LABORATORY 2

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.

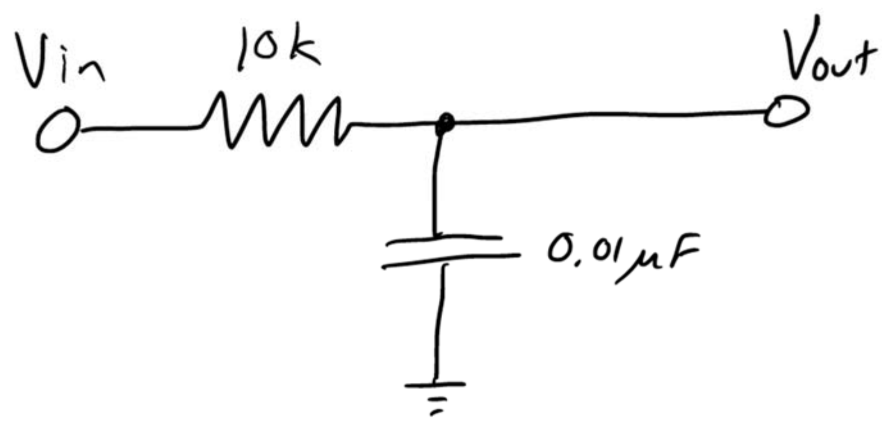
Reading: 2.23-2.29, 2.33

a) Use the LC-meter (or C-meter or DMM) in the lab to measure capacitance of two 0.01 μF capacitors in series and then in parallel. (The C and LC meters are old-school. You have to turn them off when you are done!)

See the note on how to read capacitors values on on the lab bulletin board. Further complicating things, note that the LC meter will display in nF even though we only ever label capacitors in the lab or on circuits as mF, μF or pF. Go to the drawers and check that you can measure a 0.15 μF capacitor correctly. Find the value printed on that capacitor and explain how to read it correctly.

** Now that you know how to read capacitors, please be sure to return your caps to the correct bin. The future hours of work you save may be your own **

b) Build the RC circuit below:

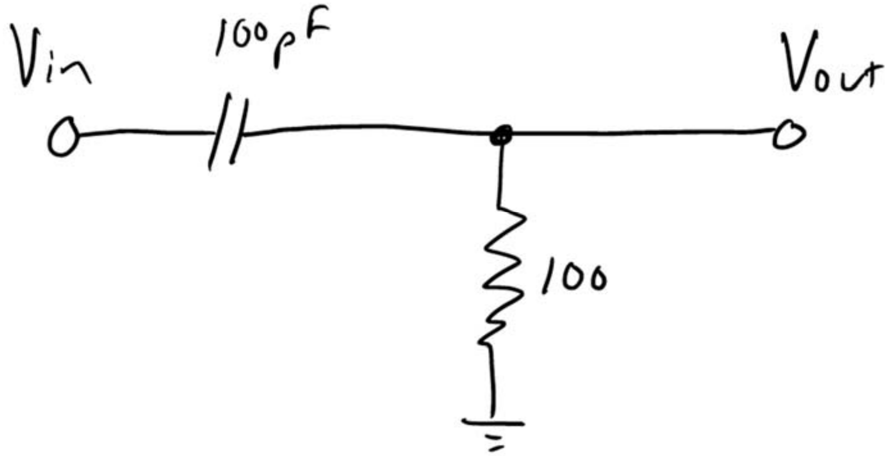


Explore and explain how this circuit works "in the time domain". You can do this by driving the circuit with a 500 Hz square wave and look at the signal output. (Hint: make sure your scope is on the "DC" setting. Why?) Measure the "time constant" of the circuit and show that it corresponds to the RC time constant. You may need to measure R and C rather than trusting their nominal values. Compare the rise time from 0% to 63% of the maximum to the fall time from 100% to 37% of the maximum. Why are these the same?

Now you can explore how this circuit works "in the frequency domain" by driving it with different frequency sine waves.

In general to "think like a physicist" about a circuit (or any other system, really), you should think about it concurrently both in the time and frequency domains. We will revisit this.

