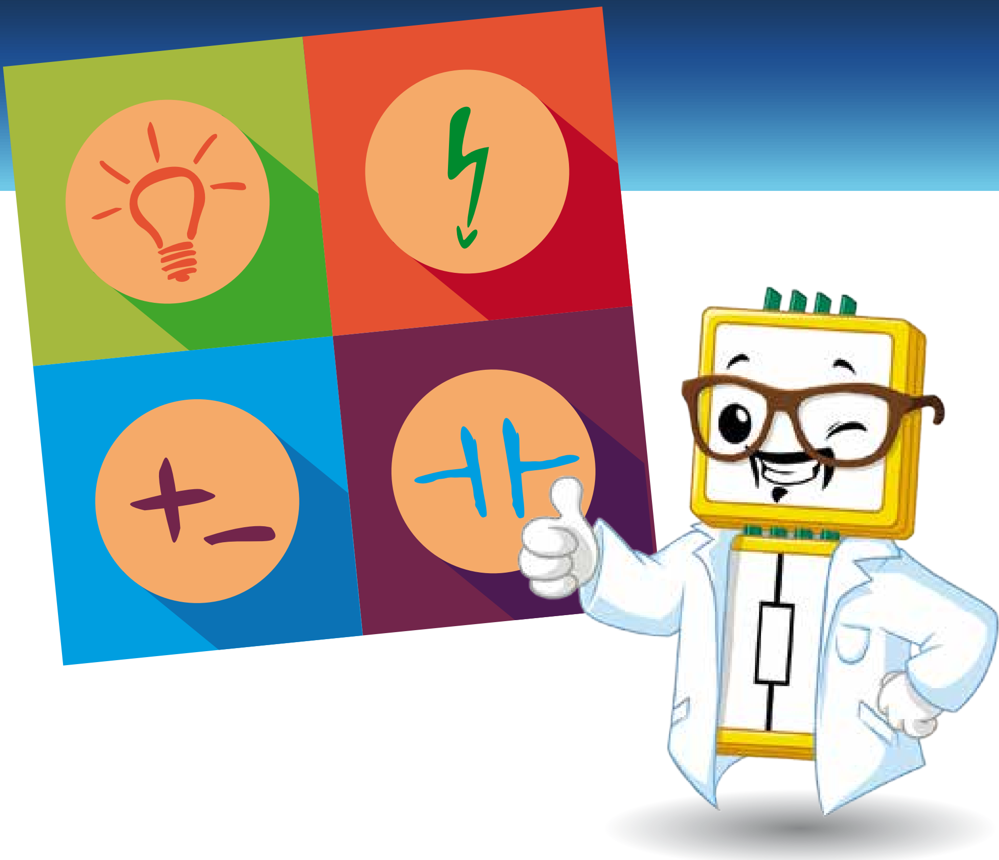
ALLNET®

Brick 'R' knowledge

Basic Set

The basics

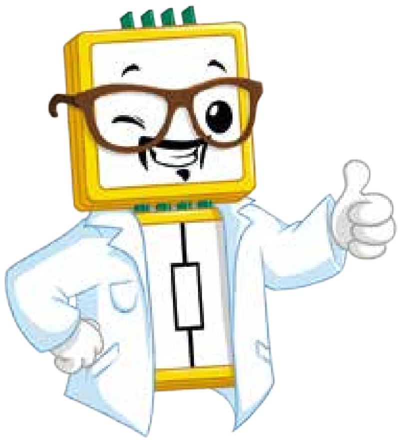


The best way to learn !

Maker Outlook:

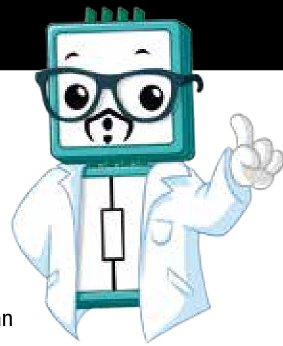
The Manual is only the beginning! Visit www.brickrknowledge.de to join our open source community. Here you can post your circuits as well as find tips and tricks. In addition we will post the latest videos, circuits, bricks and a lot more.

The future of the maker generation is in your hands! We also ask for help, please feel free to send any corrections, wishes and hints to improve the quality of the manual, which we give to you in a very quick translated way, to be one of the first getting the new Brick'R'Knowledge system to work.



Contents

1. Safety information



Attention, never connect the bricks directly to a 230V power supply!
This can cause fatal injuries!

Please use only the 9V battery-brick for power supply. The voltage is only 9 volts at a current of 1 Ampere, which is not hazardous to life.

Please ensure, that no wires get in contact with power outlets. This might cause an electric shock or other risks to health.

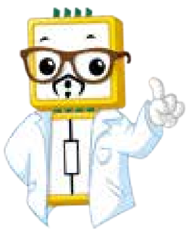
Please never look directly into an LED, since there is a risk of damaging the retina.

The set contains two LED-bricks, green and yellow, with 2mA power consumption each.
Never connect the polarized capacitor with the plus directly or indirectly to minus of the power supply-brick. This might destroy the brick and can lead to danger of explosion.

Always check the polarity, before integrating a polarized capacitor in your circuit.

Please disconnect the power-brick everytime after finishing your experiments. Otherwise there is a danger of an electric fire.

Children under 8 years of age should use Brick`R`knowledge only under adult supervision.

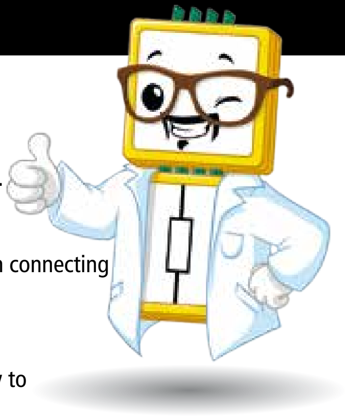


Do not swallow modules or other parts of electronic sets,
Otherwise, seek immediate medical attention!

The latest information on all Bricks and example circuits as well as direct ordering options are available at:

www.brickrknowledge.com

1. Introduction



Brick'R'knowledge premiered at the 2014 maker world in Friedrichshafen.

The special thing about our electronic set is that all bricks share universal connections, so even complex circuits can be understood very easily. Even connecting bricks in different angles is possible. For returning the 0 Voltage (ground) two contacts are used.

This allows creating compact circuits, that are easy to document and easy to be used for exploring and explaining electronic circuits.

3. Introduction of the elements

To understand the functionality of the bricks, we need to explain three basic criteria in the theory of electricity.

First the **electric voltage** (unit: Volt "V" and the German symbol "U"): It describes the strength of the electric field with the charge forced to perform a directed movement. It is named after Alessandro Volta, a famous pioneer of physics. He lived in Italy from 1745 to 1827.

The **electric current** (unit: Ampere "A" and the German symbol "I"): It describes the number of electric charges in a certain time a cross section of an example flow through the electrical line. It is named after Andrè-Marie Ampère, a famous French physicist and mathematician, he lived from 1775 to 1836.

The **electrical charge** or electrical quantity (unit: Coulomb "C" and the German symbol "Q"): It is a basic size of physics. If charges are moving through an electrical conductor, we speak of a current flow. It is named after the famous French physicist Charles Coulomb. He lived from 1736 to 1806.

The **electrical resistance** (unit Ω (Ohm), symbol "R") is the simplest and most frequently used component in electronics. It limits the flow of current in a series circuit and divides the voltage in a parallel circuit. If the resistance is incorporated in an electrical circuit, flows in dependence on the voltage across it exactly the current which permits its resistance value. Georg Simon Ohm was a famous German physicist, he lived from 1789 to 1854.

Another electrical resistance is the **photoresistor**. It is variable. If it is irradiated with light, it has a very low resistance value, at darkness the resistance value is getting higher.
It is a semiconductor component that enables the flow of current only under certain conditions.
It's attributes is based on the photoelectric effect, for which Albert Einstein received the Nobel Prize for Physics in 1921. The phenomenon was already discovered by other researchers in 1887.

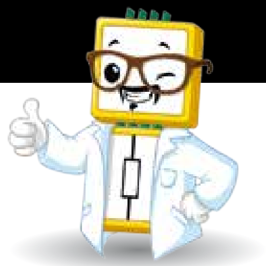
The **Diode** is another semiconductor element that allows a current to flow only under certain conditions
At a diode the voltage must be applied with the correct polarity. It must be connected in the direction of the technical current flow.

Our Basic Set contains a special diode, **a LED**. This behavior of semiconductors is often used in technology. This phenomenon was discovered in 1874, from 1925 semiconductor behavior is used in the industry.

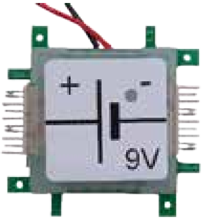
The **Capacitor** is a special electronic device to store electric energy in the form of charge (Coulomb) to voltage (Volts). The capacitor can be charged with electric power, so his property is the capacitance "C". The unit of capacitance is Farad, named after the famous English physicist Michael Faraday. He lived from 1791 to 1867. Although a capacitor is often described with two opposite plates, its shape can also be cylindrical. First capacitors behavior was already demonstrated independently in 1745 and 1746. Also Alessandro Volta catched up with the capacitor, the storage of electrical energy in the form of charge and voltage and thus significantly influenced the development of the capacitor to its present importance.

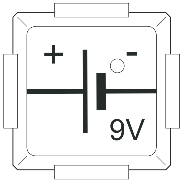
The Transistor is a semiconductor device, which actually does not conduct current under the conditions already known. It has to be integrated correctly in the circuit, such as a diode, but passes the current under a further condition. Transistor actively intervenes in the management processes within a circuit. It controls the flow of current at two of its ports on the third. The transistor was discovered in 1925, in principle, but named transistor since 1948. It is used since the 1960s on a large scale. Approximately 1.9 billion transistors are now built into a modern home computer processor.

4. The bricks



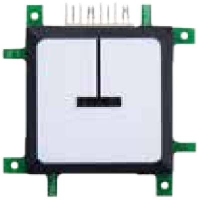
Battery / power supply

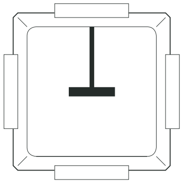




The battery-brick supplies the circuit with electrical energy. It is supplied with an AC adapter. The supply voltage is 9 volts (9V). Please connect the battery-brick when the circuit is finished, otherwise there is a risk of short circuit.

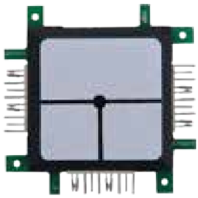
Ground(3x)

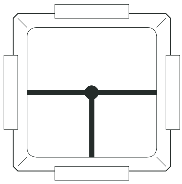




A very important element, because it ensures a closed circuit in more complex circuits. Without it is more difficult to build complex circuits. It connects the two middle contacts with the outer contacts, that are reserved especially for a closing of the circuit. In electronics ground is the reference voltage of 0V (zero volts).

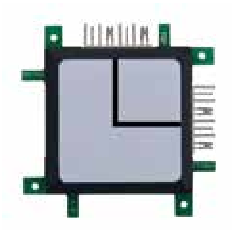
T-corner (3x)

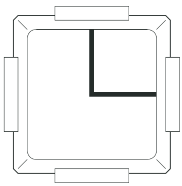




It offers an additional diversion. The ground is connected through the outer contacts.

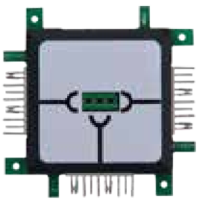
Corner (2x)

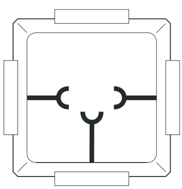




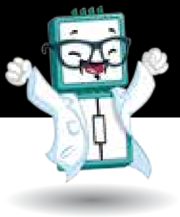
The corner-brick can connect two bricks at a 90° angle.

Contact

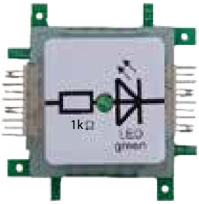


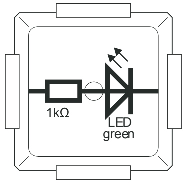


The three contacts are suitable for uncomplicated and quick installation of additional components, which are not included in the set.

