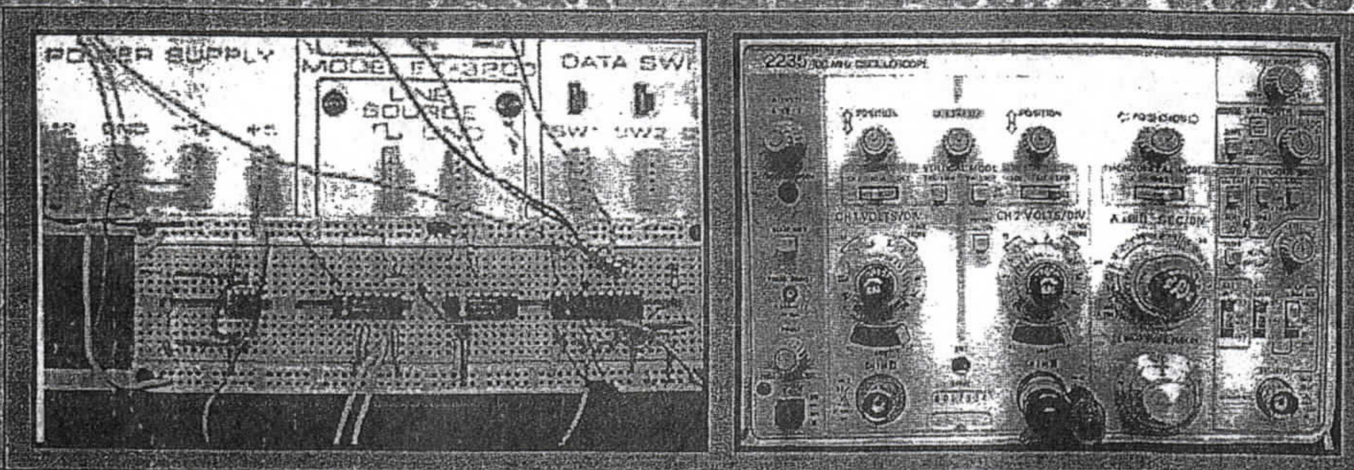
29:128

Electronics Laboratory Manual

John A. Goree



Department of Physics and Astronomy
The University of Iowa

2004

[illegible]

TABLE OF CONTENTS

* An average students will require approximately 3 hours to complete a lab that is indicated as 1 week. Some students will require more than 3 hours, and the TA should make additional lab hours available as needed.

† indicates Lab that can be deleted entirely to allow time for a special project

Copyright © 2004, John A. Goree

PREFACE

GOAL

The purpose of the experiments described here is to acquaint the student with:

(1) analog & digital devices
(2) design of circuits
(3) instruments & procedures for electronic test & measurement.

The aim is to teach a practical skill that the student can use in the course of his or her own experimental research projects in physics, astronomy, or another science.

At the end of this course, the student should be able to:

(1) design and build simple circuits of his or her ownd esign.
(2) use electronic test & measurement instruments such as oscilloscopes, timers, function generators, etc. in experimental research.

REFERENCE

This manual is intended for use with the following textbook.

Horowitz and Hill
The Art of Electronics
2nd Edition, 1989/1990
Cambridge University Press

DATA BOOKS

Data books, such as the Texas Instruments or National Instruments references for TTL, CMOS and LINEAR circuits, should be used by the student to check pin designations, outputs, and other data not given in this lab manual.

LAB NOTEBOOKS

As a part of training to be a scientist, students should maintain a personal notebook just as a research scientist does. This lab notebook will not be graded, but the student must have one and use it. A lab notebook with a sewn-together binding is preferred.

Here is a guideline for lab notebooks: a notebook should contain sufficient detail so that a year later the experiment could be duplicated exactly.

