Introduction

In this course you will learn to build, understand, and debug working electronic circuits; you will develop a basic understanding of the way modern laboratory instruments interface with microcomputers; and you will perform physical measurements using microcomputer–controlled electronic devices built in the course of the lab. To quote Brock Calendar, the course covers "operational amplifiers, converters, switches, microcomputers and their application to physical measurements."

General Remarks

Electronics is a tool. Physics, like everything else in everyday life, is greatly influenced by the continuous explosive developments in electronics, and one's success in physics, like everywhere else, often depends on mastering this tool. That is why we study electronics as part of the physics curriculum. The hope is that by understanding how our instruments work and what their limitations are we can use them to do better science.

One cannot learn electronics all at once. Like in any complex subject, gaining a reasonable level of electronic skills requires going back over the material several times. Repetition and review are crucial in any learning situation. This course will provide you with a small opening into a much larger world; you will have to expand your knowledge and enhance your expertise in electronics on your own.

Get your hands dirty! This is a laboratory course, and you will need to get actively involved. You will be given few instructions on how to proceed, and sometimes these instructions will be deliberately vague. The results you get and the time you spend on experimental work will depend strongly on your ingenuity.

Use the best tools for the job. For example, you will be given access to personal computers; you are encouraged to use them to plot and analyze your data and to prepare lab reports. Often, only the raw data needs to be filled in the tables in your lab book, and all calculations can be done inside the computer program on the entire data set at once.

Safety is a state of mind. Take this trite slogan to heart. Be alert, look out for possible dangers, check your circuits and *think* before turning the power on. Acquire and maintain good working habits around your workbench, keep your work area tidy and free of loose wires and components. Turn the power off before leaving.

Conducting an experiment

- Begin by reading through the entire description of the experiment. Make sure you understand the goals of the experiment *before* you begin. Make note of and attempt to resolve all questions that may arise during preparation, by consulting the references and/or the instructor. Do not perform experimental steps whose purpose you do not understand!

- Aim to complete each experiment in the scheduled time. Keep clear and complete records; write down answers to the questions asked *as well as* your own observatons without waiting to be prompted. Remember to describe the problems you encounter and how you solved them. You might run into the same difficulty a few weeks later.

- Make a preliminary measurement before you start to acquire your final results. This way, you will:

  – understand the operation of the equipment;
  – ensure that the equipment is working correctly;
  – establish the range of values, so that you can choose the optimal settings on all your instruments;
  – find out what takes the most time, and budget accordingly.

- Graph the experimental curves and staple or glue them into the lab book.

  Remember the importance of proper captions, axes' labels, specification of units, and definition of symbols. These must be done *as you go along*, do not wait until later as you will lose track of the settings once you change them in the course of an experiment.

- Analyze your measurements and estimate the errors.

- Keep your reports *brief*, with an absolute maximum length of ten pages. Reference your work, do not copy text from manuals and books. However, make sure your reports are *complete*. Always include properly annotated diagrams of your circuits, make sure pinouts, meter settings, and other "trivial" details are clearly marked. Pay attention to these details: what may seem obvious at the moment will be forgotten soon after you complete the experiment. Your lab book should contain all of the information necessary to reproduce your experiments later, and to write your lab reports away from your lab station.

  You will be required to submit seven lab reports over the course of the first ten weeks of labs (experiments #4, #5, and #6 take two weeks each). Each report is due one week after the lab date. All of these lab reports together will account for 70% of your final mark.

  Attempt to write your lab reports as if they were scientific papers. To find out what format you are expected to follow see, for example, *Canadian Journal of Physics*. Generally speaking, you should address the following points clearly and explicitly:

  Title The name of the experiment performed.

  Abstract A brief summary of the most important factors in the experiment including the statement of the final result and conclusions.

  Introduction Describe the motivation for doing the experiment, the physical principles involved, how the technique used differs from other techniques, *etc.*

  Procedure A carefully labelled diagram of the apparatus, with a description of its features; a careful account of how the measurements were done including the precautions taken to eliminate systematic errors. In simple cases, it may be sufficient to simply state that the procedure as described in the Manual was followed exactly. All changes in the procedure, modifications of the circuit or of the component values, *etc.* must be clearly noted.

  Results A tabulation of the experimental data, graph(s) where appropriate, derivation of the desired result, plus an estimate of the random and systematic errors as well as numerical fit of theoretical curves to the experimental data points where appropriate. If a computer program or a macro is used to analyze the data, its listing should be attached as an Appendix to your report.

