Name:

Electricity and Electronics

Block 2

Electronics

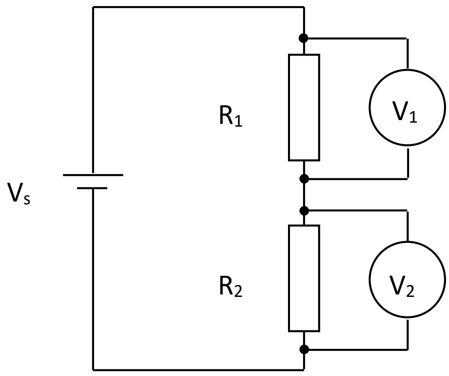
I can use the equations $V_2 = \left(\frac{R_2}{R_1+R_2}\right)V_S \quad \frac{V_1}{V_2} = \frac{R_1}{R_2}$ to solve problems involving potential divider circuits			
I can describe the symbol, function and application of electronic components: LED, diode, capacitor, thermistor, LDR, relay and transistor			
I can draw and identify the symbols for an npn transistor, and an n-channel enhancement MOSFET			
I can explain the function of the transistors above as a switch in transistor switching circuits			
I can calculate the resistance of protective resistors in LED circuits			
I can preform calculation involving Switching Circuits			

Learning Block 2

Analogue Circuits (Sensor Circuits)

The Potential Divider

A potential divider (or voltage divider) consists of two components, usually resistors, connected in **series**.

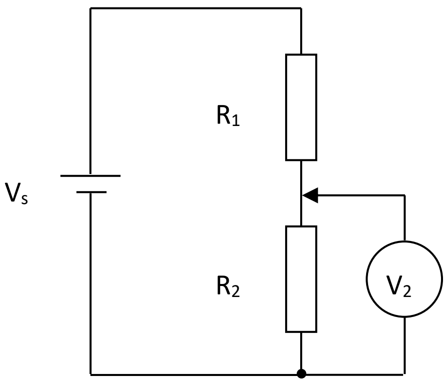


There will be a *potential difference* (or voltage drop) across each resistor.

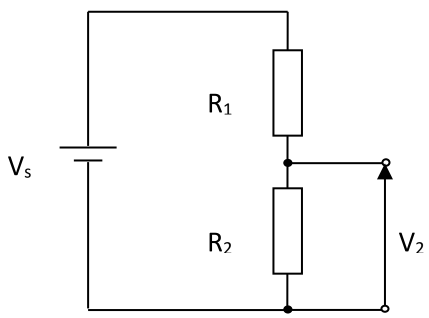
As the resistors are in series then:

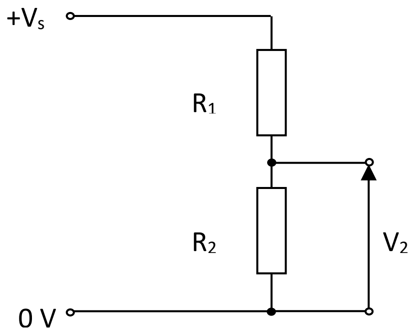
$$V_s = V_1 + V_2$$

Either voltage, V_1 or V_2 could be used as the input to an electronic system. It is usual however to use the voltage measured from the negative, or from the zero volt, connection from the supply, ie. V_2, as the input voltage to an electronic process device.



As all electronics circuits must have a power supply to work, the supply is taken for granted in the circuit diagrams. Diagrams are therefore drawn as "circuits" between power supply rails. One rail being at 0 volts and the other at the supply voltage ($+V_s$). The output from the potential divider is then normally measured from the 0 V rail. The next two diagrams are different representations of the same circuit.





The output voltage, V_2, is the potential difference across resistor R_2.

Equations:

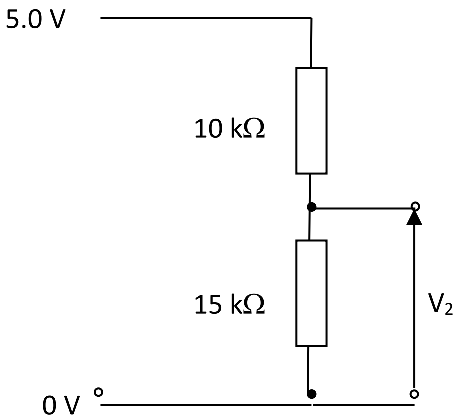
$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

Symbol	Name	Unit	
V_1	Potential Difference across component 1	volts	V
V_2	Potential Difference across component 2	volts	V
R_1	Resistance of component 1	ohms	Ω
R_2	Resistance of component 2	ohms	Ω
V_s	Supply Potential Difference	volts	V

Worked Example

Calculate the output voltage, V_2, in the potential divider shown below:



$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_S$$

$$V_2 = \left(\frac{15000}{10000 + 15000}\right)5.0$$

$$V_2 = 3.0$$

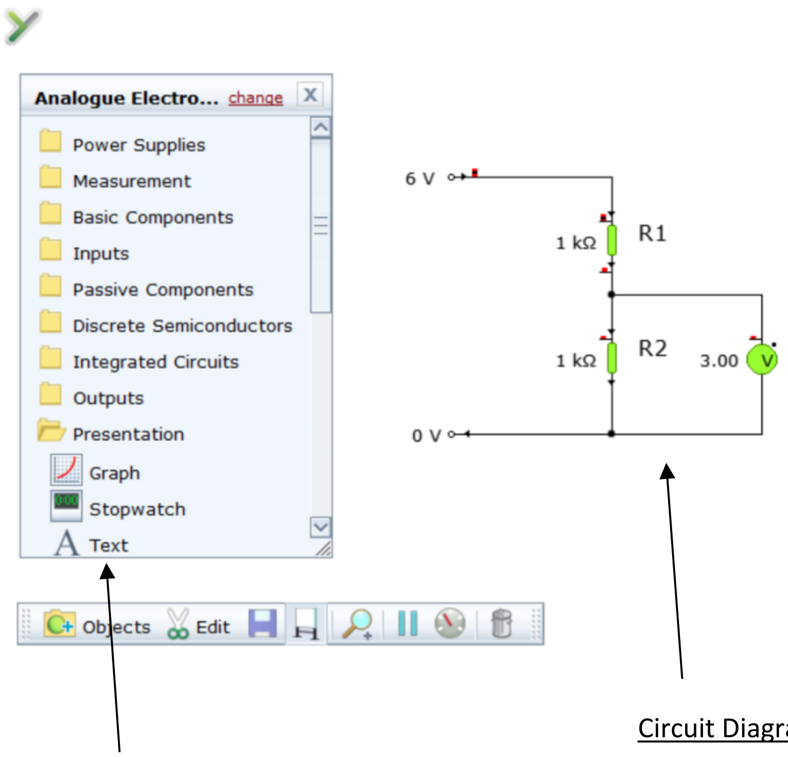
Output voltage is 3.0 V

In a potential divider, the supply voltage divides across the resistors in proportion to the size of the resistors. This gives us another equation useful when doing potential divider problems.

Electronic Circuit Simulation using Software Packages

Simulation of electronic circuits is a very important part of the design process. The simulation software uses mathematical modelling and computer coding to predict the behaviour of an actual circuit or device.

There are many simulation software packages available. In this course, you will gain experience in using a software package called *YENKA*



Component Gallery

An extensive list of real components and instruments that can be simulated as part of a circuit.

Circuit Diagram Area

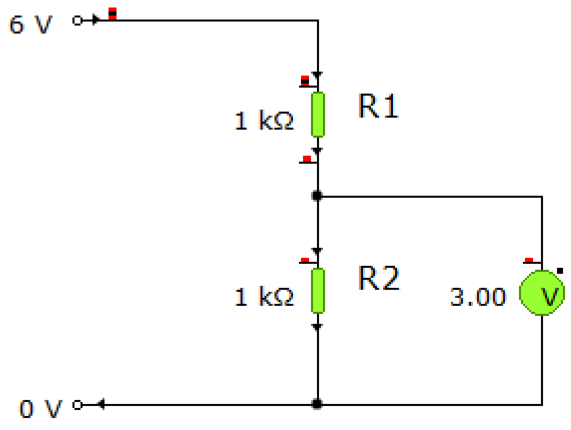
Components and connections are placed here and can be easily edited.

Advantages of circuit simulation

- establishes if a circuit works/functions correctly as designed so speeds up production process
- circuits can be saved and easily edited, making it cheaper and easier to modify and test as you go along
- doesn't require any physical components, so money isn't wasted on expensive parts
- allows the testing of sub-systems of a large circuit.

Practical: **Investigating Potential Dividers**

AIM: To investigate the relationship between the output voltage (V_2) and the resistances of R_1 and R_2 by simulation.



METHOD:

1. Open up a new page in *YENKA, Analogue Electronics*.
2. Create the above simulation. (*Your teacher will demonstrate how to do this)*
3. Record the results in the table below and repeat for the other resistor combinations.

RESULTS

V_S / (V)	R_1 / Ω	R_2 / Ω	V_2 / V
6	10	100	
6	10	220	
6	10	1k2	
6	1k2	1k2	
6	1k2	10	
6	68k	68k	
6			
6			
6			
6			

Pre-power up Check

It is essential that a *pre-power up check* is carried out on all circuits to ensure they are constructed properly prior to the power being switched on. This can prevent any damage to components and/or wrong circuit function. A pre-power up check is pre-planned and the results of it recorded in a table. The number/type of checks will depend on the size and type of circuit tested.

Common pre-power up checks

- Supply voltage – is it correct?
- Continuity of wiring – are all connections between components correct and secure?
- Component values – are all resistors and capacitors the correct values?
- Orientation of components – are all capacitors, diodes, LEDs correctly orientated?
- IC connections– are all connections to IC pins the correctly assigned as designed?

Functionality Test

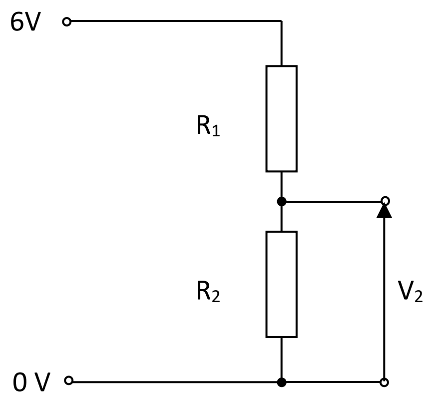
A *functionality test* is carried out on all circuits once the power is switched on. This is to check for correct operation of the circuit. A functionality test is pre-planned and the results of it recorded in a table. The results are often compared to the test results from the simulation. The number/type of checks will depend on the size and type of circuit tested. Any faults are then found, diagnosed and corrected before being re-tested.

