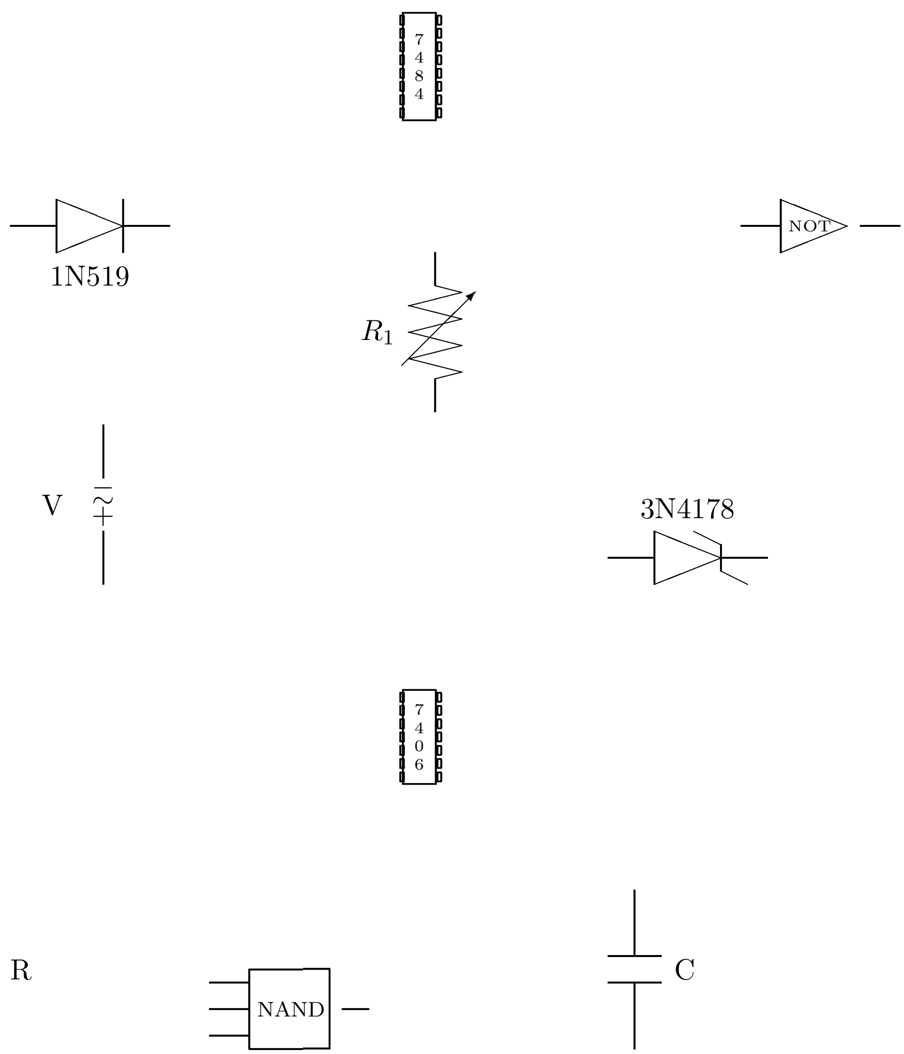
EE211
Laboratory Manual
SPRING 2002



Contents

1 INTRODUCTION

The purpose of the laboratory program is to acquaint the student with experimental procedures and techniques, laboratory instrumentation, methods of good record keeping, and the performance characteristics of the devices and equipment used in the laboratory.

Laboratory work is a fundamental part of the work experience for any engineer or scientist. The essential idea of lab work is twofold: determine that systems perform as expected and determine what is wrong with a particular system. Implicit in this idea is the notion that you know, before entering the lab to collect *ANY* data, how the system under consideration should perform.

