Laboratory #1

Lab Familiarity and Wattmeter Measurements

I. Pre-Laboratory Assignments

1. Number all the right-hand pages of your lab book in the upper right-hand corner with ink. Create a table of contents for your lab book on page 1. Do all of your pre-lab and laboratory work in your lab book in ink. Do not bring any loose paper to the lab.

2. Use the right-hand pages for your lab work and the left-hand pages for scratch work. Tape or paste your lab assignment, computer simulation circuits and results into the lab book.

3. Divide your work for all labs into three sections, which you'll complete sequentially. The sections must be labelled Pre-Laboratory, Laboratory, and Conclusions.

4. This experiment involves investigating the circuit shown in Fig. 1 in which the source is a "variac" connected to the 120-Vrms, 60-Hz AC power mains. The output of the variac is 40-Vrms so that $v_S(t) = 56.57 \cos(377t)$ V. The other circuit elements are a resistor $R = 100\ \Omega$, a non-ideal inductor $L = 100$ mH in series with $R_L = 6.6\ \Omega$ (for inductor wire losses), and a capacitor $C = 25\ \mu$F.

5. Perform a "hand analysis" of the circuit in Fig. 1, using the values listed above in part 4, to obtain:
   a) Voltage across each circuit element.
   b) Current through each circuit element.
   c) Power generated by or absorbed by each circuit element.
   Place the results of your hand analysis in your lab logbook. The reason for this is to completely understand what you are expecting from the circuit.

6. Perform a PSpice simulation of the circuit in Fig. 1. The outputs of the simulation should at least contain:
   a) Voltage across each circuit element.
   b) Current through each circuit element.
   c) Power generated by or absorbed by each circuit element.
   Place the data from simulation in your lab logbook.

7. Compare your results from parts 5 and 6 above. Note similarities and explain any discrepancies.

8. Draw a schematic of the circuit, including the measurement equipment, which you will use for measurements in parts 7(e), 7(g), 7(h), and 7(i).

General comments relating to lab work:

1. In several of the sections below, you are asked to have the TA review your setup before proceeding to the next step. This is to minimize the chance of damaging or destroying our department's test equipment, and to ensure your own personal safety. As you become more familiar with the test equipment, you will be able to confidently make measurements without undue risk.

2. The most common **mistakes** made in previous years of lab work (and also occasionally by the most seasoned practitioners) are:
   a) Applying short circuits across power sources causing lots of heat, sparks, and smoke (be careful with test lead placement and low values of impedance across the output of the power source).
   b) Making voltage measurements with the test leads in series with the component (voltages are always measured with the meter leads across a component).
   c) Making current measurements with the test leads in parallel with the component (current is always made with the meter leads in series with the component, but a break in the circuit is required to add the current meter in series).
   d) Making resistance measurement with power applied to the component. Always power down the circuit and remove one lead of the component from the circuit, or the entire component from the circuit, to make a resistance measurement.
   e) Making measurements with the range selector of a meter in a low range, accidentally causing too much current to flow through the meter either blowing a fuse or destroying the meter. Start at higher ranges, and then work down toward the lower values until digital values become evident.
   f) Touching a bare wire with your fingers and receiving a shock. Always make measurements with one hand only. Don't put yourself in a position where current can flow through your arms and chest or from your arms through your body to your feet which might be near ground potential.

3. Keeping a reasonably neat benchtop during the experiment helps to ensure that you maintain the proper connections and that jumper wires remain securely connected to the components.

