

# An Introduction to Electronics

Name \_\_\_\_\_ Class \_\_\_\_\_



" I'M A DO-IT-YOURSELFER, BUT I'VE NEVER BEEN A  
DONE-IT-YOURSELFER..."

## MRGS Year 10 Technology Electronics 2009

Available online from [www.techideas.co.nz](http://www.techideas.co.nz)



B. Collis Mt Roskill Grammar School 2002-2009

This work is licensed under the Creative Commons Attribution-NonCommercial-Share Alike 3.0 License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0>. The licensor permits others to copy, distribute and transmit the work. In return, licensees may not use the work for commercial purposes — unless they get the licensor's permission. The licensor permits others to distribute derivative works only under a license identical to the one that governs the licensor's work.

# Table of Contents

Introduction to Year 10 Electronics.....	3
Your learning this year .....	3
Your learning this year .....	4
Electronic Theory .....	5
Darkness Detector .....	6
Making Electricity .....	7
ESD Electrostatic Discharge .....	9
Group Power Supply Assignment.....	10
Circuit basics.....	11
Conventional Current .....	11
Conductors.....	12
Insulators .....	12
Making circuits on a Breadboard .....	13
Semiconductors .....	14
Wire Assignment.....	14
Resistors .....	15
Resistor Prefixes .....	16
Resistor Values Exercises.....	17
Combining resistors in series .....	22
Combining resistors in parallel .....	24
Ohms law .....	26
Power Calculations .....	27
Resistor Combination Circuits .....	28
Multimeters .....	29
Multimeter controls.....	30
Choosing correct meter settings.....	31
Voltage & Current Measurements .....	32
Measuring Resistance.....	33
Variable Resistors .....	34
Capacitance .....	35
Capacitor Codes and Values.....	36
Converting Capacitor Values uF, nF , pF.....	36
The Voltage Divider.....	37
Semiconductors .....	38
Diodes.....	39
Diode Research Assignment.....	39
LED's .....	41
LED research assignment .....	42
Using LEDs in circuits .....	43
The LDR.....	44
The Transistor.....	45
Transistor Specifications .....	46
Transistor Case styles.....	46
TDA2822M Portable Audio Amplifier Project.....	47
Portfolio Assessment Schedule.....	48
Initial One Page Brief .....	49
TDA2822M.....	50
Audio Amplification.....	51
Speakers.....	52
Tone Controls.....	<b>Error! Bookmark not defined.</b>
Eagle Schematic and Layout Editor Tutorial.....	53
Year10 PCB Making.....	63
Component Forming Codes of Practice.....	66
Soldering.....	67
Soldering Wires to LED's and Switches.....	70
SKETCHUP Quick Start Tutorial .....	71
Workshop Safety.....	72

# Introduction to Year 10 Electronics

This course has 2 main focus areas.

1. Developing a solid set of electronic understandings and skills in students.
  - Electronic component recognition and correct handling
  - Hand soldering skills
  - Use of Ohm's law
  - Current limiting resistors
  - The voltage divider
  - The transistor as an amplifier and switch
  - CAD PCB design and manufacture
  - Introductory microcontroller programming and interfacing
  - Breadboard prototyping
2. Developing student's technology practice.
  - Understanding the situation a product exists within
  - Stakeholder consultations to decide design
  - Brief writing - statement/specifications/constraints
  - Modelling solutions through testing and trials
  - Fitness for purpose
  - Following codes of practice



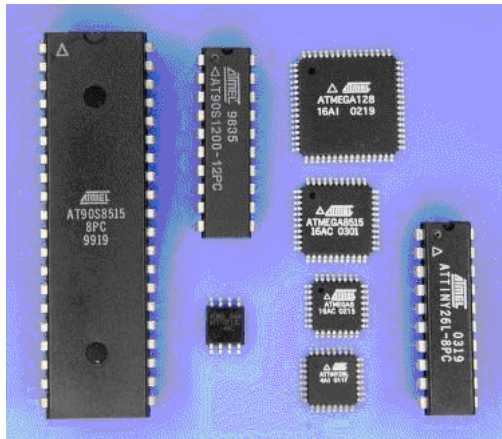
Term One: Electronic component theory and simple circuits

Term Two: Audio Amplifier Project

Term Three and Four: Microcontroller Programming



Project



## Your learning this year

### Technology Achievement Objectives from the NZ Curriculum

#### Technological Practice

**Brief** – beginning to develop your own specifications for your technology projects.

**Planning** – thinking about things before you start making them and using drawings such as flowcharts, circuit diagrams and plans while working.

**Outcome Development** – building electronic circuits, designing and making PCBs and programming microcontrollers.

#### Technological Knowledge

**Technological Modelling** – before building an electronic device or writing software for it, it is important to find out whether it will work or not first by modelling or trialling it.

**Technological Products** – getting to know about components and their characteristics.

**Technological Systems** - an electronic device is more than a collection of components it is a functioning system with inputs, outputs and controlling processes

#### Nature of Technology

**Characteristics of Technological Outcomes** – electronic components especially microcontrollers as the basis for modern technologies

**Characteristics of Technology** – electronic devices have a key role within our modern society; one fundamental portion of this is the energy they use, where does this come from?

### Key Competencies from NZ Curriculum



**Thinking** – making sense of instructions and developing understanding of what you are doing (asking if you don't understand something is crucial), identifying implications (possible consequences) of something before you do it, problem solving using flowcharts and algorithms to express ideas, writing computer programs, identifying resources you can use.

**Relating to others** – working together in pairs and groups, sharing and negotiate workshop resources and equipment, actively listening to each other and assisting each other.

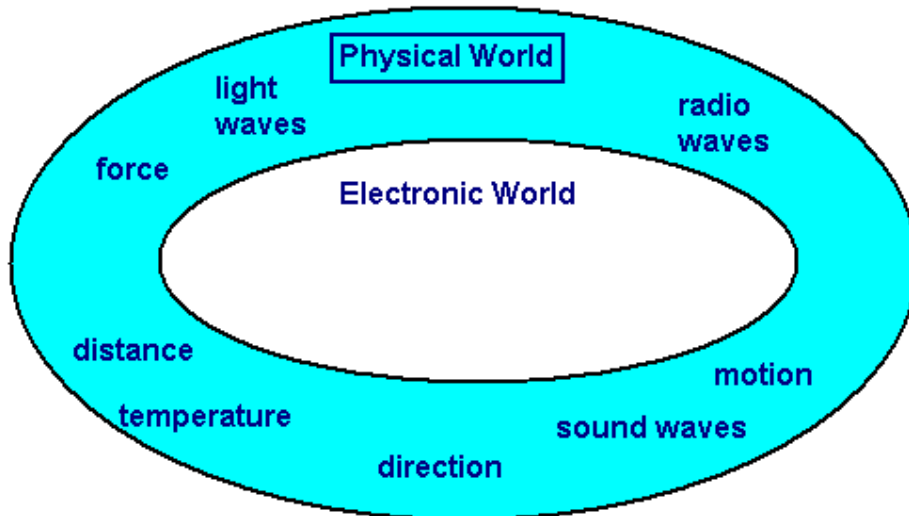
**Using language symbols and texts** – recognising and using electronic components symbols accurately, draw circuit/schematic diagrams according to recognised practices, and communicate ideas correctly using flowcharts and programming language syntax.

**Managing self** – using the tools and equipment in the workshop confidently and safely, disciplined and efficient use of workshop and homework time.

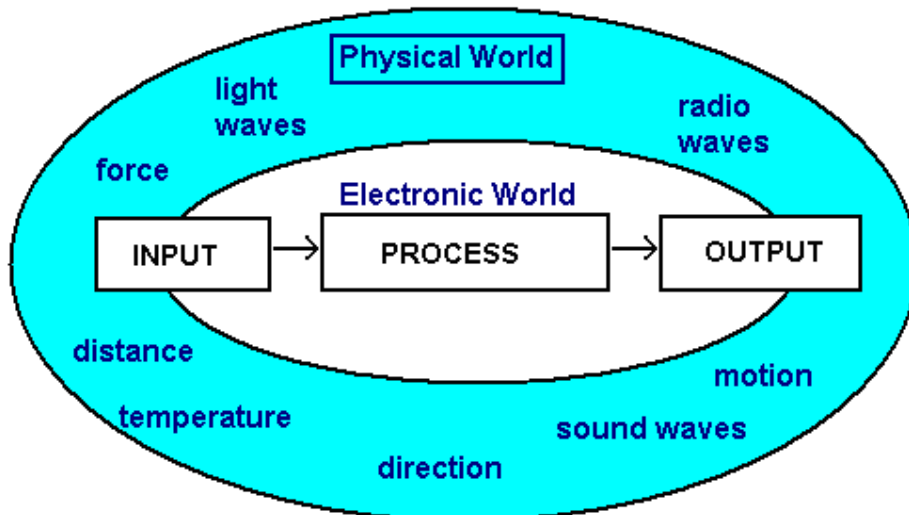
**Participating and contributing** – developing an awareness of the importance of electronics in our society today and recognising that their projects have a social function as well as a technical one.

# Electronic Theory

Electronics is all about controlling the physical world. Physical objects have properties such as temperature, force, motion, sound/radio/light waves associated with them



Electronic devices convert the physical world to electronic signals where some process is applied to these electronic signals and then they are converted back to the physical world where we can see the outcome of the process.

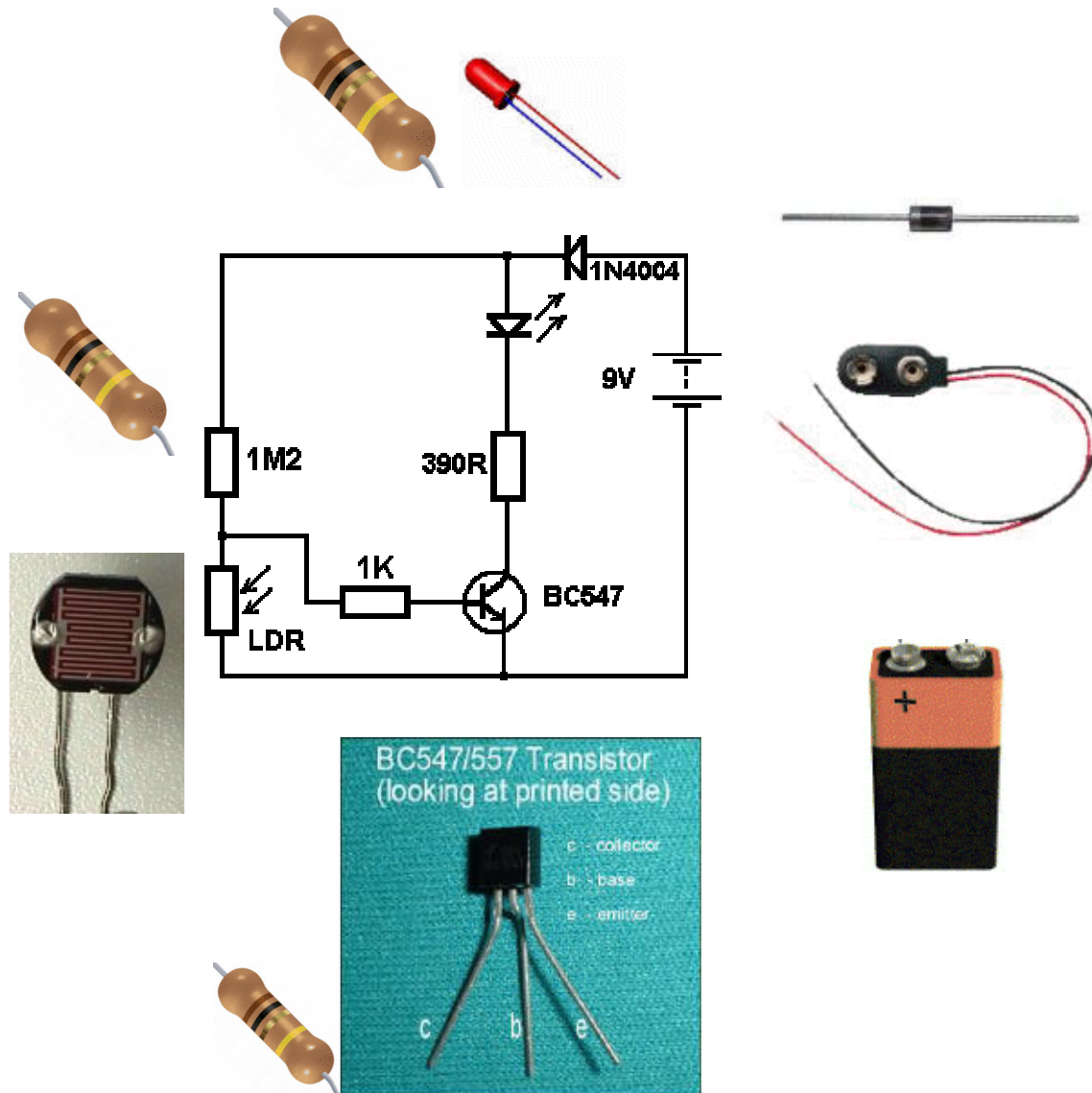


Take an example such as a television, the physical world radio signal on the input is converted to an electronic signal, this is processed by the electronic circuit and converted to light which we see and sound we can hear.

## Darkness Detector

This circuit was designed to help a younger child orientate themselves at night, to find the door in a darkened room.

The function of the circuit is to detect light level. When it is dark the LED is switched on, when there is light present the LED is switched off.



Note that when a circuit is drawn, symbols are used rather than real pictures of components. This makes a circuit easier to understand as there are so many different types of each component that it would be impossible to draw the circuit with pictures. The same symbols are standard around the world.

Draw lines from the components to the symbols to help you remember them. Find the required components and build the circuit. Take care as some of the components are polarised (require wiring into the circuit the right way around).

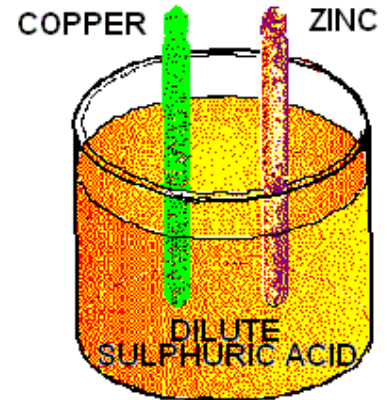


## Making Electricity

Electronic circuits need energy, this energy is in the form of moving charges.

There are a number of ways that we can get charges moving around circuits.

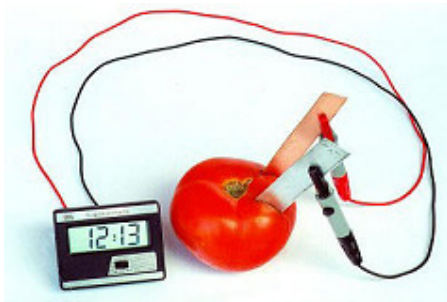
- from chemical reactions (cells, batteries and the newer fuel cells),
- from magnets, wires and motion (generators and alternators),
- from light (photovoltaic cells),
- from friction (electrostatics e.g. the Van de Graaff generator),
- from heat (a thermocouple),
- from pressure (piezoelectric).



## Cells

A cell is a single chemical container, and can produce a voltage of 1.1 volts to 2 volts depending on its type.

In the diagram on the copper side there are plenty of electrons(-), on the zinc side (+) there is an absence of electrons.



Here is a tomato cell powering an LCD clock.

Lemons make good cells too!

## Batteries

A battery is a collection of cells in series e.g. a 12 volt car battery six 2 volt lead-acid cells in series.

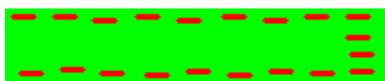


## Different types of cells

- Primary cells (not rechargeable)
  - Zinc-carbon - inexpensive AAA, AA, C and D dry-cells and batteries. The electrodes are zinc and carbon, with an acidic paste between them that serves as the electrolyte.
  - Alkaline - Used in common Duracell and Energizer batteries, the electrodes are zinc and manganese-oxide, with an alkaline electrolyte.
  - Lithium photo - Lithium, lithium-iodide and lead-iodide are used in cameras because of their ability to supply high currents for short periods of time.
  - Zinc-mercury oxide - This is often used in hearing-aids.
  - Silver-zinc - This is used in aeronautical applications because the power-to-weight ratio is good.
- Secondary Cells (Rechargeable)
  - Lead-acid - Used in automobiles, the electrodes are made of lead and lead-oxide with a strong acidic electrolyte.
  - Zinc-air - lightweight.
  - Nickel-cadmium - The electrodes are nickel-hydroxide and cadmium, with potassium-hydroxide as the electrolyte.
  - Nickel-metal hydride (NiMh).
  - Lithium-ion - Excellent power-to-weight ratio.
  - Metal-chloride

## Electrostatics

When certain materials such as wool and a plastic ruler are rubbed against each other an electric charge is generated. This is the principle of electrostatics.



The rubbing process causes electrons to be pulled from the surface of one material and relocated on the surface of the other material.



As the charged plastic moves over a piece of paper the electrons within the paper will be repelled (The paper is an insulator so the electrons cannot move far). This causes a slight positive charge on the paper.

This will mean that the negatively charged plastic will attract and pick up the positively charged paper (because opposite charges attract).

### The positive side effects of Static Electricity

Smoke stack pollution control, Air fresheners, Photocopiers, Laser Printers, Car Painting, <http://www.school-for-champions.com/science/staticuse.htm>

### The negative side effects of static electricity

Lightning, Sparks from car - very dangerous at petrol stations, Damage/reduce life of electronic components, Danger around any flammable material



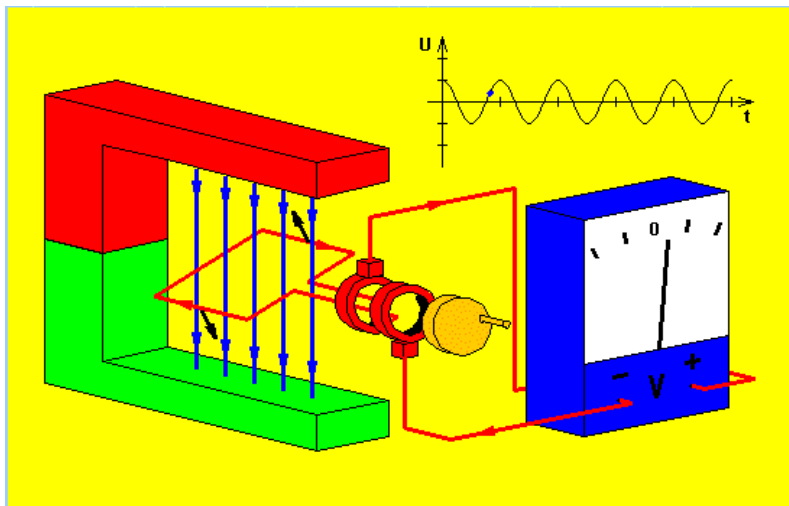
## ESD Electrostatic Discharge



<b>A</b> Static dissipative mats/sheets	<b>G</b> ST-Poly APET	<b>M</b> Wet tissue with antistatic agent
<b>B</b> Antistatic flooring	<b>H</b> ESD shoes and slippers	<b>N</b> Conductive adhesive mat
<b>C</b> PCB Holders	<b>I</b> Wrist straps and alarms	<b>O</b> Wafer Transport System
<b>D</b> Parts Boxes	<b>J</b> Ion Blower	<b>P</b> Static eliminators
<b>E</b> Antistatic bags	<b>K</b> Electrostatic tester	
<b>F</b> Static dissipative seat cover	<b>L</b> Grounding Wire & Conductive Steel Plate	

Many components can be damaged by the high voltages of static electricity that we produce (we can easily generate several thousand volts). A large industry exists to provide anti-static devices to prevent this from damaging electronic components.

