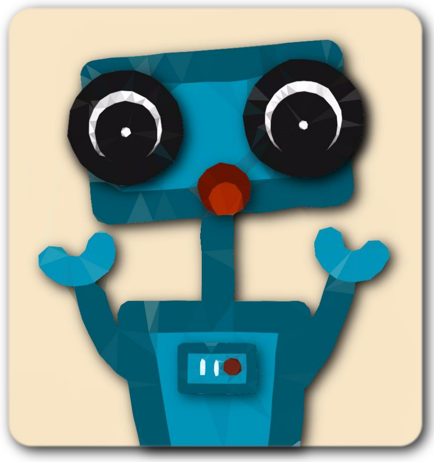
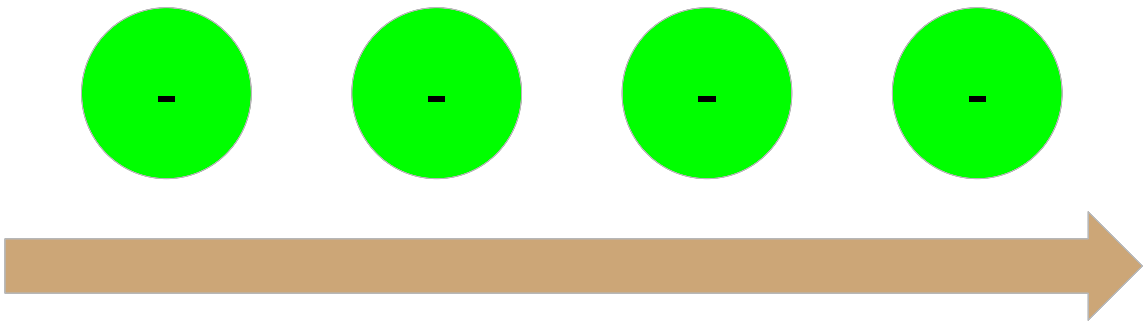
EaRS



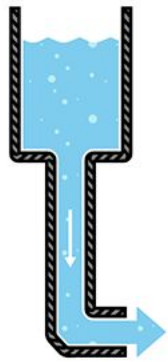
Electronics workshop - Part 1

Circuits and Electricity



Electricity is just the flow of electrons. Electrons are tiny particles that every atom has. Electrons have negative charge, just like magnets where opposite charges attract and same charges repel. A circuit is a loop of conductive material (ie material that allows electrons to flow easily).

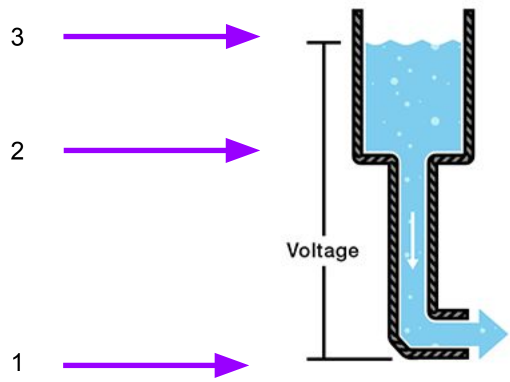
The Grand Water Tank Analogy



Water tank images from
SparkFun CC-BY-SA 4.0

The next few slides attempt to explain the concepts of current, voltage and resistance. We will do this by using an analogy to a water tank. Since the concepts apply to how electrons move, we shall say that each molecule is like an electron.

Voltage

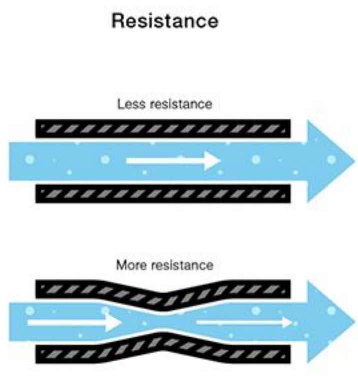


Water tank images from
SparkFun CC-BY-SA 4.0

Voltage is the difference in charge between two points. In a water tank, this would correspond to pressure (how much water is above a point). The difference in charge between two points is like saying how many free electrons are there between the two points you are measuring voltage at. Voltage always has to be measured across two points otherwise it makes no sense (cannot say voltage through). The voltage across points 2 and 1 is less than the voltage across points 3 and 1.

The unit is volts (V)

Resistance



Water tank images from
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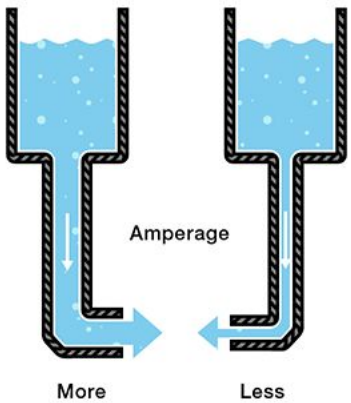
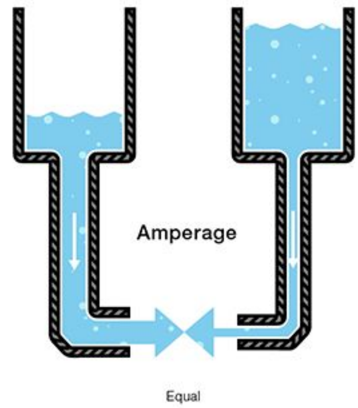
Resistance is how hard it is for an electron to move. For example it's harder for an electron to move through a rubber tyre than through an iron bar since the bar is conductive and the tyre is not. We say that the tyre has a high resistance and the bar has a low resistance. This would correspond in our analogy to the pipe getting thinner that the water has to squeeze through.

The unit is ohms (Ω)

Current





Water tank images from
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Current is the rate of flow of electrons past a point. Current is the same everywhere in a series circuit. This depends on both voltage (pressure) and resistance (narrowness). It’s the same concept in the water tank analogy.

The unit is amps (A)

Ohm's Law or Your New Best Friend

$$V = IR$$

Voltage

Current

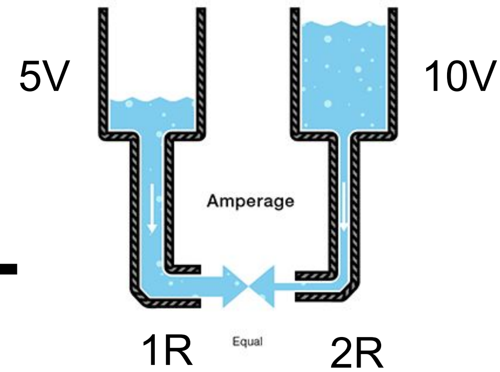
Resistance

This is a very important equation that will come up again and again when doing electronics. Voltage = Current (I) times Resistance. This makes intuitive sense in relation to the water pipe, as if you have the same flow rate of water (I) and the pipe gets narrower (R increases) then the pressure on the water (V) must have increased. Similarly, if the pipe remains the same width, but the pressure increases, then the rate of flow must increase.

Ohm's Law or Your New Best Friend

$$V = IR$$

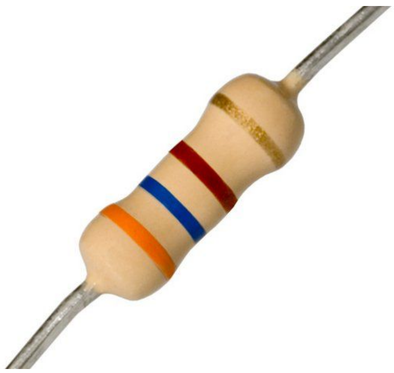
$$I = \frac{V}{R} \quad \frac{5}{1} = \frac{10}{2}$$

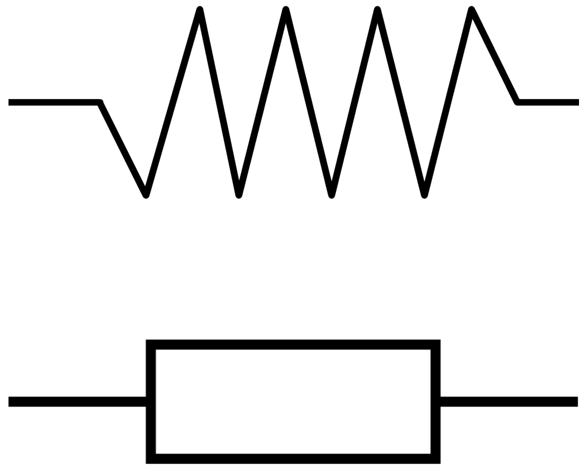


This is a slide demonstrating the use of ohm's law to calculate current and show that voltage can affect it equally as resistance.

