LABORATORY 3

PHYSICS 117, Winter 2017

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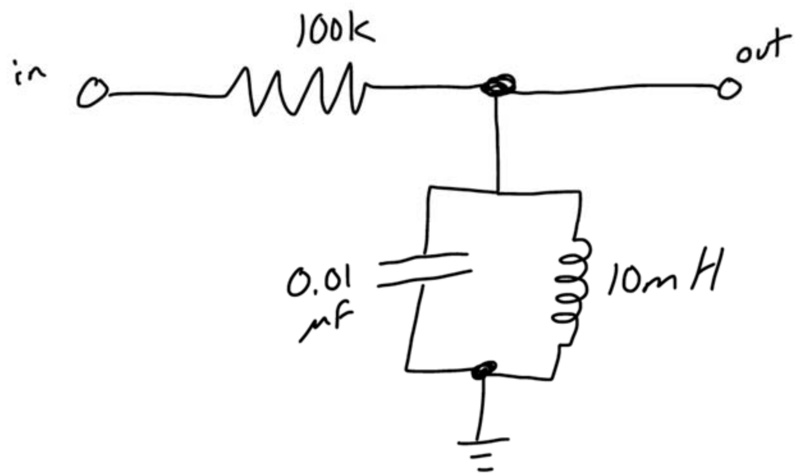
The lab write-ups are based on the laboratory manual by Hayes and Horowitz, but have been modernized and adjusted by the professor. If you find mistakes or unclear items, let the Prof. know so he can update these sheets.

Reading: Section 4.2

a) Modern scopes such as yours have a "Fast Fourier Transform" (FFT) option in the math menu. Really this is the "Power Spectral Density" (PSD) but it is often just called the FFT. Find the "Fourier transform" (meaning PSD) of a 1 kHz sine wave. Repeat for a square wave. Describe what you see and explain why it behaves that way. (You may find this link helpful:
http://mathworld.wolfram.com/FourierSeriesSquareWave.html)

b) Build the LC resonant circuit below:



Drive it with a sine wave, varying the frequency using the knob on your signal generator over a range from below to above the resonant frequency which you calculate. (The peak pass band does not exactly match what you calculate due to some losses/damping—how far off is it?).

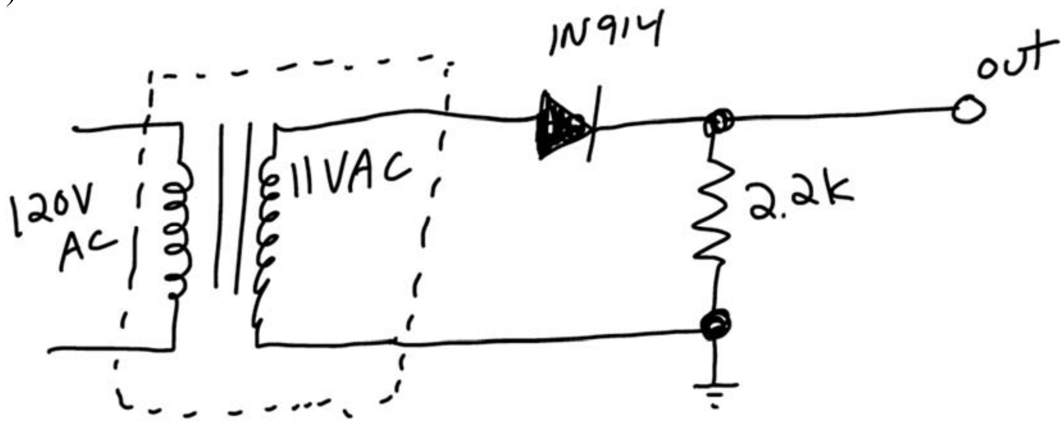
For the two parts below, the Wikipedia page on "Q factor" may help as a good reminder.

c) Repeat this using the "sweep" function of your function generator. Trigger the scope off of SYNC. Choose starting and stopping frequencies so you can easily read off the x-axis of your oscilloscope as if it were frequency instead of time. Explain what you did. Using the width of the distribution, calculate the resonant circuit's "Q factor". This is a measurement in the "frequency domain".

