Circuit Analysis Laboratory Workbook

Synthesis Lectures on Electrical Engineering

Editor
Richard C. Dorf, ***University of California, Davis***

Circuit Analysis Laboratory Workbook
Teri L. Piatt and Kyle E. Laferty
2017

Understanding Circuits: Learning Problem Solving Using Circuit Analysis
Khalid Sayood
2006

Learning Programming Using MATLAB
Khalid Sayood
2006

Circuit Analysis Laboratory Workbook
Teri L. Piatt and Kyle E. Laferty

978-3-031-00890-0 paperback
978-3-031-02018-6 ebook

DOI 10.1007/978-3-031-02018-6

A Publication in the Springer series
SYNTHESIS LECTURES ON ELECTRICAL ENGINEERING

Lecture #4
Series Editor: Richard C. Dorf, *University of California, Davis*
Series ISSN
Print 1559-811X Electronic 1559-8128

Circuit Analysis Laboratory Workbook

Teri L. Piatt and Kyle E. Laferty
Wright State Univesity

SYNTHESIS LECTURES ON ELECTRICAL ENGINEERING #4

ABSTRACT

This workbook integrates theory with the concept of engineering design and teaches troubleshooting and analytical problem-solving skills. It is intended to either accompany or follow a first circuits course, and it assumes no previous experience with breadboarding or other lab equipment. This workbook uses only those components that are traditionally covered in a first circuits course (e.g., voltage sources, resistors, potentiometers, capacitors, and op amps) and gives students clear design goals, requirements, and constraints. Because we are using only components students have already learned how to analyze, they are able to tackle the design exercises, first working through the theory and math, then drawing and simulating their designs, and finally building and testing their designs on a breadboard.

KEYWORDS

circuits, circuit design, analog circuit lab, electronics, electronic circuits, electrical engineering, circuits labs, operational amplifiers (op amps), analog circuits, circuit analysis lab, circuit analysis

Contents

Preface

Philosophy This workbook integrates the theory covered in a first circuits course with the concept of engineering design and teaches troubleshooting and analytical problem-solving skills. Traditionally, circuits labs give step-by-step instructions for building a circuit and taking measurements from a given schematic to demonstrate physically the theory learned in class, point out differences between measured values and theoretical calculations, and teach measurement techniques.

In contrast, this workbook asks students to use the theory they are learning in class to design circuits that are simple and functional. In doing so, they learn design techniques, develop their analytical problem-solving skills, and gain a better understanding of theoretical principles. So, instead of demonstrating theory, these labs ask students to apply theoretical principles to a design problem.

Approach This workbook uses only those components that are traditionally covered in a first circuits course and gives students clear design goals, requirements, and constraints. It begins with very simple design exercises and progresses to fairly complex circuits, all while using only basic components, such as resistors, potentiometers, capacitors, and operational amplifiers. Because we are using only components students have already learned how to analyze, they are able to complete the design exercises, first working through the theory and math, then drawing and simulating their designs, and finally building and testing their designs in the lab.

Since they are not merely wiring a given circuit, they must understand the theoretical concepts in order to complete their designs. The process of troubleshooting their circuits then teaches them both analytical problem-solving skills and the difference between theory (circuit works on paper) and real life (wired circuit is not accurate).

Audience This workbook is meant to accompany a first course in linear, analog circuit analysis that covers topics such as Kirchhoff's laws, Ohm's law, node analysis, equivalent circuits (e.g., Thevenin), superposition, first- and second-order circuits, and AC steady-state analysis. Components covered include resistors, capacitors, inductors, operational amplifiers, and voltage sources (DC and AC).

Background We are assuming students have no previous experience using breadboards, multimeters, or other lab equipment.

Student Workload We are assuming that students will spend 1-2 hours on each pre-lab and will have the pre-lab completed before their scheduled lab period. If students are prepared, the in-lab portions and post-lab questions can be completed in a 2-hour lab period.

TA Workload We have found it helpful for the TAs to spend 10-15 minutes at the beginning of the lab period giving a short lecture or demonstration to the class. This should include a demonstration on how to use a new piece of equipment, safety reminders, reviews of measurement techniques (e.g., measuring voltage versus measuring current), and a list of troubleshooting ideas (we have provided some in Appendix C).

