{1-\omega^2 LC}{1-\omega^2 LC + j\omega RC} \right)$$

$$V_{out}/V_{in} = 1 \text{ at low f and at high f}$$

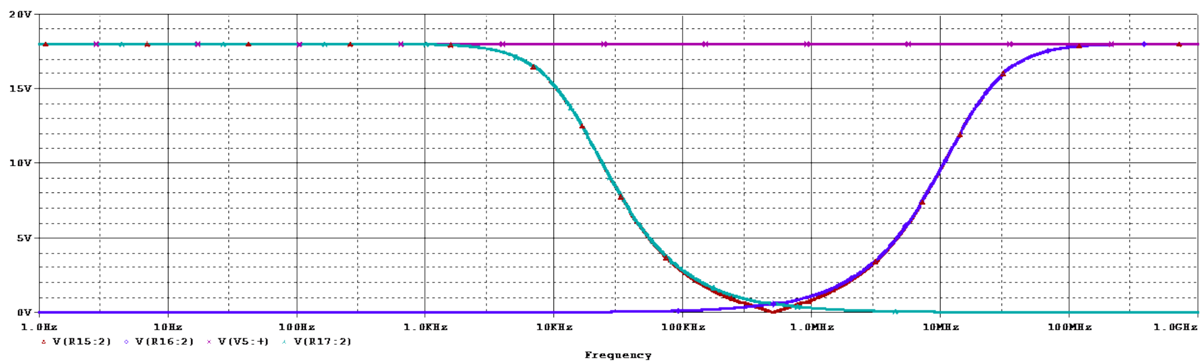
$$f_{res} = \frac{1}{2\pi\sqrt{LC}} = 503\text{kHz}$$

Transfer funct at resonance is zero. The impedance of L & C goes to zero at resonance.



Note: The horizontal scale goes from 100Hz to 1GHz and the vertical scale from 0V to 20V.

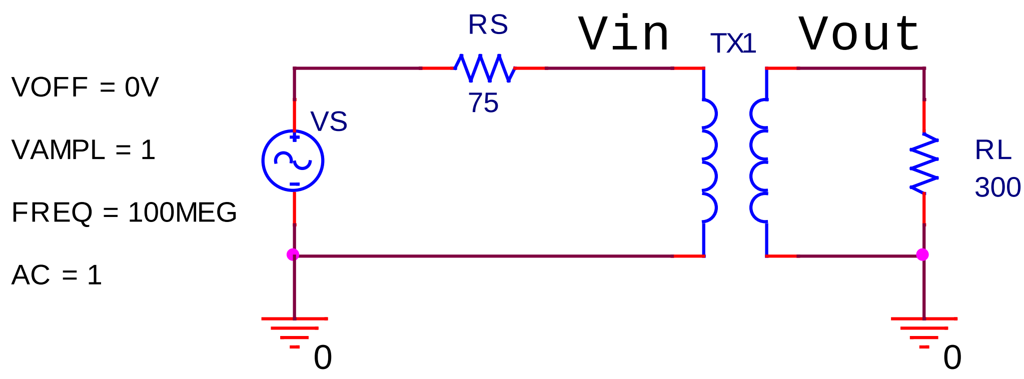
d) The plot above shows the input and output voltages as a function of frequency for one of the three circuits. Identify which one it is (RC, RL or RLC) and label the input and output voltages. From your answers to parts a) thru c), carefully sketch the input and output voltages for the other two circuits. (5 pts)



The plot is for the RC because the high freq transfer function goes to zero. For the RL, the low frequency function goes to zero, so it looks like a mirror of the RC. The RLC is the combination of the two. Red is RLC, light blue is RC, dark blue is RL.

The resonant freq is the minimum, the two corner frequencies give the .707 points.

III – Signals, Transformers and Inductors (25 points)



a) Given the circuit above, assume an ideal transformer with full coupling. With RS = 75Ω, RL = 300Ω, L1=2.5μH, and L2=10μH, find Vin, Vout, and the power in RL. (9 pts)

$a = \sqrt{\frac{L2}{L1}} = 2 \quad R_{in} = \frac{RL}{a^2} = 300/4 = 75 \quad V_{in} = VS/2 = 0.5 \quad V_{out} = aV_{in} = 1$

$PL = 1/300 = (.5^2)/75 = 3.33mW$ (should also have a ½ in it for average power, but both answers are OK).

