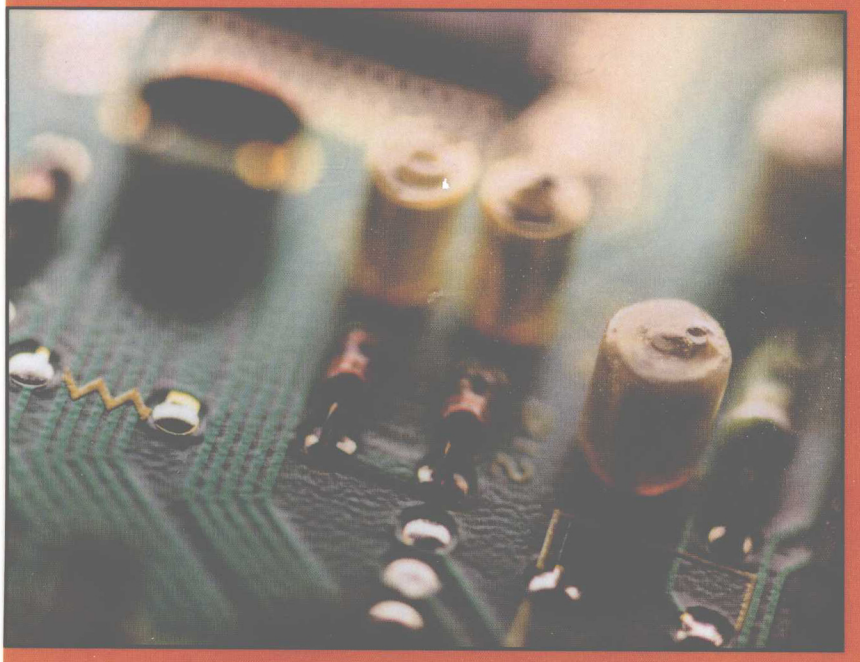
Alexander Ganago

Circuits Make Sense

A New Lab Book for Introductory Courses In Electric Circuits



Fifth Edition

Practice in the Lab

WILEY
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This Lab Book will serve you as a workbook:

Doing Pre-Lab and Lab experiments, you can record your data in the book, then tear out the pages and include them in your lab reports (in your lab notebook).

Sign your copy right now!

(Or risk losing it and having to buy another)

This copy belongs to _____
(Please write your name legibly)

E-mail _____

Lab section # _____ meets every _____ at _____
(Weekday) (AM / PM)

Lab instructor's name _____

Year _____ Semester _____

August 4, 2006

Acknowledgments

I am deeply grateful to Rich Brown and Brian Gilchrist for encouragement and support, to Fred Terry for support and valuable discussion, and to Gabriel Rebeiz for many stimulating discussions. I also appreciate the critique made by graduate students Emre Enginarlar, Yongsoon Eun, and Paul Pelzl who taught the labs in introductory circuits courses for several years and were enthusiastic about the creation of these labs. My special thanks go to Matt Smith who taught the labs in Spring terms of 2002-2004 using all previous editions of this lab book and shared his comments and insights. Many typos and errors were corrected due to feedback from many undergraduate students who took this course over the years. Writing this book could not be possible without the support and patience of my family.

Alexander Ganago

University of Michigan
Ann Arbor

August 4, 2006

New Features in the Fifth Edition

To help students save valuable time during the Lab experiments as well as writing Pre- and Post-Lab assignments, **the Fifth edition includes many tear-out pages,** which may be filled in with lab data, pre-lab circuit designs, etc., and pasted into the lab notebook as part of each lab report.

The Fifth edition includes more illustrations and MATLAB plots in the introductory part of each Lab assignment that show examples of circuit properties, their measurements in the lab, and their analysis with MATLAB. It also includes larger-than-life photographs of circuits actually built in the lab, which help the students work more effectively.

Several Lab experiments were revised for the Fifth edition, and some new experiments and lab procedures are added, notably soldering the circuit in Lab 5. All revisions are based on the teaching experience and formatted for the standard 3-hour lab sessions.

The Fifth edition includes 6 lab experiments that can be performed every other week during a standard 14-week semester.

Lab 2 = AC Lab is written in two versions: for the Hewlett-Packard equipment (HP 54645A oscilloscope and HP 33120A function generator) and for Agilent equipment (3000-series oscilloscope and 33220A function generator).

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Contents

 August 4, 2006

Introduction:

Rules of the Lab

First and Foremost: Laboratory Safety

Although the voltages you apply to your circuits do not exceed +12 or –12 V, and currents are within safe limits, **always think about Lab Safety.** Remember that you will be working with laboratory equipment connected to the 120 V, 60 Hz AC voltage. **This voltage can be lethal under certain conditions.** Therefore, it is always important to observe safe laboratory procedures and carefully follow the instructions.