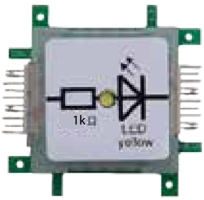


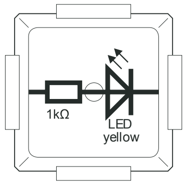
LED green 2mA





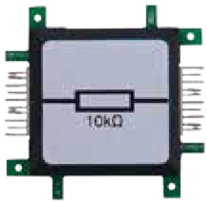
LED yellow 2mA

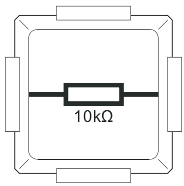




Our set contains LED-bricks in colours yellow and green. These colours are only visible when an electric current is flowing through the diode. The current must be at least 2 mA.
The 1k Ohm resistor protects the LED, and is designed so that the diode is not destroyed by the electrical voltage of 9V. Without a resistor the LED has an operating voltage of 1,6 to 2,5V. The correct polarity is important, otherwise the LED won´t light up. The arrow on the LED module must be equal to the circuit direction, i.e. from "plus" (+) to "minus" (-).

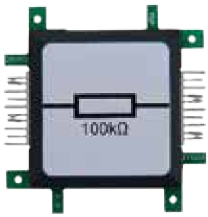
Resistance 10k Ohm

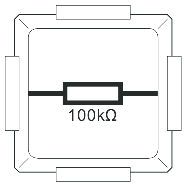




This brick is an electrical resistor with the size of 10.000 Ohms (10k Ohms). Resistors are used in electronic circuits to regulate current and voltage. The higher the resistance, the worse it conducts the current. The resistance is a measure of the current flow in response to the voltage. 1 Ohm corresponds to a current of 1 Ampere at 1 Volt - 10k Ohm correspond 0,0001A (100µA) at 1V.

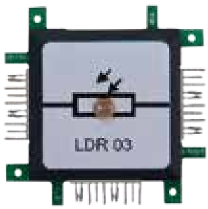
Resistance 100k Ohm

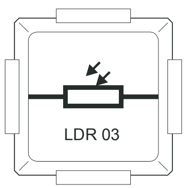




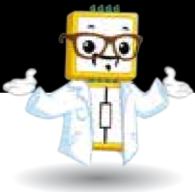
This block is an electrical resistor with 100.000 Ohm or 100kOhm. This value corresponds to a current of 10 micro-amperes (10µA) at a voltage of 1V.

LDR 03

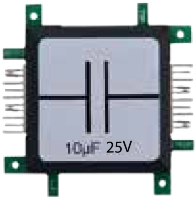


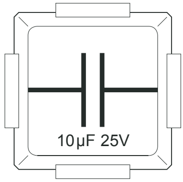


The LDR is a photoresistor, the current is influenced by the light shining on it. The resistance is at 100 ohms by light and changes to several thousand ohms at darkness. The change in the resistance value is continous.



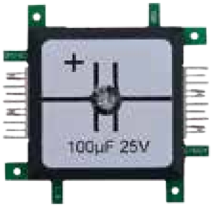
Capacitor 10µF

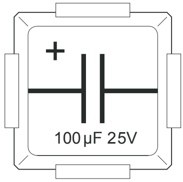




Our set includes a capacitor with the capacity of 10 millionths of a Farad (10uF). It can store an release electric energy very quickly, like a rubber band, does with mechanical energy. 1 Farad means that a voltage of 1 volt is reached when being charged for 1 second with a current of 1 Ampere. Capacitors usually have very small capacity. The voltage must not exceed 25 volts!

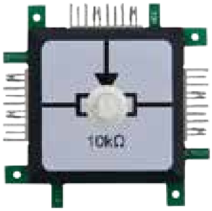
Capacitor 100µF

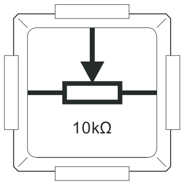




Our set also contains an electrolytic capacitor with 100uF, which may only be operated up to a voltage of 25 volts. The capacitor protrudes from the brick. This polarized capacitor may only be connected direct or indirect to the positive port (+) of the 9V power supply.

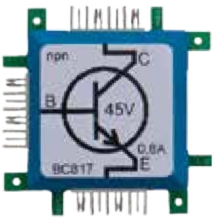
Potentiometer 10kOhm

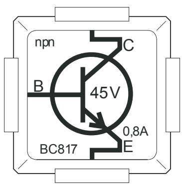




The potentiometer is a manually changeable resistor. Here changes a third contact (wiper) the length of the resistance from, and thus changes the amount of electrical resistance at its terminal. The value can be changed from 0 to 10kOhm. Always avoid short circuits. Never connect the wiper directly to the power supply-brick, because this may cause a short circuit.

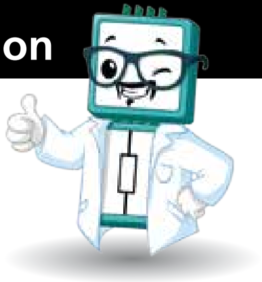
Transistor npn BC817





The transistor can be destroyed when between terminals B (base) and E (emitter), or the terminals C (collector) and E a voltage is applied directly with no resistance! Transistors are electronic switches that, not like a light switch that is operated manually, but by a current flow at its B port. The switched current flows then between the C- and E-contacts. The switched current flow (C to E) must not exceed 0.8 amperes in order to prevent destruction of the device.

4.1. Power Circuits - a brief introduction



In our example 3.2 the term "worker" will be used to describe the operation of the electric current. The following information will explain the circuit and these "workers" in more detail. With the "workers", electrons are described, that can move freely in metals. This is very important because the electrons bring the energy provided by the voltage source to the place where they do their work.

The technical direction is specified from the positive pole (anode) to the negative pole (cathode).
This is known as the technical current direction, which has been described as the structure of the smallest indivisible bodies, the atoms were not yet so well known. Today we know that the actual direction of current flow the other way around, the current runs from the negative to the positive pole. But that's not too bad, because the principle of the current flow is still correct.

Anode and cathode are the Greek words for "ascending" and "descending". Based on observations 230 years ago, scientists came to the conclusion that charge carriers move directly to an electrode and repel from the other. The target electrode of this movement is called anode and the start electrode cathode.
Because our "workers" are all negatively charged, they move in the circuit from the cathode to the anode.
The actual direction of the current in metals is therefore the technical opposite from the anode to the cathode. "Negative" does not mean that our "workers" all bad particles were, only that they behave oppositely in relation to something exactly. Now we come to our circuit.
The first rule is: The circuit must always be closed. This allows a directed movement of the workers.
In the natural sciences, especially physics, there is the principle of causality. Therefore, an event occurs only if there is a cause. In addition, cause and effect are interconnected through the mediation.

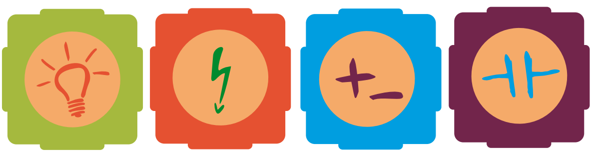
The exact sequence is as follows: First the cause, then the mediation and finally the effect.

Related to our circuit, this means: The voltage at the voltage source is the cause, our "workers" are the mediator and the energy conversion example, a LED, is the effect. Is the circuit interrupted, the electric current, our "workers", can no longer reach the site of action. We would like to explain the electric voltage by the following example: Tensing a rubber band between the right and left hand, the further the right and left hand move away from each other, the higher the back pressure of the band will be.

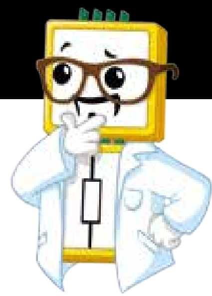
The rubber band is under tension and wants to relax again. The "workers" in our power source were taken from their homes, the energetically more favorable state and strive home now again. The stronger the "workers" were separated from their home, the greater is the tension to return to the initial state. This is called charge separation.

The reciprocal power acting between the two ends of the rubber band, may be referred to as a potential difference.
This makes in turn from the electrical voltage. The "workers" are converted back into the discharged state in a closed circuit. For this purpose they release their energy to the LED. Our "workers" are very diligent and take us not resent that they have been separated from their homes. Because they are actually electrons, tiny particles that have no consciousness and behave exactly how we want it, as long as we do not interrupt the circuit or a short circuit.

Have fun with our Basic Set - your Brick'R'knowledge Team!



4.2. LED lights up

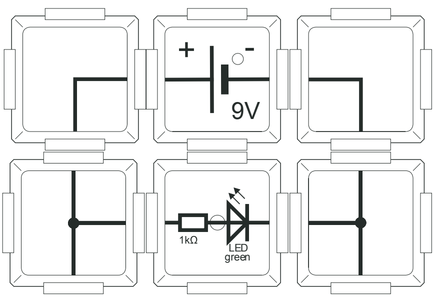


The first structure of a circuit consists of two components: a voltage-brick and a LED-brick with an electrical on-resistance. (in addition: 2 corner-bricks and 2 T-bricks)
The power source-brick is marked with a long thin line (+) and a short thick dash (-) as well as the lettering "9V". The voltage source has poles, that means that the negative pole (short thick line) sends out "workers" to the connected bricks. After finishing their works the y were sent to the plus pole.
The term "9V" indicates how many of them do this. "V" (Volt) is the electrical voltage and thus also a feature of our voltage source. Thus, this voltage source sends out our "workers" with nine volts on the way. Our "workers" are electrons and form as a function of resistance (R) and voltage (V) the current (A).

The LED is the place where our "workers" accomplish their work, thus producing light. LED stands for light emitting diode. Note: Not every light source is a diode and not every diode is a light source)

This means that our "workers" can do their job only when the positive pole of the voltage source is connected to the end of the indicated LED arrow. If the „top“end of the arrow is attached to the positive pole of the voltage source, our workers are blocked - thats the reason why the arrow has a box before the sharp end of the arrow. The additional resistor at the LED reduces the number of worker, because the high number of workers would destroy the LED in a very short time. That is also called series resistor.

When setting up, please note, that our "workers" have difficulties to move in other materials such as plastic, ceramic, glass and air. But they are very mobile in metals such as iron, copper or gold. In order to bring our "workers" to their workplace and send them back, when finished, the circuit must be closed. Our power-supply-brick is starting and finishing point simultaneously. To set up a so called circuit the two corner- and T-bricks are needed. When connecting the bricks, make sure that the connectors a plug safely. In the following sections, we will replace the term "workers" by the term „current flow“, since it better describes the behavior of our "workers" in general.



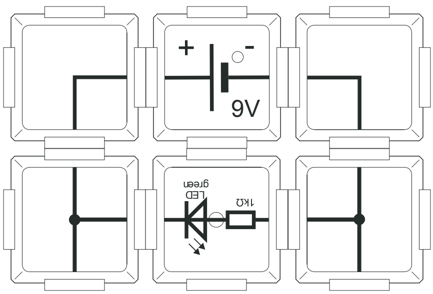
4.3. Open circuit

Experimental set-up: **power-supply-brick, LED-brick green, 2x corner-brick, 2x T-brick**

The second structure of a circuit consists of two components: a power-supply-brick and a LED-Brick with an electrical on-resistor. (in addition: 2 corner-bricks and 2 T-bricks)

In this experiment the LED is integrated in reverse direction, the LED will not light up. It´s very important to understand the functionality of the LED. The LED will light up only when it is integrated in the forward direction to the circuit. The circuit symbol of the LED indicates an arrow. The arrow must point from the positive potential (plus) to the negative potential (minus) to allow a correct flow - then the LED will light up. The arrow base is called anode, the top is called cathode. The box at the cathode indicates that the current cannot flow correct, when the positive potential of the voltage source is applied here.

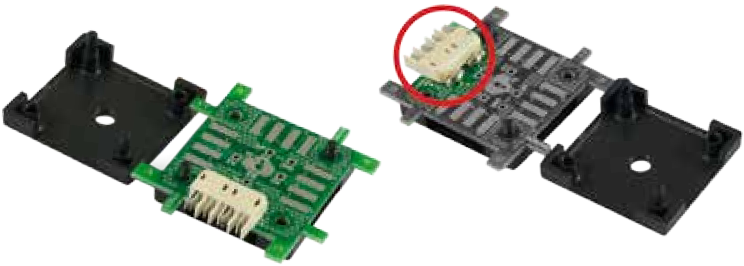
In this case the LED acts like any other diode. It is comparable with a door that can swing only in one direction and can be accessed only from the same direction.



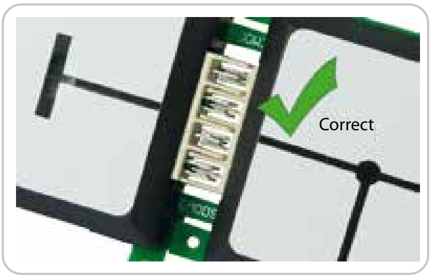
The LED will not light up !!!