First on the left, we rearrange the equation to get current on the left hand side. We then plug in the numbers indicated on the water tanks to get a current of 5A. Both of the water tanks have the same current as one has a higher voltage (pressure) whereas the other has a higher resistance. The higher pressure pushes water out faster meaning the rate of flow is higher and the higher resistances mean that the flow is reduced.

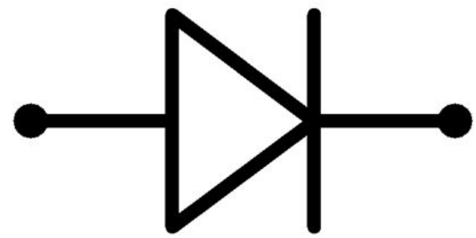
Resistor





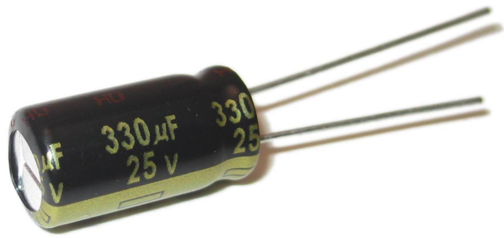
A resistor just adds resistance into a circuit. It's like a pipe-narrower. Wires on their own don't have very much resistance, so if we want to increase it, then a resistor is a good choice. As an example, we may want to increase the resistance of a portion of a circuit to decrease the current going through it.

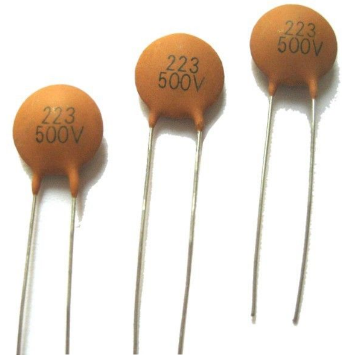
LED

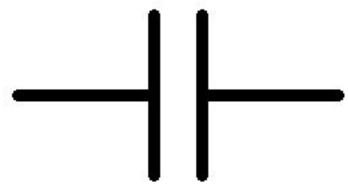


An LED (Light Emitting Diode) is a component that acts as a light source (shines) when current goes through it. It only allows current to flow through it one way. This is represented in the symbol for it with an arrow and a blocking line. The side of the LED that relates to the blocking line in the symbol has a shorter leg and the casing around the LED has a flattened side there. For an explanation of why it only allows current through it one direction, look up diodes and P/N semiconductors.

Capacitor

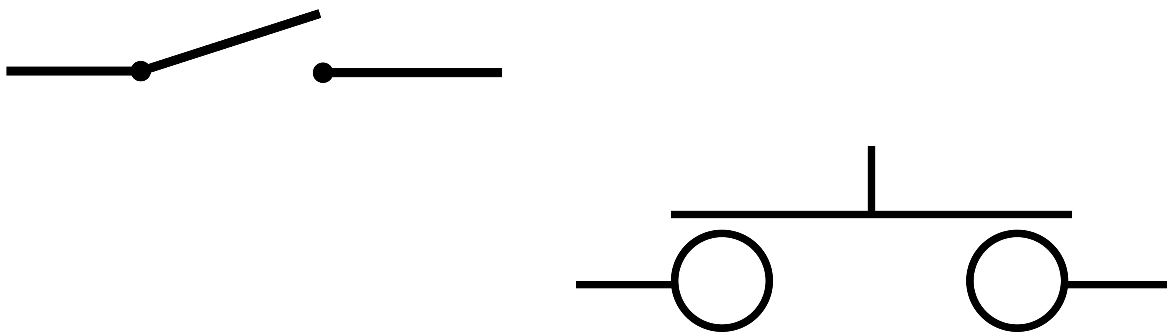






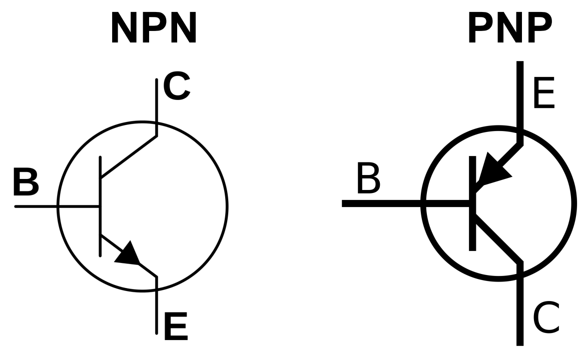
A capacitor acts like a mini rechargeable battery as in it stores charge. By applying an external voltage to it, you can charge it up. This means that its charge increases and with it, the voltage across it. When there is no longer external voltage across it, it will discharge, ie acting as a battery. NB electrolytic capacitors (like the one on the left) can only be placed in a circuit one way, usually with the negative end placed towards ground. Placing it the other way in a circuit may cause it to explode. The negative end is indicated on electrolytics with a stripe lined with “-” and a shorter leg.

Switches



There are two types of switches above. The one on the left is a switch that stays closed when closed and the one on the right is a push switch that will default to being open. When a switch is closed it will conduct current just like a regular piece of wire, but when it is open, it will not conduct at all (has infinite resistance) meaning that current cannot flow from one side to another. This usually has the effect of turning on or off a portion of a circuit.

Transistors (NPN and PNP)



Electronic switch
Two types above but both just inverses
NPN - put high voltage on B turn on
PNP - put low voltage on B to turn on
Why NPN/PNP - don't ask/in person

A transistor acts just like the switch from the previous side except to turn it on or off you do so electrically. The two types of transistors above work in similar but opposite ways. Each of them has three pins, labelled base, collector and emitter. These are usually shortened to B, C and E in diagrams. You can recognise the base as it is on its own behind the vertical line. The emitter always has an arrow and the collector is the other one.

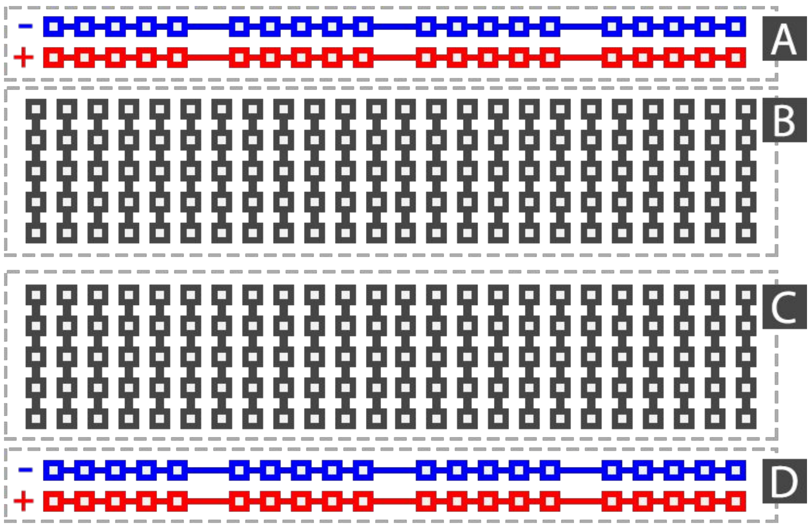
To turn on an NPN transistor you have to provide a relatively high voltage across the Base and Emitter (which is usually connected to ground). This will allow a large current to flow from collector to emitter. When an NPN is off nothing can flow between collector and emitter. In this way it acts like a switch.