- **Immediately report any dangerous conditions** such as stripped 120 V AC lines, sparks in laboratory equipment, loose wall sockets, unknown smells and fumes, etc. **to your Lab instructor even if you are not sure of the hazardous level.**
- **In case of emergency** (fire, medical, police, etc.) immediately notify your Lab instructor and/or **call 911** (there is a phone in the lab near the door).
- **No student is allowed to work in the lab alone at any time.** The student must be accompanied at all times by a laboratory partner and/or the Lab instructor. **The Lab instructor should supervise all student work, including the Lab exam.** This rule is observed for regular and make-up lab sessions as well as office hours in the lab.
- **Immediately report *any* equipment failure to the Lab instructor.**
- Any student who knowingly imposes a dangerous electrical situation on himself or herself, on other students, or on the Lab instructor (for example, stripping 120 V lines; electrocuting himself or other students, etc.) will be immediately denied access to the laboratory and will receive a failing grade in the class (F).
- **When in doubt, ask your Lab instructor for help and do not touch anything!**
- **You will learn more about the Lab Safety in Lab 1**, when you just begin to apply any voltages to your circuits.

The Honor Code

The Engineering Honor Code applies to all lab work, including the Pre-Lab assignment, the in-lab data, and the Post-Lab report. Every student is expected to abide by the Honor Code. At the end of your lab report (that is after the Post-Lab) please write, sign, and date the following statement:

"I have neither given nor received aid on this report,
nor have I concealed any violation of the Honor Code."

Lab reports lacking the Honor Code statement, the author's signature, and the date will *not* be graded.

 August 1, 2006

The Structure of a Lab Report

Each lab report includes three parts:

(1) **Pre-Lab (25% of the total grade for the Lab report)** consists of several assignments such as solving **problems,** making **MATLAB plots,** etc. These assignments are focused on the topics of the forthcoming Lab Lecture and Lab experiment. Every student should **complete the Pre-Lab before the beginning of the Lab experiment.** Results of the Pre-Lab calculations are frequently needed for the Post-Lab data analysis, thus the students who failed to do the Pre-Lab on time are encouraged to complete it while writing the lab report, although late work does not bring any points.

(2) **Lab data (25% of the total grade for the Lab report)** include the **results** of laboratory measurements **in the form of tables, sketches of waveforms and spectra,** as well as explicit **statements** of comparison between the observations and the Pre-Lab calculations and plots, with **conclusions** on their similarity and/or distinction. Refer to **Appendix A2** at the end of this book for details. **This Lab course is *very* detail-oriented.**

(3) **Post-Lab data analysis (50% of the total grade for the Lab report)** brings together the theoretical predictions made in the Pre-Lab and the results of experiments made in the lab. It includes making **MATLAB plots,** calculations of **percentage difference,** writing **conclusions,** etc.

All parts of the lab reports should be written in ink in the Lab notebook with numbered pages. No separate sheets will be accepted for grading as parts of Lab reports. If you absolutely have to write on separate sheets, inform your Lab instructor, clearly write your name and date of work on every page, use only one side of each sheet, and neatly paste every sheet to your Lab notebook before turning it in for grading.

The Attendance Policy is *Very* Strict

The EECS 215 Labs traditionally have a **strict** attendance policy, which is necessary for the student success in the course. **Basically, there is no time to make-up a missed lab.** In the Fall / Winter terms the lab room itself is used many hours a week for lab sections. In the Spring the pace of class is very intense and anyone who missed a lab is left behind.

If you need to reschedule a Lab, inform your Lab instructor ahead of time (preferably, in a week).

Any student missing a Lab (not present in the lab at scheduled time) without a proper, reasonable excuse **will get 0 points for that specific Lab report and will have his/her final letter grade reduced by a full letter** (for example, from A^- to B^-).

Any student missing *two* Labs without a proper excuse will automatically get a failing grade (F) on the entire course.

Three simple rules about Lab Reports

1. Label your notebook

On the <u>outside front cover</u> of *each* lab notebook write clearly:

- Your name
- Your e-mail
- Course: (for example, EECS 215)
- Semester: (for example, Fall 2006)
- Your laboratory section #
- Lab instructor's name
- Lab notebook # with Lab report #'s

Without this information the notebook will *not* be accepted for grading.

2. Use only pen in the lab notebook

Use of pencil is not allowed in lab notebooks (tradition of all engineers).

Parts of the lab report written in pencil may *not* be graded *at all* (no points can be earned for them).

3. Conclude each lab report with the Honor Code statement

At the end of each lab report (after the Post-Lab), write and sign the following statement:
"I have neither given nor received aid on this report, nor have I concealed any violation of the Honor Code."