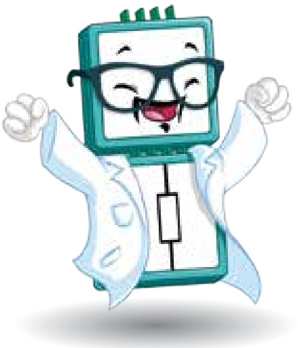
4.4. Ground & connection

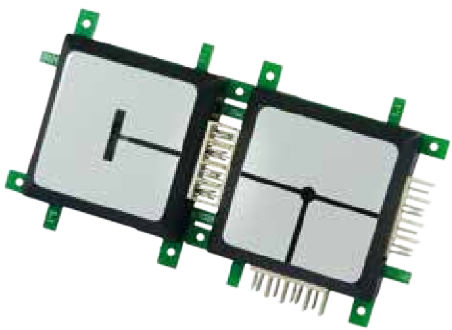
The ground-brick is a essential component of our basic set. The ground-brick reduces the number of connections in the circuit. This is the secret of our four-pole connectors. Both middle contacts are reserved for signal transmission, as the imprint reveals. Our ground-brick delivers this connection to 0V. In our circuit its 9 volts versus 0 Volt: You simply speak just "nine volt". Electronic circuits are created the same way, so that all the components in more or less complex circuits are connected to the "ground". This allows reading the circuits. Our ground-brick connects the two middle contacts with the two outer contacts. This does not cause a short circuit, because the current runs thru the components inside the bricks.



When connecting the bricks, please make sure that the contacts are placed correct, otherwise this can lead to disruptions or even short circuits!

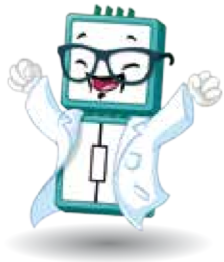




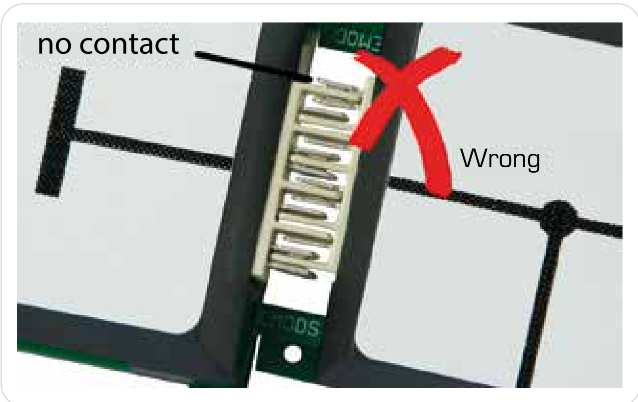


Here is an example of a correctly plugged connection. The compound consists of small pins that are stucked mechanically and are also electrically. In order to ensure insulation between the contacts and to prevent short-circuit, plastic bridges are placed in between, which does not conduct the electric current.

When assembling the modules it must be ensured that the contacts are connected correctly, as this can lead to disruptions or even short circuits!



An example of a faulty connection can be seen in the image below. Here are distances between the contacts, which can not ensure a safe flow of current. The circuit remains "open" or is unstable and the operation of the circuit is not given.

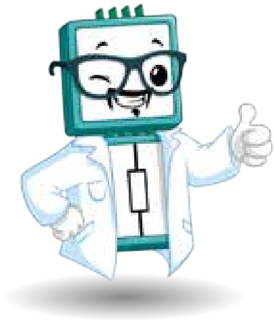


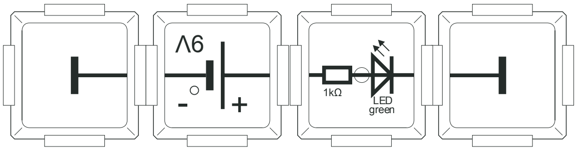
It is very important to check the correct fit of the pins, if they are too far from one another, there might be a short circuit. Then the current flows not the desired way, but looks for the lowest resistive (most shortest) path back to the power source. A short circuit results in a maximum current flow, because the only resistance that the current has to overcome is the inner resistance of the voltage source. This resistance is clearly very small, this is why the short-circuit current can lead to overheating. This may cause a fire!

Important: Always check the correct position of the contacts!!!!

4.5. Simplified circuit with ground-brick

Experimental set-up: **power-supply-brick**, **LED-brick** with green LED, 2x **ground-brick**



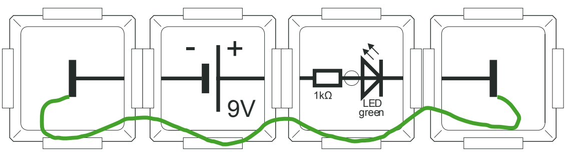


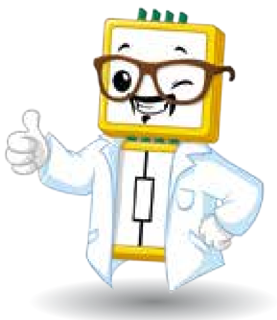
The ground-bricks allow a more clear experimental set-up, because only 4 instead of 6 bricks are needed for a circuit. It is really a closed circuit, even if the connections at the ground bricks seems to end nowhere. The ground-bricks ensure the connection between the ends.

This is done with a connection from the both inner contacts to the outer contacts. Every expert recognizes the "blunt end" of the ground symbol and knows that the current returns and its a closed circuit.

The ground-symbol used in professional applications saves time and allows a better overview of complex schematics.

Flow of the ground connection:



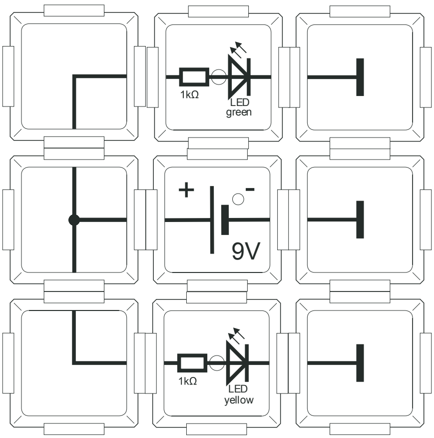


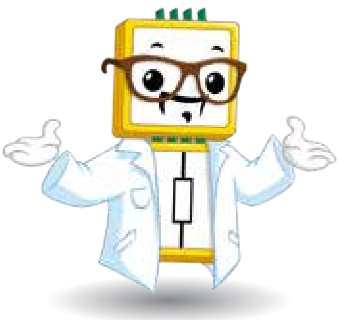
4.6 Two LEDs parallel circuit

Experimental set-up: **power-supply-brick**, **LED-brick green**, **LED-brick** yellow, 3x **ground-brick**, 2x **corner-brick**, **T-brick**

Our basic set includes two LED-bricks, one green and one yellow. They can be used together in a circuit. Both LED-bricks light up only when they are connected properly, ie with the anode at the positive potential of the voltage source. A parallel circuit is always present when the current flow has two or more options to find the way from the positive to the negative pole. In this example, the LEDs lights up simultaneously, because the current flows through both LED-bricks in different directions.

Our supplied LED-bricks both have a series resistor of 1kΩ, because green and yellow LEDs require approximately the same operating voltage, this is 1.6 to 2.5 volts. LEDs with different colors have different operating voltages, so different resistors are needed. For example, red and blue LEDs do not light up simultaneously, because of their different resistance. As the red LED has a lower operating voltage than the blue, it should light up first and will be dimmed when the blue LED lights up. The power supply must continue to rise in a parallel circuit. LEDs have a relatively small operating voltage, so that they are hardly used without series resistor. If an LED is operated by mistake without a series resistor, it is usually broken.

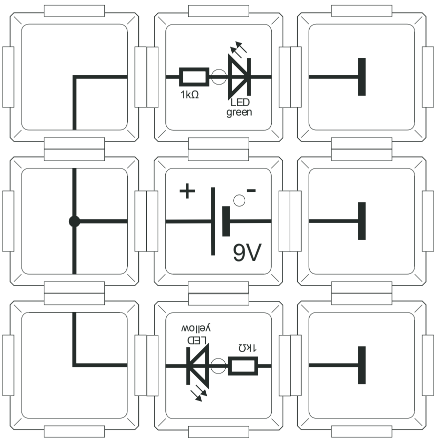


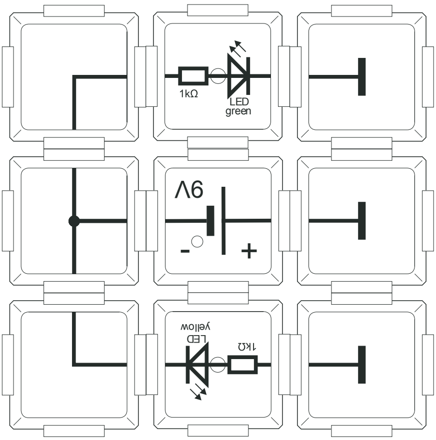


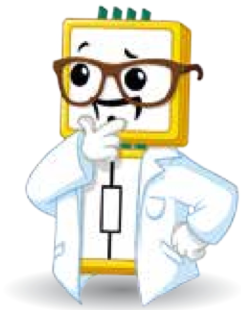
4.7 Polarity measurement

Experimental set-up: **power-supply-brick, LED-brick green**, **LED-brick yellow**, 3x **ground-brick,** 2x **corner-brick, T-brick**

If both LEDs are switched antiparallel, the polarity of the battery used (PSU) can be determined. There is always only one of the two LEDs lighting up, no matter in which direction the battery moduls are inserted.







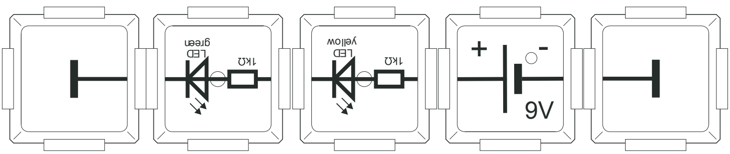
4.8 Two LEDs - series circuit

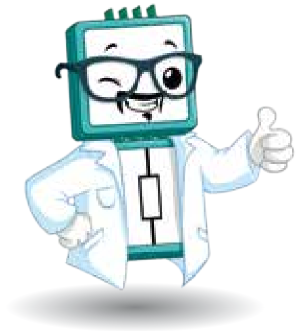
Experimental set-up: **power-supply-brick**, **LED-brick green**, **LED-brick yellow**, 2x **ground-brick**

Now we are building a series circuit as an example of a basic circuit. The series circuit is, in addition to the parallel circuit, the second way to realize a flow of current through two or more electronic devices.
This is also referred a series circuit. In this case our LED devices are so placed in the circuit, that they are arranged one after the other. The cathode of the voltage source is connected to the anode of the yellow light emitting diode.

The current flow through the yellow LED at cathode leads to the anode of the green LED. The electric current is now forced to flow through both bricks, before reaching the negative pole of the voltage source and closing the loop through the positive pol to the yellow LED.

The resistance of both LED-brick sums up, while the current flow is reduced by 50 percent. This can be observed on the luminance of the light-emitting diodes, whose intensity is lower than in the parallel circuit.





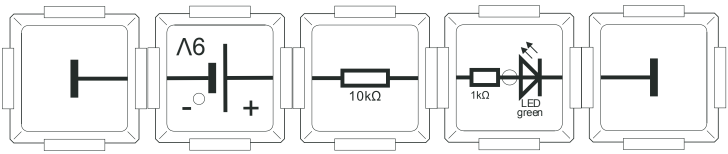
4.9 The resistor

Experimental set-up: **Power-supply brick**, **LED-brick** green, **LED-brick yellow**, 2x **ground-brick**, **resistor-brick (10KΩ)**

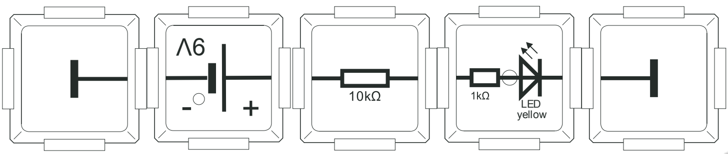
The electric resistance decreases the electric current flow. This property is essential for electronic circuits.
Through it, the current flow can be manipulated or a desired voltage can be adjusted. It is therefore a desired and required property of an electronic component, other than the name would suggest. Insulators and superconductors are the extreme examples of an electrical resistance. The insulator has an ideally infinite resistance and the superconductor has no resistance. The electrical resistance is measured in ohms (Ω). If a circuit with a ideal voltage source no resistance, the flowing current would be infinitely high, which is not possible in reality.

Each circuit has, even at short circuit, has to overcome an internal resistance. Comparing the electric current with a stream of water through a reduced diameter at one point in the pipe, so it quickly becomes clear that the amount of water gets reduced, when the diameter of our tube gets smaller. The pressure on the input side has to be increased, if the same amount of water should flow at the same time. The pressure is the equivalent of the electrical voltage, the water flow is the electric current and the frictional resistance of the water pipe is the electrical resistance. By increasing the water pressure, more water will flow in the same time.