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

1MHz 3MHz 10MHz 30MHz 100MHz 300MHz 1GHz

The corner frequencies for both the primary and secondary circuits are both about 47MHz. Thus, the three frequencies chosen are well above the corner. If a more stringent condition is set, then only the last two frequencies are OK. A transformer like this is used for cable TV and works fine for the entire band because attenuation is not great even in the high 70MHz range where VHF begins.

c) Which of the two resistors (RS & RL) sets the lower limit on the frequency range or, in this case, are the two limits the same? Explain your answer. (4 pts)

Both corner frequencies are the same in this case, so the two limits are indeed the same.

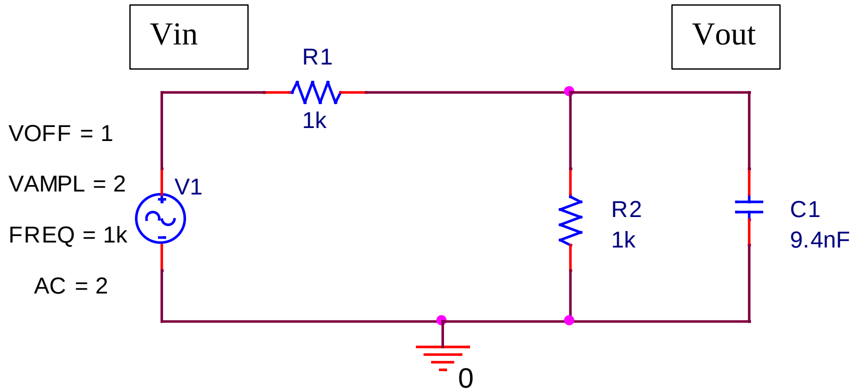
d) You decide to build this transformer by winding 28 gauge wire into two ring-shaped coils similar to the ones used in the Beakman's motor. The two coils are to be wound on a cylinder with a radius of 12.6cm (this will be the coil radius). Determine the number of turns for the primary and secondary coils (N1 and N2) to realize the primary and secondary inductances given above. (8 pts)

Using the parameters given the number of turns is 4 and 8 for the primary and secondary. $L = N^2 \mu_o r_c \left[\ln\left(\frac{8r_c}{r_w} \right) - 2 \right]$ with *r_c=.126m; r_w=(0.000321)/2m; and*

$\mu_o = 4\pi x 10^{-7}$

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

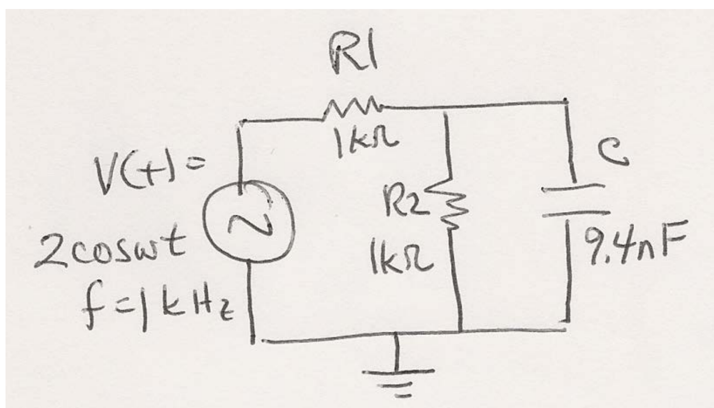
You are given the following PSpice generated circuit diagram to address the three ways we do just about everything in this course: paper and pencil analysis using simplified formulas, simulation with PSpice and experiment with Mobile Studio.



a) Label the location of V_{IN} and V_{OUT} on the plot above. (2 pts)

There are many ways to hand-draw this circuit. One common approach is shown below. This diagram is to be used for all three approaches to characterizing this circuit.