Some of the in-lab exercises begin with a statement like,"Your TA will demonstrate how to use the function generator." This is another way we have deviated from a traditional circuits lab: we do not have pictures of equipment with detailed wiring diagrams. Students watch their TA give a demonstration, see the diagrams the TA draws on the board, and then they are ready to tackle that week's circuit build.

In addition, the TAs are also expected to supervise students' work throughout the lab period, and each lab has at least one "TA Verification" space for the TA to sign off on students' work.

Organization Since these lab exercises are constrained to use only those components students have already learned how to analyze in class, this workbook follows the traditional outline of most circuits textbooks. This means that the first six labs use only voltage supplies and resistive elements (e.g., resistors, potentiometers, and thermistors). We use these early labs to introduce the basics, such as using a breadboard and digital multimeter, identifying resistor values, and wiring resistors in parallel and series. These early labs also introduce the idea of design work, setting out problems that get gradually more difficult and include design requirements and constraints.

The schedule in more detail is as follows.

- Lab 1 has no pre-lab and is meant to be completed the first week of the term.
- Lab 2 is dedicated to students learning the basics of drawing and simulating a circuit using Multisim. This lab is easily skipped, if there is not time or if Multisim skills are not a part of your curriculum. If included, Appendix B gives instructions for basic Multisim work. Also, we usually allow two weeks for this lab, as the pre-lab is time-consumming for those students not already familiar with Multisim.
- Labs 3, 4, and 5 use only resistors, potentiometers, DC voltage supplies, and multimeters. These labs also introduce the concept of design goals and constraints.

- Lab 6 introduces the idea of a resistive sensor (in this case, a thermistor) used in a Wheatstone bridge.
- Lab 7 introduces the use of ICs and operational amplifiers, as many circuit classes do not begin discussing op amps until five or six weeks into the term. All of the remaining labs use op amps in a series of design challenges.
- Lab 8 brings back the Wheatstone bridge from Lab 6, with the new challenge of adding an amplifier and indicator light to improve the circuit's functionality.
- Labs 9 and 10 challenge students to design and build an analog calculator.
- Labs 11 and 12 introduce AC inputs, function generators, and oscilloscopes and ask students to integrate phase shift into their designs (Lab 11) and to design two simple, first-order filters (Lab 12).

Required Lab Equipment Our labs rely on standard circuits lab equipment. Each lab station should have:

- a breadboard,
- a power supply,
- a digital multimeter (for measuring voltage and current),
- a function generator (for producing a sinusoidal and triangle-wave supply voltages), and
- an oscilloscope.

Each lab station should have access to:

- standard $\frac{1}{4}$ W or $\frac{1}{2}$ W resistors, with values from 100 Ω - 1 MΩ,
- at least five 10 kΩ potentiometers,
- operational amplifiers (LM741),
- red and/or green LEDs ,
- capacitors: 10 μF, 0.33 μF, 0.03 μF, 0.02 μF, 0.0075 μF, 0.002 μF,
- two audio jacks (we use Kycon STX-3120 3.5 mm PCB mount),
- ear buds or headphones (students can bring their own), and
- one NTC thermistor (10 kΩ at 25°C; we use Dale/Vishay 01C1002KP, whose data sheet is provided in Appendix F).

In addition, the TAs should have access to a heat gun and a lamp (incandescent bulb). These are used to heat up the thermistors, and alternative means, such as a hair dryer, blowing on the thermistors, or holding them between two fingers, would also be fine.

Teri L. Piatt and Kyle E. Laferty
June 2017

Acknowledgments

The authors would like to thank the students who volunteered to test early versions of all of these labs: Thomas Beard, Jeremy Hong, Nick Miller, Zach Quach, Christian Stewart, and Emma Sum. We are also very grateful to our proofreader and sounding-board, Dr. Greg Reich, and the great team at Morgan & Claypool Publishers.

Teri L. Piatt and Kyle E. Laferty
June 2017