exploring electronics

A Transition Year Module

DEVELOPED BY CORK INSTITUTE OF TECHNOLOGY
AND THE TRANSITION YEAR CURRICULUM SUPPORT SERVICE

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Exploring Electronics

A Transition Year Module

By

Rosemarie Ferriter and Irene Sheridan

Cork Institute of Technology

and

The Transition Year Curriculum Support Service

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Main Text
R Ferriter, I Sheridan

Development Team
P Sliney, J O Sullivan, P Collins, S Rea, S Coughlan, J O Shea, J Harrington
– Cork Institute of Technology
M Philpot, P Lyne – St Mary's Secondary School, Macroom
L O Toole, G Simmie – Transition Year Curriculum Support Service
D de Bhailís – Cork Electronics Industry Association

Co-ordinator
A Twohig – CIT Press

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St. Angela's College, St. Patricks Hill – Ms Brid O'Connor

St. Mary's Secondary School, Macroom – Mr Patrick Lyne

St. Peter's Community School, Passage West – Mr Con Murphy

St Vincent's Secondary School, St. Mary's Road – Ms Rosemarie Ferriter

Sponsor's Note

The Integrated circuit industry is one of the largest knowledge driven industries in the world growing 10% per year with revenues of 200 billion euros in 2007. As Ireland moves towards a knowledge driven economy, this industry will be one of the key pillars of the new economy. Irish graduates have played a significant role over the last 25 years designing and manufacturing integrated circuits for export across the world.

MIDAS Ireland is the representative group for electronic design in Ireland. MIDAS was founded in 2001 – now has 21 industry and 17 academic members representing 90% of micro-electronic designers in Ireland. The success of MIDAS member companies depends on high quality electronic engineers and technicians graduating from the third level institutions in Ireland.

The Exploring Electronics Transition Year Module provides a valuable introduction to the theory and concepts of electronic design for second level students. MIDAS is honoured to have been asked to sponsor this project. We would like to thank and acknowledge Irene Sheridan/ Paul Sliney and their colleagues in CIT for the creativity and commitment they've shown in the development of this module. We look forward with great enthusiasm to working together to ensure that Ireland remains at the forefront in the development of electronic design.

Noel Murphy
Chair of MIDAS Ireland
Principal Engineer
Intel Shannon
Co. Clare

CONTENTS

Foreword

The rapid advances that we see in information, communications and technology all around us stress the growing importance of electronics as a driver of our economic growth and success. Technical knowledge, competence and skills will be key requirements for the workplace of the future.

Ireland is well placed to compete in this arena and is now a major participant in the world of Electronic Engineering and the associated fields of Communication and Information Engineering and Software Engineering.

In order to continue to grow and to remain at the forefront of this revolution we need even more people to choose to study sciences and technology-related subjects at second-level and to pursue third and fourth level qualifications in Electronic Engineering.

The transition year module, Exploring Electronics, has two primary objectives. First, to give all participating Transition Year students an appreciation of the underlying science of electronics. Secondly, to encourage those interested in this field to develop their knowledge and understanding and to consider courses and careers in this exciting and dynamic area.
The module aims to satisfy these objectives by introducing students to the basic theory of simple electronic circuits, by developing computer simulations of these circuits on a widely-used software package, Crocodile Clips, and finally enabling students to build their own working models of the circuits in the laboratory. In this revised edition the module has been reworked to be directly supportive of the new Junior Certificate Science Syllabus.

Industry groups, such as the Microelectronics Industry Design Association (MIDAS) and the Cork Electronics Industry Association (CEIA), are fully supportive of these objectives and are committed to helping schools and teachers to deliver the module. Engineers Ireland and its STEPS program are also fully supportive of the objectives and will help in every way possible.

The Department of Electronic Engineering at Cork Institute of Technology is pleased to be able to contribute to what has been a very hard working and effective development team and will continue to support in every way possible the schools who run the module.

While the module aims to promote and demystify the world of Electronics we also hope to open the door to a world of new challenges and the satisfaction that comes from building a circuit that works!

Irene Sheridan
Head, Department of Electronic Engineering,
Cork Institute of Technology

Introduction

This introductory course in electronics is aimed at transition year students. It is hoped that having completed the course the student will appreciate the prevalence of electronics and information technology in the world around them. Developments in such diverse fields as communications, biomedical systems, automation, travel, entertainment and information technology have all been made possible through advancements in the field of electronics. The transition from development of the very first transistor in 1947 to the current situation where millions of transistors can be made in a single tiny piece of silicon has allowed these advancements to be incorporated into almost everything we do.

This module focuses on some of the basic steps in developing simple electronic circuits. It is structured to provide background theory on components and circuits, as well as computer simulation and practical circuit assembly in a coherent straightforward package. Through this approach of **theory, simulation and practice,** it is hoped to achieve learning and stimulation for the student as well as a sense of achievement. Transition year is a time when students make choices about subjects for Leaving Certificate and think about career options. This module hopes to help demystify the Electronics Industry and includes information on careers in electronics.

Aims

- To develop the student's understanding of electronics as a valuable 'life-skill'
- To raise the student's awareness of the significance and impact of modern technology on the social, economic, cultural and other dimensions of society
- To improve the student's problem solving, analytical and manual dexterity skills
- To promote creative thought and inventiveness
- To develop the student's skills in independent learning, communication and team work
- To develop the student's understanding of design and test in the electronics field
- To introduce the concept of computer simulation and develop the link between simulated and actual results
- To develop the student's ability to record and present experimental results
- To build on the Junior Certificate science program and allow the student to make informed choices about Leaving Certificate subjects
- To raise the student's awareness of the many and varied career opportunities in the Electronics and related industries in Ireland today

Objectives

At the end of the Module the student will:

- be able to identify different electronic components
- be able to outline the functions of those components
- be able to build simple electronic circuits and be aware of practical applications of these circuits
- have made a simple electronic circuit
- be familiar with many of the career opportunities available to them in the electronics industry
- realise the enormous influence of Electronics on our lives and Society

Outline of the module

The programme covers some career exploration as well as seven different teaching units:

- Unit 1 Basic Electricity
- Unit 2 Thermistor and LDR
- Unit 3 Semiconductors and Diodes
- Unit 4 Transistors
- Unit 5 Soldering
- Unit 6 Flashing Lights circuit
- Unit 7 Bagpipes circuit

Each teaching unit comprises:

- Unit Aims
- Objectives
- Equipment list
- Procedures
- Exercises/Assessments

The Teacher's pack includes:

- Detailed manual covering theoretical and practical material
- References to relevant books, videos, web sites, and organisations which will be of interest to students and teachers
- Relevant assessment sheets
- Module Certificate
- Details of where all required equipment and materials can be obtained
- Details of the kits chosen and options for further development and application of the circuits

The module takes the student from component basics to simple circuits through theory and simulation. The practical element then allows the student to assemble simple kits and to test actual circuits in operation and compare these to the simulated response. The kits chosen for the module represent a small section of what is available and are chosen for their ease of assembly and simplicity of operation. The layout of the module has been designed to facilitate photocopying where required.

Implementation of the module

Each of the teaching units is intended to be of two-hour duration (three forty-minute classes). It is preferable if two of these classes are available as a double period in order to facilitate the practical work. The main teaching units of the module could then be covered in a seven-week period. It is proposed that a cross–curricular approach be adopted to the section on Electronic Engineering in Practice. The background work and assignment could be included as part of a career guidance session either before or during the delivery of the module. The use of the computer simulation package requires that a computer lab be available for some of the double sessions. If the students are taking a computing or IT module then the use of the simulation package '*Crocodile Clips*' could also be introduced during that session.

Units 5, 6 and 7 involving soldering practice and assembly of *MadLab* circuits, should be undertaken in a laboratory that can facilitate soldering.

While the material presented is complete, it is recognized that transition year groups tend to be of mixed ability. The teacher may decide if it is appropriate to take a less demanding approach and some sections, in particular the one dealing with semiconductor theory, could be omitted. In every unit there are opportunities to expand the treatment, and the references and web sites provide ample additional material. The units are designed to run in sequence, although an individual teacher may choose to rearrange or indeed omit some units if appropriate. Teachers may find that the soldering and the simulation package will require advance preparation.

Materials and Equipment

Appendix C gives details of the components and consumables required for the module and ordering information for these. A summary of requirements is provided here for information.

Each school will need the following:

- 5 Personal Computers with CD drive
- 5-user site licence – *Crocodile Clips* software
- 5 Digital Multimeters
- 5 25-watt soldering irons each with stand and sponge
- 5 Desoldering tools
- 5 Long-nosed pliers
- 5 Side cutters
- Safety goggles for soldering

The number 5 is in no way an absolute number. It is chosen as a minimum requirement for a class of twenty students in schools who are introducing this module for the first time.

In addition to this general equipment the following consumable material is required for each class group:

- Colophony-free solder
- 9-volt batteries
- Discrete components – resistors, capacitors, diodes, transistors, etc.
- Single-sided stripboard for soldering practice
- *Madlab* circuit kits - Flashing Lights, Bagpipes

Assessment and evaluation

Each teaching unit includes assessment methods by which the students assess the work they have done and the skills they have acquired. The assessment sheets are developed at a level that recognises the mixed ability of most transition year classes. The teacher may decide to develop more challenging homework assignments where it is appropriate. Provision is also made for evaluation of the module by the students and teachers.

Recognition

On completion of the module each student should have two working electronic circuits which they have assembled and tested. In addition they will be awarded a certificate of participation in the module – a sample of which is included in the pack.

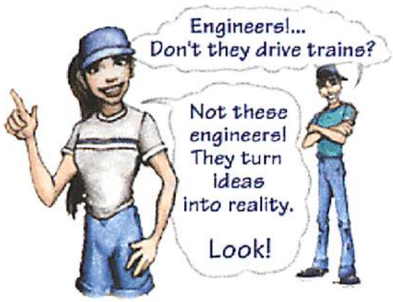
Note: All definitions used in this module are intended to be in line with the relevant curriculum as taught in Junior and Leaving Certificate courses.

Electronics in Practice

Electronic Engineers invent new products to improve the quality of our lives all the time. They use state-of-the-art technology to create fun things like games consoles, MP3 players and mobile phones, but also devices that are essential for our well being like heart monitors and vital life-saving equipment.

No matter where you go you will encounter electronics in action.

- Would you like to know how brain surgeons are trained before operating on live patients? Electronic Engineers develop computer based systems that replicate a person's skull to allow the surgeons to practice in advance.
- Maybe you are more interested in music technology? You could join the electronic engineering teams that create software to automatically write out the notes played in a piece of music.
- What about helping society combat road safety issues by developing new test processes to ensure better reliability of automobile electronics?



The list of possibilities are endless given today's rapidly advancing technological world but the one thing that all of these options have in common is that they need electricity to operate. The job of the electronic engineer is to develop the way electricity is used to control equipment. Many electronic devices are controlled by built-in microcomputers, and these need to be programmed to work correctly. They require a list of instructions that tell them what to do when certain things happen. They take measurements or wait for input signals and then decide what to do based on these signals. All of this software programming is done by electronic engineers.

What qualifications can I get?

Technical people working in the electronics industry fall into two broad categories – technicians and engineers. The course for a technician takes two years for a Certificate. To become an engineer, you need to do a degree course. The ordinary level degree course is of three years duration and the honours level takes four years to complete. The honours degree course is accredited by Engineers Ireland which means graduates are qualified to work as engineers internationally.

A technician is typically involved in test, repair and servicing of equipment. For example, if a factory is making mobile phones, then each phone is tested after it is made. If any of them don't work then a technician has to figure out why they don't work and how the fault occurred. It is important to identify as quickly as possible what went wrong because it is possible that one of the machines is faulty and still producing product that is wrong. The technician would also be involved in servicing the equipment used to produce the phones.

Engineers are typically involved in design and project management disciplines. The engineer is the person who decides how the product will be made. Take for example, an MP3 player. It is the job of the engineer to get the MP3 player to do all of the things it is supposed to do. The electronic engineer designs every feature of the MP3 player – from the size and type of battery to the brightness of the display. The engineer has to design how the device will store tunes and videos and ensure it is compatible with internet downloads. A product like this is so complicated that a team of engineers would be involved in the design and each would be responsible for a particular area. One engineer would be

responsible for the battery and the power supply, another for the section of the MP3 player that stores the data, and so on.

What sort of career can I have in electronics?

A technical qualification in electronics allows you to work in practically any area of the electronics industry. In reality, Electronic Engineers are needed to develop new technologies for every discipline you can imagine from Medicine to Formula 1 Motor Racing. The qualification is general enough that you could work with a company that is developing the next generation of mobile phones or you could be a researcher developing robotics to be so human-like that they can play football against the winners of the world cup! Your choice of jobs is not limited to a particular type of company or product. You could start working with a local company that creates software programs and go from there to a large multinational corporation that produces data storage solutions for the worlds financial markets.

The range of jobs and companies is not limited to Ireland. A qualification in electronics is recognised internationally. You will find it very easy to get a job abroad. It is possible to get a job that allows you to travel or to gain some experience abroad before returning to Ireland.

Career Guidance Assignments

There are a number of projects that can be carried out as part of your career guidance activities to see if electronics is an area in which you would be interested in working. The following are some examples:

- Company visit
- Interviews
- In-schools talks or presentations
- Research project on a company or product

Company visit

A good way of getting an idea of what it is like to work in the electronics industry is a company visit. It gives you an opportunity to see the environment in which you would work and to get a feel for the types of jobs on offer. To make best use of such a visit it is important to be well prepared beforehand.

Preparation for the visit

Contact the company and see if they can send any brochures or leaflets that outline what it is the company does. Most companies have some leaflets that describe the history and structure of the company and that outline the products and services that they provide. Another useful source of information is the internet. Most companies have a web site that will provide a lot of useful information.

Investigate the product that the company manufactures. It does help, and it makes the visit more interesting, if you have an idea of what their product does. This type of information can be found on the internet or from a library.

The visit itself

During the visit you should have a list of questions to ask. Some of these will be answered during the visit by the people from the company as part of their presentations, but for some of them you will have to request the information. You should have a visit report sheet which you fill out during the visit. A sample questionnaire is shown on the next few pages:

Company Visit

Background

1. Company name ____

2. Company address ____

3. Date of visit____

Company Products

4. What product does the company make or what service does it provide?

Products manufactured	Quantity produced per week	Possible uses of product(s)

5. Who are their competitors? Are there other companies in Ireland that produce something similar?

____

____

6. Is the company part of a larger corporation? If so, where is the company headquarters? Are there sister plants in other countries?

____

____

Careers

7. How many people work there?

____

8. How is the workforce split – how many operators, how many administrative staff, how many technical staff?

____

9. How many people with qualifications in electronic engineering work in the company?

10. How many of these are at technician level and how many at engineer level?

11. What are the typical responsibilities of a technician working with the company? What is a normal day's work and what activities would one usually be involved in?

12. What are the typical responsibilities of an engineer working with the company? What is a normal day's work and what activities would one usually be involved in?

13. Do technical people get much opportunity to travel with the company?

14. What are the hours of work for technicians and engineers?

15. What are the promotional prospects for technicians and engineers?

16. What are the pay scales of the company – taking shift allowances and share options into account?

17. Take note of the areas where technicians and engineers work – how much space do they have, do they have much equipment. Take note of the work atmosphere in the factory – the noise level, the general mood, the layout, etc. Try to talk to people as you go around and, in particular, try to talk to technicians or engineers. Try to get their opinions about their jobs and the profession they have chosen. Ask them about what they do and what their day-to-day activities are. Ask them why they chose to work in electronics.

After the visit

You should write a report that summarises all that you saw and heard during the visit. Often things that seem clear at the time can be hard to remember at a later date, so it is important to write a report while the visit is still fresh in your mind. A useful way to write the report is to write out the answers to the questions given previously. This will cover all the main aspects of this visit.

At the end of the report there is one more question to add – would you like a job in electronics? ________

Interview

If it is not possible or practical to go on a company visit then perhaps it would be possible to interview someone who works in the industry. There are a number of ways that you can go about this – contact a local company to see if they would allow you to interview a member of their staff or contact a third level institution such as CIT to see if you could meet a member of staff in the electronics department. Perhaps you might ask your career guidance counsellor to nominate someone who works in electronics, or maybe yourself or a friend knows someone who works in the industry. A possible list of interview questions is given below:

1. What product does your company produce or
2. What services does it provide?
3. What qualification in electronics do you have?
4. What do you do with the company?
5. Is your job technical or do you have a management role?
6. What is a typical day's work for you?
7. What are the promotional prospects with the company?
8. Why did you decide to get a qualification in electronics?
9. When did you know that you wanted to work in electronics?
10. Why did you choose to work for this company?

In-school talk or presentation

If it is not possible for you to visit a company, perhaps the company can come to you. Many companies will make presentations to schools if asked. They will send a member of staff to describe the operation of the company and to answer any questions. This would be an opportunity to ask the questions already outlined above.

Research project on a company or product

Perhaps it would be possible for the class to do a research project on different companies or different electronic products or electronics as a career. The class could be split into groups and each group could cover a different topic. At the end of the project each group could make a presentation to the class. In this way everybody would get a good overview of the topic. Information can be found by using the internet, by contacting companies, by talking to people who work in the industry and by using the library.

Unit 1
Basic Electricity

Unit 1 | Basic Electricity

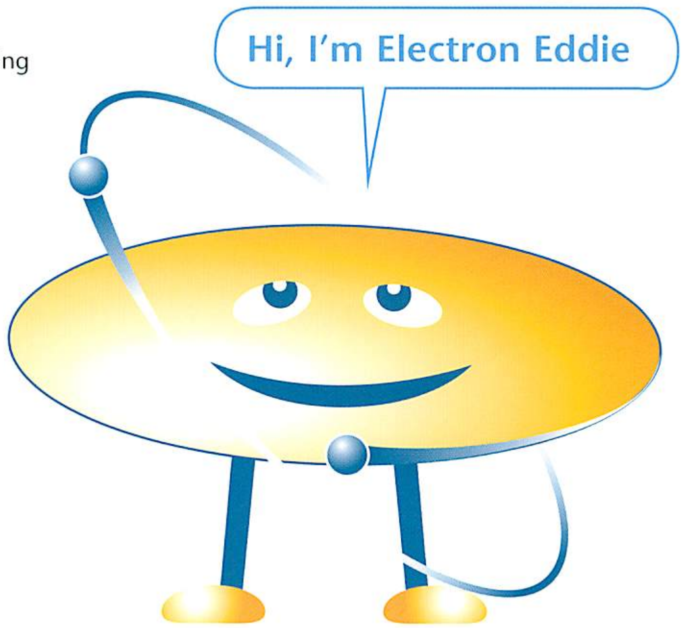
Duration
Three Hours

Equipment
Resistors, Diodes, LEDs, Multimeter, Computer Simulation Software: *Crocodile Clips*

Aims
The aims of this unit are to revise and build on concepts introduced at Junior Certificate Science:
Electric charge, electric current, conductors, insulators, voltage, resistance, capacitance
Calculation of voltage, current and resistance using Ohm's Law
Component symbols and simple circuit diagrams

Objectives
After this lesson the student will be able to:
- define or explain the meaning of the following terms:
  - Resistance
  - Resistor
  - Ohm's Law
  - Current
  - Capacitance
  - Capacitor
  - Conductor
  - Insulator
  - Electric Charge
  - Electric Current
  - Potential Difference
  - Voltage
- Perform simple experiments
  - (i) to use a multimeter
  - (ii) investigate how resistors behave in both series and parallel circuits
  - (iii) investigate how Current changes with Voltage for resistors and diodes
- perform simple calculations involving Ohm's Law
- identify some circuit components
- interpret and draw simple circuit diagrams
- perform simple experiments

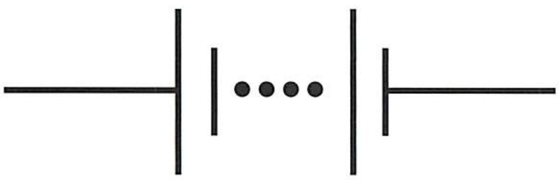
Assessment Method
The student is asked to complete a practical exercise and the multiple-choice test at the end of this unit.