## Magnets, Wires and Motion



When a wire moves in a magnetic field electricity is produced. This picture shows the process of generating electricity from motion.



This mechanical torch has no batteries, this means that it will only generate electricity while the lever is being worked.



Turning the hand crank on the front of this radio will charge the internal rechargeable batteries. A one minute crank will give 30 minutes of listening; 30 minutes of cranking will fully charge the batteries for 15 hours of listening

## Group Power Supply Assignment

In groups of six, choose one of the following each:

A. Power stations: Geothermal, Gas Fired, Hydro, Wind, Solar, Wave

Describe in detail its operation, typical uses, hazards, advantages and disadvantages, where it is used (if used) In New Zealand

B. Cells and Batteries

Zinc Carbon, Alkaline, Lithium, Lead Acid, NiCad, NiMh

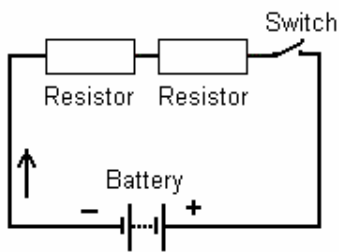
Describe in detail its operation, typical uses, hazards, advantages, disadvantages

	Achieved	Merit	Excellence
Power Station technology	Diagram, location(s), some attempt at description of operation in own words	Pictures and Diagrams with clear descriptions of operation.	Thorough explanations and clear diagrams and pictures of working, sources are referenced.
Battery / Cell Technology	Diagram, location(s), some attempt at description of operation in own words	Pictures and Diagrams with clear descriptions of operation.	Thorough explanations and clear diagrams and pictures of working, source, explains mAh ratings, energy to weight ratio, sources are referenced

In your group you will need to agree on a common format for presentation: A2, A3 or Web, fonts, colours, layout. You will have 2 periods in class to work on this together. Please do not copy information straight from wikipedia or some other source, write the information in your own words.

## Circuit basics

A circuit consists of a number of components and a power supply.



Charges (electrons) cannot flow unless there is a complete circuit (a closed loop).

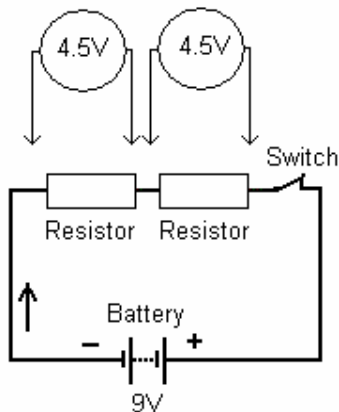
Voltage from a battery is the pressure or force in the circuit that causes the charges to flow.

Current is the flow of charges from the battery around the circuit and back to the battery again. Current is measured in Amps (usually we will use milliamps or mA). It is the measure of the number of electrons that are moving in one second through a point in a circuit.

Note that current doesn't flow charges flow. Just like in a river the current doesn't flow the water flows.

Resistance works to reduce current, the resistors in the circuit offer resistance to the current. They offer friction to the charges flowing and this gives off heat.

Conductors such as the wires connecting components together have (theoretically) no resistance to current flow.



Voltage drop is across components. As charge flows through a component, energy is converted to heat, and voltage is dropped across the component.

If the two resistors are equal in value then half the voltage (4.5V) will be measured across each one when the switch is closed.

Energy is often changed from electrical to heat or light in a circuit.

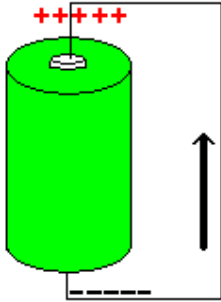
Power is the amount of energy used by a component over time.

## Conventional Current

Before the electron was discovered it was thought that the movement of charge was from positive to negative.

It is common when current is being discussed for conventional current to be meant, that is current will be from positive to negative. If we want to make the difference clear we will say conventional current (positive to negative) or electron current flow (negative to positive)

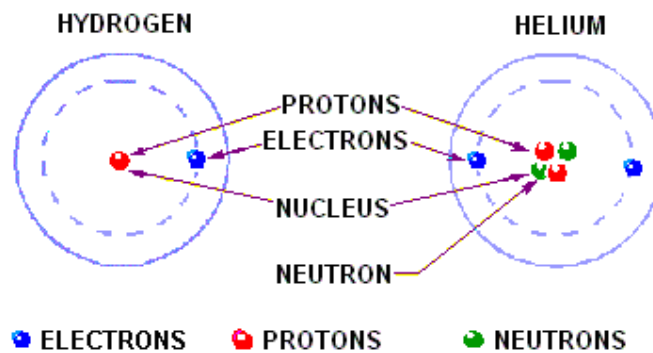
## Conductors



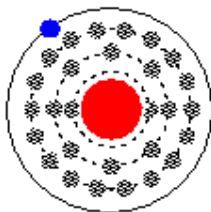
When a difference in potential exists electrons (charges) want to flow from the negative to the positive to balance or cancel it.

Materials that allow electrons to flow freely are called conductors. Insulators are materials that do not allow electrons to move freely.

Materials that have high conductivity are silver, gold, copper, aluminium, steel and iron. To understand why these are good conductors some knowledge about atoms is required. Everything is made up of atoms or structures of atoms. Atoms themselves are made of a nucleus of Protons and Neutrons surrounded by numbers of Electrons. The electrons spin around the nucleus. Electrons have a negative charge, protons a positive charge, neutrons a neutral charge. The sum of all charges in a normal atom is zero making the atom electrically neutral.



The numbers of different neutrons, protons and electrons determine what type of material something is. With larger atoms the nucleus is larger and the electrons are arranged in layers or shells.



Copper

Less electrons in the outer shell means that a material is better at conducting. A single electron in an outer shell on its own tends to be held weakly or loosely bound by the nucleus and is very free to move. This is shown in the copper atom.

The atoms in the outer shell are known as Valence electrons

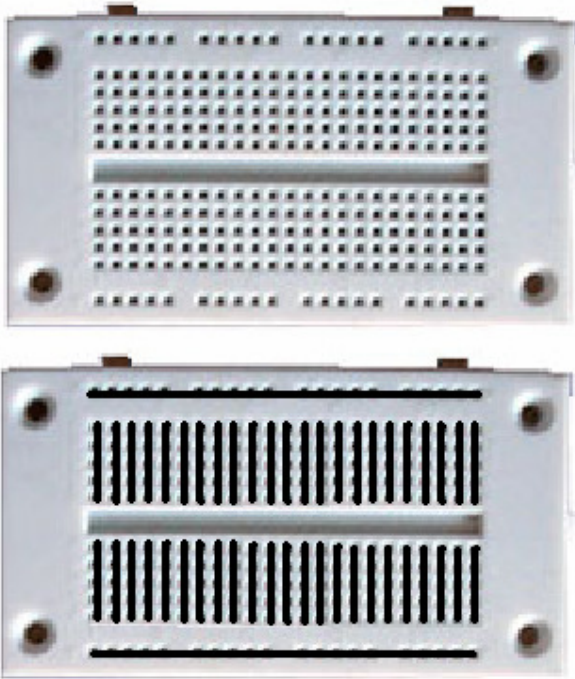
## Insulators

When the outer shell of an atom is full there are no free electrons, these tightly bound valence electrons make the material better at insulating, i.e. no current can flow.

Insulators are used in electronics just as much as conductors to control where current flows and where it doesn't.

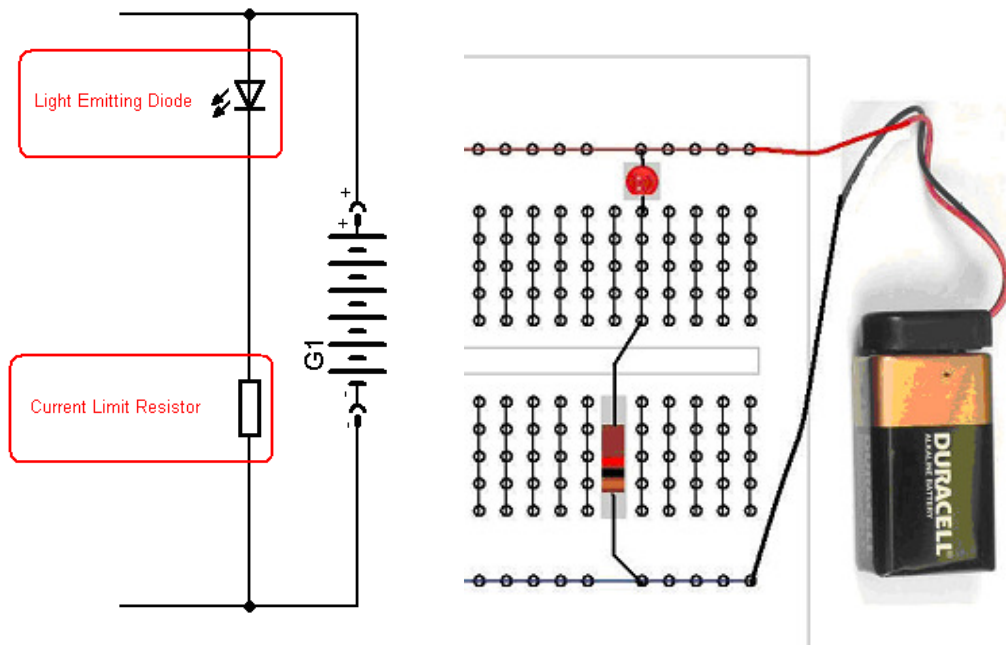
An insulating material can break down however if enough voltage is applied, this is known as an insulators dielectric strength.

## Making circuits on a Breadboard

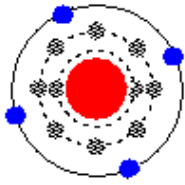


A breadboard is a plastic block with holes and connections in it to make circuits. The holes are arranged so that components can be connected together to form circuits. The top and bottom rows are usually used for power, top for positive and bottom for negative.

This circuit could be built like this, note that the LED must go around the correct way. If you have the LED and resistor connected correctly the LED should light up.



## Semiconductors



Silicon

A semiconductor has a half filled outer shell and its conductivity is not particularly good, it is about halfway between an insulator and a conductor.

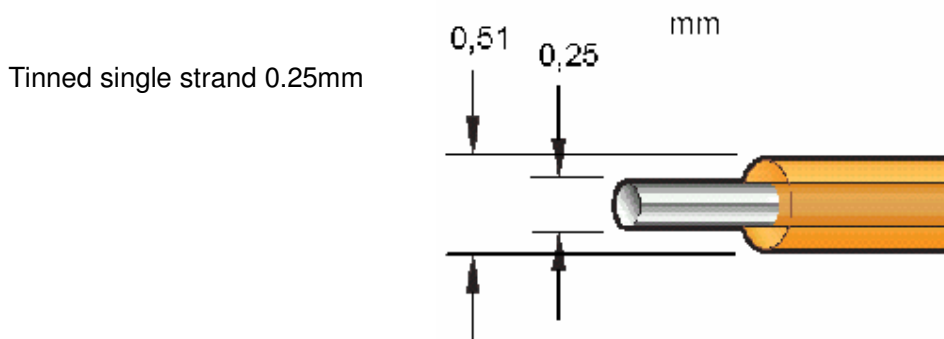
Silicon is the usual semiconductor used in electronics currently.

Normally silicon is not used in its pure or intrinsic form it has other impurities added to it in a process called doping.

## Wire Assignment

We use different types of wire for different jobs. Wires are categorised by the number and diameter of the strands and whether they are tinned or not.

Collect samples of the different types of wire used in class, label each with the wires by its characteristics: e.g. single or multi-stranded, tinned or un-tinned and number and thickness of the strands.



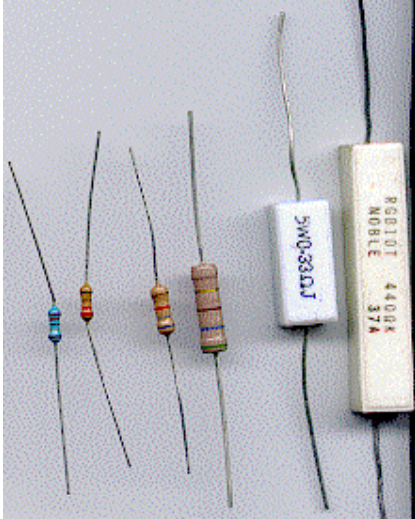
In groups work on the following questions and record the answers in your exercise book.

1. What are some advantages, disadvantages and characteristics of each type of wire?
2. What is tinning, and why are wires tinned?
3. When would you prefer single over multi-stranded wire?
4. When would you prefer multi-stranded over tinned wire?



# Resistors

Resistors reduce the flow of electrons in a circuit.



The unit of resistance is ohms and the symbol is the Greek symbol omega. (Note that we often use the letter **R** on computers because an omega is harder to insert.)

Resistors can be variable in value (used in volume controls, light dimmers, etc) or fixed in value. Common fixed resistor types are Metal Film and Carbon Film.

## Prefixes

Some common resistor values are 1k (1,000) 10k (10,000) 1M (1,000,000) 2k2 (2,200) 47k (47,000).

Conversions between, ohms, kilo and Mega are very important in electronics.

So how do you remember that 1 kOhm = 1000Ohms or 22,000 Ohms = 22k?  
First know that the prefixes are normally in groups of thousands and secondly writing them into a table helps.

Giga	Mega	kilo		milli	micro	nano	pica
G	M	k	R	m	u	n	p
	1 0 0 0	0 0 0	0				
		2 2	0 0 0				
			0 1 4				
			1 8	2 0 0			
2 0	0 0 0	0 0 0					

- 1Mohm = 1,000,000 ohms
- 22k ohms = 22,000 ohms
- 18.2 ohm = 2,200 mohms
- 20,000,000,000 = 20Gohms

Every conversion in in groups of three or thousands so decimal points and commas can only go when lines are shown on the table



## Resistor Prefixes

Note that we use 2k2 not 2.2K when using resistance.

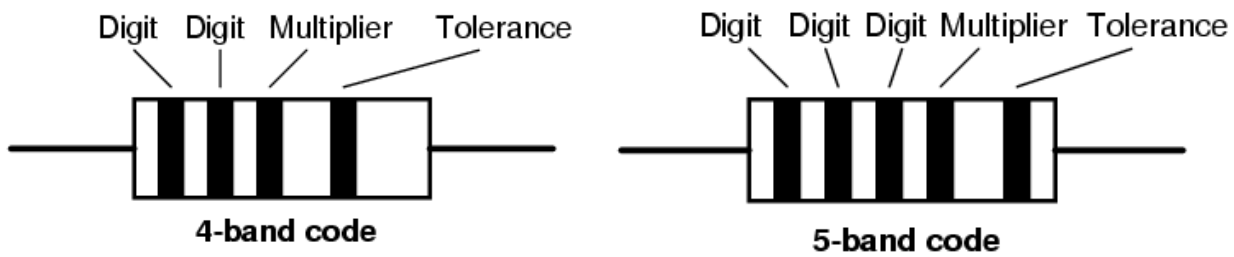
The reason for this is that when a schematic or circuit diagram is photocopied a number of times then the decimal point may disappear leaving 2.2 as 22. This cannot happen when using 2k2 (2,200) 2R2 (2.2) or 2M2 (2,200,000).

Convert the following:

Ohms	Correctly formatted
1500	1K5
5,600,000	5M6
3,300	3k3
12.5	12R5
9,100,000	
	4,500
4,700	
	5R6
10,000	
	9k1
1.8	
22,400	
	1G
10.31	
	100k
	100M
1000k	
4,300,000,000	
0.2	
4580M	
91,000	
3.9k	

## Resistor Values Exercises

Resistor values are normally shown on the body of the resistor using colour codes  
There are 2 schemes, one with 4 bands of colour and one with 5 bands of colour

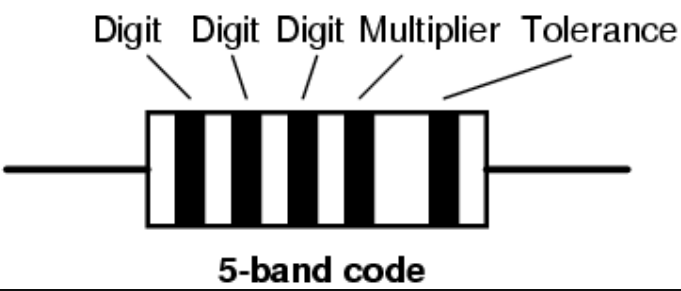


The colour code is

4band	1st	2nd		3rd	4th	
5band	1st	2nd	3rd	4th	5th	
Colour	Value	Value	Value	Multiplier	Tolerance (%)	Colour Abbreviation
Black	0	0	0	0	-	Bk
Brown	1	1	1	1	±1	Bn
Red	2	2	2	2	±2	R
Orange	3	3	3	3		Or
Yellow	4	4	4	4		Y
Green	5	5	5	5		Gn
Blue	6	6	6	6		Bu
Purple	7	7	7	7		Pu
Gray	8	8	8	8		Gy
White	9	9	9	9		Wh
Gold				-1	±5	
Silver				-2	±10	
None					±20	

You will need some practice at using this table.