Since knowledge about the system is usually in the form of a mathematical model dictated by theory, lab work then consists of verifying that the model adequately describes the system at hand. Any model being used has associated assumptions, both about the system itself and the conditions under which the model may be applied. It is important to verify that the assumptions are adequate and complete, as well as verifying that the model performs suitably within the constraints imposed by these assumptions. For example, Ohm's Law is a good model for a real resistor when the signal amplitude stays within the linear portion of the resistor's operating curve, when the signal frequency is small enough, when the temperature remains relatively constant, when proper sign convention is followed, etc.

2 LAB SCHEDULE

The schedule of lab experiments for this semester is listed in the table below.

Table 1: EE211 Lab Schedule.

The Week of	Experiment
Jan. 6	No Lab classes
Jan. 13	Orientation/S
Jan. 20	Spice Analysis
Jan. 27	Scopes & Supplies
Feb. 3	Function Generator
Feb. 10	No Lab classes
Feb. 17	Impedances
Feb. 24	Transient Response
Mar. 3	Op Amps
Mar. 10	555 Timer
Mar. 17	Spring Recess
Mar. 24	Single Phase Power
Mar. 31	Frequency Response
Apr. 7	Combinational Logic
Apr. 14	Make Up

3 OPERATIONS

The following sections describe the responsibilities of the student in this course and the policies under which the class will operate. If you have questions or comments, please bring them to one of the staff members associated with the course.

3.1 Office Hours

Office hours for the instructor and the TAs will be anounced later.

3.2 Lecture

Lectures will be held in the room scheduled by the Registrar according to the schedule shown in the table below. It is expected that you will attend these lectures since you will receive information about the various laboratory experiments which do not appear in a handout, but are usually necessary to perform the experiment or are to be included in the lab write–up.

Table 2: EE211 Lab Lecture Schedule.

Date	Topic
Jan. 11	Introduction
Jan. 18	Scopes & Supplies
Jan. 25	Function Generator
Feb. 1	Impedances
Feb. 8	No lecture
Feb. 15	Transient Response
Mar. 22	Op Amps
Mar. 1	555 Timer
Mar. 8	Single Phase Power
Mar. 22	Frequency Response
Mar. 29	Combinatorial Logic

3.3 Preliminary Report Due Dates

All preliminary reports are at the beginning of your lab. Failure to place the preliminary report will result in a loss of 10 points. Also, without a Dean's excuse, late prelabs will have a 10 point penalty per day.

3.4 Preliminary Report Returns

Your preliminary report will be graded within two working days following the preliminary report due date. If the preliminary report is not acceptable — incomplete or significantly incorrect — the TA or the instructor will contact you and explain the changes that need to be made. A meeting at a mutually acceptable time prior to lab will also be arranged to grade the revised preliminary report. If it is again not acceptable, you will not be permitted to perform that experiment resulting in a full lose of points.

3.5 Laboratory

You are expected to appear for your scheduled lab period to perform the required experiment for each week. Refer to the Lab Schedule (Table 1, page 1) for the appropriate weekly assignment.

Students will work in groups of two. However, the instructor may allow three people to work in a group for unavoidable situations. Lab groups will be determined during the orientation lab. The work should be divided between the members of the group in such a way as to give each member an equal opportunity to gain experience in all phases of the experimental work. This is especially important as each student should learn how to perform *all* the experiments.

Each group is expected to prepare a preliminary and a final lab report. It is expected that data collection will typically require from 1.5 to 2.5 hours. This leaves you from 80 to 140 minutes extra time should you need it. *The lab TA must initial your collected Data before you leave the lab.*

It is *strongly* recommended that you complete the Results section of the final report *before you leave the lab*. You may discover, while calculating your results, that some of your data is incorrect. If you have not left the lab, you may revise the errant data. However, if you leave the lab and later discover your data is wrong, you will *NOT* be permitted to recollect the data.