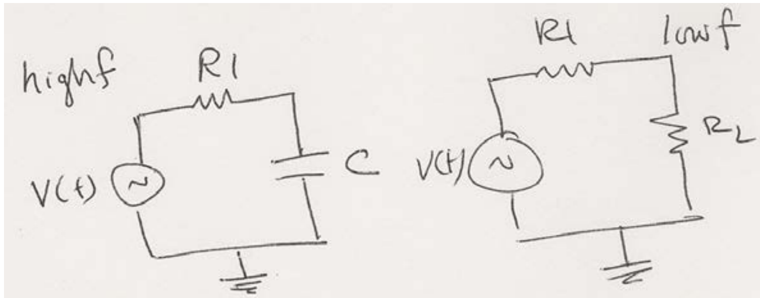
b) Find the transfer function for this circuit, simplify it for both high and low frequencies, and redraw the diagram for high frequencies and low frequencies (2 diagrams). (6 pts)



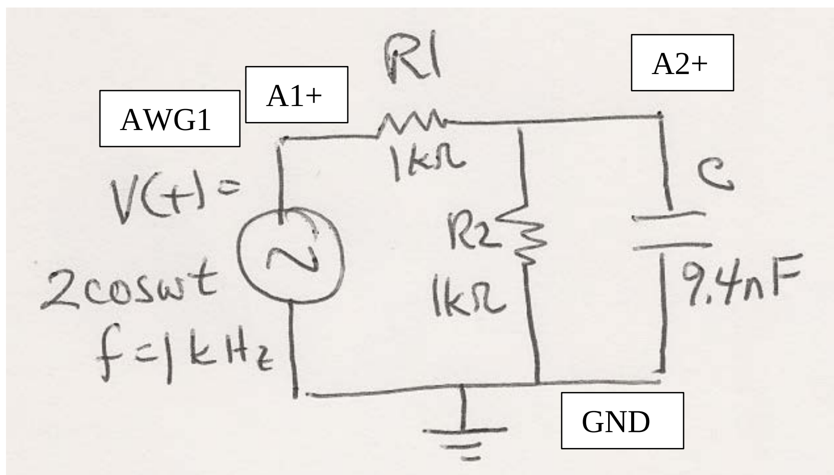
The parallel combination of R2 and C $Z = \dfrac{\dfrac{1}{j\omega C}R2}{R2 + \dfrac{1}{j\omega C}} = \dfrac{R2}{1 + j\omega RC}$

$V_{out}/V_{in} = \dfrac{Z}{R1 + Z}$ $\quad V_{out}/V_{in} = 1/2$ at low f and $V_{out}/V_{in} = \dfrac{Z}{R1 + Z} = \dfrac{1}{j\omega R1C}$ at high f

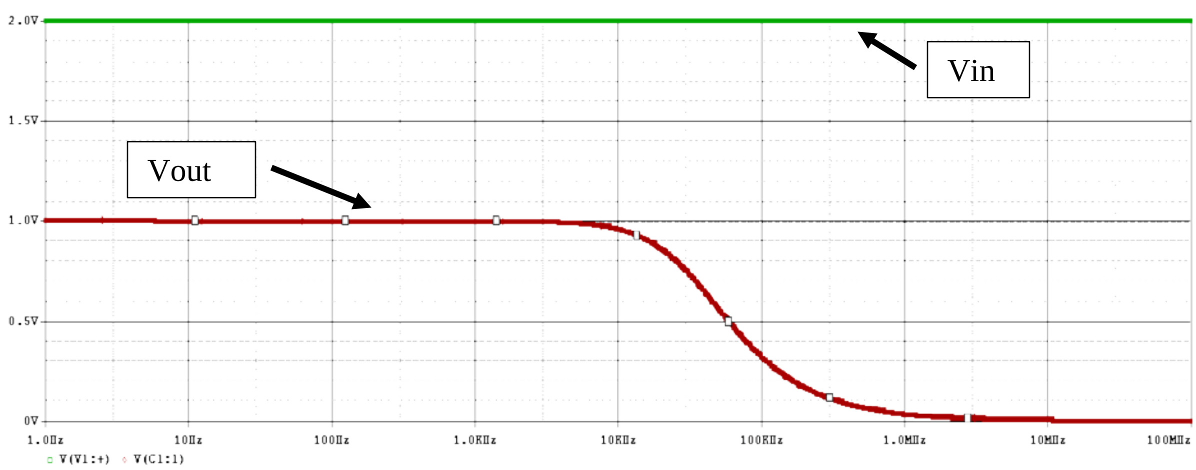
At high f, drop R2 from the diagram. At low freq drop C from the diagram.