		<p>1st band, Bn = 1          2nd band, Bk = 0          3rd band, R = 00          4th band, gold = 5%          Answer: 1000 ohm, +/- 5%</p>	
1.	<p>1st band: R _____          2nd band: R _____          3rd band: Or _____          4th band: G _____          Answer:</p>	2.	<p>1st band: R _____          2nd band: R _____          3rd band: R _____          4th band: G _____          Answer:</p>
3.	<p>1st band: R _____          2nd band: P _____          3rd band: R _____          4th band: G _____          Answer:</p>	4.	<p>1st band: Y _____          2nd band: P _____          3rd band: OR _____          4th band: R _____          Answer:</p>
5.	<p>1st band: Y _____          2nd band: P _____          3rd band: Y _____          4th band: G _____          Answer:</p>	6.	<p>1st band: GN _____          2nd band: BU _____          3rd band: BN _____          4th band: G _____          Answer:</p>
7.	<p>1st band: GN _____          2nd band: BU _____          3rd band: R _____          4th band: G _____          Answer:</p>	8.	<p>1st band: O _____          2nd band: O _____          3rd band: Y _____          4th band: G _____          Answer:</p>
9.	<p>1st band: BN _____          2nd band: BK _____          3rd band: BU _____          4th band: Y _____          Answer:</p>	10.	<p>1st band: OR _____          2nd band: W _____          3rd band: BU _____          4th band: G _____          Answer:</p>

 <p style="text-align: center;"><b>5-band code</b></p>		<p>1st band, Bn = 1            2nd band, R = 2            3rd band, BK = 0            4th band, Y = 0000            5th band, R = 2%            Answer: 1,200,000 ohm, +/- 5%</p>	
21.	1st band: Y _____ 2nd band: BU _____ 3rd band: BK _____ 4th band: R _____ 5th band: R _____ Answer:	22.	1st band: BN _____ 2nd band: BK _____ 3rd band: BK _____ 4th band: BK _____ 5th band: BN _____ Answer:
23.	1st band: BN _____ 2nd band: GN _____ 3rd band: BK _____ 4th band: BN _____ 5th band: Bn _____ Answer:	24.	1st band: OR _____ 2nd band: Y _____ 3rd band: R _____ 4th band: G _____ 5th band: R _____ Answer:
25.	1st band: R _____ 2nd band: GY _____ 3rd band: BN _____ 4th band: BK _____ 5th band: BN _____ Answer:	26.	1st band: P _____ 2nd band: GN _____ 3rd band: Y _____ 4th band: R _____ 5th band: R _____ Answer:
27.	1st band: BU _____ 2nd band: BK _____ 3rd band: BU _____ 4th band: R _____ 5th band: BN _____ Answer:	28.	1st band: R _____ 2nd band: BN _____ 3rd band: BK _____ 4th band: S _____ 5th band: R _____ Answer:
29.	1st band: BN _____ 2nd band: BN _____ 3rd band: BN _____ 4th band: G _____ 5th band: BN _____ Answer:	30.	1st band: Y _____ 2nd band: P _____ 3rd band: BK _____ 4th band: Y _____ 5th band: R _____ Answer:

<b>4 BAND 4700 ohm, 5% = yellow, purple, red, gold</b>			
41.	100 ohm, 2%	42.	1000 ohm, 5%
43.	150 ohm, 5%	44.	270 ohm, 5%
45.	3300 ohm, 5%	46.	10 ohm, 1%
47.	470 ohm, 2%	48.	6800 ohm, 10%
49.	3K3, 5%	50.	1K, 5%
51.	150 ohm, 1%	52.	2M9, 10%
53.	10M, 10%	54.	1 Megohm, 5%
55.	1 ohm, 1%	56.	3M9, 20%

<b>5 BAND 4700 ohm, 2% = yellow, purple, black, brown, red</b>	
73. 10 ohm, 2%	74. 1000 ohm, 1%
75. 150 ohm, 1%	76. 270 ohm, 1%
77. 3300 ohm, 2%	78. 10 ohm, 1%
79. 470,000 ohm, 2%	80. 68,000 ohm, 2%
81. 3K3, 1%	82. 1K5, 2%
83. 1500 ohm, 1%	84. 2M9, 1%
85. 100M, 1%	86. 1 Megohm, 2%
87. 1 ohm, 1%	88. 3M9, 2%

## Combining resistors in series

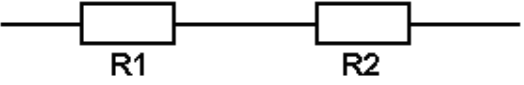
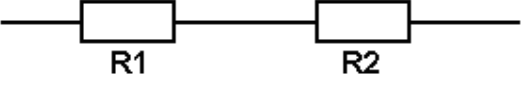
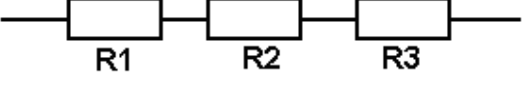


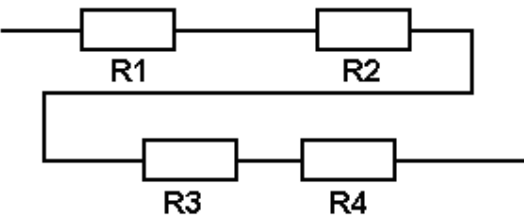

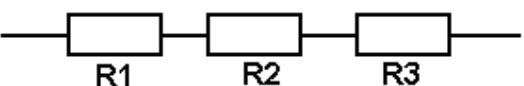
Sometimes it is necessary to put resistors in series to get the value we need.

In circuit diagrams we use names for components such as R1, R2, R3, R4 and Rt means the total resistance.

Wherever you see **ohms** you should replace it with the symbol  $\Omega$  in your work

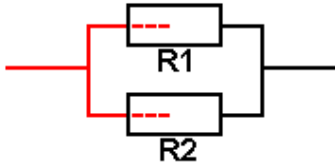
1.		R1= 100R R2=300R	Rt =
2.		R1= 10k R2=30k	Rt =
3.		R1= 1k8 R2=10k	Rt =
4.		R1= 1M R2=22k	Rt =
5.		R1= 1R5 R2=68R	Rt =
6.		R1= 220R R2=4K7R	Rt =
7.		R1= 4R2 R2=10R	Rt =
8.		R1= 33k R2=1k5	Rt =



<p>9.</p> 	<p><math>R1 = 22M</math> <math>R2 = 6M8</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>10.</p> 	<p><math>R1 = 1R9</math> <math>R2 = 4R6</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>11.</p> 	<p><math>R1 = 2R7</math> <math>R2 = 3R3</math> <math>R3 = 5R6</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>12.</p> 	<p><math>R1 = 4k7</math> <math>R2 = 1K8</math> <math>R3 = 9K2</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>13.</p> 	<p><math>R1 = 2M6</math> <math>R2 = 110K</math> <math>R3 = 330K</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>14.</p> 	<p><math>R1 = 1M8</math> <math>R2 = 720K</math> <math>R3 = 390K</math> <math>R4 = 180K</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>15.</p> 	<p><math>R1 = 2R2</math> <math>R2 = 7R6</math> <math>R3 = 14</math> <math>R4 = 10</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>
<p>16.</p> 	<p><math>R1 = 22K</math> <math>R2 = 7K4</math> <math>R3 = 3K9</math> <math>R4 = 2K7</math></p>	<p><math>R_t =</math> <math>R_t =</math> <math>R_t =</math></p>

## Combining resistors in parallel

When two resistors are put in parallel the current has 2 paths it can take



The current will split between the two resistors, the current in each split will be related to the values of each resistor. The overall effect is the same as if a **smaller** value of resistance was used.

The formula for calculating the total resistance is:

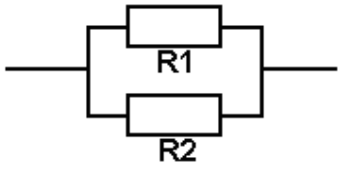
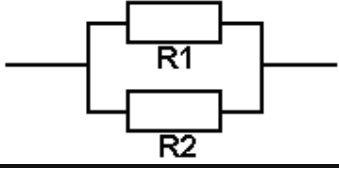
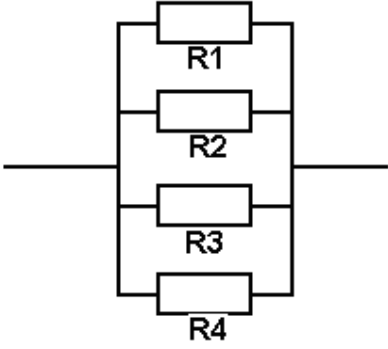
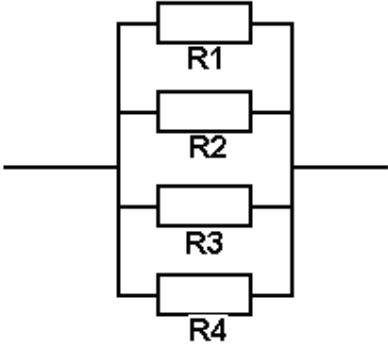
$$1/R_t = 1/R_1 + 1/R_2 \text{ or}$$

$$R_t = 1 / ( 1/R_1 + 1/R_2 )$$

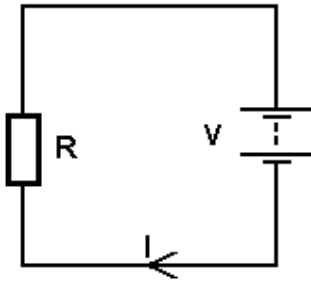
On a calculator this can be entered directly using the inverse function the **1/x** button.

**enter R1 press 1/x press + enter R2 press 1/x press = press 1/x**

1.		R1 = 9K R2 = 6K	Rt = 1/(1/9,000 + 1/6,000) Rt = Rt =
2.		R1 = 100 R2 = 400	Rt = Rt = Rt =
3.		R1 = 1K R2 = 2K2	Rt = Rt = Rt =
4.		R1 = 1M8 R2 = 4M7	Rt = Rt = Rt =

5.		$R1 = 1K$ $R2 = 1K$	$R_t =$ $R_t =$ $R_t =$ What is significant about this answer?
6.		$R1 = 100K$ $R2 = 60K$	$R_t =$ $R_t =$ $R_t =$
7.		$R1 = 2K2$ $R2 = 3K3$ $R3 = 2K$ $R4 = 4K7$	$R_t =$  $R_t =$ $R_t =$
8.		$R1 = 90M$ $R2 = 20M$ $R3 = 10M$ $R4 = 80M$	$R_t =$  $R_t =$ $R_t =$
9.	Draw 3 resistors in parallel	$R1 = 90R$ $R2 = 15R$ $R3 = 3R3$	$R_t =$  $R_t =$ $R_t =$
10.	You need 180R, you have the following resistors choose 2 in parallel that would give the value closest to the desired value:  360R, 4k7, 680R 2k2		

## Ohms law



This is perhaps the most important formula in electronics. You must be able to use it and begin to develop an understanding of its meaning.

In a circuit a potential difference of one volt will drive one ampere of current through one ohm of resistance.

The formula is Voltage = Current times Resistance or  **$V=I \cdot R$** .

If 0.5A is flowing through a 10 ohm resistor then what is the voltage?  
 Answer:  $V=I \cdot R$ ,  $V=0.5 \cdot 10$ ,  $V=5$ Volts.

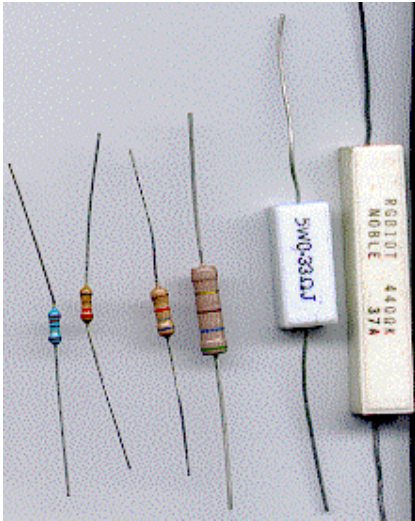
If the voltage is 10volts and the resistance is 2ohms then what current is flowing? Answer:  $I=V/R$ ,  $I=10/2$ ,  $I=5$ A.

At 9V, if 0.0019A is flowing what is the value of R? Answer:  $R=V/I$ ,  $R=9/0.0019$ ,  $R=4,700$  ohms

1.	$I= 0.002A$ , $V= 16V$	$R =V/I$ , $R=16/0.002$ , $R=8000$ ohms = 8kohms
2.	$V= 12V$ , $I= 0.015A$	$R =$
3.	$V= 9V$ , $I= 2A$	$R =$
4.	$I= 0.0001A$ , $V= 5V$	$R =$
5.	$R= 2000$ , $V= 6V$	$I =$
6.	$V= 50V$ , $R= 10,000$	$I =$
7.	$V= 3V$ , $R= 100,000$	$I =$
8.	$R= 47,000$ , $V= 20V$	$I =$
9.	$I= 0.00183A$ , $R= 12000$ ohms	$V =$
10.	$I= 0.0015$ , $R= 1000$ ohms	$V =$
11.	$R= 20R$ , $I= 0.2$	$V =$
12.	$I= 0.4$ , $R= 120R$	$V =$

## Power Calculations

When a resistor reduces the flow of current in a circuit power is used. Power is the rate at which energy is converted from one form to another. In a resistor this is from potential energy to heat.



Power = voltage times current,  $P=V*I$  , Power is measured in Watts. 2V across a 10ohm resistor.  $I=V/R$ ,  $I= 2/10$ ,  $I=0.2A$ , so  $P=V*I$ ,  $P=2*0.2$ ,  $P= 0.4W$ .

Resistors come in different power ratings so it is important in a circuit to understand that the power ratings should not be exceeded or the component may overheat, become burnt and have its life shortened or be destroyed.

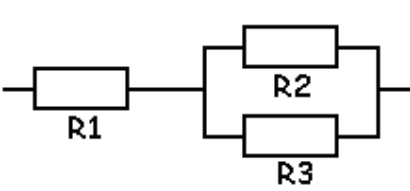
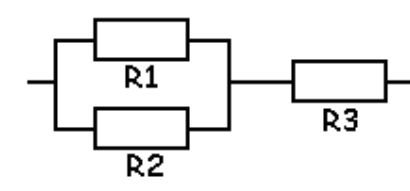
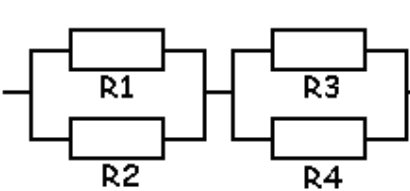
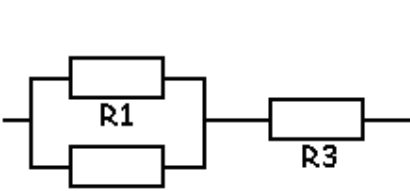
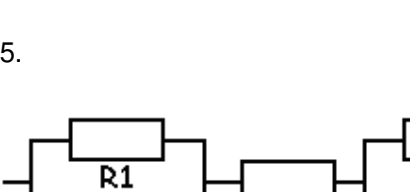
Resistors can be bought in various ratings, here is a selection

1/8, 1/4, 1/2, 1, 5 & 10 Watts

Note that the size grows with the rating

$V = 10V$ $I = 2A$	$P = V * I$ , $P = 10*2$ , $P=20W$
$V = 5V$ $I = 0.3A$	
$I = 200mA$ $V = 12V$	
$V = 100V$ $I = 3mA$	
$V = 100V$ $P = 50W$	
$V = 48V$ $I = 20mA$	
A 5 Watt bulb draws 1.6A what is the voltage?	
A 12 battery supplies 20mA to a resistor, what is the power?	
What wattage resistor would you use for 15V and 0.2A	
What wattage resistor would you use for 36V and 100mA	

## Resistor Combination Circuits

<p>1.</p> 	<p><math>R1 = 10k</math>  <math>R2 = 2k</math>  <math>R3 = 3k</math></p>	<p><math>R_t =</math></p>
<p>2.</p> 	<p><math>R1 = 4k7</math>  <math>R2 = 8k2</math>  <math>R3 = 1k5</math></p>	<p><math>R_t =</math></p>
<p>3.</p> 	<p><math>R1 = 16k</math>  <math>R2 = 12k</math>  <math>R3 = 18k</math>  <math>R4 = 15k</math></p>	<p><math>R_t =</math></p>
<p>4.</p> 	<p><math>R1 = 1k1</math>  <math>R2 = 1k5</math>  <math>R3 = 470R</math>  <math>R4 = 680R</math></p>	<p><math>R_t =</math></p>
<p>5.</p> 	<p><math>R1 = 4k7</math>  <math>R2 = 1k8</math>  <math>R3 = 33R</math>  <math>R4 = 560R</math>  <math>R5 = 330R</math></p>	<p><math>R_t =</math></p>

## Multimeters

To understand how circuits function and to find faults with them when they are not working it is necessary to know how to use a multimeter.



There is a rotary switch to select the correct measurement scale.

If you are measuring voltage in a circuit with a 9V battery you would put the meter scale onto 20V

. As the range gets closer to the actual value the accuracy gets better.



## Multimeter controls



This multimeter is a common type.

The display has \_\_\_\_\_ digits. It can display numbers from 0.00 to 1999.

There are \_\_\_\_\_ different positions on the rotary switch.

V is for \_\_\_\_\_ and the ranges are

\_\_\_\_\_

A is for \_\_\_\_\_ and the ranges are

\_\_\_\_\_

The ohms scale has an \_\_\_\_\_ symbol.

Its ranges are \_\_\_\_\_

\_\_\_\_\_

There are 3 different sockets for the probes to plug into these are labelled

\_\_\_\_\_

The hFE selection is for testing

\_\_\_\_\_

COM stands for \_\_\_\_\_ and the black/red probe goes into it.

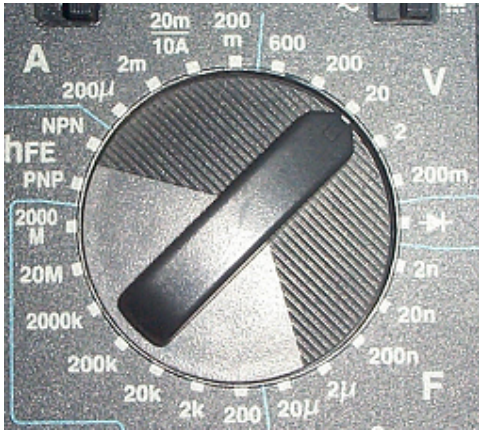
The black/red probe goes into one of the other sockets.

What is the power source for the meter itself? \_\_\_\_\_

## Choosing correct meter settings

Selecting the switch position is very important to making accurate measurements. Know what you want to measure voltage, current or resistance.

The second step is selecting the range of the measurement. If an approximate value is known then choose the next higher setting on the range switch. Generally we use 9 volt batteries in our circuits, if you want to measure voltages around a 9 volt circuit then what range would you choose for the meter? \_\_\_\_\_



If you did not know the voltage in the circuit which range would you choose? \_\_\_\_\_

Many of the resistors we use are 5 band, very small size and hard to read. What range would be best to choose first on the meter? \_\_\_\_\_

What range would you choose to measure a resistor you thought was 91Kohms. \_\_\_\_\_

What range would you choose to measure a resistor with colours red, red, orange, brown? \_\_\_\_\_

What is the highest resistance value that can be read on the meter? \_\_\_\_\_

What is the lowest resistance that could be measured on the meter? \_\_\_\_\_

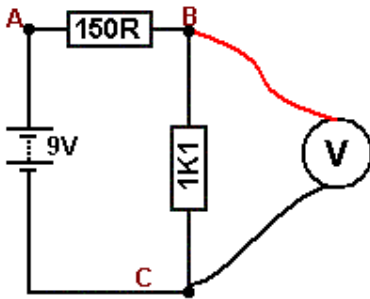
When measuring current where would you put the probes and what range would you choose to start with?  
\_\_\_\_\_

If no current readings are being shown on the meter it is possible that the  
\_\_\_\_\_.

When making a measurement and its value is greater than the scale used the display shows  
\_\_\_\_\_

## Voltage & Current Measurements

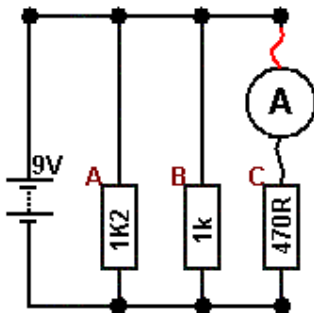
### Measuring Voltage



- Calculate the voltage across each resistor
- Circuit current first.
- $I = V/R =$  \_\_\_\_\_
- $V(1k1) = I \times R =$  \_\_\_\_\_
- $V(150R) = I \times R =$  \_\_\_\_\_
- Setup the multimeter correctly and measure the voltages in this circuit.
- What was the voltage measured across the 1k1  
\_\_\_\_\_ across the 150R \_\_\_\_\_

### Measuring Current

To measure current in a circuit the circuit must be broken and the meter inserted into it.



- Calculate the current through each resistor.
- $I_A = V/R_A$ ;  $I_A =$  \_\_\_\_\_
- $I_B = V/R_B$ ;  $I_B =$  \_\_\_\_\_
- $I_C = V/R_C$ ;  $I_C =$  \_\_\_\_\_
- Measured Values
- $I_A =$  \_\_\_\_\_,
- $I_B =$  \_\_\_\_\_,
- $I_C =$  \_\_\_\_\_

There are at least two reasons for differences between calculated and measured values in this circuit what could they be?

---



---

### Meter Safety

- The meter is a delicate instrument handle it with care.
- Estimate what your measuring first and set the meter range to a larger value( or even to the maximum value),
- Do not measure resistance in a circuit when the circuit is on.
- Check the internal fuse is correct before measuring current.
- Turn the meter off after use.