d) Drive it with a square wave of a fairly long period, but zoom in on the transition edge. You should see some resonance behavior after you “whack” the circuit with the sharp transition. Is the frequency what you expect? Calculate the “Q factor” using the energy lost per cycle. This is called a measurement in the “time domain”. You should get about the same Q factor each way.

e) Now drive the circuit using a square wave, which you now know contains many frequencies. Set the frequency of the square wave to be at the resonant frequency. You should see the circuit “pick out” the principle component. Change the frequency of the square wave until you find its first harmonic. Is it the frequency you expect? Is it a lower amplitude. With some careful work, you should be able to locate 5 or so harmonics.

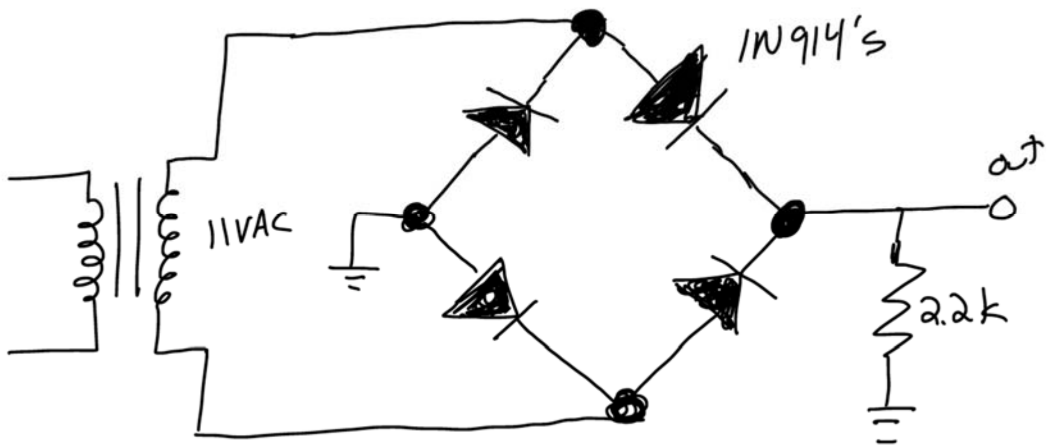
f) Construct the “half-wave rectifier” circuit below:



Use your 11V (RMS) output transformer that steps down from the AC “mains”. (Note that diodes start with the prefix “1N” to denote that there is one “P-N” junction, which we will discuss more in class later.) Is the output what you expect?

Can you change the circuit to flip the polarity?

g) Construct the “full-wave rectifier” circuit below:



Be careful what you do with your scope. Note that the outer conductor of its BNC connector is connected to ground so you cannot stick it just anywhere, only where ground is already.

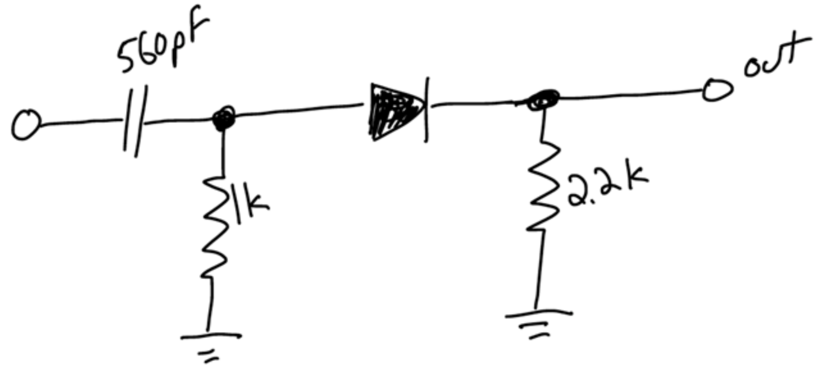
Here's how you can look at the output across the secondary windings of the transformer. Connect one channel of the scope (ie, connected to pin of BNC connector) to one side. Use another channel to look at the other. Both grounds should be connected to the ground on the circuit above. Then you use the "math" mode on your scope to subtract the two channels. Do you see the waveform you expect based on working with the transformer previously?

