ECE 304 Laboratory Handbook

University of Arizona

Tucson, Arizona

ORIENTATION MANUAL

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A modification of the manuals by
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Program Objectives

The main objective of this program is to assign basic, open-ended design projects in an laboratory setting. Each participant can put into practice the techniques learned in analog circuit lectures. However, the emphasis now is on a working circuit, which requires troubleshooting, using measuring instruments, and dealing with non-ideal, real world circumstances. Some examples are pickup noise (like stray 60Hz bench noise), circuit parasitics (like stray capacitance and resistive connections) and unknown device behavior (due, for instance, to manufacturing tolerances and temperature variations). The specific laboratory program objectives are as follows:

1) To experience "hands-on" design and construction of electronic circuits.

2) To understand the strengths and weaknesses of the many stages of circuit design and implementation, in particular:
   - a) Establishing conceptual framework for approach to design
   - b) Using "paper and pencil" design
   - c) Using PSPICE - a computer simulation program
   - d) Building a working prototype in the lab
   - e) Testing and trouble-shooting the prototype.

3) To design circuits that meet various requirements, such as:
   - a) Bias and Q point placement
   - b) AC small signal response at midband
   - c) Frequency response, *e.g.* bandwidth
   - d) Input and output impedance
   - e) Circuit stability
   - f) Large signal effects and dynamic range
   - g) Temperature effects and power dissipation
   - h) Operability despite device parameter variations

4) To use specification sheets

5) To keep lab notebooks using standards required for use in a patent dispute

6) To write clear technical reports that meet professional standards

7) To use a variety of measurement and troubleshooting techniques

8) To work closely with a colleague or team, and appreciate its virtues

This program requires at least 4-6 hours of lab work, 4-6 “in-class” hours, which include mini-lectures, and in-class exercises, and 8-12 hours of preparation time per week, on the average. In order to match time with credits, some days classes will not meet, as published in the day-by-day schedule. The labs are scheduled with structured format. Each participant, without exception, is required to sign up for a specific laboratory section with specified hours. Every week participants will do their lab work during their assigned section times. For each project each participant will be assigned to a lab team of two individuals, and the teams will change with each project.

Evaluation Policy

More experienced engineers will serve as mentors and "teaching assistants" or TA’s for this program. Each TA will be assigned groups of participants, on a rotating basis, throughout the program. A point distribution will also be issued for each design project. This will help the TA's provide more uniform evaluation of all written works.

1. Evaluation Guidelines

See the syllabus for details.

At the close of each lab project, a table will be provided showing the point distribution for each part of the lab report. This will ensure that the evaluation is as fair as possible.

Participants will have seven days from the date of return of lab notebooks and reports to discuss evaluation scores with the TA who evaluated the particular work in question. Participants should write down their complaints and give them to a TA during the time he or she is scheduled to be in lab or during a scheduled office hour. The TA schedules will be posted on the bulletin board across from the stockroom.

If a participant questions any of the evaluations done by a TA, the participant must see the TA first. The program supervisor will not discuss the specific evaluation scores with the participant until it is established that the TA and participant cannot resolve the problem. If the participant still questions the evaluation, the participant should then make an appointment to discuss the situation with the program supervisor. The program supervisor will discuss the problem with both TA and participant prior to making the final decision.

2. Penalties

Punctuality and time scheduling to allow for contingencies in meeting deadlines is part of the corporate philosophy! All work is due at the end of the last lab session for a particular project unless otherwise announced, either in the lecture or by electronic mail. A late penalty of 20 points will be applied for each day the notebook is late. For example, if the due date is Thursday at 4:30 PM and the notebook is stamped the following day at 2:30 PM, the penalty is 20 points. If the notebook is stamped two days later at 11:30 am, the penalty is 40 points. Weekends and holidays are not necessarily excluded when figuring late penalties since participants may work on reports during these periods. No work will be accepted for evaluation after the last day of the formal program unless specific permission for unusual circumstances is given. Being busy is not unusual! Short Illnesses, jury duty, work-related and personal travel, and other like events are not considered valid excuses to avoid late penalties -- these are contingencies that must be considered in time scheduling. No letter grade of A, B, C, or D will be given if all work is not completed by the end of the program, even if zero points are involved.

General Laboratory Instructions

1. Laboratory Schedule and Sign-Up

The lab work will be done in ECE 302 on the third floor of the Electrical and Computer Engineering Building. The laboratory will begin during the first full week of classes, regardless of whether or not there is a preceding lecture due to a Monday holiday.

All the laboratory benches are numbered. Each design project has a definite finish date (The schedule will be distributed either in lecture or in a document available from the EES Copy Center, as announced).

2. Bench Sign-In and Sign-Out Procedures

When you come to the lab at your assigned section time, go to the stockroom and sign-in the check-in form and the inventory list. You will then be issued your notebook, toolbox and any special equipment. This list gives the number of each piece of equipment that should be on the bench. Check to see that everything is there. If anything is missing, notify the TA immediately. When you are done with your work, make sure that you leave the bench clean and ready for the next participant or team. Unplug all of the equipment and go to the stockroom to sign out.

Stockroom procedure is as follows:

- You surrender your UA ID card
- You sign the check-in form
- When finished with the bench, you sign out and your UA ID card is returned
- If you forget your UA ID card, only once you can use your AZ Driver's License instead.

Alternatively, the TA may have already obtained parts for the lab, and you can get them from him. If you do, the same procedures apply, except the TA will act in the stockroom's place.

You are responsible for everything on the bench from the time you pick up the key until you return it. Thus, if you should leave for a short time, for a break, etc., you should lock your bench.

3. Equipment Sign Out

For many design projects, all of the equipment necessary will be on the assigned benches. In some cases, this is not practical and you will have to sign some equipment out of the stockroom. Tell the attendant what you need and check out the piece of equipment. When you return the equipment, make sure the stockroom attendant has removed your name from the list. Don't just leave the equipment at the stockroom window. **As long as the stockroom has you on the list, you are responsible for the equipment.** If you do not return all equipment and specified components to the stockroom by the last day of the program, **you may be given an *Incomplete (I)* or *Failure (E).***

Stockroom procedure is as follows:

- You need a UA ID card
- You must fill out a form "ECE Equipment/Parts Check Out/In Form". Items checked out are the financial responsibility of the individual.

4. Parts and Supplies

The Department maintains a stock of commonly used parts, such as transistors, diodes, resistors, capacitors, etc. You may draw on this stock as needed for various experiments and design projects connected with your lab program . All components, except resistors, must be returned to the stockroom whether good or bad. The participant must replace all components that are not returned, even if defective, from outside sources.

5. Laboratory Notebooks

Each participant will keep a laboratory notebook. Detailed instructions are in the section Instructions for Laboratory Notebooks. For this purpose, each participant should purchase two spiral bound quadrille notebooks, National Form No. 33-209. **Two such notebooks are required**, one to work in while the other is turned in for evaluation.

It is important that participants develop the habit of keeping up their lab notebooks as they go. It seems to be a natural tendency to scribble results on sheets of scratch paper, with the intent of copying them over later. There are two major objections to this: first, it's a lot more work to copy it over than it is to write it down correctly the first time; second, you often have to do the work over because you can't figure out what your scribbling means. The lab TA's will frequently check to see that notebooks are up-to-date and that participants are not taking lab notes and data on scratch paper.

Participants may use any type of non-erasable pen with black ink as long as the notebook is neat, legible and orderly, and the ink does not bleed through the paper (some soft-tip pen inks will soak through). It is also important that your lab notebook is neat and that proper English grammar and spelling is used. Systematic, orderly work goes naturally with orderly thought processes. An engineer's work will be judged accordingly.

There is no single "best" format for a lab notebook. Each engineer keeps his or her notebook slightly differently than anyone else. However, a basic rule should be kept in mind. The running account in the notebook should contain sufficient detail that any person of technical competence could repeat the work exactly and verify the results.

This basic rule implies the inclusion of certain information, rules about corrections, dating of entries, and so forth, as discussed in the section "Instructions for Laboratory Notebooks". Participants should remember that a laboratory notebook may be quite important should patent litigation occur. Then technical and legal experts on both sides of the case scrutinize the notebook, perhaps even a decade or more after the entries were made!