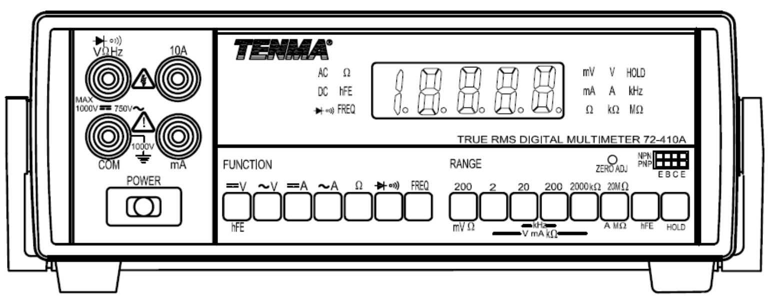
4. Record all pertinent information about your set-up, equipment, measurements, and observations. It may seem like it takes lots of effort to record what seems, at the time, to be redundant or useless information. But its value will be evident, if after going back to your desk or office and analyzing your data, something doesn't make sense. You will often find that you did not document nearly enough of your setup and measurements to decide where a problem may lie, and you are many miles and hours distant from the lab. Sometimes you will be able to isolate a faulty piece of test equipment if you document all of your settings and some details about the equipment. There probably isn't such a thing as too much information entered in your log book. Don't confuse your data taking activities with your reporting activities. Your lab book should look organized and professional, with some well thought out conclusions. But your raw data can be in any format that you (or someone else) can figure

out later. Do not be afraid to enter questions that come to mind or something that didn't quite look right.

5. Notice the differences between your calculations, your simulation results, and your measurements. Perform some error analysis. How close were your measured values to your calculated (expected) values? Probably you would say that if your measurements were off by a "little bit" you wouldn't be concerned that you made a mistake in your analysis, simulation, or measurement. But if the measurement was off by "quite a bit" you would start to suspect that an error was made somewhere. At what point would you start being concerned?

II. Laboratory Experiments

1. DIGITAL MULTIMETER



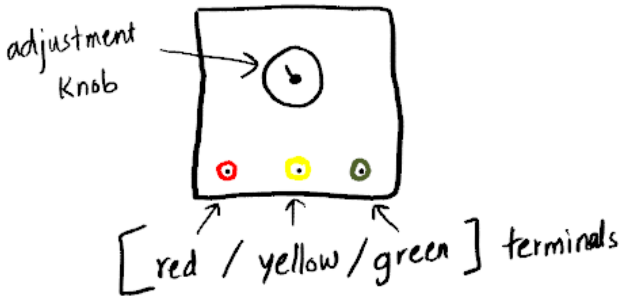
a) The Tenma True RMS Digital Multimeter 72-410A (concisely called 'the DMM') will be used to measure voltage and resistance.
b) Plug a red test lead in the "VΩHz" terminal.
c) Plug a black test lead in the "COM" terminal.
d) Select the "Ω" function and the "20MΩ" range. Separate the ends of the test leads so that they are not touching. The display should read a flashing "0.0000" indicating that there is an open circuit.
e) Connect the ends of the test leads together. Select the "200Ω" range. The display should read a very small resistance value indicating that there is a short circuit.
f) Organize your observations in a table in your logbook as follows:

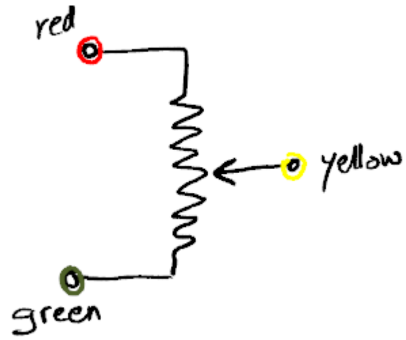
Date:		Time:	
Equipment:		Lab Bench #:	
Terminals (DMM)	Leads (open/short)	Function / Range	Display (with units)
Conclusion:			

The conclusion is tentative and can be something like: "The DMM seems to be measuring resistance as expected." Or "I was expecting to see a readout of "…", but I saw "…" instead. There is an offset being introduced somewhere. The test lead contacts were cleaned because they

looked corroded and shouldn't be adding resistance due to corrosion." Or anything else that is noteworthy or unexpected.
g) Perform similar organization of data as per (f) in your logbook for each of the measurements taken in the remainder of the experiment. This may seem like a lot of obvious information to enter in your logbook. But it is useful if, after going back to your desk or office and analyzing your data, something doesn't make sense. You can then go back to the lab and re-take your measurement.