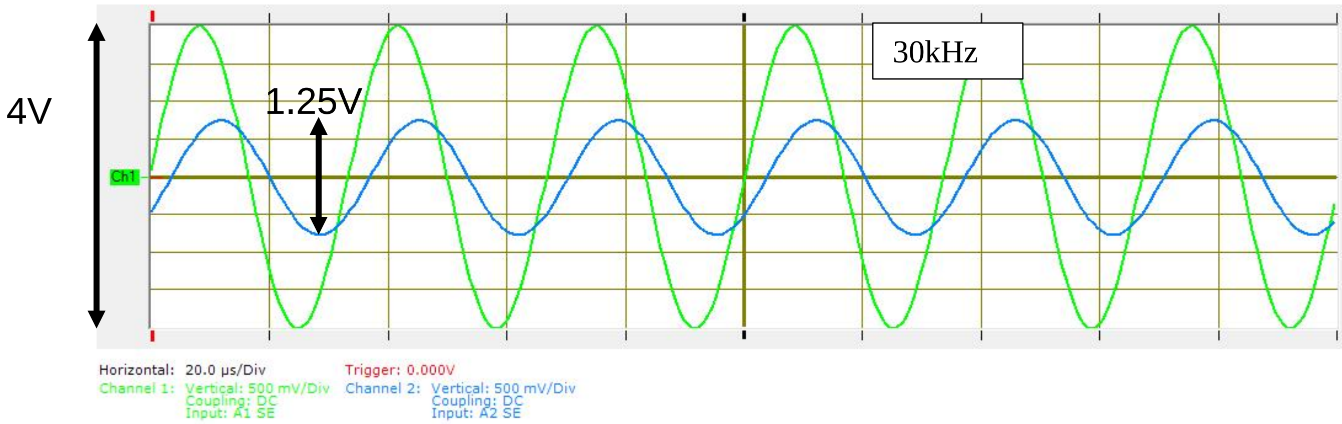
c) On the hand-drawn circuit diagram (repeated here), label where connections are to be made with the Mobile Studio board to experimentally study the circuit. That is, use the labels from the board (e.g. A1+). *Hint: You must show at least 4 connections (there is more than one way to do this). The pinout diagram is on page 4.* (4 pts)

