Introduction to the Physics Year 2 Electronics Laboratory

Introduction

In days past, in order to make electronic circuits for use with a physics experiment, or in a commercial product, one had to design and assemble circuits using a large number of low-level components (transistors, for example). The procedures were laborious, arcane and did not always give satisfaction. Today, the cleverest and most productive electronic designers (who work for integrated circuit manufacturers) will sell you their circuits, for a few pence or a few pounds — built, tested, with instructions and guaranteed performance.

In this laboratory, you will use some of these integrated circuits (frequently called “chips”, after the small pieces of silicon they contain) in a variety of exercises that represent some of the uses that electronics is put to in experimental physics. You will discover that the circuitry you have to build outside the chips is governed by the familiar laws of electric circuits containing resistors, capacitors, inductors and the like. An important objective is to understand how the circuits work: not how the solid-state physics of the silicon chips gives rise to their functions, but how signals flow around the circuits external to the chips, and in turn produce other signals until finally something desirable is produced. This will entail using the primary weapon of electronics, the oscilloscope, along with a variety of other instruments and tools. Along the way, you will gain experience in building prototype circuits, making them work, and looking critically at their performance.

Laboratory Organisation

Each of the four experiments described in the accompanying manuals takes two sessions in the laboratory, i.e. six hours. Experiments will be done in roughly the order presented here:

1. The Switch-Mode Power Supply
2. Negative Feedback — Servo Control
3. Handling Small Signals
4. The AVR Microcontroller

but your demonstrator may vary this. You can leave your circuit set up between the first and second session, but should disassemble everything at the end of the second session. You must record your work *as it proceeds* in a laboratory notebook, which you will hand in for marking at the end of the second session of each experiment. The manuals provide guidance about what should be included in your book: in the text, by use of the **Q** symbol in the margin, and in the final “checklist” section.

You should aim to complete all or almost all of the sections of an experiment. It is possible to get good marks ($\sim$65%) by following the manual, understanding the circuits and responding to the questions posed by the manual. The highest marks (80%+) are given for a really good job of understanding and documenting the circuits, and the more sophisticated parts of the experiment, where the manual provides less guidance.

You should expect to discuss your work with the demonstrators several times during each experiment. Some people will want to check their understanding of subtle points, while others will need to ask what seem like very basic questions, which is fine. Just don't expect the demonstrator to do your experiment for you!

Practical advice

All the circuits you assemble will be built using plug-in breadboards. At first, translating the theoretical circuit diagrams or "schematics" in this manual into components and connections on the breadboard may seem difficult, but by the time of the second experiment, the difficulties will be forgotten. Some important practical points:

Components, their values and connections can usually be identified using the "frequently used components" appendix to this manual.

Breadboards Be aware how the connections inside the breadboards are arranged. In particular *beware of the central break* in the horizontal power rails.

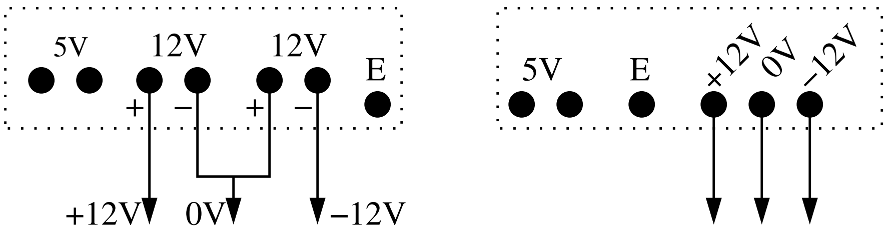
Connecting wires should not be excessively long and should be of more than one colour, the colour being related to the function of the wire (e.g. red for positive supply, black for negative supply, green for ground, yellow for signals ...). This helps with fault finding — plan on faults: they'll be there regardless. Strip about 8mm of insulation from the ends of the wire, being careful not to nick the wire itself (it'll break) and keep the end straight so it will go into the breadboard. Wires that are too thick or too flimsy to go into the breadboard with a positive feel should be soldered to stubs of wire that will go in nicely.

Chips must be inserted in the correct orientation, and must be pulled out *vertically*. Chips with more than eight pins should be removed by sliding a screwdriver between the chip and its sockets, parallel to the chip. If the chip does not come out vertically, it comes out at an angle. This causes half its pins to bend or break off in the socket, and the other half to become embedded in your thumb. Neither is desirable.

Oscilloscopes The scopes used in the lab have various bandwidths and memory sizes. Some also have an analogue mode that can be useful in difficult cases. Consult the "brief guide" appendix or a demonstrator for information on the fancier options. Note that the probes have a x1/x10 switch which should normally be set to x1, but which might accidentally get altered.

Soldering occurs when metal is hot enough to melt solder and clean enough for the solder to adhere. Scrape the enamel, dirt etc. off the metal, then use a clean soldering iron tip to heat the metal until solder applied *adjacent to* the soldering iron melts. The solder should wet and flow over the surface. Anything else is a failure.

Power supplies The usual lab supplies have three entirely independent outputs: one of about 5V and two that should be set to 12V. Interconnect them as shown below left. Other supplies (below, right) have slightly simpler connections.



Earth, ground and zero volts These words tend to be used interchangeably but *sometimes* mean different things. Whole books[1] have been written to help sort things out. The "ground" crocodile clip emerging from an oscilloscope probe is both the "zero volts" with respect to which the scope measures voltages, and is also connected to the centre pin ("earth") in the mains plug (and thence to everything else so connected). The ground clip should be connected to the zero volts reference point in your circuit. This is normally the negative side of the power supply if there is only a single power supply voltage, but the centre point of the power supply if there are both positive and negative supply voltages. The lab power supplies and the signal generators are alike in that their outputs have no connection to earth (unless you connect to their separate earth terminals), but one of their terminals (usually coloured black) is intended to be connected to the zero volts point in your circuit.

Books The lab handouts are self-contained; a textbook is not required. Occasional reference is made to Tipler's *Physics for Scientists and Engineers*. Horowitz and Hill: *The Art of Electronics* is a very good book for enthusiasts and project work.

[1]M. Morrison: "Grounding and shielding techniques in instrumentation"

Top ten reasons for circuits not working

1. Wires accidentally placed in wrong holes (very popular).
2. Misunderstood internal wiring of breadboard.
3. Wires not pushed into breadboard far enough.
4. Power not turned on.
5. Switch incorrectly wired.
6. Wrong resistor values.
7. Ground wires not connected at scope or power supply.
8. Scope probe set to x10 by mistake.
9. Flexible wires to off-board components broken or shorted.
10. Component broken owing to previous misuse (surprisingly rare).

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