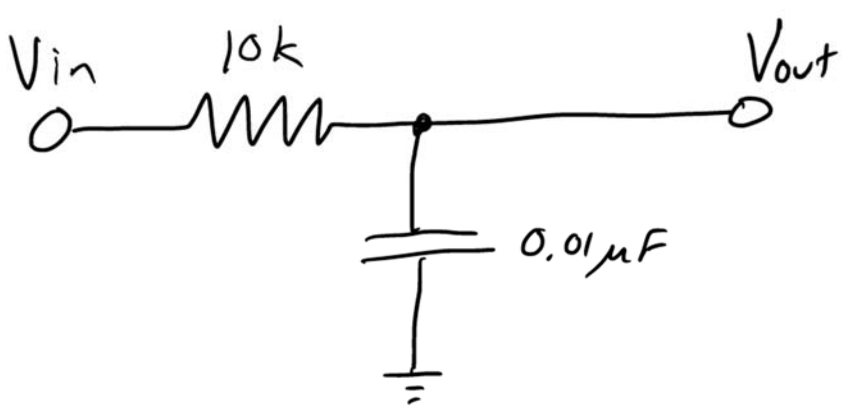
c) Circuits can do calculus! This RC circuit below is known as a "differentiator".



Drive it with a square wave, saw-tooth wave, triangle wave, and sine waves. Use two channels of your oscilloscope so you can look at the input and output signals at the same time. Does the output behave as a differential? Explain.

What is the input impedance of this circuit at 0 Hz? At infinite frequency?

d) Build the "integrator" below (note the same as an earlier circuit).



Drive it at 100 kHz with a (large amplitude) square wave. Try the other functions. Explain why it is working as an integrator. Look carefully at the integral of the triangle wave to see the output is not a sine wave although it looks close. What function is it? Are the conditions about RC vs. the time scales as discussed in class obeyed?

Show that the amplitude of the output of the sine wave is roughly what you expect.

We will build better integrators and differentiators when we learn about "operational amplifiers" (op-amps).

e) Now use integrator circuit you just built now as a low-pass filter. Again you should be looking at both the input and output simultaneously on your scope. Calculate and then measure ν_{3dB}. Drive the circuit with a sine wave of various frequencies, especially deep into the "stop band" (if you go too far though the components may stop working as advertised though). Compare the phase of the input to the output sine waves when you are deep into the stop band, deep into the pass band, and at the "3 dB point".

The low pass filter should attenuate at the famous "6 dB per octave". An octave is a factor of two in frequency. Show that it obeys this rule reasonably well.

Now use the 3rd channel of your scope to look at the SYNC output of your function generator at the same time. That output defines a t=0 with a fast rising edge. Watch what happens if you vary the trigger level while trigging on the input sine wave. Now watch what happens if you vary the trigger level on the sync pulse. Explain why it will often be best to trigger your scope on the SYNC output instead of your actual signals of interest.

f) Reverse the positions of the capacitor and resistor and show that it works as a high pass filter.

Put the SYNC output of your scope and trigger on it using a time base of 0.1 seconds per division. Let the function generator's sweep take 1 second to cover a range of interesting frequencies (chosen to be nice round values for easy computation.) You can now easily read off the "3 dB point" of your circuit this way. (Hint: you may find putting your scope on "peak detect" gives you a better image.)

g) Working with a transformer.

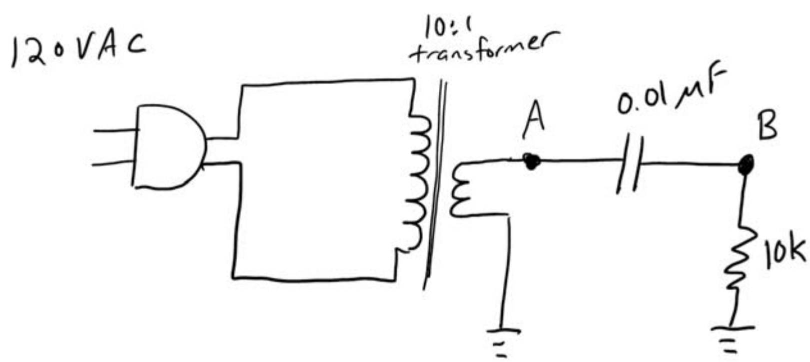
TRANSFORMER

Grab a small transformer from the shelf (marked “audio transformers”). Use the one marked “TM018” which has equal numbers of windings on the “primary” and “secondary”. Put a 1 kHz signal into the outer leads on one side and measure the signal between the outer leads on the other side. Show on your oscilloscope that the ratio of voltages is 1:1, but inverted. What is the frequency range over which the transformer works as expected? Now go back to 1 kHz and look at the output between an outer lead and the center-tap. Explain the voltage ratio.