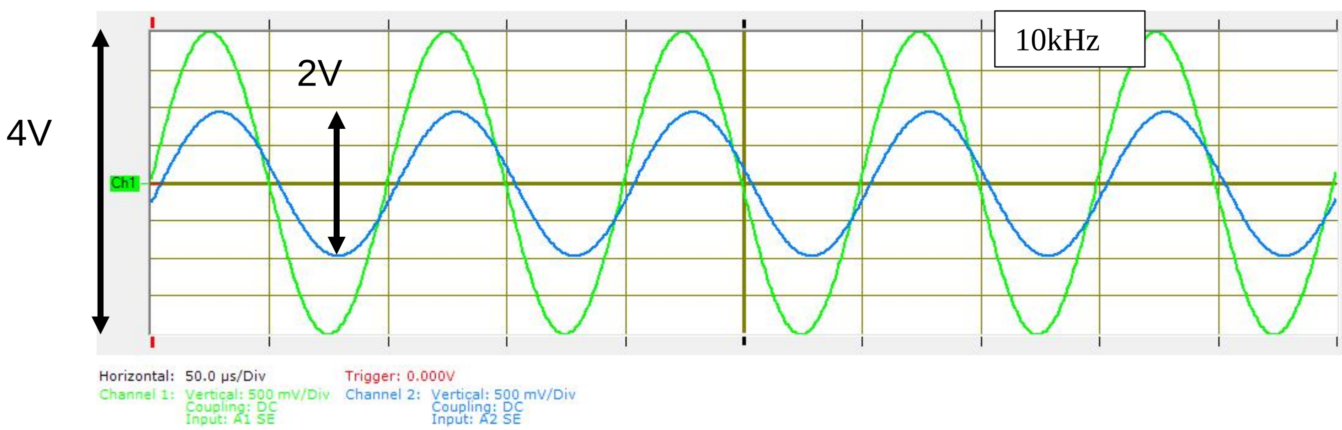


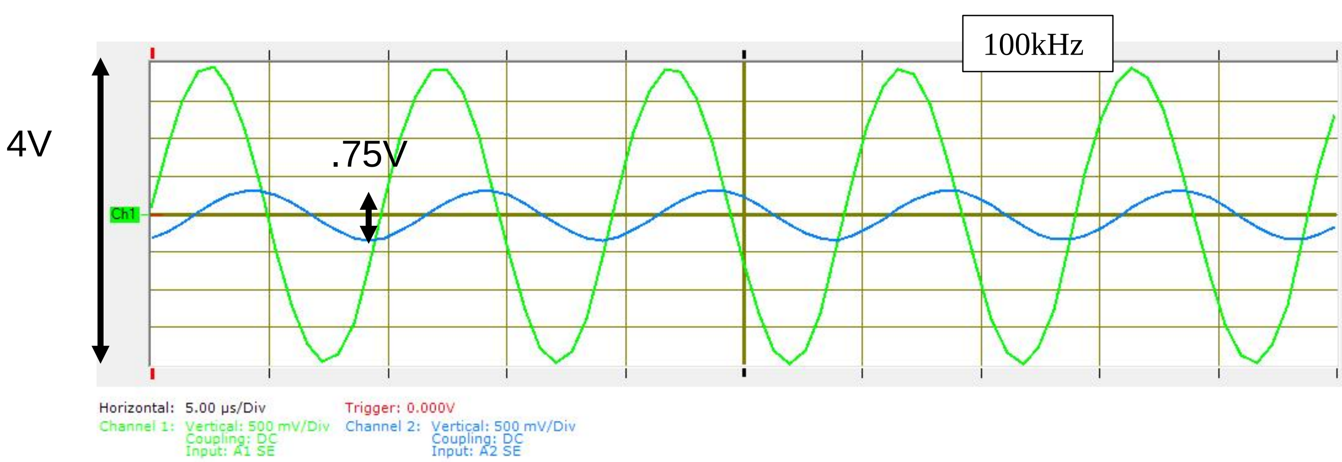
d) Shown below is the PSpice output for the circuit. Label the input and output voltages. (2 pts)



e) Three measurements are made of the input and output voltages for this circuit at three different frequencies (10kHz, 30kHz, 100kHz). The results are shown below. Label the input and output voltages, the peak-to-peak amplitudes of the input and output voltages and the frequency for each case. (6 pts)