2. POWER RESISTOR



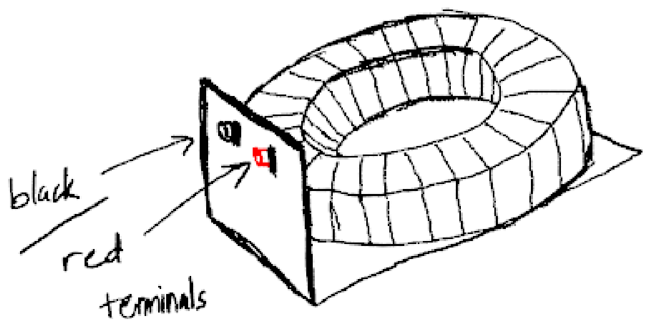


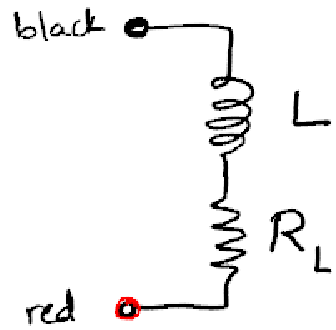
a) The power resistor is a large potentiometer (POT). Review section 2.8.2 of your text. Its physical configuration and schematic are shown above.
b) For the following measurements, nothing except the DMM should be connected to the POT.
c) Adjust the POT so that the indicator is approximately in the 12:00 position.
d) Select the 2000 Ω range of your DMM.
e) Connect the black test lead to the red terminal of the POT. Connect the red lead to the yellow terminal of the POT. Record the resistance.
f) Reverse the red and black test leads. Record the resistance. Comment.
g) Connect the black test lead to the green terminal of the POT. Connect the red lead to the yellow terminal of the POT. Record the resistance. Reverse the red and black test leads. Record the resistance.
h) Connect the red test lead to the red terminal of the POT. Connect the black lead to the green terminal of the POT. Record the resistance. Reverse the red and black test leads. Record the resistance.
i) Does it make any difference which way the test leads are connected when making a resistance measurement? Why?
j) Would you ever want to make a resistance measurement in a circuit that is powered up?
k) With the red test lead connected to the red terminal of the POT, and the black test lead connected to the yellow terminal of the POT, make a table of resistances vs. adjustment knob position as follows:

Date:	Time:
Equipment:	Lab Bench #:
Knob Position	Resistance:
Full CCW	
8:00	
9:00	

…
4:00
Full CW
Conclusion:

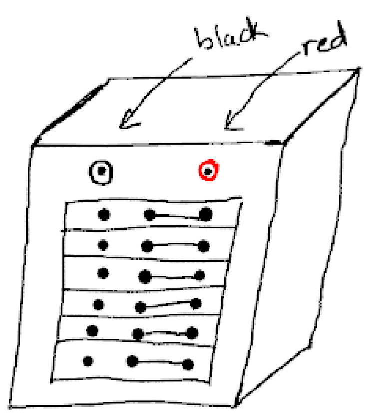
3. POWER INDUCTOR

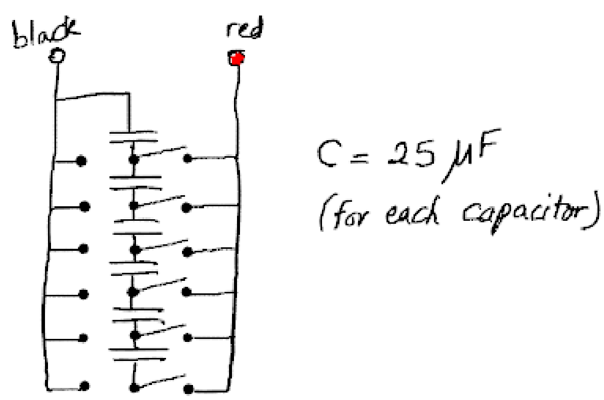




a) The power inductor is a coil of wire wound around a magnetic core. Review section 6.4 of your text. Its physical configuration and schematic are shown above
b) Bring your inductor to the TA and measure the value of its inductance (*L*).
c) Since the inductor consists of turns of wire, it will have resistance (*R*L). Measure the resistance of the inductor.
d) Draw an equivalent circuit of the inductor (showing its resistance and inductance).
e) Assuming 60 Hz circuit, calculate the impedance of the inductor in rectangular and phasor representations.