PNP transistors act in a similar way. When they are switched off nothing can flow from emitter to collector (note the change in direction, reflected in the arrow). However, to switch a PNP on you have to provide a relatively low voltage across base and collector. This has to be low compared to the voltage across emitter and collector.

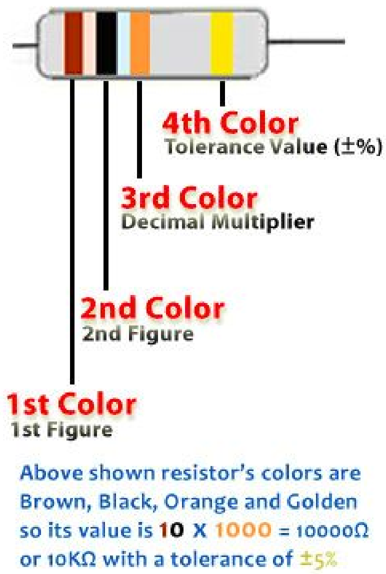
The arrow on the emitter both tells you what kind of transistor it is and gives you a hint as to which direction current flows during operation.

Don’t worry about the names, but if you are curious search them. It relates back to diodes and semiconductors.

Breadboards



In the bad old days, every time you wanted to test a circuit, you would have to solder it together. This was time consuming and it is difficult to desolder a component once you have it in place. However, nowadays there is the option of breadboards, which don't require soldering and can be reused for many circuits. On the diagram above, each square is a hole and the lines between them are connections. The lines across the top and the bottom (in A and D) are generally used for power rails (ie constant voltages, like +9V or ground). The sections in between are where you build most of your circuit. It's generally a good idea to have power rails going down in voltage as the board goes towards you (A > D), for example, having the +9V and +5V power in A and the ground in D.



Color Name	Value As Figure	As Decimal Multiplier	Tolerance ±
Black	0	x 1	±20%
Brown	1	x 10^1	±1%
Red	2	x 10^2	±2%
Orange	3	x 10^3	-
Yellow	4	x 10^4	±5%
Green	5	x 10^5	±0.5%
Blue	6	x 10^6	±0.25%
Violet	7	x 10^7	±0.1%
Grey	8	x 10^8	±0.05%
White	9	x 10^9	±10%
Golden	-	x 10^{-1}	±5%
Silver	-	x 10^{-2}	±10%

This diagram explains how to read colour codes on resistors. The first two colours dictate the digits, so in this example 1 and 0. The third is the multiplier so x10^colour. In this example 3. That means this resistor is 10 x 10^3 Ohm or 10Kohm. The tolerance band is to do with how well the resistor was produced. It means that the real value sits somewhere in between (in this case 5)% less than the value and (5)% greater than the value.

3 6 x10^1 = 360Ω

Color Name	Value As Figure	As Decimal Multiplier	Tolerance ±
Black	0	x 1	±20%
Brown	1	x 10^1	±1%
Red	2	x 10^2	±2%
Orange	3	x 10^3	-
Yellow	4	x 10^4	±5%
Green	5	x 10^5	±0.5%
Blue	6	x 10^6	±0.25%
Violet	7	x 10^7	±0.1%
Grey	8	x 10^8	±0.05%
White	9	x 10^9	±10%
Golden	-	x 10^{-1}	±5%
Silver	-	x 10^{-2}	±10%

4 7 x10^2 = 4700Ω

Color Name	Value As Figure	As Decimal Multiplier	Tolerance ±
Black	0	x 1	±20%
Brown	1	$x\ 10^{1}$	±1%
Red	2	$x\ 10^{2}$	±2%
Orange	3	$x\ 10^{3}$	-
Yellow	4	$x\ 10^{4}$	±5%
Green	5	$x\ 10^{5}$	±0.5%
Blue	6	$x\ 10^{6}$	±0.25%
Violet	7	$x\ 10^{7}$	±0.1%
Grey	8	$x\ 10^{8}$	±0.05%
White	9	$x\ 10^{9}$	±10%
Golden	-	$x\ 10^{-1}$	±5%
Silver	-	$x\ 10^{-2}$	±10%

