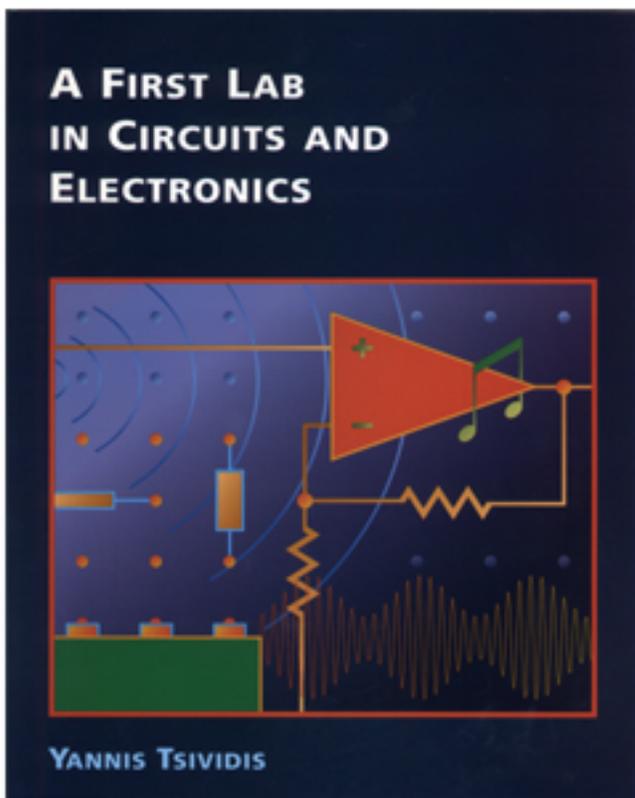


# **A First Lab in Circuits and Electronics**

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## **Preface**

"This is a book for a lab course meant to accompany, or follow, any first course in circuit analysis and/or electronics. It has been written for today's students, who, as is by now widely recognized, are very different from students of years past, when most of the traditional teaching approaches were developed. Among other things, today's students are simply bored when required to go through a long series of procedures, the only purpose of which is to teach measurement techniques and to verify the theory. They want to see the theories they learned applied to something useful, and they want this right away. Telling them that they will see the application next year, or even next semester, is not good enough. And if students become disaffected in the first lab, a golden opportunity to excite them about electrical engineering may have been lost forever."

This lab manual has the following objectives:

1. As is the case with any lab manual, to support, verify, and supplement the theory; to show the relations and differences between theory and practice; and to teach measurement techniques.
2. To convince students that what they are taught in their lecture classes is real and useful, and to get them involved in several applications they can relate to. Thus, circuits and electronics are combined in the same lab.
3. To help make students tinkerers (at least for the duration of the lab, and some, hopefully, for a lifetime).
4. To make them used to asking "what if" questions and to acting on their own to discover new things.
5. To motivate their further study. The idea is to explore several concepts in a simple way, which can serve the dual purpose of applications and motivation. For example, the experiment on modulation can whet their appetite for a communications course in subsequent years.

## **Audience**

This book is intended for sophomore or junior electrical and computer engineering students who are taking their first lab, either concurrently with their first circuit analysis class or following that class (or even following a term of electronic circuits). It is also intended for first-year students in electrical and computer engineering at institutions that have started a first-year course in circuits and electronics (an increasing trend). Finally, it is appropriate for nonmajors, such as students in other branches of engineering or in physics, for which electronics is a required course or elective and for whom a working knowledge of circuits and electronics is desirable.

## Required Student Background

The lab is meant to run concurrently with, or following, any introductory electrical engineering course. Most electronic circuits used here to make the lab interesting and stimulating for beginners are covered in conventional circuit analysis courses (e.g., op-amp circuits). A few simple circuits, such as rectifiers, which may not be covered in a circuit analysis course, are introduced in a self-contained manner. The electronics experiments can extend the lecture material and can serve as excellent motivation for a subsequent course in electronic circuits. Alternatively, the lab may be run concurrently with a course in electronic circuits, in which case the students may not need the introductory background provided or may use it as a concise review. No background in frequency-domain analysis techniques is required, so the lab can be run concurrently with any first circuits course if desired. Nevertheless, the subject of frequency response is adequately covered and applied.

What if circuits is not the first EE course? There is considerable discussion by electrical and computer engineering educators about whether the traditional introduction of students to the field through circuits makes sense today. Some schools are trying other approaches for the first course, such as DSP or "light" control systems. This issue is largely irrelevant as far as the use of this book is concerned: the book is intended for use in a first lab for circuits in electronics, whenever its time comes in a given curriculum. In some schools this will not be the first lab; for example, a computer lab might come before it.

## Approach

Although in this book I have adopted the current trend of tightly coupling to applications, I have maintained the classical approach of keeping the experiments largely independent (as opposed to making them being part of a larger, kit construction project). In this way, flexibility has been maintained in designing the experiments to reinforce certain important concepts and to give the instructor considerable freedom in choosing which experiments to cover. Also, in this way applications can be introduced early and students can see results right away.