Discussion A discussion of the precision of the result, how the experiment can be improved and its ultimate limitations, possibly a comparison with other methods of obtaining the same result.

Conclusions As appropriate.

References All texts, publications, and other references used to assist in the experiment should be listed.

Handwritten reports will **not** be accepted. You are encouraged to use TEX/LATEX to write your reports. A skeleton report is available for you to copy into your own filespace and to edit as appropriate. Several different programs capable of data analysis and plotting are available on the PC's in the lab and on the University Unix servers, including `physica/edgr`, `gnuplot`, `maple`, `xmgrace`, and `SigmaPlot`. All of these are capable of generating PostScript output which can then be included in your lab report. Consult your instructor for details.

- The last three weeks of the course are reserved for your term project, although you are encouraged to select one and start preliminary work on it as early as possible. A list of available projects should be posted in the lab early in the semester. Unlike the step–by–step experiments in this lab manual, you will be given a task, and a minimum of instructions on how to proceed.

  In lieu of a final exam, you will be required to present your project and demonstrate its operation, as well as to submit a written report on your work. Several Faculty members and representatives from the Electronics Shop usually attend these final presentations.

  Your project report may take the form of a lab report, or that of a User's Manual for your particular device. Under certain circumstances, the report may be replaced by an interactive Help facility built into the software that you have written to support your device.

  The term project (including the report) is worth 30% of the final mark.

Please refer to this outline, and to this introductory chapter throughout the course of the experiments. The marking scheme used to evaluate your work is implicitly contained here.

Conventions used in this manual

(!) Whenever you see a paragraph marked off with this symbol, it indicates an experimental step. You are expected to perform one or several operations and write down your results and observations in the lab book.

[?] When you encounter this symbol, it indicates a question or a problem. You are expected to perform the necessary calculation and to provide a written answer and, possibly, a brief explanation in your lab book *before* you proceed to the next stage of the experiment.

References

Numerous excellent introductory electronics books exist, and you are encouraged to refer to them often. Some selected titles are listed below, with Brock Library calling numbers shown where appropriate.

Other references such as manufacturers' data books and the equipment manuals should be consulted as needed. Photocopies of selected parts of some of the references are available in the lab, and other reference material can be obtained from the University Technical Services (see your instructor if you require access). You are encouraged to consult journals such as *American Journal of Physics*, *Electronics*, and *Reviews of Scientific Instruments* for further reading.

1. H. Austerlitz, *Data Acquisition Techniques Using Personal Computers*. Academic Press, 1991.
2. D. Barnaal, *Analog and Digital Electronics for Scientific Applications*. Waveland Press, 1982. TK7816 B34.
3. J. J. Brophy, *Basic Electronics for Scientists*. McGraw–Hill, 1990. TK7815 B74.
4. M. M. Cirovic, *Basic Electronics: Devices, Circuits, and Systems*. 1974. TK7815 C53. A.J. Diefenderfer and B.E. Holton, *Principles of Electronic Instrumentation*, 3rd ed.[1] Saunders, 1994.
5. W. L. Faissler, *An Introduction to Modern Electronics*. J. Wiley & Sons, 1991.
6. B. Grob, *Basic Electronics*. 1989. TK7816 G75.
7. P. Horowitz and W. Hill, *The Art of Electronics*. Cambridge University Press, New York, 1989. TK7815 H67.
8. H. V. Malmstadt, C. G. Enke, and S. R. Crouch, *Electronics and Instrumentation for Scientists*. Benjamin/Cummings Publishing Co., 1981.
9. J. O'Malley, *Theory and Problems of Basic Circuit Analysis*. Schaum's Outline Series, McGraw–Hill, 1992. TK454 O46.
10. M. Plonus, *Electronics and communications for scientists and engineers*. Harcourt/Academic Press, San Diego, 2001.
11. R. E. Simpson, *Introductory Electronics for Scientists and Engineers*, 2nd ed. Prentice Hall, 1987.
12. W. F. Stubbins, *Essential Electronics*. John Wiley and Sons, New York, 1986.
13. J. C. Sprott, *Introduction to Modern Electronics*. John Wiley and Sons, New York, 1981.
14. B. G. Thomson and A. F. Kuckes, *IBM–PC in the Laboratory*. Cambridge University Press, 1989. QC52 T46.

[1] This is the required text for PHYS 2P31/32.