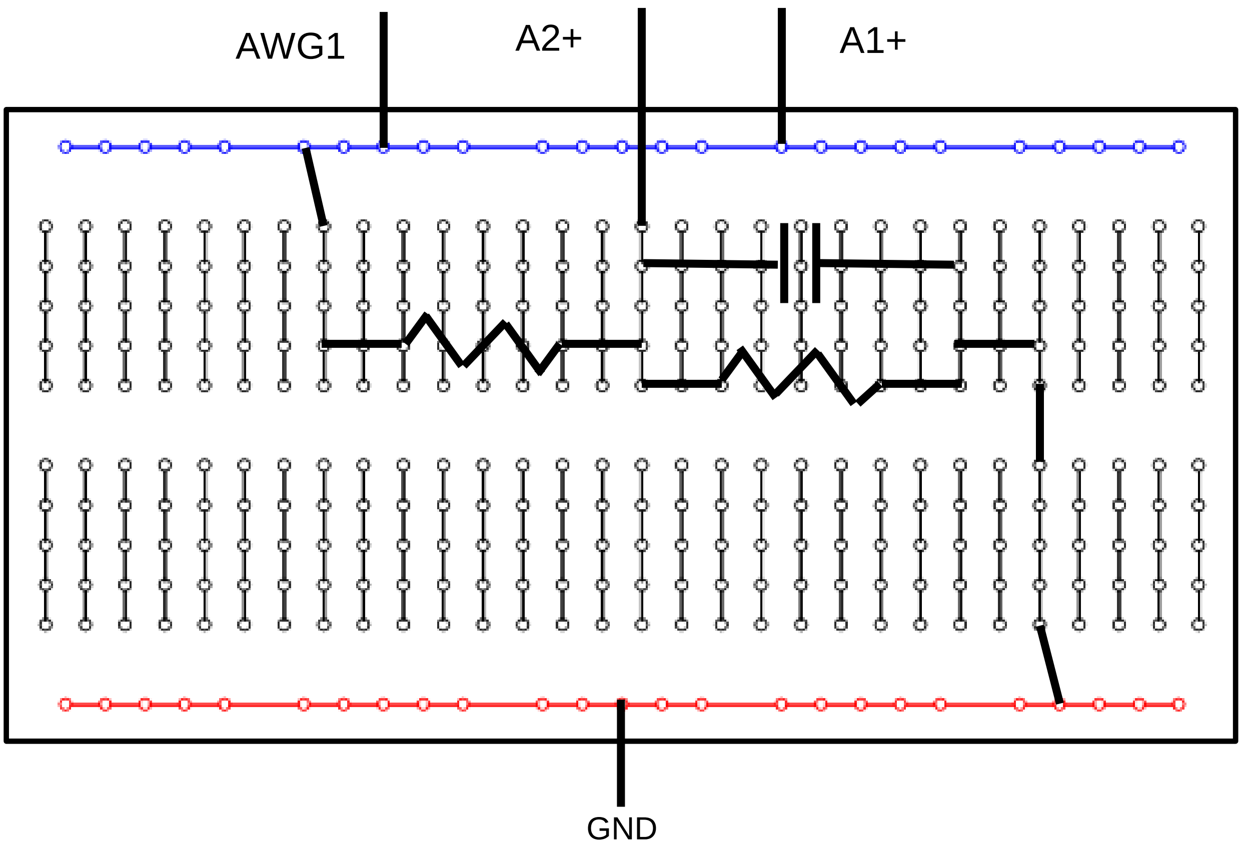


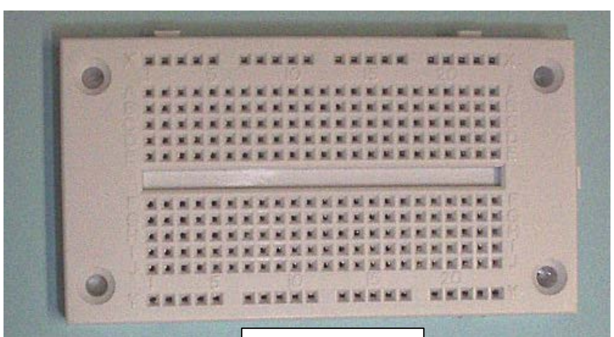




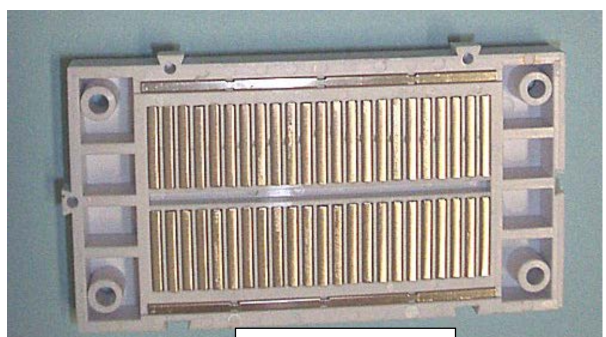
Green is in (larger wave) and blue is out (smaller wave)

f) Configure the circuit 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 resistors and all other connections to the Mobile Studio board so that, through measurements, it is possible to demonstrate that your circuit is working. Note that your protoboard diagram must be neat and 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. Also, photos of the top and bottom view of a protoboard are shown at the bottom of this page. (5 pts)





Top View



Bottom View