All equipment needed, except that provided as permanent bench equipment, must be requisitioned from the Instrument Room using the regular form provided for this purpose. All members of the group must sign the requisition form, and they are equally responsible for damage to the equipment. Upon completion of the experiment, all requisitioned equipment must be returned to the Instrument Room. The Instrument Technician will certify its return by placing an appropriate stamp on the first page of the group's laboratory record for the experiment. *NOTE*: all equipment must be turned in no later than 20 minutes prior to the end of the lab period, even if you are not finished collecting data. *NO EXCEPTIONS.*

Students are *NOT* allowed in the Instrument Room or the Shop. In case of difficulties requiring special equipment or services, a laboratory instructor must be consulted. The TAs are responsible for taking the appropriate steps to correct such difficulties.

Each student is completely responsible for the proper use and protection of all equipment used by the student or the student's group. Any damage to or malfunction of equipment *must be reported* to a laboratory instructor *immediately*. Whenever a group is responsible for damage to laboratory instruments or equipment, each member of the group can be fined. Final judgement regarding the possible assessment of fines rests with the instructor in charge of the laboratory section concerned. A burned out fuse, for example, is to be considered evidence that something is *seriously* wrong with the experimental setup and must be reported immediately to the laboratory instructor. The instructor will approve the issuance of the proper replacement fuse once the problem has been located.

3.6 Final Report Due Dates

Students will have a week to submit the final report. All final reports are due in the lab period for each section. Failure to turn in the lab reports at the required time will result in a loss of points. The reports should be submitted to the TAs along with the preliminary report for the for the next experiment.

3.7 Make–Ups

If you are unable to attend a scheduled lab period and you have a Dean's excuse (due to illness, family emergency, sports, etc.), or, if there is a significant equipment failure for which you are not responsible resulting in a major loss of lab time (verified by the lab instructor), you will be expected to complete that experiment during the make–up period. (See the schedule in Table 1, page 1 for the make–up period.) Missing a lab due to extended vacations, over–sleeping, etc. *do not* constitute a valid reason. If you know beforehand that you will be absent, please see your TA to schedule an alternate time to do the experiment. *Note*: if your lab partner misses doing an experiment, you are still expected to perform that experiment at the regularly scheduled time. You may work with another group for the experiment if you wish. Please notify your lab instructor that this is the case.

3.8 Grading

You will perform 9 experiment. Each experiment will be worth 100 points. At the end of the semester the TAs in each section will assign a perfomance grade (out of 100) to each students. (This will be explained in the orientation classes).

The grade for experiments will be divided as noted below. Please refer to the section on Write–Ups (page 4) for the specific contents of each portion of the write–ups.

The preliminary report will be worth 25 points. One of the following letter grades will be assigned to each of the preliminary reports: A (25), B (20), C (15) and F (not acceptable). After submitting your preliminary report, it will be graded and will be available for return in one or two days. A late preliminary report will incur a penalty of 10 points per day. If the preliminary report is unacceptable or significantly incomplete, it will be returned for you to redo it. The grade you receive after redoing it satisfactorily will be a C. If the second try at your preliminary report is unacceptable, you will receive zero (0) points and will not be permitted to perform that experiment. The final report will be worth 75 points. The details of the grading of the final report is described in Section 4.6.

If you disagree with the grading on a particular experiment, please discuss it with your TA. If you feel you cannot obtain satisfaction, the instructor in charge of the course will review your question. *It is recognized that there will be grading inconsistencies/differences in a multi–section course of this size. We will make every reasonable effort to minimize these discrepancies. At the end of the semester, your scores will be normalized against only other students in the same lab section. These normalized scores will then be combined with the remainder of the class to determine the resultant grading scale.* The net effect of this grading scheme is that each lab section effectively has its own curve determined solely by the performance of the students in that section. Note that it is expected that the final *median* class average will be in the C+ to B range. A raw grade of 90% or 80% does not guarantee a letter grade of A or B, respectively.

You may, at any time during the semester, discuss your current standing in the course with the instructor in charge. You are encouraged to do so at least once during the semester. Additionally, once or twice during the semester, you will receive a computer printout of your recorded scores. This will permit you to check to see that your grades have been recorded properly. You may, of course, check this at any time during the semester.