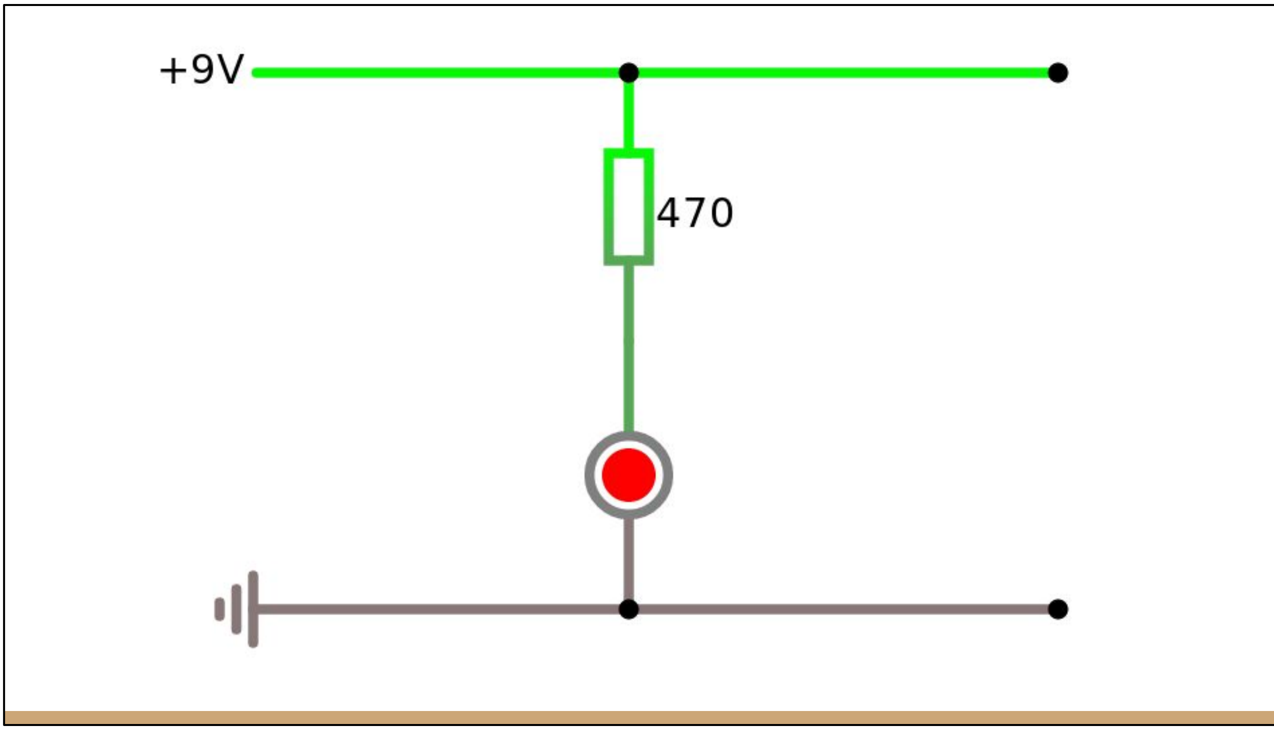
Circuit 1 - LED and resistor circuit

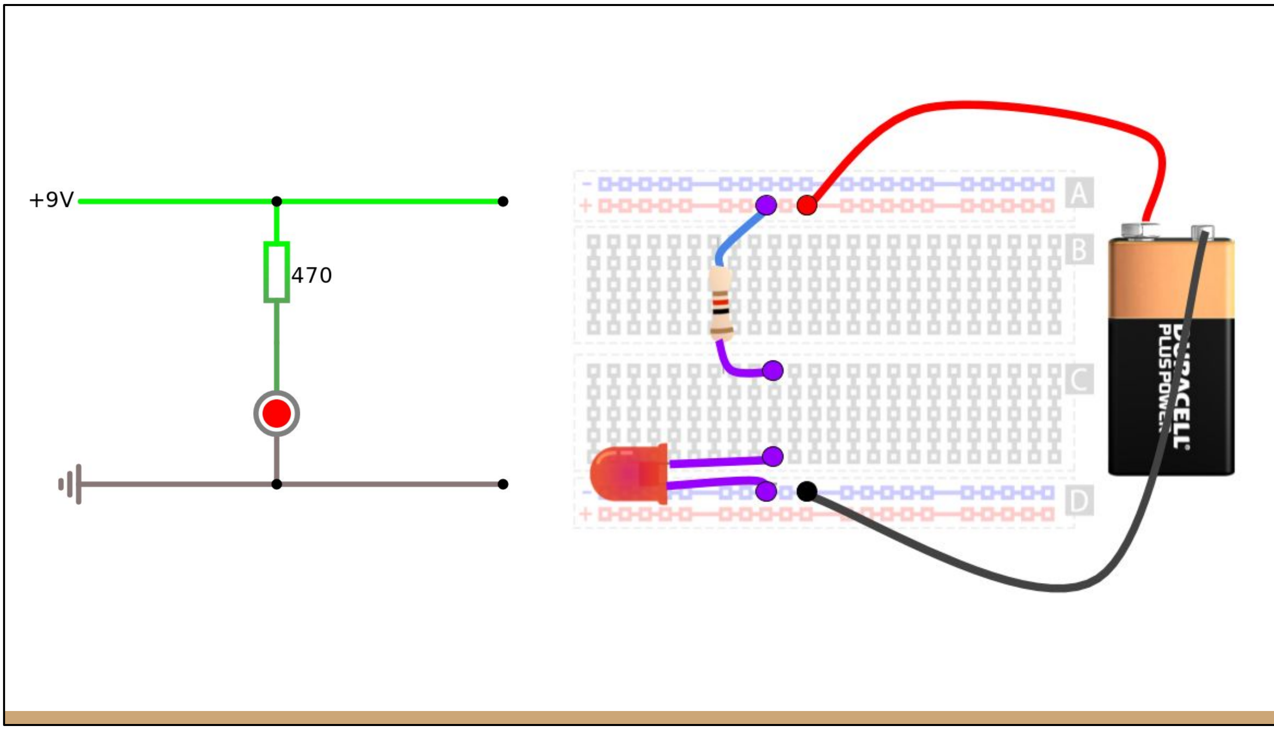
You will need:

- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 1x 470ohm resistor
- 1x LED of any color
- jumper wires

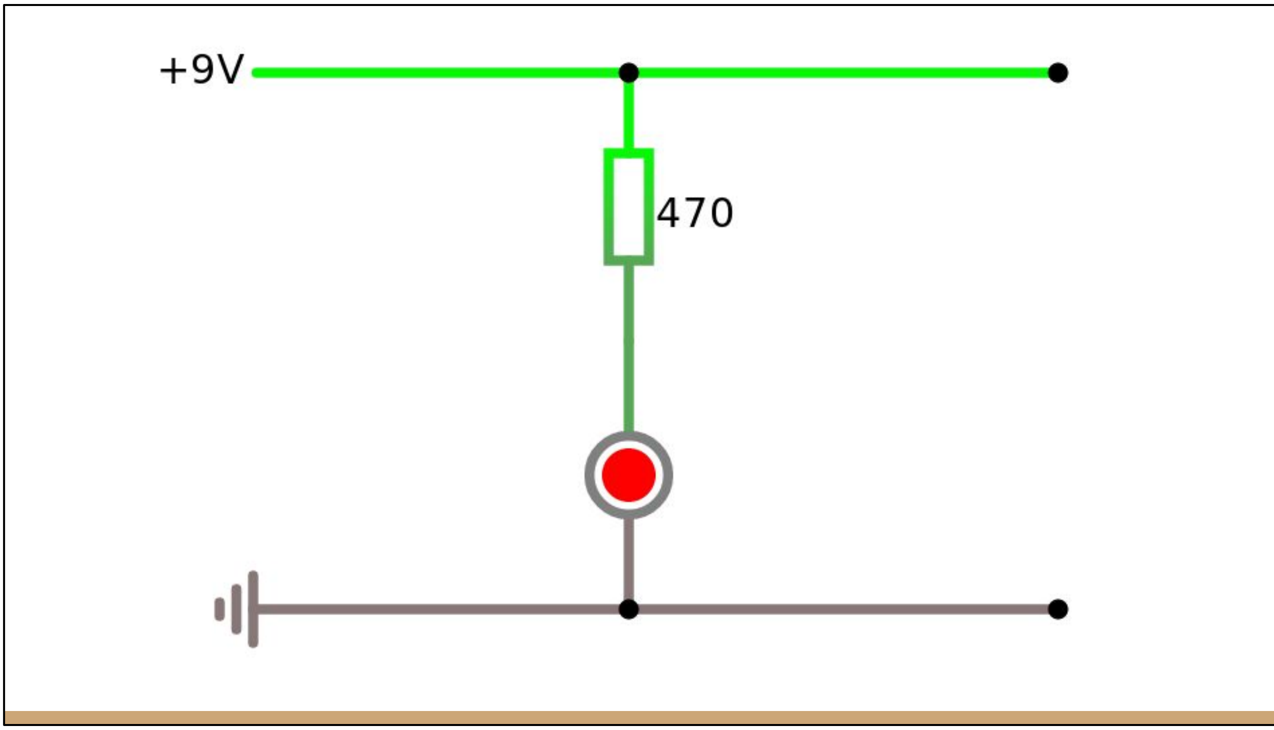
We're going to make an LED light up
Things to remember:

- Connect the LED the right way round
- Don't plug in battery until you're sure the circuit is correct
- Don't forget the resistor, you'll kill your LED

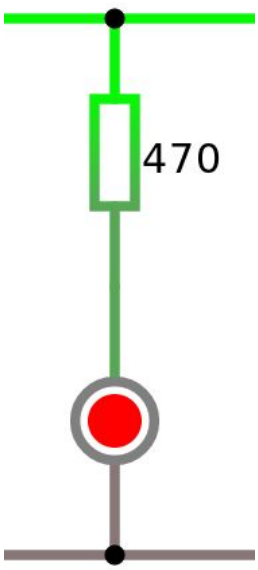

+9V
470



This slide contains a quick picture of what the circuit will look like roughly on the breadboard. In this case, ground is the negative side of the battery. The circuit doesn't have to be placed exactly as in the diagram, what matters is the connections (that the lines on the breadboard connect the components in the right way).



LED always wants a constant amount of voltage across it (around 2V)
However, we have 9v across the whole circuit
So, we need something to soak up the rest of the voltage



9V across whole thing

2V across LED

9 - 2 = 7V across resistor

V = IR

V = 7 I = 15mA

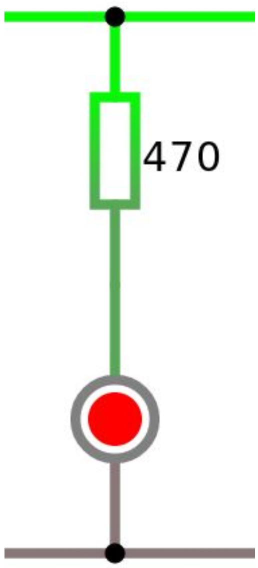
R = 466.6666666…..

Standard series of resistors

… 330, 390, 470, 560, 680…

Choose next one up

We need the resistor to soak up 7V



9V across whole thing

2V across LED

9 - 2 = 7V across resistor

V = IR

V = 7   I = 15mA

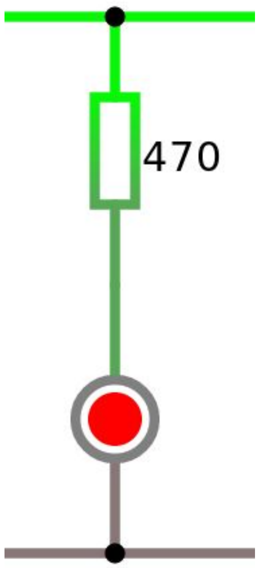
R = 466.6666666…..