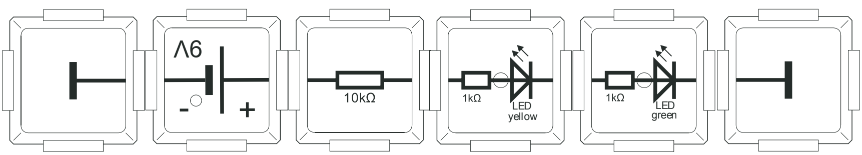
The water pressure difference between input and output of our pipe is analogous to the voltage drop across an electrical resistance. That means the characteristics voltage (U), current (I) and resistance (R) stand in a strict relation. The following relationship applies: voltage (U) is equal to the product of current (I) and resistance (R) (U = R x I). A flow of current of 0.9 Ampere is thus achieved by a resistance of 10Ω with a voltage of 9 volts. In our circuit, resistors are much larger, which at the same voltage has a much smaller current flow. (10Ω to 10.000Ω result 0.9 amps to 0.0009 amperes at 9 volts)



With yellow LED-brick



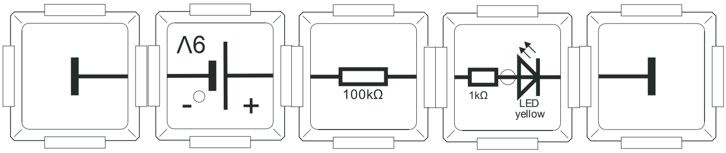
Or even lower light intensity as both LED modules are connected in series.



4.10 The resistance is getting larger

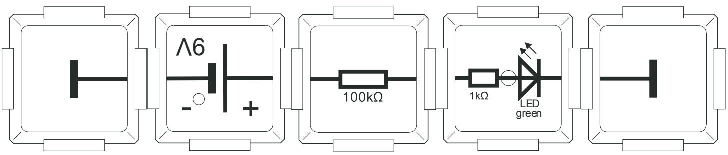
Experimental set-up: **power-supply-brick**, **LED-brick green**, **LED-brick yellow**, 2x **ground-brick**, **resistor-brick (100KΩ)**

By using the included 100kΩ resistor we reduce the current flow still further. Since the voltage (9V) remains the same, the light-emitting diode reduces its intensity again.



This will also work with the green LED because of the similar operating voltage.

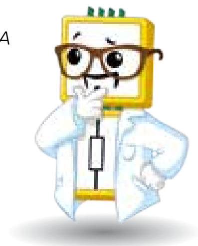
The now more than possible current flow results from the quotient of voltage (9V) and the resistance of 100,000 Ohm.
When neglecting the internal resistance of the power source and series resistor in our LED package of 1.000Ω it is 0.00009 amps. The increasing number of decimals is stated as negative powers of threes.
0,009 spoken 9 milli (thousandth) -Ampere or 9mA; 0.00009 ampere, as in our example, we are already as millionths, ie 90 micro-amperes, 90µA. Although the current flow is greatly reduced, our LED is still on a bit.
This speaks for the excellent quality of today's LEDs.

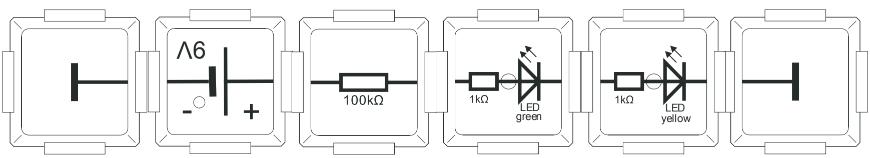


If you connect both LED bricks in series, the light intensity of the green LED is now weaker than before.
The current flow is still further reduced since the series resistance is added to the total resistance and our source voltage remains constant at 9 Volt. This gives the total current flow (I)

$$I = \frac{Ubattery - ULEDgreen - ULEDyellow}{R100k\Omega + R1k\Omega + R1k\Omega}$$ with specified values $$I = \frac{9V - 0{,}7V - 0{,}7V}{100.000\Omega + 1000\Omega + 1000\Omega} = 0.000074A$$

This value is very low.





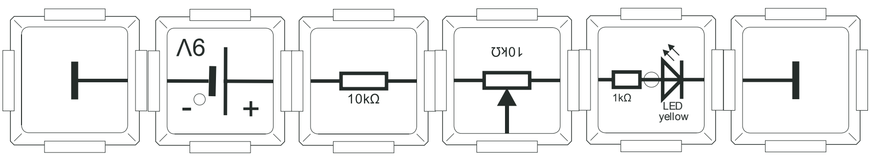
4.11 The resistor in a series circuit

Experimental set-up: **power-supply-brick**, **LED-brick yellow**, 2x **ground-brick**, **resistor-brick (10KΩ)**, **potentiometer-brick**

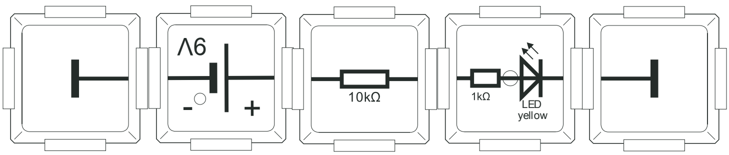
Let's do another experiment with series circuits to show the effects of the total resistance. For this purpose we need an additional 10kOhm. We already used the single 10kOhm brick. There is a 2nd brick with 10kOhm in our set, the potentiometer brick. Though it has a different meaning, we also can use it as a 10 kOhm fixed resistor. In this case we don´t need the variability of the resistance, so we use the potentiometer the same way as we did the 10KΩ resistor.

We connect the potentiometer brick in longitudinal direction with the two opposite contacts. The slider does not change the resistance here, but only the resistance value at its third contact. Prefixes are used for the increase as well as the decrease of numerical values. The prefix "kilo" is expressed by the small "k" before the unit of resistance. The magnitude of the respective prefixes are also available for other variables such as the voltage (V,U) can be used.

Comparing both resistance values with some tolerance, you can expect a doubling of 10kΩ to 20kΩ.



For comparison a single resistor of 10kΩ.



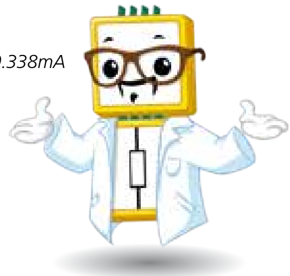
For an approximate total current value with two resistors (20kOhm) by the LED:

$$1 = \frac{Upowersource}{R10k\Omega + R10k\Omega} = \frac{9V}{20\ 000\Omega} = 0.00045A = 0.45mA$$

For an approximate current flow through the LED with a resistance ok 10kΩ the value of 0.45 mA must be doubled to 0.9mA, as resistance and current flow are in an indirect, inverse proportion to each other.

For the exact total current value with two resistors (20kΩ) by the LED follows (ULED yellow is assumed with 1.9V):

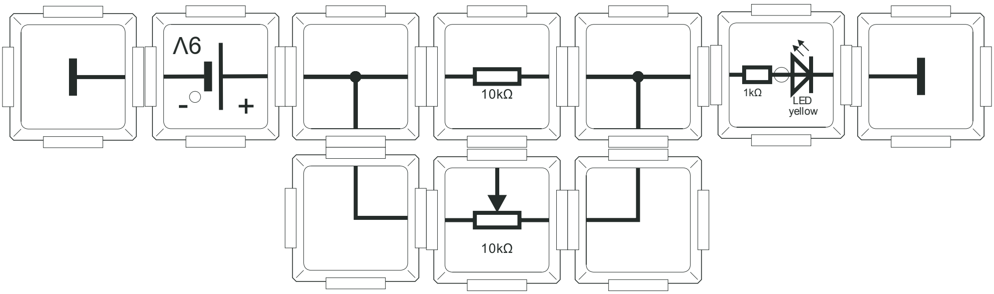
$$1 = \frac{Upowersource - ULED\ yellow}{R10k\Omega + R10k\Omega + RLED} = \frac{9V - 1.9V}{21.000\Omega} = \frac{7.1V}{21.000\Omega} = 0.000338A = 0.338mA$$



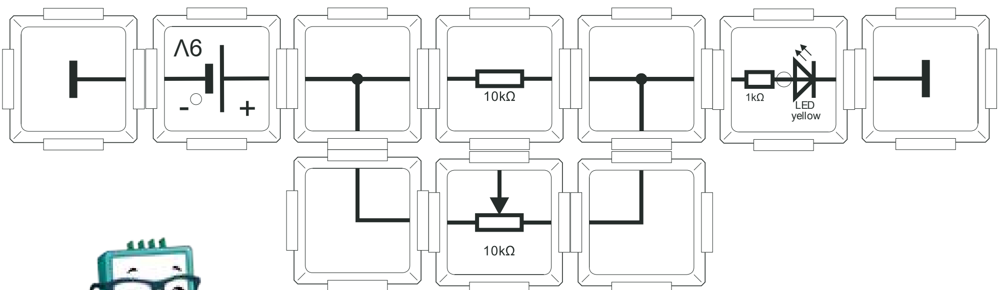
4.12 Resistor as a parallel circuit

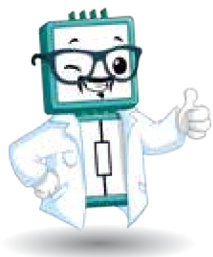
Experimental set-up: **power-supply-brick, LED-brick yellow,** 2x **circuit-brick, resistor-brick (10KΩ), potentiometer-brick**, 2x **T-brick**, 2x **corner-brick**

In electronics, it is very rare that only pure series or parallel connections are used. In most cases mixed circuits - a combination of series- and parallel circuits are used. This will be the case in the following example.
We refer to this attempt as a parallel circuit, since only the current flow through the adjacent resistors is examined. There we examine the light intensity of the LED. Since both resistors, 10k and potentiometer have the same resistance, the current flow has two equal possibilities, to get to the LED. The total resistance of the parallel resistors is reduced to the half, that means to 5kΩ.



To make a change in the current flow visible, we remove one of the two resistance components from the circuit. Which one is choosen doesn't matter, because the current has always a path to the LED. We can see the brightness of the LED decreasing. The current flow has now only one way to reach the LED. Now the total resistance is 10 kOhm, that means it doubled the half value we had before.

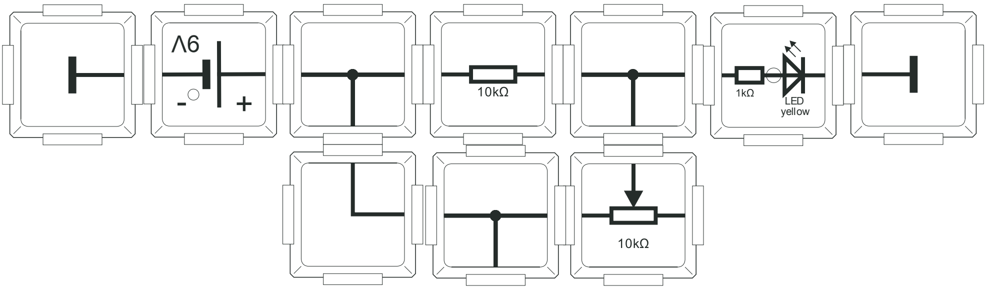




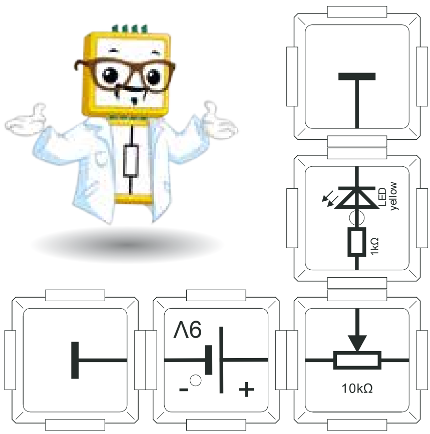
4.13 The Potentiometer

Experimental set-up: **Power Supply-brick, LED-brick yellow,** 2x **Mass-bricks, resistor-brick (10KΩ)**, **potentiometer-brick**, 2x **T-brick**, 2x **corner brick**

The potentiometer is a very important electronic component allowing to change a resistance value continuously. Now we use this brick in its intended function. By turning the knob on top of the potentiometer, the resistance can be adjusted from 0Ω to a maximum of 10KΩ. The resistance can be changed by turning the knob. The total resistance of our parallel circuit can be set from 0Ω to maximum 5kΩ. The increase of the current can be seen by the intensity of the LED.



Here another example of using the potentiometer. The parallel resistor will be removed and the LED brick connected directly to the potentiometer. The resistance changes from 0Ω to a maximum of 10kΩ.