OPTIONAL: You may find at some frequencies, the output voltage that is greater than the input voltage. What’s going on?

h) Now we can make a real application using a filter. Let’s measure the “garbage” on the physics building’s AC power lines. We have 12 Volt (“12 VAC”) step-down 11:1 transformers so that not too many of you accidently kill yourselves with the 120 Volts. Note that although these look like DC power supplies that you might use for your consumer electronics, these really are just a transformer. There is a disassembled one on the shelf you can look at, but should not use.

Build this circuit below. (Please be careful not to short the two output wires which can blow the fine wires inside transformer. I have put a 50 ohm resistor inside to reduce that possibility.)



At point **A** you should see what looks like a reasonable sine wave at 60 Hz. Is the period correct? (You don’t get the world’s greatest sine wave from the power company.) Is the peak-to-peak voltage what you would expect? (Hint 120V is the “R.M.S.” voltage so there may be a sqrt(2) involved depending on what you are measuring.) Calculate the filter’s attenuation at 60 Hz. Now look at point **B** to see all the noise.

(Note that the transformer itself says its RMS output is 9V but they are being “conservative” and you should see more like 11V RMS.)

i) Note that electrolytic capacitors have an orientation. If you connect one to a power supply backwards it will fail dramatically. (I do not recommend doing this.) Why do electrolytic capacitors have a polarity? (You can use the web to find out.)

Capacitors are often used to “block” DC while coupling in an AC signal. The circuits below do this:

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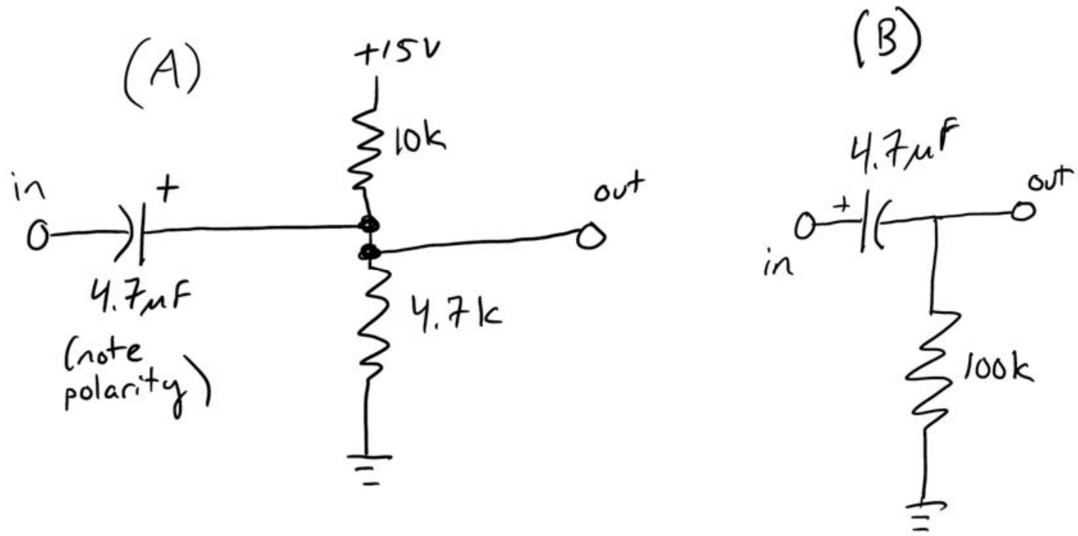

You can think of it as a high-pass filter with a really low 3dB point compared to all the signals that interest you. But it really is a different way of thinking about it. This blocking capacitor is really just there to block DC.

Build the circuit labeled A above. Drive it with the function generator and look at the output on the scope (remember to be DC coupled). The circuit lets the AC signal ride on top of +5V without exposing your function generator to +5V input to its output, which might damage it. Now add the circuit labeled B to the output of A. Notice the signal swings around ground again. What is the low frequency limit of this blocking circuit (circuit B)?

Circuit B is essentially what your scope does on “AC coupling” but with a 1 MΩ resistor. Try looking at the output of circuit A with that instead.

The two circuits above when put together seem pretty useless. But we will use each one individually as we go on.