Basic Concepts

Electronics gets its name from the electron. Electrons have a negative charge. Charge is measured in units called Coulombs (C). When electrons move together in a unified way we say there is a **current** flowing. Electrons can't flow through every material. Materials that allow a current to flow easily are called **conductors.** Materials that don't allow a current to flow are called **insulators.**

Materials called **semiconductors** fall between these two extremes (more later). The free electrons in an isolated metal conductor such as a piece of copper wire are in random motion. There is no net motion along the wire. If we now connect the ends of the wire to a battery an electric field is set up along the length of the wire. This electric field gives the electrons a resultant motion along the wire and we can say a current flows. A battery supplies the 'force' that makes the electrons move. This force is called the **voltage**. The bigger the voltage the more force. (Voltages are sometimes called **potential differences**). Currents are measured in **amperes (A)** and voltages are measured in **volts (V).** When we draw diagrams to represent components and voltages applied we use symbols. The symbol which represents a battery or a voltage applied is like this:



Resistance & Resistors

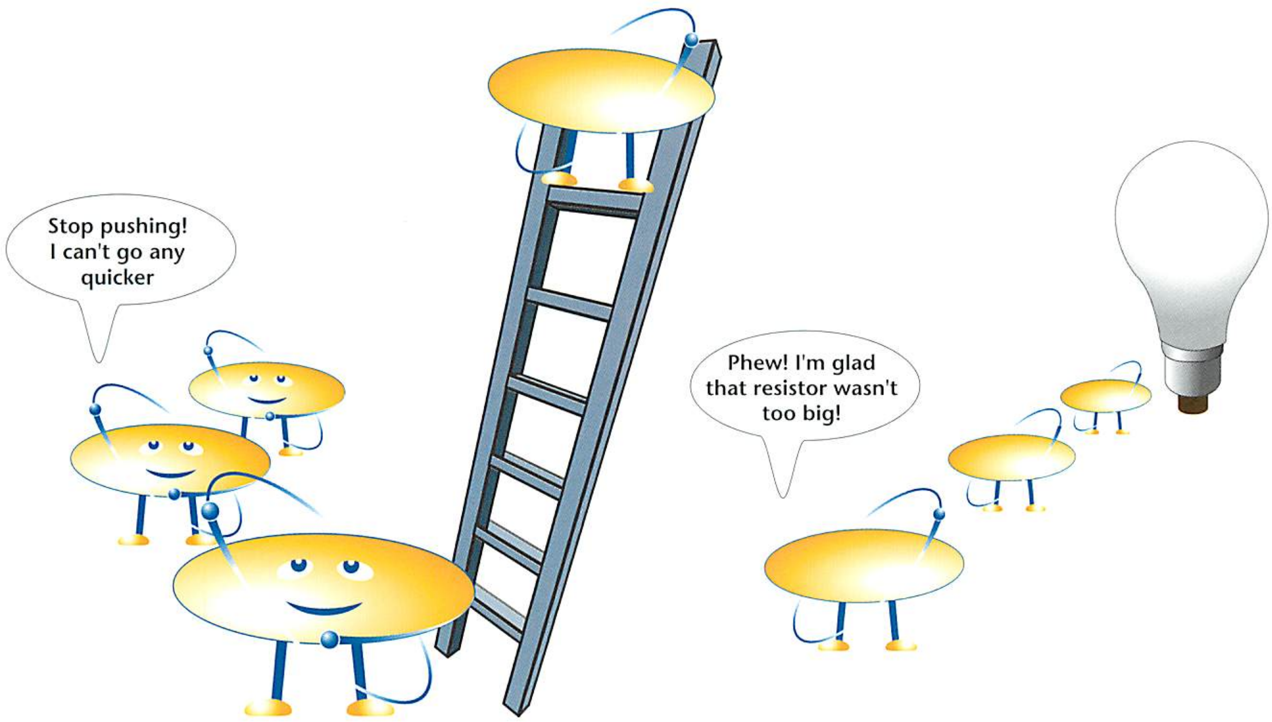


Figure 1.1 Think of a resistor as an obstacle that must be overcome

- We measure opposition to electric current as **resistance (R).**
- The main function of **resistors** in a circuit is to control the flow of current to other components. If too much current flows through a bulb it is destroyed. A resistor is used to limit the current – the bigger the resistor the smaller the current.
- In a **series** resistor circuit the resistance adds directly

$$R = R_1 + R_2 + \ldots\ldots\ldots$$

- In a **parallel** resistor circuit the resistance adds inversely

$$1/R = 1/R_1 + 1/R_2 + \ldots\ldots\ldots$$

- Unit of resistance is the Ohm (Ω)

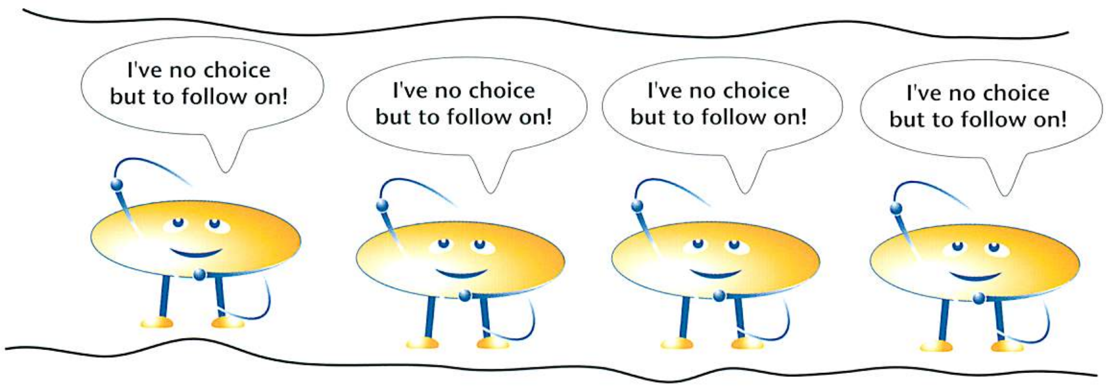


Figure 1.2 *With resistors in series there is only one path for the current to follow*

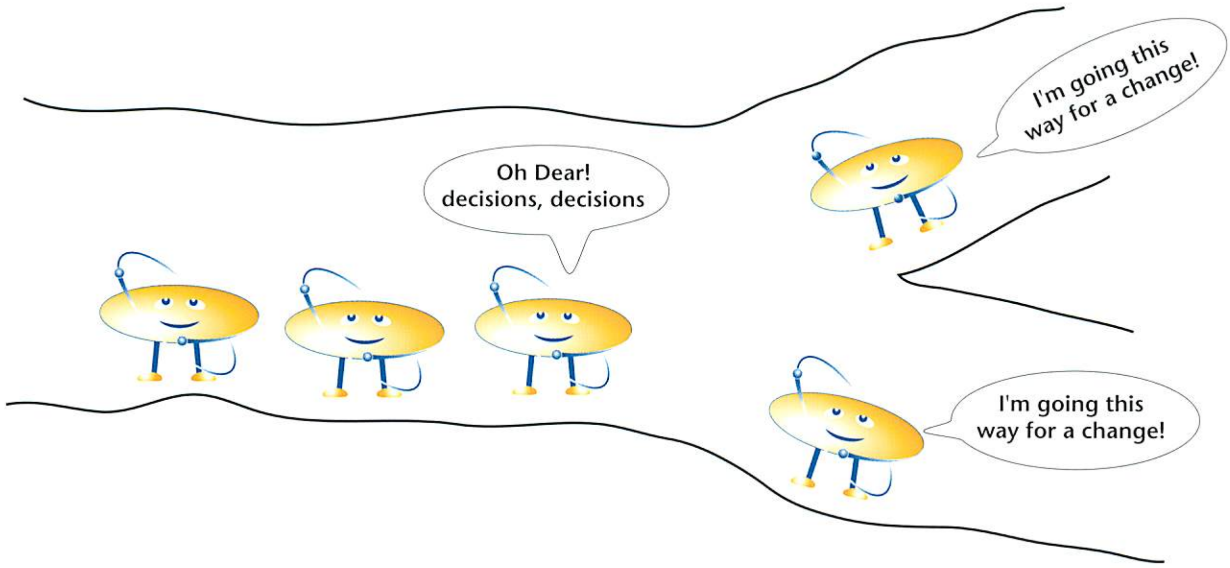


Figure 1.3 *Resistors in parallel cause more than one current path*

Combinations of Resistors

When two or more resistors are connected one after another in a circuit, as shown in Fig. 1.4, they are said to be connected in **series.** Resistors in series are connected so that there is only one conducting path through them. The effect is to **add more resistance** to the circuit. The total resistance can be found by simply adding up all the resistance values. The circuit diagram uses symbols to represent the components in the circuit.

Experiment 1: Investigate how Resistors behave in Series Circuits

Planning:- Assemble the components shown in the diagram and have pencil and paper ready to record the data (or set up a spread sheet in excel for data)

Apparatus:- Multimeter, Resistor block one, calculator

Resistors in Series

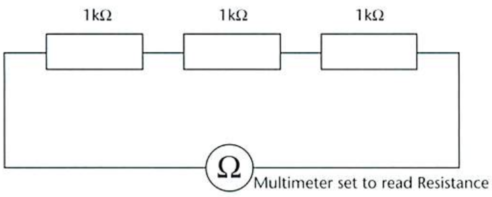


Figure 1.4 *Resistor Block 1: Resistors in Series*

Procedure

1. Set up the circuit as shown using Resistor Block 1. This contains three resistors connected in series (one after the other)
2. The Multimeter is set to read Resistance and initially it is placed across the first resistor and the value recorded. This is repeated for the second and third resistor. Use connector wires to connect up the resistors as shown
3. Now connect the multimeter across all three together and record the total resistance

Check how the total resistance relates to the individual resistances. you should find if you add them directly that they give the final resistance. This confirms that resistors in series add directly. i.e. $R=R_1+R_2+R_3$

You can now repeat the experiment using the LED block and connecting them in series. Record the results carefully and show your calculations.

LED's in Series

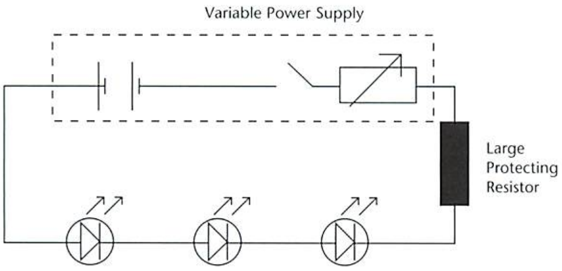
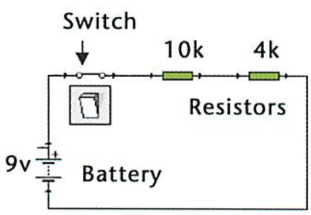
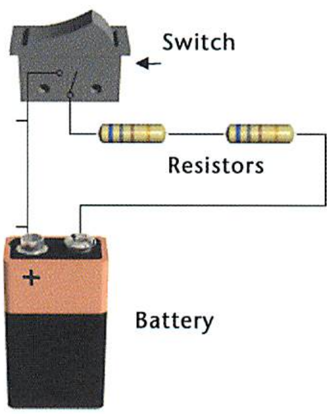


Figure 1.5 *LEDs in Series*



Circuit Diagram



Battery

Resistance calculation:

R = R1 + R2

R = 10kΩ + 4kΩ = 14kΩ

So in this circuit the total resistance is 14kΩ.

Experiment 2: Investigate how Resistors behave in Parallel Circuits

Planning:- Assemble the components shown in the diagram and have pencil and paper ready to record the data (or set up a spread sheet in excel for data)

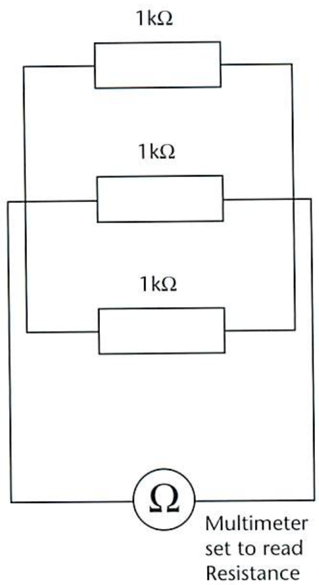


Figure 1.7 *Resistors in Block 2: Resistors in Parallel*

Apparatus:- Multimeter, Resistor block two, calculator

Procedure

4. Set up the circuit as shown using Resistor Block 2. This contains three resistors connected in parallel
5. The multimeter is set to read Resistance and initially it is placed across the first resistor and the value recorded (R_1). This is repeated for the second and third resistor. Use connector wires to connect up the resistors as shown. (notice that the current has three possible pathways whereas before it had only one pathway)
6. Now connect the multimeter across all three together and record the total resistance.

Check how the total resistance relates to the individual resistances. You should find if you add them directly that they do **not** give the final resistance. This confirms that while resistors in series add directly, resistors in parallel behave differently. Now try to add them using the following formula.

$$1/R=1/R_1+1/R_2+1/R_3$$

The total resistance is represented by R

This confirms that resistors in parallel add inversely. $1/R=1/R_1+1/R_2+1/R_3$

You can now repeat the experiment using the LED block and connecting them in parallel. Record the results carefully and show your calculations.

LED's in Parallel

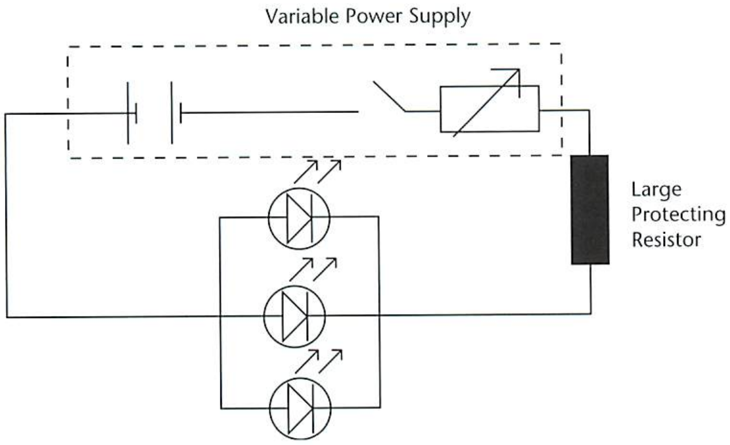
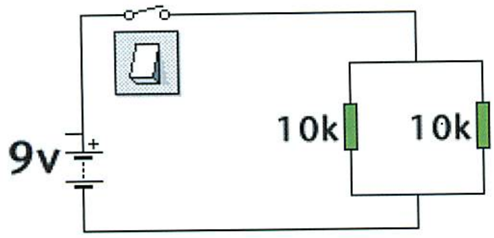


Figure 1.8 *LEDs in Parallel*



When two or more resistors are connected 'side by side', as shown in Fig 1.9, they are said to be connected in **parallel.** When resistors are connected in parallel there is more than one conducting path through the circuit. We can think about the electrons having a choice about which way to go.

Figure 1.9 *Resistors in Parallel*

Resistance calculation:

1/R = 1/R1 + 1/R2
1/R = 1/10K + 1/10K
R = 5K

So the total equivalent resistance in this case is 5kΩ.

Ohm's Law

We can state a relationship between the voltage applied across a resistor and the resulting current in the circuit. This relationship is called 'Ohm's Law'. Ohm's law states that at constant temperature the current in a circuit is directly proportional to the voltage. (This law is true for the conductors in which we are interested).

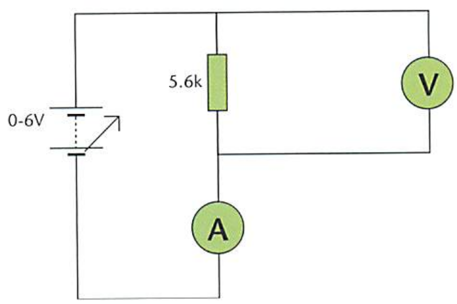


Figure 1.10 *Ohm's Law*

We usually write this as: $V = I\,R$

where the voltage, V, is expressed in volts the current, I, in amperes and the resistance, R, as ohms. Ohm's Law says that if more voltage is applied to a resistor, then more current flows through it. If the voltage is doubled then the current doubles, if the voltage is halved then the current halves and so on.

Example: (see fig. 1.10)

Question: - If the voltage of a battery connected across a 5.6k resistor is 6V, what is the current flowing in the circuit?

Answer: Voltage = Current * Resistance
V = I * R
6 = I * 5600
I = 6/5600
I = 0.003A

Note that current is measured in Amps (A)

Ohm's Law:
At constant temperature the current in a circuit is directly proportional to the voltage.

Experiment 3: Investigate how Current changes with Voltage

Planning:- Assemble the components shown in the circuit diagram and have pencil and paper ready to record the data (or set up a spread sheet in excel for data).

Apparatus:- Two multimeters, Single Resistor Block, Power supply (0-6V), connecting wires, Diagram.

Ohm's Law

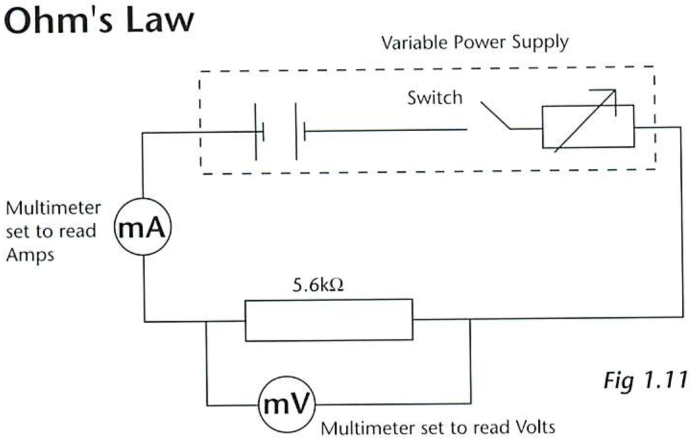


Fig 1.11: Ohm's Law Circuit Diagram

Procedure

1. Set up the circuit as shown in the diagram making sure that the multimeter connected in series is set to read Current while the multimeter connected in parallel is set to read Voltage.
2. Check that both multimeters read zero when the switch of the power supply is off
3. Turn on the power supply and increase the Voltage in small steps recording both the Voltage (V) and the Current (I) at each step. (the steps can be checked and adjusted so that you get at least 6 values)
4. Draw a graph of Voltage versus Current. Also calculate the resistance at each step using the formula R=V/I. What do you notice about the results at each step? What shape is the the graph? What does this tell us about the mathematical relationship between Voltage and Current?