Standard series of resistors

… 330, 390, 470, 560, 680…

Choose next one up

Just like LEDs work with a certain voltage, they like a certain amount of current as well. Too much current will kill them, but too little will not turn them on. About 15mA will do, and since current is the same everywhere in a series circuit, we have our V and our I to calculate the resistance of the resistor.



9V across whole thing

2V across LED

9 - 2 = 7V across resistor

V = IR

V = 7 I = 15mA

R = 466.6666666…..

Standard series of resistors

… 330, 390, 470, 560, 680…

Choose next one up

They don’t make every value of resistor as that would be impractical
Instead there is a standard series of values
We choose the next one up as the LED would definitely work with less current, but may blow up with more

$$R = \frac{V_s - V_f}{I}$$

Where:
Vs - voltage of the power supply
Vf - voltage required on the LED
I - the current we want flowing thorugh the circuit

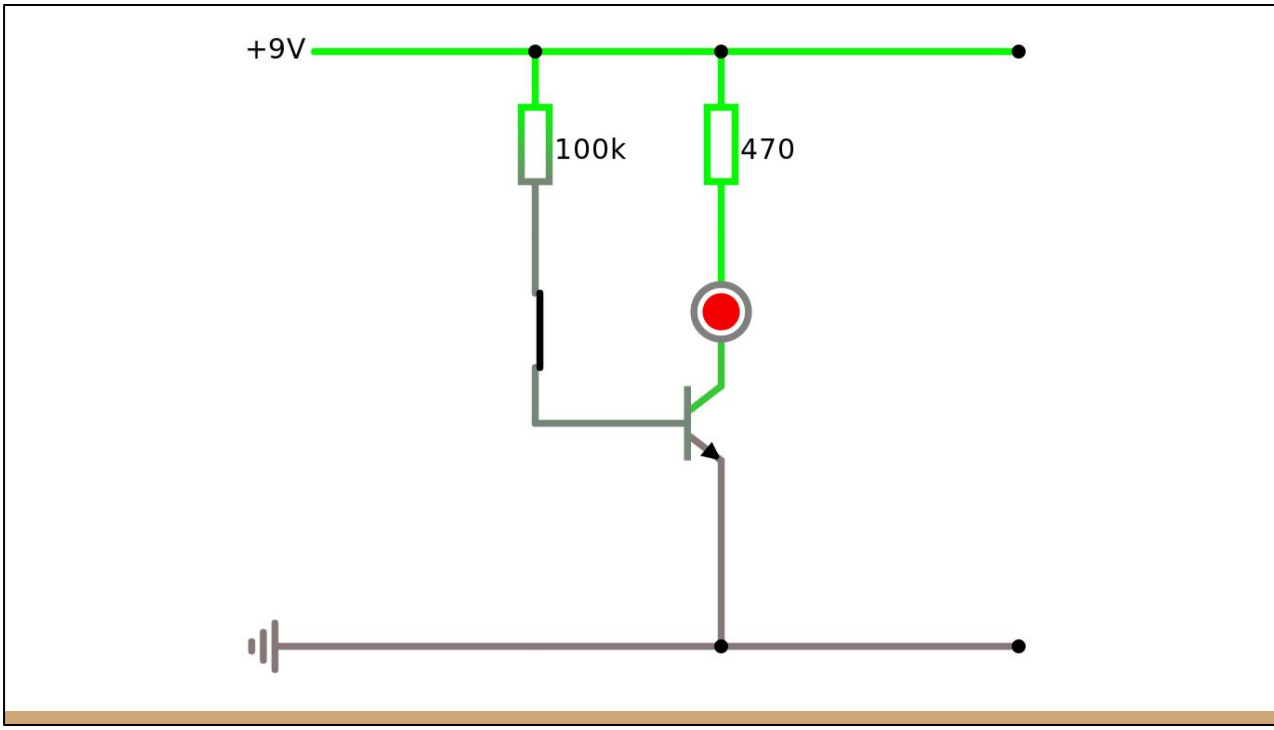
White	Red	Blue	Green	Yellow
3.2 - 3.4	1.9 - 2.1	2.8 - 3.0	2.8 - 3.0	1.8 - 2.2
20mA (10^-3 A)	20mA	20mA	20mA	20mA
290	350	305	305	350

Different types of LEDs have different voltage and current requirements. These are some calculations to say what the minimum size of resistor you would need for each is.

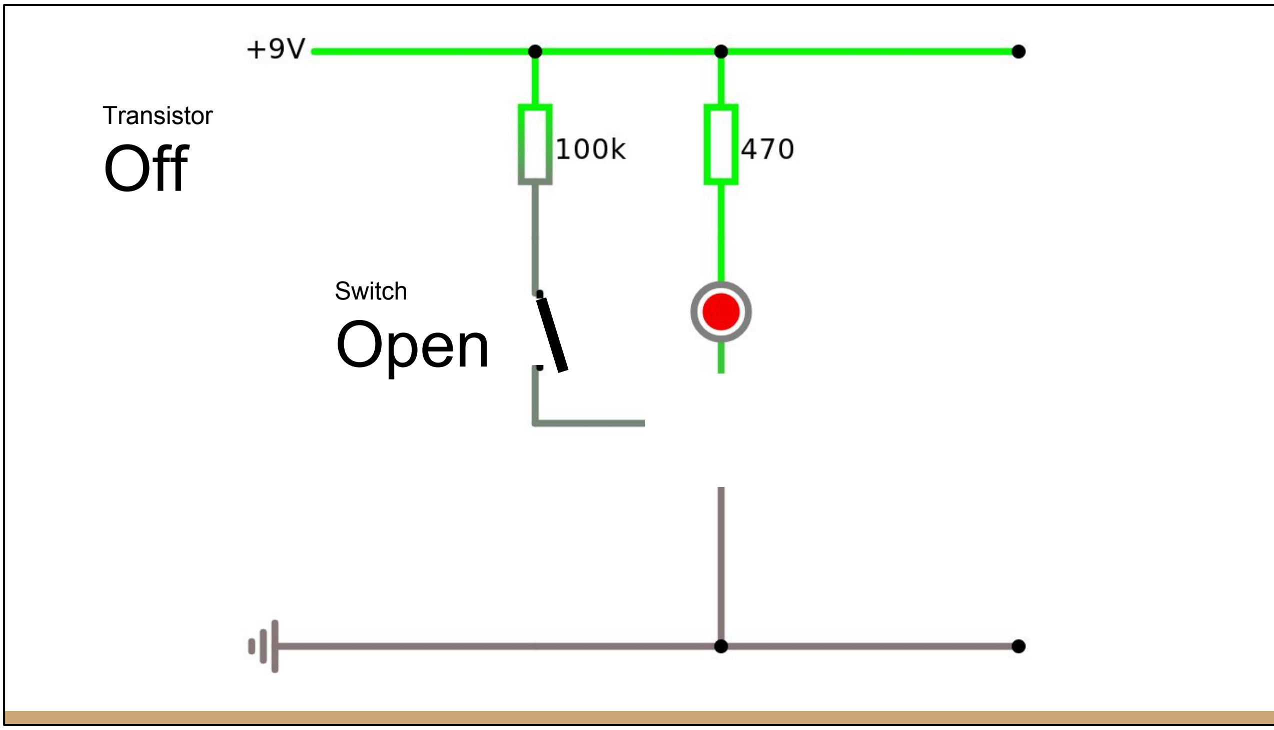
Circuit 2 - LED lights up with an NPN transistor

- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 1x NPN transistor
- 1x 470 ohm resistor
- 1x 1k ohm resistor
- 1x LED of any color
- jumper wires