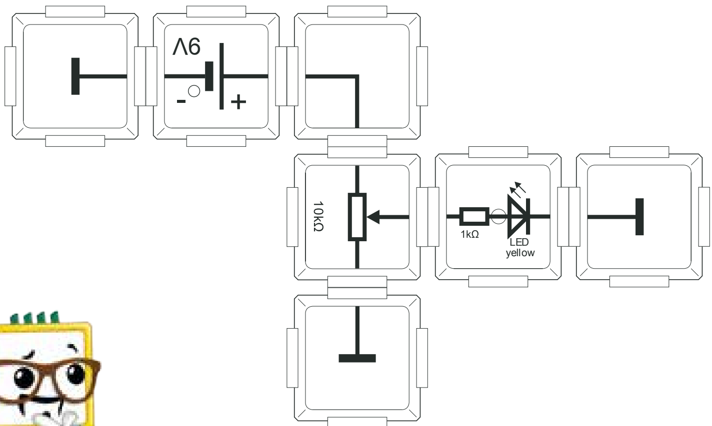
4.14 The potentiometer as a voltage divider

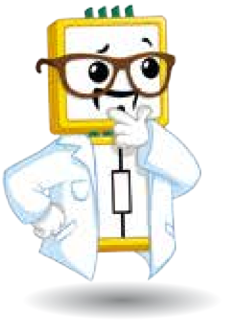
Experimental set-up: **Power-supply-Brick, LED brick** yellow, 3x **ground-brick, potentiometer-brick, corner-brick**

In the following experimental setup we use the potentiometer block for its intended purpose. All three contacts are connected. Here it is important to note that the wiper contact is not connected to the positive connection of the voltage source or to the mass block. This can lead to a short circuit, that can destroy the potentiometer brick. It must only be connected to the supply voltage of 9 volts divided depending on the position of the wiper contact, proportional from 0 volts to 9 volts..

Only the LED brick should be connected to the wiper contact. That means: If the knob set fully to the left, 9 volts are present at the anode of the LED brick and LED lights with highest intensity. If the knob is set completely to the right, the LED diminishs and 0 volts are present. In middle position half of the supply voltage (4.5 volts) is present. The intensity of our LED is now continuously adjustable. It is interesting that we have again created a parallel connection of potentiometer module and LED module.

The current flow has again two alternatives to flow from the positive pole of the voltage source to the negative pole. We have realized a closed circuit through our ground-bricks. Current permanently flows through the potentiometer, the other in parallel through the LED-Brick. The current flow through the potentiometer module can not be stopped. The current flow through the LED module can be stopped completely.



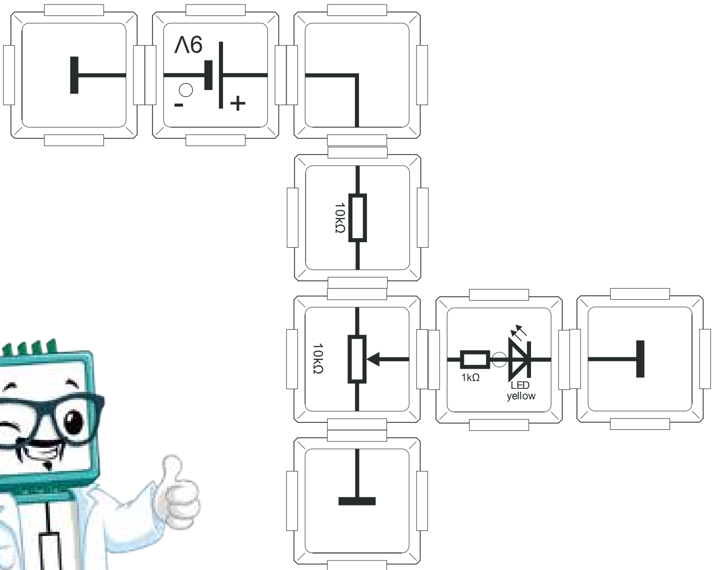


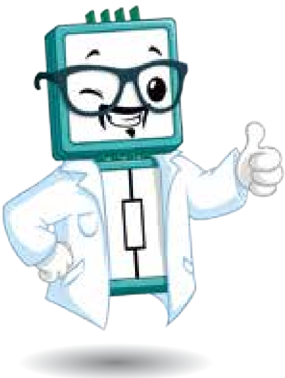
4.15 Extended range of the potentiometer (below)

Experimental set-up: **power-supply-brick, LED-brick yellow**, 3x **ground-brick, potentiometer-brick**, **corner-brick, 10kΩ-resistor-brick**

The potentiometer is placed in a series circuit with a resistor (10kΩ). This limits the range of voltage at the wiper output of the potentiometer. The two resistors: 10kOhm of the series resistor and the series resistor of the potentiometer result in a voltage divider. Therefore only 4.5V is at the upper connector of the potentiometer in our schematic. The output range at the wiper of the potentiometer is acting as an additional voltage divider and therefore results in range of 0..4.5V. Also in this experiment: make absolutely sure that only the LED module is connected to the wiper contact of the potentiometer-brick. This prevents the destruction of the potentiometer-brick.

In electronics: Always safety first!



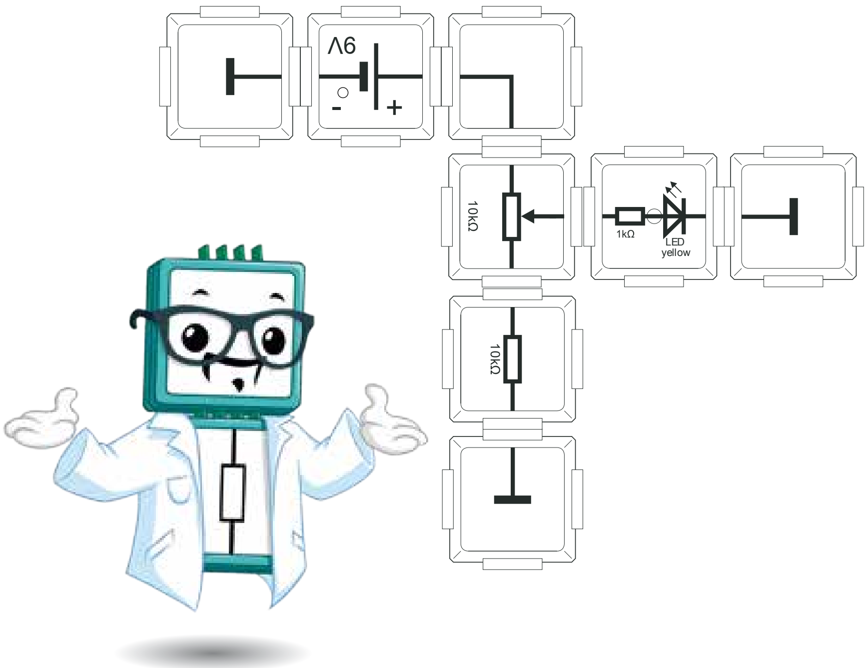


4.16 Extended range of the potentiometer (above)

Experimental set-up: **power-supply-brick, LED-brick yellow**, 3x **ground-brick, potentiometer-brick**, **corner-brick, 10kΩ-resistor-brick**

The potentiometer is placed in series circuit with a resistor (10kΩ) and is thus limited to a certain voltage range. This time the potentiometer is in the upper half of the circuit. Therefore its gets 9V at the upper edge and 4.5V at the lower edge. Now the wiper can sweep between 4.5V and 9V when turning the potentiometer knob.

Also in this experiment make absolutely sure that only the LED module is connected to the wiper contact of the potentiometer-brick. Otherwise this will lead to a destruction of the potentiometer.



4.17 Threshold

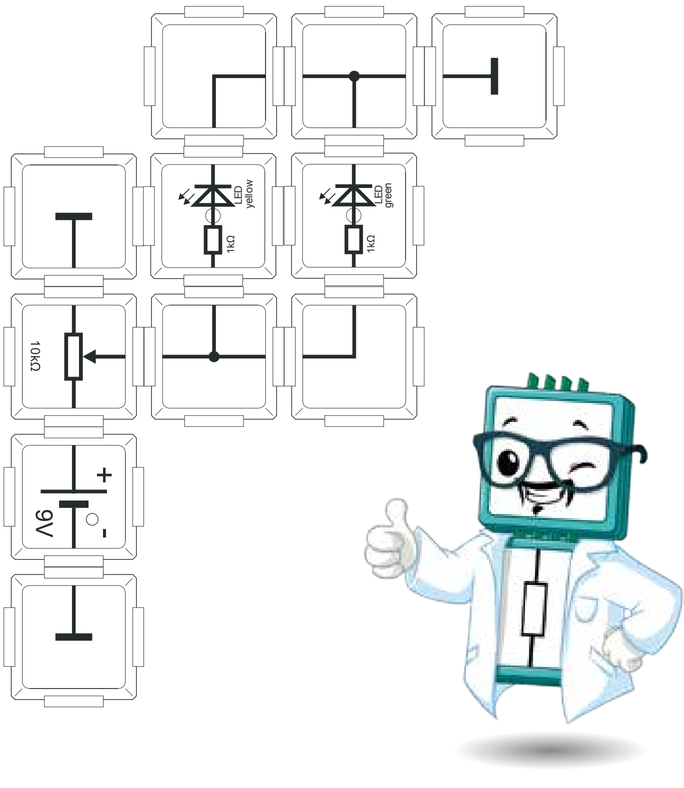
Experimental set-up: **power-supply-brick, LED-brick yellow**, **LED-brick green**, 3x **ground-brick**, **potentiometer-brick**, 2x **corner-brick, 10kΩ-resistor-brick**, 2x **T-brick**

The threshold is a term which is used in electronics and semiconductor elements. Our basic set contains LED-bricks and transistor-bricks, which are semiconductors. In our case the voltage threshold defines the voltage, where the current through the LED begins to flow. The LED beginns to glow. In the following experiment we build a circuit in which we bring the LEDs to glow by exceeding the threshold voltage. We determine this by the position of the rotary knob on our potentiometer-brick.

The knob should be turned to the left, and slowly turned to the right. Then we see that first, the green or yellow LED lights up, in rarer cases both light up at the same time. Which LED lights up first, is determined by the unavoidable tolerance in manufacturing. Our potentiometer acts again as a voltage divider, as described in previous experiments. Again, it should be ensured necessarily that the wiper contact may only be connected to the LED modules. Otherwise, there is danger of short circuit and potentiometer module could be destroyed.

If the knob is turned on one side, there is no output voltage at the wiper, and therefore the LEDs are dark, Turning the knob slowly increases the voltage to a maximum of 9V where all LEDs should be bright (the current is limited by the 1kOhm resistors in the bricks).
For low-current LEDs (2mA) the operating voltage is depending on the color, typically: red 1.6 - 2.2V, yellow 1.7 - 2.5V, green 1.7 - 2.5V, blue 3 - 4V.

The lower value is roughly the threshold.

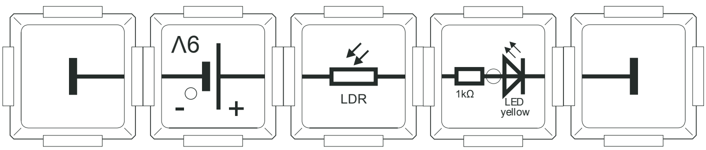


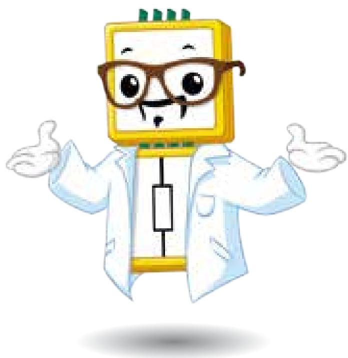
Experimental set-up: **power-supply-brick, LED-brick yellow**, **LDR-brick**, 2x **ground brick**

Our LDR-brick changes its resistance value in dependence of the light intensity that is received. The LDR changes its resistance by the influence of the incoming light, and not due to a mechanical movement like a potentiometer. If the LDR block is illuminated by the light, it changes its resistance value in favor of the conductivity, the resistance value becomes smaller and the current flow there through is larger.

Its resistance value reaches a very high amount of several 100 kOhm in the dark, but its very low on low light condition of a few 100 Ohm. The difference is about a thousand times. In the following experiment, the LED is only illuminated when the LDR-brick is irradiated by light. However, it diminish when the LDR is darkened.

The effect has a short delay time. Again we have a pure series circuit of the LDR brick and the LED brick together with the voltage source.