4. CAPACITOR BANK





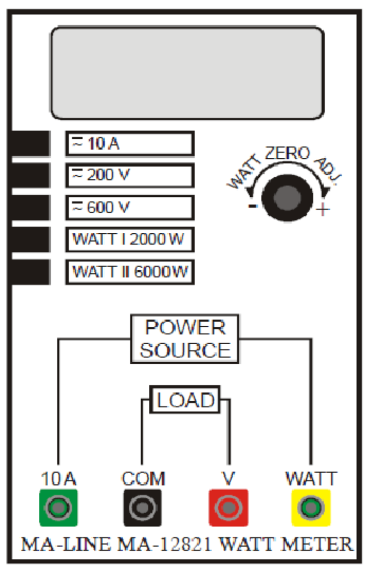
a) The capacitor bank contains six capacitors that may be configured in series or in parallel. Each of the six capacitors has a value of approximately 25 μF. Its physical configuration and schematic are shown above.
b) Place all knife switches in the right-most position. Bring your capacitor bank to the TA and measure the value of its capacitance. Is this value expected? Explain thoroughly.

5. VARIAC

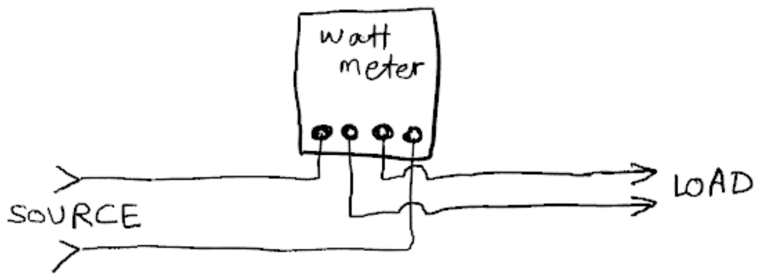
a) The variac is a variable transformer used to convert the 120 Vac from the power mains to a lower value of voltage in an adjustable, continuous manner. Adjusting the control knob on the front of the variac to the fully CCW position reduces the output of the variac to nearly 0 Vrms. Adjusting the control knob fully CW increases the variac output voltage to its maximum value.
b) Use the DMM to complete the following table:

Date:	Time:
Equipment:	Lab Bench #:
Knob Position	Output Voltage (Vrms)
Full CCW	
10	
20	
…	
130	
Full CW	
Conclusion:	

6. WATTMETER



a) Review section 11.9.1 in the text which provides a nice review of how a wattmeter operates, and how to connect a wattmeter into a circuit. Please be careful with the wattmeters. Make sure to connect them to the circuit properly. If in doubt on any point, ask the TA.
b) The wattmeter is a device that measures AC current through a load, the AC voltage across the load, and power absorbed by a load. A general connection for the wattmeter is:



7. CIRCUIT MEASUREMENTS

a) The objectives are to build a parallel combination of a resistor, inductor, and capacitor fed by a 40-Vrms voltage from the variac, as shown in Fig. 1 below, then measure the current through, voltage across, and consumed power for each branch of this parallel circuit and for the circuit as a whole. As a first step, construct the circuit below but don't turn on the variac yet.