Lab reports lacking the Honor Code statement and the author's signature will not be graded.

Laboratory Procedures

Lab sections meet once a week according to the schedule. Each lab session is scheduled for 3 hours and consists of alternating parts of **Learning in the Lab** and **Lab experiments.**

Learning in the Lab provides detailed, step-by-step explanations of lab procedures and includes experiments, in which students learn to use the equipment, do measurements (somewhat simpler than those required in Lab experiments), and learn how to write good lab reports. The data are written in the blanks on the pages of this book.

The Lab experiment immediately follows **Learning in the Lab** focused on the same topic. Students build circuits, do measurements, and write their results and conclusions in their **Lab notebooks. Every student needs two (2) Lab notebooks for this course.**

Any bound notebook is good enough for the Lab. Quad-ruled notebooks are preferable, because it is easier to sketch plots and write tables.

Each Lab session is designed so that a well-prepared student performs it within the scheduled 3-hour time. **To prepare for the Lab, do the following:**

Read the description of the whole experiment, including the Introduction, the Pre-Lab assignments, the Learning in the Lab and Lab experiment, and the Post-Lab;

Complete the Pre-Lab **before** you come to the Lab;

Draw the circuit diagrams for the Lab experiment in your notebook **before** you come to the lab: it will help you focus on the assignment and save valuable time in the Lab.

At the beginning of the Lab session, the Lab instructor checks Lab notebooks of all students in the section to certify that the Pre-Lab assignment was completed. The Lab notebooks are not collected yet: **students keep using *the same Lab notebook* for writing all parts of the report, including the Pre-Lab, Lab data, and the Post-Lab.**

In the Lab, students work in teams of two. Each student should learn how to build circuits and use the lab equipment. Each student has to write the Pre-Lab assignment, in-Lab data, and the Post-Lab report individually. Please see the section **"Team work, collaboration, and the Honor Code"** on page 7 for details. **If in doubt, ask your Lab instructor for advice.**

Every student is entirely responsible for his or her own work before, during, and after the Lab. However, if a student, who works without a Lab partner, feels that doing all required Lab procedures *alone* takes too much time, he/she should ask the Lab instructor for help.

At the beginning of Lab 3 each student team (two students working as partners or one student working without a partner) signs for a circuit board, which they will keep using till the end of the semester. On that circuit board the student team will build amplifier circuits and save them till the end of the term. **At the end of the term in the Audio Lab (Lab 6) each student team will connect the circuits they built and tested during the term into a working Audio System.** Each System will include volume control and tone control, and be free of distortion of the music played from a CD player to a large speaker.

During each Lab experiment students are expected to

Record experimental data in the form of numbers, tables, plots of waveforms and spectra, etc. (All records of lab data are hand-written: no printers are used.)

Make simple calculations to determine how well the lab data agree with theoretical expectations (most time-consuming calculations are done in the Post-Lab)

Write brief comments on the measurements, for example, compare the waveform observed in the lab with the waveform plotted in the Pre-Lab, etc.

Students should *not* leave the Lab until the Lab instructor signs their Lab data in their Lab notebooks or on tear-out pages in this book.

After the student team has completed the Lab experiment, **each student should submit his or her Lab notebook to the Lab instructor who certifies the completion of all Lab assignments.** Until your Lab instructor signs all your data, keep your workstations turned on and your circuits connected to the instruments so that you can repeat any measurement if needed. Thus you can promptly correct a mistake or make up for inadvertently skipped measurements. ***After* the instructor signed the Lab reports, students should turn off the workstations and clean their workbenches.**

Lab work in EECS 215 helps students develop professional skills and habits. For example, **all engineers use *exclusively* ink and write their lab reports in well-bound notebooks with clearly *numbered* pages.** This is extremely important in companies where patent issues and prior work or knowledge of work may be challenged in a court of law at anytime. Thus our requirement that you use ink and number the pages in your notebooks in EECS 215 Labs simply helps you **develop good professional habits.**

Start learning the professional way to handle Lab data. **If you make a mistake, neatly cross it out and continue on.** If a graph you sketched is incorrect, cross it out with a large X, and continue by making a new, better graph. See more examples in Appendix A2 at the end of this book.

As long as your report is neat overall, you will *not* lose points for a crossed out material. However, lab reports with hash marks all over the place, data presented in haphazard way, and *general sloppiness* will suffer as much as a 50% loss of points for the lab report.

Never use "white-out" in your Lab notebooks. Never tear out the pages with wrong data.