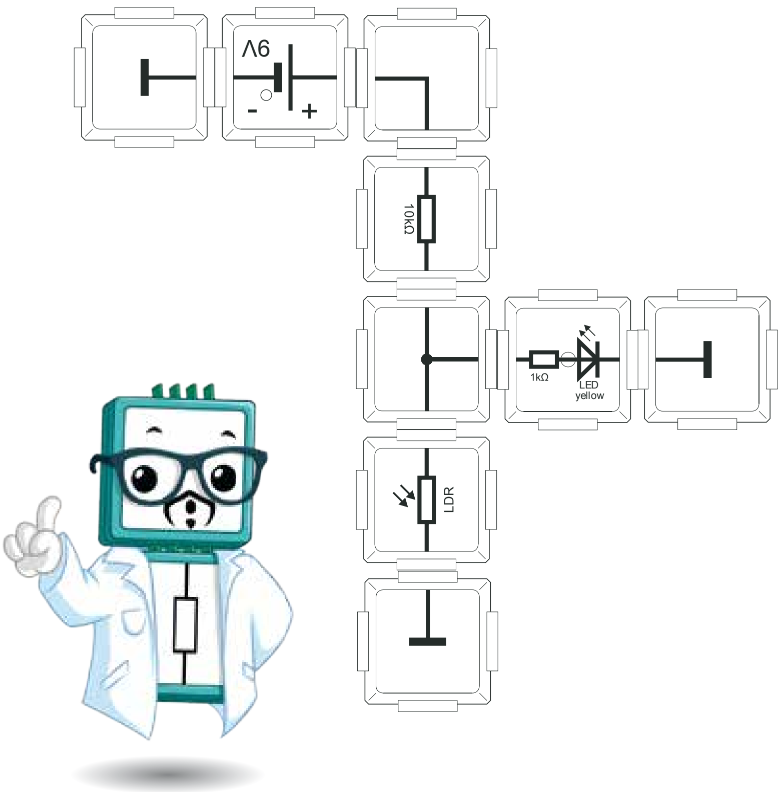
5.1 LDR - light on at darkness

Experimental set-up: **power-supply-brick, LED-brick yellow**, **LDR-brick, 10kΩ-resistor-brick**, 3x **ground-brick, potentiometer-brick, corner-brick, T-brick**

The last example can be used where a secondary light should go on, when the primary source is switched on for example in a basement. Usually in every day life, it does not make much sense to have a light source lit on when the environment is bright. Its better the other way round.

The effect of the LDR is this seemingly contrary. The electronics can reverse the use of LDR and LED with an simple trick. For this, we build a branch of parallel and serial connections. The resistor component and the LDR-device are connected in series. The LED brick is parallel tapped from the center of the resistor and LDR. If the LDR is darkened, this significantly increases its resistance and the current flow very small.

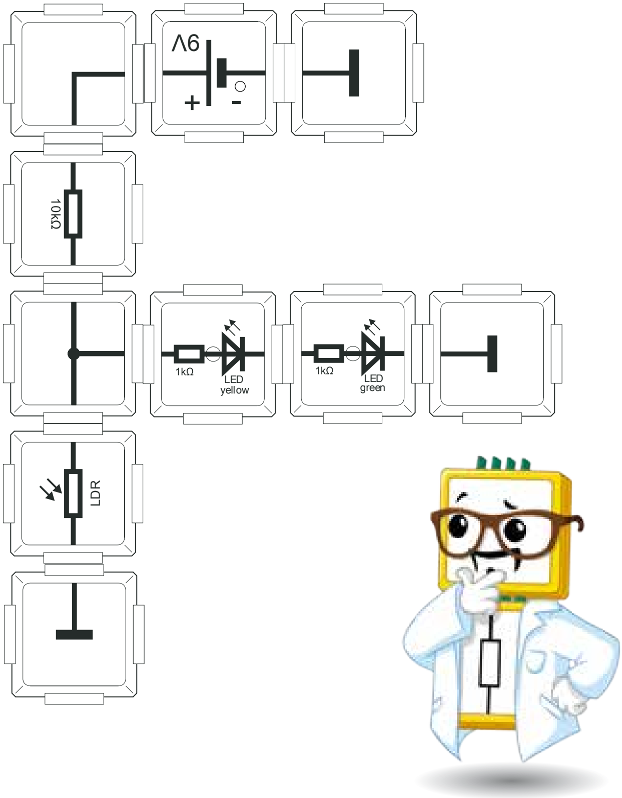
The current "seeking" a better alternative to get to the mass-brick behind the light-emitting diode. The LED will light up. If the LDR-brick is illuminated the voltage increases across the 10kΩ resistor. The voltage at the T-brick decreases due to the voltage divider and the necessary threshold for the operation of the LED is no longer reached, the LED gets dark.
Note: The additional corner-brick must not be used. It is shown for illustration purposes only.



5.2 LDR - Light on at darkness - more sensitive

Experimental set-up: **power-supply-brick, LED-brick yellow**, **LED-brick** green, **LDR-brick, 10kΩ-resistor-brick**, 3x **ground-brick, potentiometer-brick, corner-brick, T-brick**

Now this may seem complicated. We use diffusion voltages from the two LEDs to improve the sensitivity. The diffusion voltage is the voltage that must be applied to a semiconductor in order to get conductivity in the interior of the semiconductor. The voltage is between 0.3..4V (diodes to LEDs), depending on the semiconductor material.
The diffusion voltage is about 1.9 volts. A mixed circuit of two resistor-bricks (LDR and 10k) and two LED-bricks (yellow and green LED) will be used. The LED-bricks are parallel to our LDR-brick. In darkness the voltage-drop at the LDR is very large, since it forms a voltage divider together with the 10kΩ resistor-brick. The supply voltage of 9 volts is almost exclusively on both LEDs and the 10k resistor. Both LEDs are lit, as the voltage is higher than the sum of both LED threshold voltages. The threshold of the intensity of the ambient light, from where the LEDs start to light up is higher. At the last experiment, the LED was not completely dark, when we put light on the LDR, where here due to the doubled threshold, both LEDs get dark when illuminating the LDR.



6. Capacitor as charge storage

Experimental set-up: **power-supply-brick, LED-brick-yellow, 10µF-capacitor**, 2x **ground-bricks**

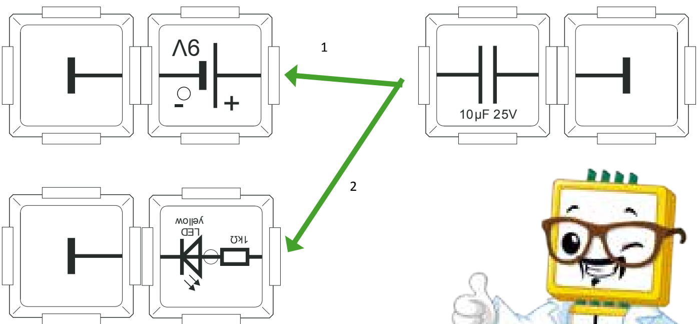
µ
The Capacitors are one of the most important components in electronics. They can store electrical energy very fast and release it again very quickly. The high speed at which capacitors can store and give off energy, along with the technically comparable little effort of their production, makes them so essential. The capacitor consists of two opposite conductive layers which are isolated from each other by a material. This material is, in addition to the size of the layers and their distance from each other, the most important component of the capacitor and essentially determines its electrical properties. This material is called dielectric.

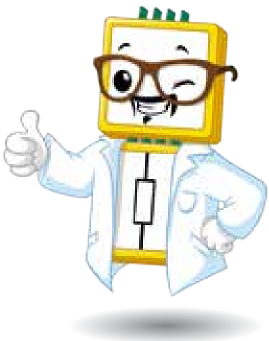
The dielectric is usually made of an insulator, but also air or a vacuum may be used as a dielectric. The most important feature is the capacity, which is measured in farads (F). A common capacity of electronic everyday life is given already in high negative powers of ten. Millionths are specified in Micro (µ), billionth in Nano (n) and trillionth in Piko (p). This set contains two capacitor-bricks.
One of them has a capacity of 10µF and the other one a capacity of 100µF. In addition, the maximum operating voltage is to be considered as well as the polarity of electrolytic capacitors. Our electrolytic capacitor is a ELKO capacitor with a plus and minus pole.

The negative pole of the polarized capacitor must be connected to the negative pole of the voltage source. The negative terminal of the capacitor is often not marked. The positive pole of the capacitor must be connected to the positive terminal of the voltage source. The positive pole of the capacitor is marked with a "plus". If the polarized capacitor is connected wrong, it can be destroyed and explode. This also important, when other components are between the electrolytic capacitor and the voltage source. The 10uF capacitor in our other brick is not polarized and can be connected as desired. The determination of the capacity takes place via the established voltage, charging time and the charging current.

1. Connect the 10uF capacitor between battery pack and ground-brick for charging.

2. Connect the 10uF capacitor between LED -brick and ground-brick, for discharging.
   You can see the LED flashing for a short time





6.1 Capacitor with high capacity

Experimental set-up: **power-supply-brick, LED-brick yellow**, **100µF-electrolytic capacitor**, 2x **ground-brick**

The 100uF capacitor-brick is, as already described, an electrolytic capacitor. In this case it is important to pay attention to the polarity, otherwise there is danger of explosion. The side of the capacitor marked with a plus (+) has to be connected with the plus (+) marked side of the power supply. Electrolyte means that the cathode of the negative pole of the capacitor is made of a conductive material that can store more energy. Therefore, it can store more load than another capacitor. An electrolyte has a higher electrical resistance than metals, but can also transport and store electric charges.

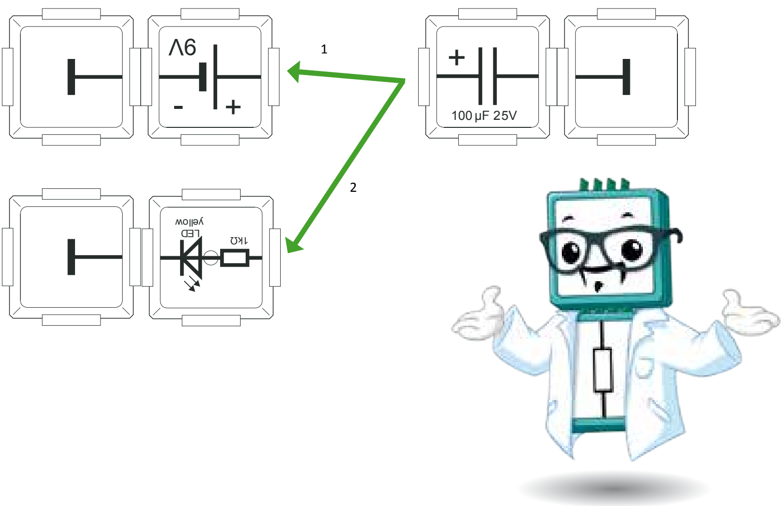
This dielectric compound is a very good insulator, so it has a very high electrical resistance, therefore the capacitance of the capacitor increases again. The LED becomes brighter and lasts longer than in the previous experiment 5.1.

Experimental set-up:

1. The charging is done via the voltage source and the mass block. The brick is connected to the negative pole (cathode) and also remains there during unloading. The positive pole of the voltage source is contacted with the positive pole (anode) of the capacitor, after a short time the capacitor is charged sufficiently to light up the LED when we discharge.

2. Now we disconnect the power supply and capacitor module and connect the anode of the capacitor to the anode of the LED module. The cathode, of the LED-brick must be connected with a ground-brick to form a closed circuit.

Now the flash of the LED lasts a little bit longer until the capacitor is discharged again.



6.2 Capacitor - like a small rechargeable battery

Experimental set-up: **power-supply-brick, LED-brick** yellow, **100µF-electrolytic capacitor-brick**, **100kΩ-resistor-brick**, 2x **ground-brick**

By limiting the discharge current of the capacitor by a 100k resistor the discharging time can be increased.
In former experiments the discharge was determined only by the resistor in our LED-brick.
Now we bring the 100k resistor-brick in series to the anode of our LED-brick and thus increase significantly the total resistance.

The discharge currenty is determined by the voltage slowly decreasing across the capacitor. We throttle the flow of current through the 100k resistor and lengthen the discharging time. The voltage across the capacitor is maintained for longer. Our capacitor is operated as a small battery, for example, like a tiny car battery. Multiplying the average current flow (I) with the discharge time (t), we obtain the charge (Q). (Q=I x t)

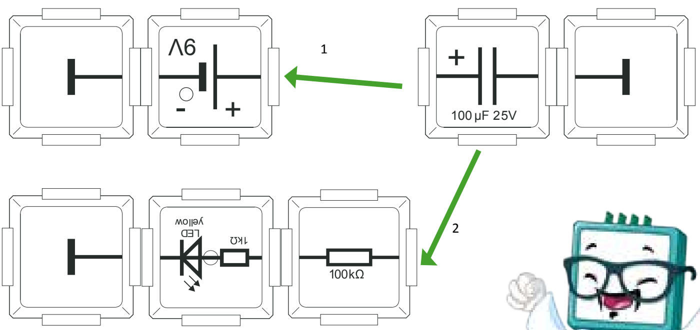
The voltage on the capacitor depends on its charge, but the charge is not a constant, the voltage changes because it gets discharged. For a constant charges states the following applies: the voltage (U) is equal to the product of the capacitance (C) and charge (Q). (U = C x Q).

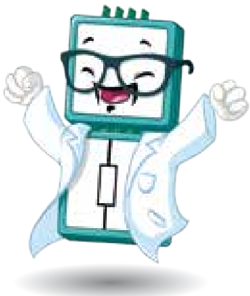
For describing the behaviour mathematically an exponential function must be used. In the following experiment, the yellow LED is used because it is somewhat brighter than the green.

Experiment:

1. The charging is done via the voltage source and the ground-brick. The minus pole of the capacitor is connected to the ground brick, and also remains there for discharging.

2. Now we remove the connection of power supply and capacitor module and connect the plus pole of the capacitor to the 100k resistor block to the anode of the LED module. The cathode, the negative terminal of the LED has to be connected to a ground-brick, in order to build a closed circuit. The LED is on for a longer time but not so bright.





6.3 Capacitor - one circuit for all

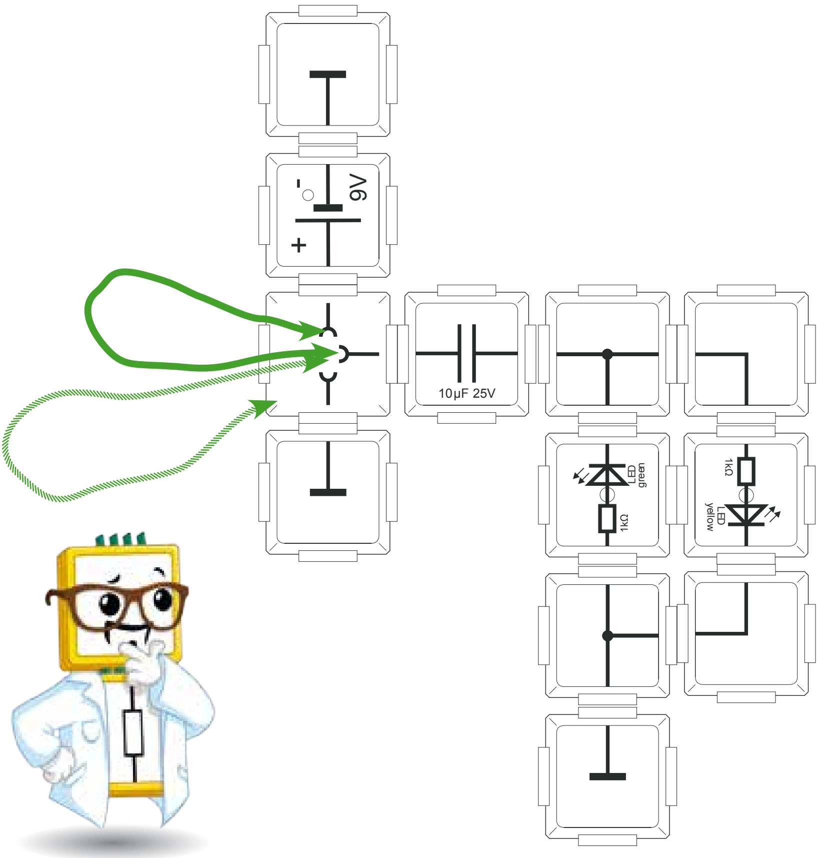
Experimental set-up: **power-supply-brick, LED-brick yellow**, **LED-brick green**, **10µF-capacitor-brick**, **universal-brick,** 3x **ground-brick,** 2x **T-brick**, 2x **corner-brick**

We already know the characteristic of the capacitor during discharge. Charging has been technically implemented, but not visually displayed. In the following experiment we illustrate both the charging and the discharge procedure. For this purpose, we use the universal-brick for the first time. The charge and discharge characteristics of the capacitor are exactly equal. This time we use two LEDs, but both connected reverse which is called antiparallel. With charging the capacitor, the yellow LED will light up for a short time and the green LED when discharging. The charging operation is done by shortening the two upper contacts in the schematic diagramm. For discharging the two lower contacts of the universal brick must be shortened.

We use the 10uF capacitor module, so there is no need to pay attention to the polarity.

Experiment:

1. Connect the upper and middle contact first and unplug again, when the yellow LED lights up
2. Now contact the lower and middle contact and unplug when the green LED lights up



6.4 Capacitor permanent

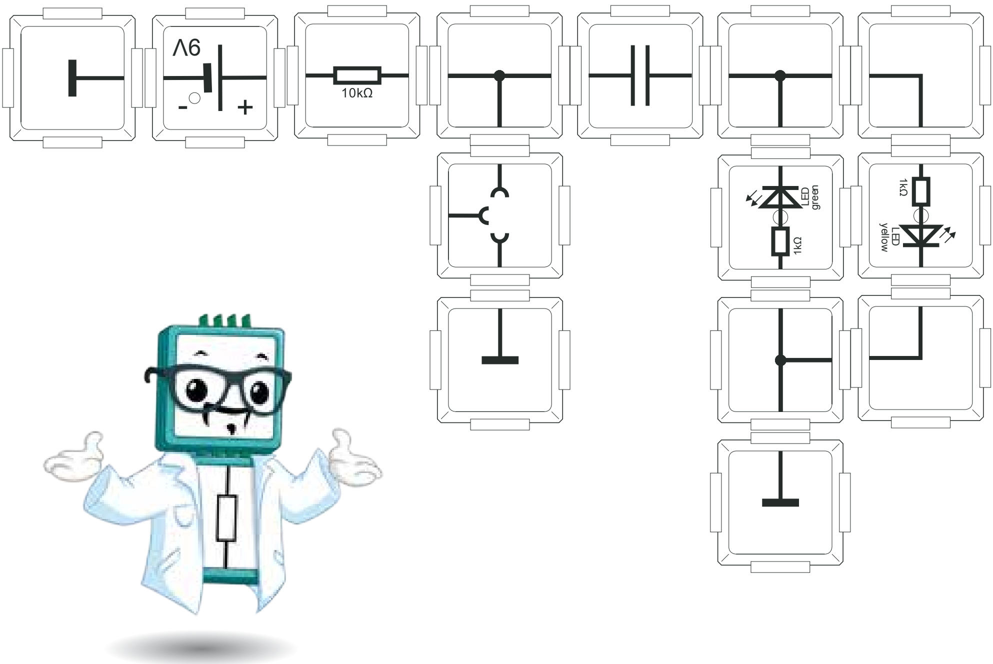
Experimental set-up: **power-supply-brick, LED-brick yellow**, **LED-brick green**, **10µF-capacitor brick**, **universal-brick,** 3x **ground-brick,** 2x **T-brick**, 2x **corner-brick**

The easy handling of an electronic circuit is an important design cirteria. It is clearly better to use just one switch to control a function instead of two or more. In our next circuit of the capacitor is continuously used and is only discharged when the opposite contacts are connected to our universal-brick. For this, the anti-parallel LED modules are integrated into the circuit so that they are in series with the 10uF capacitor and 10k resistor.

If now a voltage source is applied, the yellow LED lights up as long as the capacitor is charged and its resistance in the DC circuit is infinitely high. If the connection to the opposite contacts of our universal-brick is closed, the capacitor is discharged immediately and the green LED-brick lights up briefly.

By connecting the two contacts in quick succession, both LEDs blink alternately. The 10k resistor is very important because it limits the highest possible current during discharge of the capacitor, thereby preventing a short circuit. The current flow through the contacts when they are closing is even higher than the highest possible current flow $I = \frac{9V}{10.000k\Omega} = 0,9mA$

The current direction is reversed during discharge, in relation to charging.



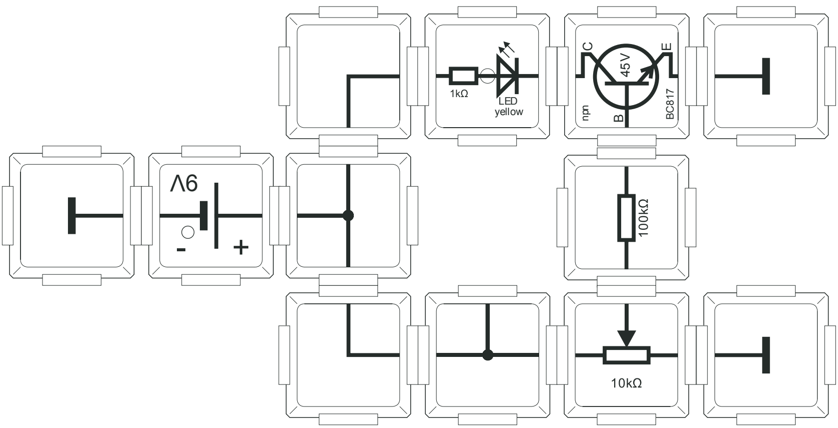
7. The transistor as amplifier

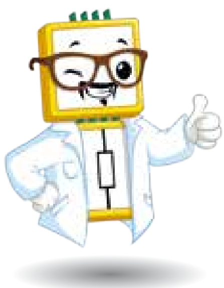
Experimental set-up: **power-supply-brick, LED-brick yellow**, **10kΩ-resistor-brick, transistor-brick**, **potentiometer-brick,** 3x **ground-brick**, 2x **T-brick**, 2x **corner-brick**

The transistor is the last unknown semiconductor device of our electronic set. The transistor is an electronic amplifier, not mechanically, like a light switch in your home, but electronically operated by a current flow at its base contact. The „working contacts“ are named with collector (C) and emitter (E).

It is very important to ensure a correct connection. The emitter contact is connected directly or indirectly to the minus pole of the voltage source. The collector is connected via the LED brick to the plus pole of the voltage source and the base is connected to a 100 kOhm resistor which is sourced by a potentiometer used as voltage divider. The current through the base determines the current from collector to emitter. The transistor acts as current amplifier, for example 100-300x of the base current.

It is important to ensure that the wiper contact of the potentiometer is not connected to ground or voltage source. The potentiometer-brick contains a voltage divider. By spinning the knob from right to left, the yellow LED lights up and is extinguished immediately when spinning back to the right.



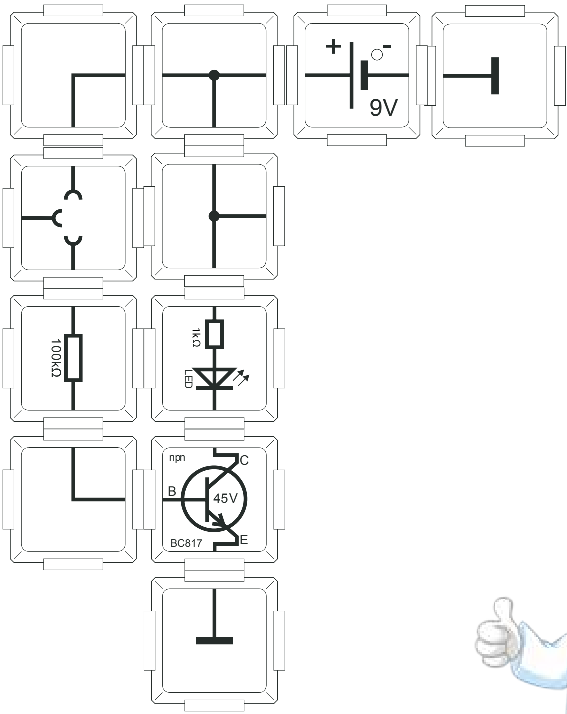


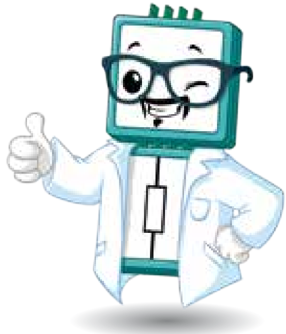
7.1 Transistor as switch

Experimental set-up: **power-supply-brick, LED-brick yellow**, **100kΩ-resistor-brick, transistor-brick**, 2x **ground-brick**, 2x **T-brick**, 2x **corner-brick, universal-brick**

The current amplification of the base current makes the circuit very sensitive. Even a very low current can result in a high current, enough to light up the LED. The 100kΩ base resistor, placed before the resistor, can be bridged by your finger to light up the yellow LED. The human body has a resistance value of approx. several thousand Ohms, which is enough after amplification to turn on the LED.