This experiment should be repeated using the Diode block. Compare the results. Do all circuit components behave in the same way when the Voltage is varied?

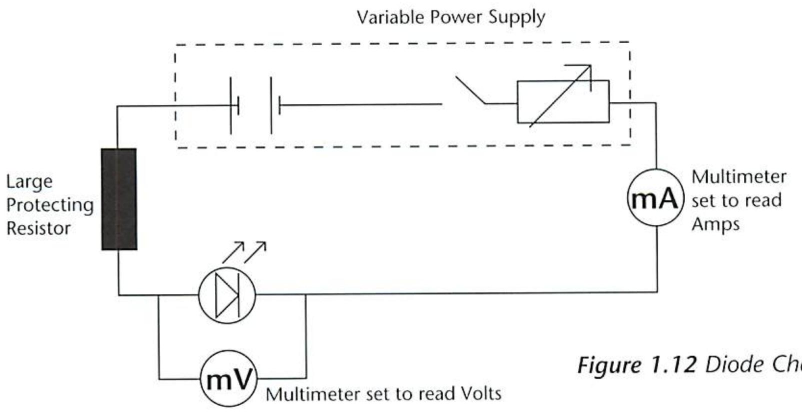


Figure 1.12 *Diode Characteristic*

An Exercise to Try:-...

Using the same circuit as shown above replace the single Resistor block with the LED block. Try connecting the LED's initially in series and notice the brightness of the LED's. Now connect them in parallel and notice the brightness. You may need to increase the Voltage a little to get the full effect. What did you notice about the brightness? With this information can you tell if the lights in your house are connected in series or in parallel?

a transition year module

Actual Resistors

In practice when we see a resistor we read the resistance from the bands of colour around the component. Each band of colour on the resistor represents a number and the order of these numbers represents the resistor value. The first two bands indicate a value. The third colour band indicates the multiplier or number of zeros. The fourth band indicates the tolerance of the resistor, e.g. ± 5%, ± 10% or ± 20 %. See fig. 1.13.

Colour Code

Colour	1st Digit	2nd Digit	Multiplier	Tolerance
Black	0	0	None	-
Brown	1	1	1	±1%
Red	2	2	2	± 2%
Orange	3	3	3	-
Yellow	4	4	4	-
Green	5	5	5	-
Blue	6	6	6	-
Violet	7	7	7	-
Grey	8	8	-	-
White	9	9	-	-
Gold	-	-	-	± 5%
Silver	-	-	-	± 10%
None	-	-	-	± 20%

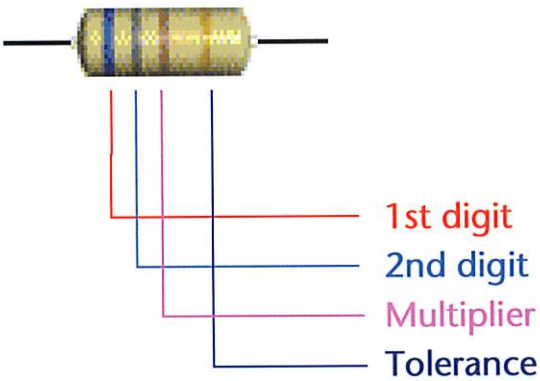


Figure 1.13 Actual resistor

Example

Red-Red-Orange-Gold - the colours represent 2, 2, 3, 5

so that is 22 by 10^3 Ohms with a tolerance of 5%, or 22kΩ ± 5%

Capacitors

A **capacitor**, fig. 1.14, is a device for **storing charge**. The **capacitance** of a capacitor is a measure of how much **charge** it can hold. Capacitance is measured in **Farads.** Practical capacitors have values in microfarads (μF), nanofarads (nF) and picofarads (pF).

$1\mu F = 10^{-6}$ F $1nF = 10^{-9}$ F $1pF = 10^{-12}$ F

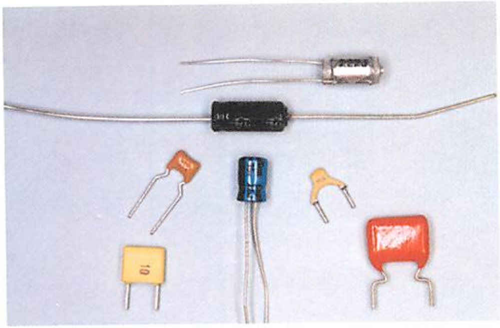


Figure 1.14 *Capacitors*

- **Capacitors** are stores for electrical charge.
- The **capacitance** of a capacitor is a measure of how much charge it can store.

Charging a Capacitor

We can look at the operation of a capacitor by considering the circuit shown in fig. 1.15.

The voltage of the battery causes current to flow. Charge builds up on the two plates, **negative** charge on one plate and the same amount of **positive** charge on the other. The flow of current stops when the voltage across the plates equals the voltage of the battery. The capacitor is now fully charged.

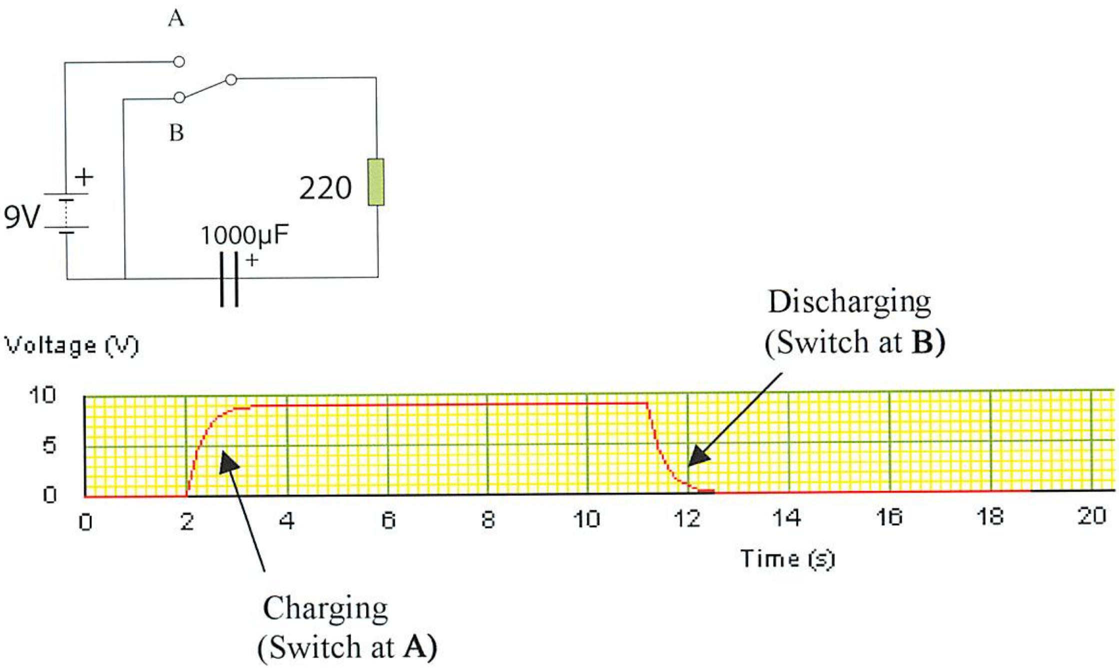


Figure 1.15 *Charging / Discharging a Capacitor*

Suppose we remove the battery. What happens? The simple answer is that the positive and negative charges remain on the two plates. So these two flat plates separated by an air gap have the ability to store electrical charge. This is the simplest form of capacitor and is known as a Parallel Plate Capacitor. The chart in Fig. 1.15 shows that when the switch is at A the capacitor charges up in a short time and then holds that charge until switched to B, when the capacitor discharges completely and waits for the voltage to be reapplied.

Meters

Ammeters are used to measure the flow of current in a circuit. They must be connected in **series** with the circuit components. In this way, the current flowing in the circuit also flows through the ammeter and therefore can be measured.

Voltmeters however, must be connected **in parallel** (across) circuit components. They are connected in this way because their job is to measure the voltage across a component.

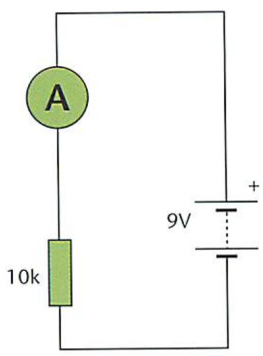


Figure 1.16 *Ammeter placed in series*

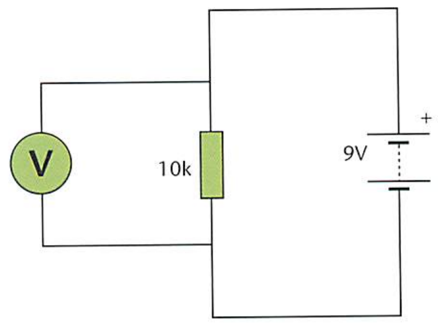


Figure 1.17 *Voltmeter placed in parallel*

Ohmmeters are used to measure the resistance of a component.
All of these meters can be incorporated into one device called a **multimeter,** fig. 1.18.

Figure 1.18 *A multimeter*

Circuit Simulation

The computer simulation package *Crocodile Clips* allows us to simulate actual circuits and to predict the operation of these circuits before we build them. All design engineers use simulation to help in perfecting their designs. There is a very extensive help tutorial included in the Crocodile Clips package. Students can use this package to build and simulate all the circuits used in this circuit.

Practical Exercise

At this stage, the student could measure the resistance of some resistors using the multimeter and look at some other components like capacitors.

The resistors in series and parallel and Ohms Law Concepts can be explained using the sample resistors provided and the multimeter.
Using the colour code determine the resistance of the following resistors

Red, Red, Brown, Gold
Yellow, Violet, Brown, Silver
Brown, Black, Orange, Silver

Confirm your results using the mulitmeter. (25 marks)

Note: In the soldering exercise in Unit 5 resistors can be soldered onto the stripboard in series and parallel configuration and these circuits can then be used to revisit Ohm's Law and series and parallel resistance.

Review

- An **electric current** is the flow of electrons around a circuit.
- Good **conductors** allow current to flow easily. Good **insulators** don't.
- We measure opposition to electric current as **resistance.**
- A **battery** supplies the force **(voltage)** that makes the electrons move.
- For an electric current to flow in a circuit there must be a **continuous path** between the **positive** and **negative terminals** of the battery.
- **Ohm's Law** says that resistance, voltage and current are all interrelated as follows:

  $V = I R$
- A **Capacitor** stores electrical energy.

Table of Units

Quantity	Unit
Voltage (V)	Volt (V)
Current (I)	Amp (A)
Resistance (R)	Ohm (Ω)
Charge (Q)	Coulomb (C)
Capacitance (C)	Farad (F)

Assessment

Place an X in the box that is next to the correct answer

1. What type of charge is found on the Electron?
   [ ] positive [ ] ampere [ ] negative [ ] None (5 marks)

2. A current is
   [ ] the random movement of electrons
   [ ] the flow of electrons around a circuit
   [ ] a build up of voltage (5 marks)

3. Insulators
   [ ] allow current to flow through them
   [ ] do not allow current to flow through them (5 marks)

4. The unit of Voltage is
   [ ] Volt [ ] Ampere [ ] Amp [ ] Ohm (5 marks)

5. When a resistor is connected in series in a circuit will the overall resistance
   [ ] increase [ ] decrease [ ] stay the same (5 marks)

6. The size of the current through a resistor increases as the voltage applied across it increases
   [ ] True [ ] False (5 marks)

7. When two resistors are connected one after another in a circuit they are said to be in series.
   [ ] True [ ] False (5 marks)

8. Ammeters must be connected in a circuit
   [ ] in series [ ] in parallel [ ] anywhere in the circuit (5 marks)

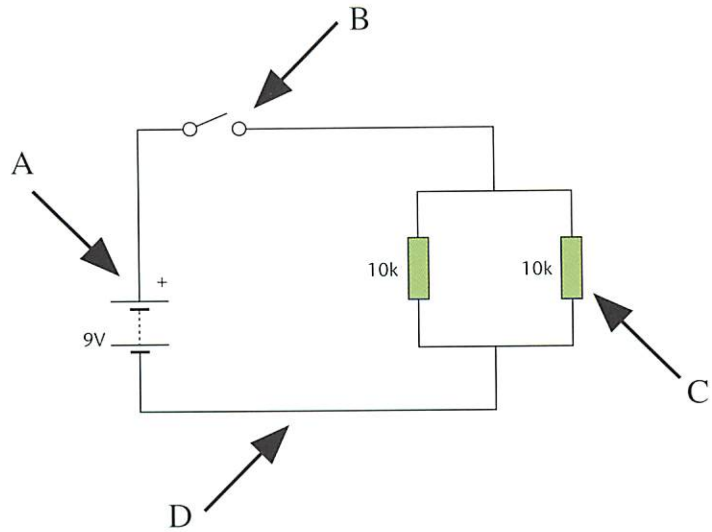
9. A capacitor is charged by connecting it across a battery.
   [ ] True [ ] False (5 marks)

10. A multimeter can be used to measure current, voltage and resistance.
    [ ] True [ ] False (5 marks)

11. What is the unit in which Capacitance is measured?
    [ ] Amp [ ] Farad [ ] Coulomb [ ] Volt (5 marks)

12. (i) Match the following words to the Letters A B C D in the diagram:-
Switch, Battery, Resistor, Connecting Wire.

(ii) Is this a series or a parallel circuit?



(10 marks)

13. Complete the following sentences:

i Electronics gets its name from the ______________________________

ii Electrons have a ________________ charge.

iii Charge is measured in units called ______________________________

iv The symbol for the unit of charge is ______________________________

v Materials that allow current to flow through them are called ________________

vi Materials that do not allow current to flow through them are called ____________

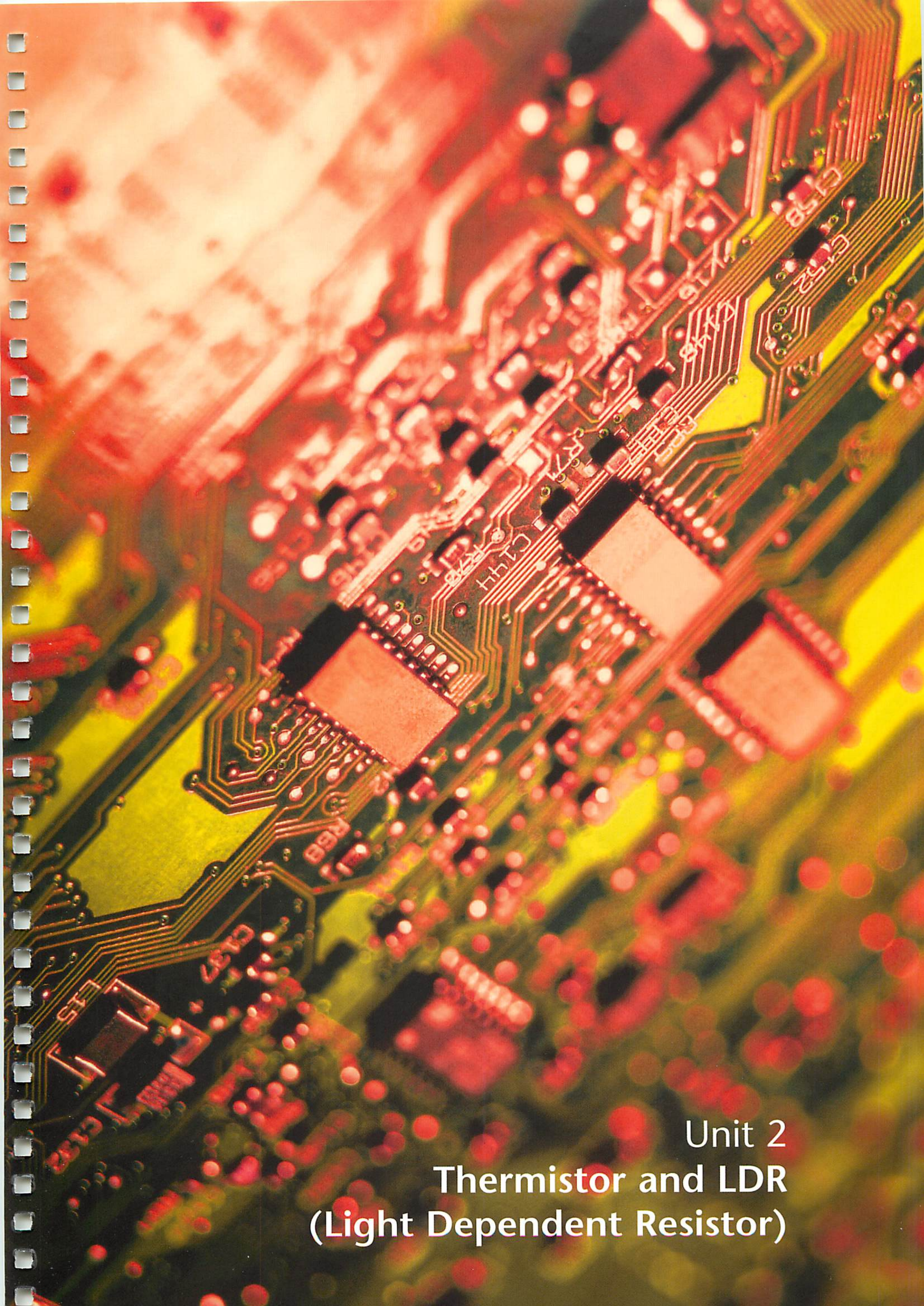
vii The name given to materials that are neither good conductors nor good insulators is ______________________

viii A good conductor has a ________________ resistance to the flow of current.

ix A poor conductor has a ________________ resistance to the flow of electrons.

x Current is measured in ________________

(10 marks)



Unit 2

Thermistor and LDR (Light Dependent Resistor)

Unit 2 | Thermistor and LDR (Light Dependent Resistor)

Duration
2 Hours

Equipment
Multimeter, beakers, kettle, battery, connecting leads, LDR, Thermistor, Thermometer.

Aims
In this unit we will examine two semiconductor devices:-

1. The Thermistor.
2. The LDR (Light Dependent Resistor).

The aims of this unit are to carry out experiments using these devices. The results will be recorded and conclusions drawn.

Objectives
After this lesson the student will know when and where these devices can be used in circuits. They will be able to describe the operation and be able to suggest other uses of these devices.

Assessment Method
The assessment of this unit is based on the student's written report using measurements taken during the LDR and Thermistor experiments.

A sample experiment report is provided for information only.

The Thermistor

A Thermistor (fig. 2.2), is a device whose resistance changes according to its temperature. The principle of the Thermistor is similar to that of the LDR. When the temperature of the Thermistor is zero degrees Celsius its resistance is very high, about 150kΩ. At 25°C (room temperature) its resistance is reduced to about 47kΩ. At 100°C the resistance of the thermistor is 2kΩ. This is a very large range. Thermistors can be used as Thermometers and in circuits that use temperature control eg. heat operated fire alarms.