Look at the output near zero volts. Is there a deviation from a sine wave? Why?

h) Repeat this by replacing your diodes with LEDs and feeding the full wave rectifier with your signal generator on 0.5 Hz so you can see which diodes are active. NOTE: To do this you need to temporarily disconnect the ground of the signal generator from the world ground. Make sure no world grounds are connected to your signal generator.

i) Now put a 15 μF electrolytic capacitor from the output of your full wave rectifier to ground. (Hint: check the polarity first!) Does the new output make sense? The remaining wiggles are called "ripple". What happens if you use a larger capacitor? If you look inside various AC-powered lab equipment, you should see a circuit similar to what you just built.

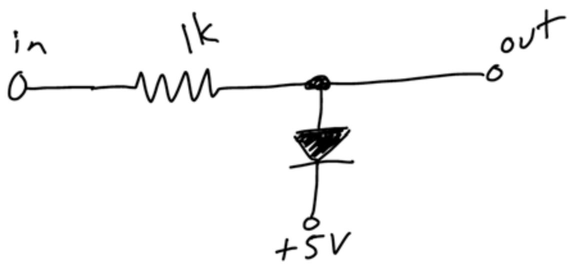
j) Use a diode to rectify the output of a differentiator as below:



Drive it with a square wave of 10 kHz at large amplitude.   Does the output make sense?

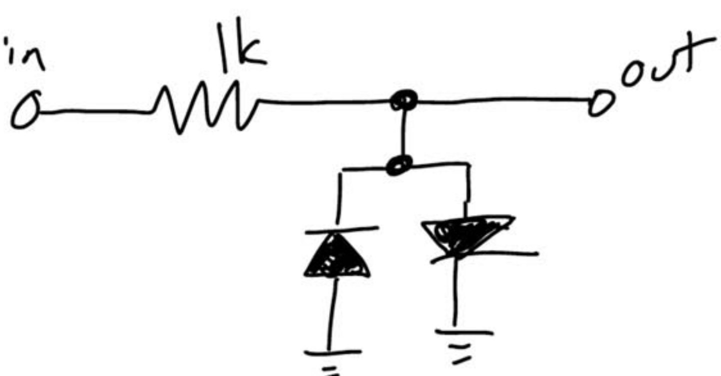
What does the 2.2 kΩ resistor do? (Try removing it.)   Hint: You should see RC discharge curves in both cases. Try looking at the data sheet of the diode for its capacitance.   Optional: does the 1N914 behave differently from the 1N4004?

k) Make the “diode clamp” circuit below:



Drive it with a sine wave of amplitude 2.0V, then 6.0V. Does the output make sense?

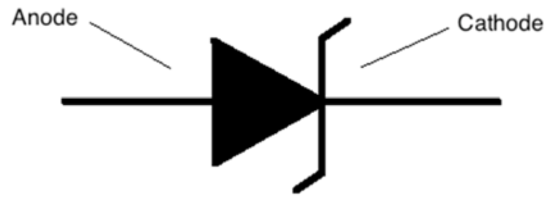
l) Build the “diode limiter” circuit below:



Drive it with various functions of amplitude 2.0V and explain the output. What use would this have?

m) We have “scope probes” on the wall. Use it on both the x1 and x10 settings and make sure you can get the same answer. (Hint: check the “attenuation setting” on your channel menu.). Using an Ohmmeter, measure the resistance of your scope probe on each setting when it is connected to the scope but not a circuit.

n) Zener diode challenge:



Design a set-up to test whether a diode is a regular diode or a Zener diode and determine the Zener breakdown voltage without having to make every individual voltage measurements by hand. Ie, you can plug in the diode into a circuit and just look at the scope. Try to do this without your TA telling you how.

The TA will give you a secret diode and you will tell him which type it is using your apparatus. (This technique is useful if you had a lot of diodes to test.) Warning: Make sure your setup will not burn out the diode. (Test it on the regular diodes first which we have many more of than the Zeners.)