VARIOBOT®
DISCOVER MECHATRONICS

varikabo + varikabo FT

A Variable Robot Kit with 12 Astounding Functions

AGE 10+

ASSEMBLY 2-4h

PARTS 36

FT 67

for soldering

Instructions

Safety instructions

Before building and using the robot, it is important to read the following precautions. Please follow them!

- **Caution:** The varikabo kit is not a toy and is intended solely for educational, instructional, and experimental purposes. Any liability is excluded when used for other tasks.
- It may only be assembled and operated by children and adolescents under the guidance and supervision of adults.
- Adults must read, the instructions before use, follow them, and keep them on hand. Please retain packaging for future reference.
- Ensure product remains out of the reach of children under the age of 6.
- Do not use in areas where small animals are present.
- For safety reasons, never leave the robot unattended.
- Caution: Due to varikabo's open structure, there are sharp edges and corners.
- Since varikabo doesn't have a cover, be extra careful to keep metal objects and tools from causing a short circuit.
- varikabo may only be used indoors. Do not use this robot in traffic areas!
- Do not use varikabo on tables and other surfaces from which it could fall.
- Only use the robot in dry, clean spaces. Dirt, dust, foreign objects, and dampness destroy the mechanics and electronics.
- Caution: Do not hook up devices to the robot, especially not ones with mains voltage!

- Although the constructions and circuits introduced in this instruction manual were designed and tested with as much accuracy and detail as possible, errors cannot be entirely excluded.
- This product was produced in accordance with the currently effective European Union directives and, therefore, has the CE symbol.
- The intended use of this kit is described in this instruction manual. If you deviate from the instructions, the guarantee and liability will be forfeited and the use of the robot is at your own risk! Build the circuits exactly as described in the instructions.
- The symbol of the garbage can/rubbish bin with an X through it means that this product may not be put into household garbage bins; it should be brought to a recycling center and added to the electronic scrap. Please take the time to find where you can best recycle your electronic scrap!

Battery Information:

- The kit requires a 9 V battery, which is not included in the package.
- Risk of Explosion: Non-rechargeable batteries may not be charged.
- Avoid short circuiting the battery, since it can cause the cables to overheat and the battery to explode. After use, the battery clip must be removed from the battery.
- Avoid deforming the batteries.
- Used batteries must be disposed of according to environmental regulations. Please take them to a designated collection container.

Introduction

We are pleased you have chosen this versatile robot assembly kit. varikabo offers you an exciting and playful approach to electronics. You will certainly have fun experimenting and tinkering with varikabo for a long time.

varikabo's "eyes" are three brightness sensors and his "brain cells" are two transistors. With the help of a patented combination of sensors, varikabo perceives the smallest contrasts in its environment and reacts to them in multiple ways.

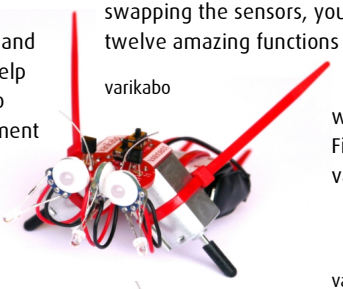
varikabo can do many things:

- skillfully avoid objects
- follow dark or light lines
- follow or push objects
- search for, chase or circle around light
- follow or circle around the shadow of your hand
- avoid dark or light areas

Building an autonomous robot was never easier! The control circuits are built using four small circuit boards.

Thanks to a selector switch and by aligning and swapping the sensors, you can gradually explore twelve amazing functions and behaviors.

varikabo



varikabo is available with cable ties and the Fischertechnik version varikabo FT.

varikabo FT

Content

A) Assembly

After a brief introduction to soldering, the assembly instructions show you step by step and with numerous illustrations how to fit the electronic components to the circuit boards.

Please note that the LEDs, the sensors, the transistors, the motors and the battery must be installed with the correct polarity. The two transistors are different and must not be mixed up.

The mechanical assembly for the varikabo kit and for the Fischertechnik version varikabo-FT is described afterwards.

B) Functions

The twelve functions of varikabo are explained in the experiment instructions from page 28 onwards.

It shows you how to set them using the selector switch and the three swivel-mounted and interchangeable sensors.

At the end you will find a fault diagnosis in case something does not work as expected.

C) How it works

From page 40 onwards, you will learn how varikabo's control circuit is constructed and how the components of the kit work.

You will learn to understand varikabo's various behaviors and how they are caused.

A) Assembly

What you need for this

- 9 V battery
- pliers and side cutters
- Soldering iron and solder
- Possibly black insulating tape (for varikabo FT)

Introduction to Solder

If you don't have much experience with soldering, read these instructions carefully and practice with some old wires before you dare to use the varikabo kit.

Auxiliaries

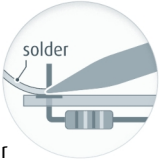
- Soldering iron: 20 bis 30 W / 300 bis 350°C
- Solder: 0.5 bis 0.7 mm in diameter
- Small side cutter
- Moist, heat-resistant sponge
- Possibly solder wick or suction pump for corrections

Way of Proceeding

1. Put the components in the marked position. Soldering is done on the other side.
2. Clean the soldering tip lengthwise with a damp sponge.

3. Press the soldering tip simultaneously against the solder pad and the lead of the component for about one second so that both are well heated.

4. Now add solder between the solder pad, the component wire and the soldering tip without removing the soldering tip. Use only enough solder to cover the entire solder pad.

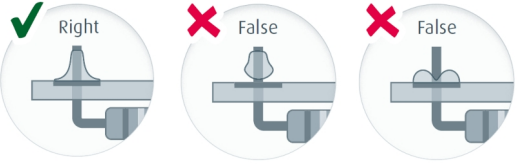


5. Stay with the soldering tip at the soldering point for about one second until the used solder is well distributed, so that a shiny silver cone appears around the wire.

6. Then short too long wire pieces with a small side cutter.

Tips

- Heat for a sufficiently long time and do not "dab" with the soldering iron
- Do not heat for too long - otherwise the solder will become "sticky"
- Not too much solder, otherwise there are thick "lumps"



If it did not work out:
Remove solder with solder suction cup or with solder wick and start over.
You'll do better the second time!

Electronics

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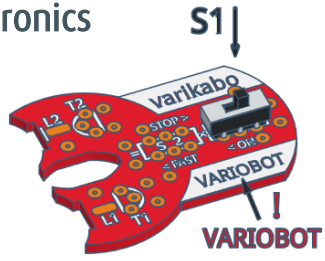

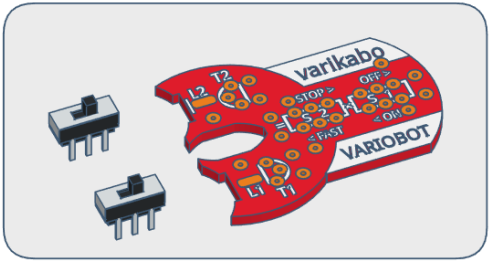

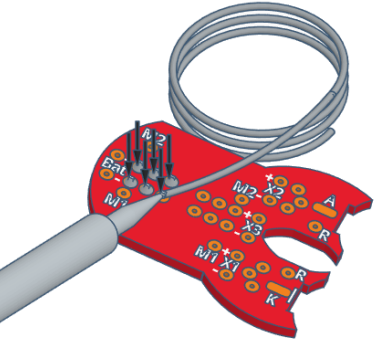

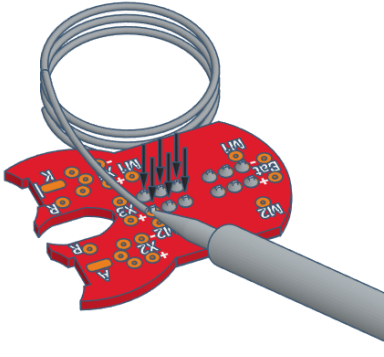

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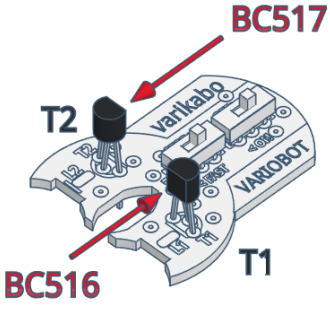

