Activity Group 1

Topic: Voltage, current, resistance and voltage dividers

HSC curriculum points covered: Item 2. Student learn to: • identify potential dividers 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 Students: • solve problems and analyse information involving resistances, voltages and currents in potential dividers
Important concepts: Voltage, current, resistance, voltage divider, power, Kirchoff's current law, Kirchoff's voltage law Secondary concepts: Load, output resistance, input resistance
Internet resources:

Activity 1.1: Basic properties of resistance and voltage dividers.

Resources needed: Voltage source, DVM, ammeters, Various resistors.

Description of activity:

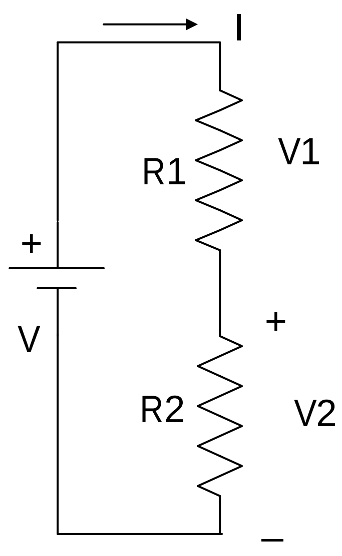
1. Resistance as a proportionality constant.

Connect up a voltage source across a 1KΩ resistor. Put an ammeter in series with the resistor and a DVM across the resistor. Vary the voltage source (0-10V) and measure voltage across resistor and current through the resistor.

(i) Does current vary proportionally to voltage?
(ii) If so, is there a constant of proportionality?

2. Voltage dividers

Connect up a voltage divider to a voltage source with R1 = 1KΩ and R2 = 4.7KΩ. Put ammeters in series with both arms of the divider. Use a DVM or DVMs to measure the voltage across both arms of the divider and across the voltage source. Vary the voltage source (0-10V).



Determine using measurement the relationship between voltages across arms of divider and across voltage source? Verify this using the voltage divider equation.
What is relationship between currents in arms of divider?
Verify that the divider "divides up" the voltage source in the same ratio as the resistors.
What is the ratio of V2/V? This voltage ratio can be called the attenuation (gain < 1) of the divider.

3. Loading

Voltage dividers can be used to study concepts encountered in amplifiers and other electronics circuits. One set of concepts is that of loading, output resistance and input resistance.

Consider two voltage dividers.

a) R1 = 100KΩ, R2 = 1KΩ
b) R1 = 10Ω, R2 = 1KΩ

In both cases, what is the voltage at the end of R1 without R2 being connected? Verify this using measurement in a circuit.

In both cases the voltage should be the same. Now connect R2. In divider (a) the voltage at the end of R2 drops significantly while in divider (b) it doesn't drop much. The exact amount of drop can be found using the voltage divider equation.

In both cases R1 is described as the output impedance of the circuit before R2 is connected. The lower the output impedance the less the voltage will drop when connected to a load (R2).
If R2 represents another circuit, R2 is called the input impedance of the circuit. The higher the value of R2 the less the voltage will drop.
The exact amount of voltage drop depends on both the input resistance and output resistance via the voltage divider equation.

Ideally, amplifiers would have very high input impedance and low output impedance.

4. Miscellaneous facts about voltage dividers.

i) The maximum power is delivered to a load when the load resistance equals the output resistance (important in connecting antennas to circuits)

ii) If the resistance in one of the arms in a voltage divider is allowed to vary about a certain value, the maximum rate of voltage change at the centre of the divider occurs when the two arms of the voltage divider have equal resistance. (important in designing circuits with themistors).

Comments:

Activity 1.2: Use of analogies

Resources needed: Imagination, open mind
Description of activity: Analogies are often useful in learning and understanding electronics concepts. Some examples are as follows. <u>Voltage:</u> Voltage difference can be considered analogous to gravitational potential. Kirchoff's voltage law can be be thought of using the following analogy. Suppose you are walking around a circuit in a park up and down hills. What is the total change in height as you walk around the circuit. If you walk by two different routes to the same point is the final height the same at the end of each route. <u>Current.</u> Water flow is a good analogy to understand current. An analogy for Kirchoff's current law is to consider two rivers joining. The rate of water flow into the junction of the two rivers before they join is equal to the out of the junction after they join. <u>Other analogies</u> What are some other analogies that can be used to describe voltage, current, resistance and voltage dividers?
Comments:

Activity group 2

Topic: Light Dependent Resistors

HSC curriculum points covered: Item 2. Student learn to: • 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 Students: • 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
Important concepts: LDR, free electrons, decreasing resistance with light intensity
Internet resources:

Activity 2.1

Resources needed: Voltage source, DVM, ammeter, 1K resistor, LDR
Description of activity: Examine the activities on the 3P: Investigating sensors using a breadboard and devices and equipment provided.
Comments:

Activity Group 3

Topic: Thermistors

HSC curriculum points covered: Item 3. Student learn to: • 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 Students: • solve problems and analyse information involving circuit diagrams of LDRs and thermistors
Important concepts: negative temperature coefficient thermistor, positive temperature coefficient thermistor
Internet resources:

Activity 3.1

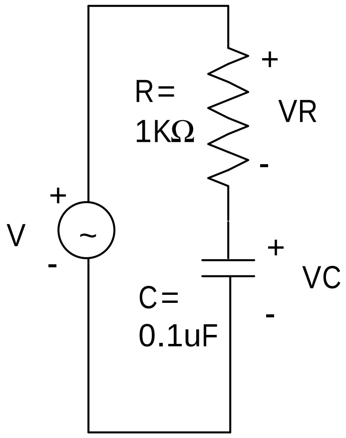
Resources needed: Voltage source, DVM, ammeter, NTC thermister, resistors.
Description of activity: The aim of this experiment is to develop some experiments which use NTC thermistors. Use the data in the Dick Smith catalogue to try and make the experiment precise in that the values used and results can be predicted on the basis of theory. Use excel on the computers if necessary to make calculations.
Comments:

Activity Group 4

Topic: AC voltages and capacitors

HSC curriculum points covered: Item2. Student learn to: Students: • identify and analyse data and perform an investigation to demonstrate the difference between digital and analogue voltage outputs over time
Important concepts: AC voltage, sine wave, frequency, amplitude, RMS voltage, peak-to-peak voltage, capacitance, impedance, 3dB frequency.
Internet resources:

Activity 4.1

Resources needed: Voltage source, DVM, 1K resistor, 1uF capacitor, signal generator, CRO, leads
Description of activity: A low-pass circuit is constructed using a 1 KΩ resistor and 1 uF capacitor.    1. Demonstration of a square wave (1KHz, 5 V amplitude) applied to a low pass series RC filter. Observe the voltage across capacitor as it charges and discharges to try and follow the applied square wave. Observe current by monitoring voltage across the resistor. Note that when the capacitor voltage changes rapidly the current is large. When capacitor voltage has stabilised no current flows. 2. Demonstration of a sine wave (1KHz, 5 V amplitude) applied to the RC filter. Observe the capacitor voltage lagging behind the voltage source as it tries to follow it. Observe resistor voltage as being 90 degrees out of phase with the capacitor voltage (when the current is at a peak the capacitor voltage is 0; when the capacitor voltage is at a peak the current is 0). Measure AC RMS voltage using a DVM. Note that RMS capacitor voltage and RMS resistor voltage add up to more than the source RMS voltage source. This is because resistor and capacitor voltage peaks do not add up. 3. Vary the frequency of the voltage source (careful to keep the voltage level constant). Observe that as the frequency increases the capacitor voltage decreases. The ratio of capacitor voltage to capacitor current equals capacitor impedance (which decreases with frequency). The 3bB frequency occurs when the capacitor voltage is 0.707 of the voltage source. This frequency is $1/(2\pi RC) = 1/(2\pi x1kx0.1uF)$ = 1591.5KHz.
Comments:

Activity 4.2

Resources needed: Williamson-Labs Capacitor
Description of activity: Investigate the web site which shows some typical applications of capacitors. It includes some animation to show how capacitors charge and discharge in the circuit.
Comments:

Activity Group 5

Topic: Relays

HSC curriculum points covered: Item 4. Student learn to: • 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 Students: • 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
Important concepts: Relay, transducer, electromagnet, pivot, switch contact, insulator
Internet resources:

Activity 5.1

Resources needed: Voltage source, DVM, relay, diode, transistor, LDR, resistors.
Description of activity: Use can use a transistor and LDR to make a light sensitive relay circuit.
Comments:

Activity Group 6

Topic: Diodes

HSC curriculum points covered: Item 2. Student learn to: • describe the structure of light-emitting diodes (LEDs) in terms of p-type and n-type semiconductors Students: • 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
Important concepts: semiconductor, intrinsic, extrinsic, n-type, p-type, diode, forward biased, reverse biased, band gap, LED
Internet resources:

Activity 6.1

Resources needed: Diode, resistor, LED, zener diode, DVM, signal generator, CRO

Description of activity:

1. Diode in series with resistor (Fig. 1). R = 1KΩ. Slowly increase the forward bias voltage across the diode and observe the voltage across both diode and resistor (which indicates current). Note that with V up to about 0.6V very little current flows. As the voltage is increased the current starts to increase and the voltage across the diode is about 0.6-0.7 V. As the V is increased VD only increases minimally. This is indicative of the exponential character of the forward biased diode.

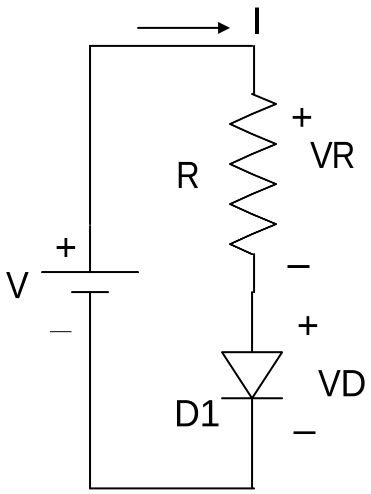


Fig 1

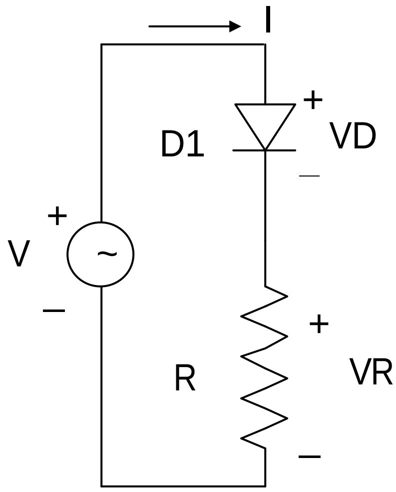


Fig 2

2. Repeat 1 slowly increasing reverse bias voltage across the diode.

3.Interchange the diode and resistor and replace the DC voltage source with an AC voltage source set to to 1 kHz and 10 V p-p. (Fig 2). Look at the voltage across the resistor with a CRO. You should only see the positive half the since wave. This is called half wave rectification. Compare the amplitude of VR with the source amplitude. They should differ by about 0.6 V. Around 0 V the sine wave is a bit distorted too.

4. Repeat 1 using an LED instead of a diode. Compare the voltage across a forward biased LED with a normal forward biased diode. Compare red LEDs with other colours.

5. Repeat 2 with a zener diode. Note the voltage when zener breakdown occurs.

Comments:

Activity 6.2

Resources needed:
Description of activity: The operation of the diode can be quite difficult to teach and understand. We will discuss how the following concepts might be explained, both individually and when they operate in combination: Free electrons Holes Extrinsic semiconductors Diffusion Drift Zero-bias Forward bias Reverse bias
Comments:

Activity Group 7

Topic: Transistors and Transistors Amplifiers

HSC curriculum points covered: Item 6. Student learn to: • 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: $\frac{V_{out}}{V_{in}}$ Students: • solve problems and analyse information to show the transfer characteristics of an amplifier
Important concepts: emitter, base, collector, BE junction, CE junction, current gain, bias, DC circuit, small signal circuit.
Internet resources:

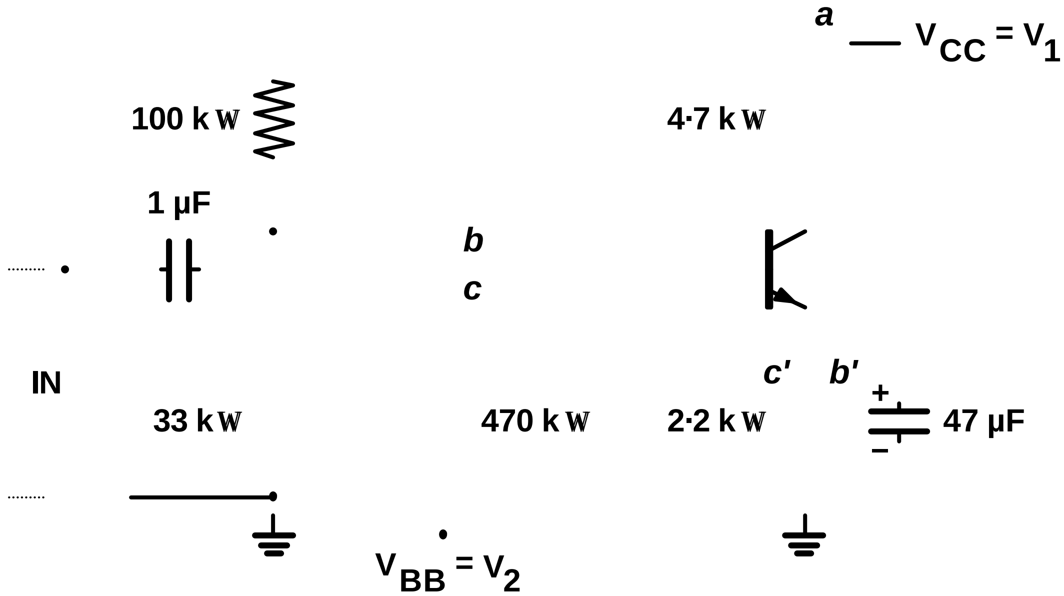
Activity 7.1

Resources needed: ELEC176 CE amplifier chassis board, voltage source, DVM, oscilloscope, signal generator
Alternative: Use a breadboard and components provided to wire up the circuit.

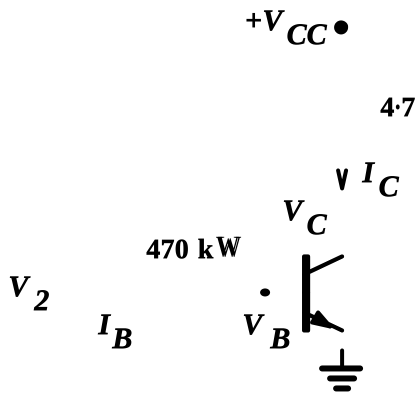
Description of activity:

The chassis of the Common Emitter amplifier experiment is as follows:

COMMON-EMITTER AMPLIFIER



Check that Vcc is set to 12 V. Insert links a, c, c' so that the following circuit is established.



Connect voltage source V2 and initially set it to 0V.
Gradually increase V2. Measure the voltage across the base emitter junction VBE, the voltage at the collector relative to ground (VC).

The collector current can be calculated or measured by inserting and ammeter. It is probably better not to insert an ammeter in the base but calculate base current.

Observe the following.

The BE junction is forward biased. The CE junction is reverse biased. This is the "normal" mode of operation of an amplifier.

If V2 is less than about 0.6 V very little collector current is flowing (begin part of the exponential curve for a forward-biased BE junction). As collector current increases the voltage across the collector resistor (4.7K) increases.

Once V2 gets above 0.6V noticeable collector (and emitter) current start to flow. By the "squeezing in" constraint of the power supply, as the voltage across the collector resistor increases the voltage at the collector decreases. VC decreases as V2 increases.

Calculate the base current when VC is 6V. Note that it is much less than the collector and emitter currents because most of the emitter current flows into the collector and very little out of the base. However, the fraction which flows out is pretty constant over a range of emitter currents. The ratio of collector current to base current is called the beta of the transistor. In this case it could be in the range 50-200.

When VC is 6V determine how much VC changes for a small change in V2.

Basically this is how our amplifier operates:

We set the level of V2 to a point where if it fluctuates up and down we get down and up fluctuations in collector voltage. In practice the input fluctuations could be from a microphone and the output fluctuations are amplified versions of that.

The point around which fluctuations occur is called the bias point (or quiescent point).
This point is determined by the various resistor values in the base and collector, power supply voltage and V2 when no fluctuations are present. Determining this point is sometimes called "DC analysis of the amplifier" or "design of the bias circuit".