### Circuit Safety

- Using the meter on a current setting when wanting to measure voltage can easily damage components and even the circuit board.
- Take care not to short parts of the circuit with the probes.

### Battery Life

- Switch the meter off when finished using it.

# Measuring Resistance

## Continuity

One range on the meter will beep when the probes are shorted together, or a very low value of resistor is connected. It is very useful for

- checking cables are not broken
- checking that tracks between parts of a PCB are not broken
- checking that tracks are not shorted together on a PCB

Find 6 items that are good conductors

---

---

and 6 items that are poor conductors

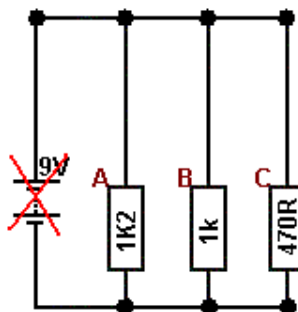
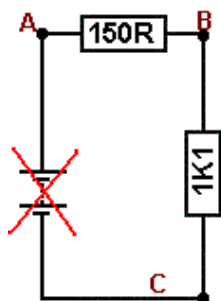
---

---

## In-circuit measurements

When a resistor is unknown or suspected faulty its resistance can be measured using the multimeter on ohms range. When measuring resistors "in circuit" you must disconnect the power. To measure resistance the meter puts current through the resistor and measures the voltage across it so current from within the circuit will confuse the readings and the meter or the circuit could be damaged.

Measure the resistors in the following circuits.



Explain your readings for the second circuit.

## Variable Resistors

Variable resistors or potentiometers, are used to change the input to an electronic circuit.



They come in different shapes, sizes and values as well 'dual-gang' (what use is a dual one?)

Some are designed to be varied by the user of the circuit, and are fitted with knobs to turn them, such as those used as volume controls.

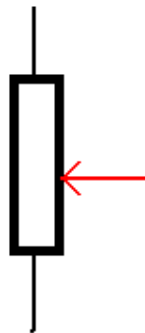
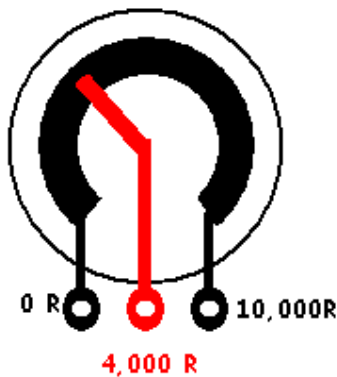


Others are called trimpots and are meant to be varied only by service people when working on the inside of equipment, these are turned with a screwdriver.

Most pots vary over 270 degrees not the full 360 degrees.

The resistance between the two outer terminals does not change, only the resistance between the centre terminal and both the outer terminals.

For this 10k pot, fill in the missing values from the table

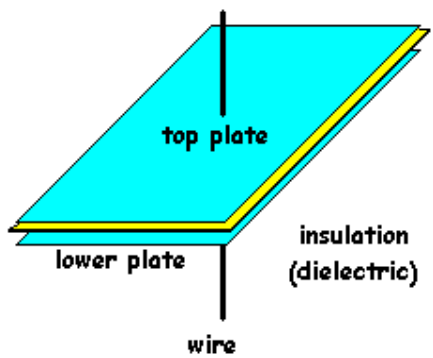


angle	0 to centre	centre to 10k
0	0 R	10,000 R
30	1,000 R	
108	4,000 R	
	5,000 R	5,000 R
190	7,000 R	
		1,000
270	10,000 R	0 R

If a lever was attached to the control of a pot what sort of things could be sensed by the circuit?

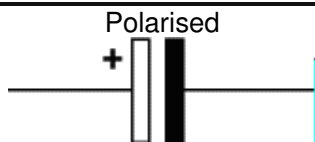
## Capacitance

A capacitor is made from 2 conductors separated by an insulator. Electrons do not flow through a capacitor, they flow onto one plate causing electrons to flow away from the other plate. Once the capacitor is full no more electrons can flow. Capacitors store charges.



There are two main symbols for capacitors

and many different types



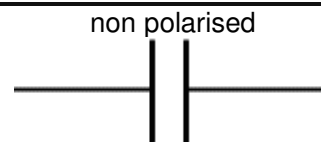
such as an electrolytic



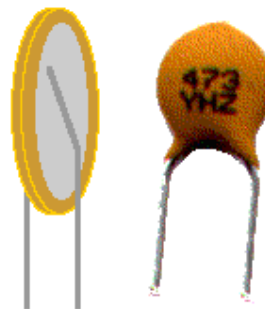
and tantalum



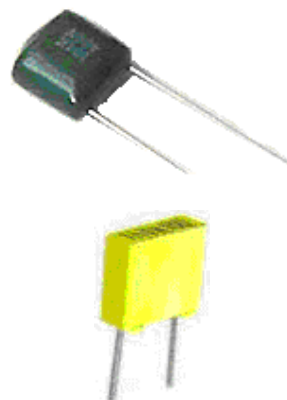
Note the 50V voltage rating on the electrolytic, all capacitors are rated up to a particular voltage, exceeding this may cause the capacitor to overheat and explode.



such as ceramic disc



polyester



## Capacitor Codes and Values

Capacitors not only come in a variety of packages but there are also a number of different ways that their values can be printed onto them. Some values are in uF, some in nF and some in pF, and it can be confusing until you learn the few simple rules.

1. learn the prefixes first, micro uF, nano nF, and pico pF micro is the biggest, nano in the middle and pico the smallest and learn how to convert between them.

2. Look at the capacitor to see what is written on it. If it has 10uF or 22n the it is obvious what value it is.

However when it is written with 3 digits such as 333, then it will be in pF even though it is not stated, and the last digit will be the number of zeros ( a bit like resistor colour codes) so 333 means 33,000 pF.

Convert the following

333 =	33,000pF
330 =	330pF
221 =	
470 =	
474 =	

33 =	33pF
685 =	
220 =	
68 =	
276 =	

## Converting Capacitor Values uF, nF , pF

farads units	micro u	nano n	pico p
	1		
	1	0 0 0	
	1	0 0 0	0 0 0

$$1\mu\text{F} = 1,000\text{nF} = 1,000,000\text{pF}$$

		1	
	0 0 1		

$$1\text{nF} = 0.001\mu\text{F}$$

- 10nf to pf
- 82nF to uF
- 2200pf to nF
- 100,000nF to uF
- 370pF to nF
- 4u7 to nF
- 3n3 to uf
- 3n3 to uF
- 220,000pF to uf
- 1800nF to pf
- 3900nF to uF
- 100pF to uF

	farads units	micro u	nano n	pico p
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				
L				

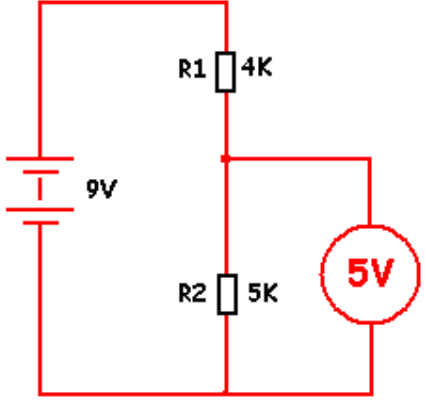
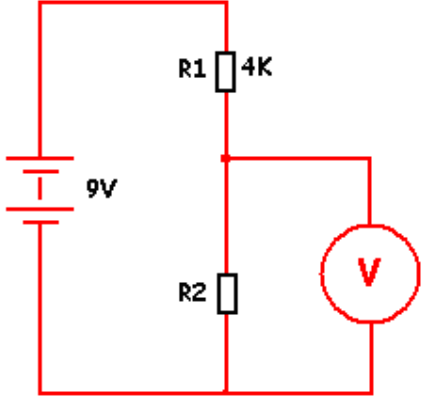
## The Voltage Divider

This is one of the most important circuits in electronics. It is used extensively in input circuits to bring physical real world data into an electronic circuit.

Below is a 2 resistor voltage divider circuit. The output voltage is the voltage across  $R_2$ .

Step 1. Voltage and total resistance are known, so  $I = V_{in}/R_t$

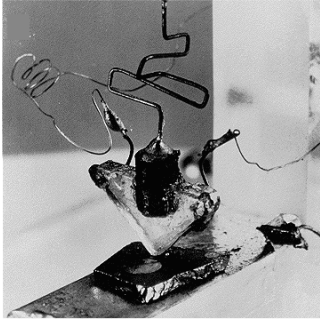
Step 2:  $R_2$  and Current through  $R_2$  are known, so  $V_{out} = I * R_2$

	<p>With 9 volts across both resistors then:</p> $I = V_{in}/R_t$ $I = 9/(4000 + 5000)$ $I = 9/9000$ $I = 0.001A$ <p>across the 5k resistor</p> $V_{out} = I * R_2$ $V_{out} = 0.001 * 5000$ $V_{out} = 5V$
<p>Work out the solution to the following.</p> 	<p><b><math>R_2 = 1K</math></b></p> $I = V_{in}/R_t$ $I = 9 / (4000 + \underline{\hspace{2cm}})$ $I = \underline{\hspace{2cm}}$ $V_{out} = I * R_2$ $V_{out} = \underline{\hspace{2cm}} * 1000$ $V_{out} =$
<p><b><math>R_2 = 8K</math></b></p> $I = V_{in}/R_t$ $I = \underline{\hspace{2cm}}$ $I = \underline{\hspace{2cm}}$ $V_{out} = I * R_2$ $V_{out} = \underline{\hspace{2cm}} * 1000$ $V_{out} =$	<p><b><math>R_2 = 4K</math></b></p> $I =$ $I =$ $I =$ $V_{out} =$ $V_{out} =$ $V_{out} =$

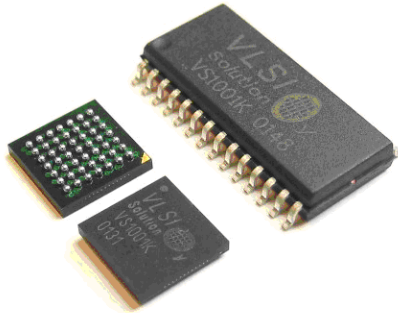
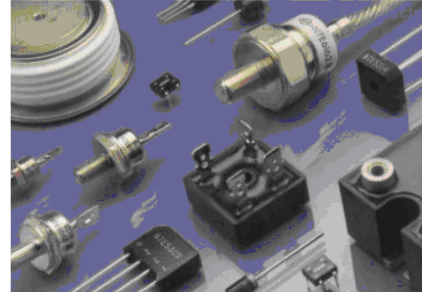


# Semiconductors

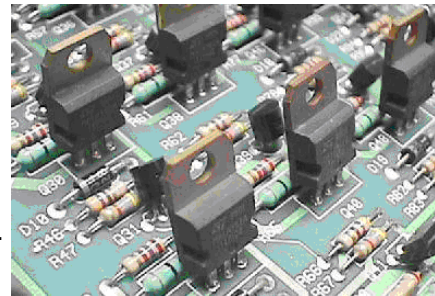
Semiconductors are the group of electronic components responsible for everything smart that electronic circuits do. Made mostly from the semiconductor silicon, which is itself a very poor conductor, they take on fantastic features when mixed with other material.



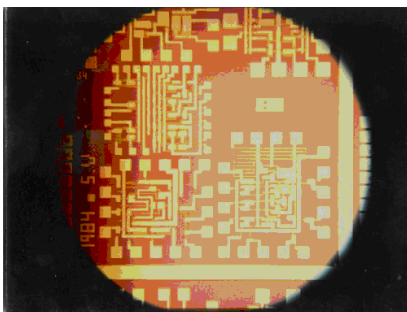
Since the first transistor was developed in 1947 they have come a long way.



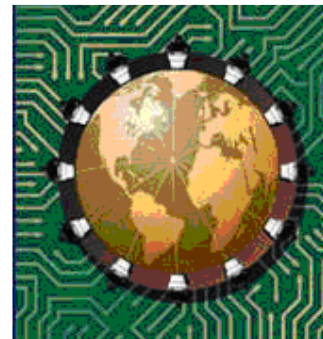
They come in all shapes and sizes. from miniature surface mount packages to large high power packages.



They amplify, switch, and control every conceivable process.



All over the world



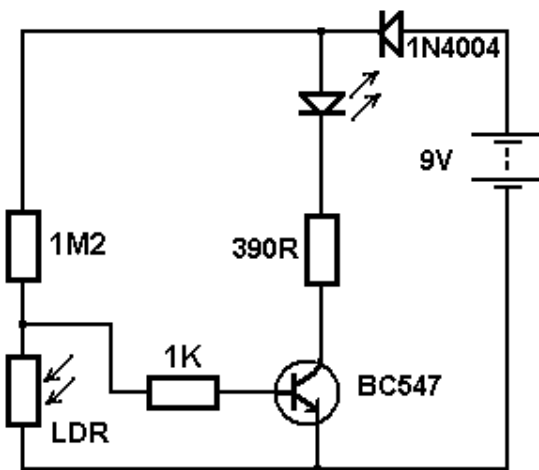
## Diodes

Diodes are very common components, they come in all shapes and sizes.



The key characteristic of a diode is that it current flow is in only one direction. You cannot reverse it in the circuit and expect it to work.

In this circuit the power is supplied from the battery.



The circuit is protected by a diode, this means if the battery is connected in reverse then the current will not flow because the diode blocks it.

Of course no diode is perfect and should the voltage of the power supply exceed the voltage rating of the diode then the diode would breakdown, this means the current would increase rapidly and it would burn up. The 1N4004 has a 400V rating.

Diodes of course can only take a certain current flow in the forward direction before they overheat and burn up. The 1N4004 has a maximum forward current of 1Amp.

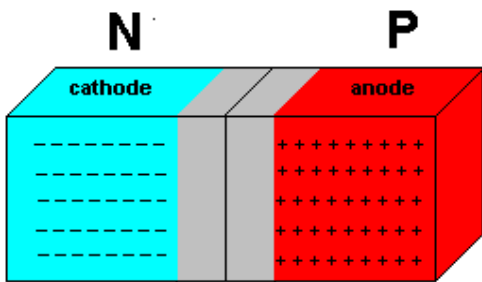
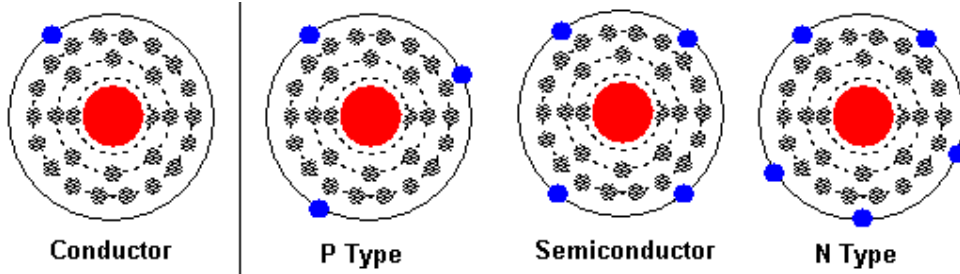
### Diode Research Assignment

Research the specifications for these two common diodes (ones we use often in class)

	1N4005	1N4148
Peak reverse voltage		
Maximum forward current		

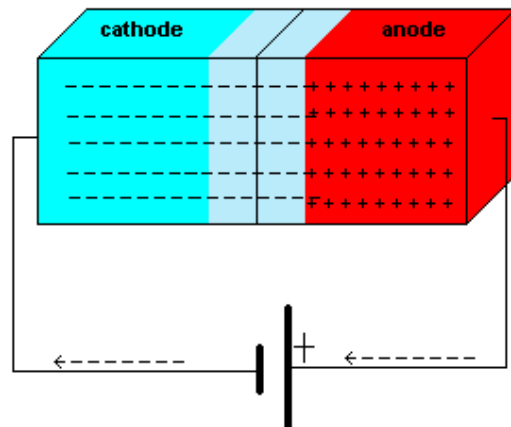
# Diode Theory

A diode is made from silicon (a semiconductor). Semiconductors have more electrons in their outer shells than conductors. To the silicon other materials (impurities) are added, these other materials have either more or less electrons in the outer shell. A diode is made from a piece of silicon which is doped with both N-type and P-type impurities.

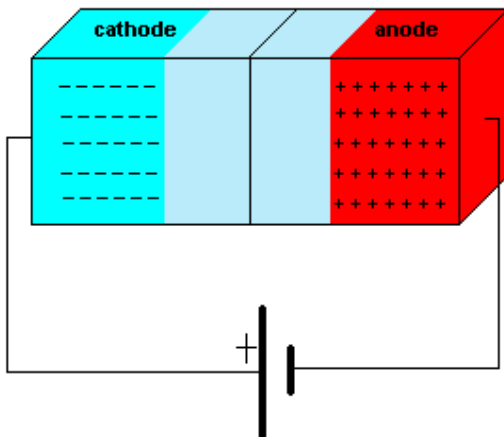


One part of the silicon has N-type impurities added (slightly more conductive), in the other part P-type impurities are added (slightly less conductive).

When a diode is connected to the diode there is a region in the middle where some electrons flow over and the effect is cancelled out (the depletion region).



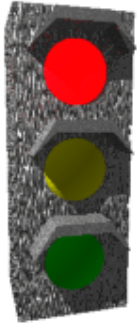
When a large enough voltage is applied to a diode (0.4v to 0.6V) electrons will flow from the negative to positive. This is called forward bias. In the process depletion region disappears.



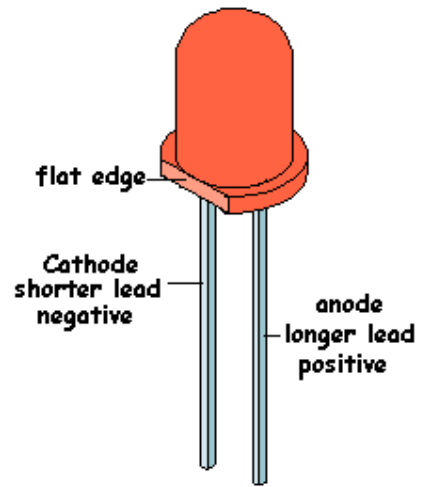
When the battery is connected back to front the diode is "reverse biased" and the depletion region in the middle gets larger, so electrons cannot flow. This explains why **diodes conduct only when connected into a circuit the right way around.**

## LED's

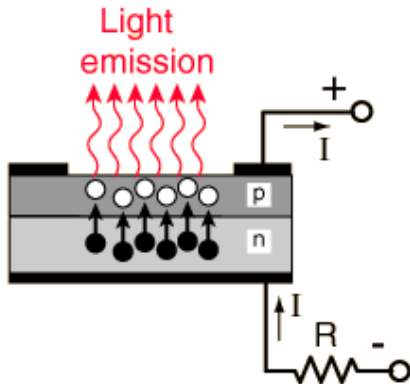
Light Emitting Diodes are currently used in indicators and displays on equipment, however future applications are replacing halogen and incandescent bulbs in many different applications. These include vehicle lights, traffic signals, outdoor large TV screens.



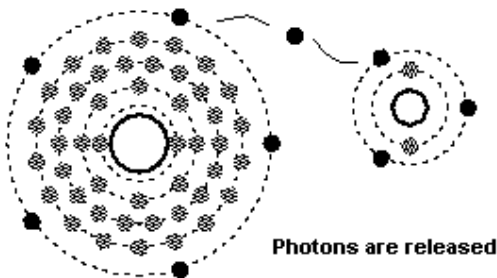
Compared to incandescent bulbs (wires inside glass bulbs that glow), LEDs give almost no heat and are therefore highly efficient. They also have much longer lives e.g. 10 years compared to 10 months. So in some situations e.g. traffic signals, once LEDs are installed there can be cost savings made on both power and maintenance.