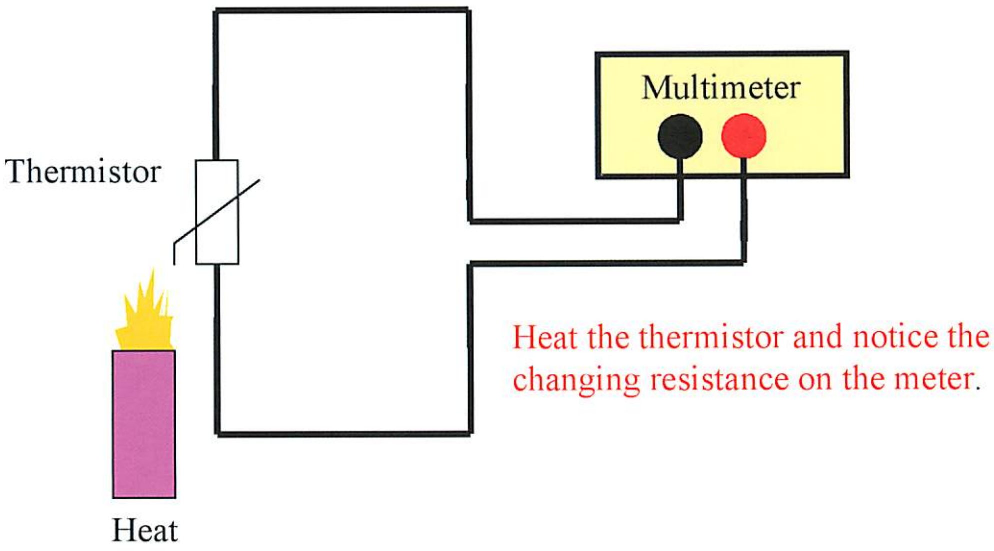


Figure 2.2 Thermistor

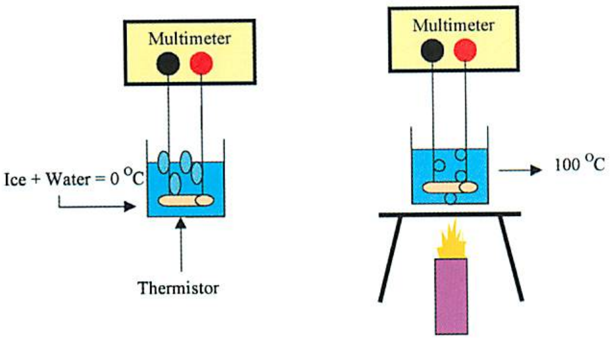
To see this for ourselves we need to vary the temperature of the device and read the resistance on the multimeter. This shows that a thermistor can in fact be a very sensitive thermometer. In the experiment below we use a thermometer to calibrate the thermistor. We can record the data and write an experimental report on it.

Experiment 2
The Thermistor Thermometer

To make and calibrate you own Thermistor Thermometer.

Apparatus: Thermistor, beakers, mercury thermometer, some ice, bunsen burner or kettle, multimeter.

Note: Be careful not to exceed the temperature range of the mercury thermometer you are using.



(Thermometer is not shown on the diagram. Place it into the beaker with the thermistor)

Procedure:

1. Put some ice cubes into a beaker of water and allow them to stand for a few minutes.
2. Place the mercury thermometer and the thermistor into the beaker. Record the resistance of the thermistor and the temperature on the mercury thermometer.
3. Using both the cold water and the hot water from the kettle vary the temperature of the water in the beaker. Record the resistance and the temperature reading every 10 degrees for at least 8 different temperature values.
4. Record your results on the table below.
5. Draw a graph of temperature (x-axis) vs. resistance (y-axis).
6. Leave the thermistor in air for a few minutes and then measure its resistance.
7. Locate this point on your graph and read the room temperature.
8. Write a full report on your experiment.

Results:

Temperature °C										
Resistance Ω										

Resistance of Thermistor at Room Temperature =

Room Temperature using Graph =

Room Temperature using Mercury thermometer =

Sample Report:- (For guidance only)

Students Name:

Date of Experiment

Partner's Name:

Object of Experiment: To produce a calibration curve for a semi conductor thermistor and to use it as a thermometer to measure room temperature.

Apparatus: 2 Beakers, Thermistor, Mercury Thermometer, some ice, kettle, Multimeter .

Diagram: (student is to draw diagram using the earlier experiment diagram as a guide for this experiment)

Procedure
Both the thermistor and the mercury thermometer were placed into a beaker of water and ice as shown in the diagram. The temperature on the mercury thermometer and the resistance of the thermistor were noted and recorded. Using the kettle and the cold tap it was possible to vary the temperature of the water in the beaker by approximately 10 degrees and at each new temperature both the resistance and the temperature were noted. This was repeated for at least 8 different equally spaced temperatures. The results were recorded on a table and a graph of temperature versus resistance was drawn. It yields an exponential curve. The thermistor was then left in air and its resistance noted. By locating this resistance on the graph it was possible to read the room temperature.

Results (Table)

Graph

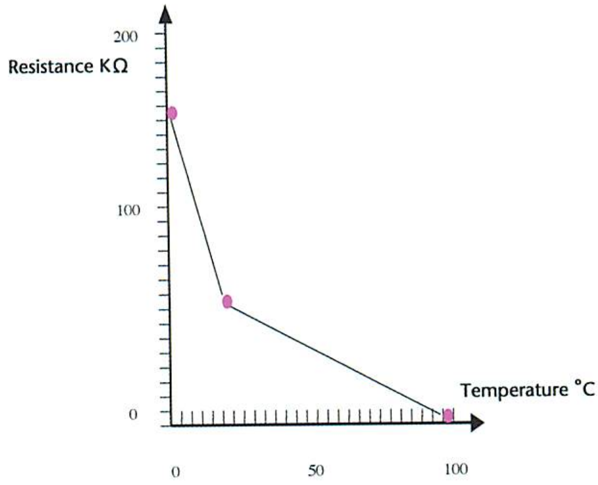


Fig 2.3 *Typical calibration curve*

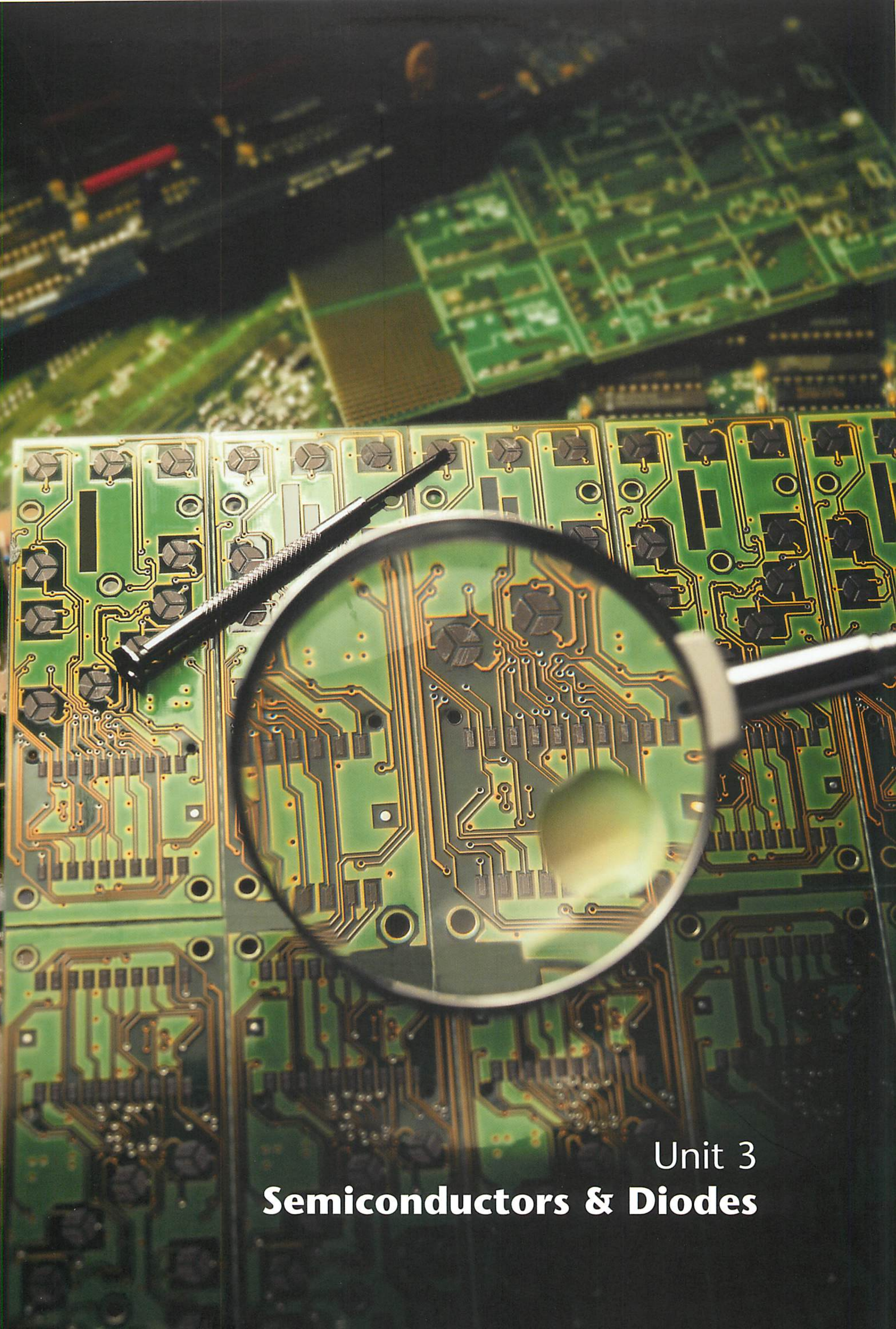
Discussion/ Conclusion

The resistance of a thermistor is high when the temperature is low but as it is heated the resistance reduces very quickly. It can be used easily as a thermometer and is less fragile than the mercury thermometer. The fact that the resistance varies measurably with changing temperature means that resistance can be used as a thermometric property just like the expansion of the mercury in the thermometer.
The thermistor is made from a semiconductor material and this experiment also illustrates that the conductivity of semiconductors is increased when they are heated.

Assessment

Experiment 1: LDR
(25 marks)

Experiment 2 : Thermistor
(75 marks)



Unit 3
Semiconductors & Diodes

Unit 3 | Semiconductors and Diodes

Duration
Two hours

Equipment
Crocodile Clips computer simulation package, diodes, resistors, multimeter, battery, connecting leads.

Aims
The aims of this unit are to introduce the students to the concepts of semiconductors and semiconductor devices. The students will need an appreciation of the performance of these active devices in order to construct the circuits in Units 6 and 7 later on.

Objectives
After this lesson the student will be able to :
1. Define or explain the following in simple terms:
   - Semiconductors
   - P-type
   - N-type
   - Depletion region
   - Diodes
2. Explain the use of a diode in a simple circuit
3. Understand how a Light Emitting Diode (LED) is connected in a circuit.
4. Identify symbols for diodes and LEDs and use these symbols in simple circuit diagrams and computer simulations.

Assessment Method
1. Practical task to be completed. (50 marks)
2. End of unit test sheet. (50 marks)

Introduction

We know that metals can conduct electricity because they have lots of loosely held electrons that can move and hence conduct current. Insulators on the other hand do not allow electrons to flow and will not conduct electricity. There is another group of materials which lie somewhere between good conductors and good insulators. These are known as **semiconductors**. They do not have enough free electrons by themselves but the available mobile charge can be hugely increased by adding an **impurity** called a **dopant.** If the impurity adds more negative charges it is called n-type and if it adds more positive charges it is called p-type.

Semiconductors Explained

When we say that a material is a conductor we mean that it will easily release some of its electrons to allow a current to flow. We say that a good conductor is one which has a low resistance to releasing its electrons for conduction. On the other hand a very poor conductor is a material which will not release any of its electrons to carry a current. These very poor conductors are called insulators and are very important to us also, as they are used to protect us from getting electric shocks.

As you know, metals are very good conductors, while plastics, glass and wood are very good insulators. However, what about the materials which are not in either category? These materials are able to release electrons for conduction - but only if they are encouraged to do so. In order to release electrons they need to be heated. This is now a new category of materials and they are known as semiconductors. The best semiconductor materials are silicon and germanium. Silicon is the most commonly used and one of the main centres for the design and development of Electronics has become known as Silicon Valley in California. These semiconductors are used to build electronic circuits and as almost every electrical device now has an electronic component, it must be obvious how important semiconductors are to our lives.

The size of the currents that these semiconductors carry is very small when compared to good conductors, usually being in the order of microamps, (0.000001A). Using silicon as our example, we will look at how to increase its conductivity. Silicon is in group IV of the periodic table of the elements and so has four electrons in its outer "shell", fig. 3.1.

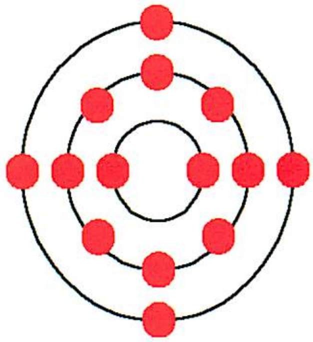


Figure 3.1 *Silicon Atom, with four electrons in its outer shell.*

These fit nicely in the silicon lattice structure as shown in fig. 3.2, with each silicon atom bonding with four other silicon atoms to have a full outer "shell". When it is heated some of the electrons are freed to move about throughout the lattice.

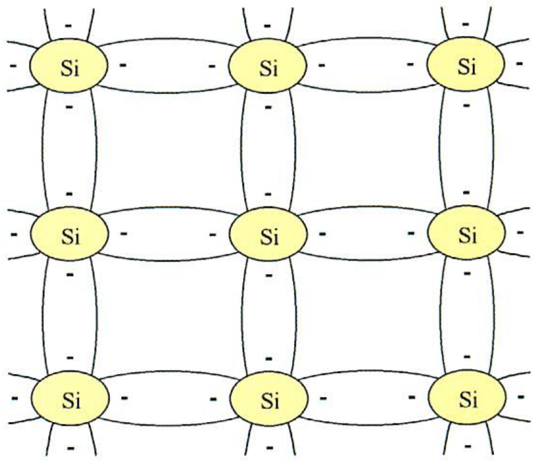


Figure 3.2 *Silicon Lattice*

When the silicon atom loses one of its four outer electrons the space left behind behaves as if it had a positive charge and can attract electrons from nearby atoms to fill the 'space'. This in turn makes a 'space' in the other silicon atoms. These spaces can, therefore, also appear to move through the lattice. We now have another type of charge carrier, "Spaces". These spaces are called

"Positive Holes" and move throughout the lattice independent of the "Negative Electrons". The more the semiconductor is heated the more electron-hole pairs are formed. Note that there are an equal number of 'holes' and 'electrons', fig. 3.3.

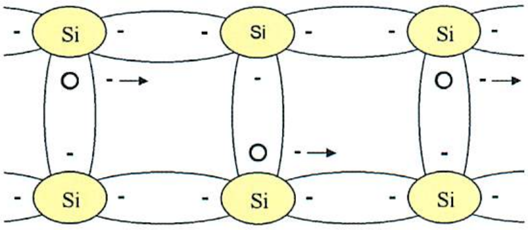


Figure 3.3 Applying heat makes electrons free for conduction.

To increase the number of electrons and holes available for conduction we could continue to heat the semiconductor, but as you know most of our computers and other electronic equipment are in plastic structures which would melt very quickly if we were to continue heating them. By looking again at the periodic table and the arrangement of electrons around atoms a very clever way was found to make silicon a thousand times better.

Boron is an element in group III of the periodic table so it has three electrons in its outer shell. If a Silicon atom is replaced by a Boron atom in the lattice you get extra "holes" as shown in fig 3.4. These holes increase the conductivity even if a boron atom replaces only one in ten million atoms of the silicon. Semiconductor materials that have added holes are said to be **p-type** semiconductors (positive-type) as most of the conduction is by the apparent movement of holes.

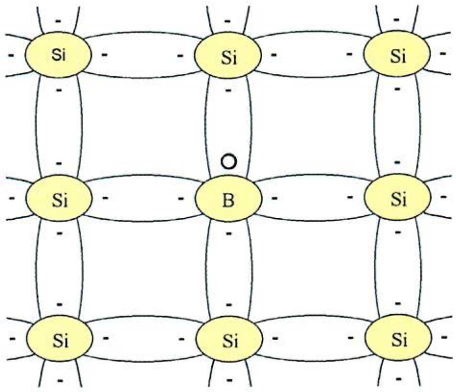


Figure 3.4 Replace a silicon atom with a boron atom

Similarly if Phosphorus which is in group V of the periodic table is used in the same way in the Silicon, extra "electrons" are made available for conduction, as shown in fig 3.5. Semiconductor materials that have added electrons are said to be **n-type** semiconductors (negative-type) as most of the conduction is by the movement of electrons.

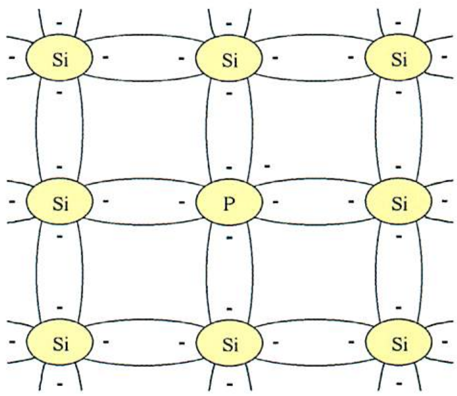


Figure 3.5 Replace a silicon atom with a phosphorous atom

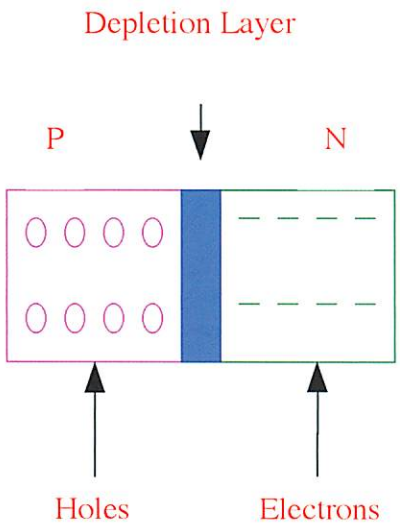
The addition of impurities such as Boron and Phosphorus to increase conduction by semiconductors is called **doping**. It is important to realise that only a very small amount of them are needed to increase the conductivity by a very large amount.

Now we have a way of getting more conduction with no heating beyond room temperature, so nearly all semiconductor devices are made using "doped" semiconductor materials.

The Diode

We make a special device called a 'diode' by joining a piece of n-type semiconductor with a piece of p-type semiconductor. In the n-type side we have extra electrons and in the p-type side we have extra positive charges or holes. When we put these two materials together in a p-n junction, the extra electrons in the n-type near the junction can cross to join with the extra positive charges in the p-type area. This means we have one less negative charge in the n-region and one less positive charge in the p-region near the junction. In simple terms there is a space left on either side of the junction that has no carriers of either type.

There is a piece in the middle that has no extra holes or electrons and this is known as the **depletion layer** of the p-n junction. As this layer has no extra charges it cannot conduct and it acts as an insulator, fig. 3.6.