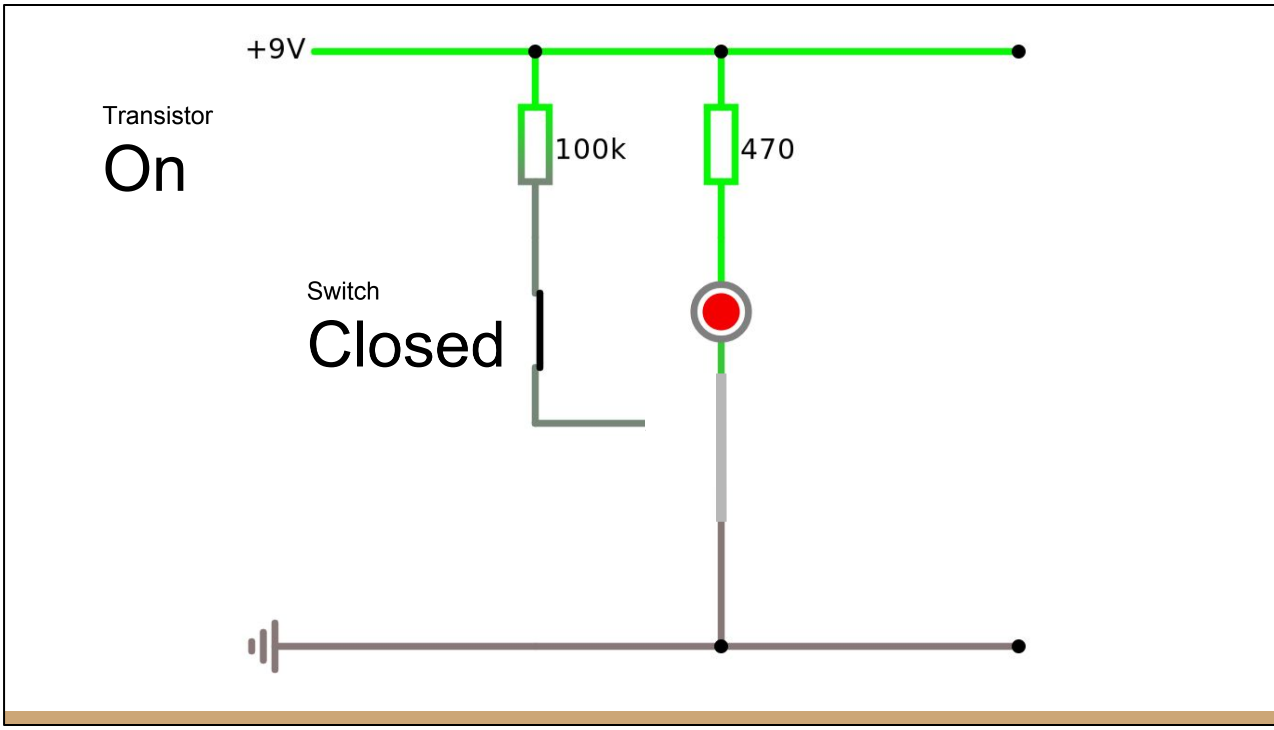
We're going to show you how NPN transistors work
There's a switch in the circuit, but we will replace that with a wire that you can pull out



Transistor acts like a switch, so it's like we wrapped the previous circuit in a transistor
Recognise the LED/resistor combo? It's the same as the first circuit
When the base of the transistor is powered, it will act like a wire from collector to emitter
There is a large resistor on the base of the transistor as we only need a very small current (V = IR)



When the switch is open, no current is flowing from the base of the transistor to the emitter so the transistor is off. This means that it acts as if there was an air gap between collector and emitter (no current can flow).

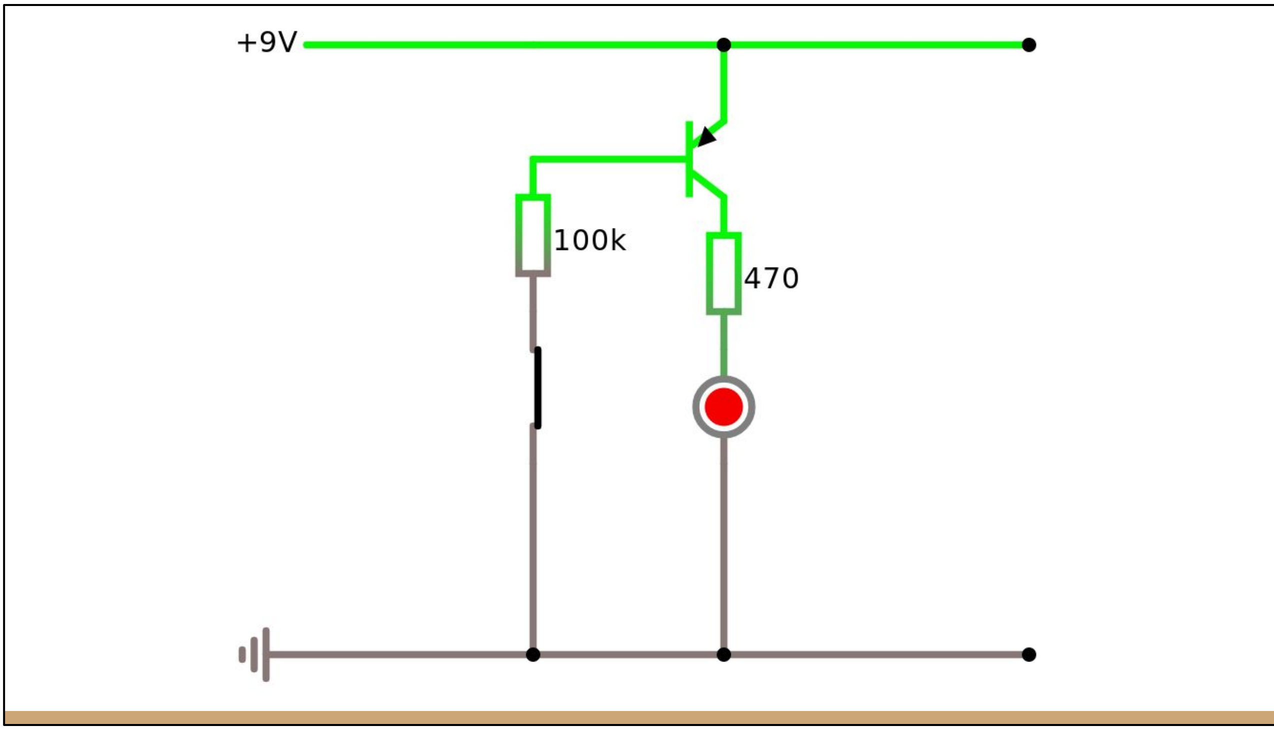


When the switch is closed, a small current can flow from the base of the transistor to the emitter. This means that the transistor turns on and acts like a wire from collector to emitter.

Circuit 3 - LED lights up with an PNP transistor

- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 1x PNP transistor
- 1x 470 ohm resistor
- 1x 1k ohm resistor
- 1x LED of any color
- jumper wires

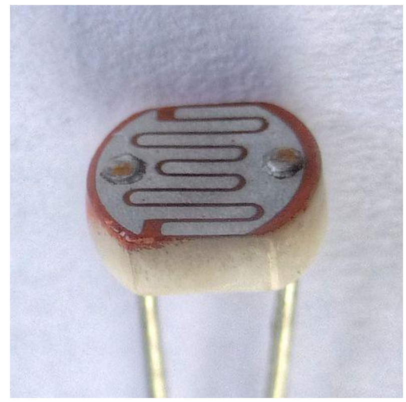
Same as before but with a PNP
Remember they are the same just with low voltage turning them on
Pins may be different than with NPN, check the sheet



