PHYS-3360/ AEP-3630
LABORATORY MANUAL

E. J. Kirkland
School of Applied and Engineering Physics
Cornell University

January 7, 2024

Preface

This electronics lab manual is modeled after a much earlier version by Prof. R. Littauer of the Cornell Univ. physics department about 1985. It has been greatly revised and expanded from the original. Many chapters have been completely rewritten.

Contents

Appendix B

Laboratory Equipment

Each lab station is set up to accommodate two people at one time and should have the following equipment (or its equivalent):

1. Oscilloscope (min. of Tektronix TDS-1072, dual channel, 60 MHz, digital storage, 2 GS/s)
2. Function generator (sine, square and triangle waves, 0 to 2 MHz, B&K 3022)
3. Two variable power supplies (0 to ± 15 volts, about 250 mAmp)
4. Solderless breadboard for circuit assembly
5. Assorted 1/4 Watt resistors (10 Ohms to 10 MegOhms)
6. Assorted capacitors (10 pfd to 220 μF)
7. Assorted wire (solid 22 gauge, BNC cables), and tools (needle nose pliers, wire cutter, wire striper, and small screwdriver for scope probe adjustments)
8. Arduino Mega microcontroller board (with digital I/O, DAC, ADC) and host computer with Arduino IDE software.
9. Other semiconductor components (transistors, diodes, integrated circuits, etc.) obtained as needed (some listed below).

   op-amps: 741, 3140

   instrumentation amplifier: AD622

   diodes: 1N914 (signal), 1N4007 (power), 1N4735 (zener)

   transistors: 2N3904 (NPN), 2N3906 (PNP), 2N7000 (n-chan. MOSFET)

   high speed CMOS: 74HC00 (NAND), 74HC02 (NOR), 74HC04 (inverter), 74HC08 (AND), 74HC14 (Schmit trigger inverter), 74HC32 (OR), 74HC74 (D flip flop), 74HC86 (XOR), 74HC161 (4 bit synch. counter), 74HC164 (8 bit par. out shift reg), 74HC194 (4 bit shift left/right), 74HC221 (dual one-shot), 74HC240 (octal 3-state invert. buffer) 74HC283 (4 bit adder), 74HC4066 (quad analog switch)

Misc.: 6.3VAC CT transformer, 555 (timer), 7-segment LED display, 40kHz acoustic transducer, small radio and audio speaker

Appendix C

Manufacturers and Distributors

Electronics components, from discrete components like resistors and capacitors to sophisticated integrated circuits are manufactured by a variety of different companies. However, in most cases, you do not buy the components directly form the manufactures. Instead you purchase the components from a distributor. Distributors range from large scale industrial suppliers who will only sell components in large quantities to other companies to small mail order companies that will sell small quantities of components to individuals.

In most cases you must get the specifications for the components and decide want you want before contacting the distributor. This information is available in the form of data books from the manufacturer (discussed more in chapter 2) or in many cases can be found on web sites set up by the manufacturers (a general listing of different IC'c can be found at www.chipcenter.com). Some manufacturers web sites are listed in table C.1 (this is NOT a recommendation for or against any particular manufactures, but only a list of some sources of information). You may find the specifications for many types of electronics components on these sites.

Most distributors now have their whole catalogs on-line for easy access. Some distributors that will sell small quantities to individuals and their web sites are listed in table C.2 (again this is NOT a recommendation for or against any particular supplies, but only a list of some that are available):

There are also several companies that produce software for computer aided design of electronic circuits. Some of these companies are listed in table C.3. These programs can be useful for analyzing complicated electronic circuits. Some of these companies offer free downloads of limited-use evaluation

AMD:	www.amd.com
Analog Devices:	www.analog.com
NXP:	www.nxp.com
Intel:	www.intel.com
Renesas (Intersil):	www.renesas.com
On Semiconductor:	www.onsemi.com
Texas Instruments;	www.ti.com

Table C.1: Some Manufactures

Arrow:	www.arrow.com
Digi-Key:	www.digikey.com
Jameco:	www.jameco.com
JDR:	www.jdr.com
Mouser Electronics:	www.mouser.com
Newark:	www.newark.com

Table C.2: Some Distributors

Circuit Maker:	www.circuitmaker.com
Electronic Workbench:	www.electronicsworkbench.com
LTspice	www.linear.com/designtools/software
Spectrum Software:	www.spectrum-soft.com
OrCad	www.orcad.com
Spice	bwrc.eecs.berkeley.edu/Classes/IcBook/SPICE/

Table C.3: Some electronics CAD companies.

or student versions. Again this list is not a recommendation for or against any particular company but just a list of some things that are available.

Bibliography

[1] A. J. Diefenderfer, *Principles of Electronic Instrumentation*, 3rd edit. Saunders 1994, ISBN 0-03-074709-0.