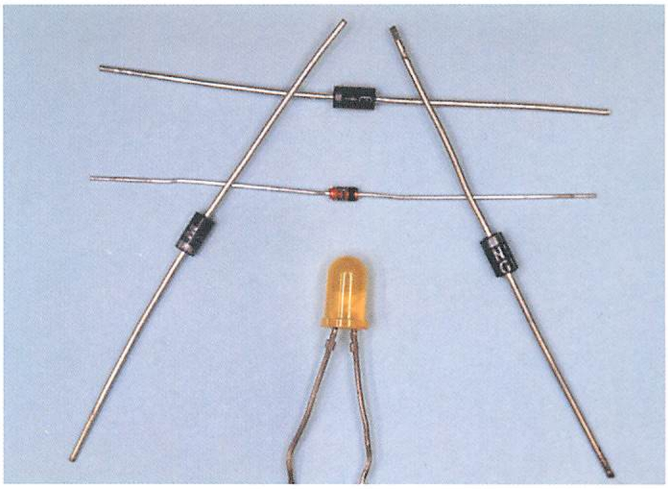


Figure 3.6 *The Diode.*

What happens if we now connect a battery across this junction? Well there are two possible ways we can connect a battery:

Forward bias

This means that the positive side of the battery is connected to the p-type material and the negative side is connected to the n-type material, fig 3.7. What happens is this: when we first apply a voltage we are pushing more electrons into the n-type material and pushing more holes into the p-region. At the beginning this is difficult because of the depletion layer but as we increase the voltage, (to approx. +0.7V for silicon) we overcome the resistance of the depletion region and current is able to flow freely. So the diode acts like a good conductor at voltages of over +0.7 Volts when forward biased.
Some diodes emit light as they conduct. This light comes from the energy given off when the holes join with the electrons at the junction. These are called **Light Emitting Diodes** or **LEDs.**

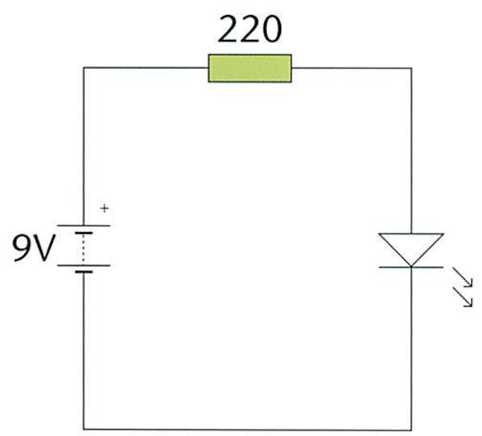


Figure 3.7 Forward Bias

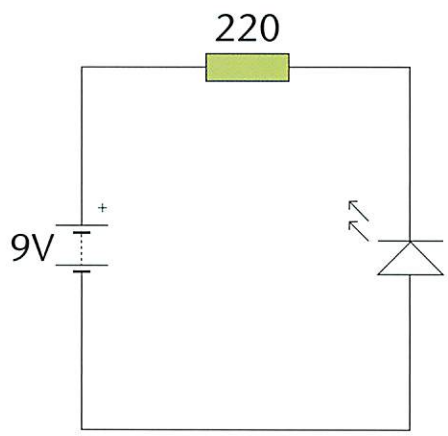


Figure 3.8 Reverse Bias.

Reverse bias

We could also connect the battery in the opposite direction. If we connect the negative side of the battery to the p region and the positive side of the battery to the n region something entirely different happens, fig. 3.8. The negative terminal of the battery attracts the holes away from the junction and the positive side of the battery attracts the electrons away from the junction and the depletion region gets bigger. The depletion region cannot conduct, the diode acts as a good insulator and no current flows.

So the diode is a very useful device that can be either a conductor or an insulator depending on how the voltage is applied i.e. it can act as a valve which allows current to flow in one direction only.

Think about the LEDs in figures 3.7 and 3.8 above. Which LED would emit light?

Assessment

Task

Draw the following circuits (fig 3.9), using *Crocodile Clips* to investigate forward and reverse bias. (The circuits could also be assembled on stripboard for demonstration).

(50 Marks)

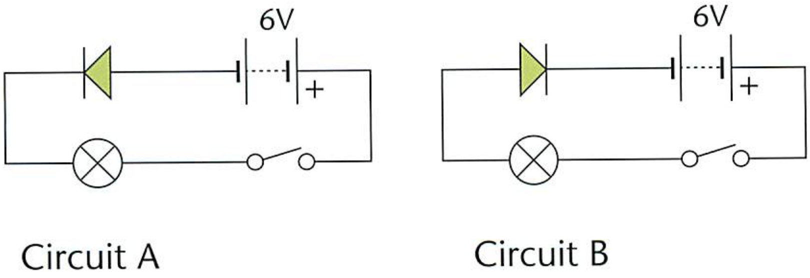


Figure 3.9 *Crocodile Clips simulation circuits for forward and reverse bias*

Questions

Q1. Fill in the blanks.

(i) ________________ is an example of a semiconductor material. It is in Group ______ of the Periodic Table.

(ii) Conduction in semiconductors is by positive __________ and negative __________ .

(iii) If the semiconductor is heated the number of electrons and holes available for conduction will (a) increase [ ] (b) decrease [ ]

(iv) The addition of small amounts of impurities to increase conduction is called ______________.

(v) If the semiconductor is doped with Phosphorus, the majority carriers are ______________.

(vi) If the semiconductor is doped with Boron, the majority carriers are ______________.

(vii) When a p-type and an n-type semiconductor are placed side by side it is known as a __________

(viii) The ________ allows current to flow in _________ direction.

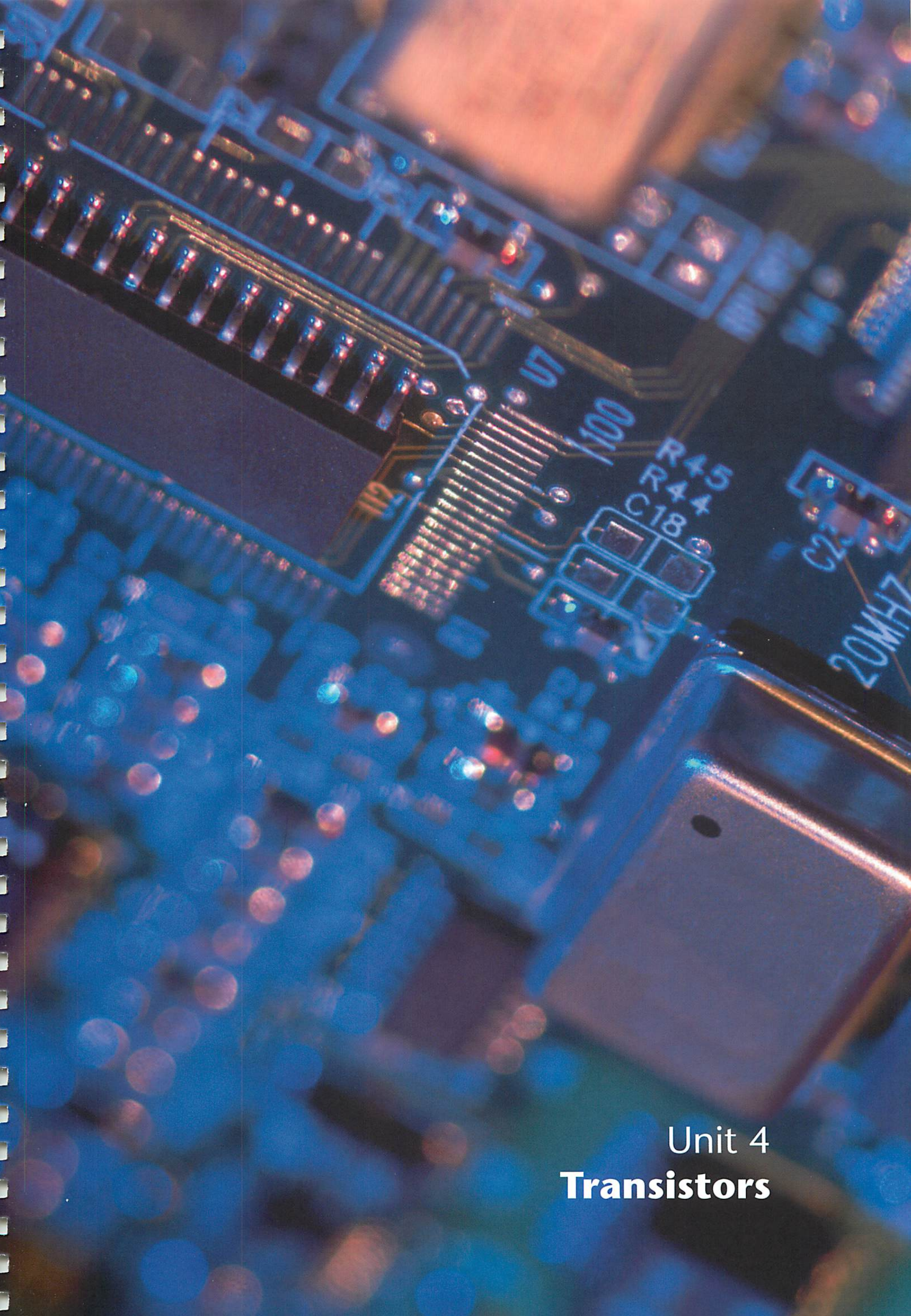
(ix) The layer where the p – n junction forms is known as the ______________ ______________.

(x) The______________ ______________ is the voltage needed to overcome this layer.

(20 Marks)

Q 2. What is a diode?
Mention two uses you would make of a diode in electronic circuits.
Does it matter which leg of the diode is connected to the positive side of the battery?
How do manufacturers overcome this problem? *(15 Marks)*

Q 3 Draw a circuit diagram showing a diode connected in
(i) forward bias (ii) reverse bias. *(15 Marks)*
What must always be connected in series with a diode in forward bias?
What would happen if this were left out of the circuit?



Unit 4

Transistors

Unit 4 | Transistors

Duration
Two Hours

Equipment
Computer Simulation Package: *Crocodile Clips*

Aims
This section is designed to build on the basics of semiconductor diodes by introducing transistors and looking at how they can be used as switches in simple circuits.

Objectives
On completing this section the student should be able to:

- draw the symbol for a transistor in a simple electronic circuit
- identify the emitter, base and collector of a transistor
- explain the operation of a transistor as a switch
- sketch a simple circuit diagram incorporating a transistor
- understand that transistors are the major components of a 'chip'

Assessment method
Each student will simulate a circuit demonstrating the operation of the transistor as a switch and will also be required to complete the question sheet at the end of the unit.

The Transistor

If you think of a diode as two slices of semiconductor joined together to form a p-n junction then a transistor is just another slice added to this. A transistor is either considered to be N-P-N type or P-N-P type depending on the dopants used. We have two P-N junctions in a transistor, fig 4.1. To simplify things we will just consider n-p-n transistors.

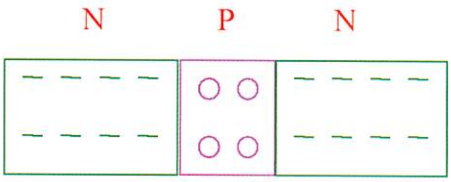


Figure 4.1 *The Transistor*

The terms **collector**, **base** and **emitter** are used to represent the different regions of the transistor, see fig. 4.2. The base is the slice of p-type material in the middle and this is thin compared to the other two sections. When no voltage is applied this is just like two diodes placed back to back – it cannot conduct at all.

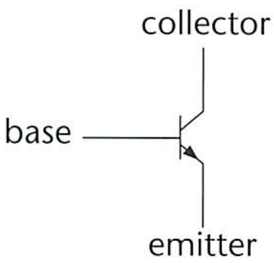


Figure 4.2 *Transistor: emitter, base, collector.*

The transistor is used in several different ways in a circuit but for this lesson we will just consider the use of the transistor as a **switch.** If we apply a voltage from the collector to the emitter the transistor will not conduct and no current can flow. This is like an open switch, (see fig. 4.3).

A transistor is a three terminal device in which the current between the collector and the emitter terminals is controlled by the voltage between the base and the emitter terminals.

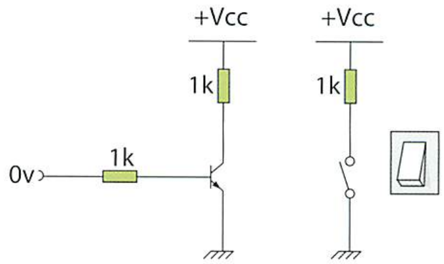


Figure 4.3 *Transistor is 'off' – equivalent to an open switch*

If we apply a positive voltage between the base and the emitter which is greater than +0.7 volts then the depletion region between the base and the emitter is reduced and a base current will flow (see fig. 4.4).

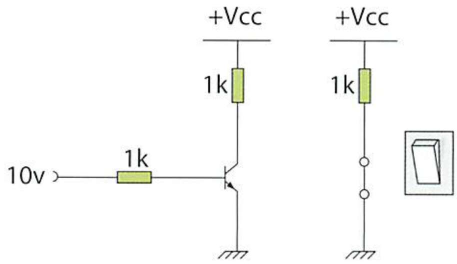


Figure 4.4 *Transistor is 'on' – equivalent to a closed switch*

Because the base region is thin and lightly doped this base current will be enough to sweep the electrons right through the base region and to allow a current to flow from the collector to the emitter (or the other way if you think in terms of electrons). Now the transistor is conducting and it acts like a closed switch.

So, if there is no voltage applied to the base the transistor will not conduct – no current will flow between the collector and the emitter. But if the correct voltage (>0.7V) is applied to the base the transistor is **switched on** and current can flow from the collector to the emitter. **So the transistor is either switched on or off depending on the base voltage.**

The circuits we will build in the lab exercises will use this feature of the transistor acting as a switch. Always remember that a forward biased junction needs to be protected by a resistor in series with it. The base of the transistor is one of these junctions.

Simulation Circuits

Using the *Crocodile Clips* simulation package we can look at the operation of a transistor and see what happens. Draw the circuit shown in fig. 4.5 and save it.

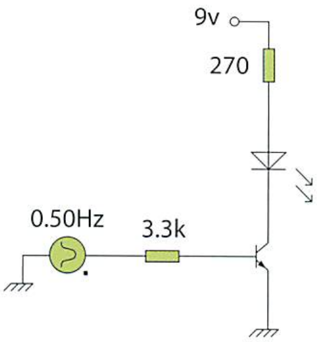


Figure 4.5 *Using a Transistor as a switch.*

The circular symbol in the diagram represents a square wave generator. A square wave is a signal that has a high voltage output for a certain length of time and then a low voltage output. This pattern is repeated over and over. In this case we want the low voltage output to be at zero volts and the high voltage to be at +9 volts. When the square wave output is high the transistor is turned on and current is able to flow from the collector to the emitter and the LED is on. Then the square wave goes low and the transistor is turned off, no current can flow and the LED goes off. This happens repeatedly. The frequency of the square wave determines how quickly this happens. With the circuit given the light should go on for one second, off for one second, on for one second and so on. You can change the speed by changing the frequency of the square wave.

Identifying transistors

Transistors come in all shapes and sizes. The most common package for individual general-purpose transistors is a plastic case with three pins, (see fig. 4.7). These three pins allow us to connect to the emitter base and collector of the transistor. In practice in your circuits you will solder connections to each of these pins.

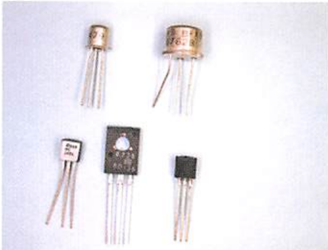


Figure 4.7 *Transistor types.*

Millions of transistors!

In our circuits in Units 6 and 7 we use one, two or three transistors to achieve the desired outcome. In very advanced computer circuits many millions of transistors are required to process data and to carry out complicated tasks. Modern integrated circuits have become so advanced that millions of transistors can be incorporated into a single Integrated Circuit (IC) or "chip", (see fig. 4.8).

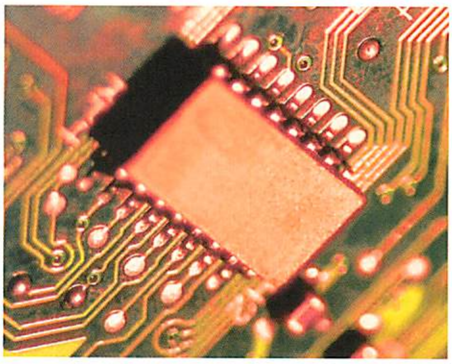


Figure 4.8 *IC chip.*

A chip contains minute circuits etched onto a substance called silicon. Remember that silicon is a semiconductor, which means that it is neither a good conductor of electric current, nor a good insulator.

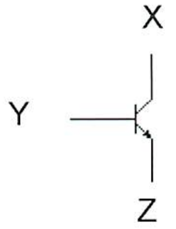
The most complicated and powerful chip in a modern computer system is the microprocessor chip. Most modern computers use a version of the *Pentium* microprocessor. These chips are manufactured here in Ireland.

Assessment

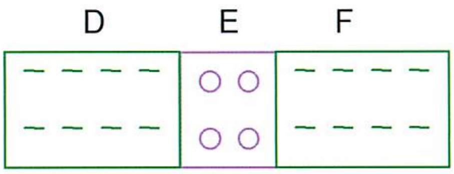
Crocodile Clips simulation circuit (Fig. 4.5) (50 Marks)

Questions

Q 1. (i) Label the parts marked X, Y, Z in the following diagram



(ii) Label the parts marked D E F in the following diagram



(iii) A transistor can be used in a circuit as a ____________________

(iv) In a transistor the base region is __________ and only lightly __________.

(v) A transistor is a __________ __________ device in which the current between the __________ and the __________ terminals is controlled by the __________ between the __________ and the __________ terminals.

(20 Marks)

Q 2. How would you recognise a transistor when working with electronic components?

____

Does it matter how it is connected into a circuit? ____________________

Explain your answer.