6. Reports

Participants will also be required to write formal engineering project reports based on their notebooks after all the lab work has been completed. These reports will be prepared on an IBM-compatible PC using Microsoft Word and Excel, importing files and graphs as needed from PSpice. Participants may also be required to turn in a 3.5" disk containing the body of the report. There are differing formats and styles of reports; this topic and the specific requirements for each report will be discussed in class. However, some general requirements are:

TITLE PAGE

Include project number, short identifying title, and names of all team members.

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Microsoft Word automatically implements this feature provided you use the *Style* feature to identify Heading 1, Heading 2, etc. Three levels of headings are sufficient unless otherwise noted. The Heading 1 sections are as follows:

INTRODUCTION

Statement of objectives, specifications, equipment list

PAPER DESIGN

1. Design requirements
2. Equivalent circuits (AC and DC) with components clearly labeled
3. Statement of circuit variables that have to be found in the design, *e.g.* resistor values, bias values, bandwidths
4. Discussion of *intuitive* idea of how the circuit works and how the design variables are interrelated in reaching the specifications. What are the trade-offs? For EACH specification, what would you change in the circuit if it failed to meet that specification, how would you change it (*e.g.* increase or decrease a component value), and why would the change improve the design in some ways and make it worse in others?
5. Equations and analysis
6. Final paper design
7. PSpice schematic showing the Q-point values of all relevant components, currents and biases for the paper design. Both the paper design and the PSpice simulation should use components actually available from the stockroom. Usually 10%-tolerant resistor values should be used, as listed below in bold font:

Standard 5% resistor values, 10% values in bold font				
10	16	**27**	43	**68**
11	**18**	30	**47**	75
12	20	**33**	51	**82**
13	**22**	36	**56**	91
15	24	**39**	62	

8. PSpice PROBE plots showing how well the paper design meets specs

PSPICE REFINEMENT OF DESIGN

1. Tabulation of specs, paper design predictions, and PSpice results
2. Discussion of discrepancies: what has to be fixed?
3. Intuitive rationale for how the circuit is to be modified to meet spec. Identification of key variables for modification
4. PROBE plots for design improvement: for example, DC sweeps of pertinent global variables
5. Final design with PSpice verification as in §7 and §8 of PAPER DESIGN
6. Tabulation of specs, paper design and final PSpice design results

BREADBOARD

1. Schematic with component values shown, measuring instruments indicated *as connected*.
2. ID numbers of all instruments tabulated, with keys to the schematic
3. Measurement data
4. Discussion of practical problems and how they were dealt with

COMPARISONS

1. Tabulation of specs, PSpice predictions and measured results
2. Identification of discrepancies
3. Discussion of the source of discrepancies between PSpice and breadboard results. An attempt must be made to show that the postulated source of discrepancy is in fact large enough to contribute to the differences. For example, if the suggestion is a temperature difference, PSpice results at several temperatures could be used to illustrate the magnitude of such an effect, or measurements could be done to show that temperature sensitivity is large enough.

7. Record Keeping and Attendance

Participants' time in laboratory will be noted by the lab TA, who will: (1) initial each notebook with the time a participant begins each session; (2) initial each notebook following the last entry for that day and enter the time a participant leaves the lab. The stockroom computer also will track attendance for each session. For attendance purposes, the week is considered to begin on Monday and end on Friday. Participants who finish their lab before the due date will not be penalized because they finished early. Participants who do not spend sufficient time in laboratory may be penalized up to ten (10) percent of the number of points assigned to the laboratory notebook for the particular project.

8. Toolboxes

Each participant will be assigned a toolbox, which will be kept in the stockroom. The stockroom attendant will be in charge of giving them their toolbox each time they come to lab. Participants are responsible for everything in their toolbox. At the end of the semester, any missing items must be either returned or replaced by the participant who checked them out; failure to do so will result in an *Incomplete* until this requirement is met. This *Incomplete* in turn may be converted into *Fail* within a month after the end of the semester in which it is given.

9. Defective Equipment

If defective equipment is discovered, a lab TA should be requested to check the equipment. It is the lab TA's job to turn in any defective equipment to Room 316, fill out a repair form and obtain a replacement.