The high sensitivity of the transistor base current allows a wide area of application for the transistor. Thus, the transistor can be used as a rain detector. The contacts shown in our diagram are then connected to long wires, for example, up to the exterior of a house to represent minimum currents caused by rain. The transistor acts like a sensor.



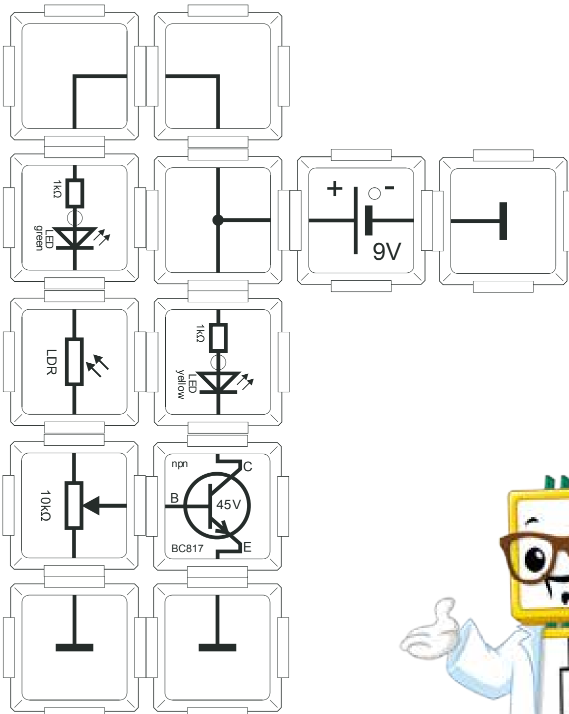


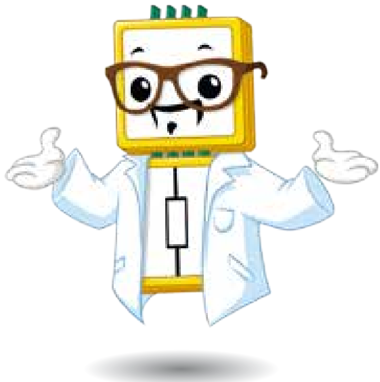
7.2 LDR and transistor

Experimental set-up: **Power-supply-brick, LED-brick yellow, LED-brick** green, **potentiometer-brick**, t**ransistor-brick, LDR-brick,** 3x **ground-brick, T-brick**, 2x **corner-brick**

Now we want to implement a circuit in which the transistor lights up the yellow LED according to the ambient light. The potentiometer and photo resistor (LDR03) are connected in series and form a voltage divider. The LDR, potentiometer and the green LED share the total voltage. Where LDR and potentiometers are variable resistors. The LDR is set automatically by the ambient light level and the potentiometer manually by turning.

The second current path leads through the transistors collector and emitter contact. Which is directly controlled by the base current and can be named the primary circuit path. The green LED is an indicator for the base current. The brighter it lights the more current flows between base and emitter. The wiper contact of the potentiometer can now be directly connected to the base of the transistor.
There is no risk of a short circuit, but any other mistake in wiring can destroy the circuit.





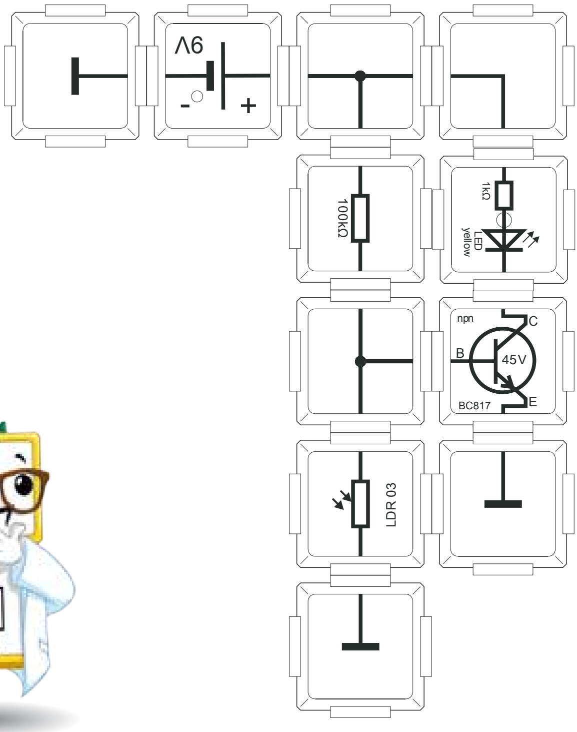
7.3 LDR and transistor - night light

Experimental set-up: **Power-supply-brick, LED-brick yellow, 100kΩ-resistor-brick, transistor-brick, LDR-brick,** 3x **current-brick**, 2x **T-brick, corner-brick**

The LED should turn on, when the light in the room gets dark. The resistance value in the LDR decreases with ambient light intensity and the voltage divider of the 100k resistor is responsible for a reduction of the current flow at the transistor.

If the LDR is illuminated, almost the fully 9V is across the 100k Ohm resistor. When reaching a resistance of 100Ω, only 0.09V remain. This is not enough to turn on the transistor. There is also no flow from emitter to collector. The yellow LED goes out. If, however, in the dark, the resistance value of LDR is very high. The voltage at the base is determined by the threshold voltage of the transistor base diode, which is around 0.7 Volt. This determines the current flow into the base. The flow is amplified by the transistor into a much larger current from collector to emitter, and if large enough the LED gets brighter. The yellow LED in our LED brick lights up.

This is called an automatic night light circuit.



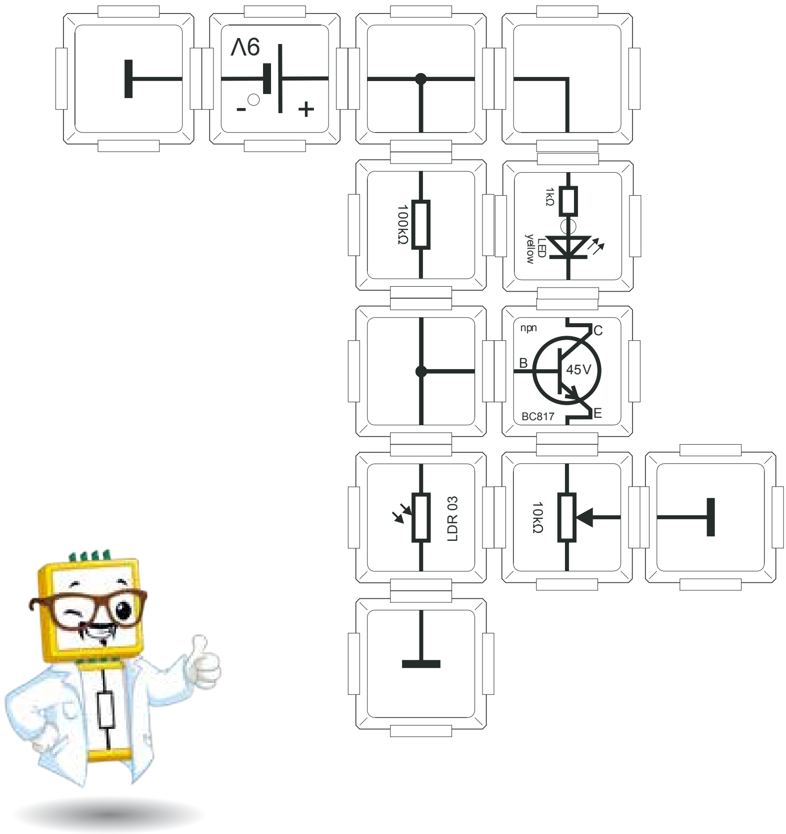
7.4 LDR and transistor - adjustable night-light

Experimental set-up: **Power-supply -brick, LED-brick** yellow, **100kΩ-resistor-brick, transistor-brick, LDR-brick, potentiometer-brick**, 3x **ground-brick**, 2x **T-brick, corner-brick**

As in previous experiments, we again use a circuit with all three semiconductor devices of our electronics sets: the LED, photo resistor and transistor. This time we added a lot of functionality to our circuit. This enhances our circuit with additional features, because we can change the resistance of the circuit and the brightness of our night light.

It is now also possible to adjust the threshold of the base current so that the yellow LED will light from falling below a certain threshold of ambient light. Now the threshold voltage at the base can be adjusted with the potentiometer, as the difference between base and emitter is always not larger than 0.7V. If current begins to flow through the transistor and potentiometer, the voltage between emitter and ground is increased. This also increases the voltage at the base by 0.7V therefore shifting the critical switch on voltage to a higher level and making the circuit more insensitiv if the potentiometer value is increased. It similar to a collector circuit, which we show next. If the potentiometer is set to the highest resistance, the light of the LED is only visible at darkness. Only then the base current is large enough to close the shunt circuit from collector and emitter.

The best possible condition is between the values and can be examined.



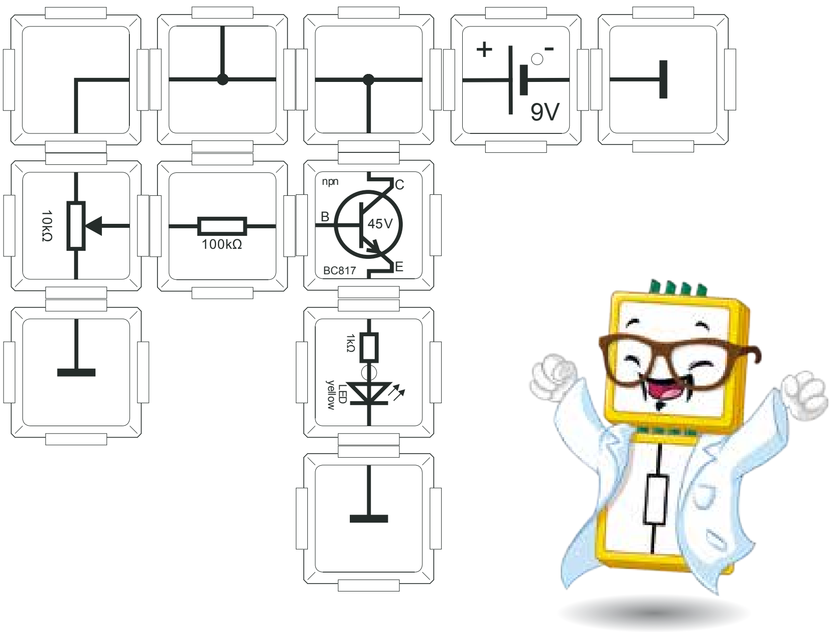
7.5 Transistor in collector-circuit

Experimental set-up: **Power-supply-brick, LED-brick** yellow, **100kΩ-resistor-brick, transistor-brick, potentiometer-brick,** 3x **ground-brick**, 2x **T-brick, corner-brick**

The transistor is one of the most used electronic components. The transistor is used billion times in the control units of standard desktop computers. The number of transistors used is much higher than the distance from the earth to the sun in kilometers. The transistor has three basic circuits, as well as three connectors and is the most used emitter and collector circuit. The base circuit is used for special circuits and will not be further explained at this point.

Here the emitter voltage always follows the base voltage by a difference of 0.7V. Therefore this circuit is also called voltage follower. It does not provide a voltage amplification, but a current amplification. The emitter circuit does both curent and voltage amplification and the base circuit only has a voltage amplication and no current amplification.

By moving the knob from right to left, the LED lights up and will light brighter. This circuit is called collector circuit, because the collector contact is directly connected to the power-supply brick.

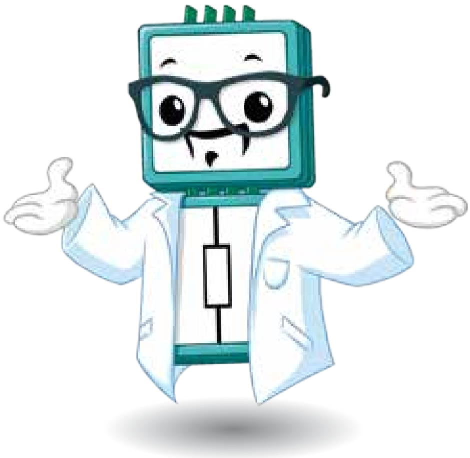


8. Appendix

We hope you had fun with our Basic Set of electronics and enjoyed walking in the footsteps of great scientists like Faraday, Ohm or Volta, then you will be definitely excited about our advanced set.

The Advanced Set enhances the functionality by complex functions with flip flop circuits or processors like Arduino, Raspberry Pi or Banana Pi. For young researchers we offer a clearer access to RF systems, appealing design elements with LEDs and of course a lot of potential to develop their own creativity.

Developed by **DM7RDK** in the context of youth development and training in Ham Radio and industrial solutions.



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