____

____

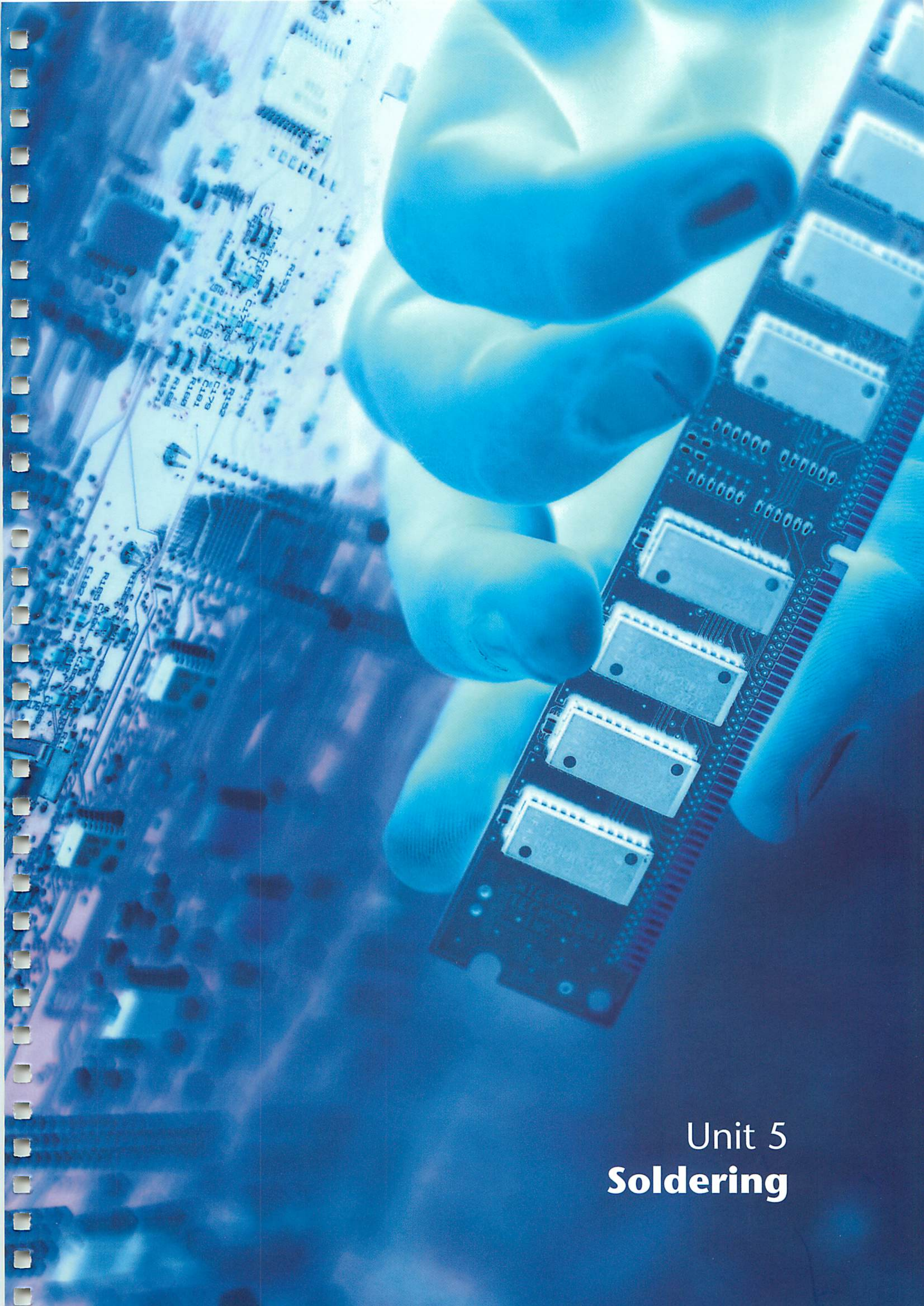
(15 Marks)

Q 3. What do the letters IC stand for? ____________________

Name two types of ICs ____________________

What other name is used to describe ICs. ____________________

(15 Marks)



Unit 5

Soldering

Unit 5 | Soldering

Duration
Two hours

Equipment
Soldering iron, Colophony-free Solder, Single sided stripoard, components, desoldering tool, battery and battery leads, multimeter.

Aims
The aims of this lesson are to teach the student how to solder components onto circuit boards and to emphasise the importance of safety when soldering.

Objectives
After this lesson the student will be able to :
- describe the safety precautions required when soldering.
- explain the meaning of, and use the following equipment:
  - Solder
  - Soldering Iron
  - Soldering Stand
- fit components correctly to the circuit board
- desolder a component from a circuit board

Assessment Method
Assessment for this unit is based on the student's achievement at soldering.

An Important Note on Safety

! Safety goggles must be worn all the time when soldering and when clipping wires.

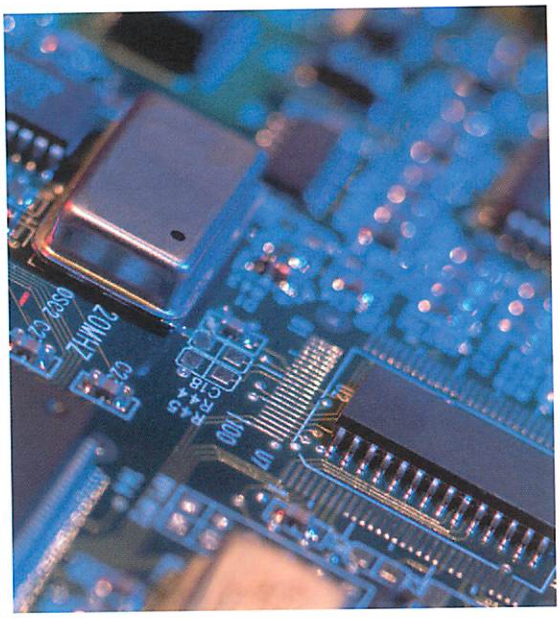
! Soldering should take place in a well-ventilated area with fume extraction where possible. Care should be taken not to inhale the fumes.

! Keep the soldering iron in its stand when not in use in order to avoid burning its lead and other pieces of equipment.

! The tip of the iron reaches temperatures of over 200°C. This would cause **serious burns**. The soldering iron should only be held by the plastic handle.

! Always wash your hands after handling solder.

!!! Remember: Soldering Irons can cause serious burns



Printed Circuit Board

Introduction to Soldering

When building electronic circuits, the various components are soldered together. There are several types of boards used for this. You will use stripboard to practice soldering and then printed circuit board to build subsequent circuits. The leads of the components are soldered to the metal tracks of the board. Soldering secures the component to the board and makes the electrical connection.

Terms associated with soldering

PCB stands for **Printed Circuit Board.** This board has metal tracks on one side and pictures and lettering on the other. Currents can flow up and down the metal tracks once a battery has been connected. The current can flow through any component **soldered** to the track. Components are fitted to the picture side and soldered to the metal side.

Solder is an alloy (mixture) of lead and tin. It is a good conductor. It makes the actual joint between the leg of the component and the track. It has a melting point of roughly 180°C.

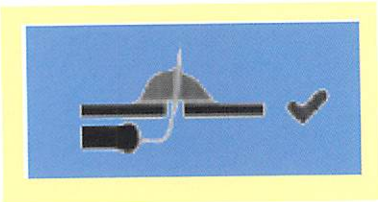
The Soldering Iron is used to apply the solder. When heated, its tip reaches temperatures of over 200°C. It melts the solder so that it flows round the lead of the component and the track on the board to make the electrical contact.

Soldering Iron, Desoldering Tool

Steps to ensure good soldering

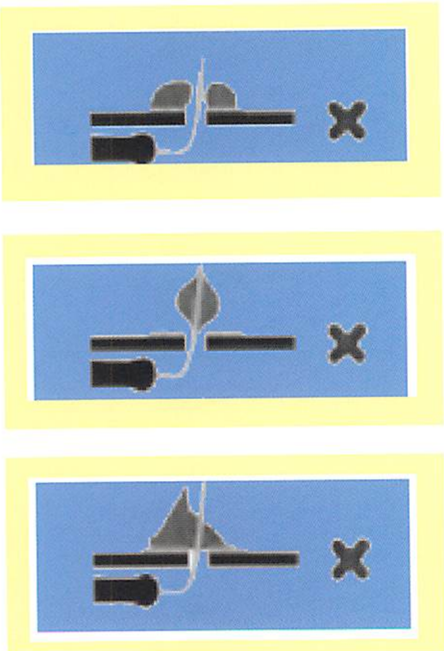
A badly soldered joint is often the cause of a circuit not working and it is a fault that is difficult to trace. Care must be taken to ensure good connections. Note the following points:

1. Use the right amount of solder – too little may not form a good joint, too much may cause a short circuit. A short circuit is any unwanted connection.
   A good solder joint looks shiny and smooth and covers the component wire and the solder pad completely.



A Good Solder Joint

2. Any movement of a joint before it sets will create a **dry joint** which will have a poor electrical connection. In a dry joint the solder has a dull grainy appearance



Examples of poor solder joints

3. Some components, such as transistors, diodes and LEDs, can be damaged by overheating. The best way to avoid overheating is to try to get a good joint formed as quickly as possible.

Fitting components onto the board

All components are fitted to the picture side and soldered to the metal side. Assemble the components in the following order:

Resistors can be fitted either way around, and should be fitted so that the body of the component is flat on the board. Bend the legs into a U-shape and then push them through the holes. Opening the pins slightly when they are inserted through the board will ensure that the device stays in place.

Capacitors
Non-electrolytic capacitors can be fitted either way around but **electrolytic** types must be fitted in a certain way – the shorter leg (- **ve**) is put into the hole with the minus (-) sign. The **negative** leg is also marked by a **stripe** on the body of the capacitor. The negative side is marked on the printed circuit board.

Transistors must be fitted in a certain way. Open the legs apart enough to fit one leg through each of the three holes in the board. Don't force the transistor all the way down.

LEDs must also be fitted in a certain way. The shorter leg is put into the hole with the line. LEDs also have a slightly flattened edge on the rim on the same side as the shorter leg.

Batteries
The metal tip of the **red** lead is connected to the +ve hole. The **black** lead is connected to the –ve hole.
Bend the legs of a component outward a little after fitting it to the board to keep it in place until it is soldered.

Assessment

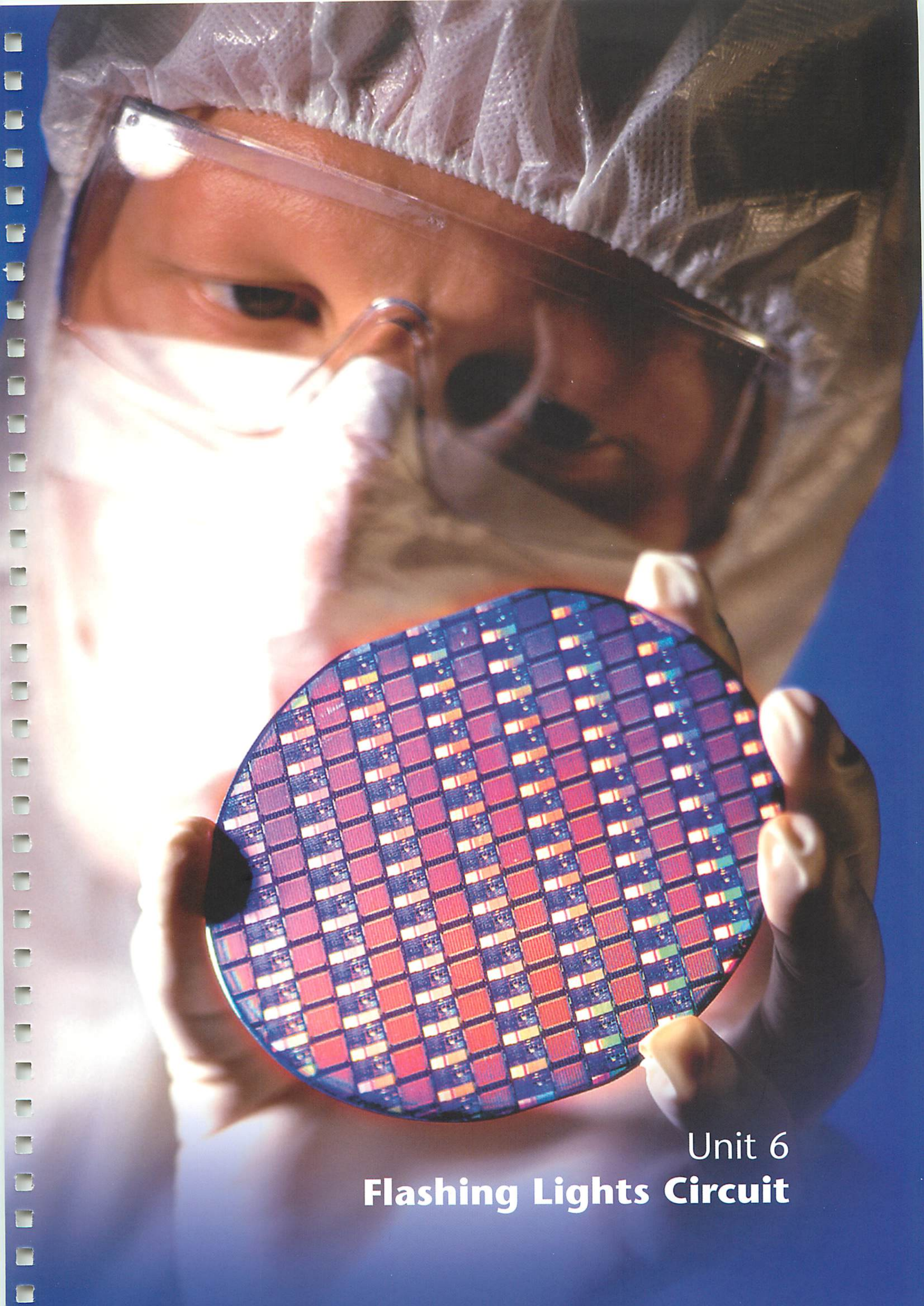
1. Practice soldering and desoldering some components onto stripboard using the directions given above. Remember to fit the body of the components to the plastic side of the stripboard so that the leads can be soldered onto the copper tracks. Are you able to follow the instructions and solder components to the board?

   Construct two of the following circuits on the stripboard:

   a. Resistors in series
   b. Resistors in parallel
   c. Forward biased diode
   d. Reverse biased diode
   e. Transistor as switch

   Test the circuit appropriately. (80 marks)

2. Work in pairs while soldering.
   Check that your partner is following all of the safety rules.
   Write a checklist of all the soldering safety rules that you can remember.
   (20 marks)



Unit 6
Flashing Lights Circuit

Unit 6 | Flashing Lights Circuit

Duration
Two hours

Equipment
Soldering iron, solder, pliers, side cutters, Flashing Lights kit.

Aims
The aims of this unit are to get the student to apply the knowledge and skills acquired so far during the module, to construct a simple electronic circuit and to appreciate some of the principles of operation of this circuit.

Objectives
After this lesson, the student will be able to:
- build the Flashing Lights circuit from the kit provided
- ensure that the circuit will function as expected when finished
- do simple calculations to predict the performance of the circuit
- analyse the action of the circuit using computer simulation
- feel confident of being able to assemble another electronics kit once the components and circuit are provided

Assessment Method
Construction and testing of the circuit.

Introduction

The flashing lights circuit, Fig. 6.1, is a nice example of using transistors as switches. You will remember from Unit 4 that a transistor can be made to act like a simple on/off switch. When the transistor is "off", it acts like an open switch and no current can pass through it. However, when the transistor is "on", it acts like a closed switch and current can easily flow through from collector to emitter.

In the flashing lights circuit, when one of the transistors, let's say TR1, is "on" and acting like a closed switch, current will flow down from the +9V line on top, through the LED indicator L1, through R1 and through TR1 to the bottom, i.e. from the + terminal around to the - terminal of the 9V battery. As current flows through L1, this indicator lights up. R1 is used to limit the current flowing so as to control the brightness of L1. During this time, the other transistor, TR2 will be "off" and acting like an open switch. Therefore no current will flow down through the L2, R4, TR2 path, and so the LED indicator L2 will not light up. After a while TR2 will switch on and TR1 will switch off causing L2 to light up and L1 to extinguish. The action repeats continuously, giving a flashing pattern on the two lights.

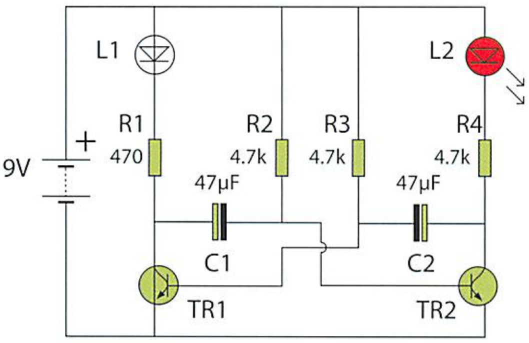


***Figure 6.1:** Circuit diagram of Flashing Lights circuit*

In fact, this is how transistors are used in nearly all modern digital computer circuits. They are used in this way to represent the two binary digits *zero* and *one*, the numbers used in modern computers. When the transistor is off, it represents the digit zero, and when the transistor is on it represents the digit one.

Construction

Identify the different components using the spotter chart supplied with the kit.

Find resistors R1,R2,R3 and R4, identifying them by the coloured bands around their bodies. Fit the resistors flat onto the picture side of the circuit board either way around. Solder the legs of the resistors to the metal side of the board then clip the legs close to but slightly above each solder joint.

Fit the capacitors C1 and C2 to the board putting the shorter leg (the leg by the stripe on the body) into the hole with the '–' sign. Solder the capacitors to the board and trim their legs.

Open the legs of the transistors TR1 and TR2 a little and fit them to the board matching the half-circle shape of the transistor to the half-circle shape on the board. Push the transistors half way down, then solder and clip their legs.

Solder the LEDs L1 and L2 to the board putting the shorter leg (the leg by the flattened edge on the rim) into the hole with the line.

Push the battery snap leads up through the larger holes in the board from the metal side of the board. Fit the metal tip of the red lead into the 'BATTERY +' hole, and the metal tip of the black lead into the 'BATTERY –' hole. Solder the metal tips to the tracks on the board.

Connect a battery (9V PP3) to the battery snap connector.

The red and green lights should flash alternately about three times a second.

Suggested use of circuit

Design a face on paper or cardboard that fits over your finished circuit board so that the lights are the eyes, the capacitors the nostrils, and the transistors the teeth. Are there any other applications for this circuit – what about using it as a hazard warning when walking in the dark?

How the flashing action is controlled

The rate at which the lights flash is controlled by how long each transistor stays switched on. This is determined by a component that you have already met in Unit 1. The component in question is a capacitor, which you'll remember is a device that stores electric charge. In this circuit two large-value electrolytic capacitors, C1 and C2, are used in conjunction with two resistors, R2 and R3.

When a voltage is applied to a capacitor, current flows into it and it charges up. However, if a resistor is connected in series with the capacitor, it reduces the current flowing, and the capacitor charges up more slowly, (see fig.1.9). The larger the values of the resistor and capacitor, the longer it takes for the capacitor to charge up. This combination is often called a "delay circuit", in fact a C-R delay circuit.

In the flashing lights circuit, there are two C-R delay circuits - C1, R2 controlling TR2, and C2, R3 controlling TR1. The action goes as follows: let's assume TR2 has just switched on. At this instant the voltage on the collector of TR2 (and on the right-hand plate of C2) falls from around +7V to 0V. This causes the voltage on the left-hand plate of C2 to fall by the same amount - in its case from about +0.7V to about -6.3V. This of course is the same voltage that's on the base of TR1, and since the base has now got a negative voltage applied, TR1 switches off. Capacitor C2 will now start to charge up with current flowing into it through R3 and the voltage on its left-hand plate will rise slowly towards +9V. However, it never gets anywhere near +9V, because when it reaches +0.7V, TR1 base becomes forward biased and switches on. This causes TR2 to switch off, and the very same sequence of activity then occurs to TR2 and its C-R delay circuit, C1, R2.

This sequence is repeated over and over again causing the lights to flash on and off. Each delay circuit keeps its associated transistor in the 'off state' for a certain period of time. This time is can be predicted fairly accurately using the formula $T = 0.7CR$ seconds, where C and R are the values of the capacitor and resistor in the delay circuit. Obviously, if different values of C and R were used, the delay periods would be different, and the flashing rate would be faster or slower.