10. PSpice

PSpice, evaluation version 9.2 will be used extensively for circuit simulation. There are approximately thirty computers in the PC lab (ECE 208) for running PSpice, Word and Excel. In addition to this, I^2TL lab (ECE 226) has forty plus machines with latest hardware and software tools that a student can utilize for pre-lab assignments. Participants with a home computer can install Orcad 9.2 using a CD-ROM borrowed from the stockroom or the disk in Herniter's book. This installation will free computer time for those without a home computer. While Orcad Lite versions other than 9.2 are available, their use may cause discrepancies due to different device libraries and defaults. Details on pasting PSpice output in the notebook are contained in the section Instructions for Laboratory Notebooks.

11. Safety Rules

Please read the rules pertaining to safety and policies. You will be required to sign a copy of these requirements at the stockroom prior to beginning any laboratory work. A short summary follows, but you must read the original documents.

- **Wear safety glasses at all times.** Prescription eyeglasses are acceptable, but sunglasses are not.
- Keep lab doors open
- In the lab, do only lab work required by ECE 304.
- Only ECE 304 students, TA's and faculty are allowed in the lab
- Safety hazards should be reported immediately to Mr. Lewis Dupont 621-6179, Room 316
- In case of fire alarm, evacuate quickly via the nearest stairwell

12. Code of Academic Integrity

A copy of the Code of Academic Integrity may be viewed on the University of Arizona website, http://w3.arizona.edu/~studpubs/policies/cacaint.htm.

General Laboratory Preparation

1. Preparatory

Before coming into the first day of a new project session , the student should have a paper design worked out and supported with PSpice simulations.

2. In the Lab

The student should have the TA sign in that the paper design and PSpice simulations are present in the lab notebook, and the TA should fill in the data and time the lab is beginning. This sign-in is a requirement for an acceptable lab book. The first day the TA also will check that the lab book is ready for use, with all pages numbered.

3. Leaving the Lab

The student should have the TA sign-off date and time of departure and put a line through any blank space at the end of the lab data.

Instructions for Laboratory Notebooks

1. Numbering Pages

Project Title	Page Number
Your Name	Date

Number all the pages of each notebook (both sides of each sheet). The page layout is sketched above.

On the first page, keep an index of the pages where the projects begin.

2. Using Record Sheets

Request from the stockroom (Room 313) two LAB NOTEBOOK RECORD SHEETS. Paste a sheet inside the front cover of each notebook.

> When a design project is ready to be evaluated, list the number of the project be evaluated in the first column of the record sheet. Then turn the notebook into the stockroom. The attendant will stamp the date and time in the second column. The TA's will pick up the lab notebooks. They will mark the date graded and sign their names in the third and fourth columns. They will then be returned to the stockroom where participants may pick them up.

3. Storage of Notebooks

The laboratory notebooks may NOT be taken out of the stockroom except for scheduled laboratory section times and for the subsequent report writing periods. In this sense, the project work is held to be "company confidential" and lab notebooks are kept in the "secure" area of the stockroom between lab sessions. Notebooks are returned to the stockroom at the end of the lab period once the TA has signed off.

4. Keeping a Notebook of Legal Value:

Engineering notebooks are used as legal evidence in patent litigation. Several conditions are required in industry to ensure that a notebook has legal status. These conditions are:

a) The notebook must be bound.

b) Each page must be numbered.

c) All entries must be made in non-erasable ink.

d) Each page must be signed and dated by the person making entries.

e) No erasures can be made.

f) Any changes must be crossed out with a single line and the original entry still must be readable.

g) Graphs, PSpice simulations, photographs or other inserted items must be pasted into the notebook: no staples or transparent tape. In legal proceedings this practice avoids suspicion about tampering with the results, particularly with when they were made.

5. Required Notebook Entries

A proper lab notebook should contain the following items for each project or set of experimental measurements.

EQUIPMENT LIST:

Every piece of equipment used should be fully identified by type, manufacturer, model number and ECE Department Identification Number (white tag).

PROJECT DESCRIPTION:

The design project handout sheet should not be included in, or copied, into your report. Assume the notebook reader has the necessary parts of the handout. However, include good schematic diagrams and also include a brief statement of what is actually being done at each part of the experiment. For example, "1. Measurement of Amplifier Input Impedance" is a sample of such a brief statement. It will take some practice to avoid excess words while being clear, concise, and unambiguous. The test to apply is this: Is the write-up sufficiently clear that a participant could exactly repeat the experiment, several years from now?