[2] L. R. Fortney, *Princ. of Electronics, Analog and Digital*, (Harcourt, 1987)

[3] Allan R. Hambley, *Electrical Engineering Principles, Prin. and Applic., 3rd edit.*, Prentice Hall, 2004.

[4] T. C. Hayes and P. Horowitz, *Student Manual for the Art of Electronics*, Cambridge Univ. Press, 1989, ISBN 0-521-37709-9.

[5] P. Horowitz and W. Hill, *The Art of Electronics*, 3rd edit., Cambridge Univ Press, 2015, ISBN 978-0521809269.

[6] J. Millman and A. Grabel, *Microelectronics, 2nd edit.*, McGraw-Hill, 1987, ISBN 0-07-042330-X.

[7] C. J. Savant, M. S. Roden, G. L. Gordon, *Electronic Design*, 2nd Edit, Benjamin/Cummings, Calif., 1991, ISBN 0-8053-0285-9.

[8] Paul Scherz and Simon Monk, *Practical Electronics for Inventors, third edit.*, McGraw Hill, 2013.

[9] A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, third edition, Saunders College Publishing, 1990, ISBN 0-03-051648-X.

[10] R. E. Simpson, *Intro. Electronics for Scientists and Engineers* 2nd edit., Allyn and Bacon, 1987.

[11] T. Williams, *The Circuit Designer's Companion* 2nd edit., Newnes, 2010.

Some books on analog electronics.

[12] P. R. Gray, P. J. Hurst, S. H. Lewis and R. G. Meyer, *Analysis and Design of Analog Integrated Circuits*, 4th edit, Wiley, 2001.

[13] M. N. Horenstein, *Microelectronic Circuits and Devices*, Prentice-Hall 1990.

[14] Edwin S. Oxner, *Power FETs and Their Applications*, Prentice-Hall, 1982.

[15] M. E. Van Valkenburg, *Analog Filter Design* (Holt Rinehart and Winston, 1982).

[16] Darold Wobschall, *Circuit Design for Electronic Instrumentation*, 2nd edit., (McGraw-Hill,1987).

Some books on digital electronics.

[17] David Money Harris and Sarah L. Harris, *Digital Design and Computer Architecture*, second edit., Elsevier, 2013, ISBN 978-0-12-394424-5.

[18] R. L. Tokheim, *Digital Principles*, third edition, Shaums Outline Series, McGraw Hill 1994, ISBN 0-07-065050-0.

[19] J. F. Wakerly, *Digital Design, Principles and Practices*, 4th edit., (Prentice Hall 2005) ISBN 0131863894

Some books on computer interfacing.

[20] D. Abbott, *PCI Bus Demystified*, LLH Technology Publishing, 2000, ISBN 1-878707-54-X

[21] Jan Axelson, *Parallel Port Complete*, Lakeview Research, 2000, ISBN 0-9650819-1-5

[22] Jan Axelson, *USB Complete, 3rd edit.*, Lakeview Research, 2005, ISBN13 978-1-931448-02-4

Some books on semiconductor device physics and manufacturing.

[23] Stephen A. Campbell, *The Science and Engineering of Microelectronic Fabrication*, (Oxford Univ. Press, 1996).

[24] David J. Elliot, *Integrated Circuit Fabrication Technology* (McGraw-Hill, 1982).

[25] D. A. Fraser, *The Physics of Semiconductor Devices*, 3rd edit., (Oxford Univ. Press, 1983).

[26] D. A. Hodges and H. G. Jackson, *Analysis and Design of Digital Integrated Circuits*, (McGraw Hill, 1983) ISBN 0-07-029153-5.

[27] S. M. Sze, *Semiconductor Devices, Physics and Technology*, (Wiley 1985).

Some books on grounding, and noise reduction and instrumentation.

[28] Henry W. Ott, *Noise Reduction Techniques in Electronic Systems*, (Wiley, 1976, 2nd edit 1988), revised as *Electromagnetic Compatibility Engineering* in 2009.

[29] M. L. Meade, *Lock-in Amplifiers: Principles and Applications*, (Peregrinus, 1983).

[30] Roland E. Best, *Phase-Locked Loops, Theory, Design, and Applications*, (McGraw-Hill, 1984).

[31] John H. Moore, Christopher C. Davis and Michael A. Coplan, *Building Scientific Apparatus*, (1st edit. Addison-Wesley, 1983; 3rd edit. Westview Press, 2002)

[32] Jacob Fraden, *Handbook of Modern Sensors*, (3rd edit. AIP Press, 2004)

[33] Ralph Morrison, *Instrumentation Fundamentals and Applications, fifth edition*, (Wiley, 2007).

Some books on ECAD.

[34] G. W. Roberts and A. S. Sedra , *SPICE*, , Oxford Univsity Press, 1992 and 1997, (see also Appendix C of Sedra and Smith).

[35] Leon O. Chua and Pen-Min Lin, *Computer-Aided Analysis of Electronic Circuit: Algorithms & Computational Techniques*

Index