In the notebook, the student should:

draw a schematic diagram for every circuit that is built
- label this diagram with
  - part numbers
  - pin designations
  - output/input designations
- show the major connections to external power supplies, etc.

list the instruments used by type and model
- include in this list: oscilloscope, multimeters, function generators, etc.

draw the appearance of the oscilloscope display, if used
- indicate the vertical and horizontal scales, with units

record a table of all measurements
- include units (e.g. mV) for inputs and outputs
- record the scale (e.g. 200 mV) of the meter or oscilloscope
- indicate where on the schematic the measurement is made
- for digital circuits, this table may be in the form of a truth table

for measurements that have an uncertainty:
- list more than one measurement as an error check
- estimate the error bar

If the student does not use a computer to make graphs, he/she will need <u>log graph paper</u> for Labs 2 and 7. Buy some that is semi-log (logarithmic on only one axis) and some that is log-log. For this course, choose graph paper with5 cycles on the log axes.

LAB REPORTS

For each Lab, students will individually prepare a lab report for grading.

This report is distinct from the notebook; the notebook is not a substitute.

Reports should be organized as a brief introduction, and then an experimental section that is organized according to the section number.
- indicates where your response is required.

Preface

brief introductory paragraph, ≈ 30 words, describing the report's theme

Experiments

REPEAT THE FOLLOWING FOR EACH SECTION

Apparatus

schematic diagram, labeled with:

part numbers (e.g. 1N914 diode)
pin designations (on IC's)
output / input terminals
list of instruments used (e.g., Tektronix 2235 oscilloscope)

Procedure

A maximum of three sentences to explain:

what was measured (e.g., amplifier gain)
what was varied (e.g., oscillator frequency)
how errors were estimated*

Results

✍ indicates a response is required

where it is appropriate, response should include:

table and/or graph of results
- label each curve
- draw smooth curves through data points
- label axes and indicate units (e.g., Hz, mV)

*estimate of errors, for analog measurements
- as a column in a table
- or as a representative error bar on a graph

sketch of oscilloscope display, if one was used
timing diagram or truth table, for digital circuits
explanation of any problems you encountered

Handwritten reports are adequate. Typewritten reports are unnecessary. Be brief, but write in complete sentences. For graphs, you may use "Graphical Analysis"‡ or other software. If preparing your report consumes significantly more than two hours, talk to your TA to ask if you are doing something that is unnecessarily time consuming.

* Some instructors may not want error analysis included in the report. Ask to be sure.

SYMBOLS USED IN THIS MANUAL

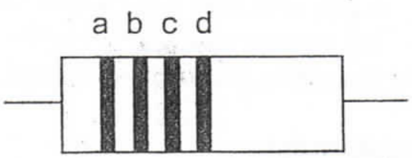
❝ For your information

☛ Instructions for you to follow

✍ Requires an answer or comment in your lab report

RESISTOR COLOR CODE

MULTIPLIERS		*TOLERANCES*	
Silver	-2		
Gold	-1		
Black	0	none	20%
Brown	1	silver	10%
Red	2	gold	5%
Orange	3		
Yellow	4		
Green	5		
Blue	6		
Violet	7		
Gray	8		
White	9		



$a\,b \times 10^{c}\ \Omega \pm d\%$

‡ as of 2001, Graphical Analysis was installed on PCs at this location: Programs\Vernier Software\GA

TREATMENT OF EXPERIMENTAL ERRORS

"Error" does not mean a mistake. It means an uncertainty.

In measuring any value, the result is not just one number, such as 5.3 Volts. It is two numbers, 5.3 ± 0.1 Volts. The second number is the experimental uncertainty, or error bar. It usually represents one standard deviation (one sigma) from the first value.

In making an analog measurement with a meter or an oscilloscope, you should record not just the first number, but the error as well.