### How does a LED give off light?



In an LED when electrons move from the N side to the P side photons are released.



Photons are released whenever electrons move from one shell level in an atom to another. In an LED the electrons move from the N to the P and also change levels within the atomic structure at the same time, therefore releasing photons.

Note that the voltage required for an LED to conduct is much greater than a normal diode. Typical values range from 1.8V to 3.6V, and like an ordinary diode they only work in one direction

## LED Colours

In an LED different colours are achieved by using different types of impurities.

<b>Light Emitting Diode Colour Variations</b>		
Color Name	Wavelength (Nanometers)	Semiconductor Composition
Infrared	880	GaAlAs/GaAs
Ultra Red	660	GaAlAs/GaAlAs
Super Red	633	AlGaInP
Super Orange	612	AlGaInP
Orange	605	GaAsP/GaP
Yellow	585	GaAsP/GaP
Incandescent White	4500K (CT)	InGaN/SiC
Pale White	6500K (CT)	InGaN/SiC
Cool White	8000K (CT)	InGaN/SiC
Pure Green	555	GaP/GaP
Super Blue	470	GaN/SiC
Blue Violet	430	GaN/SiC
Ultraviolet	395	InGaN/SiC

### Some LED Specifications

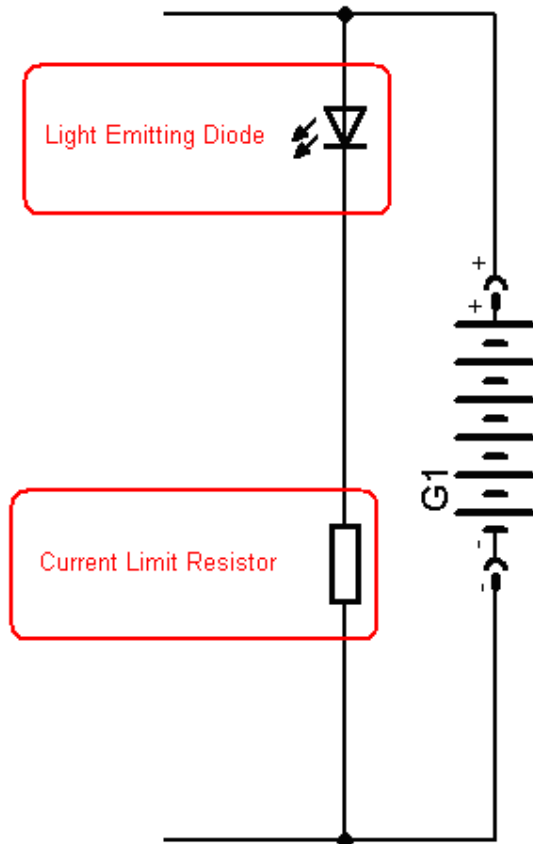
- Intensity: measured in mcd (millicandela)
- Viewing Angle: The angle from centre where intensity drops to 50%
- Forward Voltage: Voltage needed to get full brightness from the the LED
- Forward Current: Current that will give maximum brightness, use a current limit to control this or the led will die!!
- Peak Wavelength: the brightest light emitted

## LED research assignment

From a supplier in New Zealand (e.g. Surplustronics, DSE, Jaycar, SICOM) find the information and the specifications for two LEDs, a normal RED 5mm LED and a 5mm high intensity LED.

LED	RED 5mm	High intensity 5mm
Supplier		
Part number		
Cost (\$)		
Brightness (mcd)		
Forward voltage (Vf)		
Wavelength (nm)		
Forward current (If)		

## Using LEDs in circuits



In the amplifier circuit there is an LED to indicate that power is on.

The resistor in series with the LED functions to **limit the current** through the LED.

AN LED requires a small forward voltage e.g. \_\_\_\_V across it to operate, however the circuit is powered by a 9V battery. The rest of the battery voltage must be dropped across the resistor.

Ohms law will assist with this calculation.

1. The resistor will have  $9V - \text{____} V = \text{____} V$  across it.
2. An led draws about \_\_\_\_mA of current, this current goes through the resistor so
3. the resistor will need to be  $R = V / I = \text{____} / \text{____} = \text{____}$  ohms.
4. Choose the closest value from the available values of resistors.

If two LEDs were placed in series what value of resistor would be required?

## The LDR

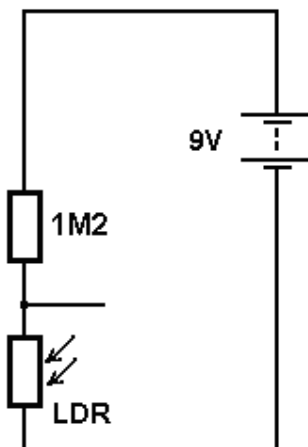


The LDR or Light Dependant Resistor is a common component used in circuits to sense light level. An LDR varies resistance with the level of light falling on it. LDRs are made from semiconductors such as Selenium, Thalliumoxid and Cadmiumsulfide. As photons of light hit the atoms within the LDR, electrons are knocked out of the outer shell, and they can flow through the circuit. This means that as light level increases, resistance decreases. Find an LDR and measure its resistance:



in full daylight the LDRs resistance is approximately \_\_\_\_\_

in darkness the LDRs resistance is approximately \_\_\_\_\_



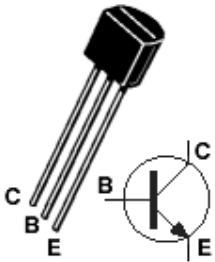
LDRs can only with stand a small current flow e.g. 5mA, if to much current flows they may overheat and burn out.

They are used within voltage divider circuits.

1. The components are a 1M2 (1,200,000) ohm resistor, an LDR, a 9V battery and the circuit is a series one.
2. This combination is the voltage divider.
3. When it is dark the LDR has a high resistance and the output voltage is high.
4. When it is bright the LDR has a low resistance and the voltage is low.

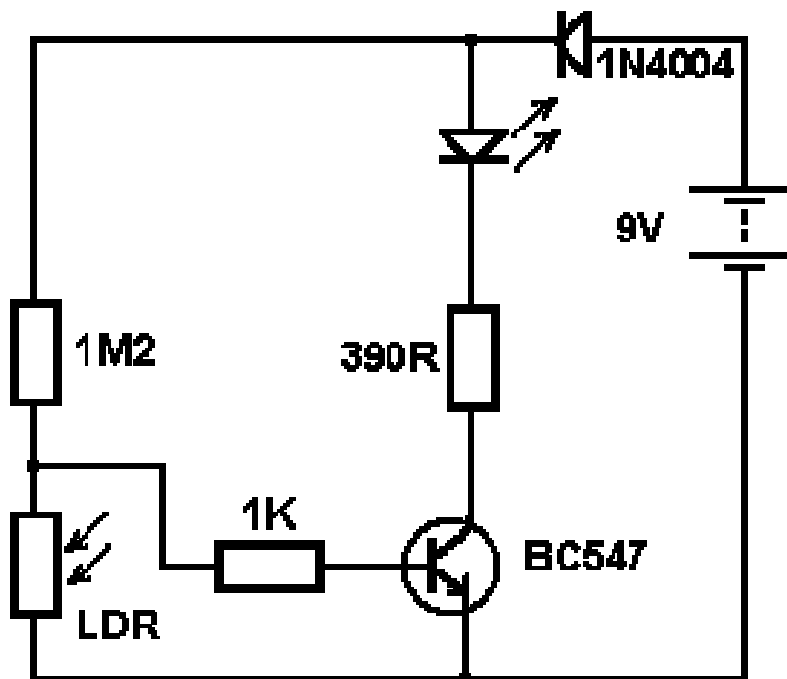
## The Transistor

There are several different types of transistor, the correct name for the normal transistor is Bipolar Junction Transistor. In this course transistor will refer to Bipolar Junction Transistor.



Transistors are semiconductor devices with three leads: an emitter, a base and a collector.

The BC547 transistor is just one of the many thousands of different types of transistors. The BC547 is an NPN transistor, there are also PNP transistors the BC557 is an equivalent PNP transistor .



Transistors are amplifiers, a small voltage across the base-emitter junction (the small arrow in the diagram) will control the current (the large arrow) from the emitter through to the collector.

The small voltage across the base is called  $V_{be}$ , the current through the base caused by this voltage is called  $I_b$ . And the current through the collector is called  $I_c$ .

Small variations in the base voltage  $V_{be}$  can create large changes in the collector current  $I_c$ .

The voltage required across the base of the transistor ( $V_{be}$ ) is normally around 0.3V to 0.7V.



## Transistor Specifications

Transistors are said to have a current gain, ( $h_{FE}$ ) this is the ratio of base current ( $I_b$ ) to collector current ( $I_c$ ). If  $I_b$  is 2mA and  $I_{ce}$  is 100mA then the gain is said to be  $100/2 = 50$ .

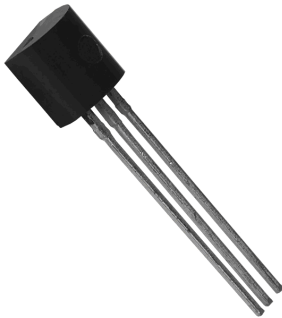
Transistors have limits to the voltages and currents applied to them in circuits. They should not be exceeded. If the voltages across the base or collector are too high then the transistor will most likely blow up internally; if you try to draw too much current from the collector then it will most likely overheat and burn up

Look up the specifications for the following transistors in a catalogue

	BC547	BC557	BD139	BD140	BD681	BD682	2N3055
Type	NPN						
Case	T092						
$I_c$ (mA)	100 mA						
$V_{ce}$	45 V						
$h_{FE}$ (gain)	110-800						
$P_{TOT}$ (power)	500 mW						

## Transistor Case styles

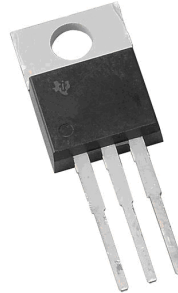
T0 \_\_\_\_\_



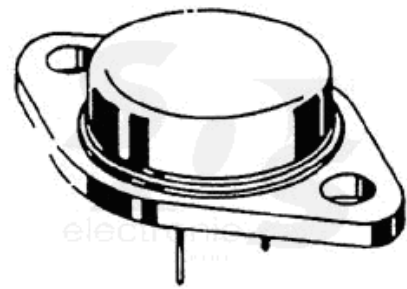
T0 \_\_\_\_\_



T0 \_\_\_\_\_

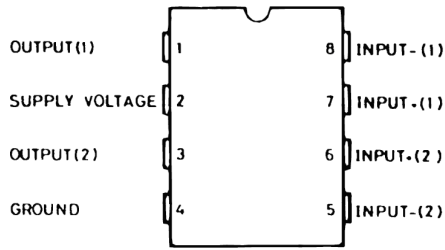


T0 \_\_\_\_\_

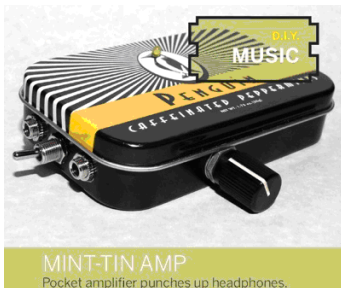
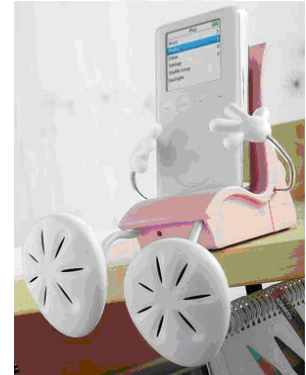
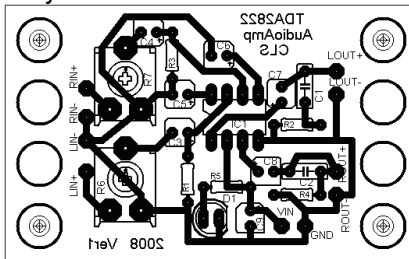


# TDA2822M Portable Audio Amplifier Project

This project is based around the TDA2822M IC (integrated circuit) from a company called SGS Thompson Microelectronics.



The project involves making a portable (battery powered) audio amplifier that can be used with an MP3 player and keeping a portfolio of the processes used. You may design and make or modify something else for your case



You will design and make the printed circuit board and case for the amplifier. You may use the provided speakers (50mm, 8 ohm 0.5W) or find your own.

## Portfolio Assessment Schedule

<b>Achieved</b>	<b>Merit</b>	<b>Excellence</b>
Planned Timeline	Planned Timeline	Planned Timeline
Actual Timeline	Actual Timeline With some explanation for changes	Actual Timeline With detailed explanation for changes
Given Brief	Given Brief	Given Brief
Modified One Page Brief	One Page Brief With some explanation for changes	One Page Brief With detailed explanations of changes
Printed Datasheet	Printed Datasheet	Printed Datasheet
Component Price List	Component Price List	Component Price List
Schematic Diagram from Eagle	Schematic Diagram from Eagle	Schematic Diagram from Eagle
Layout Diagram from Eagle	Layout Diagram from Eagle	Layout Diagram from Eagle
OHT of PCB	OHT of PCB	OHT of PCB
Board works	All solder joints reliable, heat shrink used correctly to strengthen joints, stress relief on all wires	All solder joints reliable, heat shrink used correctly to strengthen joints, stress relief on all wires
CAD Design drawing for case	At least two design drawings for case With changes made	AT least two design drawings for case With detailed explanation for changes
Photo of case	Photos of case + some description of process of making	Photos of case With detailed explanations of process of making
Final Outcome	Quality outcome, (refer to codes of practice)	Final product shows some flair, elegance, innovation or creativity, and explanation is given of these elements
<b>Key Competencies</b>		
Interacts with others occasionally or when asked to work in groups	Works cooperatively, relates easily and shares workshop resources freely with others.	Helps others and seeks others help in the workshop often
Cleans up after self	Works cooperatively with others to clean up the workshop	Takes initiative in keeping the workshop clean and tidy, puts tools and materials away for others regularly
Generally uses workshop time well	Efficient use of workshop time	Disciplined, optimised and efficient use of workshop time
<b>Presentation</b>		
Material is readable	All materials are clear, labelled, named and follow a logical sequence	Overall presentation is easy to follow and all materials are very well presented, a table of contents is given and page numbers are used.

## Initial One Page Brief

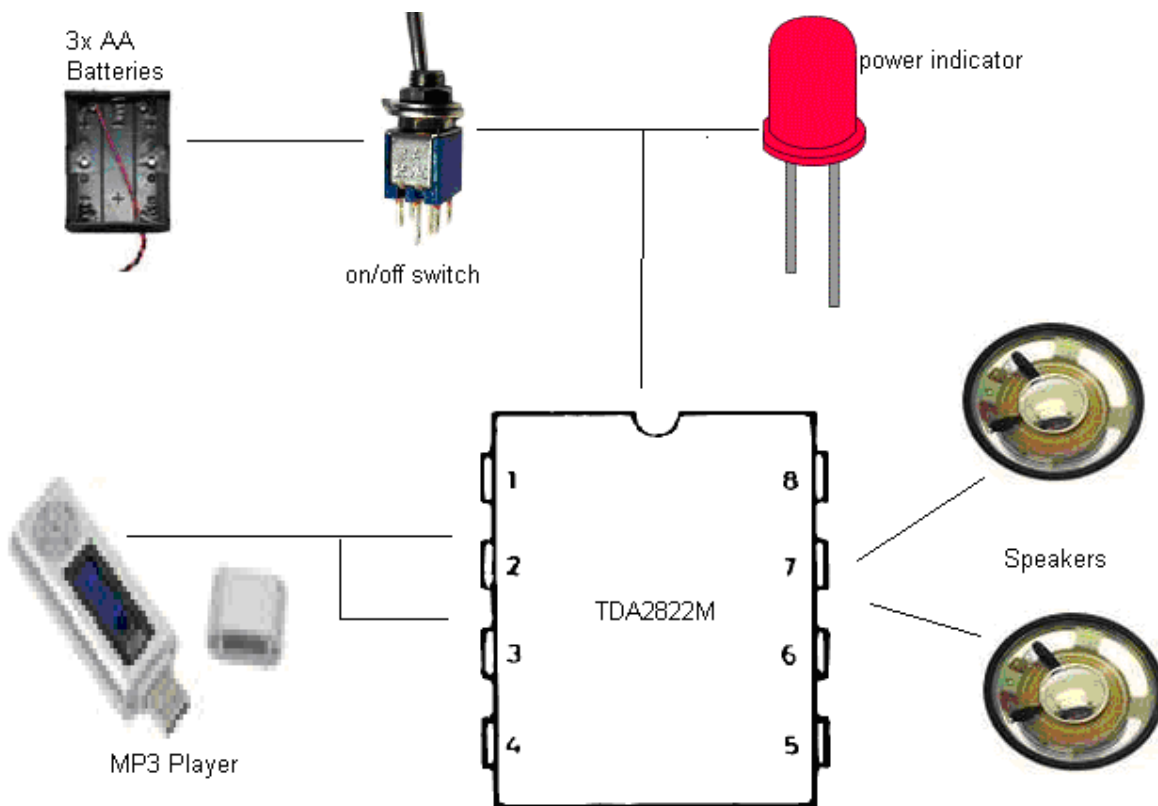
Project: **TDA2822Portable Audio Amp** Date: \_\_\_\_\_

Client, customer or end-user: **ME!**

Description of the problem, issue, need or opportunity(diagrams may be required):  
**MP3 players are useful personal items however the music cannot be shared with others**

Conceptual Statement:  
**Design and construct a portable audio amplifier to allow music to be played when with a group of friends**

System Block Diagram: (include all input and output devices)



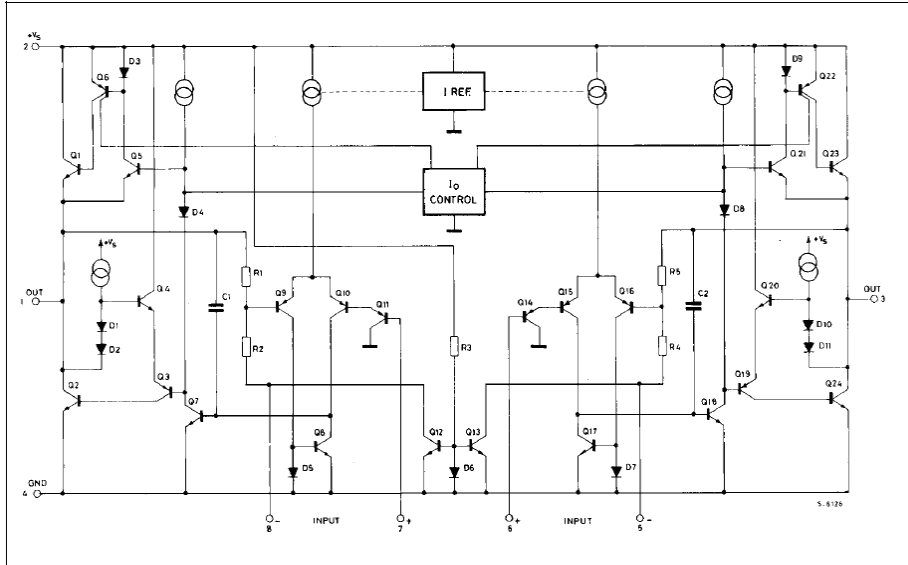
Further written specifications:  
**Need to make or find a case for it all**

## TDA2822M

Electronic components are complex (especially IC's) and manufacturers provide detailed specifications called **datasheets** for their products.