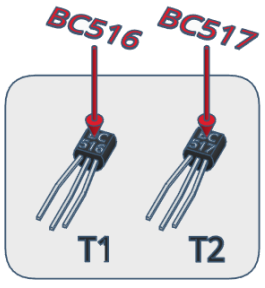

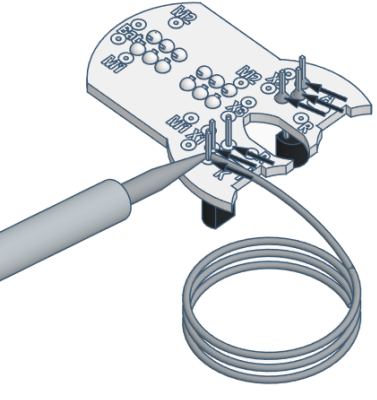

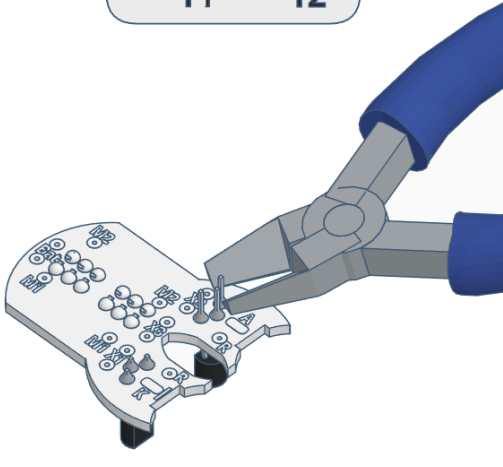

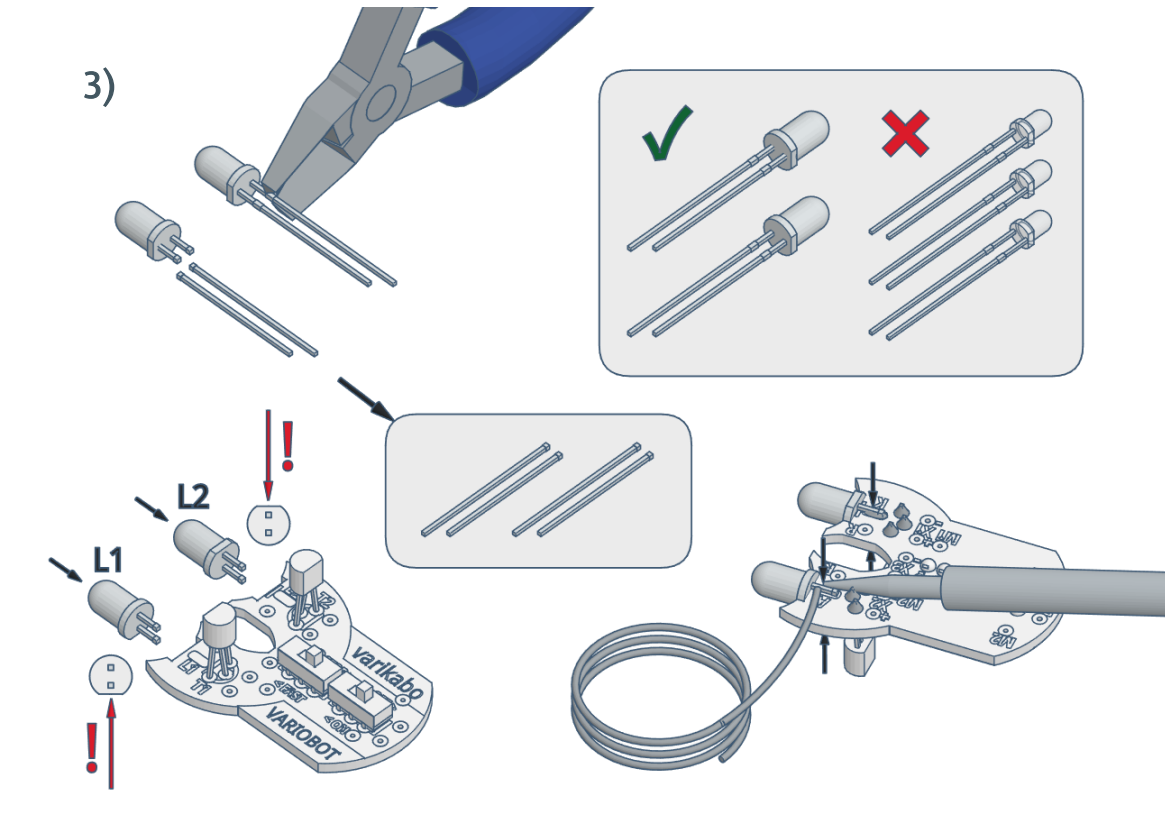
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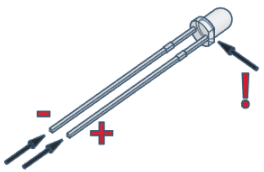

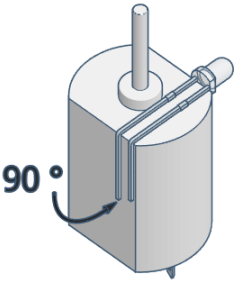

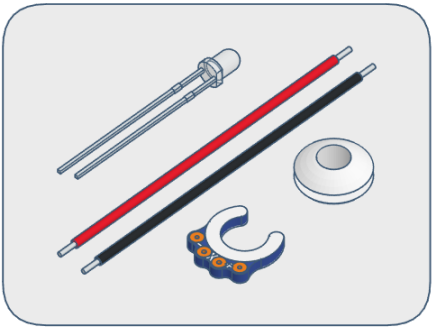

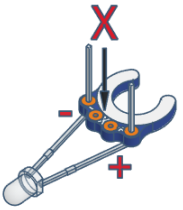

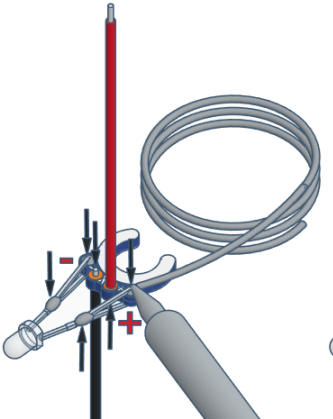

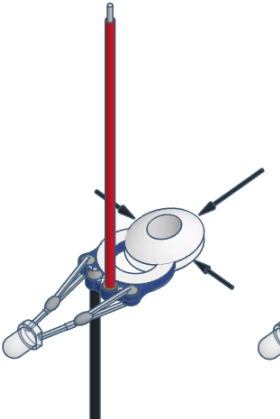

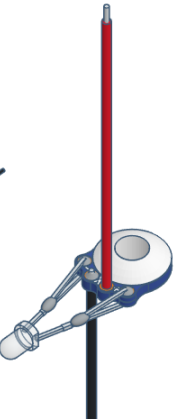

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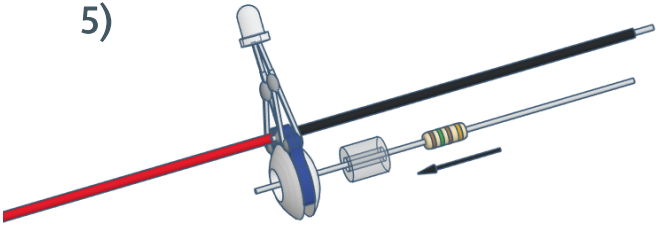

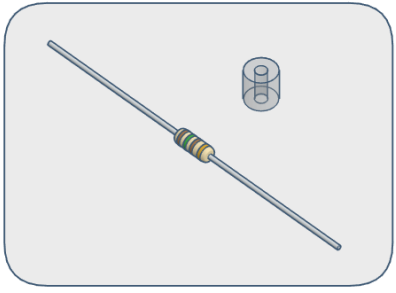

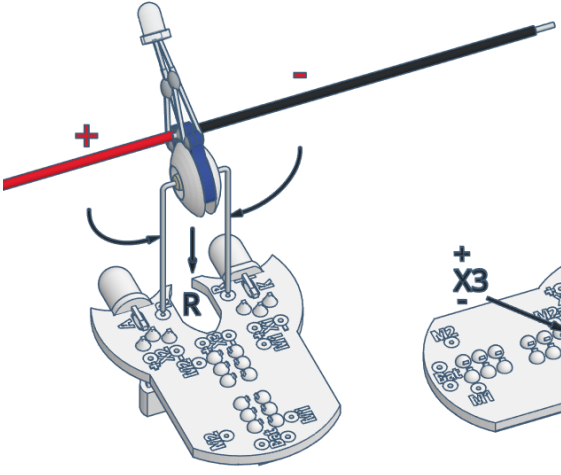

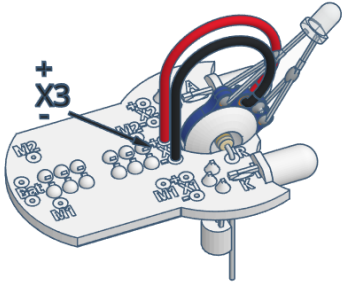

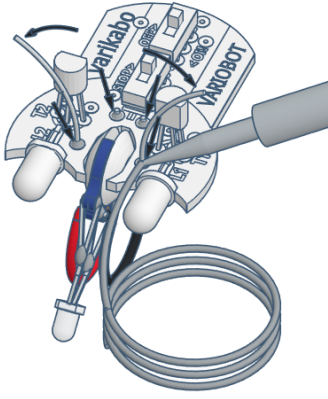

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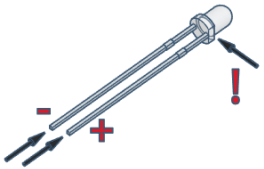

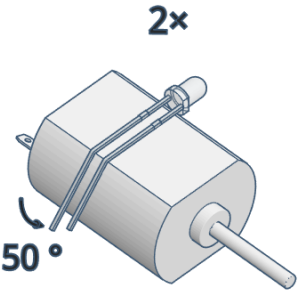

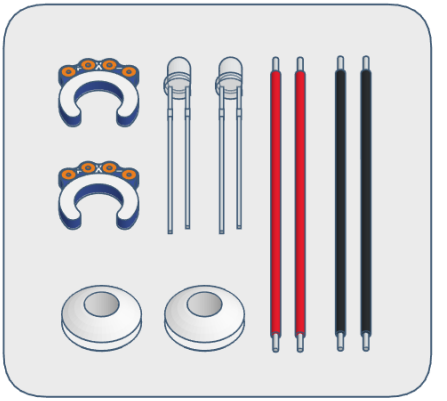

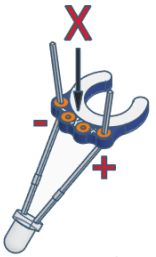

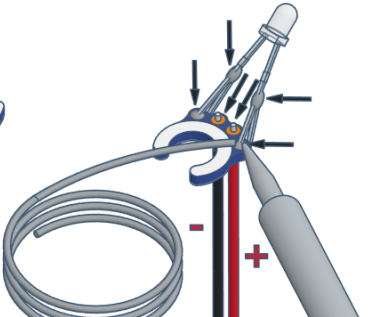

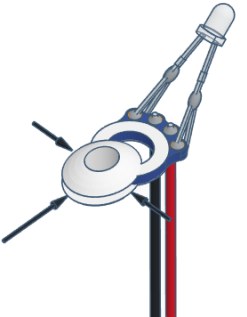

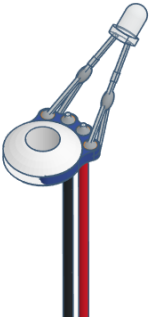

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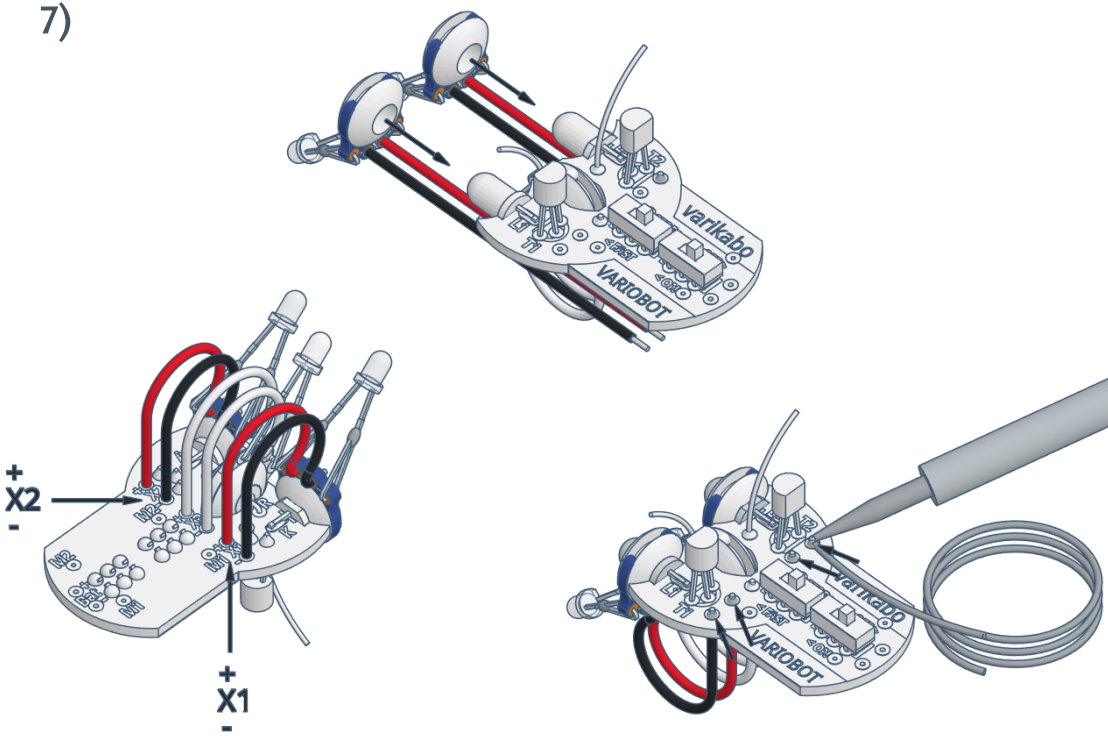

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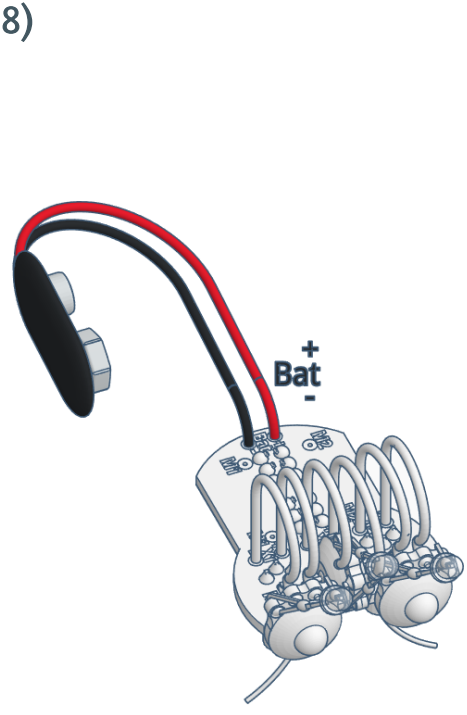

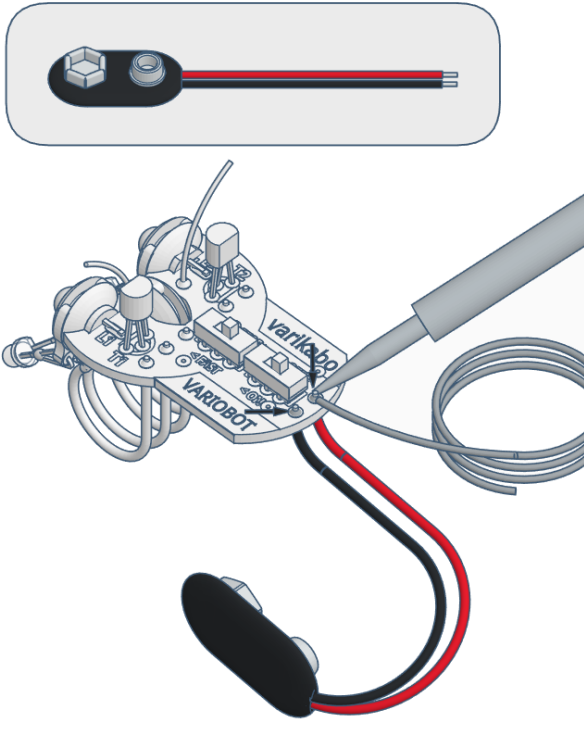

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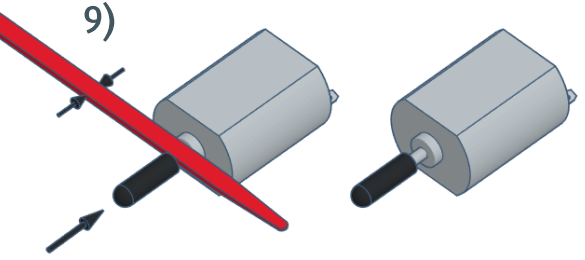

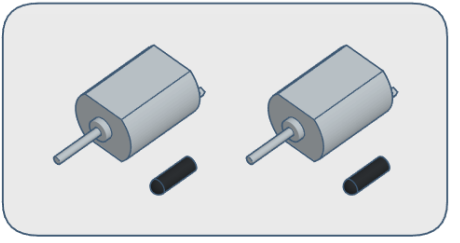

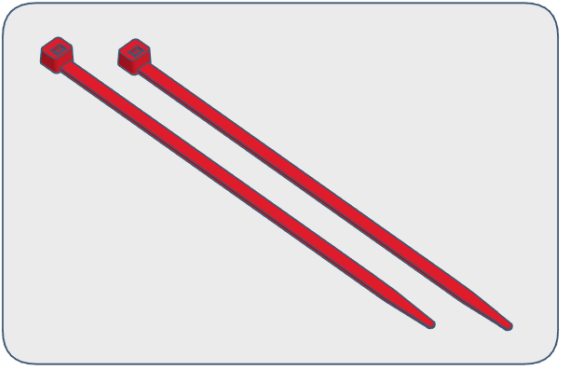

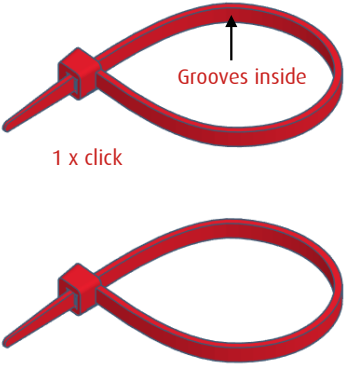

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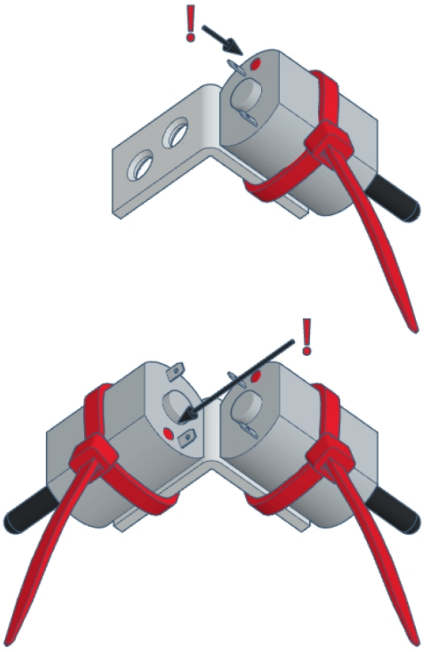

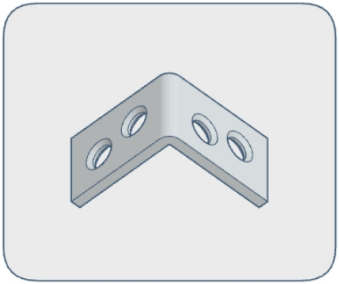

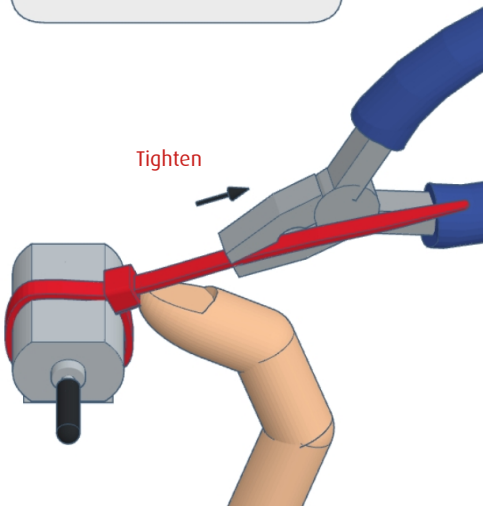

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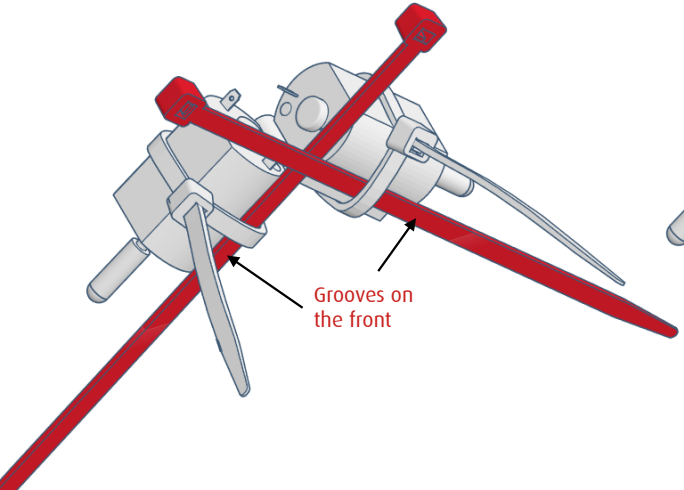

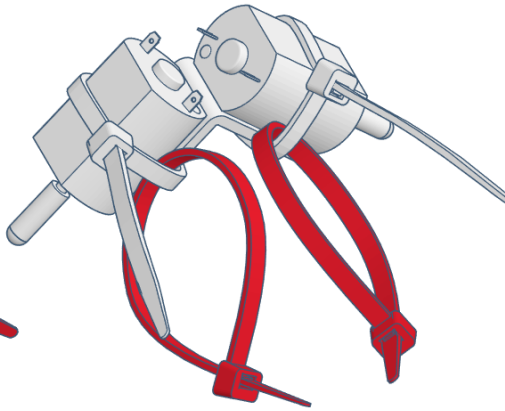

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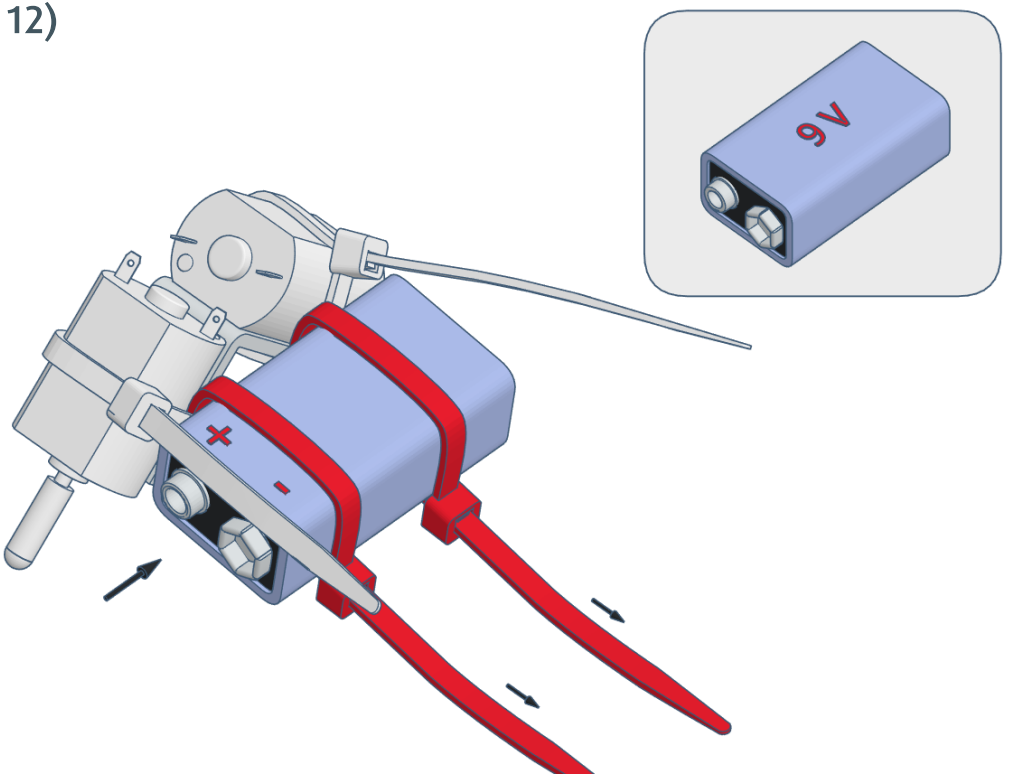

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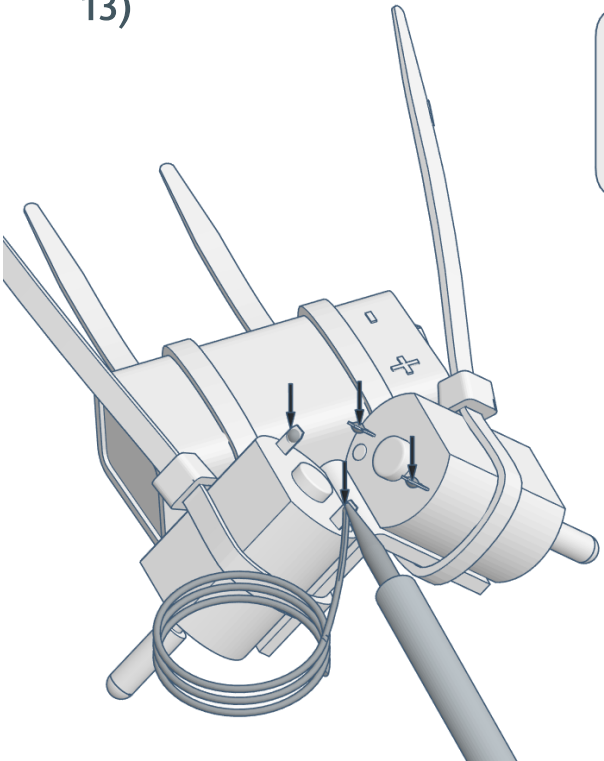

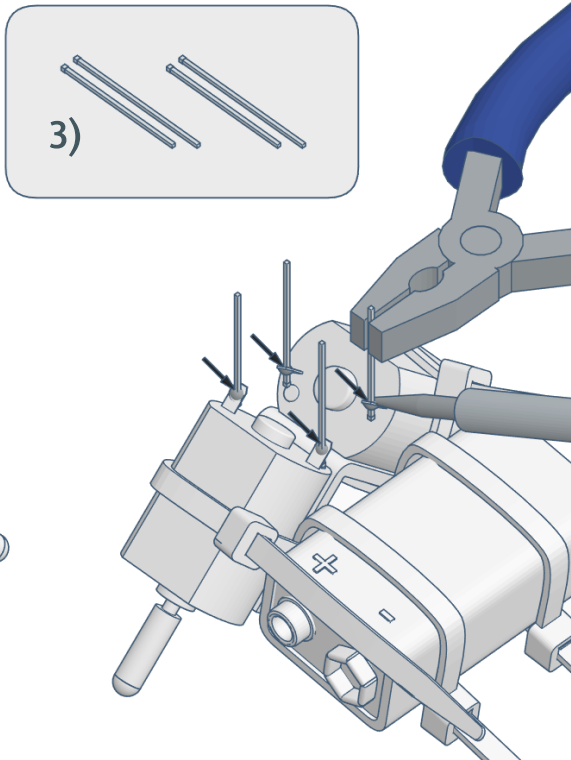

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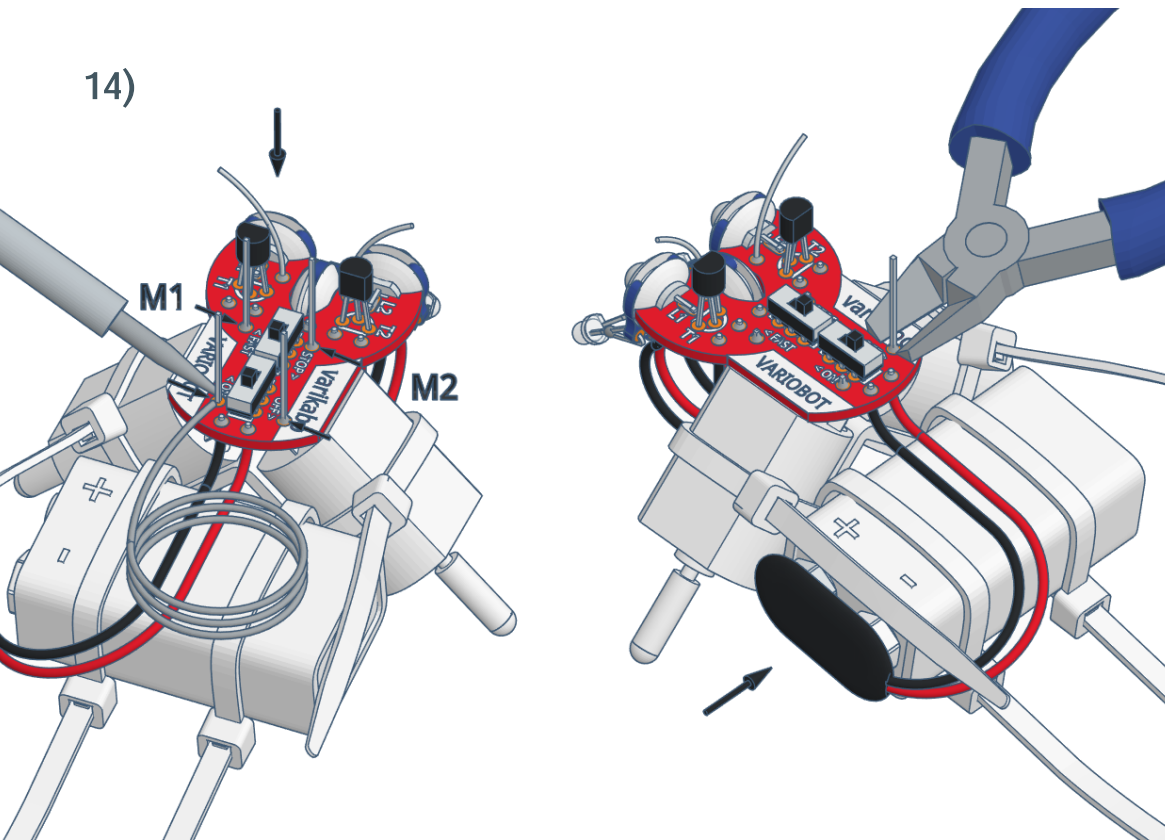

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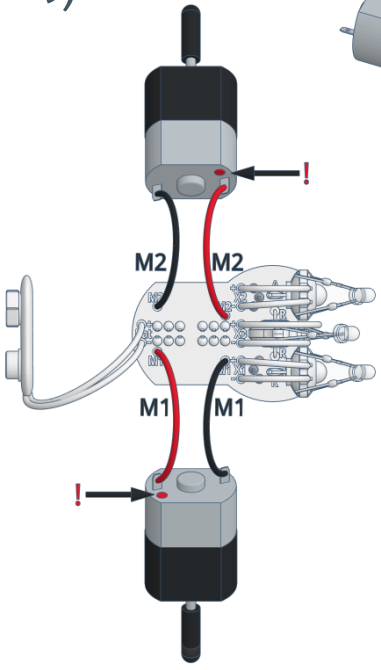

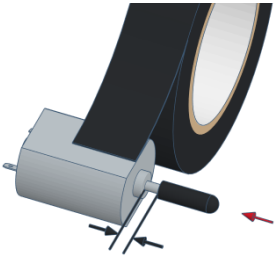

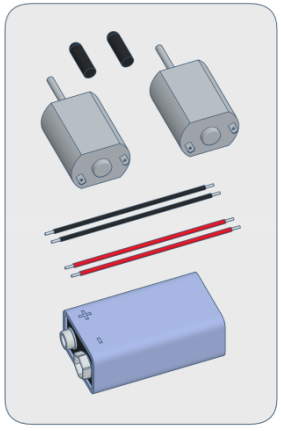

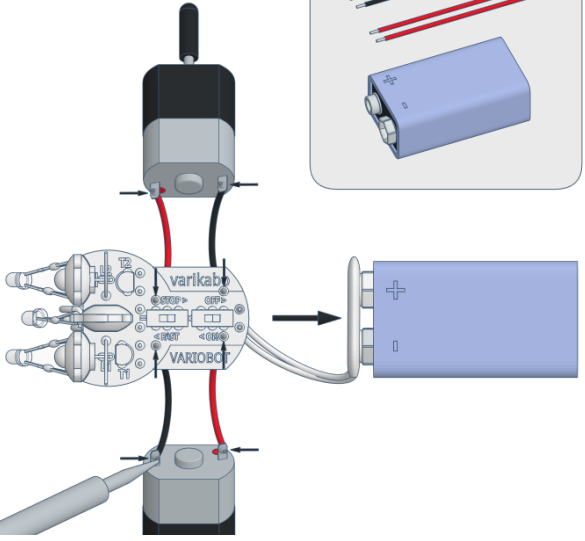

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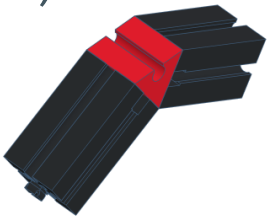

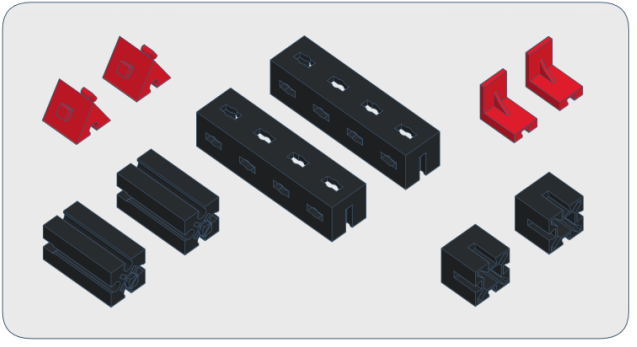

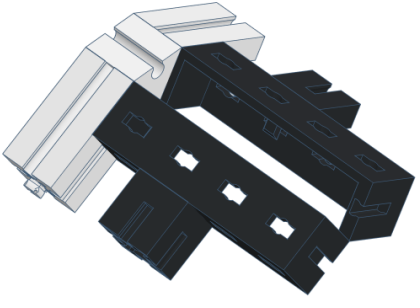

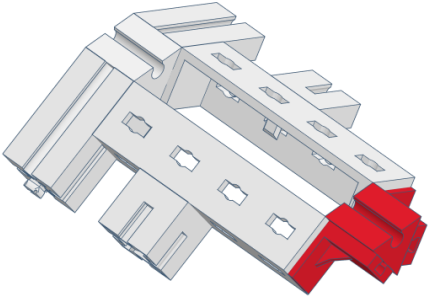

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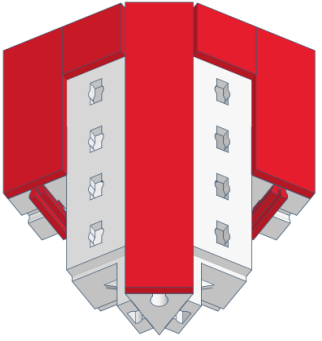

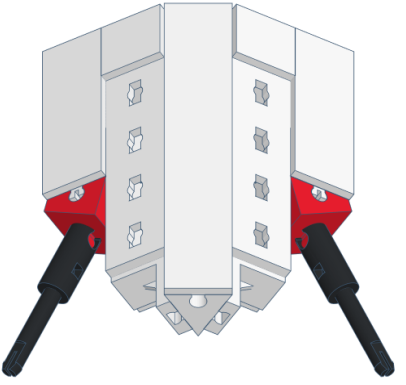

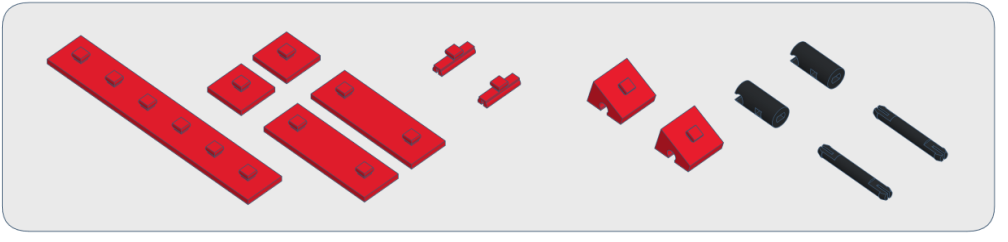

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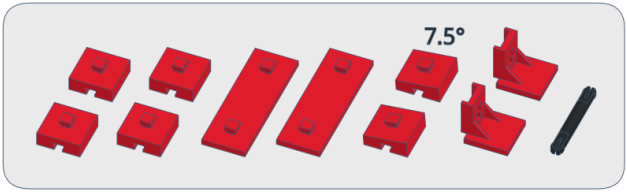
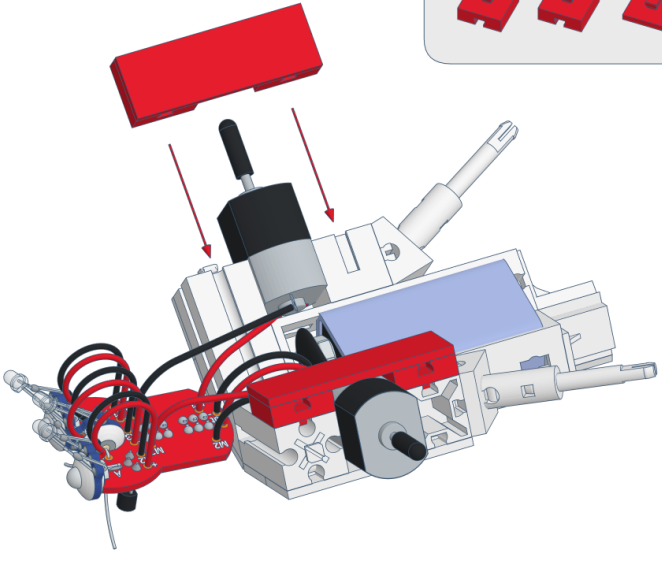
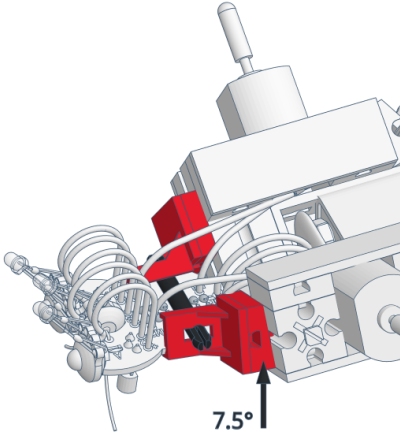






Startup Procedure

First point the middle sensor vertically upwards. Swap the right sensor with the left sensor and point them about 45° to the side. Test varikabo on a smooth and light-colored floor.

When you now switch on varikabo, it moves towards light and avoids objects. If you hold your hand over the middle sensor, varikabo moves quickly or stops.

varikabo compares the brightness via its three sensors. Depending on the orientation of the sensors, it detects the light conditions on the ground, ahead, or above itself.

Unlike other robots, varikabo doesn't need to emit infrared light to detect lines or objects, for example. This simplifies the circuit and reduces power consumption. Since varikabo responds to the differences in brightness, however, it is important to pay attention to the type of lighting in the room.

Notes on Lighting

To ensure varikabo's sensors aren't blinded by the light sources, make sure varikabi is well positioned in relation to lamps and windows.

- Operate varikabo preferably under a distant light source or beneath a window on the floor.

If light comes from the sides, varikabo might follow this light or its own shadow instead of moving towards the desired goal.

- When using LEDs or fluorescent light bulbs, ensure the lighting is bright enough for varikabo to detect it.

The light from LEDs and fluorescent light bulbs has a low red component and isn't easy for varikabo's sensors to detect.

- Make sure the ground does not reflect light.

Fault Diagnosis

Problem	Possible Reasons
varikabo does not move at all.	• The left and right sensors are incorrectly polarized. • The battery cable is incorrectly installed. • The battery is empty or defective.
Only one of the motors is running.	• A transistor is installed with the wrong polarity. • The transistors BC516/BC517 are installed reversed. • Either the left or the right sensor is incorrectly polarized. • A motor is not soldered on correctly.
A motor runs backwards.	• This motor is installed with the wrong polarity and soldered on.
varikabo only drives straight ahead.	• The center sensor is connected incorrectly.
varikabo gets stuck on the ground.	• varikabo is placed lopsided on the cable ties. • The surface is too uneven for varikabo.

If none of these causes apply to your problem, check carefully that all components are installed as described in the construction plan.

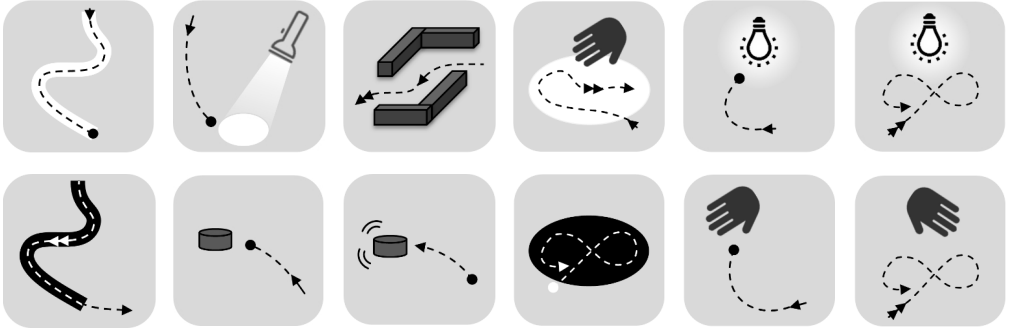
If you need help, please contact us with a detailed error description and a photo or video of your varikabo robot: ***info@variobot.com***

B) Functions

The selector switch and the position of the side sensors determine these 4 behaviors:

- Light follower / Shadow follower
- Acceleration mode / Braking mode

By additionally aligning the sensors differently, you can create 12 amazingly versatile application possibilities. varikabo reacts to light and shadow as well as to markings and different objects.



varikabo stands still

varikabo moves slowly

varikabo moves fast

If varikabo is moving fast, its eye LEDs light up red. If varikabo is not moving, the LEDs light up blue.

The four basic settings

You can remove the left and right sensors from the LEDs and swap them with each other. This determines whether varikabo moves towards dark or light areas.

- Sensor cable crossed: light follower
- Sensor cable parallel: Shadow follower

For functions 10 and 12, the side sensors are directed to the rear.

Use the selector switch to decide whether the sensor signals are connected directly (=) or reversed (×) to the transistors (T_1/T_2) or the motors (M_1/M_2). This selects the acceleration or braking mode.

- Switch to "FAST (=)": varikabo accelerates when a shadow falls on the middle sensor.
- Switch to "STOP (×)": varikabo brakes when a shadow falls on the middle sensor.

Aligning the sensors

By pointing the three pivoting sensors downwards, forwards or upwards, you can determine whether varikabo perceives impressions on the ground, in front of it or above it.

The brightness ratio between the side sensors determines varikabo's direction of travel. The brightness ratio between the center and side sensors determines its speed.

On the following six pages, you will learn how to set up each function. If varikabo does not immediately work as expected, readjust the orientation of the sensors.

Once you have familiarized yourself with the various functions, the four diagrams at the end of this section will help you to adjust them even more quickly.

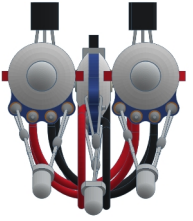
1) Following Light Lines

varikabo moves along light-colored lines (e.g. over white paper strips on a dark background).

varikabo stops at the end of the line.

Setting:
- Light follower
- Brake mode

Sensors:
Point the side ones approximately parallel downwards and the middle one a little more towards the ground.



Adjust the distance between the side sensors to the line width. Experiment with the inclination of the sensors so that varikabi comes to a standstill at the end of the line.

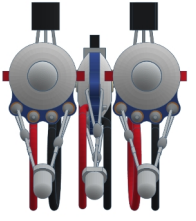
2) Following Dark Lines

varikabo travels on dark lines (e.g. black insulating tape).

varikabo accelerates on straights and brakes in sharp curves.

Setting:
- Shadow follower
- Acceleration mode

Sensors:
Point all 3 parallel forwards and approx. 45° downwards.



Experiment with the distance between the side sensors and the inclination of the center sensor to adjust the speed control as well as possible.

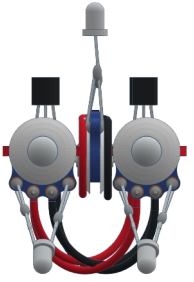
3) Tracking Light

varikabo follows a light on the ground (from a flashlight) and stops before the light.

varikabo also stops when it sees a shadow above it.

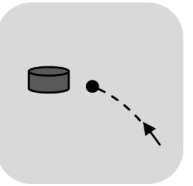
Setting:
- Light follower
- Brake mode

Sensors:
Point the side ones approximately parallel downwards and the middle one vertically upwards.



The ambient light should not be too strong for this function so that varikabo can recognize the light well. Experiment with the distance and inclination of the side sensors.

4) Tracking Objects

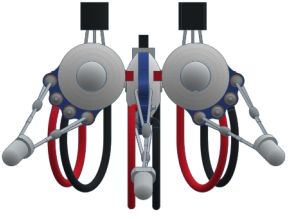


varikabo moves towards dark objects directly in front of it and stops in front of them.

varikabo tracks moving objects.

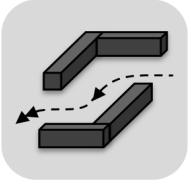
Setting:
- Shadow follower
- Brake mode

Sensors:
Point the side ones about 45° downwards and the middle one also approx. 45°.



Adjust the distance between the side sensors to the size of the object. Experiment with the inclination of the sensors so that both following and stopping work well.

Avoiding Obstacles

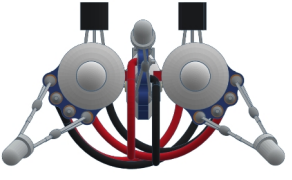


varikabo avoids dark obstacles and can accelerate when it has a clear run.

It masters an obstacle course.

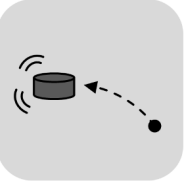
Setting:
- Light follower
- Acceleration mode

Sensors:
Point the side ones approx. 45° downwards and the central one approx. 30° upwards.



The further down you point the side sensors, the closer varikabo moves to obstacles. The middle sensor must be positioned slightly above the obstacles.

6) Pushing Objects

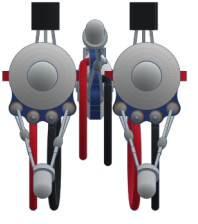


As long as nothing is in sight, varikabo stands still.

If there is a small dark object directly in front of varikabo, it pushes it in front of itself.

Setting:
- Shadow follower
- Brake mode

Sensors:
Point the side ones approx. parallel downwards and the middle one approx. 30° upwards.



Adjust the distance between the side sensors to the size of the object to be tracked. Adjust the tilt angle of the middle sensor so that it is only slightly above the object.

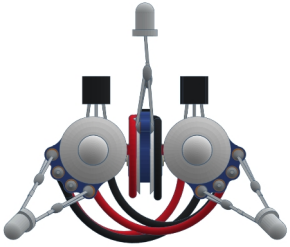
7) Avoiding Dark Areas

varikabo stays on light-colored surfaces and avoids dark obstacles.

When it sees a shadow above it, he accelerates and flees.

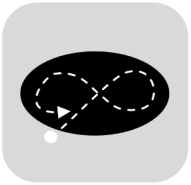
Setting:
- Light follower
- Acceleration mode

Sensors:
Point the side ones approx. 45° downwards and the middle one vertically upwards.



The bright area can be your room floor or a well-lit bright table, for example. If you hold your hand over varikabo, it will only move straight ahead without paying attention to its surroundings.

8) Avoiding Bright Areas

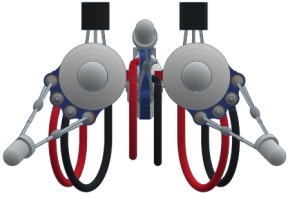


varikabo runs its course and stays on dark ground.

It turns away from light-colored objects or stops in front of them.

Setting:
- Shadow follower
- Brake mode

Sensors:
Point the lateral about 45° downwards and the central one approx. 30° upwards.



Adjust the inclination of the side sensors so that varikabo always turns on time at the edge. Adjust the tilt angle of the middle sensor so that varikabo stops on a light-colored surface.

9) Following Light

varikabo follows a lamp above it and stops under it.

varikabo turns away from a shadow to drive back into the light.

Setting:
- Light follower
- Brake mode

Sensors:
Point the side ones backwards/upwards and the middle one approx. 45° upwards.

The further you point the middle sensor upwards, the closer varikabo moves to the lamp. If you hold your hand between the lamp and varikabo, it will try to get back into the light.

10) Following Shadows

varikabo avoids light and moves towards a shadow above it (e.g. hand).

varikabo stops in the shadow or follows it when the shadow moves.

Setting:
- Shadow follower
- Brake mode

Sensors:
Point the side ones approx. 60° upwards and the middle one vertically upwards.

First hold your hand over varikabo to stop it. Then slowly move your hand forward or to the side so that varikabo can follow it. Be careful not to wear dark sleeves.

11) Remaining in the Light

varikabo drives quickly towards a light.

Then varikabo turns to stay under the light and accelerates when there are shadows above it.

Setting:
- Light follower
- Acceleration mode

Sensors:
Point the middle one vertically upwards an the side ones approx. 60° upwards.

If you place varikabo on the floor at some distance from the lamp, it will move quickly towards the light. The inclination of the sensors must be well adjusted so that varikabo always turns back.

12) Remaining in a Shadow

varikabo moves away from light and accelerates when a shadow is over it.

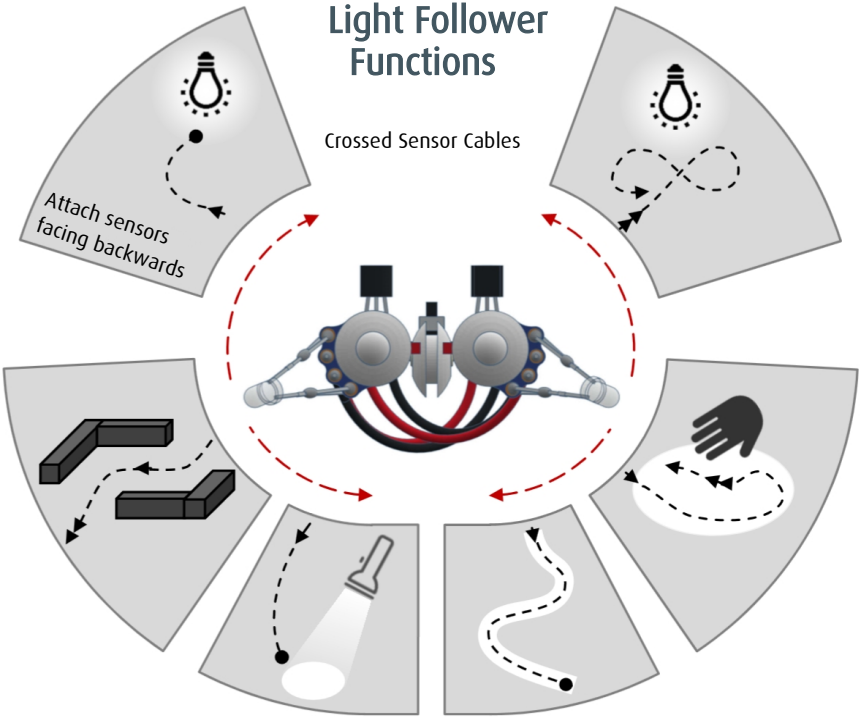
Then varikabo constantly tries to turn to stay in the shadow.

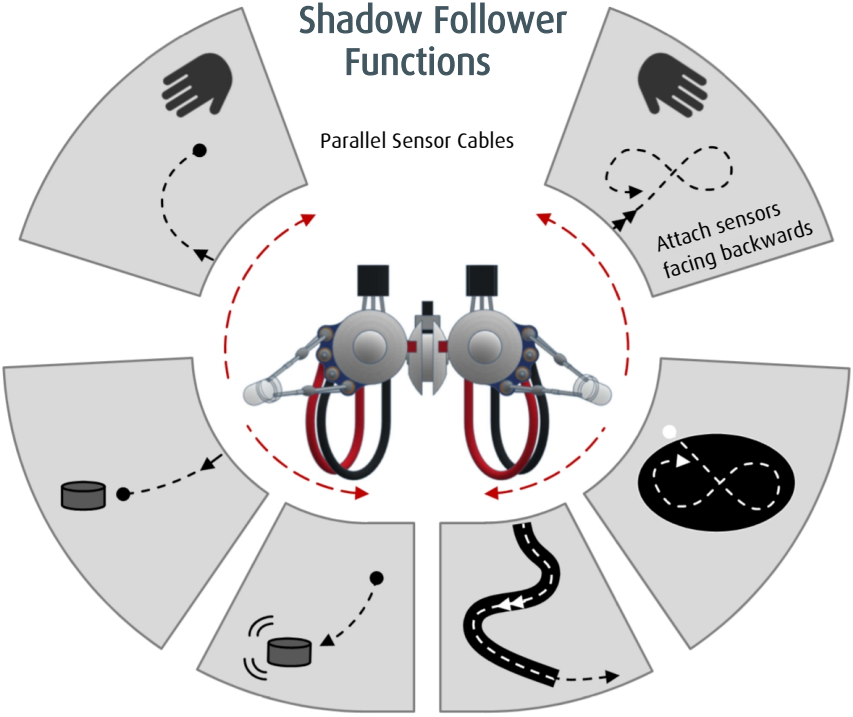
Setting:
- Shadow follower
- Acceleration mode

Sensors:
Point the side ones backwards/upwards and the middle one vertically upwards.

For this function, it is particularly important to use very uniform lighting. The inclination of the sensors must be very well adjusted so that varikabo always turns back.

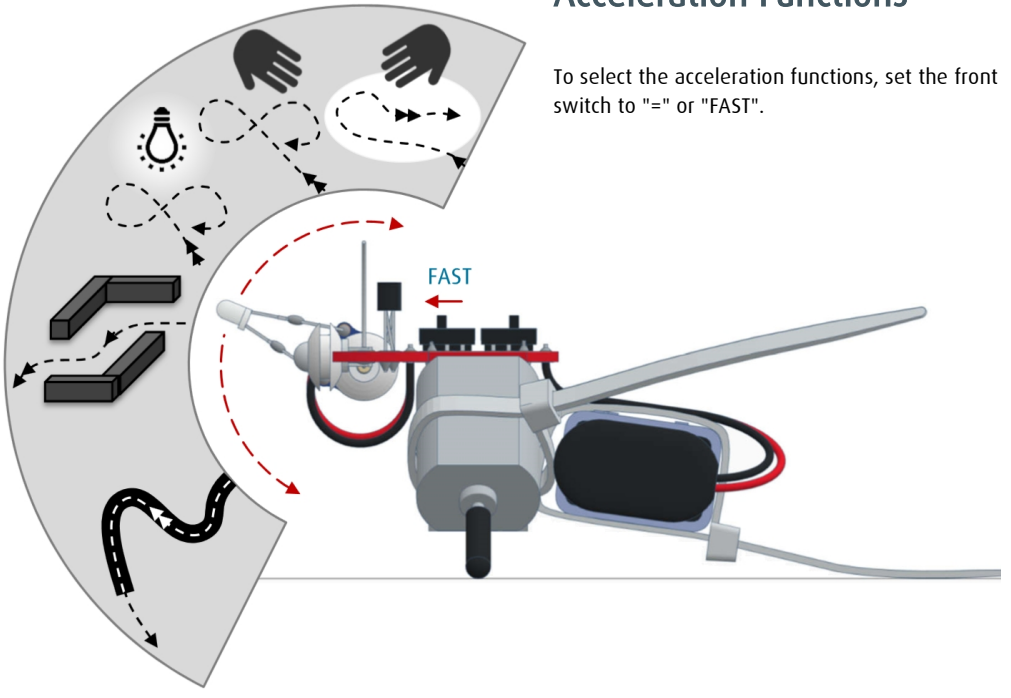
Light Follower Functions




Shadow Follower Functions
Parallel Sensor Cables
Attach sensors facing backwards

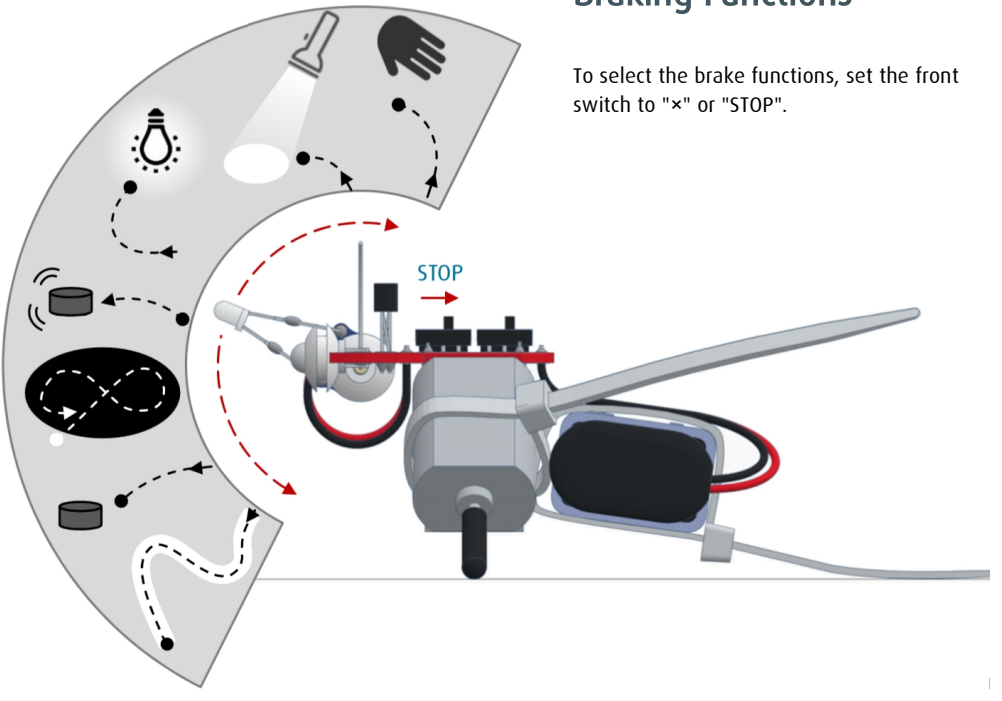
Acceleration Functions

To select the acceleration functions, set the front switch to "=" or "FAST".



Braking Functions

To select the brake functions, set the front switch to "×" or "STOP".



C) How it works

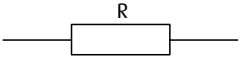
1) Resistor

A resistor limits the flow of current in a circuit and releases energy in the form of heat.
It is used for voltage division, controlling current strengths, and as protection for sensitive components.

Resistors often have 4 or 5 colored rings printed on them, which are referred to as color codes.
In 4-band resistors, the first two rings represent the value, the third ring is the multiplier, and the fourth ring is the tolerance.

The 150 Ω (Ohm) resistor in the varikabo kit limits the current flowing through the two LEDs. The first brown ring stands for "1", the green for "5", the second brown one for "times 10" and the gold ring for an accuracy of ±5%.

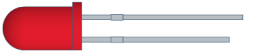
The schematic symbol for a resistor:



2) LEDs

Light Emitting Diodes (LEDs) are components that convert electrical energy into light by conducting electrons through a semiconductor layer. They are known for their energy efficiency, longevity, and compact size, making them a popular alternative to incandescent and fluorescent light bulbs.

LEDs must be correctly polarized. The shorter leg and the flat side on the casing marks the negative terminal (cathode). However, the two-color LEDs from varikabo light up in both directions.

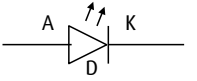


A Anode (+)

C Cathode (–)

Additionally, LEDs require a current-limiting resistor connected in series with the LED to regulate the current flowing through it.

The schematic symbol for an LED:



3) Transistors

A transistor is a fundamental electronic amplifier with three terminals: Base (B), Emitter (E), and Collector (C).

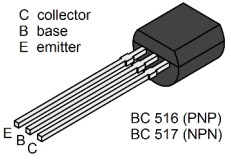
The amplification factor β is defined as the ratio between the collector current I_C at the output and the base current I_B at the input.

To control varikabo's motors using sensor signals, so-called Darlington transistors are used. These have a particularly high current amplification of β = 30000.

A motor and two LEDs together require a current of about 30 mA (milliamperes). For this, a base current of only 1 µA (microampere) is sufficient.

30 mA / 30000 = 0.001 mA = 1 µA

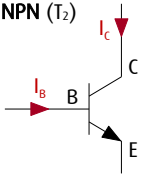
The configuration of pins may vary with different manufacturers.

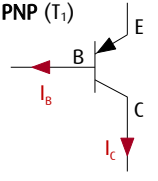


With a voltage between the base and emitter of about U_{BE} = 0.7 V (V = Volt), a transistor reduces the resistance between collector and emitter and switches through.

Darlington transistors have two transistors connected in series. Therefore, they require approximately U_{BE} = 1.4 V to switch through.

In order for varikabo's motors to respond in opposite directions to the left and right sensor signals, complementary transistors are used. NPN transistors (T_2) require a positive voltage U_{BE} and PNP transistors (T_1) require a negative voltage U_{BE} to switch through.





4) Collector Configuration

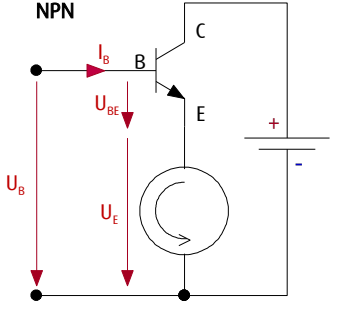
There are three types of transistor configurations: common base, common emitter, and common collector. varikabo uses the **common collector configuration**. It's called common collector (CC), because it's connected to a constant voltage source, in this case a battery. The voltage amplification is less than 1, but the current amplification is very high.

Because the emitter voltage U_E follows the base voltage U_B up to the difference of U_{BE}, this configuration is also called an **emitter follower**.

The illustration on the bottom left shows a simple collector configuration with an NPN transistor, a battery, and a motor. On the bottom right is the corresponding circuit with a PNP transistor.

In each case, the current flows in the direction of the transistor's black arrow, from positive to negative.

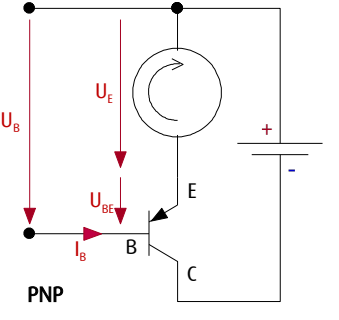
With the control voltage U_B and a very small current I_B, the voltage U_E and with that, the speed of the motor can be controlled.



The red arrows indicate the voltages.

It can be seen that the voltage at the motor (U_E) is smaller than the base voltage (U_B) by the base-emitter voltage (U_{BE}).

$U_E = U_B - U_{BE} = U_B - 1.4\ V$



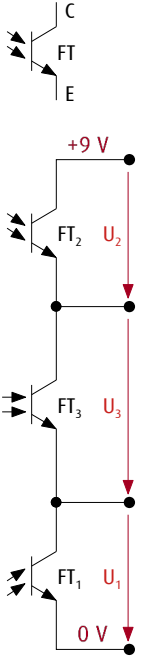
5) Phototransistors

varikabo's sensors are so-called phototransistors (FT). Just think of them as variable resistors whose resistance value decreases with increasing brightness.

However, their structure is more like a transistor. Instead of a base connection, a phototransistor has a light-sensitive area.
The intensity of the light determines the conductivity between collector (C) and emitter (E).

In the illustration, it can be seen that varikabo's phototransistors FT_2, FT_3, and FT_1 are all interconnected. Such a **series connection** of (variable) resistors forms a so-called **voltage divider**.
This divider splits the supply voltage of the 9 V battery depending on the lighting conditions of the respective phototransistors.

The variable voltages U_1 and U_2 control (via the transistors) the speeds of varikabo's motors.



Two examples:

- If all three sensors are lit up equally, regardless of the overall brightness, the supply voltage divides evenly:

  $U_2 = U_3 = U_1 = 3$ V

- If the middle sensor FT_3 is lit up four times brighter than FT_2 and FT_1, a voltage four times smaller would drop across FT_3, and the supply voltage would divide as follows:

  $U_2 = 4$ V, $U_3 = 1$ V, $U_1 = 4$ V

U_1, U_2, and U_3 are inversely proportional to their respective lighting conditions.

6) The control circuit

Depending on how the sensors are connected to the transistors via switch S_2 and whether the sensors FT_1 and FT_2 are arranged in parallel or crossed over, the four basic control variants result.

- Acceleration mode / Braking mode
- Shadow follower / Light follower

In the circuit diagram, the lateral sensors FT_1 and FT_2 are arranged as shadow followers.

The selector switch S_2 is in the acceleration mode position.

If less light falls on the middle sensor FT_3, both transistors switch through more and the motors become faster. If, on the other hand, switch S_2 were in the crossed position, the motors would slow down accordingly.

If, for example, more light falls on sensor FT_2, the voltage at both transistor inputs increases. The motor M_2 then speeds up and M_1 slows down.

As a result, varikabo turns away from the light. If, on the other hand, the sensors were arranged crosswise, varikabo would move towards the light.

The two two-color LEDs are connected in series with the resistor and arranged between the transistors. They light up red when the current flows through both transistors and blue when the current flows in the other direction through the motors, provided they are at a standstill.