Why? Because in the real world your Lab notebook may become a legal document the moment you turn the page. Common sense dictates that all pages *belong* to the legal documents, and *no alterations* are allowed. If you found a mistake or omission in your Lab data while writing the Post-Lab, you should *not* go back to that page and replace the wrong data with better ones. **If you wish to make a correction, write on the page with wrong data: "See correction on page such-and-such" (be specific) and *add the right stuff after the Lab data, without trying to change your original Lab notes.***

[Many of these Rules, lab policies, and suggestions were formulated by Professor Gabriel Rebeiz in his EECS 210 Laboratory Manual (University of Michigan, 1998).]

Points you earn in EECS 215 Labs

Points for each Lab report

Each Lab report can bring you 100 "small" points, including:

25 points for Pre-Lab

Pre-Lab assignment is based on theory; you do NOT have to use lab equipment to complete the Pre-Lab.

Pre-Lab should be written ***in ink*** in your Lab notebook. Check the schedule for Lab notebook turnover to see which notebook you should use for the particular Pre-Lab.

Pre-Lab is due at the beginning of the Lab. During the Lab your instructor will check the Pre-Lab, but will ***not*** collect it. You will keep using the same Lab notebook for all parts of the Lab report.

25 points for Lab data

Lab data should be written in ink in the same Lab notebook where you did the Pre-Lab.

Your Lab instructor should sign your Lab data after you completed the Lab experiment, before you leave the lab. The Lab instructor will NOT collect the Lab notebooks until you complete the Post-Lab.

50 points for Post-Lab

Post-Lab is based on both theory and your Lab data. It is the most demanding and thus the best rewarded part of the Lab report.

Post-Lab should be written in ink in the same Lab notebook where you wrote the Pre-Lab and Lab data.

Check the schedule for Lab notebook turnover to see when the work is due.

Teamwork, collaboration, and the Honor Code

In the lab you work in teams of two. At home you talk with classmates, roommates, friends and relatives about your Lab reports. This is perfectly OK. After all, everybody knows that engineers work in teams.

At the same time, *you* are entirely responsible for your *own* Lab report. Any part of your Lab report should be *yours*, not a copy of somebody else's. When you turn it in, you sign the Honor Code thus claiming authorship and full responsibility for its contents.

There is no contradiction between teamwork and individual authorship of each report.

To do the Pre-Lab, you need *your* knowledge of the theory and *your* MATLAB skills.

In the lab, you work with your partner to build the circuits and collect the data. Even though you have the same set of data as your Lab partner, **every student is responsible** for learning the equipment and lab skills. Your partner might provide a valuable second opinion, but *you* are responsible for *all* your records.

It might look great to have a partner who knows everything – but if you don't learn yourself, your partner might feel you as a burden and start looking for someone else to work with.

In the Post-Lab, you apply *your* understanding of the theory to the analysis of your lab data. The lab work involves a lot of thinking, which is always unique for every individual. Your lab report should reflect *your* thinking.

Nobody can work *without* using someone else's results. After all, we all rely on Ohm's law thus we use his achievements. **Using someone else's results is fine, provided that you give the author due credit and explicitly quote the source.**

Sometimes you might need to rely on someone else's Lab data to do your Post-Lab. Clearly write in your Lab notebook what data are *not* yours and clearly quote the sources.

You should clearly feel and never cross the borderline between using someone else's expertise and advice (which is a part of learning) and turning in someone else's work as if it were your own (which is plagiarism and blatant violation of professional ethics).

If in doubt, ask your Lab instructor for advice.

Keys to success in EECS 215 Lab

The main key to success is time management. Plan ahead!

To *survive* in this course, read the Introduction and do the Pre-Lab *before* you go to the lab.

To *succeed* in this course, also read the entire Lab, and try to think about the lab procedures and the data you will need for the Post-lab *before* you go to the lab.

The attendance policy is very strict. Read the "Rules of the Lab."

Pre-Lab is due *at the beginning* of the lab. No late work is accepted.

Every week you will write a Post-Lab (for the most recent Lab) and a Pre-Lab (for the future Lab).

Each Pre-Lab may take about 2 hours. Each Post-Lab may take about 2 hours.

Each Pre-Lab and each Post-Lab will require access to a computer with MATLAB and a working printer.

Come to the lab on time, well prepared.

If other commitments (such as midterms in other courses) interfere with your lab schedule, inform your Lab instructor ahead of time (preferably, a week ahead) and arrange for a make-up. You are responsible for your attendance.

Bring your calculator to the lab.

Come to the lab during office hours for extra practice.

If you have a question, ask. Do not be shy. We all learn by asking good questions. Your Lab instructor will be happy to help you. (But do not expect that e-mail you send at 2 a.m. will be *immediately* answered.) Plan ahead!

Lab 1 = DC Lab

Your lab report is due one week after the lab

 August 1, 2006