4 LABORATORY WRITEUPS

The idea behind a lab report is to include everything necessary for someone else to be able to perform the experiment from what you have written. Your report should be clear, concise and complete.

The laboratory report will actually be completed in two phases; there will be a preliminary report and a final report. The preliminary report serves two purposes. First, it ensures that the student is prepared to actually perform the experiment when he or she comes to the lab, and second, he or she knows what the expected outcome of the experiment is.

The final report, then, consists of those things which can only be done in lab or after the data is collected. A well–prepared preliminary report will greatly minimize the amount of work and number of mistakes in lab, increasing the amount of time you have in lab to work on your final report.

4.1 General Write–Up Guidelines

The preliminary and the final reports should follow the general guidelines described below.

Use the indicated headings for each section of your reports. Also use the same step and question numbers as are given in the experiment handout.

There is usually material in the lab handout which may has to be included in the lab write-up. Copy this material into your report; do not cut out pieces and staple them in the lab report. It is permissible to use photocopies of complicated figures and circuit diagrams, however, but do not do so for simple figures and texts. You will be told in lecture specificly which, if any, figures may be cut from the handout and pasted into your notebook.

4.2 Tables

Please use the following guidelines for presenting tables in your report.

1. Number all tables in your report, beginning with Table 1 and continuing consecutively.

2. Label each table at the top with a description of the contents of that table. For example, "*Table 2. Expected and Actual Power Dissipation for the Circuit in Figure 6*".

3. Use headers to indicate the contents of each column. If a column consists of numeric data, indicate the units for that data in the column header.

4. The independent variable(s) should appear in the first column(s). The dependent quantity(ies) should appear in the remaining column(s). The independent variables are those which you manipulate in the experiment. The dependent variables are those which you measure as a result of the various manipulations or calculations based upon measured data.

4.3 Equations

Please employ the following guidelines when using equations in your reports.

1. For each result or calculation which you must determine in the experiment, you should have an equation or equations detailing how such calculations should be made.

2. Number each equation in your report, beginning with 1 and continuing consecutively. Use these equation numbers when referring to equations.

3. When determining expected data or results, you only need to show the complete derivation of the desired quantity once. You may compile the result of further calculations using the same equation(s) into a table and refer to the equation(s) as the source of the numbers. For example, to determine the expected power absorbed by a resistor as the resistance is varied in a specified manner, you should derive the necessary equations using a variable to denote the variable resistance, then show a sample calculation using one of the values which the

Table 3: Preliminary Report Outline.

Section	Highlights
Title Page	course, section, semester, year, experiment title, name, partner's name, group number, date
Equipment List	equipment, numbers
Objective	what the experiment does
Figures	circuit diagrams, figures of experimental setups (when applicable)
Preliminary Preparation	simulation results and answers as required

resistor can assume, and, finally, summarize the absorbed power in a table and/or figure for the different resistance values.

4. In general, equations should appear on a line by themselves with its reference number at the end of the line. Very short equations or inequalities which are not otherwise referred to can be included in–line with your text.

4.4 Figures

Please follow the following guidelines in incorporating figures within your report.

1. Number all figures, beginning with Figure 1 and continuing consecutively.
2. Provide a descriptive caption at the bottom of the figure.
3. Denote which variable is being displayed on each axis. The independent variable goes on the horizontal axis. The dependent variable goes along the vertical axis.
4. Indicate the units in which each axis is displayed.

4.5 Preliminary Report

The preliminary report should be structured using the outline described in Table 3. These sections are explained in more detail below.

Title Page

The title page should contain the following: the course number, section number, semester, year, the name of the experiment, your name, your partner's name, your lab group, and the date the experiment is performed.

Equipment List

You should copy the equipment list given on the last page of the experiment handout. When you get into lab, mark the number of those major pieces of equipment which are separately numbered in your raw datasheet. Equipment numbers are used if there appears to be an equipment problem.