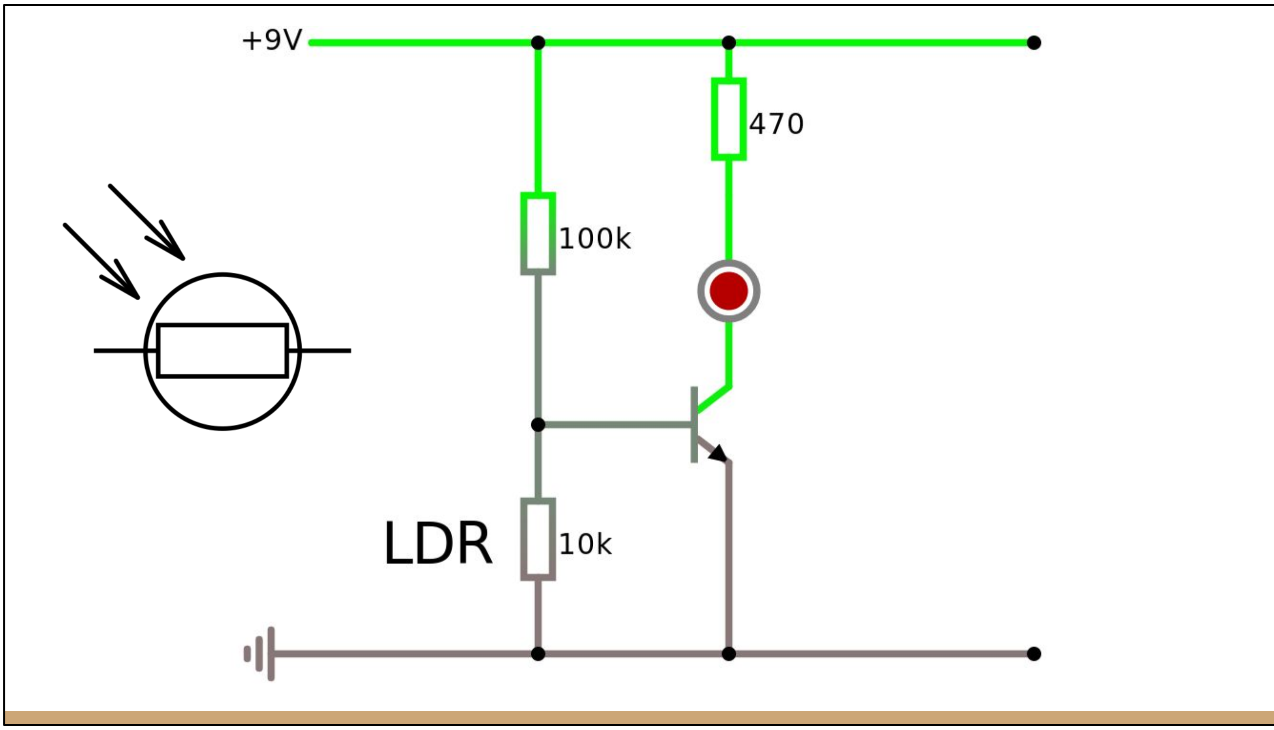
This acts like the previous circuit, except when the base of the transistor is connected to 0V it will turn on instead of connected to +9V. This is a PNP transistor (remember those?). When the switch is open, no current can flow from emitter to base, therefore the transistor is off. When the switch is closed a small current can flow however, so the transistor turns on.

Circuit 4 - LDR

- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 1x 470 ohm resistor
- 1x 1k ohm resistor
- 1x LDR
- 1x LED
- jumper wires

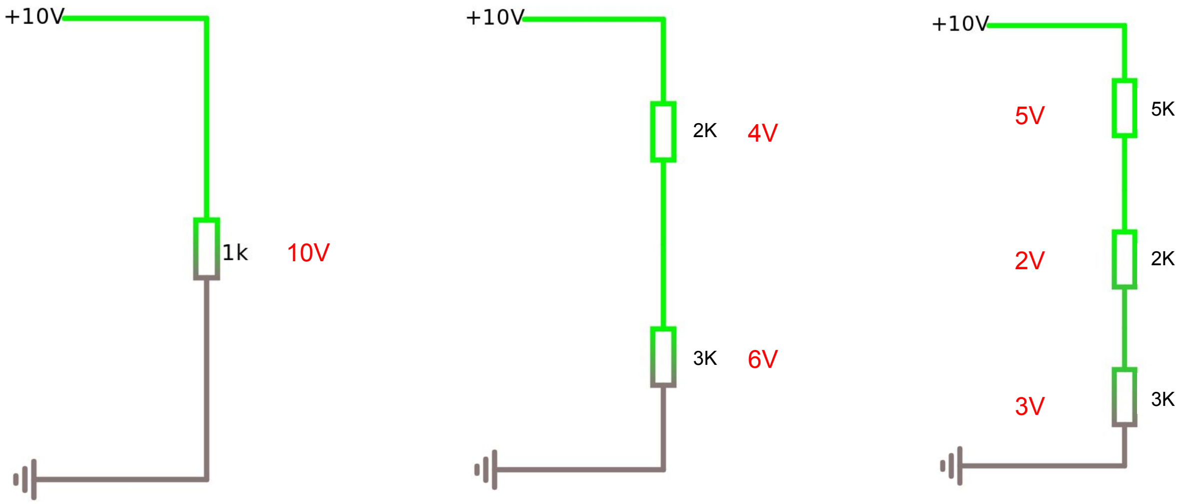


We're going to make an automatic light (turns on when it's dark)
LDR = Light dependent resistor
Like a resistor, but resistance decreases when light shines on it.

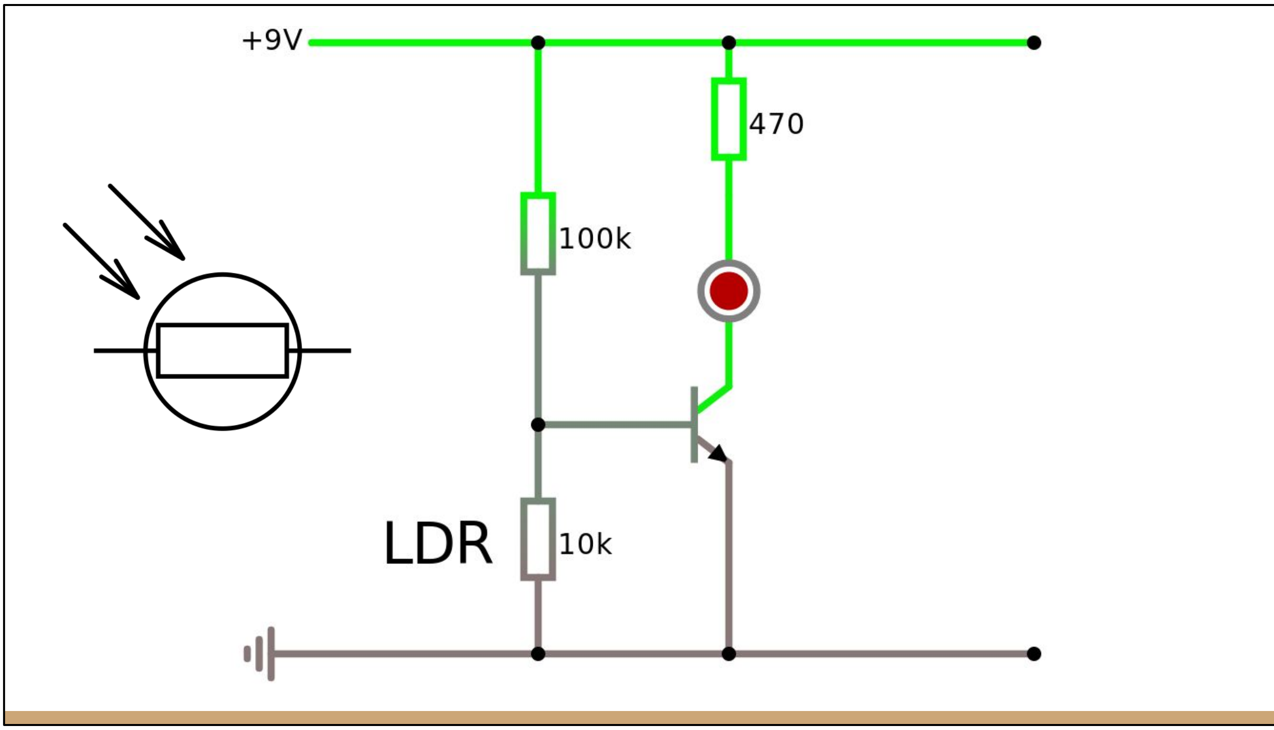


The symbol for LDR in the circuit is not correct, we replaced it with a resistor because our drawing software doesn’t have it, however the correct one is placed by it.
NPN transistor, so turns on when positive voltage on base, ie when LDR has big resistance (because voltage is proportional to resistance)