In developing this book, I have experimented a lot with the level of freedom appropriate for the first lab. On the one hand, I have found that complete freedom is not appropriate, as many students do not know how to begin and become stuck very often. In addition, in the course of a "free" lab, it is possible that the students will not run across some important concepts, which they normally should be taught; so some guidance is in order. On the other hand, a completely regimented approach stifles

creativity and does not ensure learning; it is entirely possible for a student to blindly follow instructions, do all required parts, and leave the lab without having really understood much. Hence I have opted for a compromise approach, which works best for the large majority of students. There are steps to be followed in each experiment, but many contain questions or suggestions for extending the results, which require the student to act rather than passively follow. I have spent a lot of time in finding ways to keep students alert and creative in the course of the experiments, often by selectively withholding parts of the story and requiring the students to search for these parts themselves. In other words, both in the choice of experiments and in the format and degrees of freedom within each experiment, I have found that what works best is a mixture of the classical and modern approaches.

The experiments are written to help the student develop intuition and to relate, as much as possible, what is learned or measured to what is perceived through one's senses. For example, in Experiment 3, which deals with time-varying signals, the students are introduced to the function generator and the oscilloscope. Through an amplifier and loudspeaker, they hear the waveforms they observe on the scope's screen; and through a microphone, they observe the waveform of their voice, whistling, or clapping. They are even asked to remove the speaker's panel, touch the paper cone of the speaker very lightly, feel its vibration for various frequencies and amplitudes, and observe how a small particle bounces when placed on the vibrating cone. This may sound overdone, but I know, from my early start as a hobbyist-experimenter, that such sensory experiences stay in memory and help make things click. They provide the confirmation that what is done in the lab is real. This removes psychological blocks, increases intuition, and motivates further study.

### **Incorporating Applications**

I have spent considerable time in identifying suitable applications for illustrating the principles and making them exciting, and I have woven -these applications into the experiments. The circuits discussed are connected to applications as soon and as often as possible. Thus, students already see sensors (a thermistor and a photoresistor) in Experiment 2 and use them to design simple temperature- and light-sensitive circuits; they see and use more sensors (microphones) and an actuator (loudspeaker) in Experiment 3; and so on. They do not just measure the gain of an op amp/resistor amplifier, but they use this circuit to amplify their own voice signal and listen to it. They apply diodes to a simple demodulator and LC circuits to receiver selectivity, and they are introduced to wireless communications by building and testing a simple radio receiver

(which puts together many of the concepts they have learned up to that point). They do not just measure the frequency response of low- and high-pass filters but also apply the latter to audio tone control, using them to process music from their favorite CD and listen to the result.

## **Choice of Experiments**

There are more experiments in this book -sixteen of them- than can be comfortably covered in one semester. The experiments are designed so that they can be completed within 3 hours each, although some students can finish some of them in about 2 hours. Other durations and adaptations of the experiments to different student backgrounds are possible. Certain parts of each experiment can be omitted if desired (although it would be a pity to omit the application parts, which are what the students are especially looking forward to). Also, parts of different experiments can be combined to form a new experiment. Suggestions are given in the Instructor's Manual. I will also be happy to discuss with individual instructors their teaching needs and offer suggestions for putting together a lab course based on this book.

## **Design Projects**

The type of "what if" questions asked throughout this manual encourage the student to experiment and build circuits of his or her own. The book makes possible the introduction of design projects at several points, if the instructor decides that there is room for them. Such projects are appreciated by the students and, if placed between experiments, can be useful as "fillers" for delaying some experiments until the lecture class on the corresponding theory has caught up with them. Several project possibilities, which I have tried over the years, are described in the Instructor's Manual.

## **Lab Equipment Required**

The book is designed for a lab that uses equipment as simple (and thus inexpensive) as possible. The basic instruments are two dual power supplies, two digital multimeters, an oscilloscope, two function generators, a inexpensive CD player, a small power amplifier, a microphone, a loudspeaker with enclosure, and assorted parts and cables (an equipment and parts list is given in Appendix G). All this equipment is widely available. For bread boarding the ubiquitous proto boards can be used, although for

the first few experiments at Columbia we prefer Plexiglas boards with plug-in leads so that beginners can clearly see all connections. Simple instructions for making these boards, if desired, are given in the *Instructor's Manual*.

### **Instructor's Manual and Web Site**

The *Instructor's Manual* will be made available by the publisher to those instructors who adopt the book. The manual contains further discussions of lab equipment, including how to select it; suggestions for running the various experiments; design projects; tips for selecting appropriate teaching assistants for the lab; and other useful information.

A web site, [www.wiley.com/college/tsividis](http://www.wiley.com/college/tsividis), will contain extra information, updates, and suggestions.

### **Class Testing of the Material in This Book**

The material in this book has been extensively class-tested over the course of four years with hundreds of students, who filled in detailed questionnaires at the end of each lab session. Every experiment has been revised at least three times. In the last two years, the lab has been run with new teaching assistants and almost no supervision by me; it has run exceedingly smoothly, confirming that by now the experiments in the book are well tuned and foolproof.

At Columbia, the book is used in a lab offered in conjunction with an introductory circuits and electronics lecture course. Students considering electrical and computer engineering are invited to try the course, to see if the discipline is for them. Within the first three years of the course, the yearly number of students who choose electrical or computer engineering as a major had doubled. This is attributed in large part to this first lab. We also found that, on the average, students who have taken the lab perform better in subsequent courses, even those that teach theory. This is not surprising, as one of the main purposes of the lab is to motivate further study.

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Yannis Tsividis

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