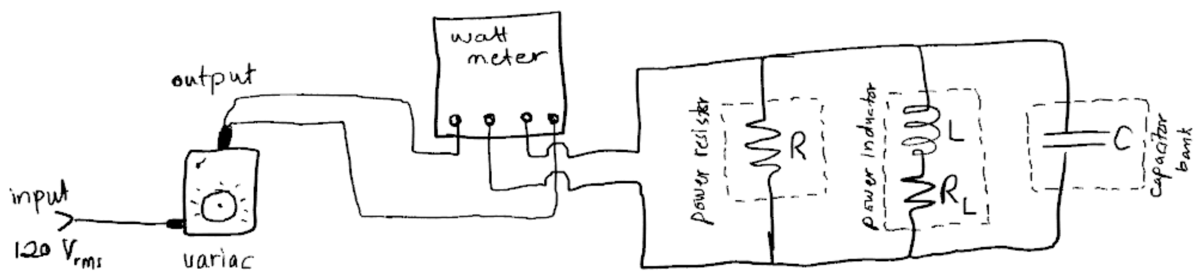


Figure 1

b) Use the DMM to set the POT to 100 Ω.
c) Set the knob position of the variac to the full CCW position (i.e. 0 output voltage). Do not flip the variac power switch "on" until after the TA inspects your circuit setup.
d) Turn the variac on. Rotate the knob position CW slightly to see if the readings of the wattmeter are tending to show slightly positive readings. If you notice anything suspicious, turn the variac off immediately and investigate the problem.
e) When you are confident that everything is correct, keep rotating the knob to reach the proper voltage (40 Vrms). Take the measurements of current, voltage, and power from the wattmeter.
f) Turn the variac off and rotate its knob to the full CCW position.
g) Next, construct the circuit in the configuration shown in Fig. 2 to take the measurements for the branch with the resistor only. Follow the steps (d), (e), and (f) to accomplish your measurements.

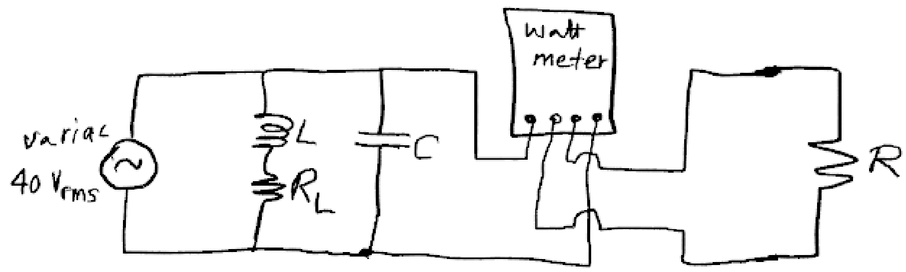


Figure 2

h) Modify the configuration of Fig. 1 to take the measurements of the branch with the inductor referring to your circuit diagram from the prelab. Follow the steps (d), (e), and (f) to accomplish your measurements.
i) Modify the configuration of Fig. 1 to take the measurements of the branch with the capacitor referring to your circuit diagram from the prelab. Follow the steps (d), (e), and (f) to accomplish your measurements.
j) Power down the circuit and disassemble.

8. ANALYSIS AND CONCLUSIONS

a) Compare the results of your hand analysis, simulation, and measurements Create a table to organize your data.
b) Are the currents, voltages, and powers you expected from your hand analysis close to (or matching with) the outputs of the simulation and your measurements? Don't do a detailed error analysis, but were you able to actually set the variac to exactly 40 Vrms? Were you able to set the power resistor to exactly 100 Ω? If your hand analysis showed an expected value of "…" amperes, how close was the measured value to it? Probably you would say that if your measurement was off by a "little bit," you wouldn't be concerned that you made a mistake in your analysis, simulation, or measurement. But if the measurement was off by "quite a bit," you would start to suspect that an error was made somewhere. At what point would you start being concerned? No numerical calculations necessary – just discuss how you would decide that you have a problem or not with agreement among your calculations, simulation results, and measurements.
c) When you are finished with your lab, make a photocopy of all the right side pages and print it out. Turn in your lab in class on the due date. If you don't have easy access to a photocopier machine, the app GeniusScan works with your smartphone and allows you to easily create a pdf that can be printed.

† Adapted from D. Anagnostou, "Lab Experiment – 1," 2015.