Exercise

See if you can calculate the delay period for each transistor, by inserting the values of C and R from your own circuit into the formula $T = 0.7CR$ seconds. Be careful here – this involves some scientific notation when dealing with the values of C and R. Now verify your answer by using your watch to time a number of flashes of the indicators, (say 10 or 20 flashes), and do the necessary sums to check if your original calculation was reasonably accurate.

While you are at it, you can use the same data to work out the number of flashes of one indicator per second. This is called the repetition rate or "*frequency of oscillation*" of the circuit - a measurement that is very widely used in electronics.

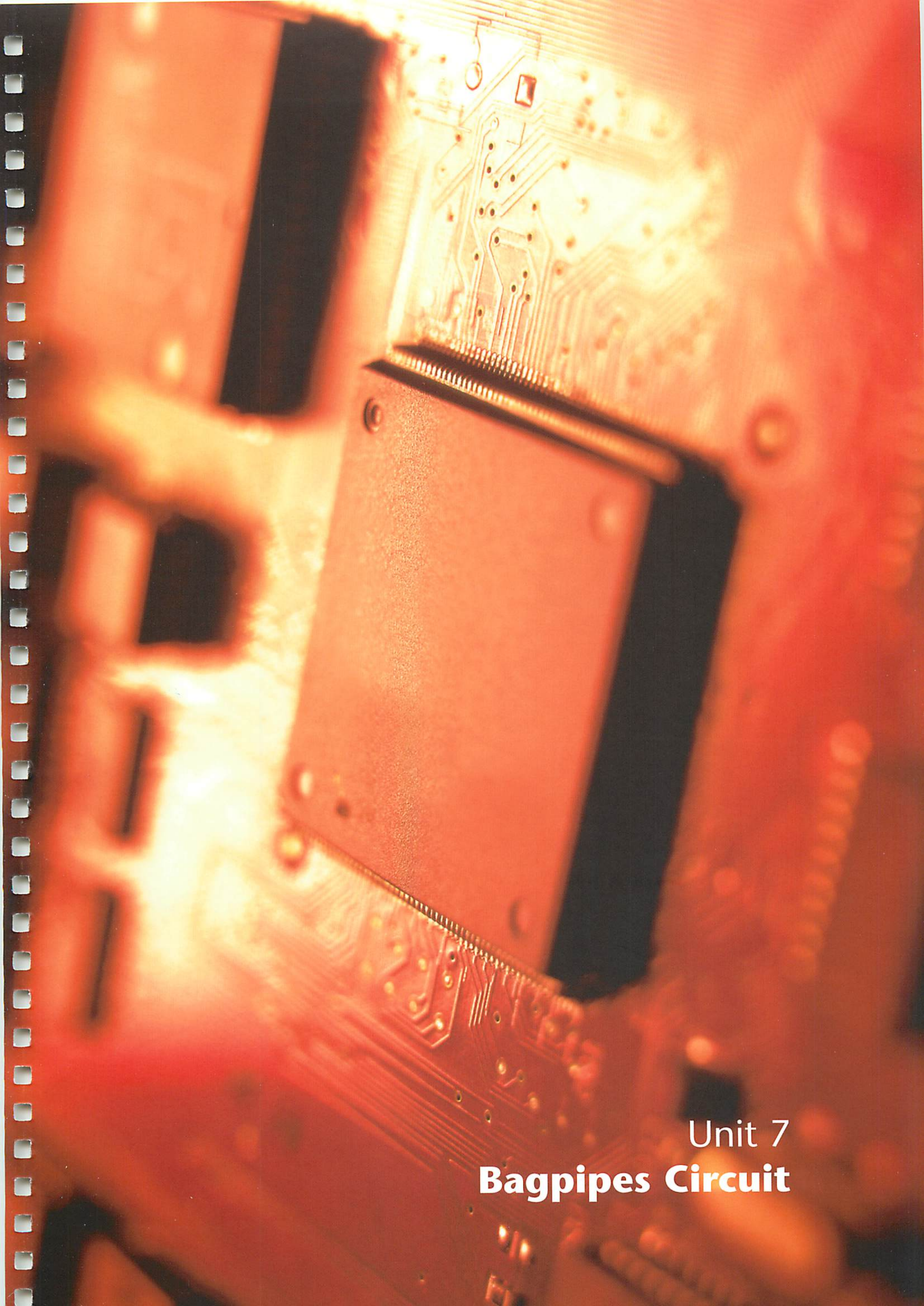
Circuit Simulation

Now that you have built your flashing lights circuit you can simulate it using the *Crocodile Clips* package. To make things easier to start with, a simulation of the circuit has been prepared and is available on your diskette - A:\FLASH.CKT. You can see the operation of the circuit on the computer simulation. It should be the same as the one you built with the same repetition rate. Computer simulations are very useful as they allow us to design circuits and predict what will happen before we build them in practice. They are also used to help us to predict what happens if we make changes to the circuit. It is easier for a designer to make changes to the simulated circuit than to change the actual circuit.

As an exercise, try changing the values of the resistors or capacitors used in the simulation and see what happens to the repetition rate. Verify your answer by calculation using the formula from the previous exercise.

Assessment

Circuit construction	(60 marks)
Calculations and verification of action	(10 marks)
Simulation of circuit using *Crocodile Clips*	(30 marks)



Unit 7

Bagpipes Circuit

Unit 7 | Bagpipes Circuit

Duration
Two hours

Equipment
Soldering iron, solder, pliers, side cutters, Bagpipes kit.

Aims
The aim of this unit is to get the student to build a second electronic circuit with minimal assistance to reinforce the theory and skills acquired during the module.

Objectives
After this lesson, the student will be able to:

- build the Bagpipes circuit from the kit provided
- ensure that the circuit will function as expected when finished
- analyse the action of the circuit using computer simulation

Assessment Method
Construction and testing of the circuit.

Introduction
Believe it or not, the bagpipes circuit shown in Fig. 7.1 is the same electronic circuit as the flashing lights circuit in Unit 6 and works in exactly the same way. The transistors TR1 and TR2 turn on and off alternately just as the flashing lights transistors did. Instead of LED indicators however, in this circuit a piezo speaker is inserted between the collector terminals of the transistors and this generates a bagpipes sound, (if you use a bit of imagination), when the transistors turn on and off rapidly. This type of electronic circuit is often called an *audio oscillator.*

Construction
1. Identify the different components using the spotter chart.
2. Find the resistors (R1, R2, R3, ... to R12) telling them apart by the coloured bands around their bodies. Fit the resistors flat onto the picture side of the circuit board either way around. Solder the legs of the resistors to the metal side of the board then clip the legs close to each solder joint.
3. Fit the capacitors (C1 and C2) to the board either way around. Solder the capacitors and trim their legs.
4. Solder the variable resistor (VR1) to the board.
5. Open the legs of the transistors (TR1 and TR2) a little and fit them to the board matching the half-circle shape of the transistor to the half-circle shape on the board (flat side against flat side). Push the transistors halfway down then solder and clip their legs.
6. Solder the speaker (PIEZO) to the board either way around.
7. Push the battery snap leads up through the larger holes in the board from the metal side of the board. Fit the metal tip of the red lead into the BATTERY + hole, and the metal tip of the black lead into the BATTERY- hole. Solder the metal tips to the tracks on the board then pull the wire loops back.
8. Solder one end of the piece of flexible wire to the hole marked STYLUS on the board. (The metal strands may need twisting together to get the wire through the hole.)
9. Firmly push the spindle into the small hole in the top of VR1.
10. Connect a battery (9V PP3) to the battery snap.
11. Touch the free end of the stylus against the metal pads on the back of the board and different tones should sound.

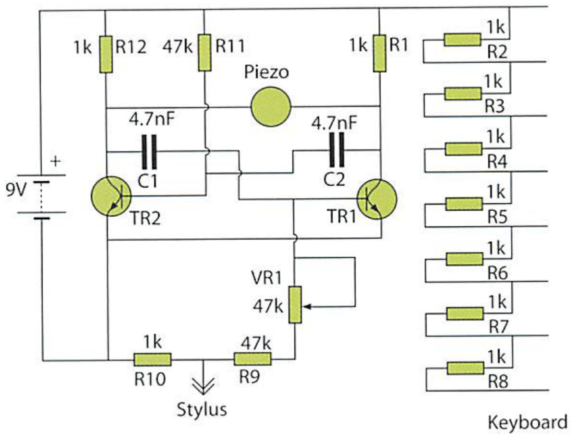


Figure 7.1 Circuit diagram of bagpipes circuit

How to use
Touch the stylus against the metal pads on the back of the board, or the legs of the keyboard resistors (R2 to R8) on the front of the board. Eight notes forming an approximate octave are available. If you wish to tune the bagpipes, see the section on tuning at the end.

How the sound is generated
In this circuit, the sound is generated by a piezo-electric speaker. This device consists of a gold-coloured circular disc of quartz crystal or similar material, which is clamped around the edge and enclosed in a black plastic housing with a hole in the middle to leave out the sound. When a voltage is applied across the disc it will bulge in one direction or the other depending on the polarity of the voltage, as shown greatly exaggerated in Fig. 7.2. This is known as the *inverse piezo-electric effect*. The rapid movement of the disc will increase and decrease the pressure of the surrounding air, shown by the arrows, and this causes sound waves to be generated, which we can hear when the device is working.

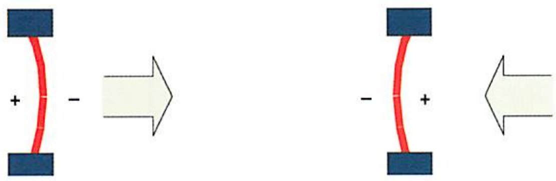


Figure 7.2 Generation of sound waves by piezo disc

The rapidly changing voltage, which causes the movement of the piezo disc, comes from the two transistors, TR2 and TR1 in the circuit. As we explained in Unit 6, at any given time one transistor, say TR2 is "off" and the other one, TR1, is "on". When TR2 is "off", no current flows down through R12 so the voltage at the top and bottom of the resistor will be at the same value, i.e. +9V. (This is an application of Ohm's Law). That means that the voltage on the left hand connection to the piezo will be at +9V.

At the same time TR1 will be "on" and current will flow down through R1 and through the transistor from collector to emitter, (and back to the negative terminal of the battery). In that case the voltage at the bottom of R1 will be very low, close to 0V, because TR1 acts like a closed switch or short circuit. Thus the voltage on the right hand connection to the piezo will be around 0V. So across the piezo there will be about 9V, positive on the left, and the disc will budge as shown on the left in Fig. 7.2. When the transistors switch the other way around, everything will be reversed, and the disc will bulge in the opposite direction as shown.

How the pitch is controlled

The pitch of a sound is determined by how fast the changes in air pressure occur - in this case by how fast the piezo disc vibrates. The faster the disc vibrates per second, the higher the pitch of the sound. The pitch is measured in cycles per second, (vibrations per second), and in this circuit the rate of vibration goes from about 680 cycles per second for the lowest pitch sound to over 3,000 cycles per second for the highest pitch. This is called the *frequency* of the sound and is measured in Hertz, (Hz). We'd say the frequency of the sound goes from 680Hz to over 3kHz.

The rate at which the disc vibrates is determined by how fast the transistors switch on and off, and we saw in Unit 6 that this is determined by a C-R delay circuit attached to the base of each transistor. If we know the values of the capacitor and resistor in each delay circuit, we can work out the approximate length of each time delay using the formula: $T \approx 0.7CR$

The delay circuit controlling TR2 on the left is very simple consisting of C2 and R11. If you put the values of these components, 4.7nF and 47kΩ, into the formula you should get a delay of about 155μs - try this, but be careful with all the scientific notation. This means that the positive voltage on the collector of TR2 and hence on the left hand terminal of the piezo will always be in pulses of about 155μs duration.

The delay circuit controlling TR1 on the right is much more complicated - it consists of the single capacitor C1 but with a complex network of resistors whose overall value can change depending on which resistor, R2 to R8, you touch with the stylus and also the value to which you set the variable resistor, VR1, when you are tuning the circuit. This means that the time duration of the voltage pulse coming from TR1 is variable.

If we were to draw a graph of the voltage applied to the piezo at TR2 collector or better still, examine this voltage using an oscilloscope, it would have two extremes. If the variable resistor, VR1, is adjusted to its minimum value and you touch the stylus to R2 on the right hand side of the board, the minimum delay will be generated and it would look something like that shown in Fig. 7.3. Each cycle takes about 310μs (twice 155μs), and if you invert this figure, you will get the number of cycles in one second, i.e. a frequency of 3,226 cycles, (3.226kHz). This is about the highest pitch sound that you can get from the circuit.

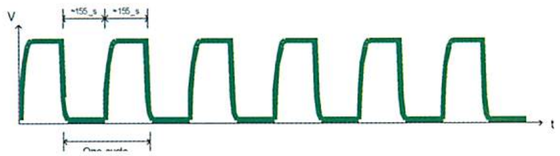


Figure 7.3 Graph of high-pitch sound

If the variable resistor, VR1, is adjusted to its maximum value and you touch the stylus to R8 on the left hand side of the board, the maximum delay will be generated and you will get a voltage at the piezo looking something like that shown in Fig. 7.4. The length of the delay generated by TR1 will be much longer than 155μs and the pitch of the sound will be very much lower. If you have an oscilloscope, it would be a very nice exercise to measure the total time taken to generate one complete cycle and then work out the frequency - it should come out somewhere around 680Hz.

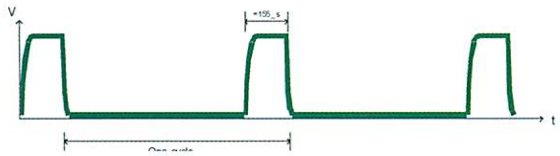


Figure 7.4 Graph of low-pitch sound

Tuning the bagpipes

For those of you who are musical, you might be interested in tuning the circuit so that you could have a go at playing a tune on the "bagpipes". Be warned however, that no matter how well you tune one note on the circuit, the remaining notes won't sound great because the frequency of each can't be adjusted independently so they won't fall very accurately on the musical scale and therefore will sound somewhat out of tune.

The easiest note to tune on the circuit is the one known as A5 - this is the second A above middle C on the piano. A5 occurs at a frequency of 880Hz and should be set by adjusting VR1 while the stylus is touching R8 on the left hand side of the board. If you are of an engineering bent you can do this using a frequency meter or more awkwardly, with an oscilloscope, (the time for one complete cycle at 880Hz is 1.136ms). If you are musical you might try tuning it by ear.

The remaining notes on the scale in ascending order as you move the stylus from left to right, (equivalent to DOH RAY ME ...) should then occur at the following frequencies, B: 987.767Hz, $C^{\#}$: 1108.73Hz, D: 1174.66Hz, E: 1318.51Hz, $F^{\#}$: 1479.98Hz, $G^{\#}$: 1661.22Hz, A6: 1760.00Hz. (A6 is the top note and is an octave higher than A5, i.e. double the frequency of A5). Unfortunately, the actual frequencies generated by the bagpipes will not coincide very closely to these, so don't be too disappointed if your music isn't the greatest - the bagpipes circuit is not a high-precision music synthesiser.

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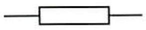
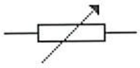
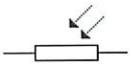
Appendix A

Circuit Components & Symbols

Appendix A
Circuit Components and Symbols

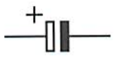
Resistor. 

Variable Resistor. 

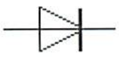
Light Dependent Resistor (LDR). 

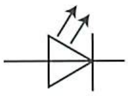
Capacitor.

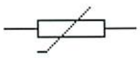
Non-electrolytic capacitor.

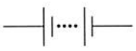


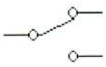
Electrolytic capacitor.

Diode. 

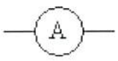
Light Emitting Diode (LED). 

Thermistor. 

Battery. 

Switches.  

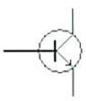
Meters.



Ammeter.

Voltmeter.

Lamp. 

Transistor. 

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Appendix B

Circuit Files http://e-eng.cit.ie/

Circuit Files
http://e-eng.cit.ie/

Resistor combinations Figures 1.6, 1.7	RESISTOR.CKT
Ohm's Law Figure 1.10	OHM.CKT
Capacitor charging/discharging Figure 1.15	CAP.CKT
Transistor as a switch Figures 4.3, 4.4, 4.5, 4.6	TRAN.CKT
Flashing Lights circuit Figure 6.1	FLASH.CKT
Bagpipes circuit Figure 7.1	BAGPIPES.CKT

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Appendix C

Ordering of Materials and Equipment

Appendix C
Ordering of Materials and Equipment

All tools and components required for the module are low-cost general purpose devices, and are readily available from any good supplier of electronic products.

A complete kit can be obtained from *Chip Electronics Ltd*. Cork. Contact details are as follows:-

Tony Moore,
Chip Electronics Ltd (for Electronic Components, Tools, Etc), Unit 1B, Enterprise Park, Innishmore, Ballincollig, Co. Cork, Ireland.
Phone: +353 (0)21 4289958
Fax: +353 (0)21 4870726
Email: sales@chip.ie
Web: www.chip.ie

The materials and equipment required for the module can be divided into two categories – an initial set of tools and equipment which can be used for all courses, and a set of consumables which need to be obtained for each running of the course. The quantity specified is for general guidance only and is an estimate of the minimum requirement for a class of twenty students undertaking the module for the first time.

Item	Quantity
25-Watt Soldering iron	5
Soldering iron stand with sponge	5
Desoldering pump	5
Safety goggles for soldering	1 per student
Long-nosed pliers	5
Side-cutters	5
Digital multimeter	5
Personal Computer with CD Drive	5
Crocodile Clips* software package	5-user site licence

* The software package, *Crocodile Clips*, can be obtained from Chip Electronics.