Table 4: Final Report Outline.

Section	Highlights
Title Page	same as in Table 3
Objective	what the experiment does
Circuit Diagrams	diagrams of the circuits used
Results	answers to questions, calculations figures, tables etc.
Discussion	comparison of expected vs actual, unexpected results and why, problems
Conclusions	usefulness of techniques and topics, other applications, summary
Data	steps taken, settings, actual data, who collected data

The offending piece of equipment can later be checked. This section may appear at the bottom of the title page.

Objective

Include a brief statement (1 or 2 sentences) describing the objective of the experiment. The objective states what the experiment is looking at or trying to do.

Figures

Draw all the circuit diagrams that will be used in the experiment. Use the same variables as in the experiment handout to denote all the elements in the circuits. In some experiments, you may also be required to draw the figures of the experimental setups.

Preliminary Preparation

This section should contain the SPICE/MAPLE/MatLab code of your simulation programs, results of your circuit simulations and answers to the questions asked in the *preliminary preparation* section of the experiment handout.

4.6 Final Report

The final report should be professional in terms of it's presentation, style and content. It is expected to look like a formal report submitted to one's superior in the industry. Note that the laboratory reports are used in the ECE department to meet some of the Writing Across the Curriculum (WAC) requirements. The final report will be typed or generated by using a computer word processor. *Hand-written final reports WILL NOT BE ACCEPTED.* The diagrams, graphs and tables must be drawn using a straightedge or a computer graphics software. The structure of the final report is illustrated in Table 4.

Title Page

In addition to the informations provided in the title page of the preliminary report, the title page should also contain the lab bench number at which the experiment was performed.

Objective

Same as in the preliminary report.

Circuit Diagrams

Include the circuit diagrams that were used in the experiment and are necessary to refer to in the Results and Discussion sections.

Results

The Results section consists of your answers to the results questions asked in the experiment handout. Refer back to your previously developed equations. For numerical answers, only use as many significant figures as can be reasonably justified. Be sure to indicate the units for numerical results.

Discussion

The Discussion section primarily contains an analysis of your data and results. Tabulate the percentage error of your measurements as compared to all predicted data and results. The percentage error can be determined by

$$\%\text{error} = \frac{\text{actual} - \text{expected}}{\text{expected}} \times 100\%$$

Comment on the amount of error in your measurements and on possible sources for those errors (measurement errors, lack of significant figures in measurements, inexact equations, violations of assumptions for equations, unverified component values, etc.). If the expected value is zero, you may sometimes compare the order of magnitude of the actual value to the order of magnitude of the component values which are used to determine the actual value.

You should discuss any unusual occurrences or problems which happened during the lab. Explain what happened, why it happened (if possible) and how it was resolved (if so). If a TA had to help you fix the problem, indicate this.

Conclusions

The Conclusion section should present a brief summary of what you did in the lab and what you determined. You should discuss other possible applications for the circuits, instruments and techniques employed in the experiment. You might also suggest additional steps to improve or extend the experiment.

Data

The raw datasheet (initialed by TA or instructor) should be included in the final report as an appendix. The datasheet is primarily the record of what you actually do in lab. You should refer to the procedure steps and circuit diagrams of the Procedure section of the preliminary report. You

Table 5: Final Report Outline and Scoring.

Section	*Points*
Title page	5
Objective	3
Circuit Diagrams	10
Results	20
Discussion	17
Conclusions	5
Appendix : Raw Data	15

should record the major knob settings used for any measurement equipment. You should record the data which you measure, using only as many significant figures as are reasonable. If the data is to be displayed in a graph, plot the data in pencil as you go along to ensure that you are getting something close to what you expect. You can then write over the pencil marks with a pen for the final copy. If you record an incorrect number, just cross it out and record the revised figure next to it.