**Find and print the datasheet** for your portfolio of the TDA2822M, it is easily available on the WEB. It contains things such as the pin connections, a simplified internal schematic diagram, recommended circuits and voltage, current and power specifications.

### SCHEMATIC DIAGRAM

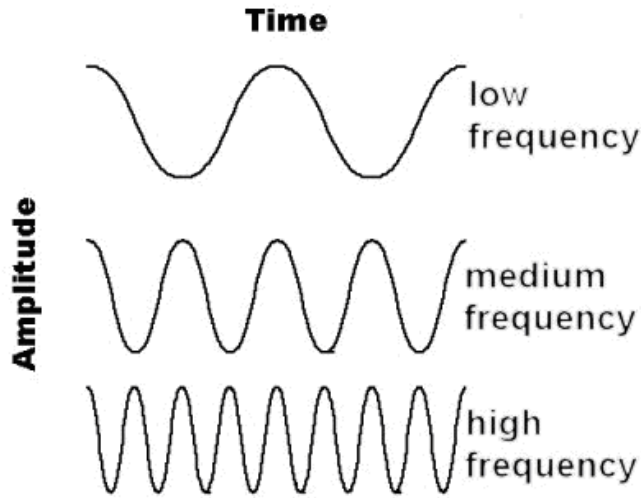


### ELECTRICAL CHARACTERISTICS ( $V_s = 6V$ , $T_{amb} = 25^\circ C$ , unless otherwise specified)

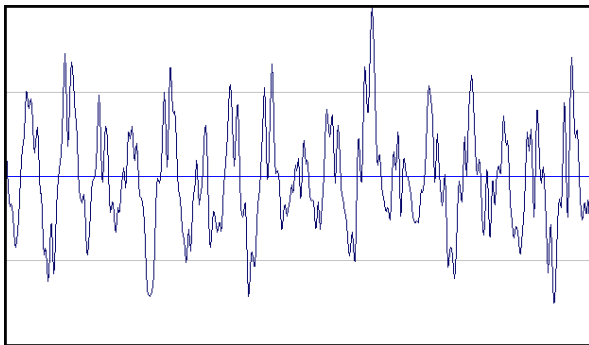
Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
<b>STEREO</b> (test circuit of Figure 1)						
$V_s$	Supply Voltage		1.8		15	V
$V_o$	Quiescent Output Voltage	$V_s = 3V$		2.7 1.2		V V
$I_d$	Quiescent Drain Current			6	9	mA
$I_b$	Input Bias Current			100		nA
$P_o$	Output Power (each channel) ( $f = 1kHz$ , $d = 10\%$ )	$R_L = 32\Omega$ $V_s = 9V$ $V_s = 6V$ $V_s = 4.5V$ $V_s = 3V$ $V_s = 2V$ $R_L = 16\Omega$ $V_s = 6V$ $R_L = 8\Omega$ $V_s = 9V$ $V_s = 6V$ $R_L = 4\Omega$ $V_s = 6V$ $V_s = 4.5V$ $V_s = 3V$	90 15 170 300 450	300 120 60 20 5 220 1000 380 650 320 110		mW
$d$	Distortion ( $f = 1kHz$ )	$R_L = 32\Omega$ $P_o = 40mW$ $R_L = 16\Omega$ $P_o = 75mW$ $R_L = 8\Omega$ $P_o = 150mW$		0.2 0.2 0.2		% % %
$G_v$	Closed Loop Voltage Gain	$f = 1kHz$	36	39	41	dB
$\Delta G_v$	Channel Balance				$\pm 1$	dB
$R_i$	Input Resistance	$f = 1kHz$	100			k $\Omega$
$e_N$	Total Input Noise	$R_s = 10k\Omega$ B = Curve A B = 22Hz to 22kHz		2 2.5		$\mu V$ $\mu V$
SVR	Supply Voltage Rejection	$f = 100Hz$ , $C_1 = C_2 = 100\mu F$	24	30		dB
$C_s$	Channel Separation	$f = 1kHz$		50		dB

## Audio Amplification

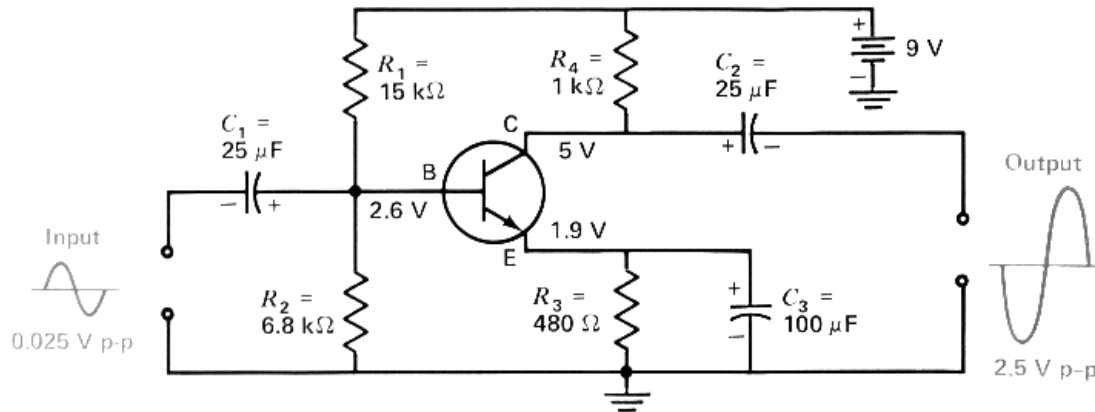
Audio signals are alternating current (AC) signals. AC is measured in frequency (number of cycles per second) and amplitude (size).



Audio signals such as voices are not single waves but complex waves of many frequencies each of differing amplitude.

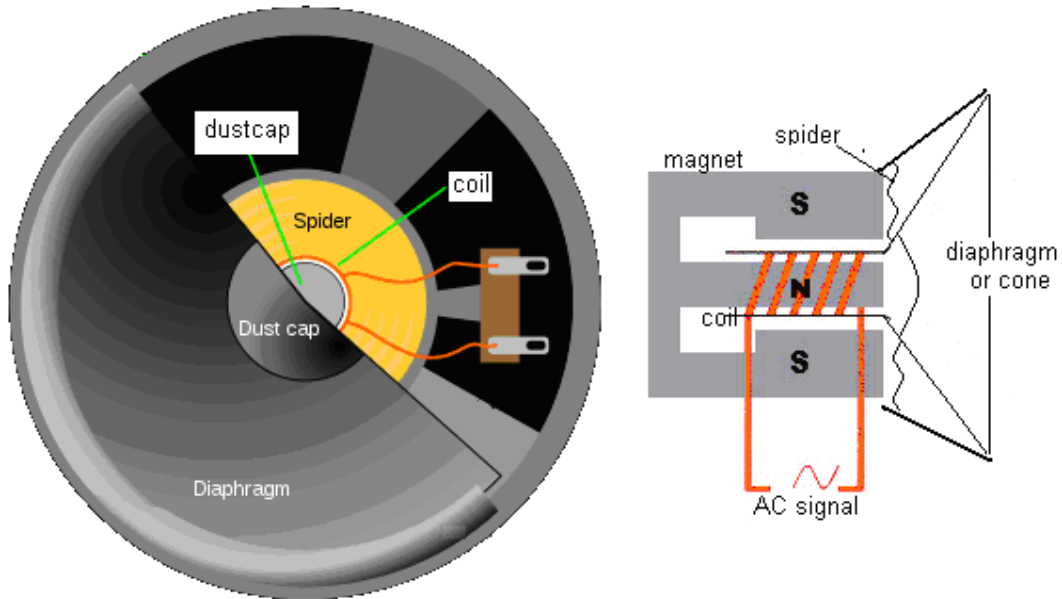


When amplifying audio through an amplifier the frequency should not change but the amplitude will.



## Speakers

Sound is vibrations of air particles; a speaker will change the audio signal from an amplifier by moving the cone of the speaker rapidly back and forth vibrating air.



Speakers come in various types each with specific frequency ranges they can reproduce: subwoofers (very low frequencies), woofers (low frequencies), mid-range speakers (middle frequencies), and tweeters (high frequencies).

Speakers have a resistance and typical values are 4 or 8ohms. They also have a power rating e.g. 100W, 20W or 0.25W.

If you connect a speaker directly to a battery you will destroy it (no smoke or explosion just a dead speaker).

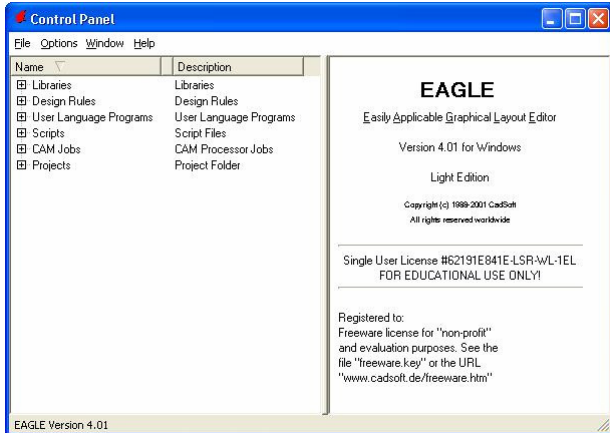


## Eagle Schematic and Layout Editor Tutorial

Eagle is a program from [www.cadsoft.de](http://www.cadsoft.de) that enables users to draw the circuit diagram for an electronic circuit and then layout the printed circuit board.

The version used is the freeware version which has the following limitations; the PCB size is limited to 100mm x 80mm and the board must be not for profit

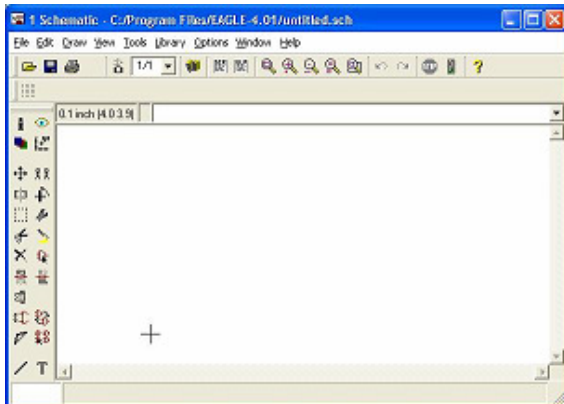
### Open Eagle Control Panel



Start - Programs - Eagle - Eagle 4.13

### Create a new schematic

On the menu go to FILE then NEW then SCHEMATIC



You will see the schematic editor

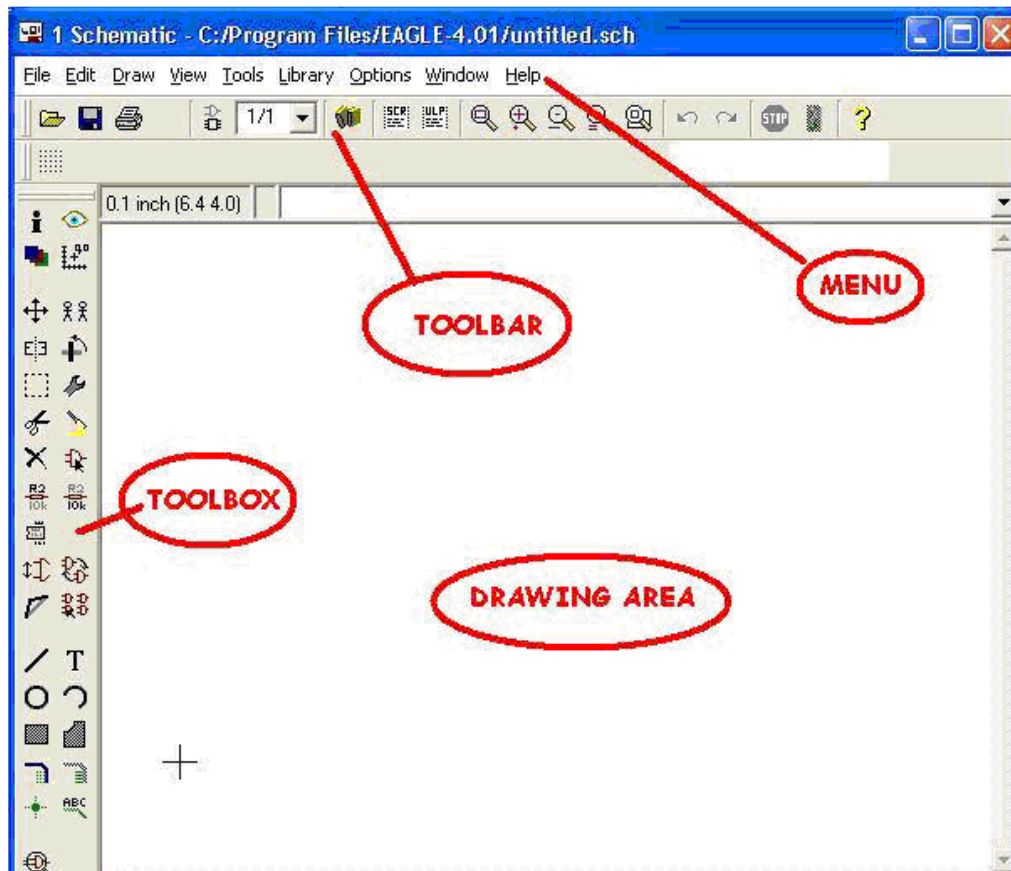
### Saving your schematic

- It is always best to save your data before you start work
- Eagle creates many temporary files so you need to keep your folders tidy.
- If this is the first time you have used Eagle create an Eagle folder within your folder on the server.
- Within the Eagle folder create a folder for the name of this project e.g. TDA2822
- Save the schematic as TDA2822verA.sch within the TDA2822 folder.

```
EAGLE
└── TDA2822
    └── TDA2822verA.sch
```



## The Schematic Editor



The first part of the process in creating a PCB is drawing the schematic.

1. **Parts** will be added from libraries
2. and joined together using '**nets**' to make the circuit

## The Toolbox

As you point to the tools in the TOOLBOX their names will appear in a popup and also their description will appear in the status bar at the bottom of the window

Find the following tools

- ADD A PART
- MOVE AN OBJECT
- DELETE AN OBJECT
- DEFINE THE NAME OF AN OBJECT
- DEFINE THE VALUE OF AN OBJECT
- DRAW NETS (connections)
- ERC (electrical rule check)

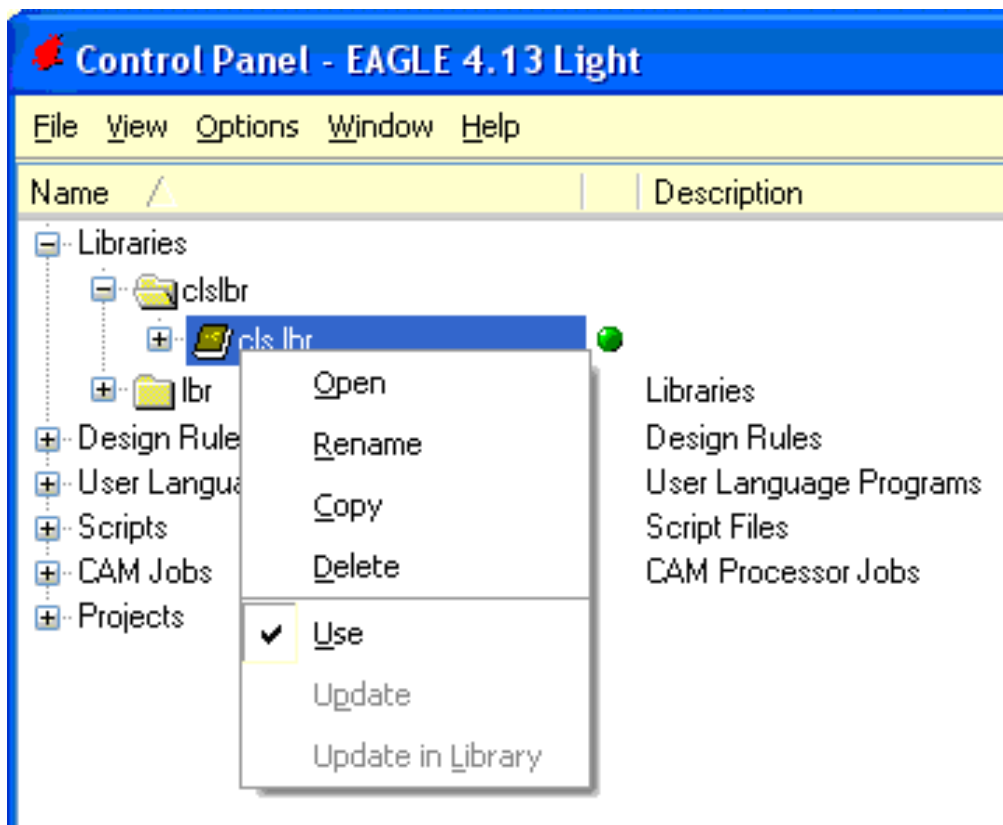
## Using parts libraries

Selecting parts libraries to use.

Parts are stored within libraries and there are a large number of libraries in Eagle.

It is not hard to create your own library and modify the parts within it. The cls.lbr has many already modified components within it. If Eagle is not setup to use the cls library you will need to do it now.

1. From your internet browser save the file cls.lbr into your Eagle folder.
2. In Eagle's control panel from the menu select **options** then **directories**
3. In the new window that appears make sure the directories for the libraries are highlighted
4. Click on **browse** and find your Eagle directory
5. Next highlight the directories for Projects
6. Click on browse and find your Eagle directory again.
7. Choose **OK**.
8. You might need to close EAGLE and restart it to make sure it reads the libraries ok.
9. To use a library right click on it from within the Control Panel
10. Make sure **Use** is highlighted. It will have a green dot next to it if it is selected
11. At this time right click on the other lbr folder and select **Use none**.



## Using Components from within libraries.

From your schematic Click the ADD button in the toolbox  
A new window will open (it may take a while)

Find the CLS library

Open it by double clicking on it or by clicking the + sign

Open the R-EU\_ section (Resistor- European)

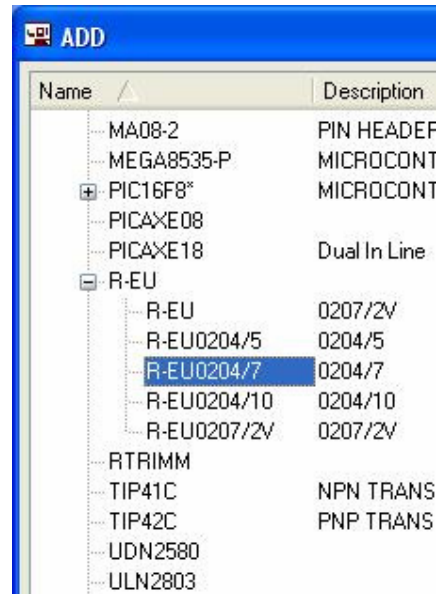
Here you will find the 0204/7 resistor.

Select it and then click OK

Add **6** more resistors of the same type.

