

**Age of Silicon
HSC Physics Option
Teachers Workshop**

27-28 July 2002

**Department of Electronics
Macquarie University**

Introduction

The "Age of Silicon" option in the HSC Physics curriculum is not familiar to many physics teachers and as a consequence the option is often not taught in schools. Nor, is there any assistance in the Excel Series HSC Physics book. The aim of this workshop is to fill this gap and provide teachers with assistance in this option. It aims to increase knowledge of the option topics and provide activities and resources which can be used for teaching and, so, increase confidence in teaching the option.

We will cover most of the basic electronics concepts in the HSC Physics Age of Silicon option in the workshop. It will have a strong interactive and practical focus. What workshop participants will get from this workshop will include:

1. Practical experience in understanding electronics concepts.
2. Coverage of major components in Age of Silicon curriculum.
3. An interactive environment to discuss teaching approaches

From our survey of teachers' backgrounds in electronics, some teachers have not been involved in Electronics teaching or study since their university or college days. Others have had a piecemeal approach learning on the job or as a hobby. As many teachers have only a little knowledge, our first aim is build up core knowledge and expertise in the relevant electronics areas. At times this will refresh what was learnt earlier and at times new knowledge will be covered. If you have never done electronics before the combination of practical work, discussion and mixing with others is a good way to get started. For those who have more experience we hope it will refine what you already know and help provide useful resources and activities which you can use.

Workshop Schedule

Day 1

9.00

Introduction, goals and outcomes of the workshop; introduce each other; how the workshop will operate; workshop folder contents, computers, web access, web page, other resources.

9.30

(20 min) Slides: Basic concepts - voltage current and resistance.

(10 min) Introduction to lab and kits.

(30 min) Activity 1.1. Resistance, voltage dividers.

10.30

Morning tea

10.45

(10 min) Activity 1.2. Use of analogies in teaching basic concepts.

(15 min) Transducers, LDRs and thermistors.

(20 min) Activity 2.1. LDRs

(15 min) Activity 3.1. Devise activities and experiments to teach students about NTC and PTC thermistors.

11.45

(10 min) Brief overview of capacitors.

(10 min) Relays

(25 min) Activity 4.1. Demo: AC circuits - RC circuit. Frequency, RMS voltage, hi-pass, low pass filter, 3dB point

12.30

Lunch

1.30

(20 min) Slides: Semiconductors - holes, electrons, diodes, LEDs

(50 min) Activity 6.1. Circuit with diode and resistor, LED circuit.

Rectifier and other diode circuits e.g. relay and diode.

(20 min) Activity 6.2. Discussion of teaching concepts and use of analogies.

3.00

Afternoon tea

3.30

(15 min) Slides: NPN and PNP transistors.

(15 min) Slides: Transistor amplifiers

(30 min) Activity 7.1 CE amplifier, bias circuit, voltage gain

(30 min) Activity 7.2 CE amplifier (cont)

5.00

Day 1 end

Day 2

9.00

(20 min) Slides: Feedback, feedback circuits (negative and positive feedback), calculation of closed loop gain, advantages of feedback.

Activity 8.1 (60 min) Negative feedback experiment.

10.20

Morning tea

10.50

(20 min) Slides. Ideal op-amp, characteristics, diff-amp, "virtual earth", inverting amp, non-inverting amp

(60 min) Activity 8.2. Summing amplifier, non-inverting amp.

(20 min) Activity 8.3 Teaching op-concepts

12.30

Lunch

1.30

(20 min) Slides: Logic circuits, difference between analogue and digital circuits,

Low/high, 0/1, true false, common logic circuit elements (AND, OR, NOT, NAND, NOR, XOR)

Truth tables, simple circuits (Half-adder and full adder).

Activity 9.1 (70 min) Logic trainer board experiment.

3.00

Afternoon tea

3.30

Developments in silicon technology, difference between integrated circuits and transistor, growth of computing power, increase in speed, Moore's law, current silicon technology, nanotechnology, quantum effect devices, quantum computing.

4.30

Review

5.00

Finish

9.9 Option — The Age of Silicon

Contextual Outline

The invention of the transistor by Bardeen, Brattain and Shockley paved the way for a wide range of new electronic devices. Today's technology, from computers and lasers, to jet engines and space probes, has been based on twentieth century advances in material science. Utilising a knowledge of the electrical, magnetic, optical and thermal properties of compounds of transition and rare earth metals allows for its application to robotics, automation in the manufacturing industry and advances in the personal computer industry.

Semiconducting material is the basis of the integrated circuits that run our computers and many modern technologies, including programmable controllers. Many modern technologies use electro-mechanical principles to interface real world sensors and outputs to microprocessors, temperature controllers, thermocouples and power regulators.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H3 assesses the impact of particular advances in physics on the development of technologies
- H4 assesses the impact of applications of physics on society and the environment
- H7 explains the effect of energy transfers and transformation
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

<p>1. Electronics has undergone rapid development due to greater knowledge of the properties of materials and increasingly complex manufacturing techniques</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> • identify that early computers each employed hundreds of thousands of single transistors • explain that the invention of the integrated circuit using a silicon chip was related to the need to develop lightweight computers and compact guidance systems • explain the impact of the development of the silicon chip on the development of electronics • outline the similarities and differences between an integrated circuit and a transistor 	<p><i>Students:</i></p> <ul style="list-style-type: none"> • identify data sources, gather, process and analyse information to outline the rapid development of electronics and, using examples, relate this to the impact of electronics on society • gather secondary information to identify the desirable optical properties of silica, including: <ul style="list-style-type: none"> – refractive index – ability to form fibres – optical non-linearity
<p>2. Electronics use analogue and digital systems, the basic circuit elements of which are potential dividers and transistors</p>	<ul style="list-style-type: none"> • describe the difference between an electronic circuit and an electric circuit and the advantages and disadvantages of each • distinguish between digital and analogue systems in terms of their ability to respond to or process continuous or discrete information • identify systems that are digital and ones that are analogue in a range of devices • identify potential dividers and transducers as common elements in both analogue and digital systems • explain how the ratio of resistances in a potential divider allows a range of voltages to be obtained • describe the role of transducers as an interface between the environment and an electronic system 	<ul style="list-style-type: none"> • identify and analyse data and perform an investigation to demonstrate the difference between digital and analogue voltage outputs over time • gather, process and present information to identify electronic systems that use analogue systems, including television and radio sets and those that use digital systems, including CD players • solve problems and analyse information involving resistances, voltages and currents in potential dividers

<p>3. Sensors and other devices allow the input of information in electronic systems</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> • define a transducer as a device that can be affected by or affect the environment • explain the relationship in a light-dependent resistor (LDR) between resistance and the amount of light falling on it • describe the role of LDRs in cameras • explain why thermistors are transducers and describe the relationship between temperature and resistance in different types of thermistors • distinguish between positive and negative temperature coefficient thermistors • explain the function of thermistors in fire alarms and thermostats that control temperature 	<p><i>Students:</i></p> <ul style="list-style-type: none"> • gather, process and present graphically information on the relationship between resistance and the amount of light falling on a light-dependent resistor • solve problems and analyse information involving circuit diagrams of LDRs and thermistors • gather and analyse information and use available evidence to explain why solar cells, switches and the light meter in a camera may be considered input transducers
<p>4. Some devices use output transducers to make connections between the product and the environment</p>	<ul style="list-style-type: none"> • explain the need for a relay when a large current is used in a device • describe the role of the electromagnet, pivot, switch contacts and insulator in a relay • describe the structure of light-emitting diodes (LEDs) in terms of p-type and n-type semiconductors • explain why voltmeters, ammeters, CROs and other electronic meters are considered output transducers 	<ul style="list-style-type: none"> • process information to explain the way in which a relay works using a circuit diagram • solve problems and analyse information using circuit diagrams involving LEDs and relays • analyse information to assess situations where an LED would be preferable to an ordinary light source

<p>5. Information can be processed using electronic circuits</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> describe the behaviour of the logic gates in terms of the high and low voltages and relate these to input and outputs identify that gates can be used in combination with each other to make half or full adders 	<p><i>Students:</i></p> <ul style="list-style-type: none"> identify data sources, plan, choose equipment or resources for, and perform first-hand investigations to construct truth tables for logic gates solve problems and analyse information using circuit diagrams involving logic gates
<p>6. Amplifiers are used in different ways in current technologies</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> describe the functions and the properties of an ideal amplifier explain that the gain of an ideal amplifier is the ratio of its output voltage to its input voltage: $\frac{V_{out}}{V_{in}}$ identify that an operational amplifier is an implementation of an ideal amplifier describe the characteristics of an operational amplifier distinguish between open-loop gain and closed-loop gain identify the voltage range over which an operational amplifier circuit acts as a linear device describe how an operational amplifier can be used as an inverting amplifier explain that the gain of an inverting amplifier is given by: $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$ explain the difference between the non-inverting input and the inverting input discuss how feedback can be used in a control system explain the use of two input resistors to produce a summing amplifier 	<p><i>Students:</i></p> <ul style="list-style-type: none"> solve problems and analyse information to show the transfer characteristics of an amplifier gather and present graphical information to show the transfer characteristics of an inverting amplifier solve problems and analyse information about setting the gain of an inverting amplifier by calculating the values of external resistors using: $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$ perform a first-hand investigation of a summing amplifier by adding voltages from two separate sources gather information to identify the different ways in which amplifiers are used in current technologies
<p>7. There are physics limits that may impact on the future uses of computers</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> identify that the increased speed of computers has been accompanied by a decrease in size of circuit elements explain that as circuit component size is decreasing, quantum effects become increasingly important 	<p><i>Students:</i></p> <ul style="list-style-type: none"> gather, process and analyse information and use available evidence to discuss the possibility that there may be a limit on the growth of computer power and this may require a reconceptualisation of the way computers are designed

9 Definitions of Verbs

Account	<i>Account for:</i> state reasons for, report on <i>Give an account of:</i> narrate a series of events or transactions
Analyse	Identify components and the relationship among them; draw out and relate implications
Apply	Use, utilise, employ to a particular situation
Appreciate	Make a judgement about the value of
Assess	Make a judgment of value, quality, outcomes, results or size
Calculate	Ascertain/determine from given facts, figures or information
Clarify	Make clear or plain
Classify	Arrange or include in classes/categories
Compare	Show how things are similar or different
Construct	Make; build; put together items or arguments
Contrast	Show how things are different or opposite
Critically (analyse/evaluate)	Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to (analysis/evaluation)
Deduce	Draw conclusions
Define	State meaning and identify essential qualities
Demonstrate	Show by example
Describe	Provide characteristics and features
Discuss	Identify issues and provide points for and/or against
Distinguish	Recognise or note/indicate as being distinct or different from; to note differences between
Evaluate	Make a judgement based on criteria; determine the value of
Examine	Inquire into
Explain	Relate cause and effect; make the relationships between things evident; provide why and/or how
Extract	Choose relevant and/or appropriate details
Extrapolate	Infer from what is known
Identify	Recognise and name
Interpret	Draw meaning from
Investigate	Plan, inquire into and draw conclusions about
Justify	Support an argument or conclusion
Outline	Sketch in general terms; indicate the main features of
Predict	Suggest what may happen based on available information
Propose	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
Recall	Present remembered ideas, facts or experiences
Recommend	Provide reasons in favour
Recount	Retell a series of events
Summarise	Express concisely the relevant details

Physics

HSC Specimen Examination Mapping Grid

For each item in the examination, the grid shows the marks allocated, the syllabus content and syllabus outcomes it relates to, and the bands on the performance scale it is targeting. The range of bands shown indicates the performance candidates may be able to demonstrate in their responses. That is, if an item is shown as targeting Bands 3–5, it indicates that candidates who demonstrate performance equivalent to the Band 3 descriptions should be able to score some marks on the item, while those who perform at Band 5 or above could reasonably be expected to gain high marks. In the case of one-mark items, candidates who demonstrate performance at or above the bands shown generally could be expected to answer the item correctly.

Question	Marks	Content	Syllabus outcomes	Targeted performance bands
Option 5: Age of Silicon				
31(a)(i)	1	9.1, 9.9.3	H7, H13	2–3
31(a)(ii)	2	9.1, 9.9.3	H13, H14	3–4
31(a)(iii)	3	9.1, 9.9.3	H9, H12, H13, H14	4–6
31(b)(i)	5	9.1, 9.9.2	H7, H13	2–6
31(c)(i)	2	9.1, 9.9.6	H7, H14	2–3
31(c)(ii)	2	9.1, 9.9.6	H7, H13, H14	2–3
31(c)(iii)	5	9.1, 9.9.6	H7, H13, H14	2–5
31(d)	5	9.9.1, 9.9.2, 9.9.3, 9.9.4, 9.9.5, 9.9.6	H3, H4, H7, H13	2–6

6.2.14 Evaluation

Sample questions that could be included in an evaluation sheet to be completed by teachers involved in the delivery of this unit

Resources identified

1. What resources would you recommend using again?
2. What resources should definitely be deleted from the list?
3. Any new and better resources identified?
4. Are there areas of content where further or different resources would be useful/are needed?

First-hand experiences

1. Mention any particular difficulties or problems with equipment or other resources.
2. Any better practical experiences identified?
3. Any better ideas for illustrating the skills required by the syllabus?

Skills development

1. Did any skills need more attention than others in this module?
2. Does the program allow practice of the skills that students need most practice in?
3. Was the selection of content from each major skill area appropriate for the students involved?
4. Was the selection of content from each major skill area appropriate for the dot point addressed?

Teaching and learning strategies

1. Were the teaching and learning strategies used appropriate for the cohort involved?
2. Were the strategies suggested effective in achieving conceptual development for all students?
3. Were the strategies suggested efficient in achieving conceptual development for all students?
4. What was the student response to the unit?
5. What problems arose for students?
6. Did this teaching program provide sufficient variation in learning opportunities for the range of different types of learners in the group?
7. Did this unit provide choice for students with different interests/abilities within the constraints of syllabus requirements?

Assessment tasks

1. Which outcomes need further assessment?

Indicative timing

1. Is the indicative time for each section appropriate? If not, which areas need more/less time?

Survey results

Below are the results of our survey.

Interest in topic:

	Topic/level of interest/no. responses	1	2	3	4	5
1.	Voltage, current, resistance	8	4	5	1	
2	LDR, Thermister	1	5	2	4	3
3	Capacitors	1	3	1	4	5
4	Relays	1	3	1	5	5
5	Semiconductors	1	2	2	2	9
6	Integrated circ. LEDs	1	1	1	3	10
7	Transistor amp	1	1	1	4	7
8	Feedback ,op-amps	1	1	1	4	8
9	Analog and digital cir	1	3	3	2	5
10	Gates, truth tables, logic circuits		3	5	2	5

Knowledge rating:

Rate knowledge	1	2	3	4	5
No. responses	3	5	4		1

Desired activities:

Proposed activities	Kit	Class and lab	problem	Resources	5
No. responses	7	7	1	4	1

Particular comments made include the following:

Previous study in electronics

1st year university

Hobby

Degree years ago

Previous workshop

Not since Physics II at university

None

Taught y(, taught opamps y11 at uni. semiconductors, circuits & systems, machine language

Taught electronics elective in Physics. Teach electronics classes yr 7-12 (analogue & digital)

Short course at TAFE years ago

Very little formal; study - mostly picked up by reading

Valve theory at university, personal interest in electronics, long interest in HiFi

Geophysics - technical (electronics) repairs

Outcomes

Theory compatible with HSC and beyond

Skills/practical work to meet HSC

Consolidate my areas of weakness

Ability to teach option

Set of clear notes

Skills taught through hands-on activity

Sufficient knowledge and breadth of knowledge to be able to cope with the requirements of the "Silicon" elective

To feel confident teaching the Age of Silicon unit.

Better understanding of level of difficulty & scope of HSC options - also increased confidence in teaching to [...] students

Lots of resources - freeware/shareware programs, educational websites, student activities

Gain an understanding at applying concepts in class

Knowledge and confidence to, in particular, run practical work

Revise some of the more abstract ideas (hole migration etc)

Outline of syllabus content

Examples of prac. activities, workshops etc

Refresh "old" knowledge and review precise relevance to NSW physics course

Kit - teaching notes, working experiments, safety notes

A working knowledge of electronics within the stage 6 Physics syllabus

Items purchased

See the following sheets for items purchased at Dick Smith (with part numbers which they like you to use to buy the components) and Tandy.

Mike's circuit ideas

Wind velocity meter using thermistor

Thermistors self heat. When wind flows over the thermistor its temperature reduces due to the cooling effect of the wind. A circuit can be built to detect this change and so, if calibrated, can measure wind speed.

Electronic candle

Modify the touch switch circuit with four transistors with the one strip replaced by an LDR so that it turns on when a light (match) is near the LDR and turns off when the other strip is touched. Replace the 6v globe with a LED and a resistor if desired.

Human temperature meter using thermistor

Carefully design and calibrate a single transistor amplifier (include a trimpot) with an ammeter in the collector circuit and thermistor in the bias circuit to measure a person's temperature.

Paper tape reader using several LEDs and LDRs

A circuit can be built using LEDs and LDRs to detect holes in a paper tape which was the old method of holding and loading programs into a computer.