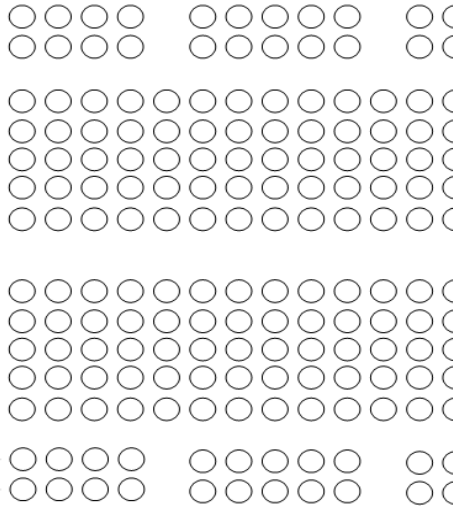
Common Functionality Tests

- Supply Voltage value.
- Voltages across specific components e.g. a LED, buzzer, resistor.
- Current through specific components e.g. a LED, buzzer, resistor.
- IC pins– are input pins / output pins of logic gates high or low?
- Does output operate properly when expected e.g. is motor on/off, LED on/off?

Practical: **Investigating Potential Dividers**

AIM: To investigate the relationship between output voltage (V_2) and the resistances of R_1 and R_2.





METHOD:

1. Create a labelled prototype plan on the diagram above for the circuit shown. Have it checked by your teacher.
2. Select the appropriate resistors as given in the table below and insert them into the prototype board according to your approved plan.
3. Carry out a *pre-power up check*.
4. Power up and measure the
   a) Supply voltage (Vs) and
   b) Output voltage with the multimeter (*what range should it be set to?)*
5. Record the results in a functionality test table and repeat for the other resistor combinations.

RESULTS:

PRE-POWER UP CHECK LIST	
What will be tested	**Result**
Supply voltage correct value?	
Continuity of wiring (are all connections in place and secure)?	
Resistor values correct?	

Functionality Test table

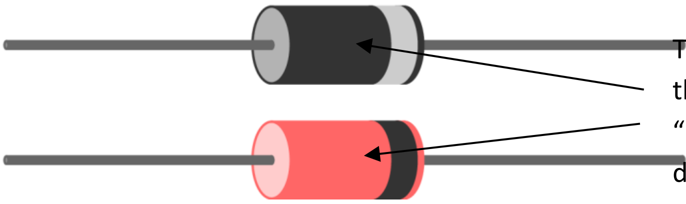
V_S / (V)	R_1 / Ω	R_2 / Ω	V_2 / V
6	10	100	
6	10	220	
6	10	1k2	
6	1k2	1k2	
6	1k2	10	
6	68k	68k	
6			
6			
6			
6			

Are the values of V_{OUT} as expected? How do these compare to your calculated and simulated answers from before? Can you suggest any reasons for any differences?

Diodes and Light Emitting Diodes

The Diode

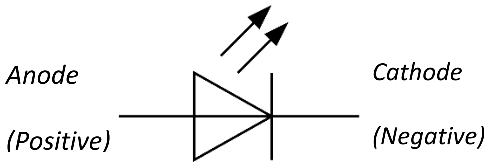
The diode is a component that only **allows current to pass in one direction** through it but blocks the current in the other direction.

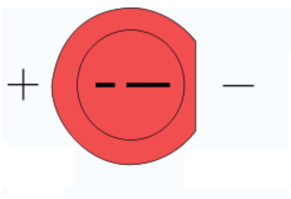


The band can identify the cathode or "negative" side of the diode

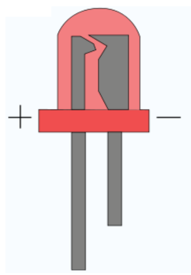
The Light Emitting Diode

The LED is similar to a diode in that it only allows current to flow in one direction but when current passes through it, the LED coverts electrical energy to light energy. LEDs are used in electronic circuits due to their small physical size. They also have a very low power consumption thus produce very little heat. They are manufactured to produce a variety of different colours of light.





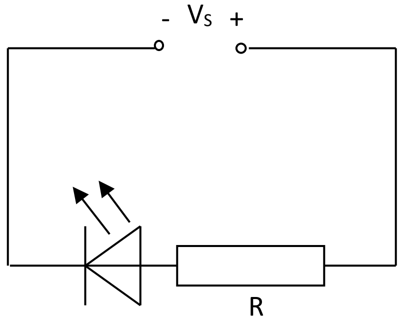
The flat edge can identify the cathode or "negative" side of the LED



The shorter leg can identify the cathode or "negative" side of the LED

Protection of LEDs

LEDs are easily damaged and must be protected from too large a current. To achieve normal operating conditions, the LED is placed in series with a protection resistor.



The purpose of the protection resistor is to ensure the normal operating voltage of the LED is achieved and the maximum allowed current for the LED is not exceeded. It is important that the value chosen for the resistor allow these normal operating conditions to be obtained.

Worked Example

The operating conditions for a particular LED are as found to be:

Typical Forward Voltage, V_F =2.0 V (max = 2.8 V)

Maximum Forward Current, I_F = 12 mA

Calculate the protection resistor value if a 5.0 V supply is used.

Part 1 : The above circuit is a potential divider thus:

$V_S = V_R + V_{LED}$

$V_R = V_S - V_{LED}$ (*V_{LED} is the typical forward voltage given in the datasheet*)

$V_R = 5.0 - 2.0$

$V_R = 3.0$ V (*Voltage across the resistor should be 3.0 V*)

Part 2:

$R = V_R / I_F$ (*I_F chosen should be less than I_F max given in the datasheet*)

$R = 3.0 / 10 \times 10^{-3}$ (*10 mA would be appropriate if max is 12 mA*)

R = <u>300 Ω</u>

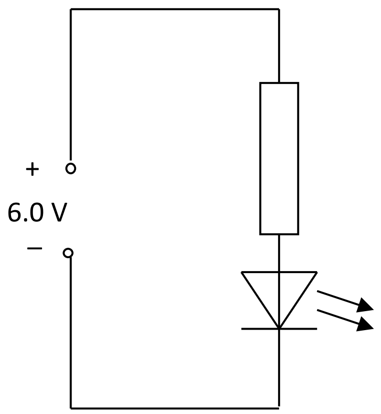
A 300 Ω resistor is not readily available, so the next highest should be chosen i.e. 330 Ω. (Alternatively, a combination of resistors can be used to give a total of 300 Ω).

Practical: **Protection of LEDs.**

AIM To investigate the current flow in an LED and protection resistor required.

APPARATUS Collect: a 6.0 V dc supply
A red LED (5mm 2.2V Red)
resistor (to be decided by you)
prototype board

METHOD You are going to design and set up the following circuit.



- Calculate the appropriate value of resistor and chose the most suitable resistor that is available from the store. Check result with your teacher.
- Create a labelled prototype board plan.
- Set up the circuit. Carry out a pre-power up check. Record results in a table.
- Measure the voltage across the resistor and LED and the current through them. Record the results in a functionality test table.

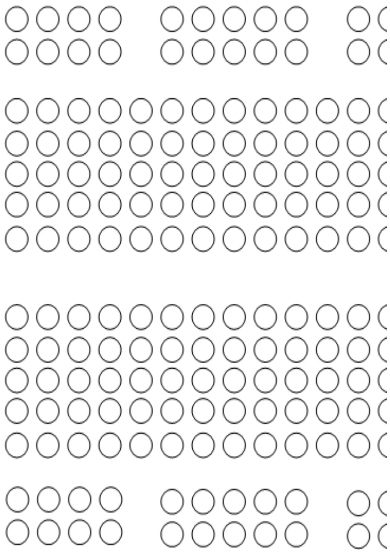
RESULTS

From datasheet:

Typical Forward Voltage, V_F typ (V)	2v
Maximum Forward Current, I_F max (mA)	12

Space for calculating protection resistor value:

Prototype plan

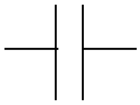


PRE-POWER UP CHECK LIST	
What will be tested	**Result**

FUNCTIONALITY TEST	
What will be tested	**Result**
Does LED operate when powered (on or off)?	
Voltage across LED (V)	
Voltage across resistor (V)	
Current (mA)	
Are current and voltage within limits?	

The Capacitor

A capacitor is a device that temporarily stores electric charge.



Capacitance, a measure of the ability to store electric charge, is measured in units called farads, F. One farad is a very large capacitance so most capacitors are quoted in microfarads (µF, 10^{-6} F) or picofarads (pF, 10^{-9} F).

Electrolytic capacitor

Must be connected the correct way around !

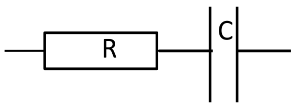
The negative side can be identified by the band down one side.

Non- Electrolytic capacitor

When capacitors are connected to a power supply, they build up charge; this is called *charging*. If given enough time, they will fully charge and the potential difference across the capacitor will equal the supply voltage. It acts almost like a temporary battery when charged.

If the capacitor is then allowed to release its stored charge through another device, e.g. a lamp, this is called as *discharging*. Once discharged, it will need recharging before use again.

An important use of a capacitor is to create a **time delay** in a circuit. Capacitors, take time to charge and discharge, and when connected in series with a resistor to form a potential divider, the time to charge and discharge can be controlled. This is commonly known as an *RC* circuit.



The Time Constant

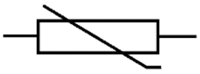
The time constant (in seconds) can be found by multiplying the value of the capacitor (in farads) by the value of the resistor (in ohms). This is a measure of the time taken for the capacitor voltage to increase by 63%.

$$\boxed{t = RC}$$

By increasing the value of the capacitor or increasing the value of the resistor, we can increase the time to charge and discharge the capacitor i.e. we can control the time delay.

The Thermistor

The thermistor is a component that has a variable resistance that changes depending on its temperature.

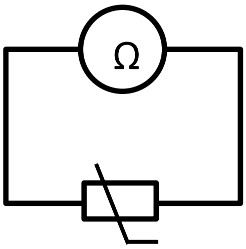


Practical: **Thermistor operation**

AIM To investigate how temperature affects the resistance of a LDR.

APPARATUS Collect: Multimeter thermistor

METHOD



FUNCTIONALITY TEST	
Resistance of thermistor when temperature cold	
Resistance of thermistor when temperature warm	

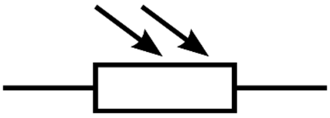
Conclusion

As temperature increases, resistance of thermistor _______________.

As temperature decrease, resistance of thermistor _______________.

The Light Dependent Resistor (LDR)

The light dependent resistor, or LDR, is a component that has a variable resistance that changes depending on the amount of light that falls on it.

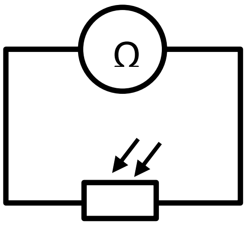


Practical: **LDR operation**

AIM To investigate how light affects the resistance of a LDR.

APPARATUS Collect: Multimeter LDR

METHOD



FUNCTIONALITY TEST	
Resistance of LDR when light levels bright	
Resistance of LDR when light levels dark	

Conclusion

As light levels increase, resistance of LDR ________________.

As light levels decrease, resistance of LDR ________________.

Transistors

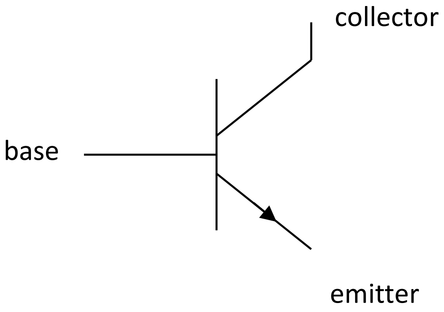
A transistor is a device that has revolutionised the world we live in and is regarded as one of the technological advances of the 20^{th} century. It can be manufactured to be microscopically small and thus enabled the miniaturisation of the electronic systems resulting in mobile phones, tablets, sat navs and most other hand held device!

They have two main functions; as a switch controlling the flow of current and as an amplifier enabling small signals to be enlarged to be used elsewhere.

The two most common types of transistors are the *bipolar junction transistor* (BJTs) and the *field effect transistor* (FETs).

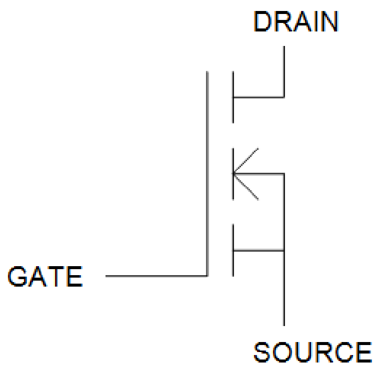
Bipolar Junction Transistor

(NPN transistor)



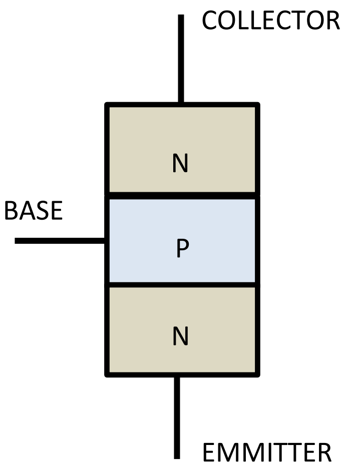
Metal Oxide Silicon Field

Effect Transistor (MOSFET)



NPN Transistor Construction

A BJT is made up of three layers of semiconductor material known as N-type and P-type semiconductor as shown below:



The P-type middle section, the *base*, prevents current flow between the two N-type sections, the *collector* and the *emitter*.

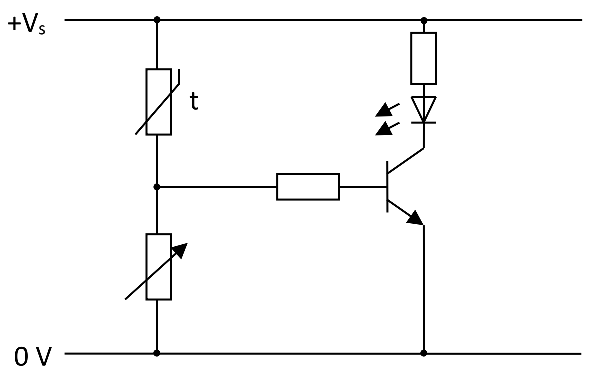
When we apply a voltage to the base, the electrical properties of the P-type alters and if the voltage at the base rises beyond a certain threshold voltage, current can flow between the collector and the emitter.

The transistor is effectively a **voltage controlled switch**. It can be turned on and off by a voltage at the base.

Automatic Switching Circuits

In the circuits below, the **variable resistor** allows the circuit to be adjusted to the temperature or light conditions for which the output device can switch on.

_____________ Temperature Switching circuit.



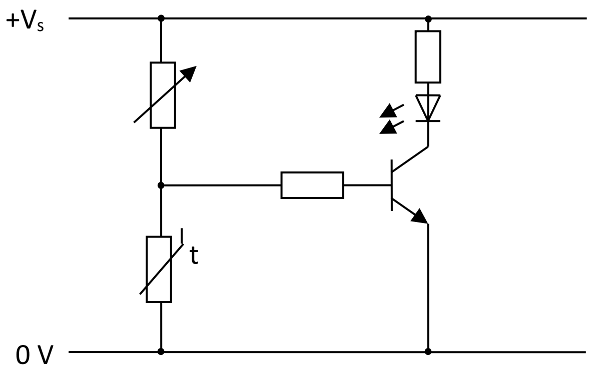
- *When the temperature of thermistor increases*

  The resistance of thermistor ___________,
- *Voltage across thermistor ____________,*

  Voltage across resistor variable _________,
- *When this reaches the **switching voltage** the*

  Transistor and LED switch on

__________ Temperature Switching circuit.

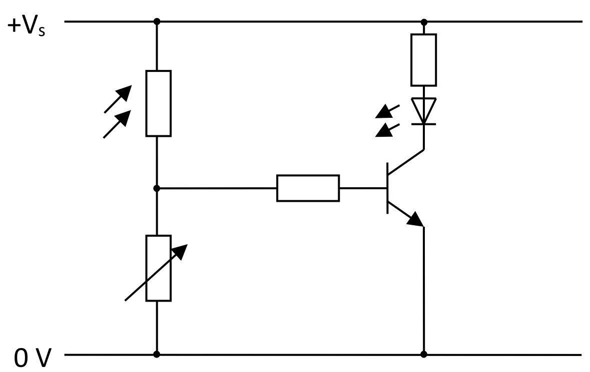


- *When the temperature of thermistor decreases*

  The resistance of thermistor ___________,
- *Voltage across thermistor ____________,*
- *When this reaches the **switching voltage** the*

  Transistor and _____ switch on

_____________ Light Switching circuit.



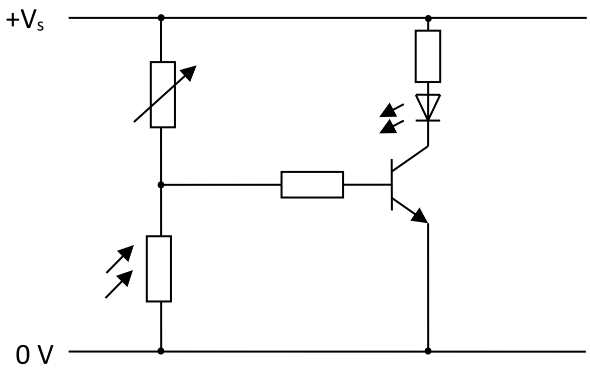
- *When the Light level of LDR __________,*

  The resistance of LDR ___________,
- *Voltage across LDR ____________,*

  Voltage across resistor variable _________,
- *When this reaches the _________ _________*

  the Transistor and LED switch on

__________ _______ Switching circuit.



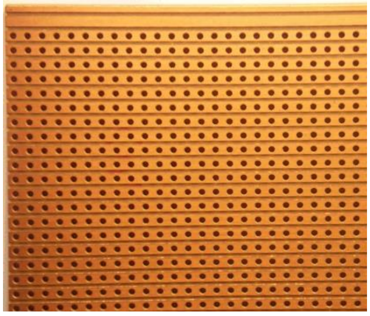
- *When the _______ of _______ ___________,*

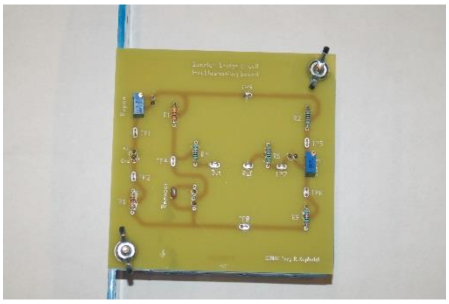
  The resistance of ________ ___________,
- *__________ across __________ ____________,*
- *When this reaches the ______________ the*

  ______________ and _______ switch on

Soldering

Once circuits have been designed, simulated and then tested on prototype board, the next stage is permanent construction. We will use two methods of permanent construction; copper stripboard and printed circuit boards (PCBs).





Both boards require you to solder components onto them using solder (*consider this like a metal glue*) and soldering iron. Soldering is fun but can be dangerous if not done safely so you will need to understand the risks and the precautions taken to minimise these risks.

Soldering Iron

- Never touch the element of the soldering iron....400°C!
- Hold wires to be heated with tweezers or clamps.
- Keep the cleaning sponge wet during use.
- Always return the soldering iron to its stand when not in use. Never put it down on the workbench.
- Turn unit off and unplug when not in use.

Solder, flux and cleaners

- Wear eye protection. Solder can “spit”.
- Always wash your hands with soap and water after soldering.

Fire Prevention

- Work on a fire-proof or fire resistant surface.

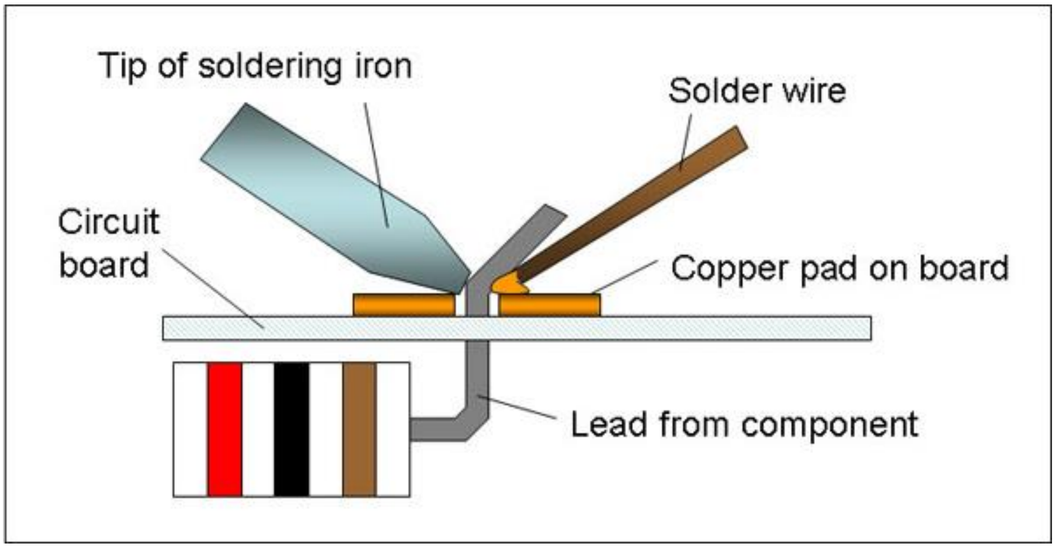
First Aid

- Immediate place any burns under cold water for 15 minutes.
- Report to a first aider if deep or extensive otherwise protect with a plaster (band-aid).

Soldering Successfully

Soldering successfully takes a lot of practise but follow these steps to improve quickly:

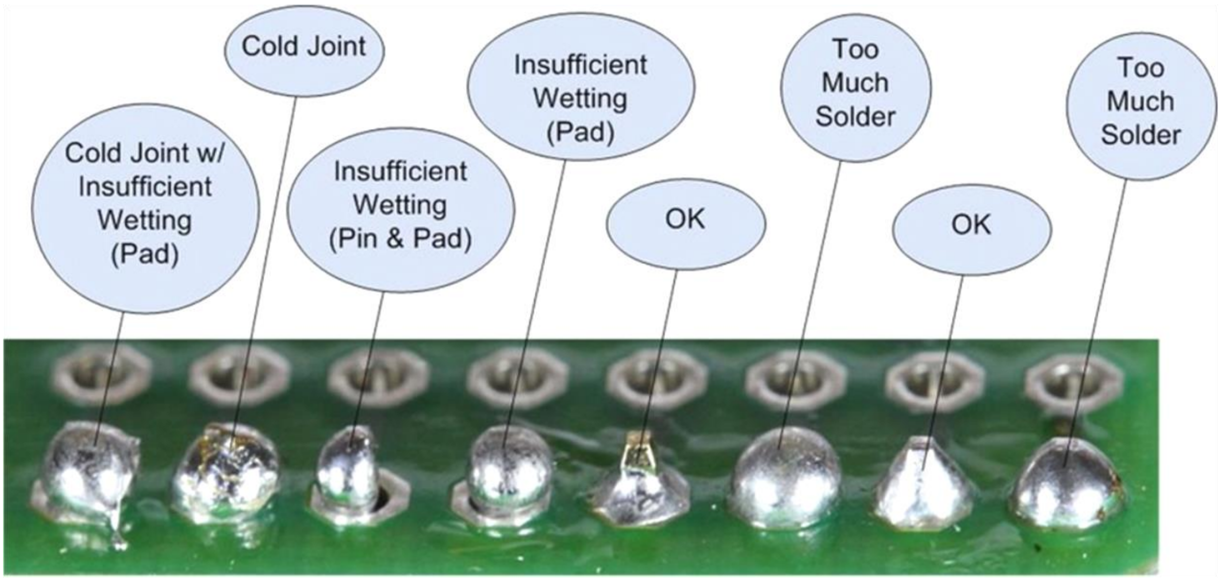
1) **Clean the metal surfaces to be soldered**
   Wipe leads, wire ends and copper tracks to remove grease and debris.
2) **Prepare the soldering iron**
   Place in stand and switch on. Allow enough time for iron to heat up. Dampen the sponge.
3) **Secure items being soldered in place**
   This can be done using the "helping hand" tool or simply by bending component leads slightly.
4) **Tin the soldering tip**
   Apply a small amount of solder to the tip and remove excess using damp sponge. This will ensure good transfer of heat.



5) **Hold soldering iron like a pencil**
   Keep at 30-45° angle to surface. Do not touch the metal tip (YOU WILL GET BURNT!)
6) **Apply tip to joint**
   Do not apply heat directly to solder. Allow joint to heat up for few seconds.
7) **Feed cold solder onto heated joint**
   Solder will melt and flow around joint. This should be done for minimum time required. Heating too long will result in poor joint. Do NOT breathe in smoke. Use fan provided.
8) **Remove solder then iron**
   Solder will cool and solidify immediately. Place iron securely into its stand.

Checking your Soldering

Once the solder has cooled, you must inspect the joint and check it is strong and conductive.



Signs of a good joint:

- Shiny
- Strong (try giving the lead a small pull)
- Solder forms an almost volcano-like bump
- Covers pad and surrounds lead fully

Signs of a poor joint:

- Solder is dull/ non-shiny/dark
- Solder forms jagged peaks or is flat
- Pad/hole partially visible
- Solder over flows and touches other tracks/pads (short circuits)

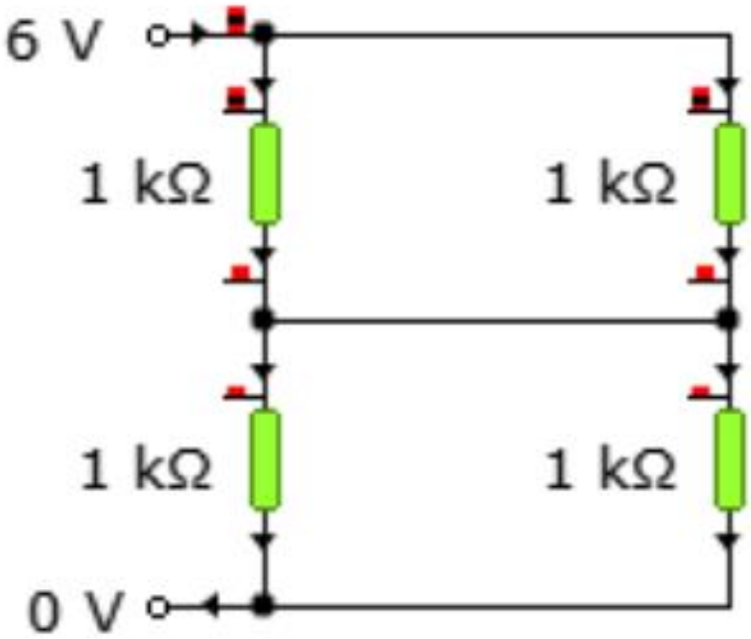
De-soldering

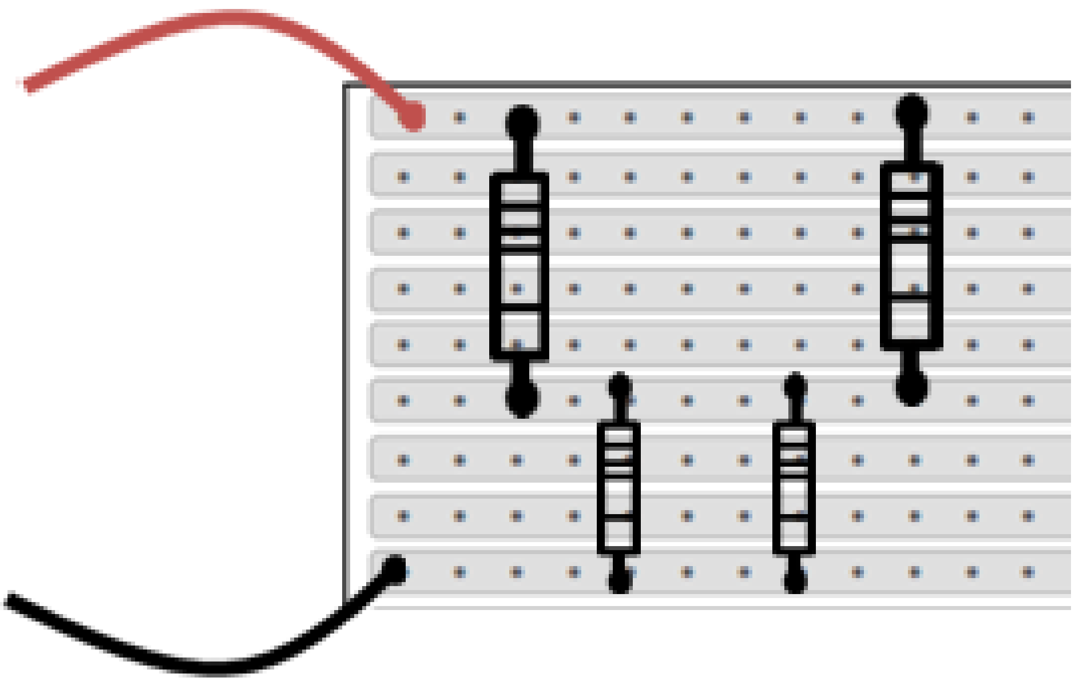
If you suspect a poor joint, it is best to start over. This will require you to remove (de-solder) the old solder joint before starting again.

You will use a de-soldering pump:

1) Depress plunger and position nozzle over joint to be removed.
2) Position soldering iron tip onto joint and heat solder. Do not touch the end of the pump.
3) When solder begins to flow, release plunger to suck up solder.
4) Depress plunger once more to expel solder from pump.

Soldering Practice 1





Soldering Practice 2