To decide what value to assign to the error, you must use some judgement. Here are some tips:

Multimeters:

The manufacturer gives specifications for the precision for the multimeter. The precision of a BK model 388-HD hand-held multimeter is:

DCV	0.50 % rdg + 1 LSD
ACV	1.25 % rdg + 4 LSD
F	2.00 % rdg + 4 LSD
ACA	1.50 % rdg + 3 LSD
DCA	1.00 % rdg + 1 LSD
•	0.75 % rdg + 1 LSD
Hz	1.00 % rdg + 3 LSD

where rdg is the reading on the display, and LSD is the least significant digit

Example:

1. You measure a DC voltage and get 5.30 Volt.
2. The uncertainty is given as 0.5 % of the reading, or 0.005×5.30, plus $1 \times$ LSD, where the LSD is 0.01 here.
3. So the uncertainty is $\pm (0.005 \times 5.30 + 1 \times 0.01) = \pm 0.0365$ Volt.
4. Rounding to ± 0.04, your result is 5.30 ± 0.04 Volt.

Analog oscilloscope:

The display has about 8 boxes (divisions) in the vertical direction and 10 boxes horizontally. It also has 5 small tick marks within each division. You can usually measure a value to about ± 0.25 of a tick mark, i.e. ± 0.05 divisions.

Example: You use the oscilloscope on the 2 Volt/div scale, and your result is 5.3 Volt. The error bar is ± 0.05 divisions, so your final result is 5.3 ± 0.1 Volt.

Propagation of Errors:

When two or more experimental measurements are combined into one by some mathematical operation (such as a product $P = I\,V$), the two errors add in a non-trivial way.

Example: You measure $I = 1.2 \pm 0.1$ mA and $V = 2.5 \pm 0.3$ V. The error on P is computed using partial derivatives, as:

$$dP = [\,(\partial P/(\partial I)^2\, dI^2 + ((\partial P(\partial V)^2\, dV^2\,]^{1/2}$$
$$= [\,V^2\, dI^2 + I^2\, dV^2\,]^{1/2}$$
$$= [\,2.5^2\, 0.1^2 + 1.2^2\, 0.3^2\,]^{1/2} = 0.44 \text{ mW}$$

so the result is $P = 3.00 \pm 0.44$ mW.

In general: for $F = F(A, B, C,\ldots)$, the uncertainty δF in terms of the uncertainties δA, δB etc. is given by: $dF^2 = S\,[(\partial F/\partial A)^2\, dA^2 + (\partial F/\partial B)^2\, dB^2 + \ldots]$. Note that errors add through their *squares*.

In this lab course, you are asked to use propagation of errors only twice, both times in Lab 1, in order to develop this skill. These two instances are indicated in Lab 1 with a *. Otherwise, to save time, do not perform a propagation of errors analysis.

TO THE INSTRUCTOR

HOW ONE CAN USE THIS MANUAL

This manual is intended for a one-semester course. The instructor probably will skip some experiments or parts of experiments due to lack of time.

The first few experiments, analog circuits, will challenge the student the most.

One option is to skip some of the Labs and then finish with a special project. This special project is a circuit invented by the student; it requires about four weeks. The student must begin planning a special project several weeks before this four-week period begins.

UPDATING THIS MANUAL

This manual for the University of Iowa's Department of Physics and Astronomy has evolved over the years in response to changes in technology and textbooks:

- The earliest version used vacuum tubes.
- The Second Edition was written by Stanley Shawhan and John Benson in 1975. After 17 years it was out of date.
- In 1992 it was retyped and edited by Edward R. McCliment.
- Beginning in 1993 it was re-written by John A. Goree, with the addition of new experiments and illustrations, and a new format. It has been updated each year since 1993.

TO THE TA:

Before the students do their experiments, you must:

- do the experiment yourself
- inventory parts to be sure they are all available
- set up each lab table.

If enough parts are available, leave your setup in working order for students to examine when they have difficulty.

You will need to schedule additional time in the lab to accommodate students who are unable to complete their work in 3 hours.

Students need their graded lab reports within a week of handing them to you. If you take longer to grade them, students will not know whether they were writing their report as expected, or whether they are omitting required information or spending too much time on unnecessary efforts in writing the report.