Potential dividers



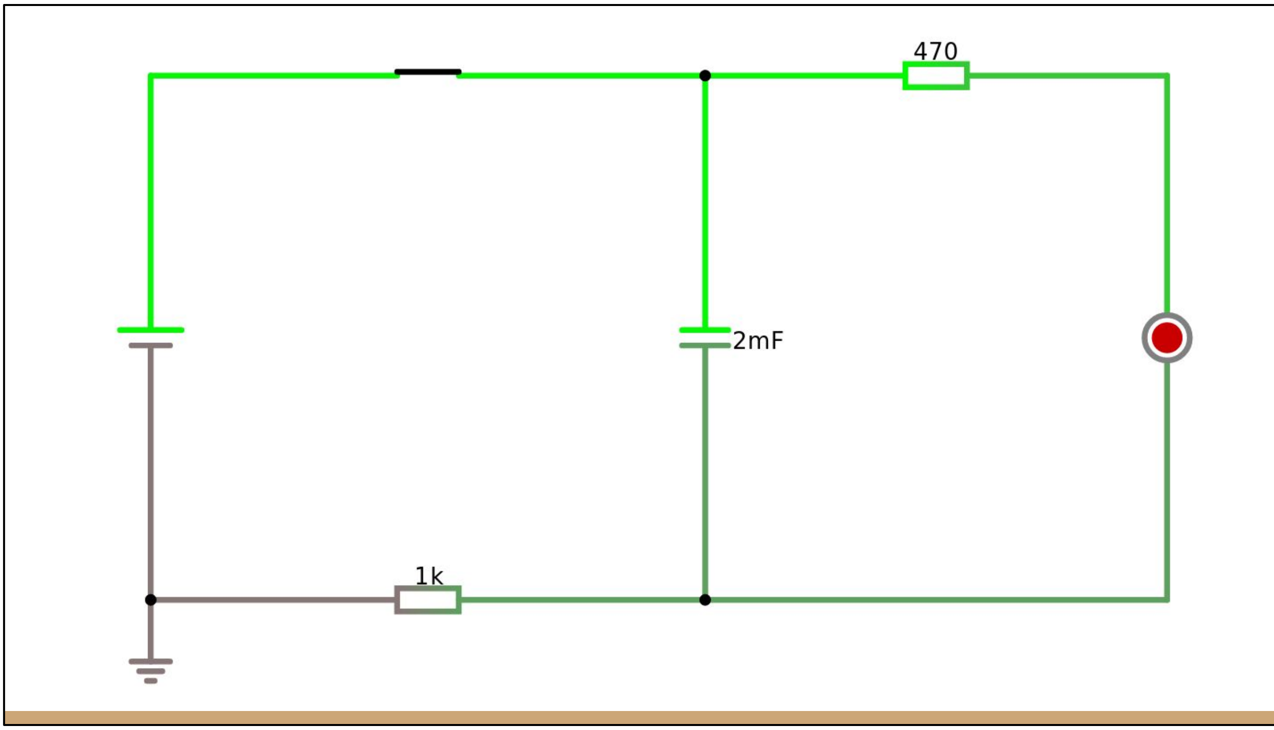
Because voltage is proportional to resistance, you can “divide” voltage to have different amounts at different points in the circuit. The amount of voltage across a resistor is the proportion of total resistance across that resistor times the total voltage available. These sorts of circuits are called potential dividers because voltage is sometimes known as potential difference.



So as it gets darker, the LDR gets a bigger resistance
As the LDR gets a bigger resistance, the voltage across it increases
V = IR and current remains same
Eventually transistor turns on because high voltage at base

Circuit 5 - Capacitor demonstration

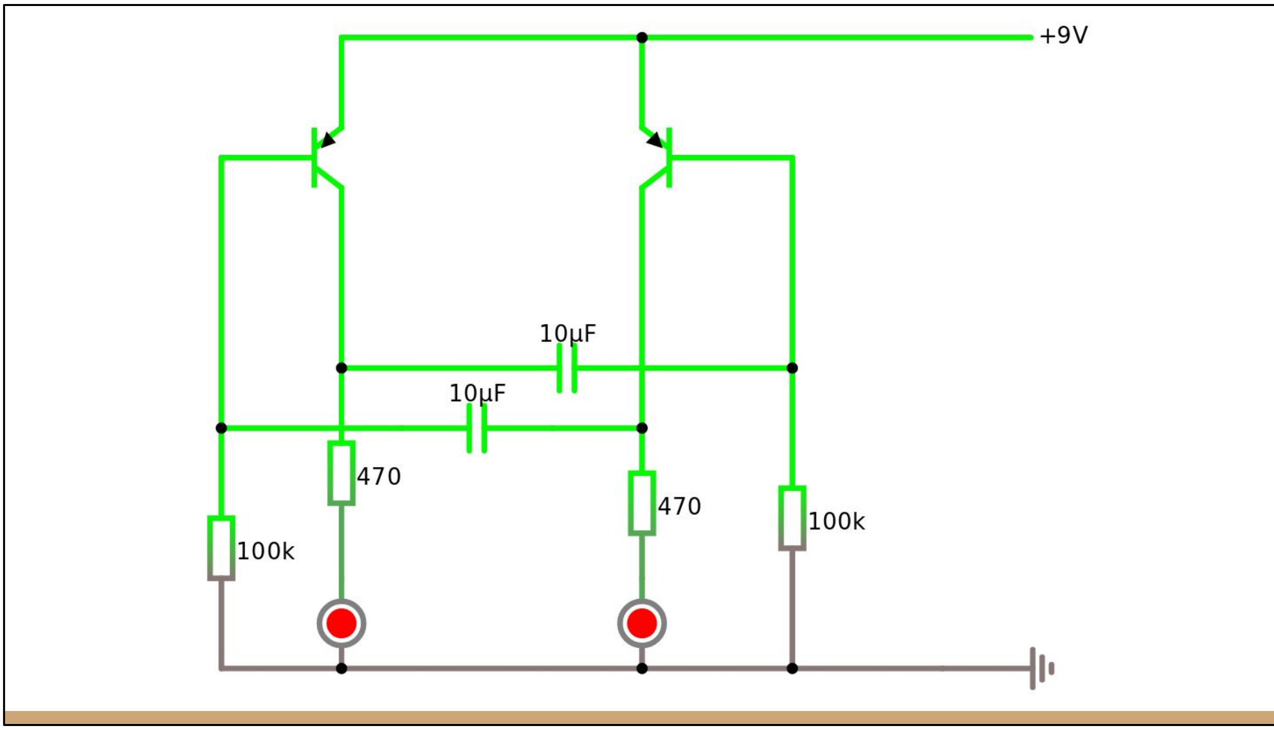
- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 1x 470 ohm resistor
- 1x 1k ohm resistor
- 1x LDR
- 1x LED of any color
- jumper wires



When switch is closed, there is a voltage across the capacitor
Capacitor charges up
At the same time, the LED is lit up because it is in parallel
When the switch is open no current can flow in the left half of the circuit and the only current flowing is in the right hand loop of the circuit
Current can only flow one way through an LED, so the capacitor lights up the LED until it discharges

Circuit 6 - blinking LED's

- 1x 9V battery
- 1x battery clip
- 1x breadboard
- 2x 470 ohm resistor
- 2x 1k ohm resistor
- 2x PNP transistor
- 2x 10uF capacitor
- 2x LED of any color
- jumper wires



For an explanation of how this works, google “astable multivibrator” and make sure you get a version with PNP transistors.