It is expected that each partner in a group will collect approximately half or one-third of the data. For any given step, one partner should wire the circuit, adjust the knobs and read off the data. The other partner should check the circuit wiring and knob settings, call out the required knob adjustments and record the data. Indicate which partner was responsible for reading the data from the measurement devices for each step of the procedure by including his or her initials. For example, include a statement like "Collected by R.K.R." after the data taken for each step.

Grading of the final report

The professional quality of the final reports will be strictly enforced in the grading. You may lose points if certain section(s) of your report does not appear to be professional. The apportionment of points for the various parts of the final report are listed in Table 5.

5 LAB TECHNIQUES

This section describes, in general terms, some experimental measurement techniques which may be useful. Additional details and methods will be described in individual experiment handouts and during the lectures.

5.1 Experimental Methods

While taking measurements, there are several generic techniques which apply to a number of measurement devices. Some of these are described below.

1. When reading analog meters, be sure to view the needle from directly above. Since there is a gap between the needle and the dial plate underneath it, reading the meter from an angle will introduce error into the measurement. This effect is called parallax. Some analog meters have a small mirror under the needle to help determine when you are directly above it by aligning the needle with its reflection.

2. For devices with adjustable ranges, use the range which gives the largest span, trace, etc. The more deflection the signal causes, the more resolution you have in determining its value.

3. Always measure the output of power supplies, function generators and oscillators. The front panel controls on these devices are calibrated for a standard load impedance which is rarely met by the circuit being examined. Also, the controls quickly become miscalibrated due to extensive use during lab.

4. When measuring voltages or currents, always start the measurement device on the highest range setting possible. The equipment has its greatest internal protection at this setting so that if something is wrong with your circuit, you won't damage the meters by excessive signal strength. Once everything is turned on and connected, you can then lower the range setting until good resolution is obtained.

5. It is usually best to turn off any power supplies and function generators when changing circuit connections, including measurement connections. This minimizes damage both to the equipment and to your circuit. This is particularly true if the circuit uses high currents and voltages or contains IC chips. Inadvertently shorting out pins on an IC chip can occur if you misplace a measurement probe.

6. Before handling any IC chips, either for installation in or removal from a circuit, be sure to touch the grounded metal case of any powered–up measurement device. This removes any electrostatic charge built up in your body. Electrostatic discharge (ESD) is one of the leading causes of damaged IC chips in the lab. An ESD of several hundred volts can occur quite readily.

7. If any piece of equipment does not seem to be working properly, please tell one of the lab TAs. The lab TA will check it out, then inform the lab manager if necessary. If the TA is not available, you can have one of the people working in instrument room come to your bench and check it out. Do not take the suspected equipment to the instrument room because they will want to check it at the bench. Please keep in mind that the people working in the Instrument Room do not know how to fix your experiment. They can, however, inspect the equipment you are using for proper operation.

5.2 Debugging Circuits

Debugging a circuit is the process of finding where something is wrong. While there is certainly some amount of intuition and art involved in quickly determining where the bug is, the process is also amenable to a straightforward, systematic approach. The best general advice is to begin at the beginning and end at the end or as soon as you find the problem. The following are some concrete suggestions towards solving the problem.

1. Make sure the power supplies are turned on. Amazingly enough, about 5% of one class forgot to turn on the power supply for the op amps during a past lab practical exam!

2. Check that the measurement equipment controls are set properly. AC input coupling on the oscilloscope will not display any DC signal component, so trying to twiddle the DC offset on the function generator will not affect the trace.

3. Measure the output of any power supply, function generator or oscillator to ensure that they are supplying the required waveform.

4. Make sure that any wires connected to terminals on the protoboard do not have their insulation under the terminal lug.

5. Make sure all banana plug connections are tight. The plugs tend to become compressed and loose with extensive use in the lab.

6. Check the signal in the system at successive points in the circuit, starting at the input. You may discover that a wire is broken inside the insulation, that a wire is improperly connected, or that a component seems not to be functioning properly. Passive components are fairly easy to pull out of the circuit and check. IC chips may require more effort to determine if they are working properly.