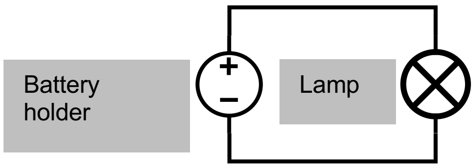
Experiment 1 – Make a lamp light up

Construction task

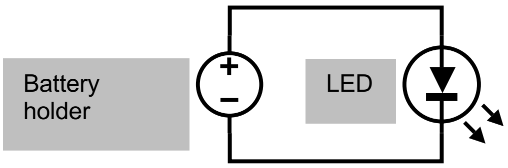
Build the model of the simple circuit with pole reversing switch using the building instructions.

Topic task

Electrical circuits are shown using *circuit diagrams*. The following circuit diagram shows the general *circuit symbols* for a lamp.



However, we are actually using an *LED* for our lamp (which stands for "*light emitting diode*"). An LED has a special *circuit symbol* in the circuit diagram:



Experimental task

Important: You can try out whatever you want using the two cables, but **never** connect the two connections of the battery holder directly together, not even through the lamp component. This is called a *short circuit*. Although our battery holder has a built-in protector against short circuits, you cannot "short circuit" a power source; otherwise, it may be damaged. The cables could become so hot that they could hurt you.

Our battery holder has a built-in *slide switch*, and we are going to test it out now. Try out the following:

1. Connect a cable of the battery holder to the "+" (called the plus pole) of the LED component, and the other cable to the "-" minus pole. Push the switch on the battery holder all the way to the right or all the way to the left. Our lamp should light up in one of the two switching positions.

2. Now, unplug either of the plugs. By doing so, you interrupt the *circuit.* No more current can flow from the battery to the lamp or back. What happens?
3. Make the lamp light up again. Switch the two plugs on the lamp. What do you observe? What happens if you push the switch to the other side?
4. Repeat the experiment by exchanging the plugs on the battery holder. What happens?

Experiment 1 – Make a lamp light up

Stefan Falk

Topic

Simple circuit with reverse polarity switch and an LED.

Learning objective

- Power supplies have two *poles*.
- Current can flow when the circuit is closed.
- Flowing current can make a lamp light up.
- Therefore, it is important that the LED has the right polarity.

Time required

45 min

Solution sheet Experiment 1 – Make a lamp light up

Example solution for topic task

First, it is important to complete the experimental tasks to make the LED light up.

Evaluating the experimental task

1. In this experiment, it is not important how the LED is wired to the battery. One of the two possible switching positions will cause the current to flow in a direction that will light up the LED. What we can learn:

   a) The slide switch in our battery holder allows no current at all to flow in the centre position ("off"). We can use the two outer switching positions (all the way to the left or right) to change the direction in which the current flows.
   b) An LED is a bulb that only lights up if the current flows through it in the right direction. Nevertheless, they are very popular because they use little current, don't get very warm, and have a much longer service life compared to incandescent bulbs.
2. Once one of the plugs is pulled out, however, the entire circuit is interrupted and the LED goes out.
3. Exchanging the plugs would also change the current direction. An LED that had previously lit up would no longer be able to do so. However, you can use the switch to set the current direction and make the LED light up even with this wiring configuration.
4. The circuit is the same as in 3. It does not matter whether the plugs on the lamp or on the battery holder are exchanged – the effect is the same.

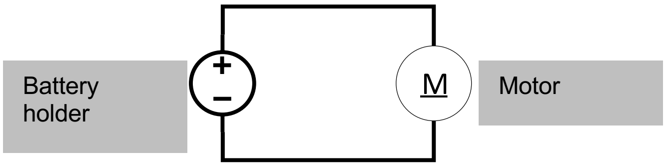
Experiment 2 – Make a motor turn

Construction task

Build the model Direct current motor with change of direction without the plug-in gearbox. This allows us to see the worm gear of the motor.

Topic task

Connect the motor to the battery holder:



Experimental task

1. Switch the current on using the switch. What happens?
2. Try to brake the silver *worm gear* of the motor using your fingers. Feel how powerful the motor is.
3. Push the switch on the battery holder in the other direction. The motor will keep running. What do you observe?
4. Now, connect the motor to the plug-in gearbox. We will leave out the snap-in adapter with the red flag. Ensure that the small toothed gear interlocks cleanly with the worm gear, to keep the motor from getting jammed. The plug-in toothed gear on the top also needs to be firmly snapped into place. Now, let the motor turn. Try again (now on the last black axle) to brake the motor using your fingers. What do you observe?
5. Now, insert the rest of the parts with the red flag. You can easily see what happens when you push the slide switch in the other direction. What happens if you instead exchange the plugs on the battery holder or motor?
6. Compare the rotational speed of the red “flag” with the rotational speed of the motor observed in 1. and 2. What do you find?

Experiment 2 – Make a motor turn

Stefan Falk

Topic

We will be operating a direct current motor and changing its direction of rotation.

Learning objective

- A direct current motor turns when (sufficiently strong) current flows through it.
- By reversing the polarity, we can change the direction of rotation of the motor.

Time required

45 min

Solution sheet Experiment 2 – Make a motor turn

Evaluating the experimental task

1. The motor is turning!
2. The motor has a lot of turning power. However, you can still brake it with two fingers.
3. When the switch is switched over, the current direction changes. Because we are using a “direct current motor”, this also changes the direction of rotation. We can easily make the motor turn in both directions.
4. The black axle on the outlet of the plug-in gearbox turns much more strongly than the “naked” motor worm gear. This is due to the toothed gears: A small toothed gear always transmits the rotation to a larger toothed gear. This is called “gear reduction”: The rotation is now slower, but more powerful.
5. Just like with the LED in experiment 1, it does not matter where or how the current direction is changed. Switching the switch or exchanging the plugs on the battery holder or on the motor will cause the same effect: The motor will change its direction of rotation.
6. The flag allows you to easily see how fast it is turning. The worm gear on the motor turns so quickly that you cannot follow it with your eye.

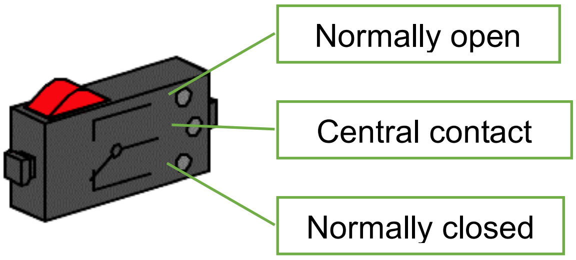
Experiment 3 - Switching on and off using a button

Construction task

Build the model Switching on and off using a button based on the building instructions.

Topic task

The fischertechnik button looks like this:

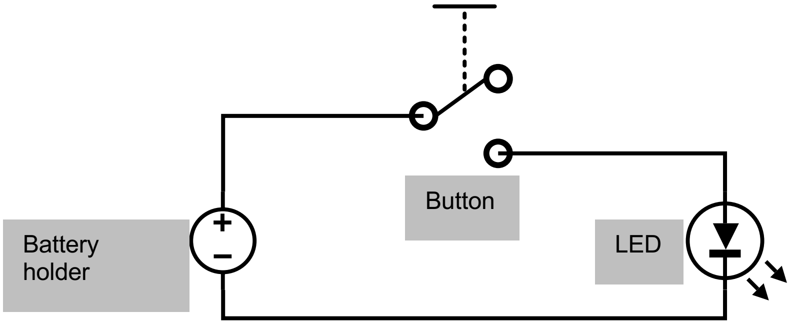


- On the page shown here, its circuit is shown in *rest condition*. This is the condition in which the button is *not pressed*. The middle connection (the *central contact*) is connected to the bottom connection (the *normally closed contact*).
- Once the button is pressed, the button switches over: The central contact is then no longer connected to the normally closed contact, but rather to the top connection, the *normally open contact.*
- The normally open and normally closed contacts are never directly connected using the button. Instead, only one of these two contacts is connected with the central contact at one time – depending on whether it is “pressed” or “not pressed”.

In this way, the central contact can be connected to either the normally closed contact or normally open contact (when the button is pressed). We will be investigating this in the following experiments. The following task sheets will show you how you can use multiple buttons to build other exciting, refined and extremely useful circuits.

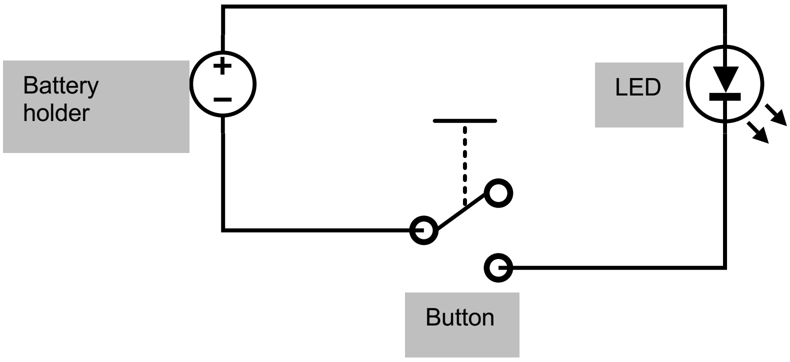
Experimental task

1. Install the button in one of the supply lines to the LED so that the central and normally open contacts are in the circuit. In the wiring diagram, this looks like this:



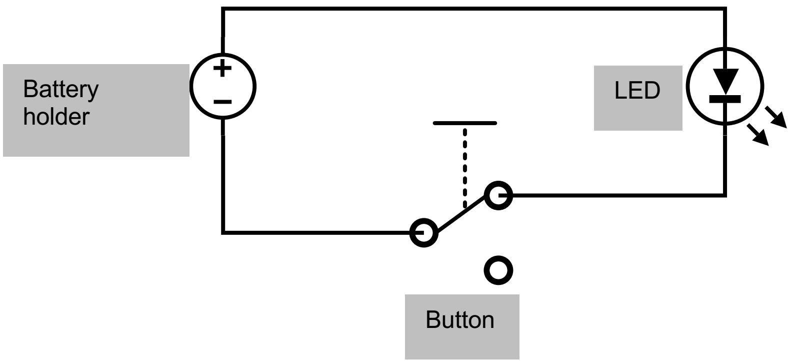
Observe when the light is illuminated, and when it isn't.

2. Now install the button in the other line between the battery holder and the LED:



What do the LED and button do now?

3. In the past, we have used the buttons as *make contacts* (with central and normally open contact) The contact is *closed* (current can flow) when the button is *pressed*. Now, move the plug from the normally open to the normally closed contact.



What do the LED and button do now?

Experiment 3 - Switching on and off using a button

Stefan Falk

Topic

Function and purpose of a changeover button as control element. In this experiment, we will be switching an LED on and off.

Learning objective

- The button can allow the current to flow or interrupt the flow of current.
- It can be connected as a normally open or normally closed contact. We will be investigating this in detail.

Time required

This and the next experiment (series connection of two buttons) can be built together and the experiments can be completed in 45 minutes.

Solution sheet Experiment 3 - Switching on and off using a button

Evaluating the experimental task

1. The LED lights up when the button is pressed. If the button is not pressed (released), the LED goes out.
2. Which of the two lines between the battery holder and LED the button is installed in does not matter. It either allows the current to flow (the LED lights up) or it interrupts the flow of current (the LED does not light up).
3. Now the LED lights up when the button is *not* pressed. It does out when the button is pressed.

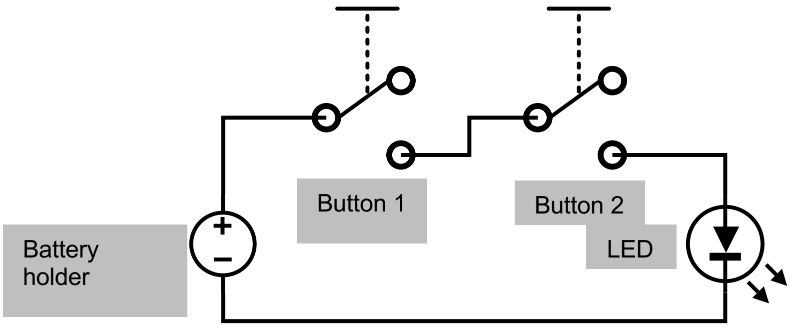
Tasks Experiment 4 – Connecting buttons in series

Construction task

Build the Button series connection model according to the building instructions.

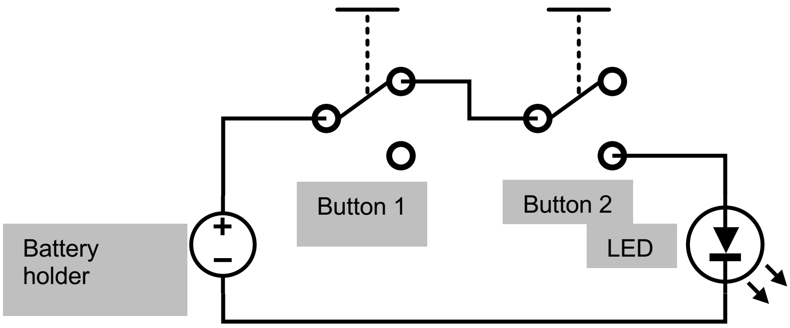
Experimental task

1. First, use the central and normally open contacts for both buttons:



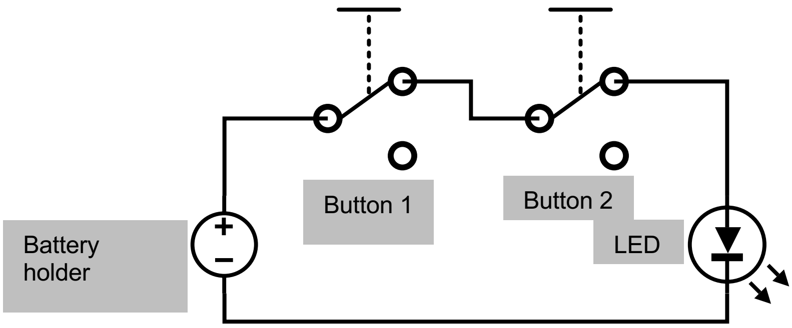
   When does the LED light up, and when does it stay off?

2. Now, use the normally closed contact instead of the normally open contact for one button:



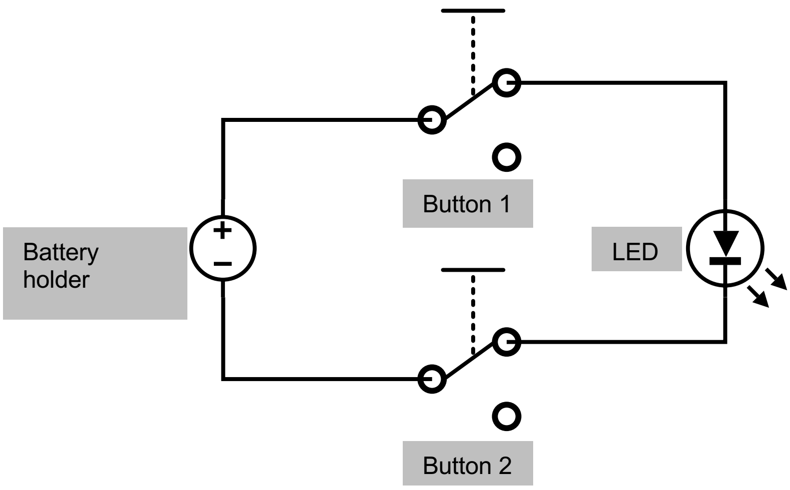
   What does the circuit do now?

3. Now, use the normally closed contacts for both buttons:



What does our circuit do now?

4. What changes if button 2 is installed in the other line between the battery holder and LED?



Experiment 4 – Connecting buttons in series

Stefan Falk

Topic

We will be connecting two buttons in series and observing how they behave.

Learning objective

- Two buttons connected in series make it possible to only switch on a device (LED or motor) when *both* buttons are pressed.
- Different controls through different combinations of the button as a normally open or normally closed contact.

Time required

45 min (if applicable together with Experiment 3)

Solution sheet Experiment 4 – Connecting buttons in series

Evaluating the experimental task

1. The LED only lights up if button 1 *and* button 2 are pressed at the same time. Therefore, this kind of circuit is called an “AND link”.
2. Now, the LED only lights up if button 2 is *pressed*. If button 1 is pressed or if you release button 2, the LED goes out. We still have an AND link, but one of the buttons acts directly opposite to the other.
3. In this circuit, the LED only goes on if *neither* of the two buttons is pressed. If you press one of the two buttons or both of them, the LED goes out.
4. It does not matter – see also Experiment 3 – which button is installed in which of the supply lines. Once the flow of current to one of the buttons is interrupted, the LED will go out. Only when both allow the flow of current will it light up.

Tasks Experiment 5 – Connecting buttons in parallel

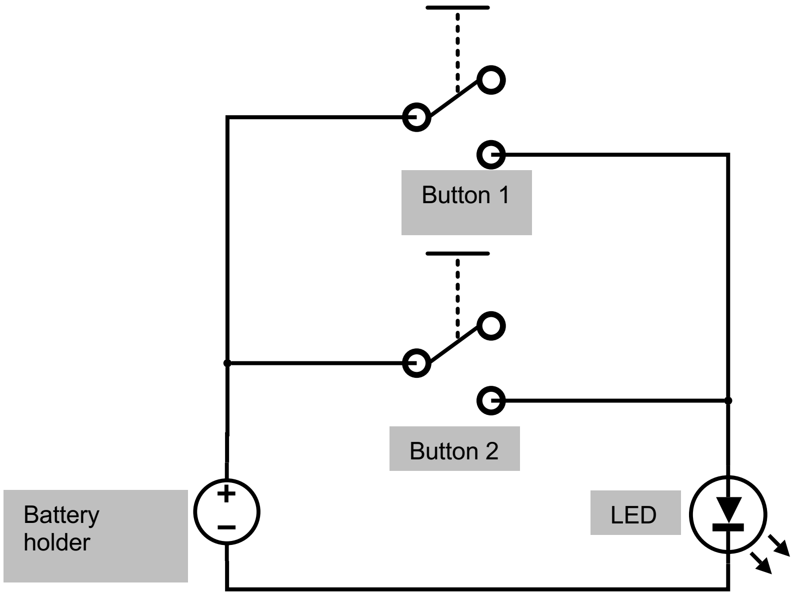
Construction task

Build the Button parallel connection model according to the building instructions.

Topic task

1. Connect one pole of the battery holder to *both* central contacts for the two buttons.
2. Connect *both* normally open contacts of the button to the LED.
3. Connect the other pole of the LED to the second pole of the battery holder.

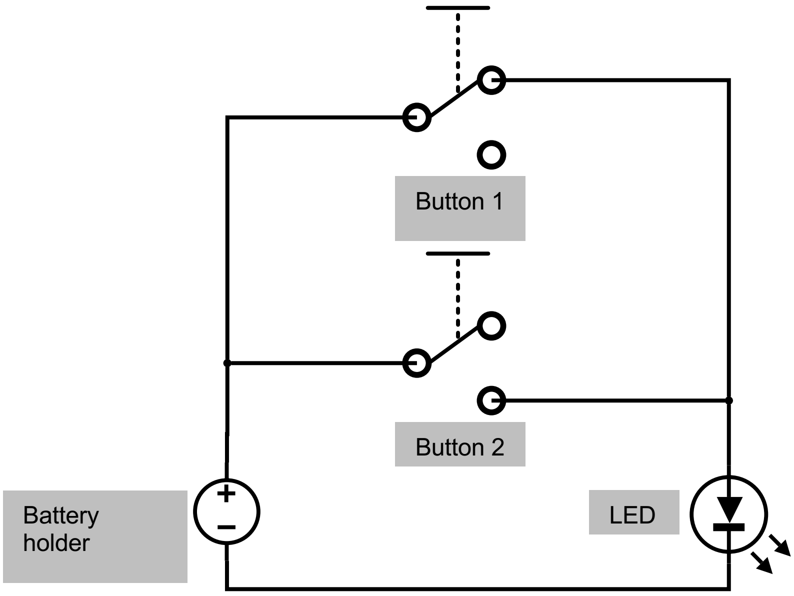
The circuit looks like this:



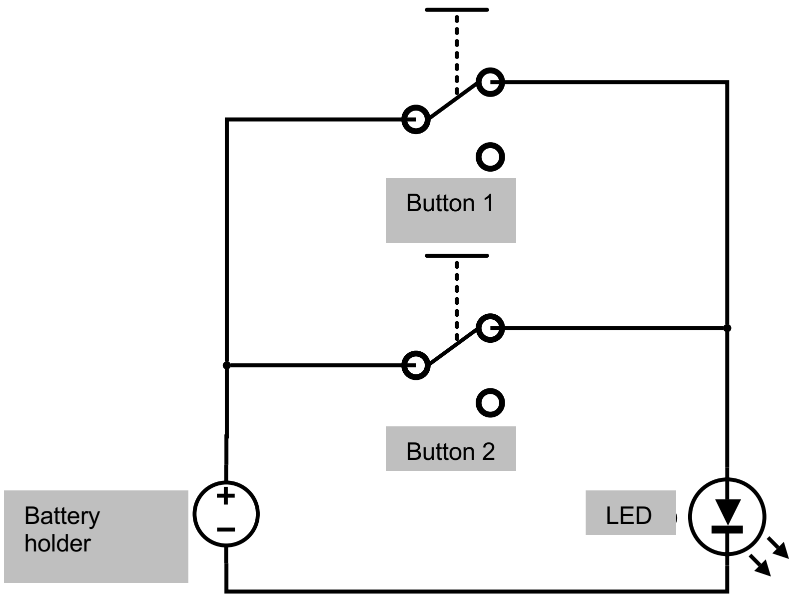
Set the position of the battery box switch so that the LED lights up when you press one of the buttons.

Experimental task

1. Play with the two buttons. When does the LED light up, and when does it stay off? Why is that?
2. What changes, for instance, if you use the normally closed contact of button 1 instead of the normally open contact?



3. What changes if you use the normally closed contacts of both buttons?



Experiment 5 – Connecting buttons in parallel

Stefan Falk

Topic

We will be connecting two buttons in parallel to create an OR link.

Learning objective

- Switch on one device from two places.
- The lamp lights up when you push one of the two buttons or both at the same time.

Time required

45 min (if applicable together with Experiment 4)

Solution sheet Experiment 5 – Connecting buttons in parallel

Evaluating the experimental task

1. The LED lights up when you push one of the two buttons. It also lights up when you push both buttons at the same time. It only stays off if neither of the buttons is pushed.
   Pushing just one button closes the circuit. If both buttons are pushed, current can even flow through both buttons. However, the LED does not light up more brightly if both buttons are pushed. This just changes the circuit.
2. If the normally closed contact for button 1 is used, the button allows the current through for as long as it is open (released). The LED lights up when button 1 is released or when button 2 is pressed, or when both (button 1 released and button 2 pressed) are true at the same time. Only when button 1 is pressed and button 2 is released does the LED go out.
3. If both normally closed contacts are used, the LED lights up when button 1 or button 2 (or both) are open. Only when both buttons are pressed does the LED go out.

Tasks Experiment 6 - Multiway switching

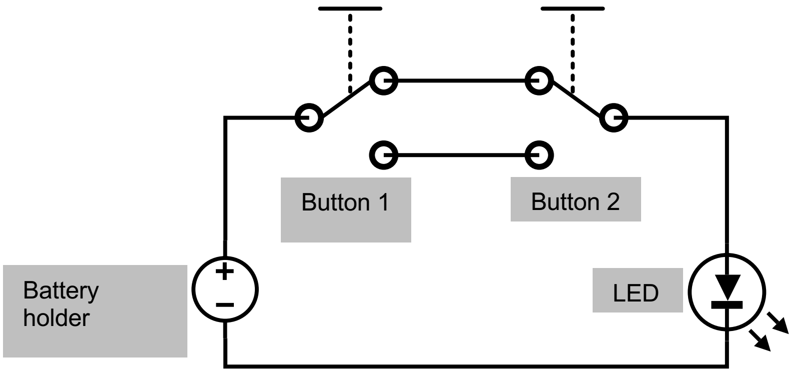
Construction task

Build the Multiway switching model according to the building instructions.

Topic task

For this experiment, we will need a total of 5 cables. Proceed carefully to ensure the circuit is constructed correctly:

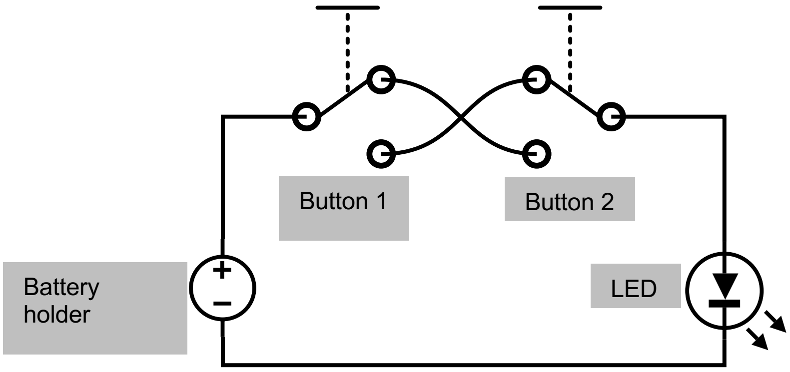
1. A cable goes from one pole of the battery holder to the central contact for button 1.
2. Connect the two normally open contacts of the button to one another.
3. Connect the two normally closed contacts of the button to one another.
4. The central contact of the second button goes to the LED.
5. Then the other connection of the LED is connected to the second outlet on the battery holder.



The circuit diagram shows that both buttons allow current through to the LED. Set the position of the battery holder switch so that the LED lights up.

Experimental task

1. Let's have some fun! Play with the buttons. When does the LED light up, and when does it not?
2. Imagine the LED is a lamp in a room, and the room has two doors. You install one of the buttons on each of the doors (you'd need longer cables, of course). What would this kind of circuit be able to do?
3. Exchange the two cables on the buttons so that each normally open contact is connected to one normally closed contact.



When does the LED light up now?

4. What would you have to change to create a usable room lighting design? Remember, you don't want to have to stand by a door to push a button all the time.

Experiment 6 - Multiway switching

Stefan Falk

Topic

We will be controlling an LED with two buttons. You can use this circuit, for instance, to switch a light on or off from two places.

Learning objective

- Use both the normally open and normally closed contacts of a button.
- Build a multiway switch using two buttons

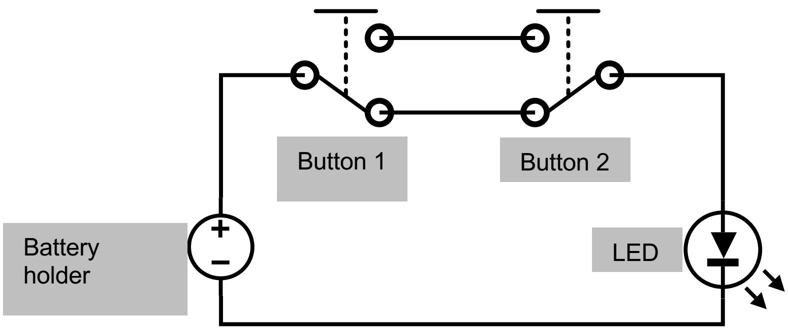
Time required

45 min

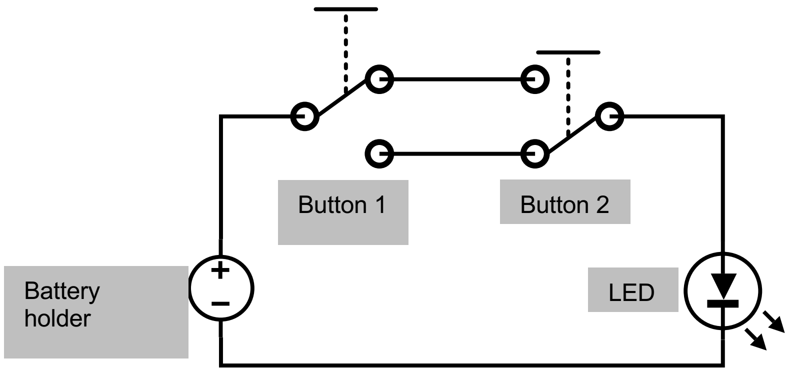
Solution sheet Experiment 6 - Multiway switching

Evaluating the experimental task

1. The LED lights up in this circuit when both buttons are pressed or when both buttons are released:



When one of the two buttons is pressed (does not matter which one) and the other is released, the LED remains off because the current cannot flow through both buttons:



2. You can use this circuit to control one lamp from two different places! No matter what the switch position for the farther button is: Regardless of where the buttons are and whether the lamp is on or not, you can switch a button and turn a lamp on or off.
3. When the normally open and normally closed contacts for the two buttons are connected "crossed", the LED lights up when *exactly one* button is pressed and the other is released. If both are pressed or both are released, the LED will stay off.
4. You normally would not use *buttons* for room lighting that would switch independently back to their resting position when they were released. After all, no one wants to have to stand by the door and hold the button down! Instead of

buttons, you would probably use *switches* that would stay in their last set position when they were released.

Systems

Experiment 6 - Multiway switching

Additional materials

To turn the buttons into *switches*:

- Two additional round spring cams
- Two additional modules (such as module 15, module 30, module 7.5).

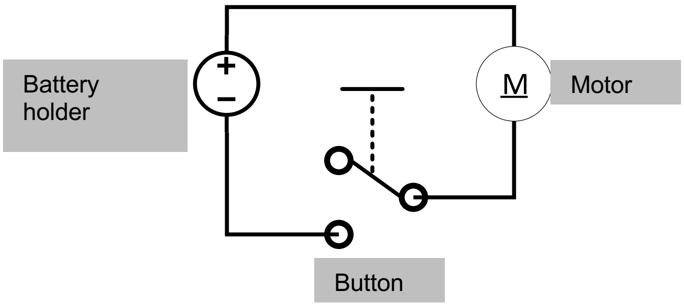
Tasks Experiment 7 - Short circuit brake

Construction task

Build the Short circuit brake model according to the building instructions. Attach the red flag to the motor as well, so that you can easily observe its rotational movements. When wiring the model, ensure that the *central contact* of the button is connected to the motor, not the battery holder.

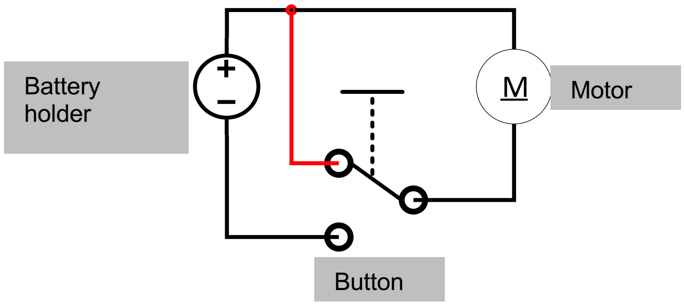
Experimental task

1. First, build the circuit you already used in experiment 2 to switch the motor on and off. Only use the normally open contact, and leave the normally closed contact of the button free:



Ensure that the central contact is wired to the motor and the normally open contact to the battery! We will need this configuration later on.
Switch the motor on and off using the button. Observe that the motor keeps running a little while after it is switched off. Why is that?

2. Now, install another cable by connecting the normally closed contact with the "other" pole of the battery box or motor;



When the button is released, the current can no longer flow from the battery as before because one of the poles of the battery (the lower one in the circuit diagram) is not connected to anything. Now, switch the motor on and off again. How long does the motor keep running now when you switch it off?

Experiment 7 - Short circuit brake

Stefan Falk

Topic

Directly stop a motor without any lag time.

Learning objective

- Short circuiting a *device* (motor) is allowed and useful, in contrast to short circuiting a power supply (battery).

Time required

30 min

Solution sheet Experiment 7 - Short circuit brake

Evaluating the experimental task

1. The motor turns quickly and has a lot of momentum. Therefore, it will keep turning for a while, even if it is no longer receiving current from the battery. However, it will continue to get slower until it finally stops. This happens because the motor and the gear attached to it experience *friction*. The motor has to *work* to overcome this friction.
   You can compare this to a situation where an object (a box, a fischertechnik component, a ruler, your school books, ...) keeps sliding a little bit when you give it a push, even if you're no longer touching it. This object also has *momentum*, which is reduced by the *friction* (for instance on the surface of the table). A ball that you push will continue to roll longer, because its friction with the floor is less.
2. This circuit causes the motor to stop practically immediately after it is shut off (when you release the button)!
   You can compare this, for instance, to a situation of pushing an object that then hits a wall. It cannot keep moving and has to stop immediately, because the wall absorbs all of its momentum at once.
   Further information for students who want to know more: Our direct current motor can be more than just a motor; it can be an electric *generator* as well. If you turn it quickly from the outside, it will produce electrical current on its connections. Now, our circuit will cause this current to be fed directly back into the motor. When the button is released, the motor is *short-circuited* – its two connections are connected directly with one another. (You can short circuit the motor in this way, but not the battery holder – you've already learned that!) This short circuit is like the wall that a pushed object runs into. It does the same thing: The motor stops suddenly, instead of running out slowly.

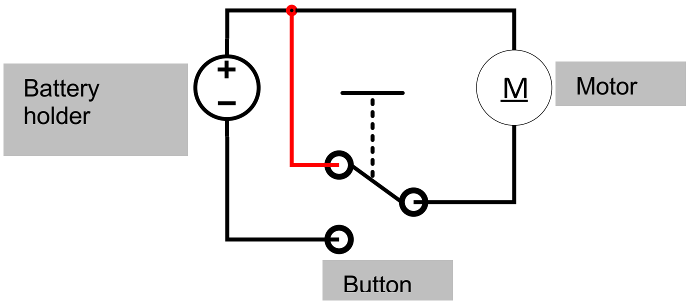
Task Experiment 8 – Left - right - off with two buttons

Construction task

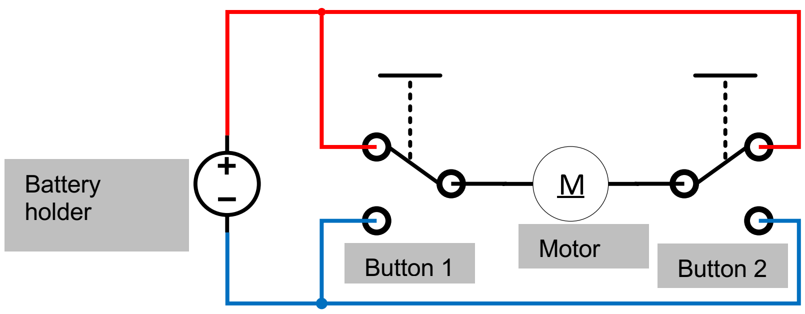
Build the model Left - right - off with two buttons according to the building instructions.

Topic task

We already learned about a circuit that can be used to switch a motor on and off, with short circuit brake.



In reality, the button in this circuit switches one of the connections of the motor between the *two* poles of the power supply. We are going to add a second button, which we will connect in the same way to the other motor connection:



You can understand the circuit as follows:

- The *central contacts* of the two buttons are each connected to one connection of the *motor*.
- *Both normally closed contacts* are connected to the *same* pole of the power supply (our battery holder).
- *Both normally open contacts* are connected to the *other* pole of the power supply.

Build this circuit. Everything shown red on the circuit diagram is connected. Therefore, it does not matter whether you

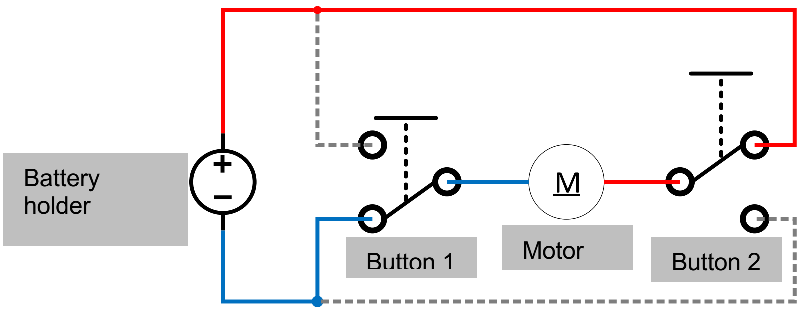
- route one cable from each of the normally closed contacts to the power supply (so that they "meet" there), or whether you
- connect the two normally closed contacts with one cable and go from there to the battery with another cable.

The same is true for the normally open contacts and the lines shown blue on the circuit diagram.

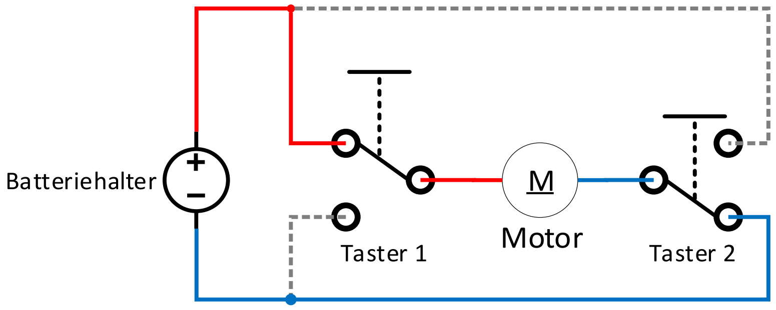
What is important is that you can use this circuit to connect both motor connections to either "+" or "-" of the power supply as desired, depending on how you press or release the button. Let's investigate!

Experimental task

1. When you release both buttons, the motor does not turn because both motor connections are short circuited (and only connected to one pole of the power supply). This is the switching position in the top circuit.
2. For instance, press button 1. That is this situation:



   The two lines shown using grey dashes are not important, because these connections are not connected.
   Now, we have connected the right motor connection with "+" (shown on the right in the diagram) and the other connection with "-". That means the motor turns in a specific direction!
3. Release button 1 and press button 2 instead:



Now the motor is connected to the poles of the battery holder in the opposite direction. Therefore, the motor will turn the opposite direction compared to when you press button 1.

4. Draw a wiring diagram showing a case where both buttons are pressed at the same time. Think about, and describe what the motor will do in this case, and why?
5. Think about what kinds of models could be controlled with this circuit.

Experiment 8 – Left - right - off with two buttons

Stefan Falk

Topic

Basic circuits for a motor controller.

Learning objective

- Use two buttons to control (left/right/off) a direct current motor.
- Understanding of electrical circuits.

Time required

Max. 45 min (easily combined with experiment 9)

Systems

Experiment 8 – Left - right - off with two buttons

Additional materials

Note: It is a good idea to leave this circuit built in preparation for experiment 9, which connects seamlessly to it.

Other fischertechnik components can be added to build interesting models with this circuit, if they are available.

Further information

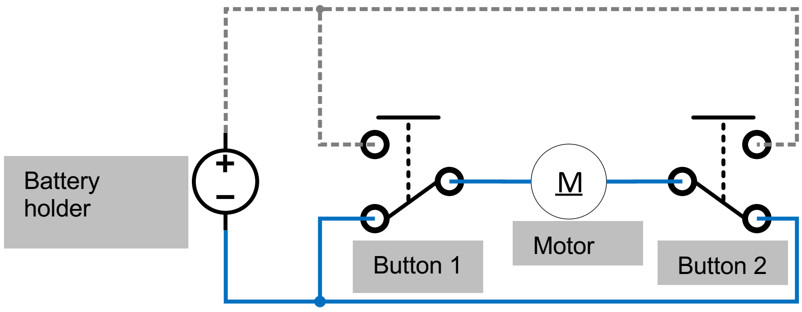
[1] Falk, Stefan: *Motorsteuerungen (Teil 1)*. ft:pedia 1/2011, S. 4-8: https://ftcommunity.de/ftpedia/2011/2011-1/ftpedia-2011-1.pdf#page=4 (Motor controllers with buttons up to the control circuit shown in this task sheet).

[2] Falk, Stefan: *Motorsteuerungen (Teil 2).* ft:pedia 2/2011, S. 19-25: https://ftcommunity.de/ftpedia/2011/2011-2/ftpedia-2011-2.pdf#page=19 (Adding the "end position shutoff' to this circuit with two additional buttons and a small crane as a suggested model; suitable for combining two classroom sets to have enough buttons and cables).

Solution sheet Experiment 8 – Left - right - off with two buttons

Evaluating the experimental task

1. When both buttons are released, the motor (not the power supply!) is short circuited and stops.
2. The motor turns (depending on the position of the switch in the battery holder) in a specific direction.
3. The motor turns, but the opposite direction as in 2.
4. When both buttons are pressed, it looks like this diagram:



   Just like when both buttons are pressed, in this case the motor is short-circuited and stops.

   Only when just one of the two buttons is pressed will the motor run. The direction of rotation is determined by which of the two buttons is pressed. **That means we can use this circuit to easily run a motor either left or right with the push of a button, or make it stop!**

5. There are countless applications for this kind of circuit.
   a) A car!
      - Make it run forwards or backwards at the push of a button!
      - You can steer left or right with two such circuits and a motor-controlled steering.

   b) A crane!
      - Make it move to the side or turn.
      - Left or lower its crane arm (using a second motor and two additional buttons).
      - Lift or lower the crane sling by driving the cable drum with a motor.

   c) A fan or propeller that can run in both directions at the push of a button.
   d) A sliding or revolving door with a motor that you can open or close.
   e) An elevator that can move up or down.
   f) A conveyor belt that can move forward or backward.
   g) A secret compartment with a cover that opens or closes at the push of a button.
   h) ... Let your imagination run free!

Attachments Experiment 8 – Left - right - off with two buttons

Other fischertechnik components can be added to build interesting models with this circuit, if they are available.

Further information

[1] Falk, Stefan: *Motorsteuerungen (Teil 1)*. ft:pedia 1/2011, S. 4-8: https://ftcommunity.de/ftpedia/2011/2011-1/ftpedia-2011-1.pdf#page=4 (Motor controllers with buttons up to the control circuit shown in this task sheet).

[2] Falk, Stefan: *Motorsteuerungen (Teil 2).* ft:pedia 2/2011, S. 19-25: https://ftcommunity.de/ftpedia/2011/2011-2/ftpedia-2011-2.pdf#page=19 (Adding the "end position shutoff' to this circuit with two additional buttons and a small crane as a suggested model; suitable for combining two classroom sets to have enough buttons and cables).

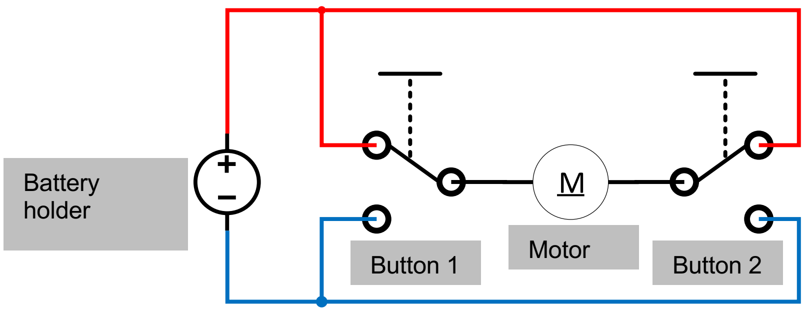
Tasks Experiment 9 – Pole reversing switch with two connected buttons

Construction task

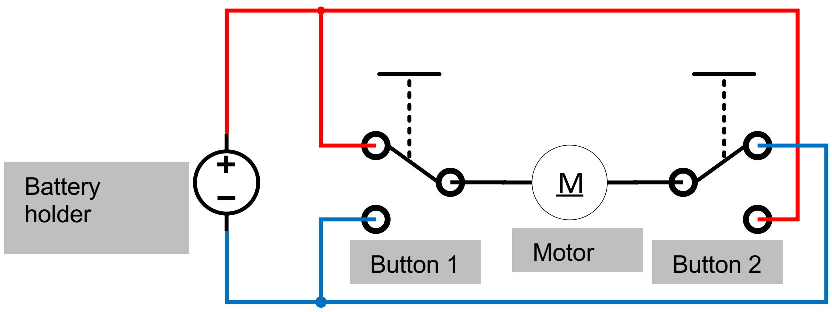
Build the model from experiment 8 once again. Both buttons should initially just be individually attached.

Topic task

We remember the circuit used in experiment 8, that we used to control the left/right direction of a motor:



Now, **exchange** the cables between the normally open and normally closed contacts for **one** of the buttons (shown here for button 2):



Experimental task

1. What does the circuit do now? When does the motor run, and in what direction?
2. On the fischertechnik button, the red button that you press runs through the entire mechanism. Therefore, you can **directly connect** two buttons to one another and press them at the same time with just one button. Build the Reverse

polarity switch model with two connected buttons for Experiment 9 according to the building instructions.

What does this circuit design do?

Experiment 9 – Pole reversing switch with two connected buttons

Stefan Falk

Topic

First, we will be exchanging the normally open and normally closed connections for a button from Experiment 8. Cascading the buttons into one unit creates a compact reverse polarity unit.

Learning objective

- Deepening knowledge of the left/right/off circuit from Experiment 8.
- Function and structure of a “reverse polarity switch”.

Time required

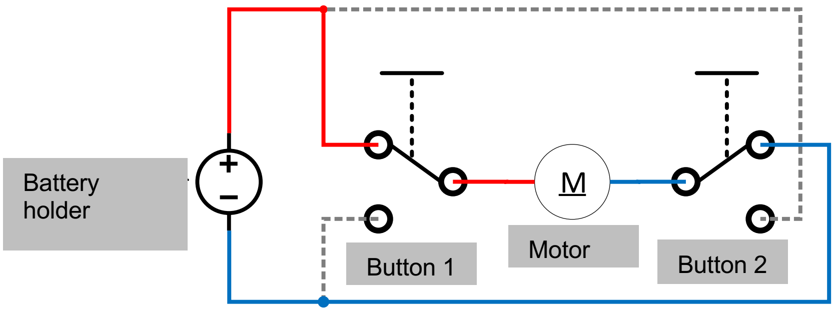
45 Min.

Solution sheet Experiment 9 – Pole reversing switch with two connected buttons

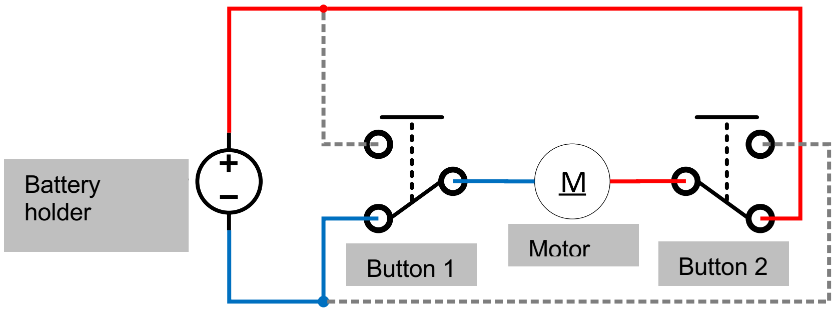
Evaluating the experimental task

1. The button with the exchanged connections now behaves in the same way it did before when it was "pressed" when it is released, and "released" when it is pressed.

   The motor runs when *both buttons are pressed* or *both are released.* When both are released, the circuit is as follows:



   When both buttons are pressed the current direction changes:



   If one of the two buttons (does not matter which one) is pressed and the other released, the motor stops.
2. The motor *always* runs now because either both buttons are released or both are pressed. This means: The motor always runs, but you can make it run in the other direction at the push of a button.