DATA:

Any data taken should be fully identified as to what it is (with reference to schematic diagram where appropriate), the units, and the instrument Identification Number. One should never attempt to insert scale factors "in your head". Always record exactly what the instrument actually reads, then multiply any necessary factors. Make sure both are recorded in your lab notebook! One will never remember exactly what one did several weeks hence. A tabular format for data recording with properly annotated headings works best.

DISCUSSION:

In a professional notebook the "discussion" should consist of the continuing comments and conclusions concerning the work as it proceeds. An engineer works in a laboratory to discover something, to develop a new device, etc. He/she tries different procedures, methods and materials, draws conclusions based on the results, and then decides what to try next. At each step he/she comments on any discoveries; what they mean, and what they suggest for the next step (sometimes it is necessary to detail your confusion and questions to be investigated and answered later, as the work proceeds).

SCHEMATIC DIAGRAMS:

Circuit diagrams must be complete and indicate clearly where in the circuit the various quantities were measured. Identification numbers of instruments should be shown.

GRAPHS:

A graph is very useful for visually presenting the relationship between two or more quantities. Lab data must always be graphed in the laboratory while the experiment is still intact. Graphing in the lab serves to identify questionable data points. If the data is graphed after the experiment is dismantled, there is no way to replace questionable data points.

Every graph must contain a short descriptive caption, author's name, date and notebook page number locating the data points. Both axes must be scaled and labeled in both quantity and units. Each data point must be clearly marked using a dot, circle, triangle, cross, etc. Extrapolated data must be graphed using a broken line. Freehand lines are discouraged; use a straight edge (such as a drafting triangle) or a French curve when completing graphs.

If more than one curve is graphed on the same sheet of paper, each curve must be identified by a label (preferable) or by using unique data point symbols such as, circles, squares, crosses, etc.

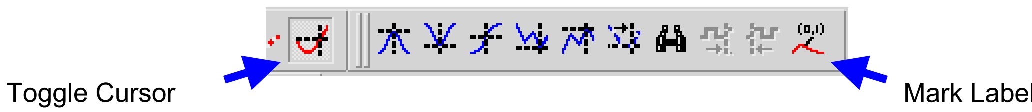
Graph paper should be attached to the notebook with an appropriate adhesive; glue is available at the stockroom window. Staples should not be used.

CALCULATIONS:

If calculations are required, samples should be shown indicating the origin of formulas, specific tabulation of variable values, and any simplifications employed. Any simplifications of the circuit schematic used to make estimates should be provided, and the basis for the simplification explained or documented by reference to the text by page number.

PSPICE SIMULATIONS

All figures require a caption and figure number. For graphs with multiple curves, select the option of displaying curve symbols and a legend to distinguish the curves. In addition, use the TOGGLE CURSOR/MARK LABEL buttons in PROBE to mark individual curves, and edit the labels to include a parameter designator on each curve.



For example, if there is a family of curves related to different values of emitter resistance R_E =1Ω, 10Ω, 100Ω (say), each curve label should be edited to include the designation (R_E = 1Ω), or (R_E=10Ω), *etc*. Accompany all PROBE plots with a figure showing the schematic of the circuit used to obtain them. The caption to the PROBE plots should reference the governing schematic by figure number. The schematic should show (i) pertinent Q-point voltages and currents indicated, (II) all component values, (iii) the labels of any named nodes, and (iv) the ●MODEL names for all active device models (*e.g.* Q2N2222). The ●MODEL listings of all custom active devices (that is, breakout library devices like power transistors or MOSFET's) should be copied form the EDIT MODEL menu and pasted in the notebook, and the ●MODEL names should appear on the schematic next to the device. Again, the basic principle is that anyone should be able to reproduce your simulations, which means that they must have all the data needed to set up the PSPICE simulation.

Appendix: Listing of Possible Lab Projects

1. Current mirror and differential amplifier
2. High-gain differential amplifier with active load, emitter follower output stage, and use with feedback as a VCVS
3.Amplifier with power output stage and use with feedback as a VCVS
4. Wide-band amplifier using cascode gain stage and emitter follower input and output stages