Crocodile Clips Ltd
11 Randolph Place, Edinburgh EH3 7TA
Scotland.
Tel: +44 131 226 1511
Fax: +44 131 226 1522
www: http://www.crocodile-clips.com/index.htm

The consumables required for each course are:

Item	Quantity
Stripboard:	
Single-sided stripboard, 0.1" pitch for soldering practice	5 boards
Solder:	
Colophony-free solder	500g reel
Batteries:	
9Volt PP3 batteries	1 per student
Resistors:	
4-band 0.25W 5% general purpose carbon film resistors 220Ω 470Ω 680Ω 4.7kΩ 47kΩ 10kΩ 1MΩ	1 packet of 10 of each value shown
Capacitors:	
47μF micro-miniature radial 10V electrolytic capacitors	20
100nF general purpose miniature ceramic disk capacitors	20
Diodes:	
1N4001 rectifier diodes	20
Transistors:	
BC548 general purpose NPN small-signal silicon transistors	20
LEDs:	
General purpose Red LEDs 5mm	10
General purpose Green LEDs	10
IC Chips:	
74HC32 quad 2-i/p OR gate chips	5
LDRs:	
ORP 12 general purpose LDRs	5
Thermistors:	
General purpose NTC thermistors	5
MadLab Kits:**	
Flashing Lights	1 kit per student
Bagpipes Kit	1 kit per student

** The *MadLab* assembly kits can be obtained from Chip Electronics.

MadLab
Edinburgh International Science Festival
8 Lochend Road
Edinburgh EH6 8BR
Scotland
Tel: +44 131 530 2001
Fax: +44 131 530 2002
Email: madlab@scifest.demon.co.uk
www: http://www.madlab.org/index.html

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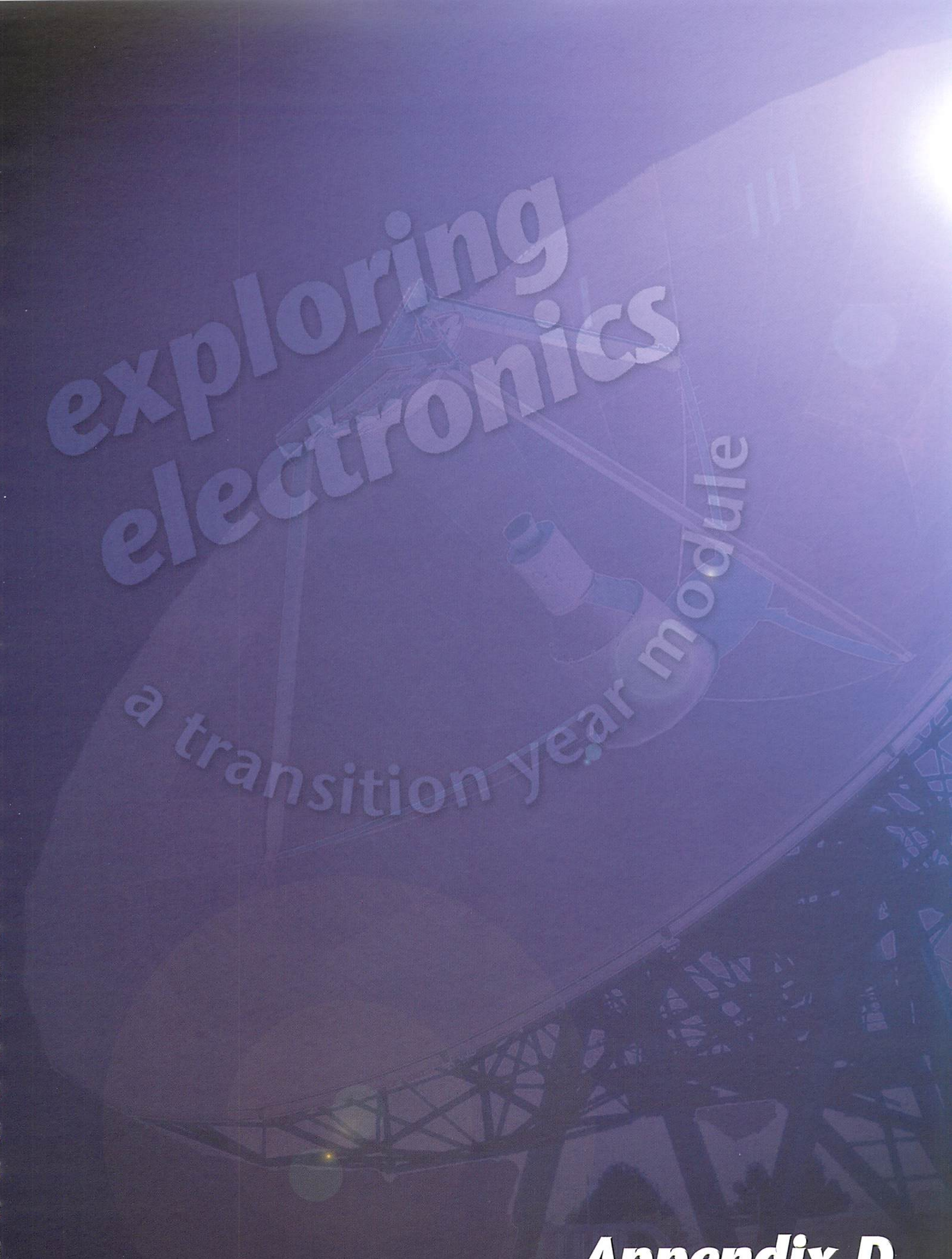

Appendix D

Industrial & Academic Contacts

Industrial and Academic Contacts

Industry

As the major multinational electronics corporations located here change their focus to knowledge-driven activities and the indigenous Irish Electronics industry continues to develop and grow strong, it is now widely accepted that the demand for highly skilled Electronic Engineering graduates is growing. The most recent ESRI report on occupational employment forecasts predict an increase in demand for engineering professionals of up to 29% and associate engineering professionals (i.e. technicians) of up to 34% by 2012. In stark contrast to this demand, college courses have seen a continuing decline in the number of applicants in recent years leading to a shortfall in the supply of suitably qualified graduates. Ireland hosts some of the best electronics companies in the world and in order for these companies to flourish in the global jobs market, we must produce the most highly skilled, capable, willing and innovative workforce possible.

For this reason, companies are generally very supportive of initiatives aimed at encouraging young people to consider electronic engineering as a career and are committed to helping schools in any way possible to achieve this goal.

Two of the main organisations in Ireland representing companies in this industry are:

1. The Cork Electronics Industry Association (CEIA)

The CEIA has 58 member companies in the greater Cork area and further details of these companies can be found on www.ceia.ie. Member companies are fully supportive of this module and eager to enhance understanding of career choices available to students. The CEIA also runs a schools liaison program, details of which can be found under the Schools and Skills section of the webpage. This program incorporates a range of initiatives aimed encouraging students at various levels from primary through secondary to develop and interest in electronics.

For further details, contact Ms Deirdre de Bhailís at deirdre.debhailis@ceia.ie or 086 2228339 or approach the company directly.

2. Microelectronics Industry Design Association (MIDAS)

This is a nationwide grouping of companies involved in the design of integrated circuits and systems with 38 or so members to date. These companies are listed at the MIDAS website www.midasireland.ie. where you can register your school with the organisation to facilitate contact between the school and the industry. Alternatively, the member companies of MIDAS are informed about this module, and are fully supportive of its objectives so please feel free to approach the company directly.

The website www.electronic.ie has also been developed by MIDAS to provide a comprehensive guide to careers in electronic engineering for second level students.

There are other companies, not members of either of the above organisations, and they also are generally eager and willing to be involved with promoting the electronics industry at schools level.

Academic

All of the third level colleges in Ireland, both Universities and Institutes of Technology, have Departments of Electronic Engineering and are already actively involved in liaison with second level schools. They are generally eager to attend Careers Guidance functions in the schools, to host Transition Year work experience, to host groups of school staff and pupils in the College and to help promote careers and courses in electronics in any way possible. Contact your nearest University or Institute of Technology if you feel they can help with the delivery of this module.

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Appendix E

Module Assessment Form

EXPLORING ELECTRONICS – TEACHER SELF-EVALUATION

1: Stated aims of module: ______________________________

____

____

2: **Realisation of objectives**: (Please tick the box which best reflects how you would rate your success)

Extremely successful	Very successful	Quite successful	Not so successful
☐	☐	☐	☐

3: **Teaching and Learning:**

I rate my use of the following teaching and learning strategies as follows:
(5=Extremely successful; 4=very successful; 3=successful; 2=unsuccessful; 0=not relevant)

Activity-based learning	☐	Formal input by teacher	☐	Research	☐
Practical work	☐	Group work	☐	Interviews	☐
Project work	☐	Use of video	☐	Visiting speakers	☐
Computer-based learning	☐	Oral presentations	☐	Debates	☐
Class discussion	☐	Pair work	☐	Demonstrations	☐
Study visits	☐	Field work	☐	Negotiated learning	☐

4: Which aspects of the module did your **students** (a) most enjoy? (b) find most useful?

____

____

5: Which aspects of the module worked especially well for **you**?

____

____

6: Do you feel your students developed a greater **awareness** of the importance/relevance of electronics?

____

____

7: What would you do differently next time? and in what way?

____

____

Appendix F

Sample Student Certificate

Certificate of Completion

This is to Certify that

____

successfully completed the

Exploring Electronics

Transistion Year Module

____________________ Teacher

____________________ Principal

____________________ School

Appendix G

Websites & Other Useful Information

Cool links on the web!

www.electronic.ie

www.ceia.ie/html/LegoRobotComp.html

www.steps.ie

www.eduplace.com/math/brain/

www.nae.edu

www.madlab.org

www.surfingthenetwithkids.com

www.engineergirl.org

www.asee.org

www.eweek.org

www.howstuffworks.com

www.discoveringengineering.org

www.pbs.org

www.ul.ie/~childsp/elements

www.sciencegems.com

www.encyclopedia.com

www.discovery.com

www.invent.org

www.clubmarconi.com

www.ideafinder.com

www.letsfindout.com

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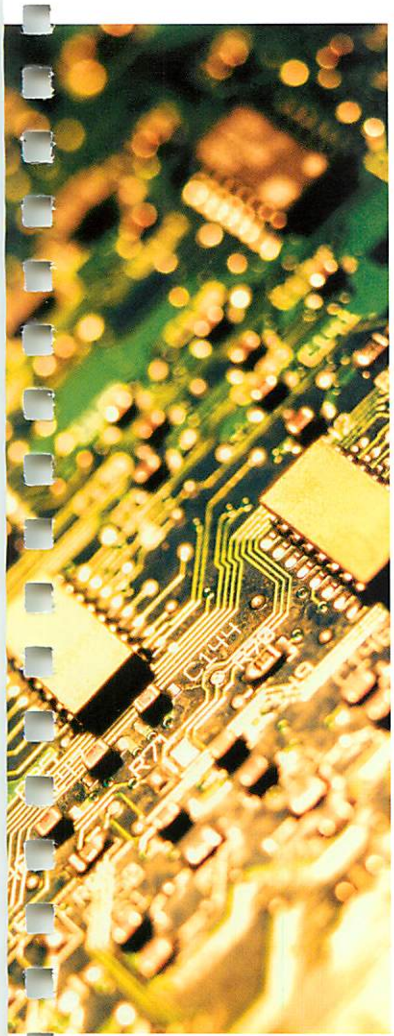
Appendix H

Additional Career Information



Michael Manning
CONTROL SYSTEMS TRACK SUPPORT ENGINEER
MF1 Racing Team

Michael graduated in 2004 with an Honours Degree in Electronic Engineering. His work experience included a five month placement with DaimlerChrysler in Mechatronics Research and Development.

"Currently I am working as a Control Systems Track Support Junior Engineer for the MF1 Racing Team based in Silverstone, England. I provide track support for the chassis/gearbox control systems fitted to the cars. It was easy for me to choose Electronic Engineering. In school, my main interests were engineering based. Physics, Mathematics and Technical Drawing were my main subjects of interest. I chose Electronics as I believed it offered the most challenges and opportunities. My desire to enter the automotive industry was also a contributing factor."

When explaining the attraction to Electronic Engineering, Michael says, "Firstly, working in a very demanding industry which happens to be the pinnacle of motor sport is a dream come true. The job is very challenging and as a result extremely rewarding. Also, the most exciting technology in the future, for me, is Nanotechnology. For electronics and mechanical engineering this has the potential to be the next big step in the advancement of technology. In electronics it can make the production of electronic devices even smaller. It is also opening up the area of MEMS which couples micro-electronics with micro-mechanical systems. It is also being researched to provide stronger, more robust material for mechanical application."

Áine McCarthy
ELECTRONIC ENGINEER

Áine graduated in 2004 with First Class Honours degree in Electronic Engineering.

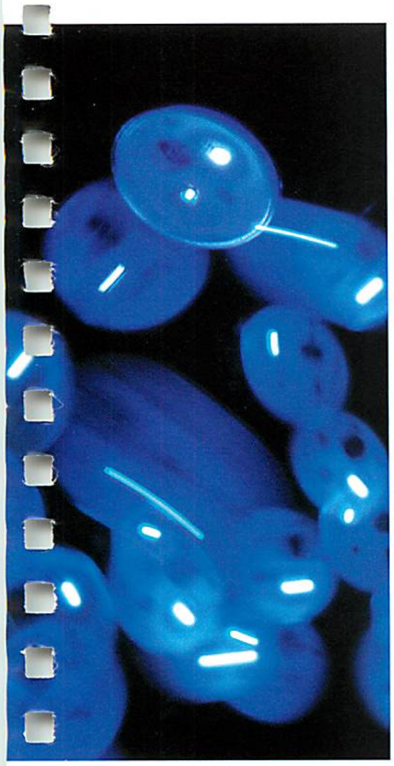
"Currently I am working as a postgraduate researcher in the Centre for Adaptive Wireless Systems, at CIT. I am working with embedded systems, developing a wireless ad-hoc testbed.

In school, like many others I wasn't too sure what exactly I wanted to do, I had a love for Mathematics and Physics and knowing that these were the foundation for Electronic Engineering, this attracted me to do Electronics.

The best thing about my job is the kick you get from solving problems that have annoyed you for days! There is always a challenge, which keeps me on my toes.

My typical day starts at 8am and finishes around 5pm; I'm an early riser and think the best of anyone's work is done in the morning when you are most alert. I start work by trying to achieve tasks that I set out. Tasks are generally put together at the beginning of each week and are taken from the overall schedule of the project. My day can also involve group meetings where the work being carried out is discussed. The main bulk of my work is software oriented, where the main tools are C programming along with the Linux Operating system.

The most exciting technology in the future for me is Nanotechnology – this area is very important in the electronics area as it is devoted to the design and production of extremely small electronic devices and circuits built from individual atoms and molecules."



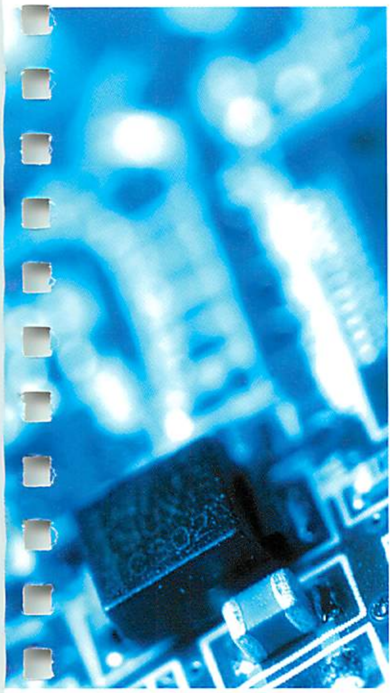
Ken Murray
ELECTRONIC ENGINEER

"I graduated in 2000 with First Class Honours in Electronic Engineering, a research Master degree in 2002 and PhD in 2005. I'm currently working as a senior researcher at the Centre for Adaptive Wireless Systems, CIT. My work focuses on enabling the deployment of large scale wireless sensor networks for disaster recovery missions.

I chose to do Electronic Engineering because I've always had an interest in technology and computing. In school, maths and physics were my favourite subjects, which I feel is certainly beneficial if deciding to study electronics.'

Working with the state-of-the-art equipment and being at the forefront of mobile technology is the best part of my job. The variety of work I encounter each day and the opportunities to work on different technologies and protocols within the area of sensor system help broaden my knowledge.

Throughout my Master and PhD research, I've travelled to many conferences in the USA, Japan and Mauritius. The continuing evolution of mobile communication networks to include small low energy devices is the most exciting advancement in technology for the future. Super high speed wireless networks will make virtual environments a common tool for communications and e-commerce."



Susan Rea

"I graduated with a BEng Honours Degree in Electronic Engineering from CIT in 1998 followed by an MSc Degree in Information Theory, Coding & Cryptography from University College Cork in 1999. Following that, I graduated with a MEng Degree at CIT in 2001 in the area of random number generation for cryptographic keys.

Susan recently completed a PhD in MANET Route Management at CIT. "My particular interest in school was maths and physics so some type of engineering seemed to be the most logical choice and electronic engineering appealed the most to me.

The best thing about my current job is the flexibility that research involves, working with new technologies and travel opportunities. Working in a college environment means that there is no such thing as a typical day; some days are spent reading up on recent research literature, software development, preparing research papers and presenting/discussing my work with other members of our research group.

In the near future I can see Robotics, virtual reality and autonomic systems as the new cutting edge of technology."

www.chip.ie

Order Form

Transition Year Module
Exploring Electronics

School Name ______________________ Phone ______________________

School Address ______________________ Email ______________________

______________________ Contact ______________________

Stock Code	Item	Price	Order Qty	VAT Rate	Line Total
	Exploring Electronics Manual				
EEM01	Manual Only	€ 30.00		0%	
EEM02	Inc Bagpipes & Flashing LED Kits	€ 41.00		0%	
StripB1	**Stripboard** Single-sided 0.1" pitch for soldering practice	€ 2.45		23%	
PP3	**Battery** Low Cost 9 Volt PP3	€ 0.88		23%	
Per pack of 10	**Resistors** 4 band .25W 5% carbon film resistors				
A220R	220Ω	€ 1.00		23%	
A470R	470Ω	€ 1.00		23%	
A680R	680Ω	€ 1.00		23%	
A4K7	4.7kΩ	€ 1.00		23%	
A10K	10kΩ	€ 1.00		23%	
A47K	47kΩ	€ 1.00		23%	
A1M	1MΩ	€ 1.00		23%	
	Capacitors				
A10V47U	47uF 10V radial electrolytic capacitor	€ 0.13		23%	
100NF	100nF capacitor	€ 0.10		23%	
1N4001	**Diodes** 1N4001 Rectifier Diodes 1 Amp	€ 0.13		23%	
BC548B	**Transistors** BC548 NPN Small Signal Transistor	€ 0.32		23%	
	Light Emitting Diodes (LED)				
LED5MR	Red LED 5mm	€ 0.30		23%	
LED5MG	Green LED 5mm	€ 0.30		23%	
	Integrated Circuits				
74HC32	74HC32 Quad 2I/P OR Gates	€ 0.40		23%	
ORP12	**Light Dependant Resistors (LDR)** ORP12	€ 1.60		23%	
	Thermistors				
Therm33k	Negative Temperature Coefficient (NTC)	€ 0.64		23%	
ML BG FL	**Madlab Kits** Flashing Lights	€ 4.13		23%	
ML BG LD	Lie Detector	€ 4.75		23%	
ML BG BP	Bagpipes	€ 6.75		23%	
	Hand Tools				
XS25240	25 Watt Soldering Iron	€22.00		23%	
ST4	Soldering Iron Stand	€ 6.69		23%	
DS1	Desolder Pump	€ 4.99		23%	
GOG1	Goggles/Safety Glasses	€ 3.50		23%	
LNosePliers	Long-nosed Plier	€ 5.80		23%	
CutterLC	Side cutters	€ 4.15		23%	
DM830D	Digital multimeter	€ 9.45		23%	
0.7mm Solder	**Solder** 500gm Colophony Free Solder	€ 19.95		23%	
	Yenka Technology Software				
YenkaTechS	Yenka Technology Bundle – School Licence	€ 750.00		23%	
YenkaTechT	Technology Bundle – Single teacher Licence	€ 230.00		23%	

Sub Total	€
VAT on Items at 23%	€
Post & Packaging (Inc VAT at 23%)	€ 10.46
Total	€

Chip Electronics
Unit 1B, Enterprise Park, Innishmore,
Ballincollig, Co. Cork, Ireland

Phone 021 4289958
Fax 021 4870726
Email sales@chip.ie