When describing the gain of an amplifier it is not the ratio of the total voltage over the total input voltage which is used but instead the change in collector voltage by the change in input voltage.
Note that since collector voltage decreases as base voltage increases and so the gain is negative. The analysis of how VC varies in terms of V2 can be done using backwards analysis from our goal (VC):
VC -> IC -> VB -> IB -> V2.

(ii) Keep increasing V2 and note that VC keeps reducing. At some point it will reach a value of about 0.3 V and stay they even if V2 has increased. This point is called the saturation point. Notice that the CB junction has gone from reverse bias to forward bias.

(ii) Reverse the voltage V2 i.e. the base is made negative. Explain what happens.

Comments:

Activity 7.2

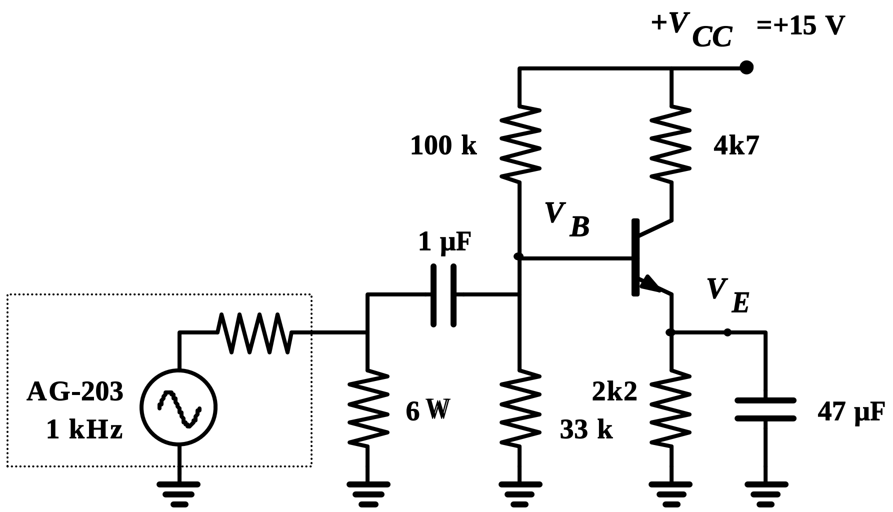
Resources needed: ELEC176 CE amplifier chassis board, voltage source, DVM, oscilloscope, signal generator
Alternative: Use a breadboard and components provided to wire up the circuit.

Description of activity:

This activity continues to use the Common Emitter amplifier experiment chassis.

The circuit in Activity 7.1 had the disadvantage that the bias point depended very much on the transistor beta which could vary significantly from transistor to transistor. That meant that if we took a circuit that worked and replaced the transistor the circuit may no longer work. The second circuit is designed to make the circuit much more predictable and robust to these beta variations.

Now insert links a, b, b' in the chassis. This amplifier circuit has a different bias circuit and some capacitors are inserted.



As is often done the DC analysis precedes the AC small-signal analysis.

Again we aim to establish a bias point where the BE junction is forward biased and the CB junction reverse biased. We aim to get about 6V at the collector, so that both positive and negative voltage fluctuations can occur.

Notice that there is almost a voltage divider in the base circuit. The base current is very small compared to current flowing in the 100k and 33 k divider and so the base voltage (relative to ground) is set to a given value determined by the resistors and power supply.

The emitter has a 2.2K resistor in series. This helps to set the emitter (and collector) current to a predictable value. To see how this is done notice that the emitter voltage is equal to the base voltage minus the voltage across the BE junction. Remembering that forward biased diodes have a voltage of about 0.6 V-0.7V the voltage at the emitter is about VB-0.6V and so the emitter current is determined by the VB and the 2.2K resistor. The emitter current value used has been chosen to give a collector current and collector voltage at about 6V.

Some people describe what is happening here in terms of feedback. Suppose we design a circuit for certain beta but the actual transistor used has a higher beta. This would cause more collector and emitter current to flow. This increased emitter current causes a bigger voltage drop across the emitter resistor which, in turn, reduces the forward bias voltage across the BE junction and so reduces the emitter current back to what we designed for. A similar thing happens if a smaller beta transistor is used.

(i) Measure the voltages at the base, emitter and collector.
(ii) Verify that the base voltage is equal to the computed base voltage divider voltage.
(iii) Verify that the BE junction has a voltage of about 0.6V.

The thing to look at is the AC analysis.

The 1 uF input capacitor in the input circuit is used to couple the AC voltage source to the base. There is an almost fixed DC voltage across that capacitor so all AC voltage variations are passed to the base. The capacitor value is chosen so this is true for the range of frequencies to be used in the circuit.

The 47 uF capacitor in the emitter is used to keep the emitter at an AC earth. It too has an -almost fixed DC voltage across it so the emitter will not experience any AC voltage variations and so all the voltage variations at the base will appear across the BE junction. This will give the maximum gain possible since all input voltage variations can be used to cause collector current variations in the transistor.

If the 47uF capacitor were not there then part of the base voltage variation would occur across the 2.2 K emitter resistor and very little across the BE junction, giving much collector current variation and hence less gain.

Using a CRO measure the AC voltages at the input, base, emitter and collector.

Comments:

Activity 7.3

Resources needed: Breadboard, transistor, resistors, voltage source, CRO, DVM Alternative: Use a breadboard and components provided to wire up the circuit.
Description of activity: 1. Do part 1 of ELEC190 Prac 7. In addition, (i) Measure voltage between base and emitter and between base and collector. Compare results. (ii) Reverse the voltage V2 i.e. the base is made negative. Explain what happens. (iii) Vary V2 and observe how VB, IB, IC and VC vary. Analyse this in backwards direction i.e. VC -> IC -> VB -> IB -> V2. 2. Do or look at Part 2. Note the presence of RE which helps to give a predictable IC even if the transistor beta varies. 3. Do or look at Part 3. Note that if the capacitors were to be removed the circuit of Part 2 is obtained. Draw the circuit you would have if capacitors were made into short circuits.
Comments:

Activity 7.4

Internet: Williamson-Labs
Description of activity: Examine the Williamson-Labs web site on transistor amplifiers.
Comments:

Activity Group 8

Activity: Negative feedback and operational amplifiers

HSC curriculum points covered: Item 6. Student learn to: • distinguish between open-loop gain and closed-loop gain • discuss how feedback can be used in a control system • 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 Students: • 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
Important concepts: Open loop, closed loop, negative feedback, positive feedback, high gain, linear device, negative feedback, inverting input, non-inverting input, summing amplifier
Internet resources:

Activity 8.1

Resources needed: ELEC176 feedback board and ELEC176 op-amp board, signal generator, DVM, oscilloscope. Alternative: Use a breadboard and components provided to wire up the circuit.
Description of activity: 1. Negative feedback Do parts 1 and 2 of ELEC176 Prac E. 2. Op-amps Do parts 4, 5a and 7 of ELEC176 Prac E.
Comments:

Activity 8.2

Resources needed: ELEC176 feedback board and ELEC176 op-amp board, signal generator, DVM, oscilloscope Alternative: Use a breadboard and components provided to wire up the circuit.
Description of activity: 1. Op-amps Do parts 4, 5a and 7 of ELEC176 Prac E. You can modify part 7 to use two separate signal sources instead in the summer.
Comments:

Activity 8.3

Resources needed:
Description of activity: We will discuss here the concepts and techniques used to teach op-amps. 1. List the concepts and ideas needed to teach and understand the summing amplifier. 2. Arrange the concepts according to hierarchy. Which are the most important concepts? Which concepts precede other concepts? Which concepts can be grouped together? 3. Which concepts do you think will cause the biggest problems in understanding?
Workspace and comments:

Activity Group 9

Topic: Logic devices

HSC curriculum points covered: Item 2. Student learn to: • distinguish between digital and analogue systems in terms of their ability to respond to or process continuous or discrete information Students: • 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 Item 5. Student learn to: • 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 Students: • 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
Important concepts: analogue device, digital device, discrete signal, continuous signal, logical signal, logic level, gate, AND, OR, NOT, NAND, NOR, exclusive OR, parity gate, difference gate, half adder, full adder, truth table
Internet resources:

Activity 9.1

Resources needed: Logic trainer board, plug pack, leads
Description of activity: Do the experiments in the attached logic trainer experiment.
Comments:

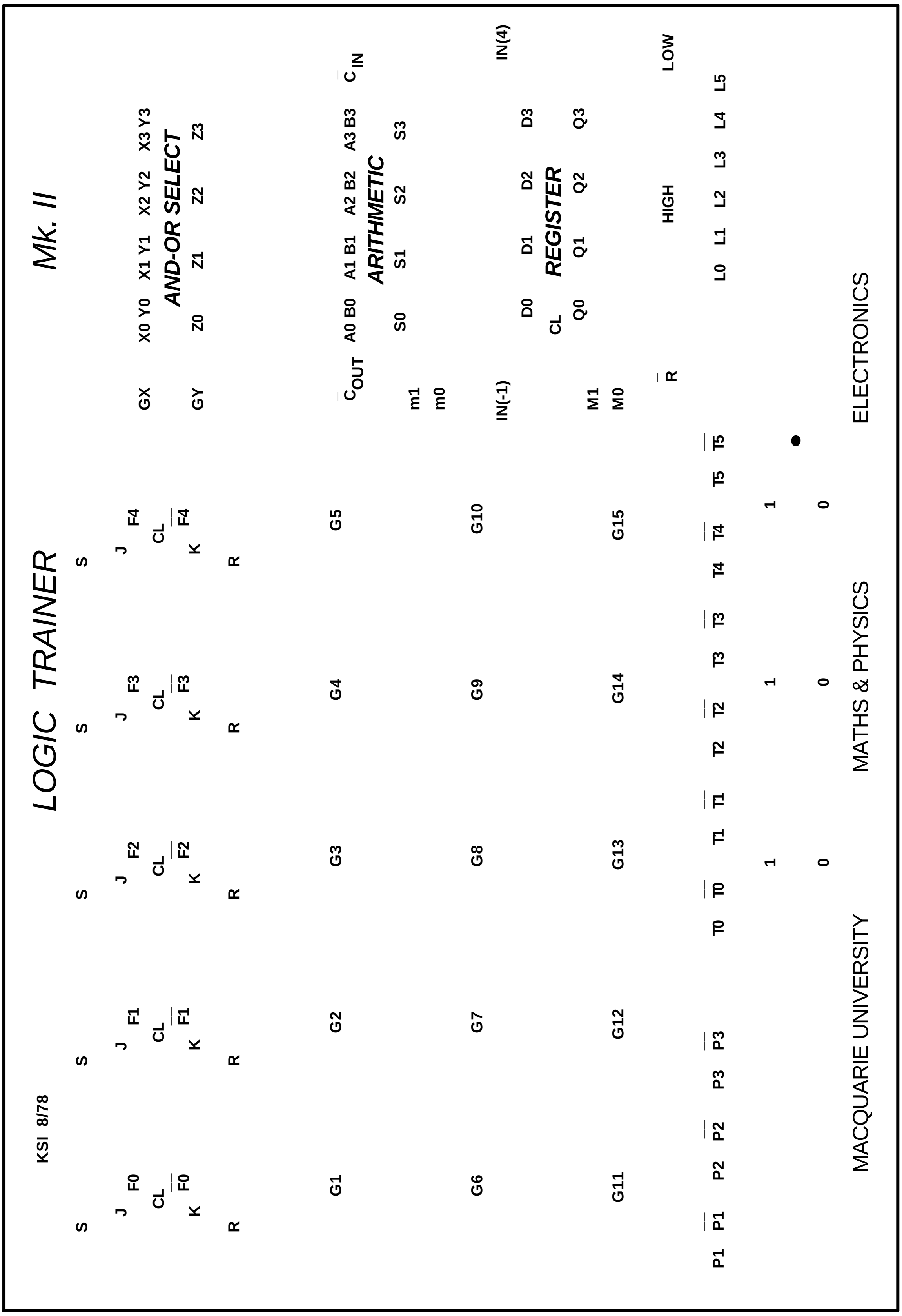

LOGIC TRAINER
Mk. II
KSI 8/78
AND-OR SELECT
ARITHMETIC
REGISTER
HIGH
LOW
MACQUARIE UNIVERSITY
MATHS & PHYSICS
ELECTRONICS

Fig. LT1

Activity sheet 10

Activity: Silicon Technology

HSC curriculum points covered: Item 1 Student learn to: • 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 Students: • 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 Item 5. Student learn to: • 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 Students: • 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
Important concepts:
Internet resources:

Activity 10.1

Resources needed:
Description of activity: This is a presentation on the growth and types of technical advances required to make high-speed and complex integrated circuits and systems.
Comments:

Blank activity sheet

Resources needed:
Description of activity:
Comments: