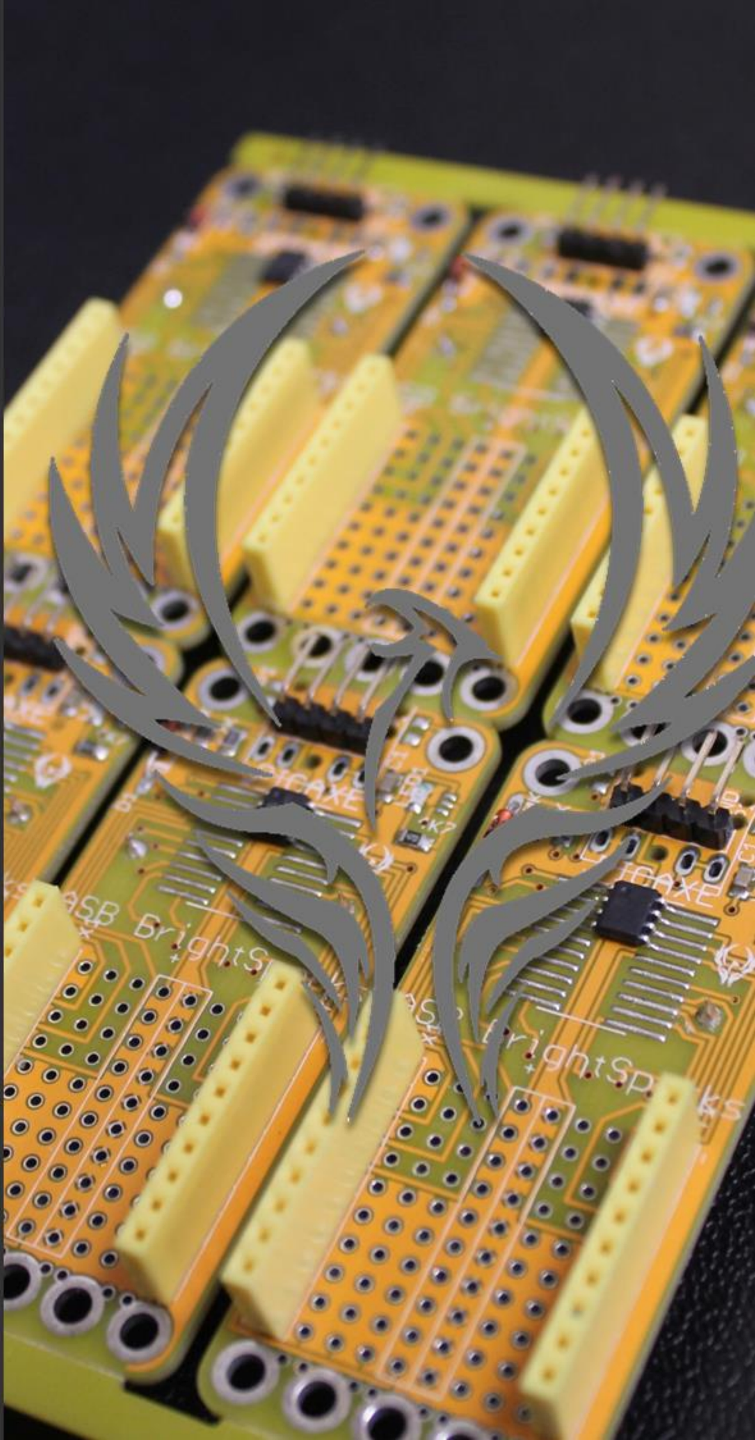
phoenix
Technology

Card Circuits

Digital Technologies Teachers Aotearoa



Teacher Notes

These circuits are not designed as a definite step by step process but more of a guide of how I have done things in the past. You can extend and use all these simple circuits in many ways and can be adapted to many different curriculum areas.

The circuits in the pictures are on white card to make it clearer in a photograph. I use the cheapest, 'grey' card I can get my hands on and cut it up into squares around 120mm to a side. Don't throw away the little bit of waste. This can be used for switches ☺

Teacher Notes - Storage

It is easier for you if each student has their own a container for all their components. It needs to be bigger than 120 X 120 X 40. I find that a small sandwich box or larger margarine container is good. A 2ltr ice-cream container would fit everything in but it takes up a lot of class storage area.

How many components they use is up to you. I am always thinking of waste and recycling so students reuse their components as much as possible for each circuit.

I encourage students to take their circuits home to show their parents (and bring it back!) If they are able to use the circuit in a ‘project’ (it could be at home or at school e.g. in Art) I ‘secretly’ help them and give them the required components.

Soldering irons – I bought a series of cheap ones that caused me no end of problems. If you can afford it, get good ones. It’s a big investment for the department but will save you much heartache in the future!

Soldering Safety

There are a number of points I ensure that all students must know before soldering.

Safe use and safety. These are points I constantly talk about. (Nearly every lesson!)

- Safety glasses MUST be worn when soldering.
- Soldering irons are hot and can burn badly. Nylon clothing can stick to the skin if heated.
- Solder can ‘spit’. It is unlikely but it can happen – They MUST wear safety glasses.
- Fumes – Don’t breathe them in, you won’t get high, just sick! It is flux, the cleaning agent you are breathing in. Use a well ventilated area.
- Don’t chew the solder! It’s REALLY not good for you!
- Cleanliness is everything – make sure everything is clean.
- Use a damp sponge to clean the soldering iron tip every time you want to solder.
- Tin the soldering iron tip – this makes the heat transfer much more efficient
- Tin the components before joining.

Components

Each student does need a container for all their components. It will drive you mad if you don't get them into good habits at the beginning!

It needs to be bigger than 120 X 120 X 40 I find that a small sandwich box or larger margarine container is good. A 2ltr ice-cream would fit everything in but it takes up a lot of class storage area.

How many components they use is up to you. I am always thinking of waste so students reuse their components for each circuit. I encourage students to take their circuits home to show their parents. If they are able to use the circuit in a 'project' (it could be at home or at school e.g. in Art) I 'secretly' help them and give them the components.

Soldering irons – I bought a series of cheap ones that caused me no end of problems. If you can afford it, get good ones.

Teacher Notes - Nomenclature

Nomenclature is a term students probably haven't come across before. I have found that they seem to remember the symbols and uses better than if I said "a system of names for a specific purpose".

I prefer the students to slowly create their own Nomenclature document/pages, adding a component symbol, name and use as they come across them rather than giving them a big scary list at the beginning.

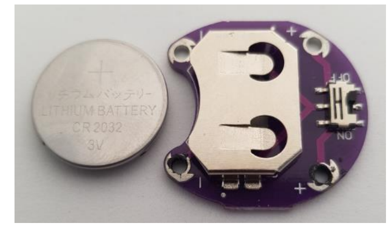
They will need to refer to the list regularly until they know the name of each component. I will suddenly 'not understand' when they ask for "the black thingy with three legs". They have to use the correct term for me to understand them. It becomes a game for them trying to get me to understand what component they are referring to ☺

Batteries/power supply

Unless you have a lab setup with bench power supplies, power is always going to be an issue. There was no such luxury for me in my classroom so I use batteries. This can be an advantage or a disadvantage to you!

Depending upon the final application, students will normally end up using batteries but managing them can be ‘a chore’!

Lillypad make an excellent little 3v battery holder with a switch that can be stitched in place. The holes are connected to the battery so they are also the power terminals. You can also get a rechargeable CR2032 sized cell for them, but, how are you going to keep a class of batteries charged?



You can have a two, three or four cell, switched AA battery holder. Physically larger this 2v, 4.5v or 6v battery holder will last longer and the batteries can be obtained quite cheaply (especially if you use your PPTA registration card!) But….. The AA batteries are desirable, they tend to ‘walk’ and of course, students forget to turn them off at the end of the lesson.

I found that the PP3, 9v battery was the easiest to manage in the classroom for most circuits. I made a block that just fitted ten batteries (a class of just under 30). It made it much easier for me to keep a track of the batteries at the end of each lesson and the batteries weren’t as ‘desirable’ to ‘forgotten in a pocket’!
One thing that I did find useful was to spend a tiny bit more and buy better quality battery snaps. The ‘flexible’ ones just don’t last.
Also, bend out the springs slightly. It makes it much easier for students to ‘snap on and off’ and they tend not to break them so easily.

ProjectComponent Requirements

1	Project container / box
As required	Solder
As required	Copper tape
2	470 Resistor
2	10k Resistor
1	1k Resistor
3	LEDs
1	LDR
2	Transistors (BC337)
2	10k potentiometer
2	100uF Electrolytic Capacitor

LEDs – protective resistor

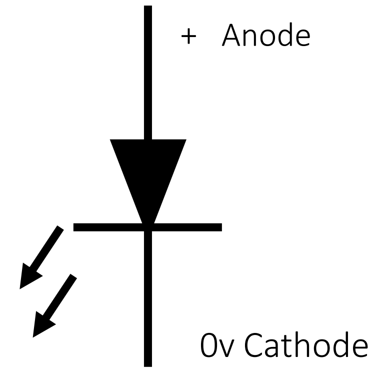
For their first circuit, making an LED light up, students will need to be able to attach their components to the circuits.
As usual, the first one is the most difficult!
I spend a good deal of time making sure students know not only the 'what' but the 'why' we do things in a particular way.

TEACHER NOTE

LED's are very sensitive to being 'wired' the wrong way round and having too much current.
A 'protective resistor' is used to limit the current flowing through (much like a restrictor in you shower to reduce the amount of water being used).
Through the projects, I use different batteries therefore the protective resistors need to change. You don't want to stock many different values of resistor, so, as a rule of thumb, I use;

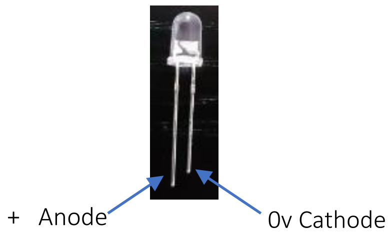
- 3v = 100 Ω
- 4.5v = 270 Ω
- 9v = 470 Ω

Using LED's

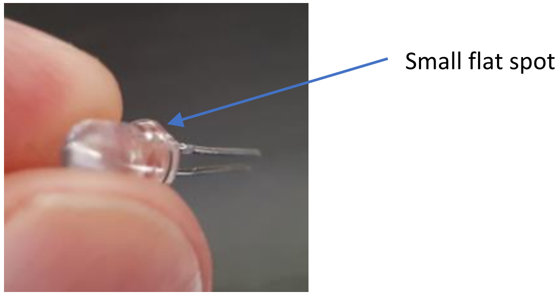


LED's are polarised, you have to get them the right way round. They really don't like the current being put in the wrong way!
To make things easier, I get my students to mark the cathode (the one pointing to Ov or ground with a marker pen. It then looks like a negative symbol

When you first pick up a 5mm LED you will notice that the legs are a different length.
This makes it easier to distinguish which one points to the positive (anode) and which one points to the zero volts (cathode).



Unfortunately for us, we're going to cut the legs to equal length shortly. But….. Luckily, looking closely at the 'rim' at the bottom of the plastic you will see a small flat spot. That denotes the cathode (points to the 0V) side of the LED.



The first circuit

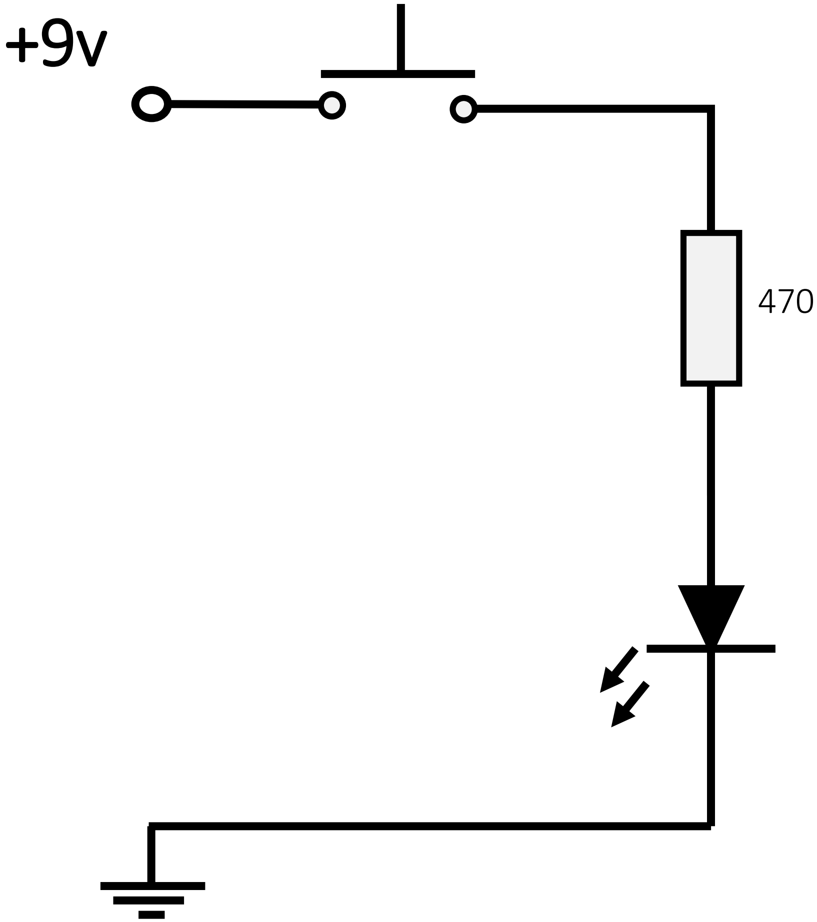
Their first circuit must be successful and quick if you are to 'hook them in'.

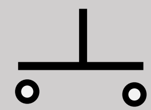
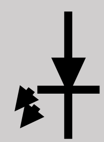
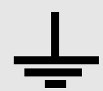
Just being able to make something quickly that turns on a light is a milestone for most students. Their eyes light up just as much as the LED!

This is also the start of their Nomenclature – now they are learning the symbols and meanings as well as how to use the components.

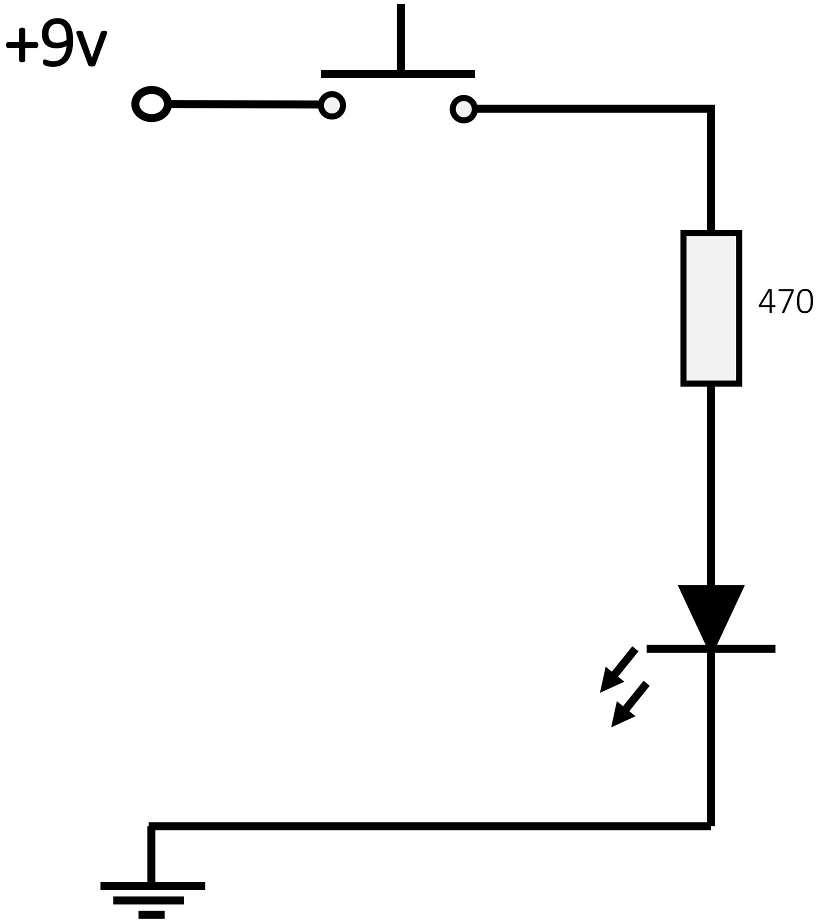
What can I use it for? - The circuit can be used in many different ways. Drawing attention to an aspect of a garment or headwear is usually the first thing that students use this circuit for.

First Circuit



Component List		
	PTM	Push To Make Switch – makes a circuit when pushed
	Resistor	Creates electrical resistance
	LED	Light Emitting Diode – A diode that emits a certain frequency of light (colour)
	Earth	Earth, zero volts, and ground (GND) are all the same common reference point

Continuity and measurement



With such a simple circuit you can add different / extra tasks to it. I have found that these tasks are best done on a very simple circuit.

Multimeter

Reading voltage across the battery, resistor and LED

- Why is the battery not exactly 9v? That's what it says it should be?
- What happens when you add the voltage of the resistor and LED up? Same or very similar to the supply voltage?

Reading resistance – Why is the resistor not exactly 470 ohms?

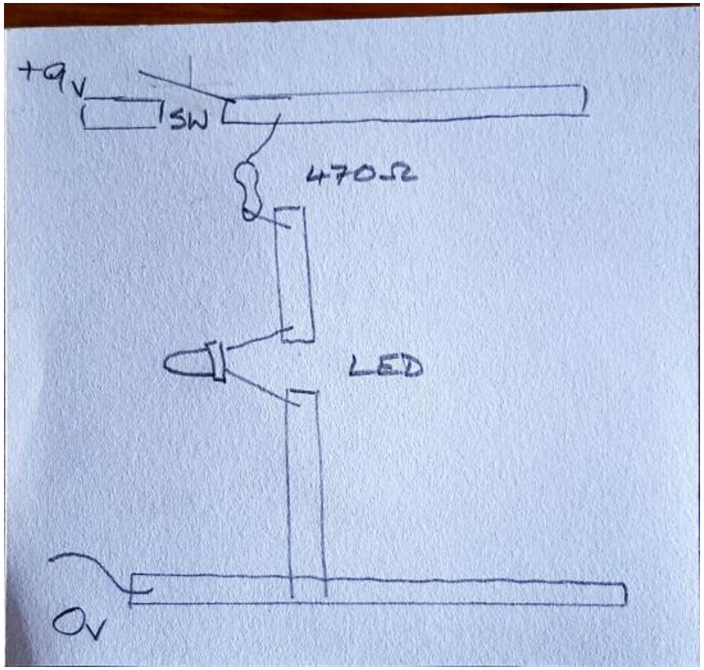
- This is a good time to teach them how to read the colours and talk about component tolerances.
- Why can't you read the resistance across an LED?

Calculating Current

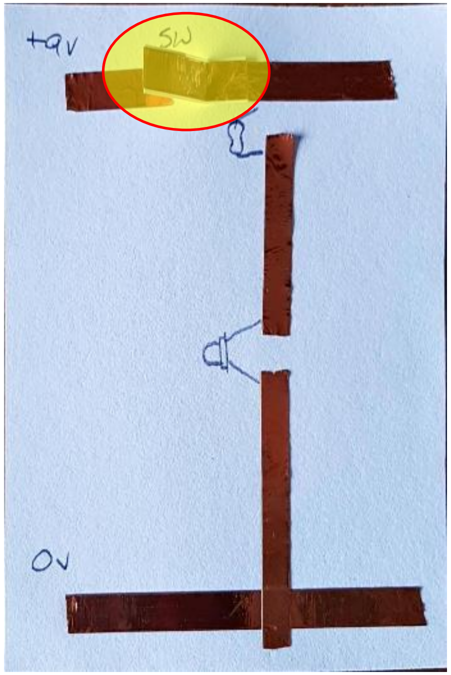
- I never do this right at the beginning of the course (it's usually scary to most students!)
- You could come back to the circuit and calculate the current using Ohms Law
- It tend not to use the multimeter in series to measure current. They always 'blow' the fuse! I come back to it later.

What does is look like?

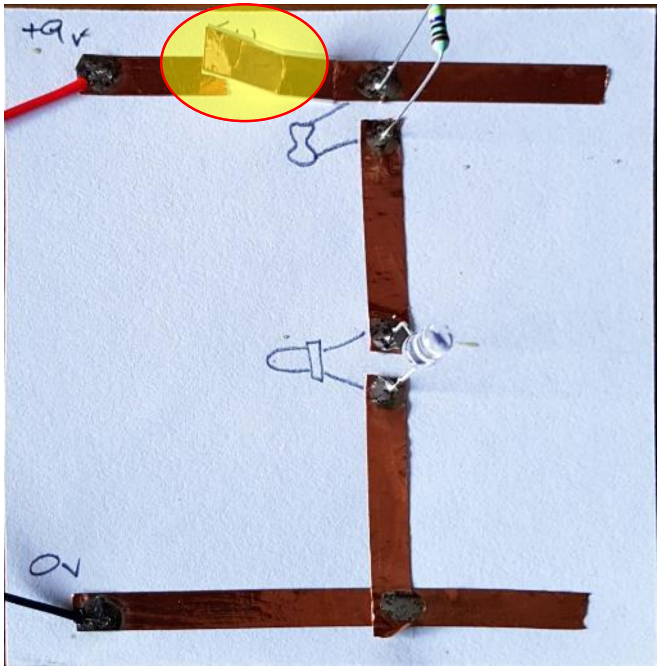
I ask the students to draw a picture (track layout) of their circuit. As close to scale as possible



They stick on the copper tape and make the switch.



All joints need to be tinned first. Then components are added



NOTE – You can see in these pictures how the Push To Make (PTM) switch was made from the scrap pieces of cardboard. The copper tape it wrapped over then under to form the switch. Bend the card up a little so it doesn't touch all the time.

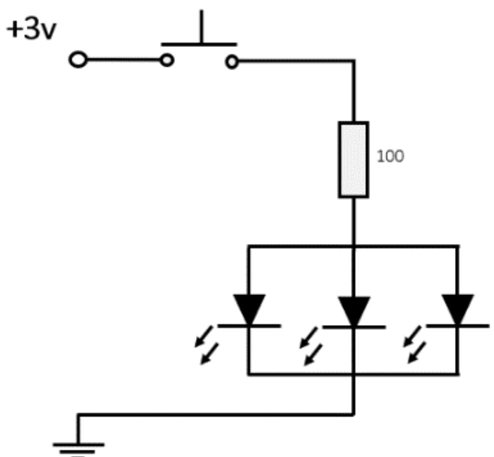
Voltage and current

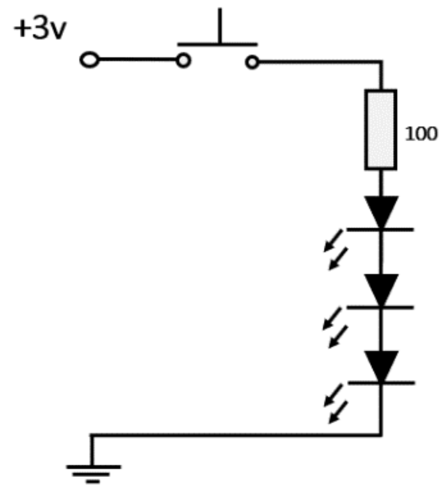
The next two circuits are good ‘teaching tools’ to use for students to understand the difference between current measured in Amps (A) and Voltage (V)

I ask my students to make the two circuits but don’t give them any power supply (batteries). This may sound ‘mean’ but there is a method in my madness.

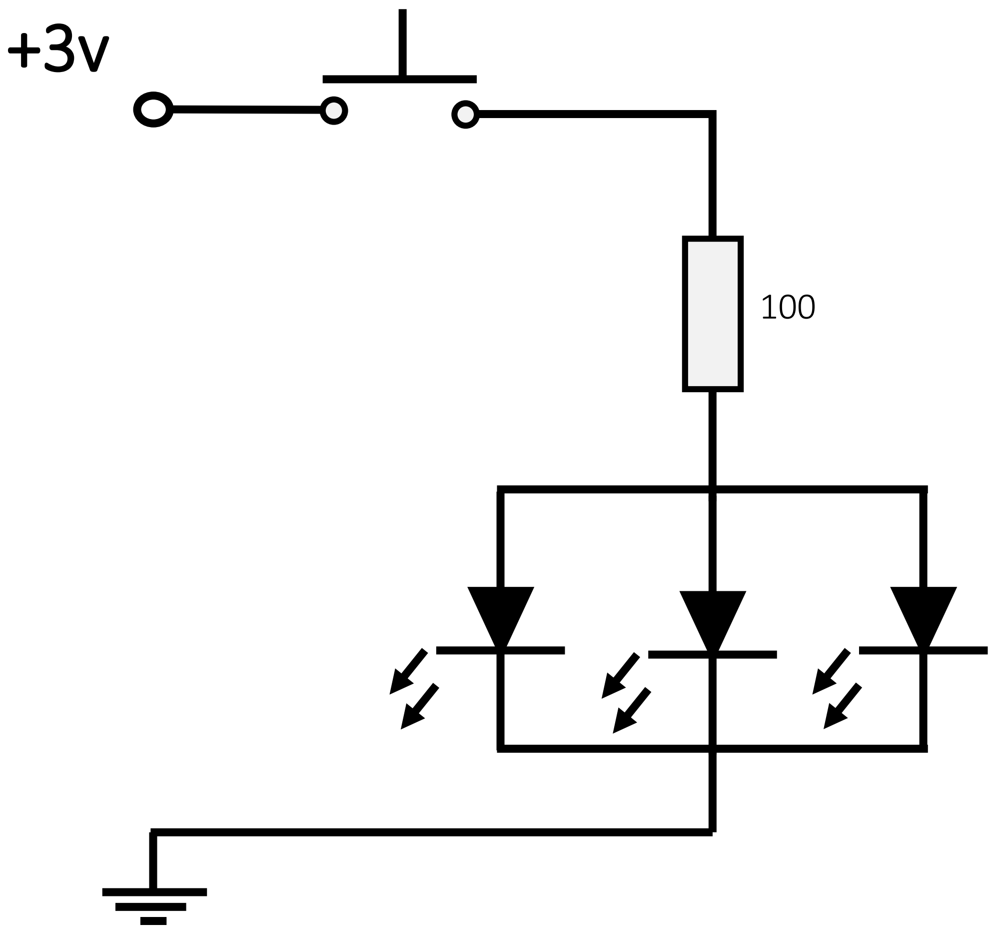
They have to use the multimeter set to Continuity (the beepy sound) to check all their circuit joints and ‘fix’ any that have any broken joints.

You can get pairs to swap circuits and test their friends circuits.





Circuits in parallel



What happens when they press the switch? Three LED's?

Measure the voltage across the resistor and the LED's

They could calculate the current using Ohms Law

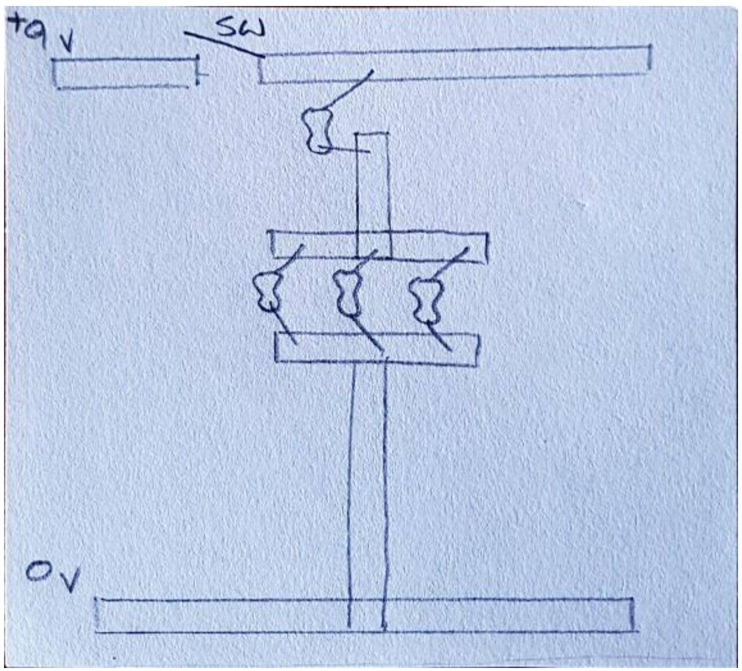
Other uses for this circuit?

This very simple circuit can be used in so many different ways. If the students are investigating Maori Myths and Legends this circuit can be incorporated into the design. A fish can be made to have an 'inner glow' mixing different colours of Led. Masks can have eyes that light up. Dioramas can be used for backlighting. Maps and charts can show locations when a button or picture is pressed.

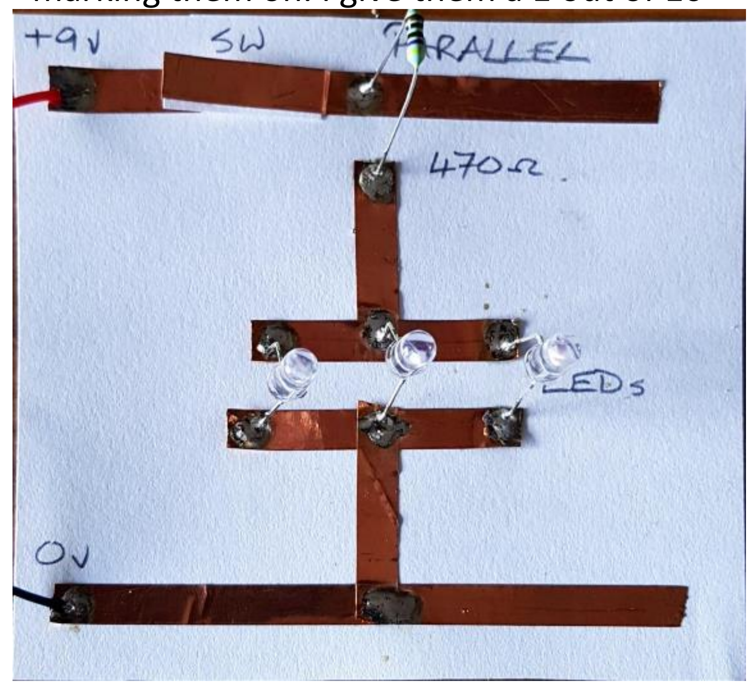
Once introduced, I have found that the students take over and use their imagination in ways I would never have expected!

Parallel Circuit

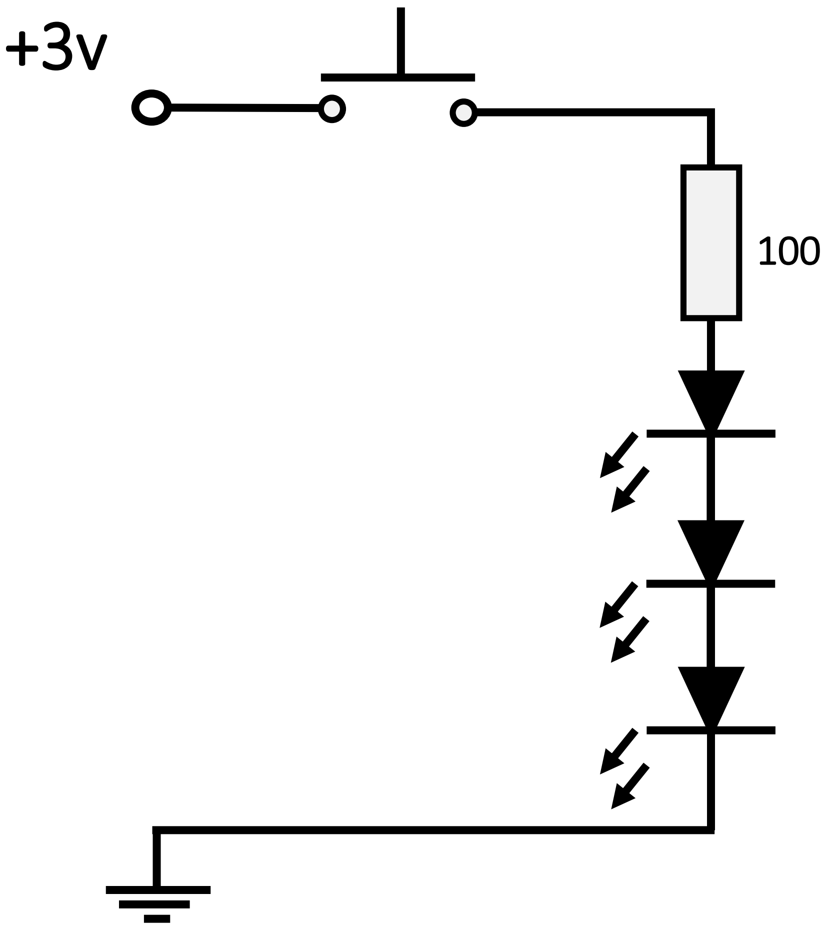
Each time they create a new track layout they have to draw it first. It gets them used to the components and the sizes of them



Now I am becoming more particular about their soldering. This is primarily what I am marking them on. I give them a 1 out of 10



Circuits in series



What happens when they press the switch? Three LED's?

Measure the voltage across the resistor and each of the LED's

Compare the total to the supply from the battery.

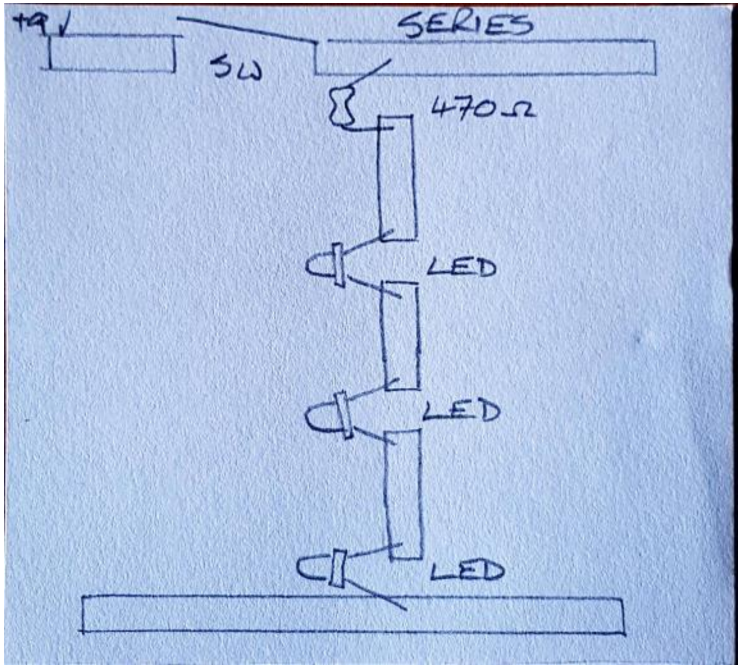
Why are the so dim or not even alight?

What happens if they swap from blue to red LED's?

Could it be due the blue and red being at opposite ends of the visible light spectrum? Blue light has a much shorter wavelength than red light therefore it takes more energy to create.

Circuits in series

More drawing. They have to get at least one other person to check their drawing – less pressure on the teacher!



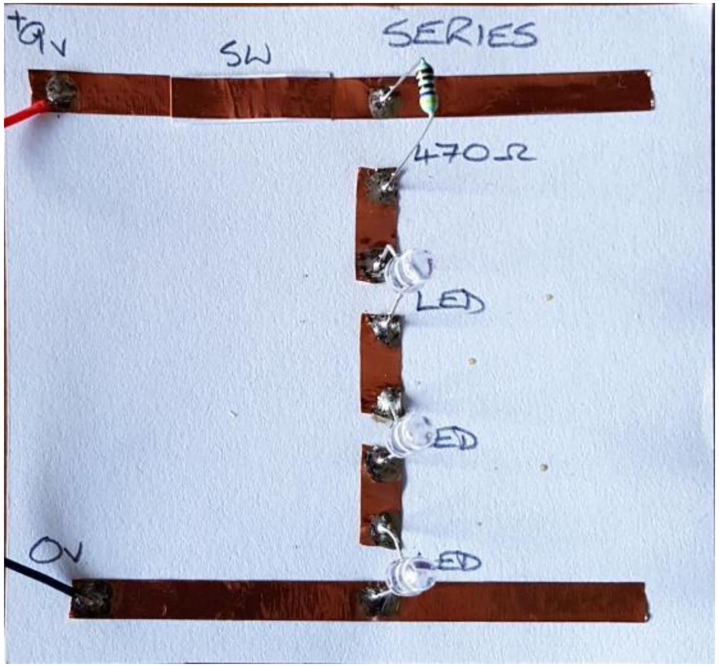
“But it doesn’t work!”

This is a good time for them to use the multimeter to find out why. Using both continuity and measuring the voltages (these they can write down on the card)

For the ‘faster’ students they replace the blue LEDs with red ones.

Why does it work now??

I mark the solder joints and layout in the same manner.

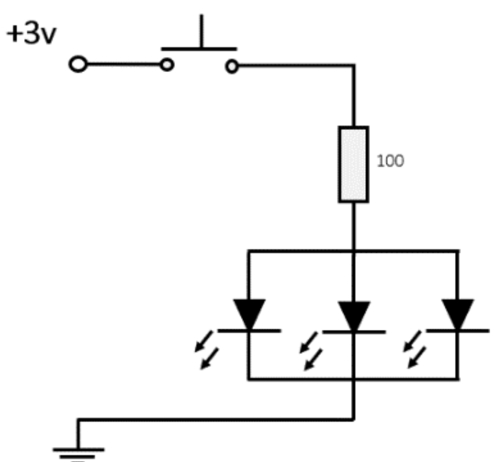


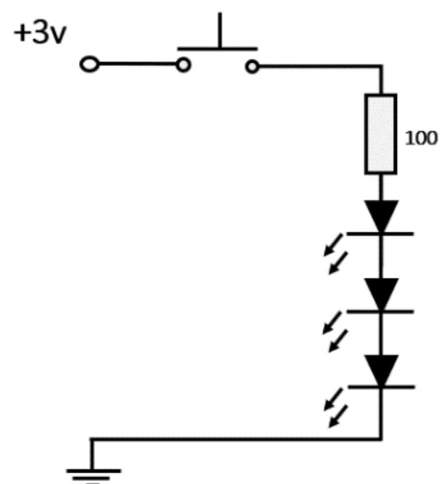
Voltage and current - Explained

Students will find that the circuit in parallel (the first one) will light up but the second one refuses to work!

I task my students with trying to find out why. I leave them to do more testing with their multimeters for a few minutes before asking them if they need a bit of help. (This means they are requesting information from me rather than me 'forcing' the information upon them!)

Here is where I introduce Current (A). I use the analogy of water in a 'pipe'. Voltage (V) is the pressure of the water measured in Volts in that pipe relative to another 'pipe' in the circuit whereas Current (A) is the flow of the water measured in Amps. I talk about how many litres of water would pass a given point in the pipe in one minute.

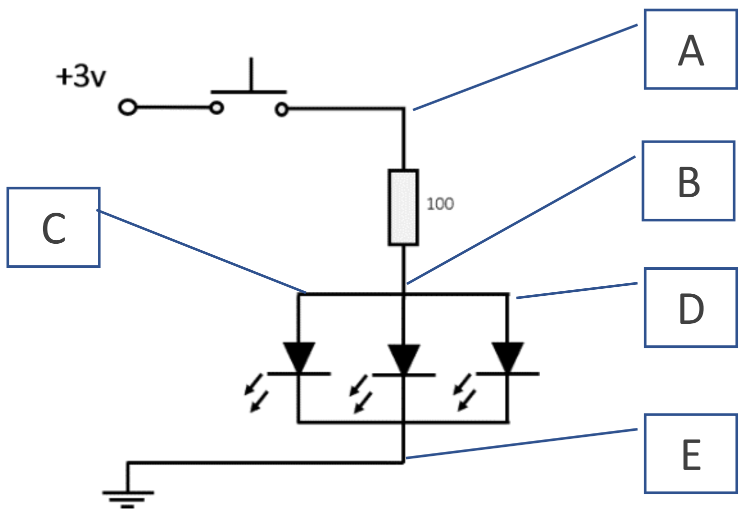




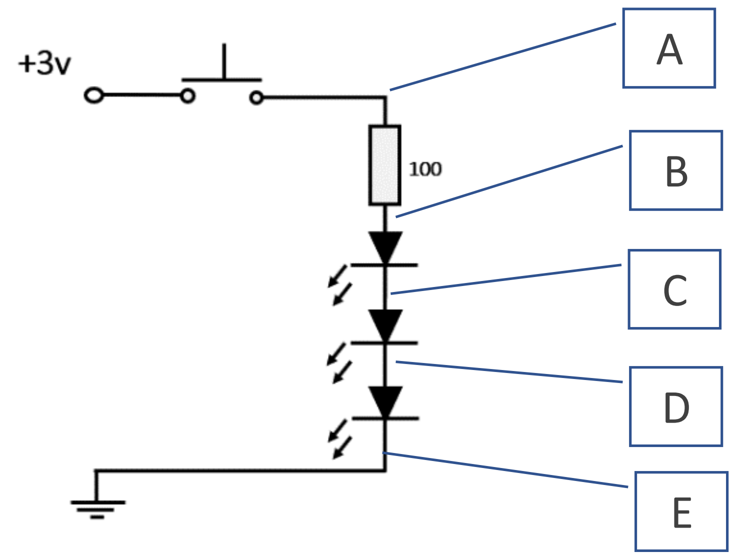
Measuring Voltage

I draw the schematics on the whiteboard and ask students to take the voltage readings. This forces them to use the multimeters again but also makes them think about not only the flow of electricity and current but how the energy of the circuit is being used.

With the parallel circuit students can measure the voltage across the power supply (A C), the resistor (A B) each LED. The readings will be the same.
Does the circuit work?
Why?



As with the parallel circuit, students read the voltage across the resistor and each LED but the results are different?
Why the different readings?
Does the circuit work?
Why not??



The Difference Between Voltage and Current

This is a difficult, but very important concept in electronics for students to grasp. You can measure it but you can't see it!

I use the analogy of water in pipes. I tell the students that this analogy doesn't work all the time when you get into more 'advanced' electronics but it does help them understand the basic principals.

I point to the ceiling and talk to the students about how the electricity gets to the lights. As the electricity/water flows through the wires/pipes (current measured in Amps) it has pressure (measured in Volts). Pressure is the difference between one point in the pipe and another point (Potential Difference – PD or Voltage).

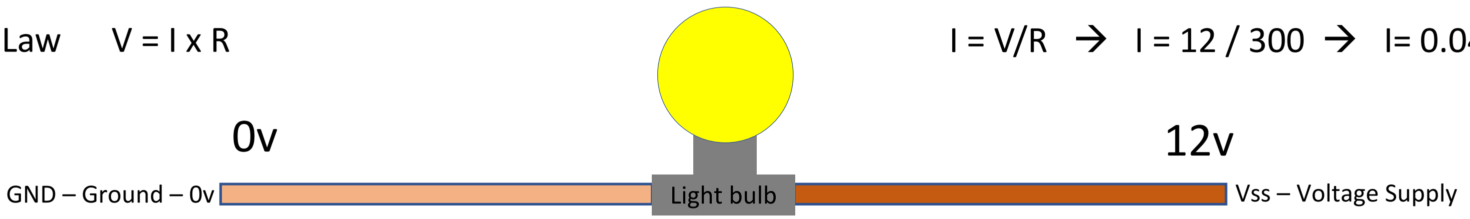
So. A pipe/wire may have a pressure of 12 psi (or you could say 12 volts). That is the pressure in the pipe/wire and ground which is at a pressure of 0 psi or 0 volts.

However, if it were to measure the difference between two points across a resistance (a filament bulb in this case) we could use Ohms Law to calculate how many litres (Amps) of electricity are flowing through the circuit.

In our case we have a pressure (voltage) difference of 12v. If we were to use the multimeter to measure the resistance across the light bulb and found that we had a resistance of 300 ohms we could calculate the flow of water/electricity through the circuit.

Ohms Law $V = I \times R$

$I = V/R \rightarrow I = 12 / 300 \rightarrow I = 0.04$ A or 40mA



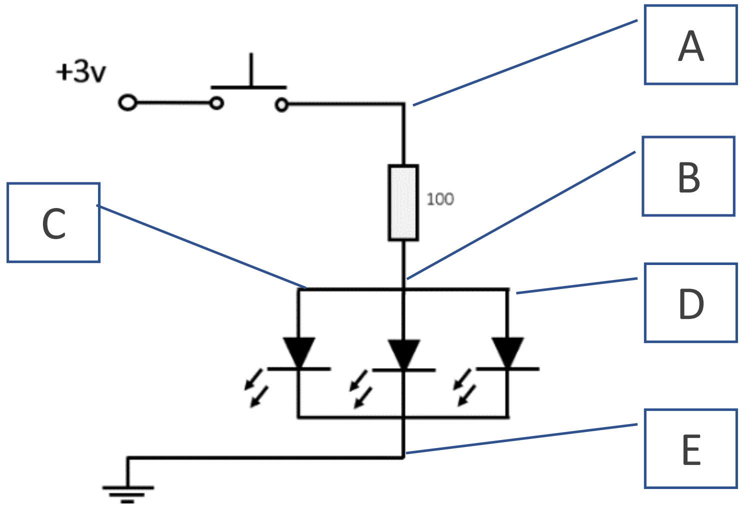
Current Through A Circuit

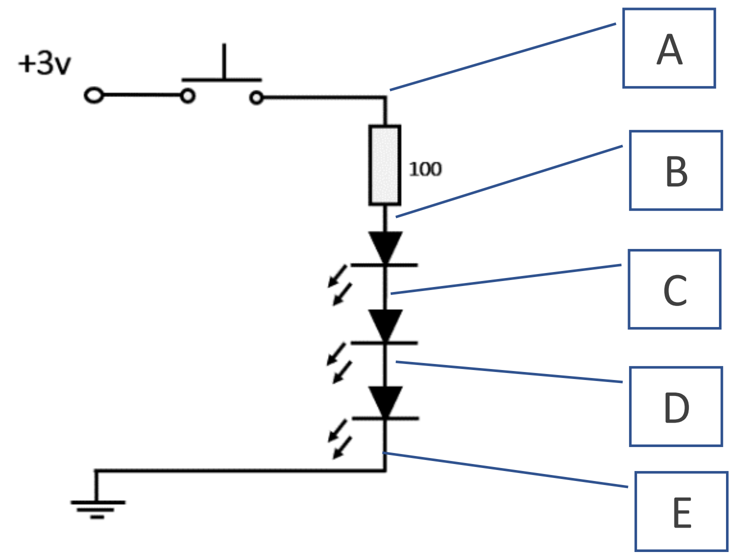
Now we know how to find out the current (A) flowing through a circuit we can start to apply it to our one.

We know that we have a 100Ω resistor because that's what it said on the packet. But….. it's probably not! This is because of tolerance or the accuracy when it was manufactured. So, the students should measure theirs to see what they have. We know that the battery (in this case) is 3v But……. it probably isn't because there is a chemical change taking place and that varies depending on how new the battery is.

I'm going to use the numbers in the diagram for this example.

Ohms Law V=IR therefore 3 = ?? X 100 → I=V/R → I = 3 / 100 → I = 0.03A or 30mA





Units of Measurement

We have talked about resistors being measured in Ohms that range from 1 and 2 Ohms all the way past one million ohms.

We are starting to talk about Current (Amps) being measured in thousandths of amps the symbols they use are VERY important! If you get it wrong it can be 'quite shocking'!

EG. If a person used the capital letter M instead of the lower case m this would make it a very 'exciting circuit'!!

30**M**V means that you have 30,000,000 volts 30 Meg ohms
30**m**V indicates that you have 0.03 volts 30 milli ohms

This means that there is a **one billion times difference** all because you used a capital instead of lower case!

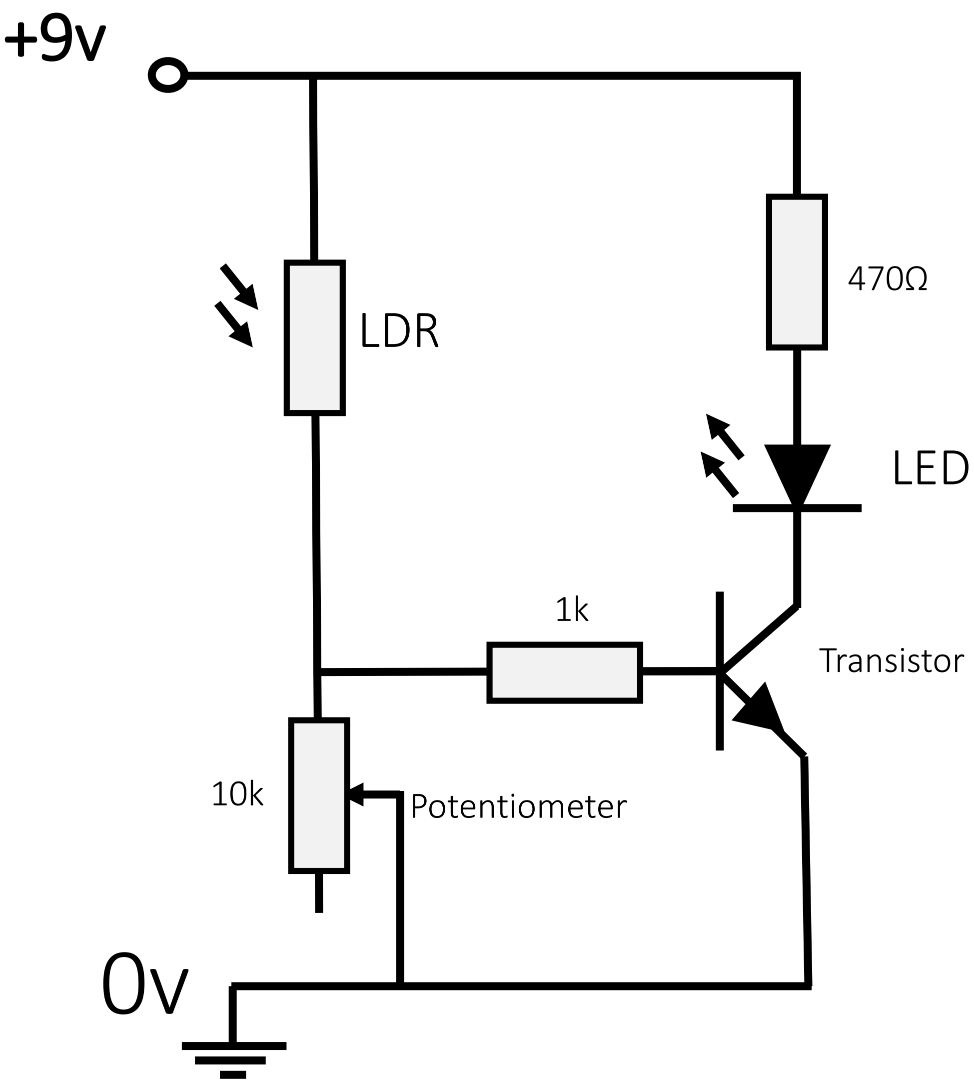
Now you can see how dangerous this could be!

Now is the time I introduce milli, micro, nano, pico and talk about the importance of using the correct symbols.

I usually build the table up on the whiteboard with help from students suggesting what comes next.

T	Terrra	1,000,000,000,000.0
G	Giga	1,000,000,000.0
M	Mega	1,000,000.0
K	Kilo	1,000.0
	One	1.0
m	milli	0.001
µ	micro	0.000 001
n	nano	0.000 000 001
p	pico	0.000 000 000 001

Introducing the transistor as a switch



Component List		
	PTM	Push To Make Switch – makes a circuit when pushed
	Resistor	Creates electrical resistance
	LED	Light Emitting Diode – A diode that emits a certain frequency of light (colour)
	Earth	Earth, zero volts, and ground (GND) are all the same common reference point
	LDR	A resistor whose resistance depends upon the amount of light falling on it. Light Dependant Resistor
	NPN Transistor	A transistor can be used as an amplifier or an electronic switch

Introducing The LDR
– looking for the *“ah haaa”* moment!

I’m a bit ‘sneaky’ when I introduce the LDR! ☺

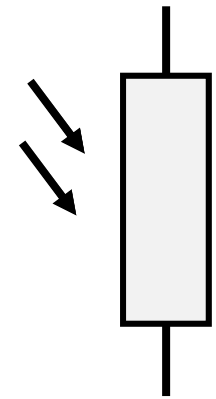
I don’t tell the students anything about the component. I ask them to tell me what it does. The only piece of equipment they are allowed to use is a multimeter.

This forces them to try to remember (they always forget!) what all the settings are for and how to use it!

Of course the first thing you will hear is the beep, beep, beep of the continuity tester. They quickly work out that this isn’t going to help them.

Eventually, they move onto resistance. Now I ask them to record the readings they get. After a while I stop the class and ask students what readings they managed to record. I have a few questions for them to answer;

- Why are all your readings different when you are using the same component?
- What happens when you move around the classroom?
- Does this make a difference to your readings?
- Why do you think that is?



Eventually (or with some hints), they work out that it is due to the light level changing the resistance.

Now is time I talk about the resistance is dependant upon the light level and why it is called an LDR (Light Dependant Resistor).

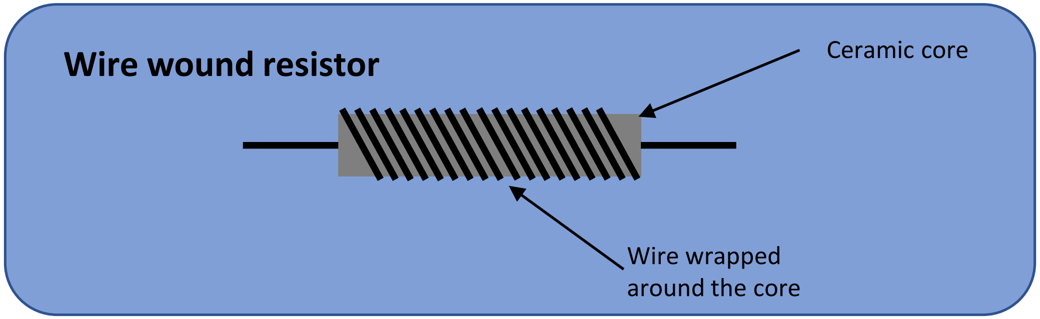
It’s <u>resistance</u> is <u>dependant</u> upon the amount of <u>light</u> falling onto it.

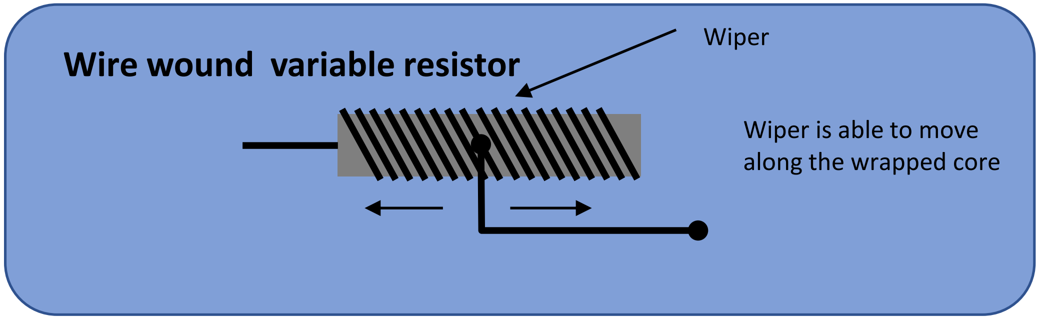
Once they realise this they find it much easier to remember and use in later circuits.

What is a potentiometer?

Resistor History

Initially, most resistors were made from different lengths of wire as nearly all wire has some form of resistance. To make them more manageable, the wire was wrapped around an insulator, usually ceramic.



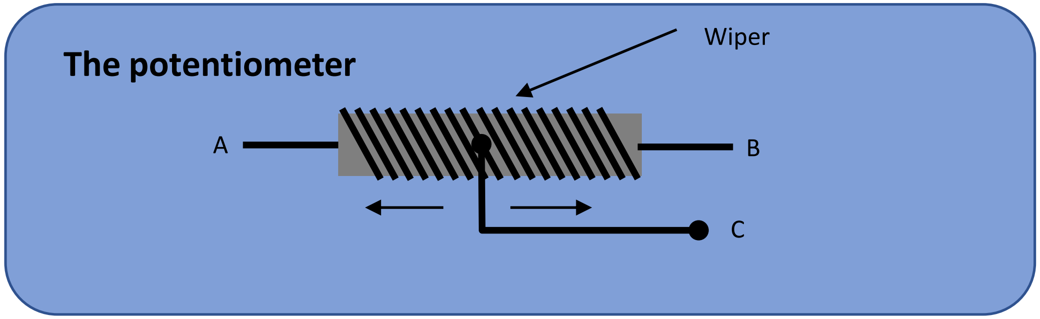


Variable Resistors

To make a variable resistor a ‘wiper’ contact would slide up and down the wire wrapped ceramic core. This effectively changed the length of resistance wire with current flowing through it. Note that there are only two terminals.

The potentiometer?

By using a third terminal, the electrical potential can be divided by changing the position of the ‘wiper’ contact.

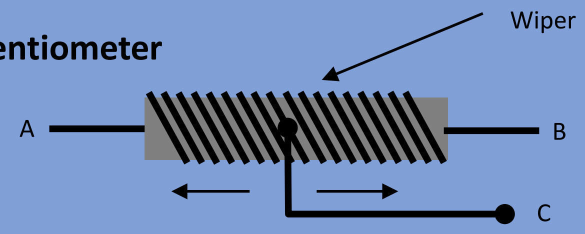


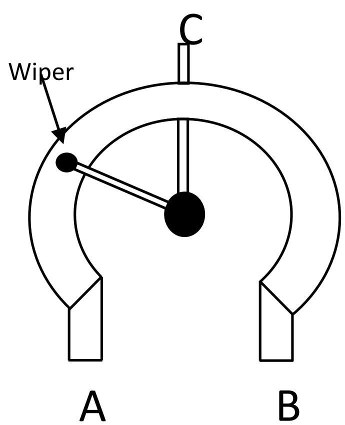
What is a potentiometer?

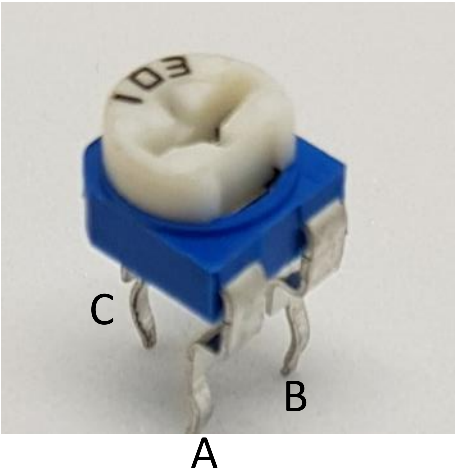
The potentiometer?

So. If we bent the resistance wire into a semicircle we could have the 'wiper' rotate around the centre point

The potentiometer







The potentiometer as a variable resistor?

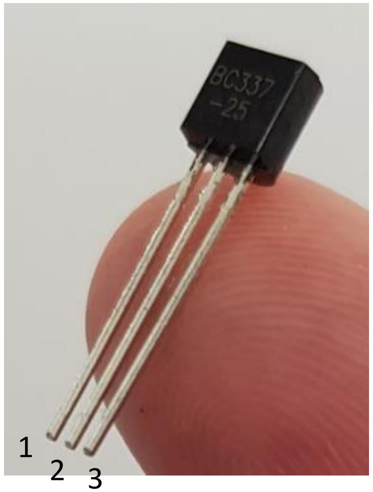
This is why I only buy potentiometers. You can also use them as variable resistors. Looking at the diagram above, you only need to use one of the ends of the resistor and the wiper. E.G. use either A and C or B and C

Using A and B will only give you the fixed resistance

But what value have I got?

On smaller potentiometers there isn't the room to print the full value so they use a form of code.
In the example above you can see the numbers 103. This is not 103 ohms. This means 10 and three zeros after it = 10,000 or 10k ohms
154 would be 15 followed by four zeros = 150,000 or 150k ohms.

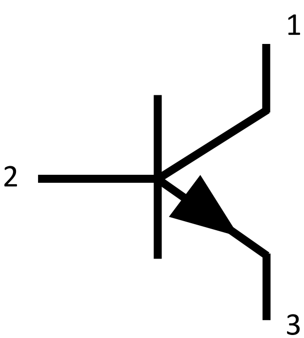
What is a transistor?



A transistor is an electronic component that can be used as a switch or part of an amplifier circuit. Made from a semiconductor material, it is arguably one of the most important technological advancements of the 20th centaury. It is considerably more reliable and uses far less electricity than the triode tube to either switch or amplify another electronic current.

Although the transistor looks very small in the picture, it is actually much, much smaller. This TO-92 type casing is greater than 99% plastic. This is so us humans are able to see it, pick it up and use it!

You can place 16,000 transistors next to each other in the width of a full stop!!

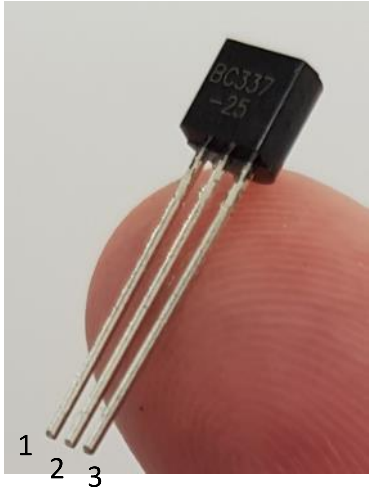


Symbol

1	**Collector**	Electricity in – this leg points towards the anode (+)
2	**Base**	This controls the flow between the Collector and Base
3	**Emitter**	Electricity out – This leg points towards the cathode (-)

Note!
Transistors come in many different packages (shapes) but none of them like too much voltage applied to the Base (2)

How to make the transistor circuit



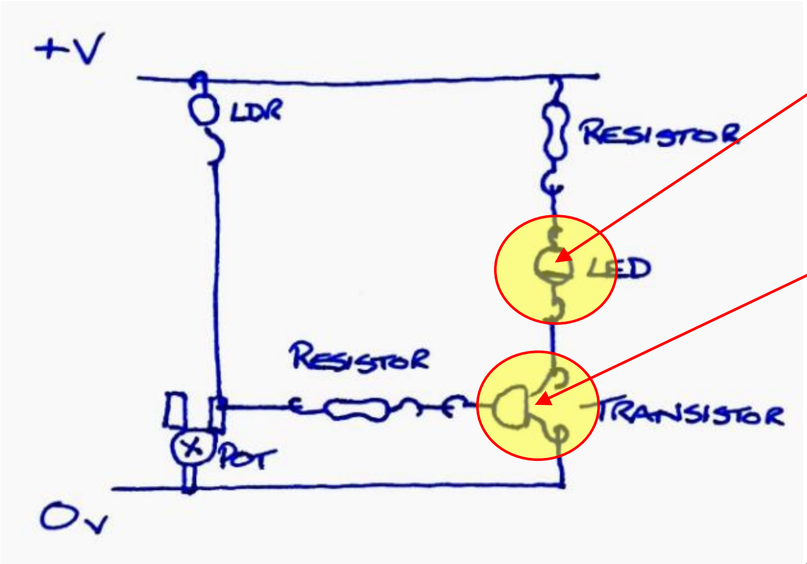
1
2 3

As we move onto more difficult/interesting circuits it is really important that we are able to place the components correctly.

I ask my students to draw a picture of what the circuit will look like (on paper/in their books) before they start to bend the legs around. It’s also good for recording their progress!

Too much bending and a let will snap off! They are far more fragile than the components they are used to.

I talk about the history of the transistor, what it is and what we are going to use if for.



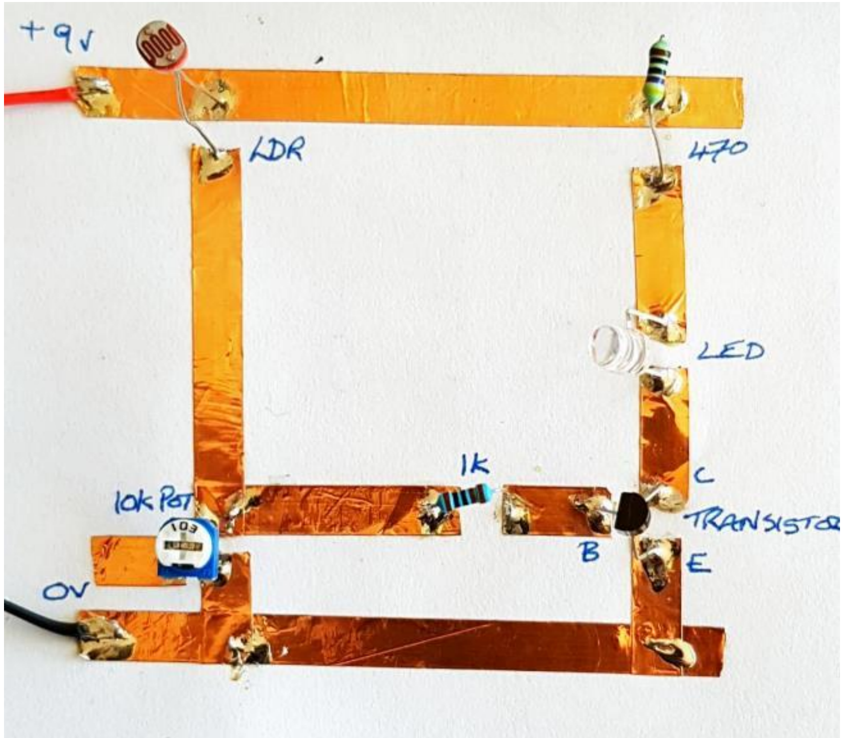
Notice that the LED has a line showing the Cathode (the flat spot) pointing towards 0v.

This is the sort of thing you are looking for!

The flat face of the transistor is facing the wrong way.

The collector has to point towards the +
The emitter points towards the ground.

Example of what it could look like



Note: For clarity I have not added the 'blobs' of conductive paint on each of the joints.

Looking at the circuit on the left, you can see that the circuit has been drawn on using a pen before hand.

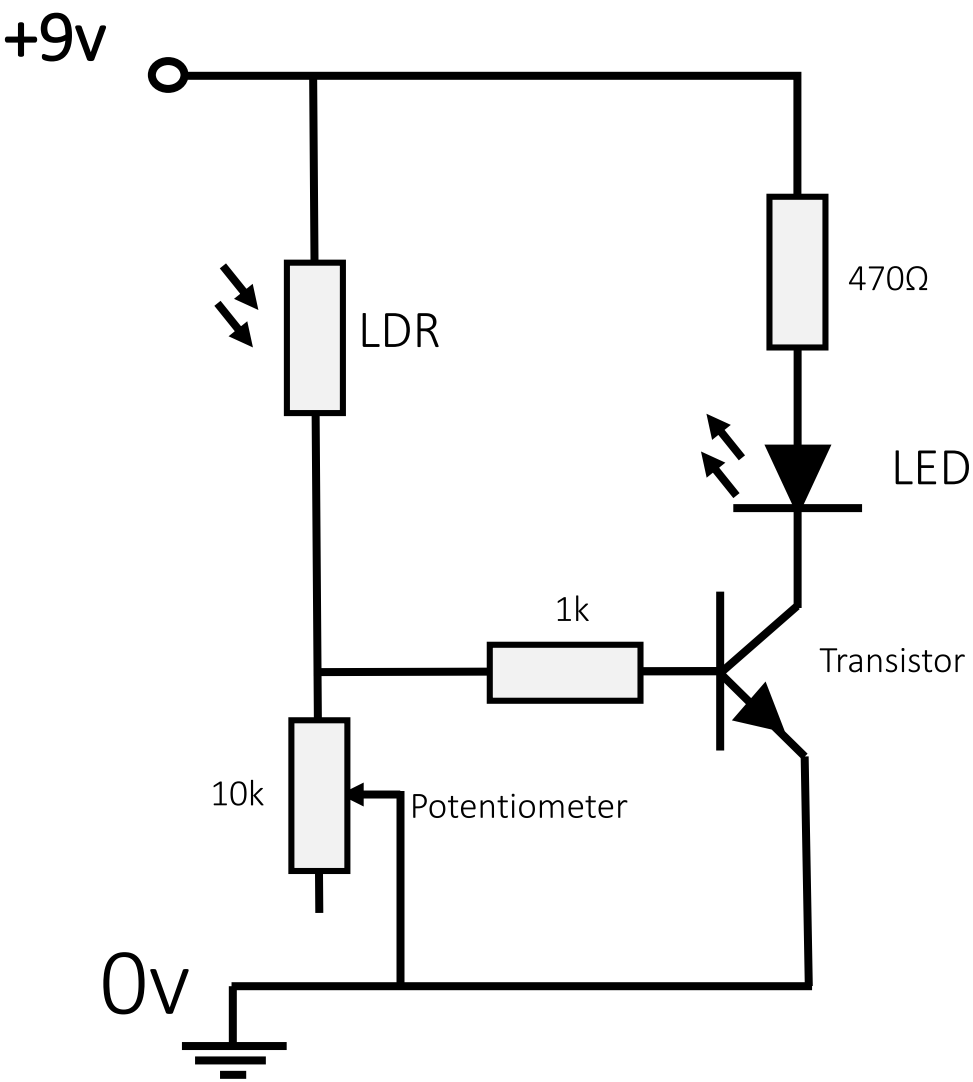
Instead of circuit symbols, I ask my students to draw a picture of the components to scale. I do this for two reasons.

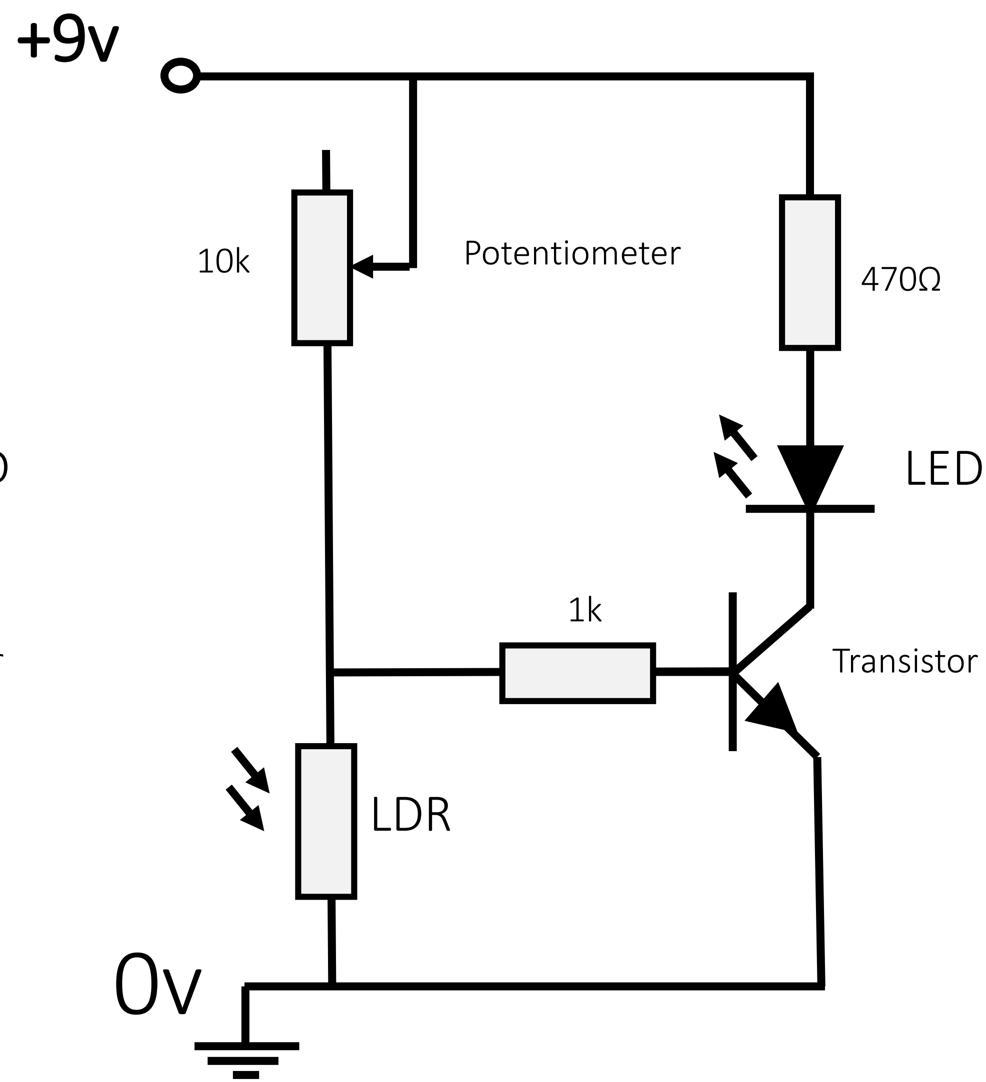
1. I can check to make sure they are placing the components the correct way round
2. Students get used to the scale / size of the components. It makes it much easier for them when using the circuit in a design of their own.

Getting the circuit to work.

Initially, the circuit will not work. This is because the circuit needs to be 'tuned in'.
For the LED to turn on and off the voltage level at the transistor collector needs to be 'just right' (0.7v).
The easiest way to do this is to turn the potentiometer all the way back and forth until you find the place where a small movement turns the LED on and off.
Make the LED only just turn on. <u>Really</u> only just!
Shade the LDR and the LED should turn off.
Electronic magic! ☺

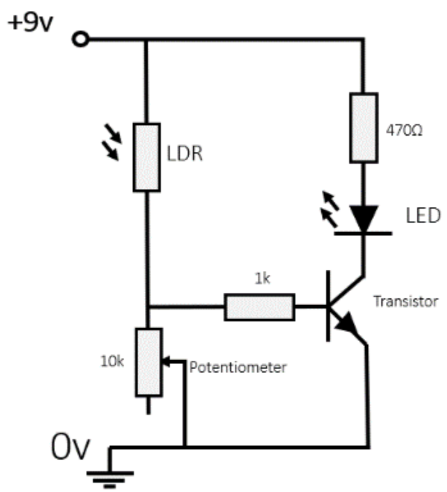
Spot the difference?



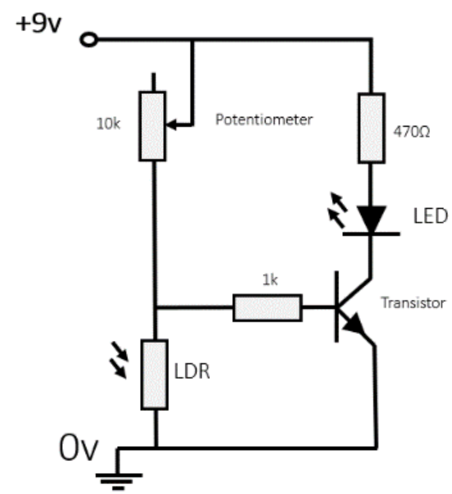


Reversing the logic

LED turns **on** with more light



LED turns **off** with more light



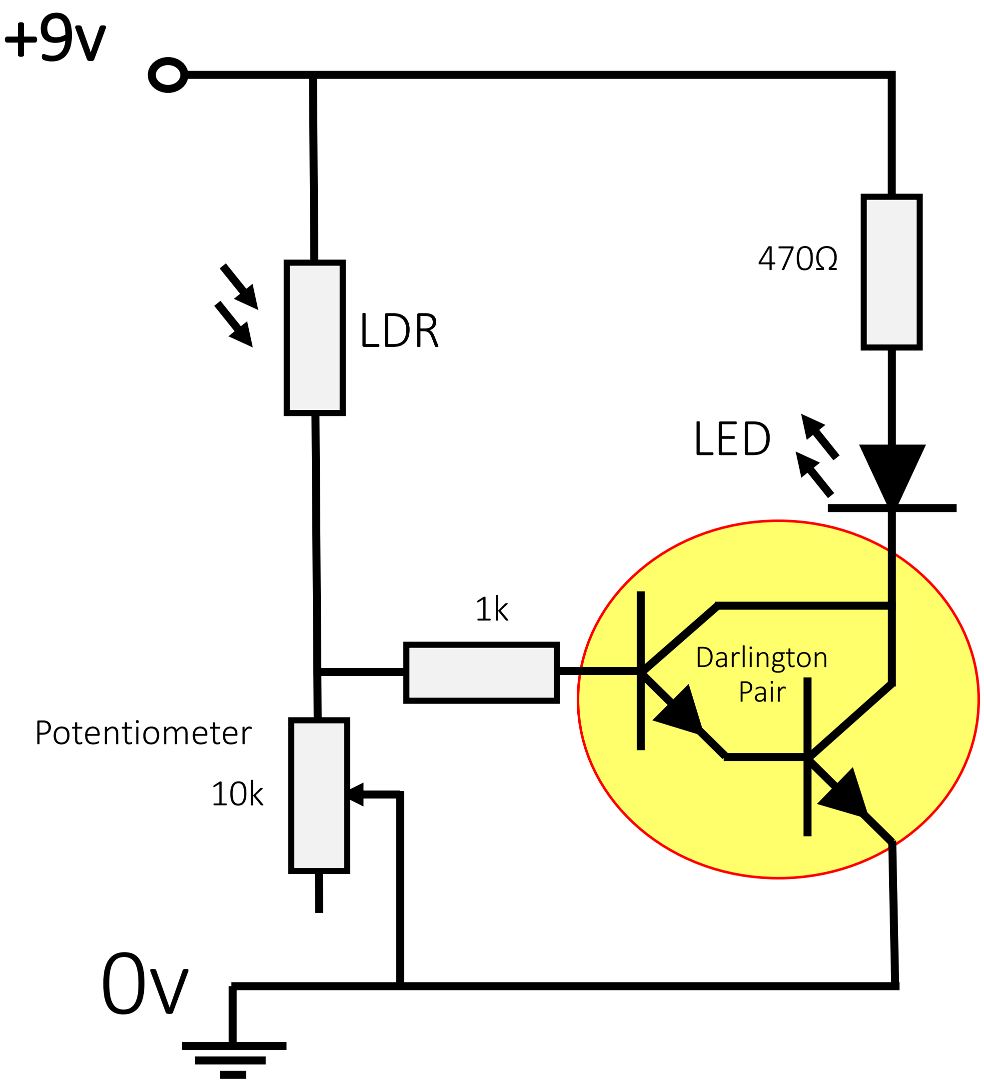
So you can see that only two components have moved. The LDR and the potentiometer have swapped places. This reverses the logic, turns the LED on instead of off.

I have used this circuit in so many applications. Using changing light levels can turn garments into ‘adaptive mode’. Moving in and out of a spotlight (light source) can make a string of LED’s turn on and off automatically.

It can be used to make burglar alarms in a door or a box. Dark box, light enters as an input and triggers an alarm. It doesn’t have to be an LED as the output. It could be motors spinning, music playing or an alarm buzzer. Introducing this to students is one of those light bulb moments where they suddenly realise the potential of such a simple circuit!

WARNING
Don’t introduce them to noise making things straight away! Your sanity is at stake when 30 buzzers are going off for the whole lesson!
You have been warned!!!

The Darlington Pair



In the previous circuit we used the transistor to amplify the change in voltage between finger on and off the LDR.
The amplification (GAIN) of a transistor is called H_{FE}

If we were to use a transistor with a gain of 10 it would amplify the base voltage on the base by ten times. Remember that a transistor is 'fully on' when the base receives around 0.7v and off when it has 0.6v so these changes on the base are very small!

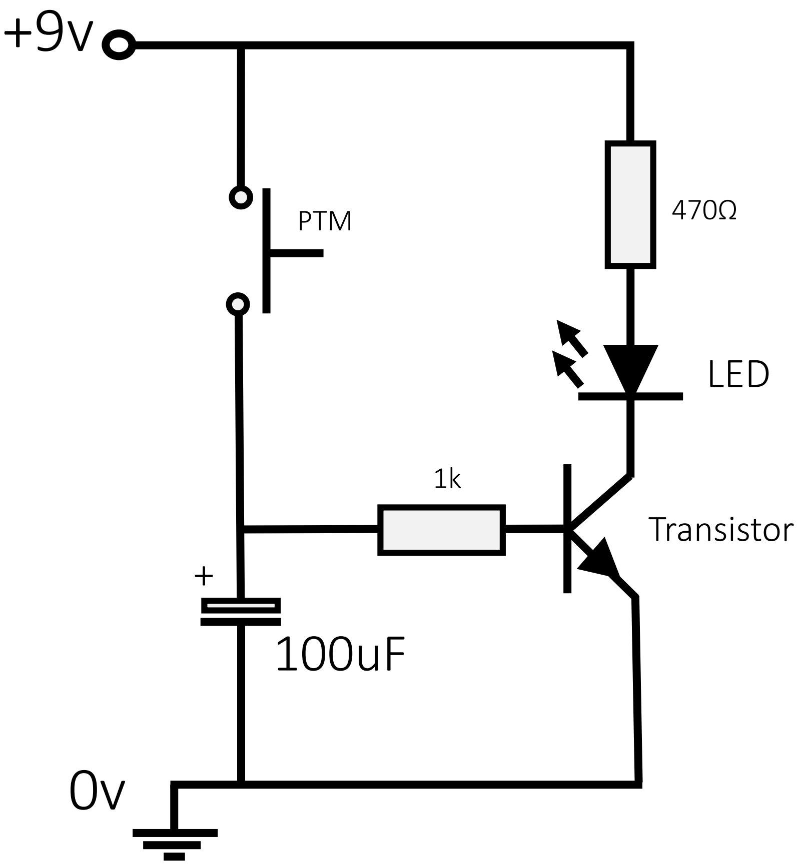
But. If we wanted our LDR circuit to be even more sensitive we could use the Darlington Pair.

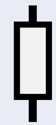
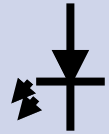
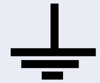
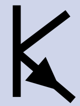
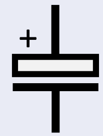
This doesn't add one gain onto another (10 + 10 = 20) it times one by the other (10 x 10 = 100)

But, I am using a BC337 transistor that has a gain of 282 (measured on my multimeter)
So…. Our circuit would have a total gain of 79,524
282 x 282 = 79,524

When students make this circuit the sensitivity can be substantially more as you can see by the difference in the gain!

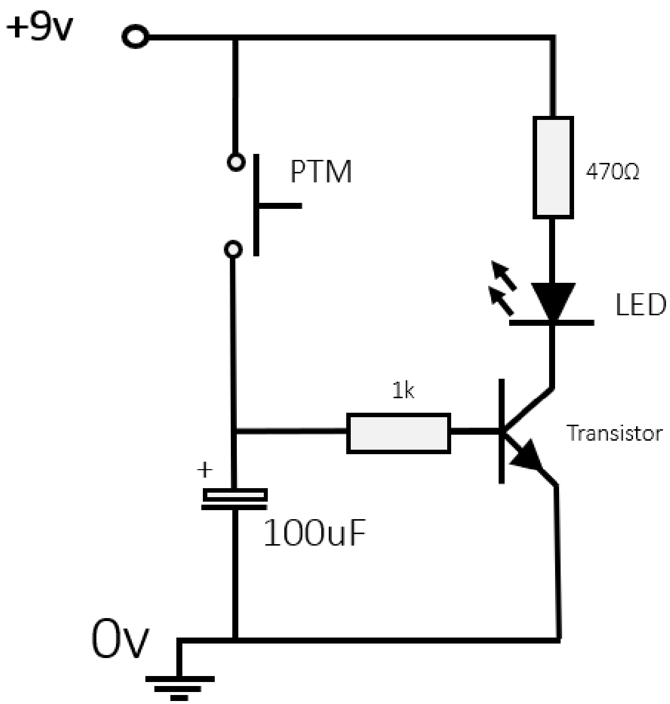
Capacitor / Timing circuits



Component List		
	PTM	Push To Make Switch – makes a circuit when pushed
	Resistor	Creates electrical resistance
	LED	Light Emitting Diode – A diode that emits a certain frequency of light (colour)
	Earth	Earth, zero volts, and ground (GND) are all the same common reference point
	Transistor	NPN Transistor – this can be used as an electrical switch or as an amplifier
	Electrolytic Capacitor	A capacitor is very much like a bucket of water. It holds water (electrical charge) which can be released or filled very quickly. Large ones can be very dangerous!

Capacitor / Timing circuits

Timing Circuits



I find this circuit to be a great teaching tool.

I get the students build the circuit first of all but don't hand out the batteries initially. Wait until they have finished building. Once the students find that the LED stays on for a time I ask them to find out what is happening with the circuit.

This is an excellent excuse for me to teach them more about using the multimeter. I ask them to work in pairs and measure all the voltages they can think of recording it.

We then have a class discussion about what it happening.

The main reading they require is across the capacitor when the PTM switch is released. Best demonstrated using an analogue multimeter (if you have one). It shows the slowly decreasing voltage. Why? What is happening??

Then I talk to them about capacitors. "Capacitors have capacity……."

I talk to them about the history of the capacitor. The laden jar and what they were used for and what they are currently used for (no pun intended!)

If you want to, it's a great time to introduce the concepts of charge and the movement of electrons. This is when I talk about electron flow and conventional current.

It also gives me a fantastic excuse to explain about milli, micro, nano and pico.

Units of Measurement

I know that we have already discussed Units of Measurement but I go over it again with the students. Measuring capacitors with a multimeter is always good practice for them. You can give them 'mystery' capacitors to measure. Use paint, tape or marker pen to obscure the value. I usually write a letter on the component so I know what it is supposed to be!

We are starting to talk about Current (Amps) being measured in thousandths of amps the symbols they use are VERY important! If you get it wrong it can be 'quite shocking'!

EG. If a person used the capital letter M instead of the lower case m this would make it a very 'exciting circuit'!!

30**M**V means that you have 30,000,000 volts   30 Meg ohms
30**m**V indicates that you have 0.03 volts   30 milli ohms

This means that there is a **one billion times difference** all because you used a capital instead of lower case!

Now you can see how dangerous this could be!

T	Terrra	1,000,000,000,000.0
G	Giga	1,000,000,000.0
M	Mega	1,000,000.0
K	Kilo	1,000.0
	One	1.0
m	milli	0.001
µ	micro	0.000 001
n	nano	0.000 000 001
p	pico	0.000 000 000 001

Now is the time I introduce milli, micro, nano, pico and talk about the importance of using the correct symbols.

I usually build the table up on the whiteboard with help from students suggesting what comes next.

A capacitor is a component that will store an electrical charge.

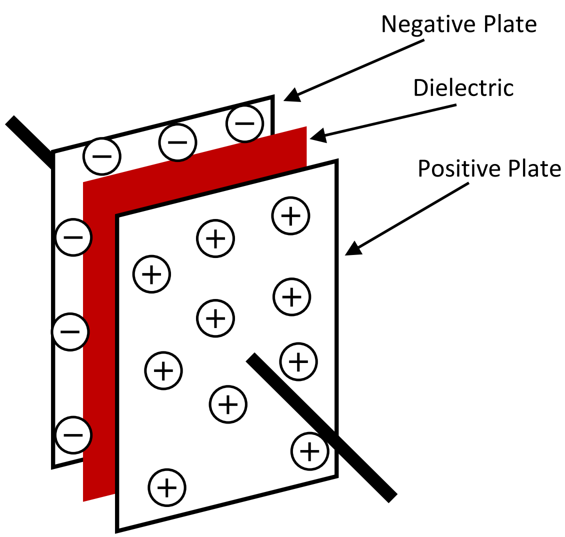
When talking to students I tell them that a capacitor can be thought of as a bucket. A big bucket full of electrons.

As with a bucket, it can be filled and emptied very quickly. This can be good and bad. A capacitor can 'give out' all of its energy in one very short 'blast'. Useful if you need to make a flash work but can be dangerous to the 'unwary user' if they touch the terminals of a large capacitor!

A capacitor is made from two metal plates separated by an insulator called a dielectric. One plate will become negatively charged with an excess of electrons and the other will have a reduced number of electrons making it positively charged. This charge is measured in Farads (named after Michael Faraday).

What is a Farad?

A farad is the unit of capacitance. Or, how big is this bucket?
One Farad of electrons it large!
6.25 billion, billion electrons
Or
6,250,000,000,000,000,000
electrons



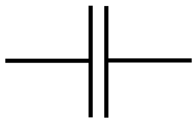
Types of Capacitor

Two main types of capacitor.

There are a number of types of capacitor made. Students will generally only use two types. Ceramic and Electrolytic.

Ceramic capacitors

Ceramic capacitors are called ceramic because they are made of ceramic, clay, as the outside coating.
They are non-polarized (doesn't matter which way around they are placed in a circuit).
Generally, they are smaller in capacity (measured in pico farads)

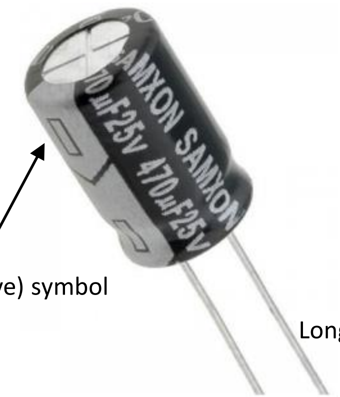


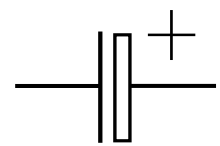
Value

104 indicates that it has a capacity of (ten plus another four zeros)
100,000pF 100,000 pico Farads or 100nF (100 nano Farads)

Electrolytic capacitors

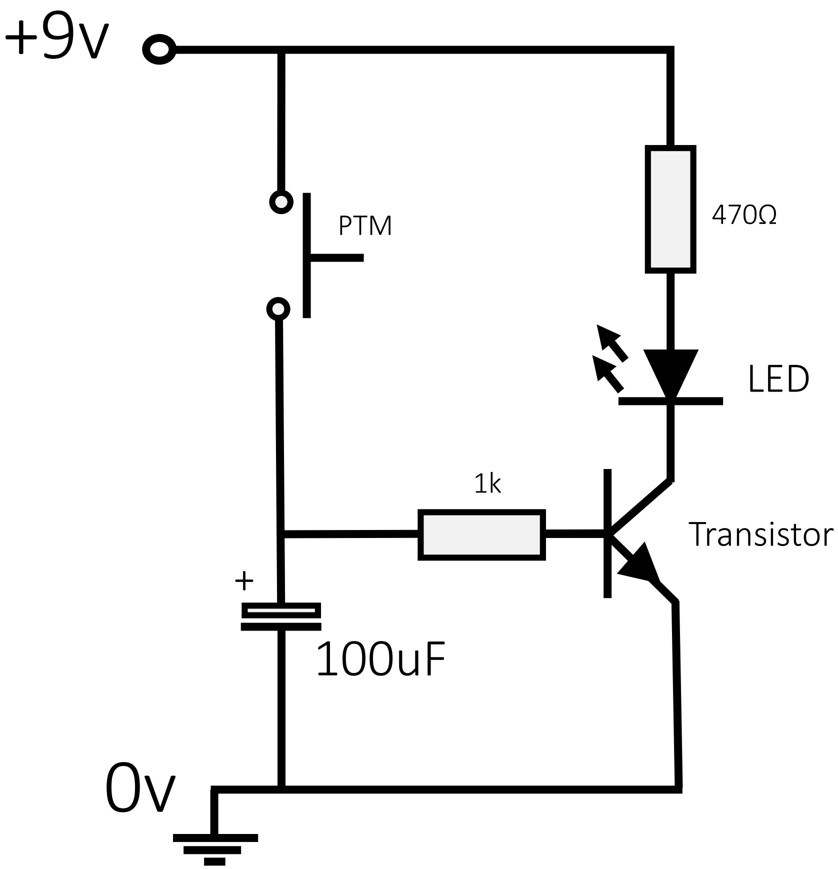
Electrolytic capacitors are larger and made by tightly 'rolling' up the plates to take up less room.
They are polarized – they need to be connected the correct way around in a circuit.





Value

The writing on the side indicates that this is a 470µF (micro Farad) in capacity and has a maximum working voltage of up to 25v



Measurement

I encourage the students to use the multimeter ‘to see what’s happening’.

The question is….. Why is this happening? The LED stays on for a time and then slowly dims.

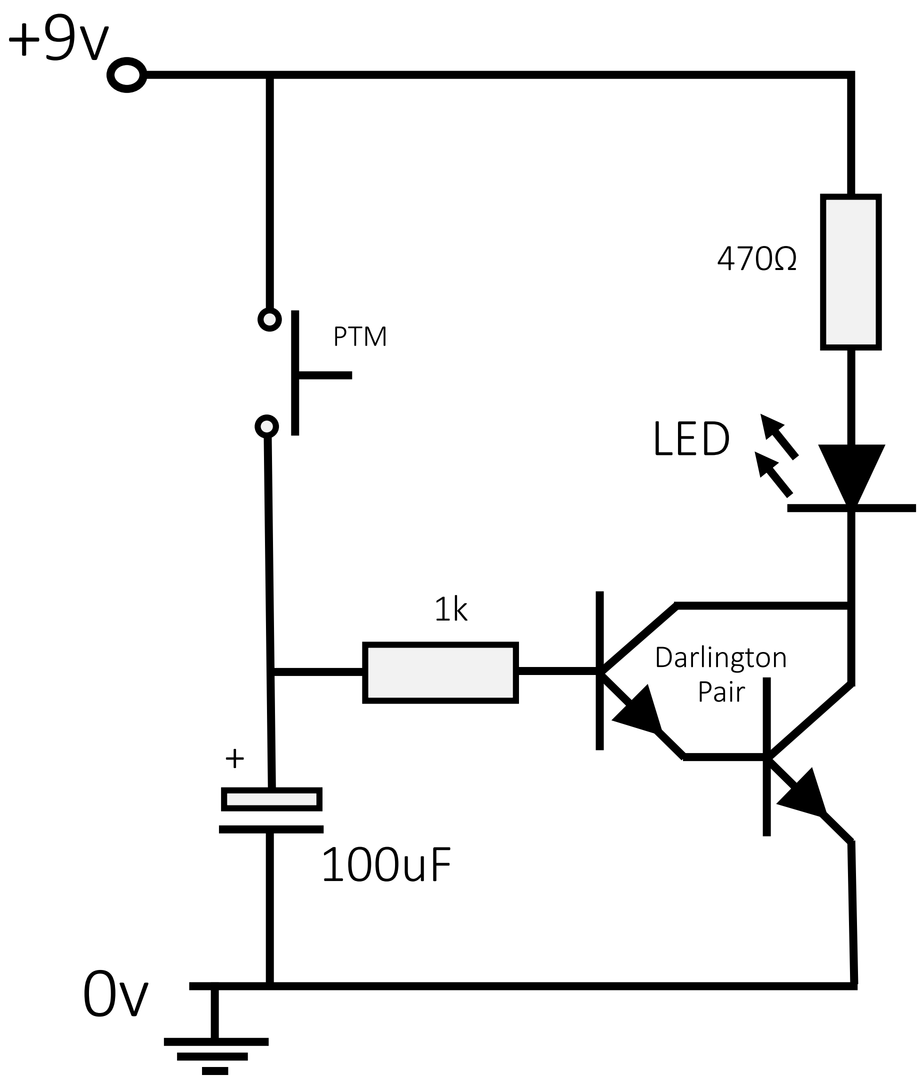
Being mean, I don’t tell them where to measure.
After a while I suggest that they measure across the base of the transistor to 0v.

Again, if you have an analogue multimeter it is easier to see the voltage slowly dropping once the push to make switch has been released. It isn’t necessary, just easier to see the needle movement rather than numbers flickering very fast.

What they will see is the voltage slowly dropping. Once it is below the 0.7v the LED will start to dim.

One question could be; What is the voltage when the LED is fully off?

Timing circuits with Darlington Pair



Any Difference?

As they are building the new circuit to include the Darlington Pair, I ask them to think about the difference of introducing the extra transistor will make.

What applications can we use this circuit for?

I'm trying to encourage the students to think about how the circuit is working.

Each time they have an idea I write it on the board (as long as it isn't ridiculous!) for discussion a class discussion later.

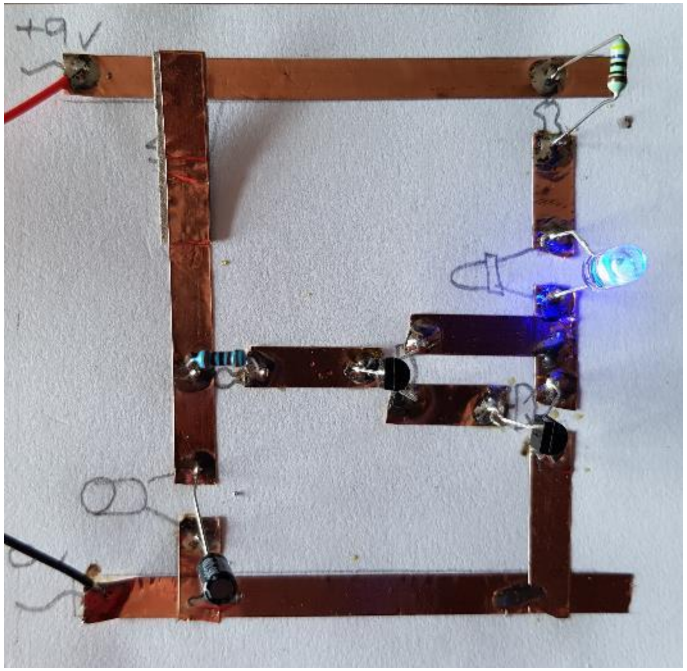
Again, I ask the students to measure the voltage across the base to 0v.

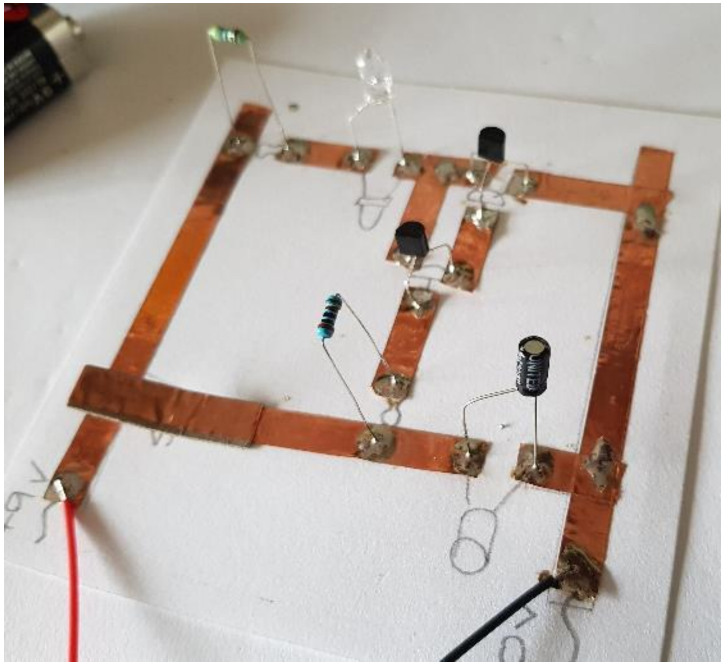
What is the difference?

What they will see it the light staying on longer but also it fades away far faster.

This is a good time to have a class discussion to find out why this is happening. The water analogy and voltage being pressure works well in this case.

I tried to show how components could be laid out. I bent some of the components from the vertical so to try to get a clearer picture.





What can it be used for?

http://nzastronomy.co.nz/pages/the-southern-hemisphere-sky

Imagine making this a class project.

It's easier to make using squares or rectangles if they are going to all join it together. (So they can take it home afterwards, use Velcro on the edges – don't forget to state which edge should be hook or loop!)

Matariki makes a good base for a project.
Find an image on the internet that you can use, project it onto a piece of fabric using a dataprojector (hang it on the whiteboard) then mark the position of the constellations.

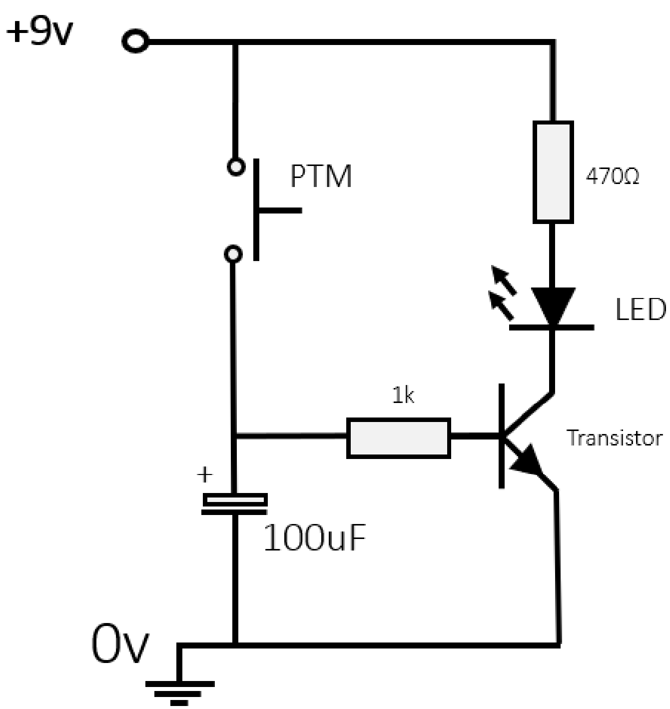
Individual projects could be native birds of Aotearoa

Making stuffed birds is always a good project but animating them makes the project 'more special'!

Making their eyes light up using LED's in parallel, making them vibrate using a motor with an offset weight or even make a noise (not recommended – imagine a class of 30 projects squawking all the time!)

http://gilliancandler.co.nz/free-downloadable-forest-birds-id-card/

Can we change the timing?



I am always looking for 'excuses'/ reasons to talk about the flow of electricity around the circuit.

In a class discussion I ask the students what happens when the PTM is pressed, reminding them to use the analogy of water in pipes. The electricity will flow through the PTM, tries to get through the 1k resistor but it's difficult.
So, it fills up the bucket (capacitor).

When the PTM is released there is no flow so why does the LED still stay on? Where is the 'pressure' (voltage) coming from to keep the 'tap' (transistor) open?

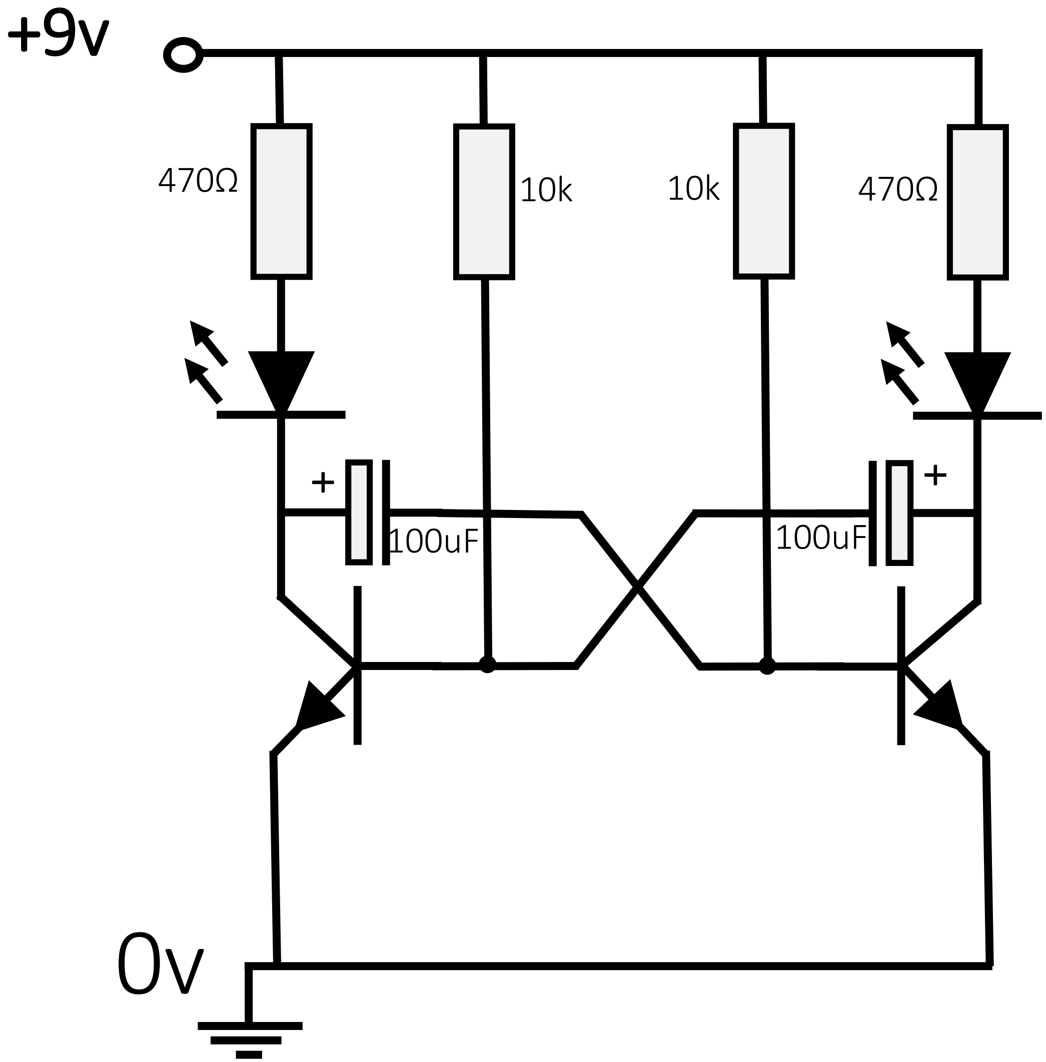
The pressure is coming from the bucket (capacitor). It forces it's way through the 1k resistor to the 'handle' (base) of the 'tap' (transistor) to hold the tap on.

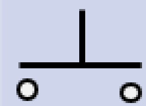
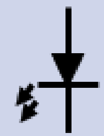
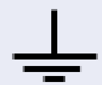
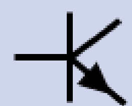
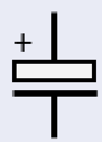
But why does the LED slowly fade? Because the 'handle' (base)of the 'tap' (transistor) 'leaks' slowly into the 'spout' (emitter) until the 'pressure' (voltage) in the 'bucket' (capacitor) is too low to hold the 'tap' (base of the transistor) open.

So… To change the timing we can change the size of the 'bucket' (capacitor) or the 'restriction' (the resistor) to the 'tap' (transistor base).

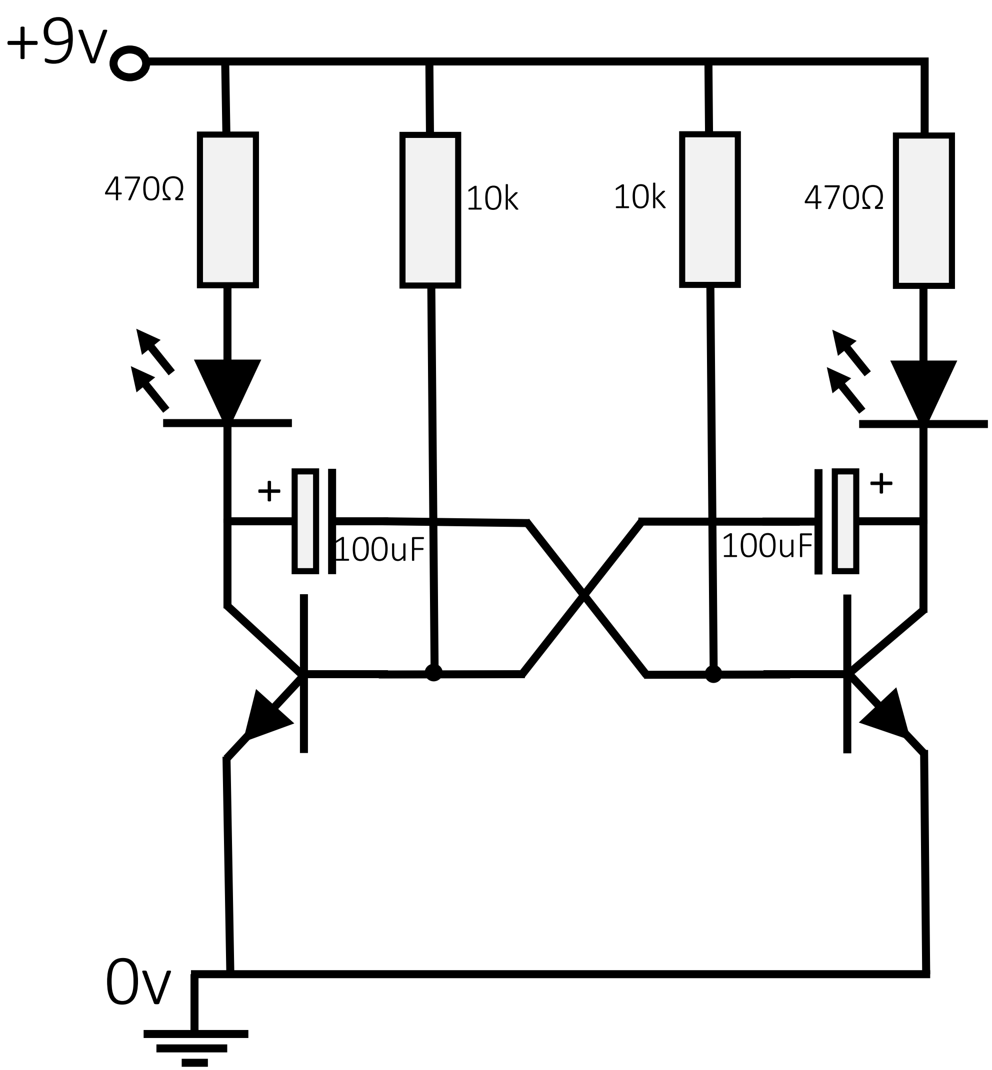
Phew! It's a big jump in understanding but you can see it in their eyes when they get that sudden "Ahaaa moment" – This is why I teach ☺

The Flip Flop Circuit



Component List		
	PTM	Push To Make Switch – makes a circuit when pushed
	Resistor	Creates electrical resistance
	LED	Light Emitting Diode – A diode that emits a certain frequency of light (colour)
	Earth	Earth, zero volts, and ground (GND) are all the same common reference point
	Transistor	NPN Transistor – this can be used as an electrical switch or as an amplifier
	Electrolytic Capacitor	A capacitor is very much like a bucket of water. It holds water (electrical charge) which can be released or filled very quickly. Large ones can be very dangerous and have killed in the past!

Schematic VS Track Layout



With all the previous circuits the schematic was the same as the track layout. This one is different, it has more components therefor is more complicated.

What is a schematic? It is an abstract representation using symbols showing how components are connected.

What is a track layout? The track layout is how the electrical connectors (tracks) are actually laid out in the circuit.

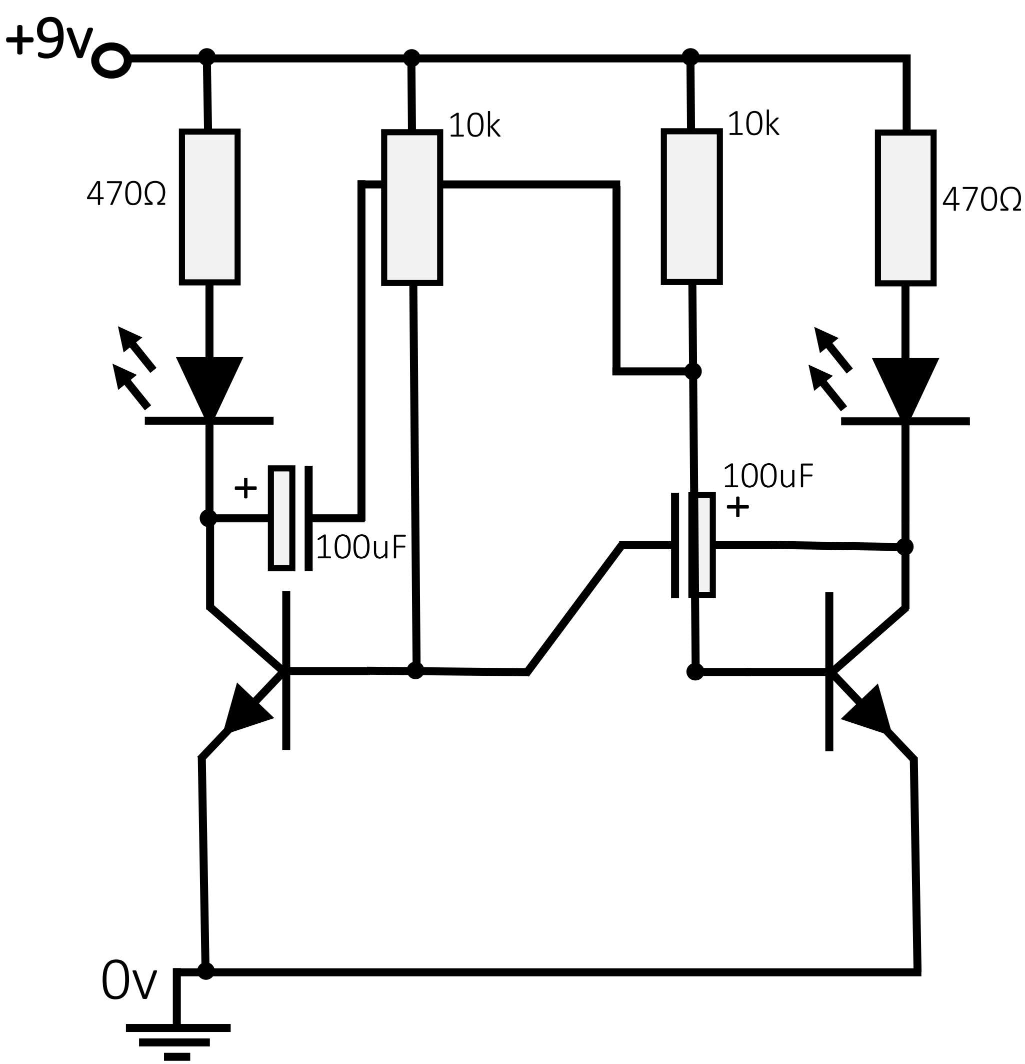
This is their first real challenge/puzzle to work out. On paper first. I am expecting them to make mistakes.

Through all the previous circuits my students draw out the first the schematic using symbols and then the track layout asking them to draw a picture of each component and showing all the pieces of copper tape they will use.

This is different though because they aren't allowed to use jumpers. Jumpers are pieces of wire that hop over another piece of wire.

I tell them that I am expecting them to find it difficult, but there are many different ways of making this circuit without resorting to jumpers.

Sneakyness!



I ask the students to try to come up with a way to construct the circuit without any jumpers (hopping over a track).

Initially, I tell them as little as I can trying to get them to work out the problem for themselves.

There are many ways to complete the task. If it works it is correct. However, some are more efficient than others.

I insist that they work individually because they won't learn how to solve problems by copying.

After a short while a student will come up with the idea that they could use a **component** to jump over a track.
As soon as you whisper loudly "SSSShhhhhhh! Keep it a secret!!" to one of the class, the rest of the class is frantic to finish the task ☺

For the ones that are struggling walk around the class giving them 'sneaky' hints.

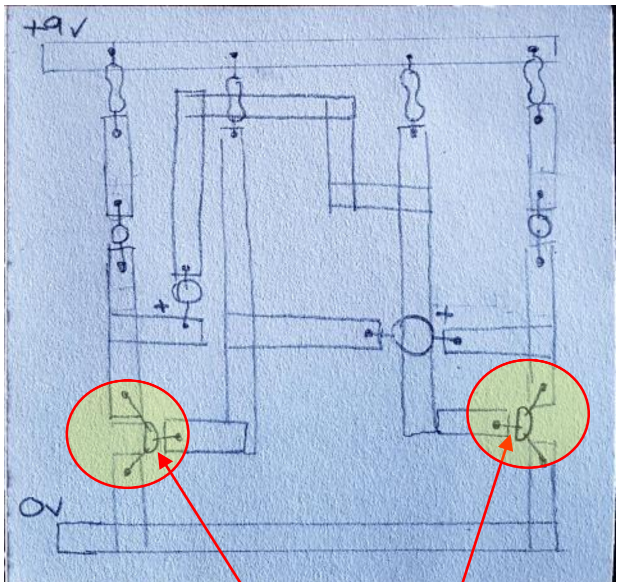
You can see that I've now started putting 'blobs' on the join between two tracks. This is to indicate that this is a join and not a crossing track. It makes it easier when their track layouts become more complicated in the future.

What does it look like?

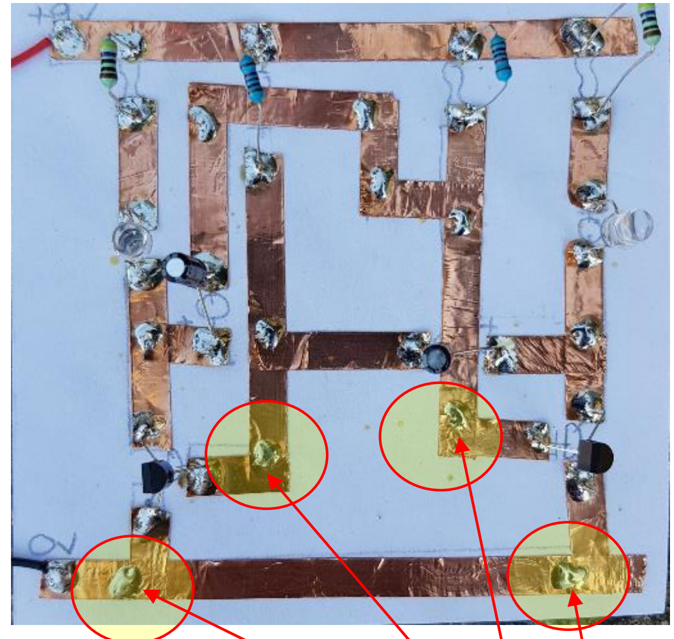
Draw the tracks beforehand (I ask them to use pencil) shows where the copper tape and orientation of components.

Components are drawn to scale (as close as possible) to get students used to their size and how to bend the legs to fit.

Particular care needs to be taken with the transistors (the legs break easily)!).



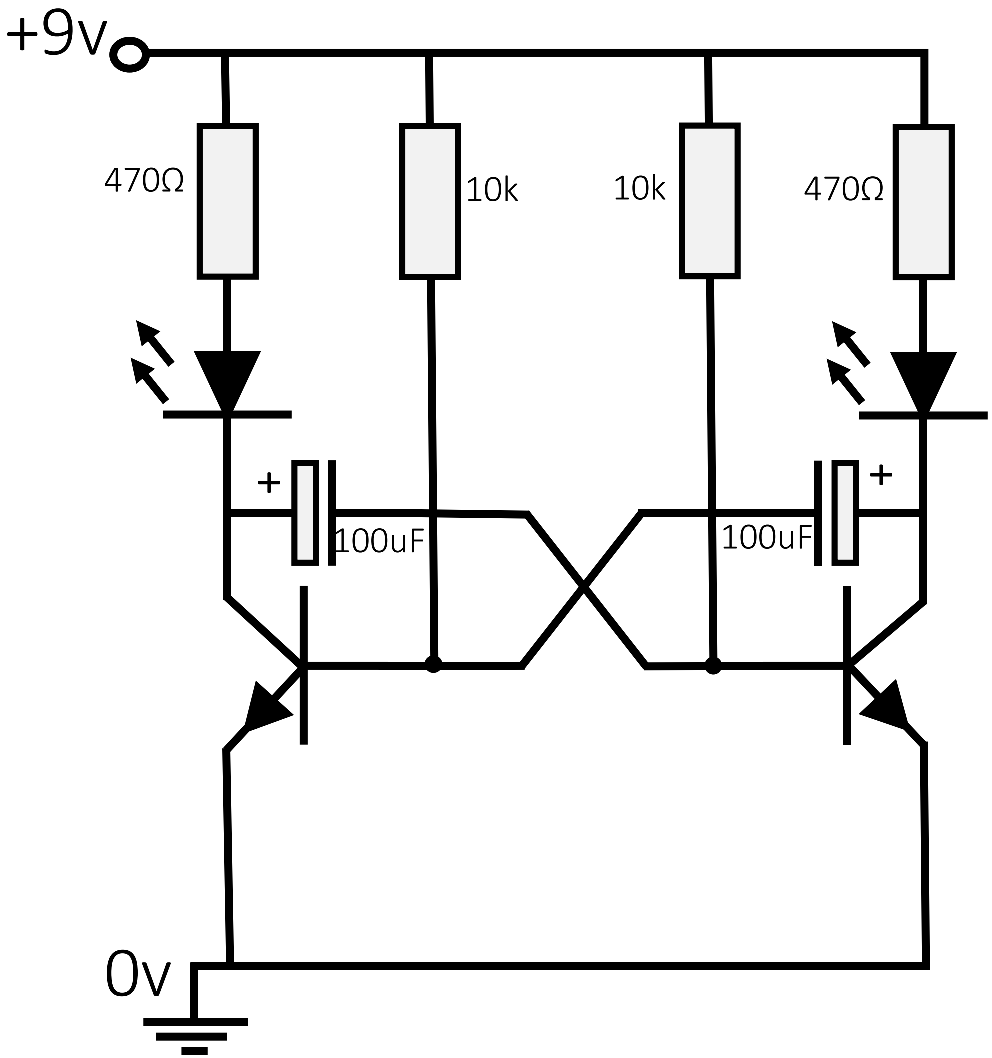
It makes is much easier for you (your sanity!) and the students if they draw on the components.
It takes time for them to figure it out and then unsolder, bend the base leg (without snapping it!) and then soldering again.
They will make mistakes, it's just better if they aren't 'silly ones'!!



Each track joint is soldered to prevent the glue from forming a dry joint.

The orientation of the transistors and capacitors is usually where students make mistakes.

Can this be changed?



At this stage, students ask if they are able to change the speed of the flashing.

This is where I allow them to come up with a plan. They have to draw it out on paper as a schematic to show me before they make any changes.

They then have to explain to me **why** it will make a change. Being mean, I ask them to predict what will happen with the change. How long will it flash for once they have made the change?

I know that this takes longer but in the explaining, students are thinking more about their circuits and what is happening.

What would happen if they only changed one component?

The easiest component to change is the capacitor (size of the bucket) but they could also change the 10k resistor.

If they wanted to vary the speed of flash, they could replace the 10k resistors with 103 (10k) potentiometers.

They can also calculate/predict the speed of flash before they make any changes to increase the challenge!

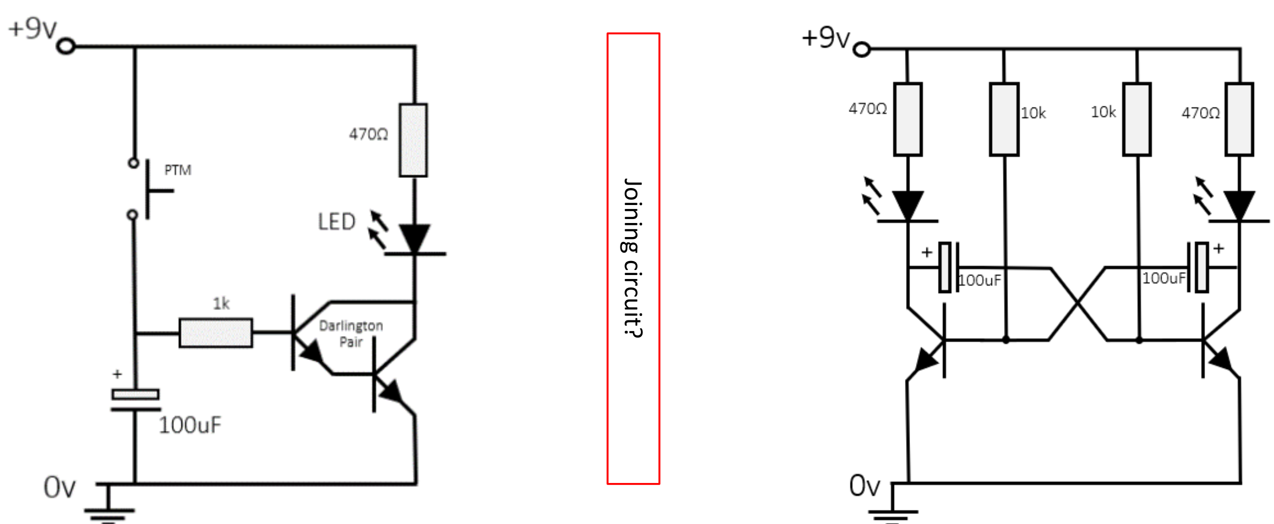
What can this be used for?

I am constantly thinking of different ways that these circuits can be used but during class discussions, I try to encourage them to come up with ideas of their own.

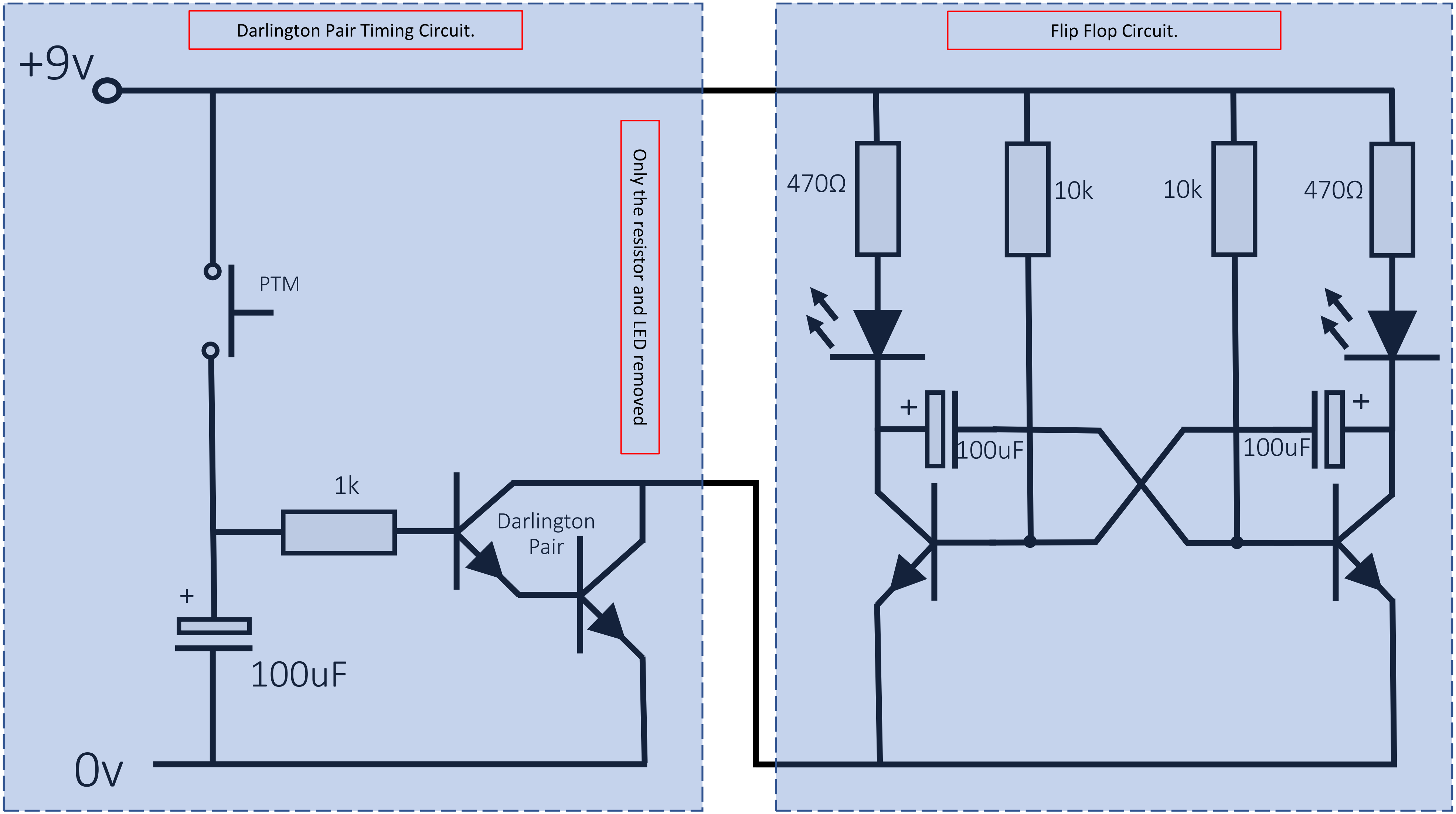
If they have 'projects' of their own that they would like to make I encourage them as much as I can. As long as they complete the work I have set I (if I have a moment!) will help them along with theirs.

It is possible to join many of these circuits together to do different things. One of the easiest is joining the Darlington Pair timing circuit to the Flip Flop circuit.

Usually, there are a number of students still finishing off so this is a good, fun exercise for those who have already finished. I talk to them about 'joining' their circuits together and ask them to try to work it out. Usually, they manage to do this. Sometimes, I give them little hints but never tell them the answer outright. I'm so mean!! ☺



Linking the circuits?

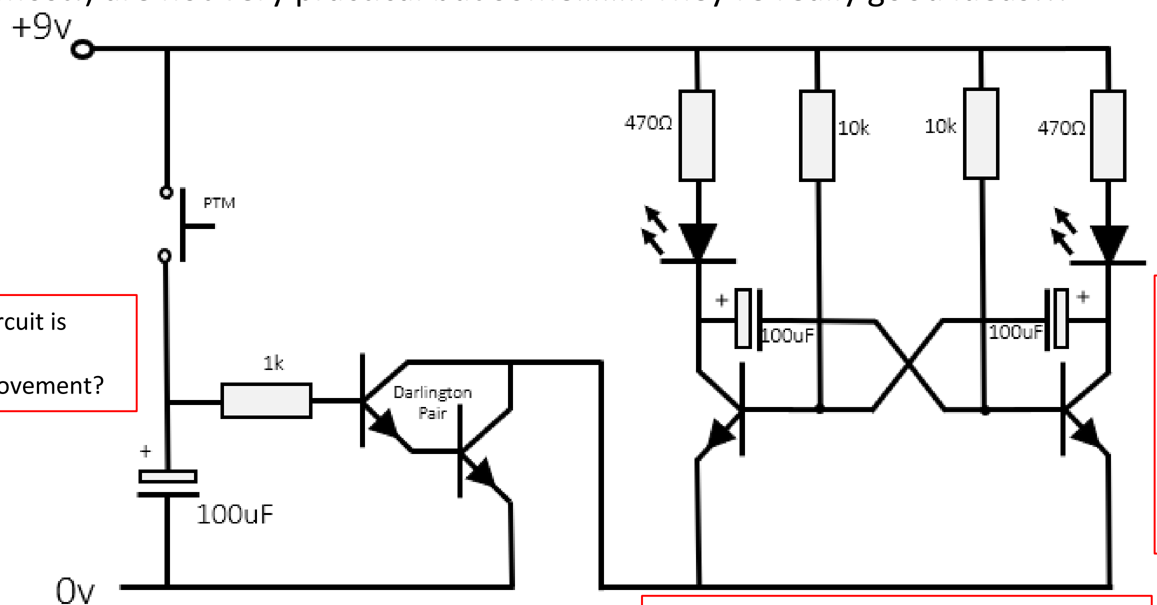


Possible extension activity

Once students realize that they are able to join circuits together, it can become a bit of a competition to see who can do what with which circuit!

For example; the PTM switch could be part of a burglar alarm circuit (pressure mat under the floor?) or, it could be the eyes in a fluffy animal glowing alternatively (evil look??) or, it could be a part of a costume where the PTM was replaced with a movement sensor to activate motors, or, an LED array (I was thinking Storm Trooper but it could be anything!) Or it could a part of a piece of artwork that was activated by the amount of light falling on it. Or, an alarm to let you know if a plant was too dry/moist using a simple moisture sensor.

Now the students have the skills and confidence I encourage them to come up with as many project ideas as they can dream up. Some of them (most!) are not very practical but some…….. They're really good ideas!!!



Change the way the circuit is triggered.
Could use heat, light or movement?

Does the output only have to be LED's?
What about using motors? They don't always have to rotate. They can be used to vibrate or move something.
Or sound?
Not just a Police siren noise. It could trigger a bird noise?

It doesn't have to be the Flip Flop circuit.

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