Add all of the following parts

LIBRARY	PART	Qty
cls	REU-0204/7	6
cls	2,54/0,8	10
cls	C-EU025-025x050	2
cls	C-POLB45181A	4
cls	C-POLB45181B	1
cls	led 5MM	1
cls	TDA2822	1
cls	RTRIMMECP10S	2
cls	GND	3

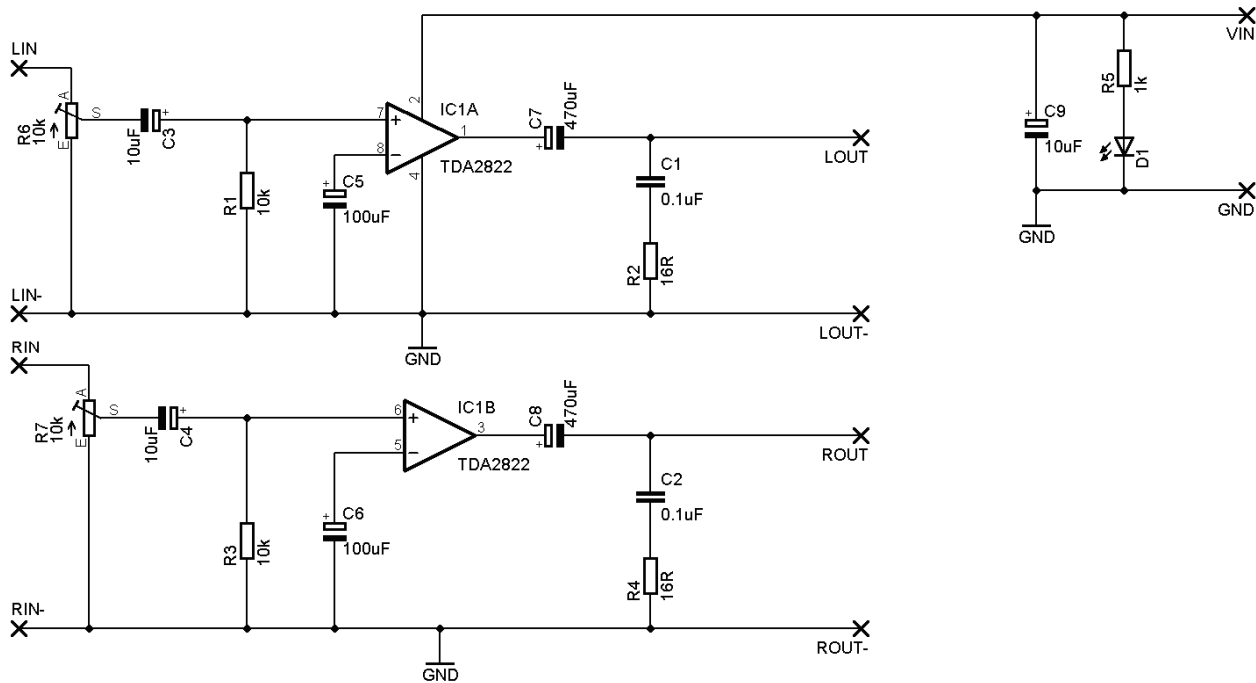


**What is difference between the three resistor types:**

**R-EU0204/5, R-EU0204/7 and R-EU0204/10**

## Moving parts

Move the parts around within the schematic editor so that they are arranged as per the schematic below. Keep the component identifiers (numbers like R1, R2, R3) in the same places as those below.



## Wiring parts together

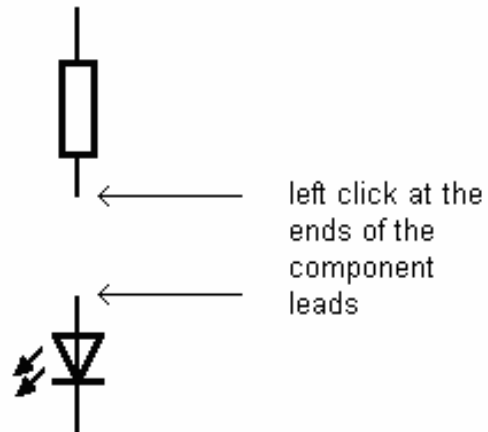
These form the electrical connections that make up the circuit.

Select the net button from the toolbox.

Left click on the very end of a component and draw in a straight line either up, down, left or right.

Left click again to stop at a point and draw before drawing in another direction.

Double left click at another component to finish the wire.



## Zoom Controls

There are a number of zoom controls that can be used to help you work in your circuit.



Find these on the toolbar and identify what each does.

## Nets

Nets are the wire connections between the components, each has a unique name.

Find the info button in the toolbox and check the names and details of the components and nets/wires.

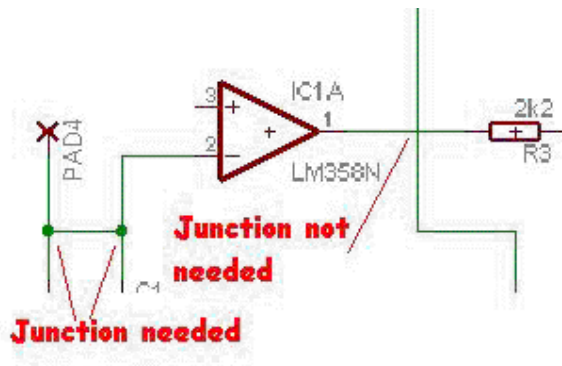
When you want to connect a new net to an existing net, Eagle will prompt you as to which name to give the combined net.

If one of the nets has a proper name i.e. VCC, V+,V-, ground... use that name, otherwise choose the net with the smallest number



## Junctions

Junctions are the dots we place on the circuit to make sure two or more wires are electrically connected. Generally you will NOT need to add these to your circuit as the net tool puts them in place automatically



## ERC

The ERC tests the schematic for electrical errors.

Errors such as pins overlapping, and components unconnected are very common.

The ERC gives a position on the circuit as to where the error is; often zooming in on that point and moving components around will help identify the error.

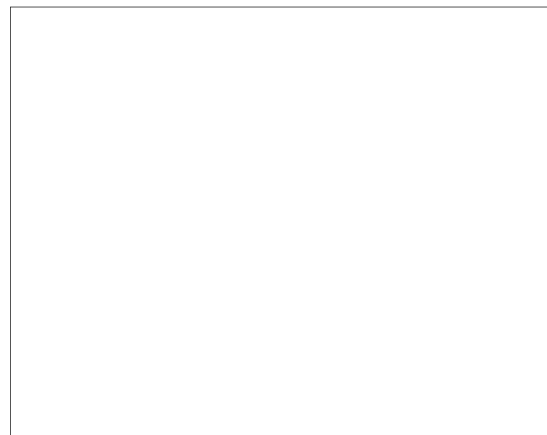
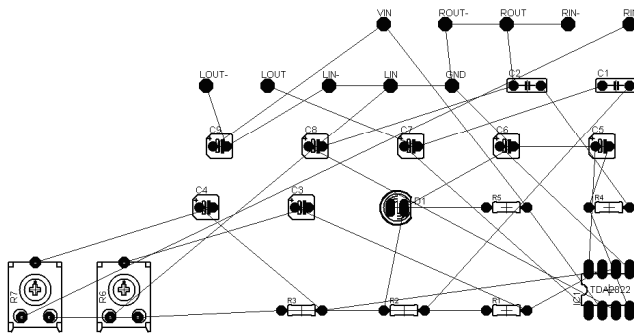
You must correct all errors before going on.

## The Board Editor

The board editor is opened using a button in the toolbar, find this button and answer yes to the question about creating the board.

The new window has a pile of parts and an area upon which to place them.

**WARNING: once you have started to create a board always have both the board and schematic open at the same time, never work on one without the other open or you will get horrible errors which will require you to delete the .brd file and restart the board from scratch.**



## Airwires

The wires from the schematic have become connections called airwires, these wires will shortly become tracks on the PCB.

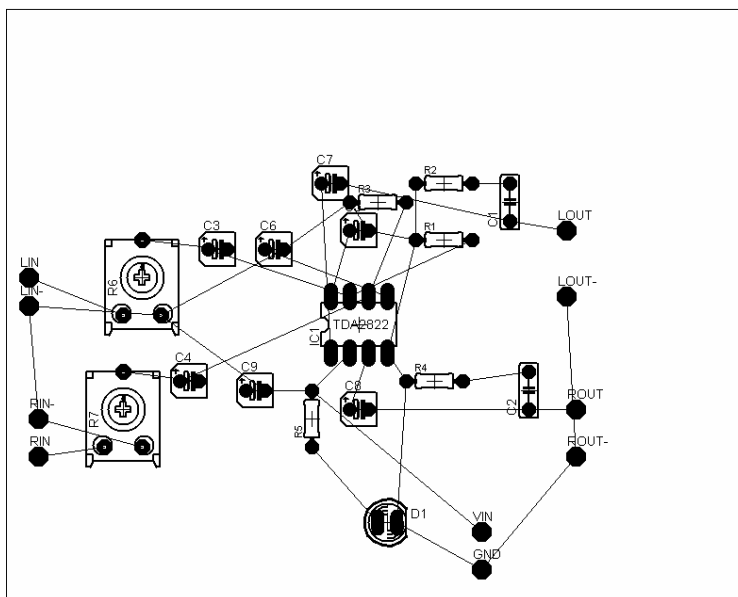
These connections can look very messy at times and at this stage it is called a **RATSNEST**.

## Moving Components

Move the components into the highlighted area. In the demo version you cannot place parts outside this area. Keep the components in the lower left corner near the origin (cross).

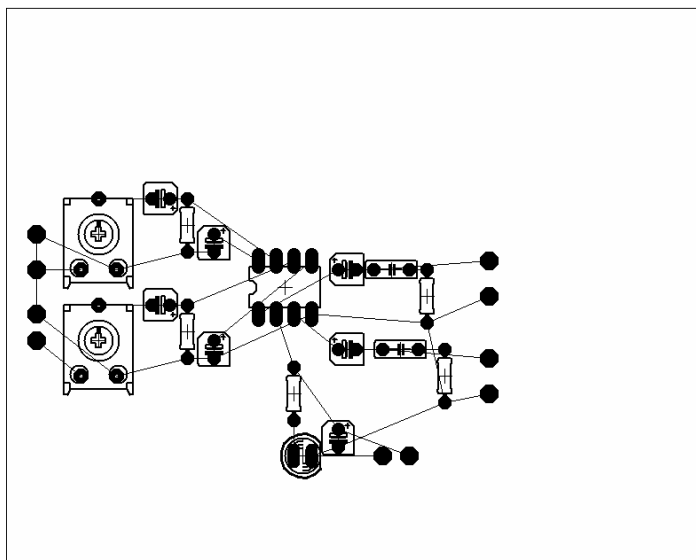
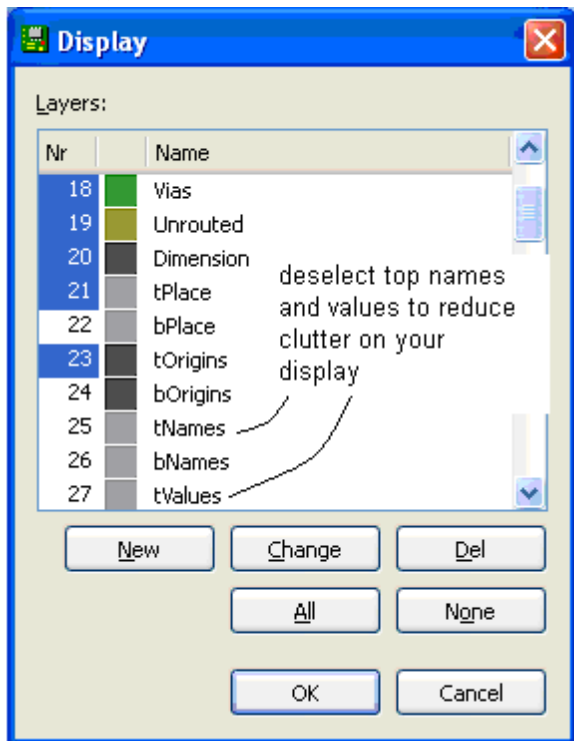
Reduce the size of the highlighted area you are using for the components. Then zoom to fit. Progressively arrange the components so that there is the minimum number of crossovers.

As you place components press the Ratsnest button often to reorganize the Airwires. Eventually your picture will look like the one on the right.



## Hiding/Showing Layers

The DISPLAY button in the TOOLBOX is used to turn on and off different sets of screen information. Turn off the names, and values while you are placing components. This will keep the screen easier to read. Turn off the layer by selecting the display button and in the popup window pressing the number of the layer you no longer want to see.



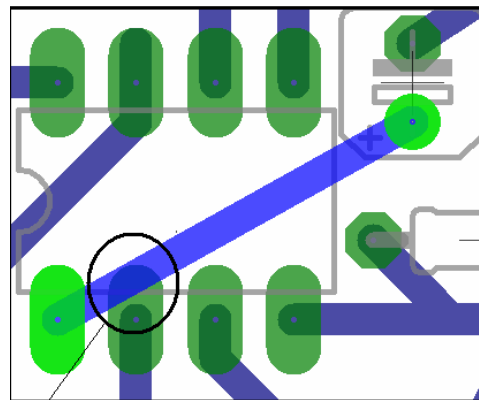
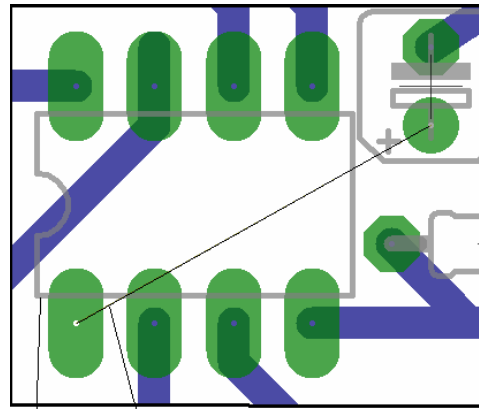
## Routing Tracks

Now is the time to replace the airwires with actual PCB tracks. Tracks need to connect all the correct parts of the circuit together without connecting together other parts. This means that tracks cannot go over the top of one another, nor can they go through the middle of components!

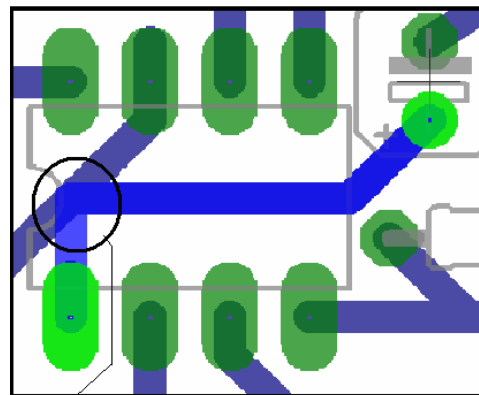
Go to the Toolbar, Select the ROUTE button

On the Toolbar make sure the Bottom layer is selected (blue) and that the track width is **0.04**. Left click on a component.

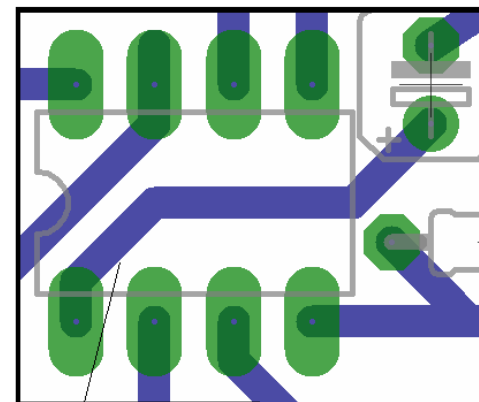
Note that around your circuit all of the pads on the same net will be highlighted. Route the track by moving the mouse and left clicking on corner points for your track as you go. **YOU ONLY WANT TO CONNECT THE PADS ON THE SAME NET, DON'T CONNECT ANY OTHERS OR YOUR CIRCUIT WILL NOT WORK.** Double click on a pad to finish laying down the track.



Wrong! The track is touching another pin



Wrong! The track touches another track



Correct! The track doesn't touch any other track or any other pin

## Track layout Rules

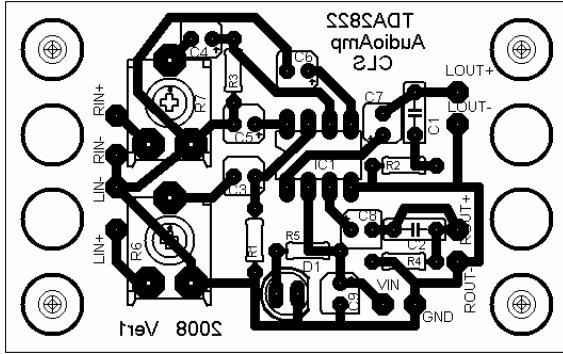
1. Place tracks so that no track touches the leg of a component that it is not connected to on the schematic
2. No track may touch another track that it is not connected to on the schematic
3. Tracks may go underneath the body of a component as long as they meet the above rules

## Ripping up Tracks

Ripping up a track is removing the track you have laid down and putting the airwire back in place. This will be necessary as you go to solve problems where it is not possible to route the tracks. You may even want to rip up all the tracks and move components around as you go.

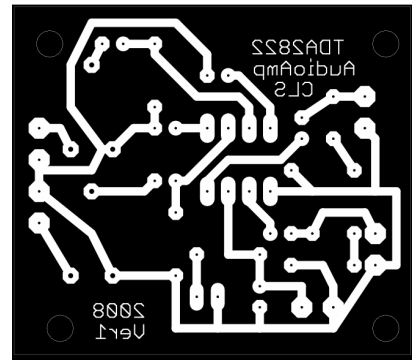


## Making Negative Printouts



Eagle is straight forward at producing printouts for a positive photographic pcb making process.

However if your photosensitive board requires a negative such as this, it becomes a slightly longer process.



image

CAM  
other

## Software

The following software is required to manipulate the special (computer aided manufacturing) files created by Eagle (and pcb CAD software) into the printed image you require. All this software is shareware with no fees attached for its use by students.

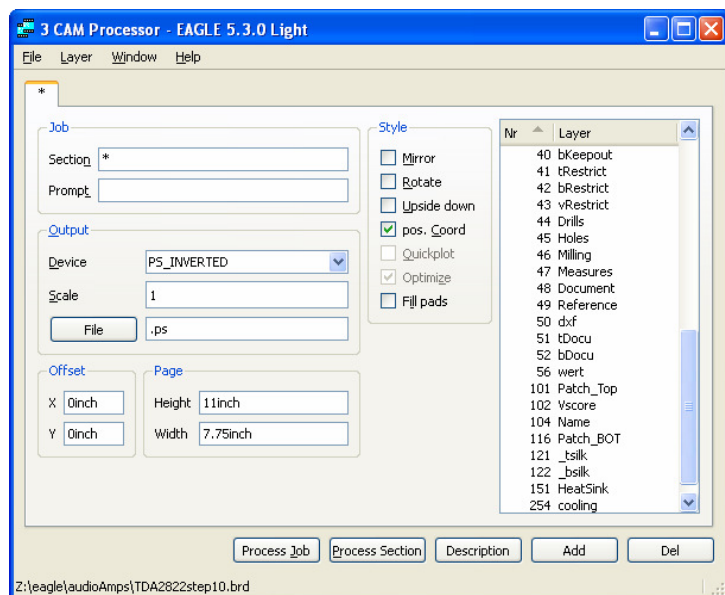
- \* Install GhostScript - from <http://www.ghostscript.com>
- \* Install GSView - from <http://www.ghostgum.com.au/>

## Conversion process

This process creates a '.ps' (postscript file), it is the best output from Eagle to manipulate. It will keep the board exactly the same and correct size for making.

