ENGG 225

Fundamentals of Electrical Circuits and Machines

Introduction to the ENGG 225 Laboratory

1 Introduction

Welcome to the ENGG 225 laboratory. In this document, we review some procedures and tips common to all of the laboratory experiments. Please read this over carefully before heading into the lab for the first time. Keep it handy as well through the course so that you can refer to important information such as resistor colour codes.

2 Acknowledgments

The course instructors for ENGG 225 greatly acknowledge the University of Calgary Engineering Endowment Fund for substantial funding toward the purchase of important high-quality laboratory test equipment and supplies needed to enhance the learning value of the laboratories in the course.

3 Laboratory Safety

3.1 Electric Shocks

While most of the experiments in ENGG 225 use harmless low-power low-voltage sources, it is always best to develop some good habits for working on *any* electric circuit. Electric shocks can be very dangerous, since your body is controlled by electrical impulses. Do not work on an energized circuit. If it is absolutely necessary to do so, it is best to make sure that your feet are insulated from the floor and that you are not touching a ground connection with any part of your body. In this way the electric current has no path through your body to ground. When making voltage measurements on an energized circuit always make them with one hand. Current as low as 10 mA through your heart can cause a cardiac arrest.

3.2 Component Failure

Quite often a component may fail if it is improperly chosen or improperly connected. Before it fails, it usually heats up, and this may happen quickly or over a period of time. Resistors, for example, can get hot enough to cause burns without smoking or glowing red-hot before they fail. Electrolytic capacitors may explode if they are connected incorrectly. An integrated circuit, such as the operational amplifier, could be destroyed. Before you apply power, double check that your circuit is correctly wired, and that your component values are correct.

Capacitors that must have a certain voltage polarity (including electrolytic capacitors) will have markings on them to indicate the proper polarity. They usually have positive and negative symbols appropriately marked next to the capacitor's terminals.

4 Laboratory Experiments

There are four laboratory experiments in the course this year. The laboratory timetable is maintained on the course website.

The laboratories are physically located on the first-floor of G-block in the Engineering Complex. These in the "Design Lab" in ENG 124 and the adjoining lab ENG 130. There are a total 34 lab stations in these two laboratories. Space permitting, students should try to organize themselves into groups of three if possible, although groups of four may be necessary. Each member must assist equally in performing the experimental work and in compiling and interpreting the results.

The laboratory experiments are organized with the first lab being devoted to familiarization with the various electronic instruments and basic measurement methods. This is done so that in later experiments, you will already be familiar with measurement techniques.

5 Laboratory Notebook Record

All lab notebook records are to be written up in a hard-cover lab notebook (available at the university bookstore; you may also re-use a notebook from a previous course). The notebook records must be completed and graded before leaving each lab session. Only one notebook record per group is required. They will be graded "PASS" or "FAIL" at the discretion of the lab instructor. Generally, a "FAIL" can be turned into a "PASS" by completing or correcting whatever is deemed necessary by the lab instructor.

The laboratory notebook record should be titled and dated, with the names of each group member clearly listed. The notebook record should be organized into the following separate sections, which are clearly titled and underlined:

- Title, date, and lab group members.
- Objectives (what's the experiment about?).
- Pre-lab (calculation of theoretical results).
- Observations and Discussion (your measurements, graphs, and observations to verify pre-lab calculations, and answers to any questions given in the lab exercises).
- Conclusions (what happened?).

Below is a more detailed description of what is expected. A simple rule of thumb is that there should be enough information in the lab notebook record so that you or someone else will be able to follow what you did, and possibly reproduce your results.

5.1 Pre-Lab Section (Mandatory Preliminary Work)

Most, but not all, of the laboratory experiments have mandatory pre-lab exercises. The pre-lab exercises are very important, and usually require some design work or calculation of expected results based upon theory. In some cases, you simply cannot start the experiment without doing the exercises, and in others, you will have no way of knowing whether your measurements are correct. *It is therefore essential that you have this done prior to the lab session. Your pre-lab will be checked at the start of the session.*

5.2 Observations and Discussion Section

This is clearly the most important section of the notebook record; it is where the central purpose of the experiment is realized, and should demonstrate a clear understanding of the material. Do the calculations match what you measured? If not, why not? How large were the discrepancies? (Note that the difference between theoretical and measured data may not be an error; it is simply a difference.)

As you proceed with the experiment, briefly describe the part of the experiment you are performing, and carefully record your measurements and observations. Record the instruments on which you have made your measurements. What are the possible sources of error?

All comparisons between measured and theoretically predicted results should be numerical. Perhaps the easiest way to present your results is to use tables with the predicted values, measured values and the differences. Differences are best calculated and expressed as a percentage. You should also attempt to answer all of the questions in the lab exercises.

5.3 Conclusions Section

After everything is said and done, what conclusions can you draw? Did the theory agree with the measurements? Can you now come up with a better equation and method for predicting what you measured? Was the method used unreliable, inaccurate or unworkable in any way?

5.4 Taking Care in Your Writeup

These are ways to avoid common mistakes we see.

1. Make sure all group members' names can be easily found. Only include a members name if they participated.
2. Date and number your pages.
3. Do not use an excessive number of digits when recording measurements or calculations. If the parts are only accurate to 5%, then there is no need to record a number with so many digits, such as 23.495906523Ω, even if that is what your calculator says.
4. Use engineering notation where appropriate; for example, 0.003 A should be written as 3.0 mA.
5. Record the correct units of what you're measuring. Was it V_{rms} on a true RMS meter or V_{pp} as measured on the oscilloscope? Unless it is clear where the measurement came from, it is worth writing down.

6 Laboratory Conventions and Tips

6.1 Connectors

Make sure that when a attaching a cable to an instrument that it is securely fastened. For example, when attaching a coaxial cable to the oscilloscope, push the cable's BNC plug onto the oscilloscope's BNC socket, and give it a right twist to lock it in place.

Also, loose-fitting connectors do not give reliable connections, and are occasionally a problem at some lab stations. If there is a problem, bring it to the attention of the laboratory technician during the lab period.

6.2 Measuring Voltage and Current

We will emphasize many times in the course that voltmeters are connected *across* (i.e., *in parallel with*) circuit elements. Ammeters are connected *in series* so that you can measure the current *through* a component. Ideally, a voltmeter appears to your circuit as an open circuit at its terminals; conversely, an ammeter appears to your circuit as a short circuit. This is very important to remember; getting them mixed up can damage your circuit, the equipment, *or possibly yourself!*

6.3 Grounding

The strict definition of grounding refers to the connection of some node in your circuit to the Earth. In this case, the Earth is being used as a world-wide "common-ground" conductor. Rarely, if ever, would you need to make such a direct ground connection yourself. However, the word "ground" is usually instead used to refer to zero volts or the circuit's "common node" or "reference node". The IEEE (Institute of Electrical and Electronics Engineers) standard ground symbol is shown in Fig. 1.

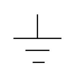

Fig. 1. IEEE ground symbol

6.4 Chassis Common Node

The symbols below in Fig. 2 are commonly used, but non-standard, and mean that a node or terminal is connected to the metal case of an instrument. Because of this, that wire must be at zero volts by definition. An example of this is the "common" terminal on the oscilloscope.

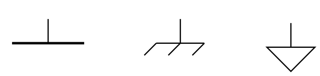

Fig. 2. Non-standard ground symbols

6.5 Wiring and Colour-Coding Conventions

Wire in various colours will be placed out in each lab to allow you to assemble your circuits. For the most part, you can choose any colours you wish, except only to observe a couple of standard and important colour-coding conventions. For most electronic circuits, black is reserved for zero-volt (ground) connections. Similarly, red is almost always used to connect to the "+" terminal on voltage sources. Otherwise, you're free to pick from a rainbow of colours.

Reserving black for zero-volt connections is particularly important because it can reduce the risk of making wiring mistakes when connecting instruments like the oscilloscope. The grounding clip on an oscilloscope probe is a black alligator clip, and is *always* at zero volts. If you follow this black-on-black rule, then you know that you are making a short circuit if you connect anything but a black wire to a black wire.

6.6 Variables and Units

By convention, in most textbooks on electric circuits, the voltage, current, power, and energy variables are defined using lower-case letters (e.g., $v(t) = V_1 \sin(t)$), while an upper-case letter indicates a constant (e.g., V_1). When naming variables for a particular circuit, it is good practice to give them names that include the names of the terminals of the device to which they apply. For example, v_a would indicate the voltage at terminal **a** with respect to the reference node (ground). v_{ab} would indicate the voltage measured between the terminals labeled **a** and **b**, where $v_{ab} = v_a - v_b$.

When expressing particular values of voltage, current, power, and energy, the units are given with an appropriate qualifier to indicate the nature of the measurement. This is primarily important for AC quantities. For DC measurements, there is little choice; for example $v = 10\ V$, $p = 150\ W$. For AC measurements, there is much more choice; for example:

- $v(t) = 10\ V_{peak-to-peak}$ or $10\ V_{pp}$ for peak-to-peak voltage in volts;
- $i(t) = 15\ A_{peak}$ or $15\ A_p$ for peak current in amperes;
- $v = 20\ V_{rms}$ for root-mean-square (rms) voltage in volts;
- $p = 50\ W$ (no subscript) for average power in watts.

7 Circuit Elements Available in the Laboratory

You will be using resistors, thermistors, capacitors, inductors, operational amplifiers, and pre-built buffer modules throughout the labs in the course. Most of the parts will be laid out at each lab table so that you can begin to use them immediately. Resistors will be kept in small drawers in a central location in each of the lab rooms so that you can pick whatever values you need.

Resistors available in the labs are listed in Table I.

Table I - Available Resistors

100Ω	1KΩ
120Ω	1.2KΩ
220Ω	2.2KΩ
330Ω	4.7KΩ
390Ω	8.2KΩ
470Ω	10KΩ
680Ω	51KΩ
820Ω	100KΩ

To help keep track of the values of resistors that you take from these drawers, it is handy (and easy) to learn the resistor colour-coding convention. Resistor values can be identified by reading the coloured bands and by using the simple formula shown in Fig. 3. The colour codes are given in Table II. You may wish to detach this information and take it with you to each laboratory session. You may also find colour-code charts physically posted in various laboratory spaces.

Please make sure that you return all your parts to where you found them when you are finished.

IMPORTANT: *It is very possible that a resistor has been placed back in the wrong drawer by a previous group, so please check the colour code when you select a resistor for your circuit. Alternatively, use the digital multimeter to measure its resistance. This can save you some considerable grief when debugging your circuits!*

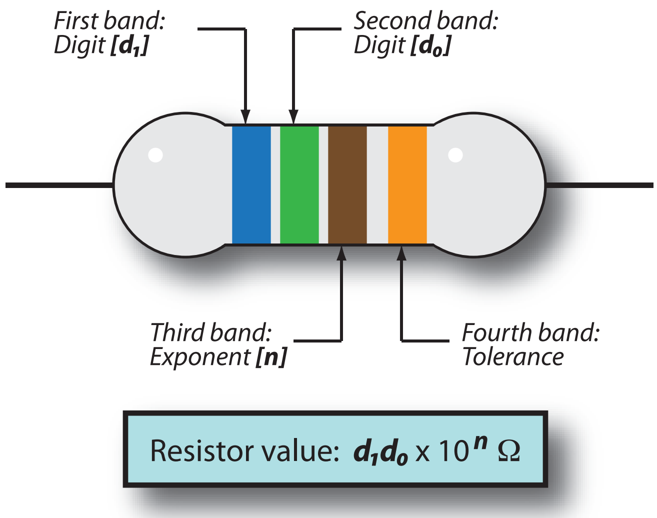

Fig. 3. Interpretation of resistor colour bands

TABLE II - RESISTOR COLOUR CODES

Colour	**1st Band - d_1**	**2nd Band - d_0**	**3rd Band - n [10^n]**	**4th Band - Tolerance**
black	0	0	0 [1]	-
brown	1	1	1 [10]	±1%
red	2	2	2 [100]	±2%
orange	3	3	3 [1,000]	-
yellow	4	4	4 [10,000]	-
green	5	5	5 [100,000]	±0.5%
blue	6	6	6 [1,000,000]	±0.25%
violet	7	7	7 [10,000,000]	±0.1%
gray	8	8	8 [100,000,000]	-
white	9	9	9 [1,000,000,000]	-
gold	-	-	-1 [0.1]	±5%
silver	-	-	-2 [0.01]	±10%

Example:

Colour bands are, from left-to-right, **Blue, Green, Brown, Gold**.
From the table above, $d_1 = 6$, $d_0 = 5$, $n = 1$, so that $R = 65 \times 10^1 = 650\Omega$, $\pm 5\%$.

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