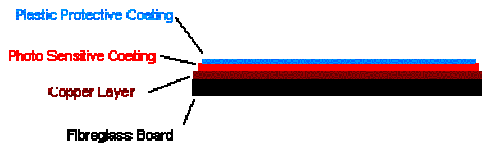
- \* Open TDA2822verA.brd in Eagle
- \* From within the Eagle Board Editor start the CAM Processor
- \* select device as PS\_INVERTED
- \* Scale = 1
- \* file = .ps
- \* make sure fill pads is **NOT** selected
- \* for layers select only **16,17,18 and 20**,
- \* make sure **ALL** other layers are **NOT** selected.
- \* Select process job
- \* if you will use this process a lot save this cam setup as so that you can reuse it again

Open the TDA2822verA.ps file with Ghostview for printing



# Year10 PCB Making

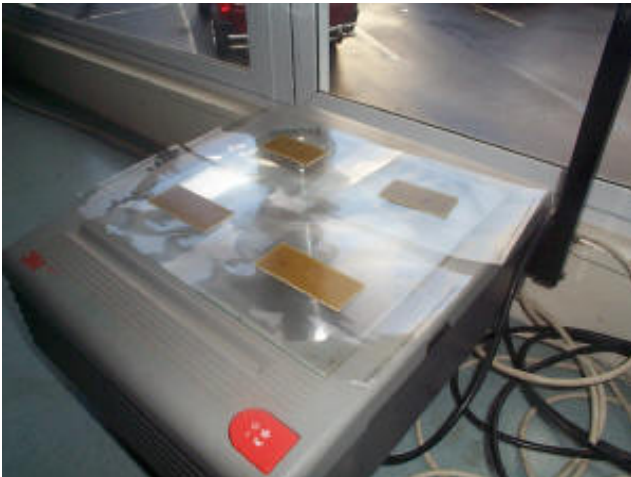
PCB Board Layers



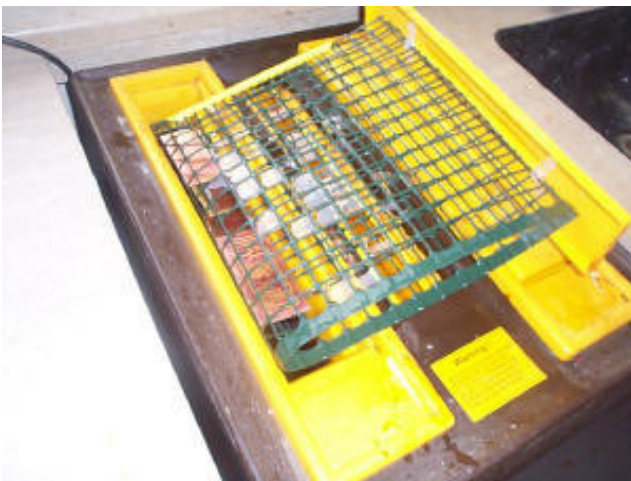
Measure, Cut:



Expose:



Develop:





Rinse:



Etch:



Rinse:

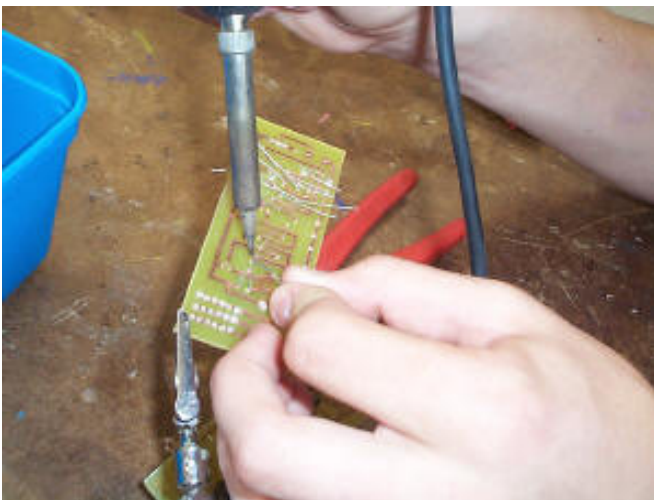
Lacquer:



Safety:



Third Hand:



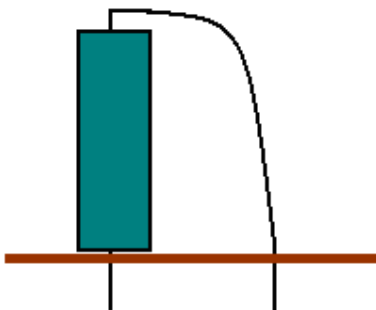
## Component Forming Codes of Practice



Component leads are bent at least 2 mm away from the component body, not bent close to the body as this would stress the component and reduce its life expectancy.



The component is placed firmly against the PCB. This helps mechanical rigidity. (Components would only be put up off the board if during normal operation they would become warm enough to damage the PCB itself)



If there is not enough room to lay the component flat on the PCB then one leg may be bent over.



Under the pcb the component leads are bent over slightly to hold the component in place during soldering, they are not bent flat as then it would be difficult to remove the component later on.

Component leads are cut off after soldering; during soldering they act as a heat sink and keep excess heat away from the component.

# Soldering

Soldering is a process of forming an electrical connection between two metals.

The most important point is

## GOOD THINGS TAKE TIME, SO TAKE YOUR TIME!

Quick soldering jobs can become really big headaches in the future, and people learning to solder tend to be quick because either they believe the temperatures will damage the components or they think of the solder as glue.

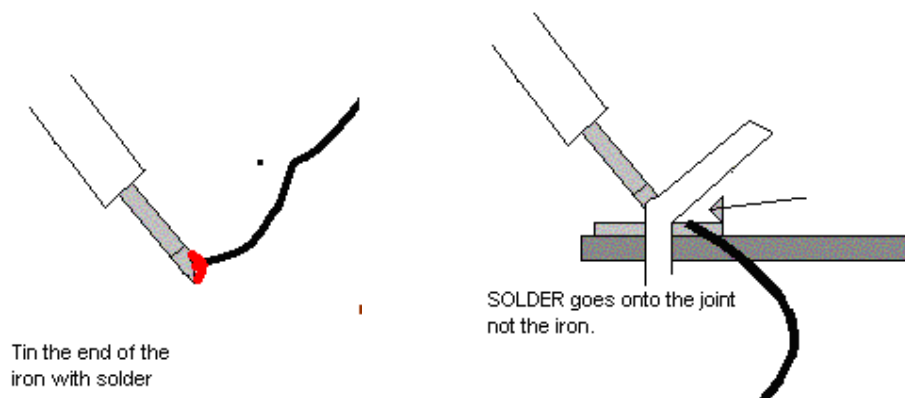
Soldering is best described therefore as a *graceful* process.

So approach it from that way, always **slowwwwing** down to get a good soldering joint.

## Follow these simple steps to get the best results.

- The materials must be clean.
- Wipe clean the iron on a moist sponge.
- The iron must be tinned with a small amount of solder.
- Put the iron onto the joint.
- The joint must be heated (be aware too much heat can ruin boards and components though)
- Apply the solder to the joint not to the soldering iron.
- Use enough solder so the solder flows thoroughly around the joint.
- Remove the solder
- Keep the iron on the joint after the solder for an instant
- Remove the soldering iron last
- Support the joint while it cools (do not cool it by blowing on it)

**DO NOT - DO NOT - DO NOT - DO NOT** dab the soldering iron on a joint this will never heat the joint properly.





## Safety

Lead is a poison so solder in well ventilated areas.

Wear safety glasses to avoid splashes of solder in your eyes.

The solder begins to melt at 360 degrees Celsius and becomes fully molten at 375 degrees - it is hot and it burns!

## Soldering facts

Solder is a mix of tin and lead with 5 cores of flux

When the solder dissolves and penetrates into the surfaces of the two metals being joined this is known as "WETTING"

As solder goes from a solid to a liquid it goes through a plastic state. This is the state of risk for your joint, if something moves during that time the solder will crack.

It is for this reason that we don't dab at a joint with a hot iron, the joint never really becomes hot enough to melt the solder hence no wetting takes place and the joint is going to be unreliable. If you apply the solder to the joint not the iron you will know the joint is hot enough because the solder will melt.

Flux is useful for only about 5 seconds. Reheating joints without fresh solder often doesn't do much good, in fact it could even damage them.

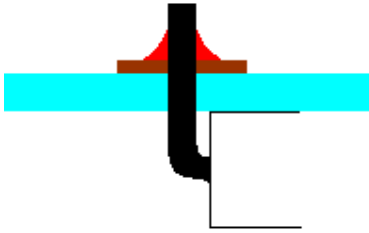
Too much heat on components during soldering can destroy the component or lift the tracks from the PCB.

If components get very hot while your circuit is on, then they can deteriorate your solder joint and cause it to fracture.

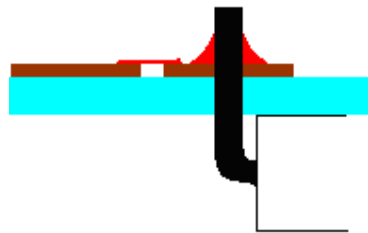
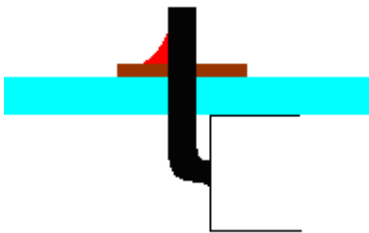
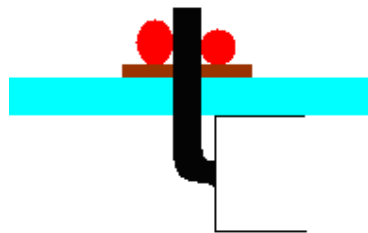
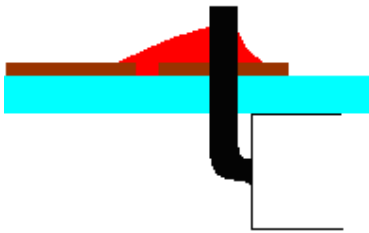
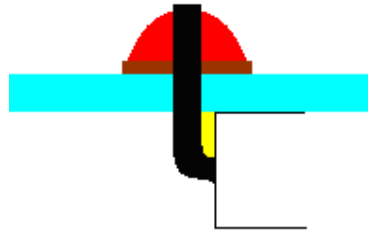
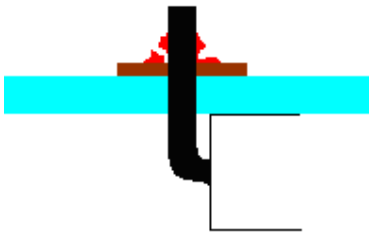
Soldering provides a certain amount of mechanical support to a joint, however be careful as to how much support you expect it to give. Very small components through the holes in a PCB are fine, some larger components may need other support, often just bending the legs slightly before soldering is enough.

## Good solder joints

The finished solder joint should be cone shaped and bright in colour.

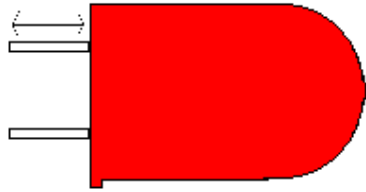
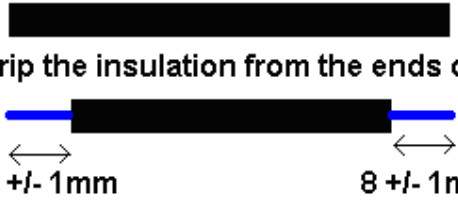
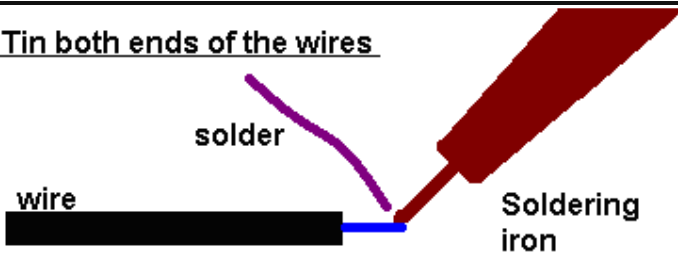
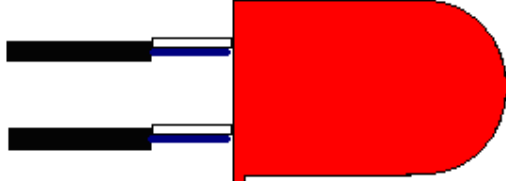
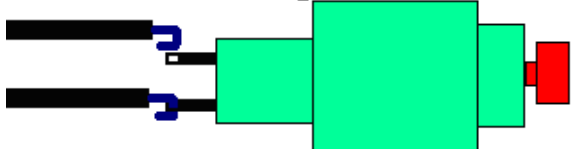
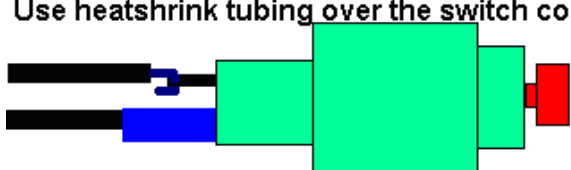


## Poor Solder Joints





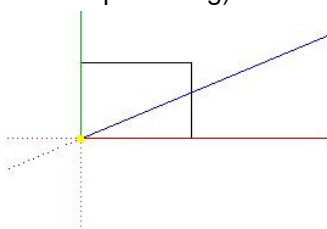
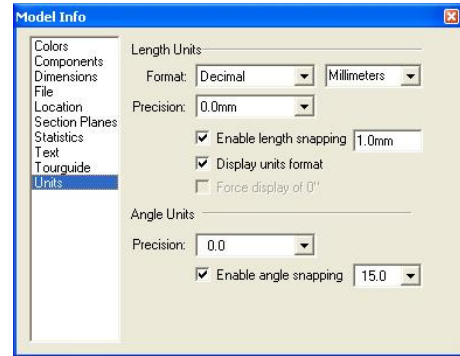
## Soldering Wires to LED's and Switches

LED's and Switches are most often attached to the circuit board with wires. These must be correctly measured, cut, stripped and soldered.	
Step 1:	<p>Cut LED leads to 8mm +/- 1mm</p> 
Step 2:	<p>Cut wire lengths to 90mm +/- 2mm</p> <p>Strip the insulation from the ends of the wire</p> 
Step 3:	<p><u>Tin both ends of the wires</u></p>  <p>Only a small amount of solder, NO BLOBS!</p>
Step 4:	<p>Solder the wires to the LED leads</p> 
Step 5:	<p>Hook the wires through the switch terminals and solder them</p> 
Step 6:	<p>Use heatshrink tubing over the switch connections</p> 

Why is the insulation only cut back 8mm?  
 What is the heatshrink for?

## SKETCHUP Quick Start Tutorial

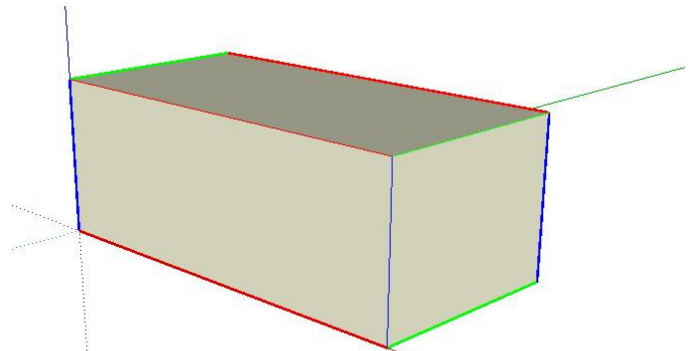
1. From the menu select Window then Model Info and then select units, set up units as shown in this picture.
2. Close this dialog box
3. Select the Rectangle tool in the toolbox (the set of tools on the left hand side of the SketchUp window).
4. Click the mouse pointer once on the origin and move it right and upwards to start drawing a rectangle (do not click again to stop drawing).



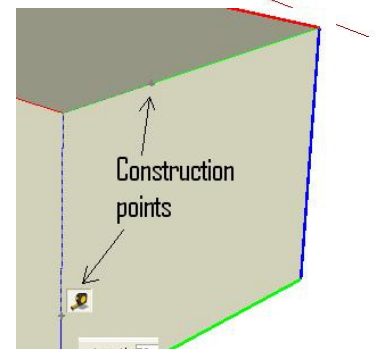
5. In the bottom right hand corner the dimensions of the rectangle are shown; without clicking there just type on the keyboard 200,100 and press Enter. The rectangle will take on the dimensions you have typed in.
6. Your rectangle may well have disappeared because you are zoomed out too much. From the tool box, identify the zoom extents tool by hovering the mouse pointer over the buttons. Get use to the other zoom controls now and zoom out a little.

7. From the menu select Window then Display Settings and change the Edge Color to By Axis (now you can see whether what you are drawing lines up with the axis you want it in).

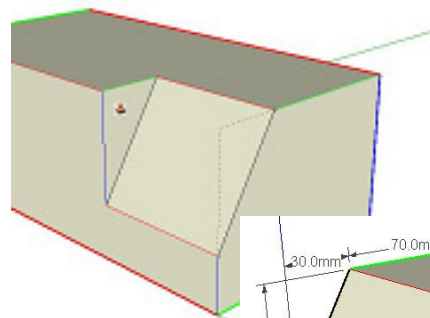
8. Under the menu is the tool bar identify the Iso view button (isometric) and click it.
9. In the toolbox identify the Push/Pull tool and then move the mouse pointer over the rectangle, the rectangles surface will change in appearance. Click once on the surface and drag the rectangle upwards along the blue axis into a 3D box; type 75 as a dimension and press enter. Your box should be aligned to the three axes and the edge colours should match the axes colours.



10. Select the Tape Measure from the toolbox and click on the upper front right corner and then move along the green axis, type 30 and press enter, a grey construction point will appear. From the same corner place another construction point 50mm down the blue axis.

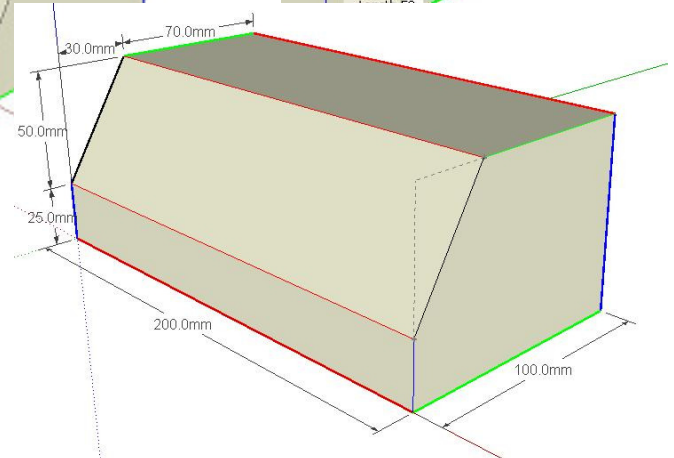


11. From the toolbox choose the line tool and draw a line between the two construction points, notice how the cursor snaps to the construction points as it nears them (it also snaps to edges, ends and centre points and each has a different colour).



12. Using the push pull tool push the new surface completely away to change your box to one with a sloping front panel.

13. From the toolbox select the Dimension tool, add dimension lines by hovering the mouse over an edge line (it will change to yellow), then click on the line and drag the new dimension away from the edge to place it.



14. This completes your first concept drawing
15. Create at least 5 different concepts for your project.

# Workshop Safety

## Bandsaw



What do supermarkets and butchers use bandsaws for? \_\_\_\_\_

What **THREE** items of safety equipment are required to be worn when using our bandsaw?

## Drill Press



Safety concerns are:

