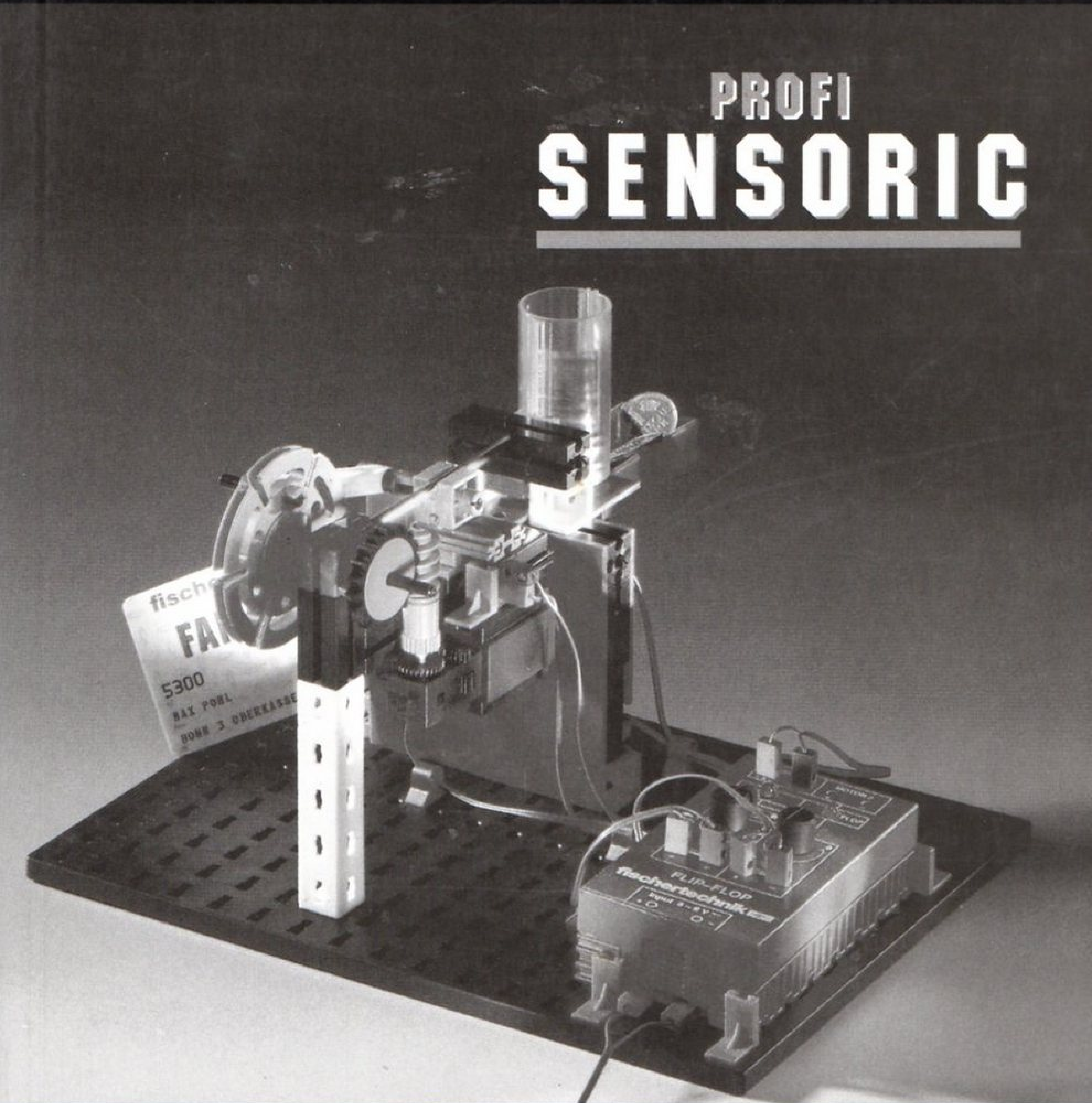
HANDBOOK / MANUEL / MANUAL / MANUALE / HANDBOEK

PROFI SENSORIC



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PROFI SENSORIC

Experiment Manual
Manuel d'experimentation
Experimenteerboek
Libro de Experimentos
Manuale di esperimenti

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PROFI SENSORIC

Experiment Manual

English version

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Contents

! All references to diagrams not contained in this experiment manual refer to the German version of the manual !

Sensors ...

... If you look this word up in a dictionary, you will find a whole series of meanings: transformer, transmitter, detector, transducer, pick-up, etc. An engineer uses it more generally to refer to any component which converts temperature, light or magnetism, for example, into an electric current. He would describe the basic technical principle as follows: a physical quantity is converted into an electrical quantity.

There are many types of sensorwhich have been around for a long time. Due to the advances made in automation systems and in computer engineering, they are nowadays extremely important components: an industrial robot which welds car bodies together cannot be controlled without so-called "tactile sensors". If you just look around your home, you will find sensors too, though they will be "hidden" in various appliances. A washing machine contains sensors for measuring the water level in the drum or the temperature of the water. Modern electric ovens also have temperature sensors which prevent the hot-plates from becoming too hot. There are hardly any branches of technology which are able to manage without sensors in today's world.

This fischertechnik construction kit uses different sorts of electrical sensor: NTC resistors as heat sensors, photo-transistors as light sensors, reed contacts as magnetic sensors and of course switches as "operator sensors" (all these sensors will be described in more detail later on). The various models will give you an idea of the many different things that sensors can do - you will be surprised how versatile your models are.

In order to switch motors and lamps with the sensors, you need a minimum amount of electronics, namely the flip-flop, which boosts the signals of the sensors and switches the motors and the lamps. You can find out more about the different sensors and the flip-flop on the next few pages. You should read them through carefully, so that when you build your first model, everything works the way you want it to straight away.

Before you start

There are a few important "minor details" and tips which you should read carefully before you start to build the models.

Fitting cables and plugs

First prepare the plugs as shown in Fig. 1. Cables of different lengths are used to connect motors, lamps, sensors and the power supply. Cut off six sections from the 2-core cable enclosed with the kit:

6 sections, each 30 cm long
2 sections, each 40 cm long

Then carefully cut open the ends of the 2-core cables with a pair of scissors to a length of about 3 cm (Fig. 2). The ends of the cables must be stripped. To do so, score carefully around the insulation with a penknife, about 4 mm from the end. Take care only to score the insulation and not to damage the fine copper cores of the cable.

Then bend back the copper wires over the insulation and fit a plug to each end. Undo the screw in the plug to do so, and insert the end of the cable. Then tighten the screw gently, taking care not to squeeze the insulation too hard (Fig. 3).

The polarity of the components is important in some circuits, in other words it sometimes makes a difference which way round you connect a component. The kit contains red plugs and green plugs, so that you don't get them mixed up later on when you connect them up; the colors have the following meanings (Fig. 4):

o Red plug = (+)
o Green plug = (-)

Plugs with the same color must thus be connected to both the ends of each cable core - green to one core and red to the other.

Power supply

Power is supplied to the models either via the battery holder and a 9 V battery (Fig. 5) or by the power supply unit, Art. No. 30180 (Fig. 6). This has two pairs of jacks (in other words four altogether) marked (+) and (-). The two (+) jacks and the two (-) jacks are connected together inside the power supply; it therefore does not matter which of each pair you use. It is however important to connect the power supply unit correctly, since the model will not work if it is connected the wrong way round, and you may even damage components.

Fig. 5:
Watch out for leaking batteries! If you do not intend to use the power supply for some time, it is advisable to take the batteries out of the casing and to dispose of them at a collection point for problem waste.

Fig. 6:
Important: The power supply unit must be checked at regular intervals for any signs of potential danger, such as damage to the cable, plug, casing or any other parts. If any such damage is found, the toy must not be used again until it has been properly repaired.

Mounting the alarm buzzer

Before you can use the buzzer, you must stick it onto a 15x30 mounting plate. A self-adhesive disk glued on both sides is enclosed. First peel off the backing foil from one side of the disk, then stick the disk onto the underside of the buzzer and press it on firmly.

Then peel off the backing foil from the other side and stick the buzzer onto the mounting plate (Fig. 7). One red plug and one green plug should be connected to the ends of the cable (red cable = (+)).

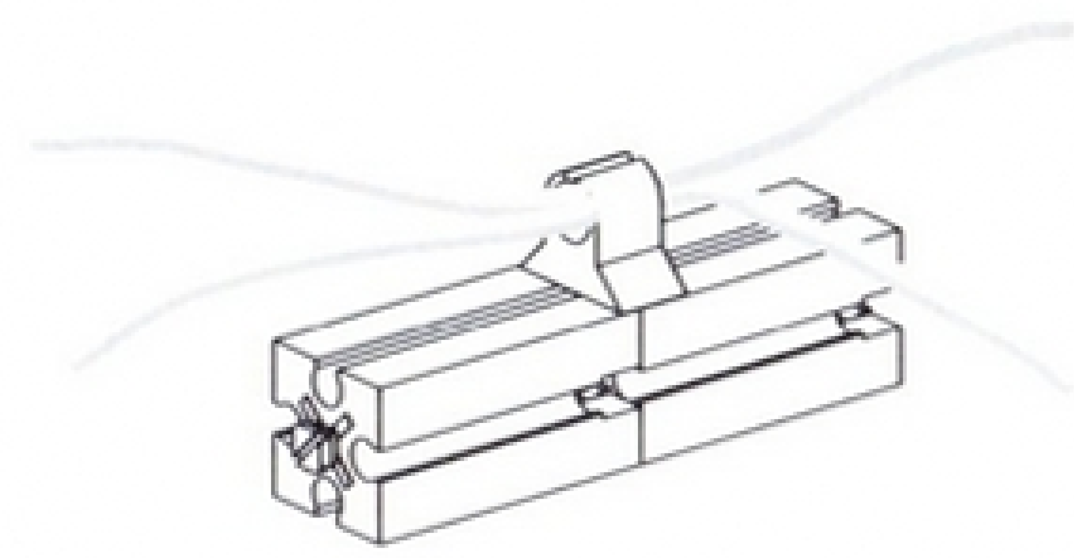
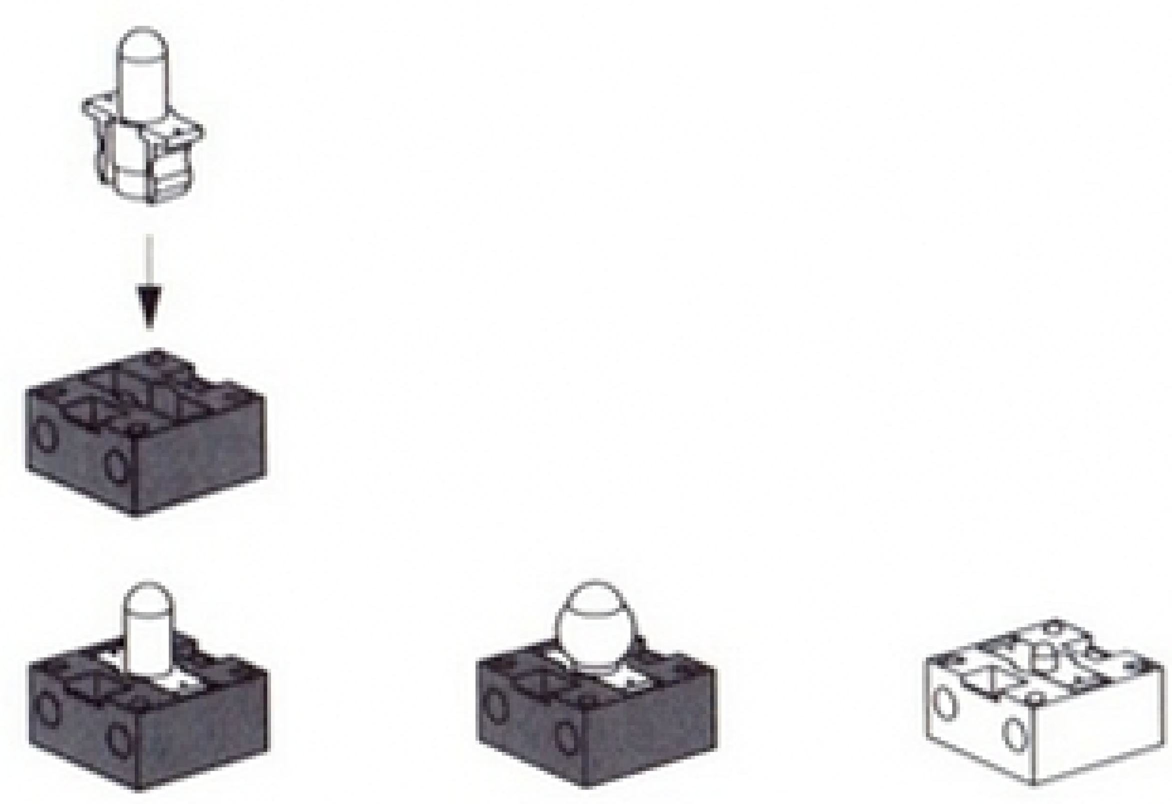


Fig. 8 Reed contact holder used as cable clip



Ball lamp   Lens bulb   Photo-transistor

Fig. 9 Light holder with lamps and light sensor (photo-transistor)

Fig. 8 demonstrates that the reed contact holder is also suitable for bunching cables together, while Fig. 9 shows combinations of light holders and lamps.
Fig. 10 shows how to assemble the hinged block comprising parts 31426 and 31436.

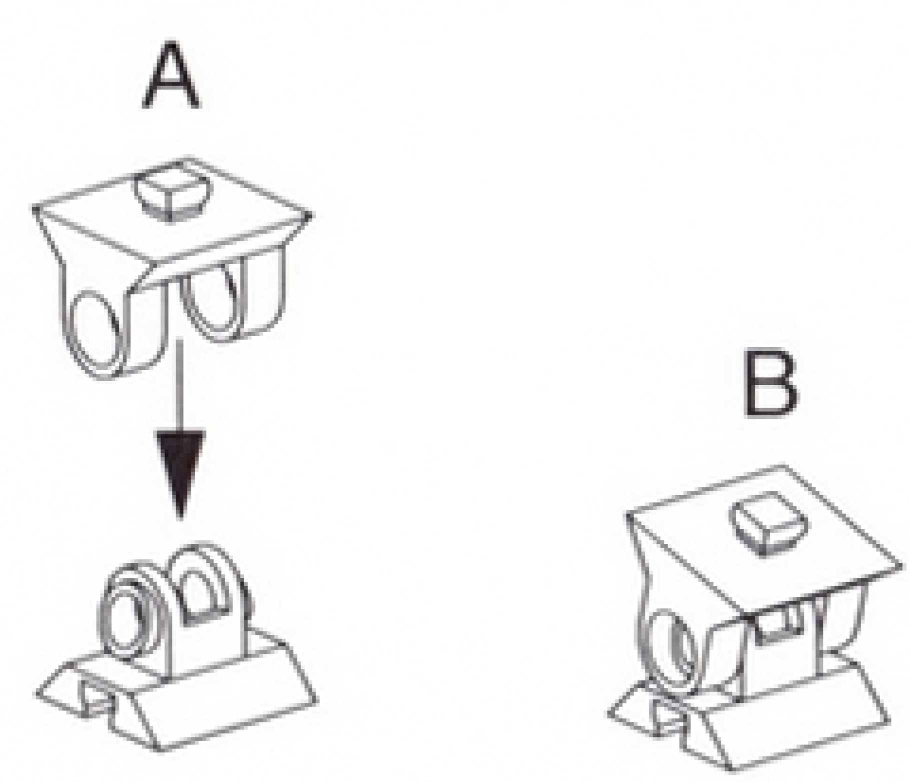


Fig. 10 Assembling the hinged block

The basics of electrical engineering

Current flowing in a circuit

Not all substances conduct electricity equally well. A current flows especially well in metals, for example in the thin copper wires used in fischertechnik kits. Brass, iron, lead, tin and fischertechnik metal axles are also good conductors. If two conductors come into contact with one another, the current can also flow across the point of contact (we benefit from this characteristic, for example, when we connect plugs and sockets). Water conducts electricity too, by the way, though not quite as well. This is why we must always keep electrical equipment and circuits dry.

Other substances are either poor conductors of electricity or do not conduct it at all. This is the reason for using plastic to protect the copper cores of the cables against accidental contact, plastic being a so-called "insulator", i.e. a definite non-conductor. Air, glass, dry wood and the majority of non-metal substances are also insulators.

A power source, e.g. a battery or a separate power supply unit, is needed to operate electrical loads (lamps, electromagnets, motors). Imagine the power source to be like a water pump, which pushes the electricity through the cables and the loads. Like the pump in an aquarium, it needs a closed circuit for the current to be able to flow (Fig. 11). The electricity flows through the "go" line to the load and then back through the "return" line to the power supply. If the circuit is interrupted at any point, the electricity is no longer able to flow.

In the same way as the pump can generate a particular water pressure, depending on its capacity, different power sources can supply different voltages (measured in volts). The power supply unit, for example, supplies 8 volts, while a normal power outlet supplies 220 volts, or in special cases 380 V. Above a particular level (around 50-60 V), the voltage starts to become dangerous as far as people are concerned. The components in the fischertechnik kits operate with a safe voltage of 6-9 V; you must never use them with a higher voltage, or you may damage them beyond repair. Now you can see the point of the power supply unit: it turns the 220 V which comes out of the power outlet into the safe voltage you need to operate your fischertechnik models.

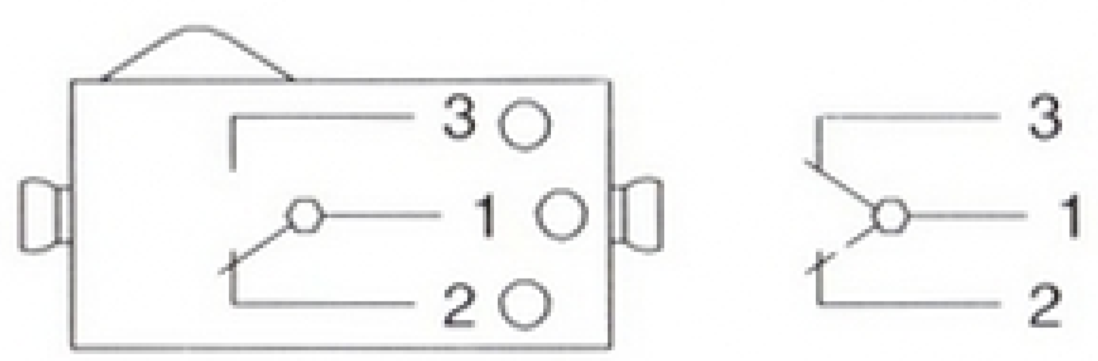
Every load requires a particular amount of electricity - once again like the water flowing through a pipe. And just as a water tap puts up a resistance against the water flow, the load acts as a resistance against the electric current. The lower the resistance of the load, the higher will be the current and vice versa. The intensity of the current is specified in electrical engineering in "amperes" (abbreviated to "A"), e.g. if you look on the circuit-breaker in your house, you will normally find either "10 A" or "16 A" indicated. The fischertechnik power supply unit supplies a current of up to 1.5 A. When we move on to the flip-flop later in this manual, you will discover components whose resistance can be altered - an engineer would call them variable resistors or potentiometers. Some of the sensors also behave like variable resistors, e.g. the temperature sensor.

If one of your circuits doesn't work for some reason, you should therefore start by chekking all the contact points, e.g. for loose plugs or loose cable connections in the plugs. Just by pulling a cable too hard too often, you can cause its copper cores to break or tear. The consequence is a "loose contact" - a little mischief-maker which only gives you trouble some of the time, but is all the harder to locate as a result.

Electrical engineering "all mapped out"

In the same way as you need a map to find your way around a strange town, you will not get far in electrical engineering without another kind of map - the "circuit diagram". And just as a city map is not an aerial photograph, including such things as houses and trees (which would only make it confusing), a circuit diagram does not shown realistic drawings of cables, lamps, switches and motors. Instead, each component is represented by a simple symbol, and the connecting cables between the components are shown as lines. If there is

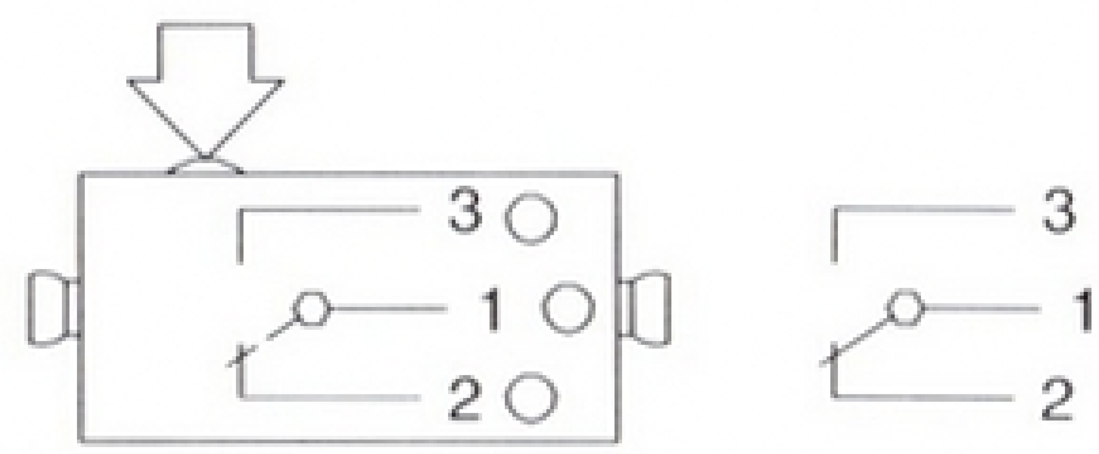
an electrical connection between two cables, a large dot will mark the connection point. If two lines intersect without a point, there is no electrical connection.
However, there is no need for us to simplify our circuit diagrams quite as much as an engineer would. When you study a fischertechnik circuit, you will still be able to see at a glance which component is which.
The parts list in the Annex contains all the graphical symbols used in fischertechnik diagrams and article numbers.
The switches have three connections (terminals): the middle terminal (1) is movable and is connected to the bottom terminal (2) when it is not actuated; the latter is therefore known as a normally closed contact or break contact. If the switch is pressed, the contact is reversed and a connection is formed between the middle terminal (1) and the top terminal (3), the normally open contact or make contact (Fig. 12).



Switch in normal (off) position

Contact between 1 and 2

Switch in working (on) position



Switch in working (on) position

Contact between 1 and 3

Fig. 12

The light holder comprises a plastic base with two little tubes, between which you can fit the lamp. You can thus connect the power supply either to one end or to both ends (Fig. 13). If you connect both the power supply plugs to the same tube however, you will cause a short-circuit (Fig. 14)! Since the tubes are like socket connectors, you can save on cables if you connect two lamps together as shown in Fig. 15.
There is an additional rule to remember about the motors. With a lamp, it is irrelevant which way round you connect it; the lamp lights up whenever the circuit is closed. With a motor, on the other hand, the direction in which it rotates depends on the polarity of the terminals, in other words where (+) and (-) are connected. You can perform a simple test with the power supply unit and a motor. Connect the two together. The motor rotates in one direction. If you then swap the motor connections around, the motor will turn in the opposite direction. If a motor turns the wrong way, all you need to do is to reverse the terminals.
You can use the same motor to perform another small experiment, which will help you to understand circuit engineering better - it demonstrates a principle known as "bidirectional motor control". You can always reverse the direction of rotation if you want by swapping the connections around. This is a very complicated way of doing things however. It is much more practical to set up the circuit shown in Fig. 16. You will need the power supply unit, two switches and a motor. Connect the components together as shown in the top diagram (Fig. 16a). Next to the wiring diagram of the type used in this experiment manual you can see the same circuit as it would be drawn by an engineer.
If the motor starts up as soon as you plug in the power supply unit, one of the switches is connected the wrong way round - in this case please reverse it, as the motor should be stopped when both the switches are in their normal (off) positions.
If you press the left-hand switch (see middle diagram, Fig. 16b), the current will flow from right to left and the motor will turn in one direction. If you press the right-hand switch, on the other hand (see bottom diagram, Fig. 16c), the current will flow from left to right and the motor will turn in the opposite direction. If you press both switches, the motor will come to a standstill again, since the circuit is no longer closed. You can use this two-way circuit, for example, to control a crane.

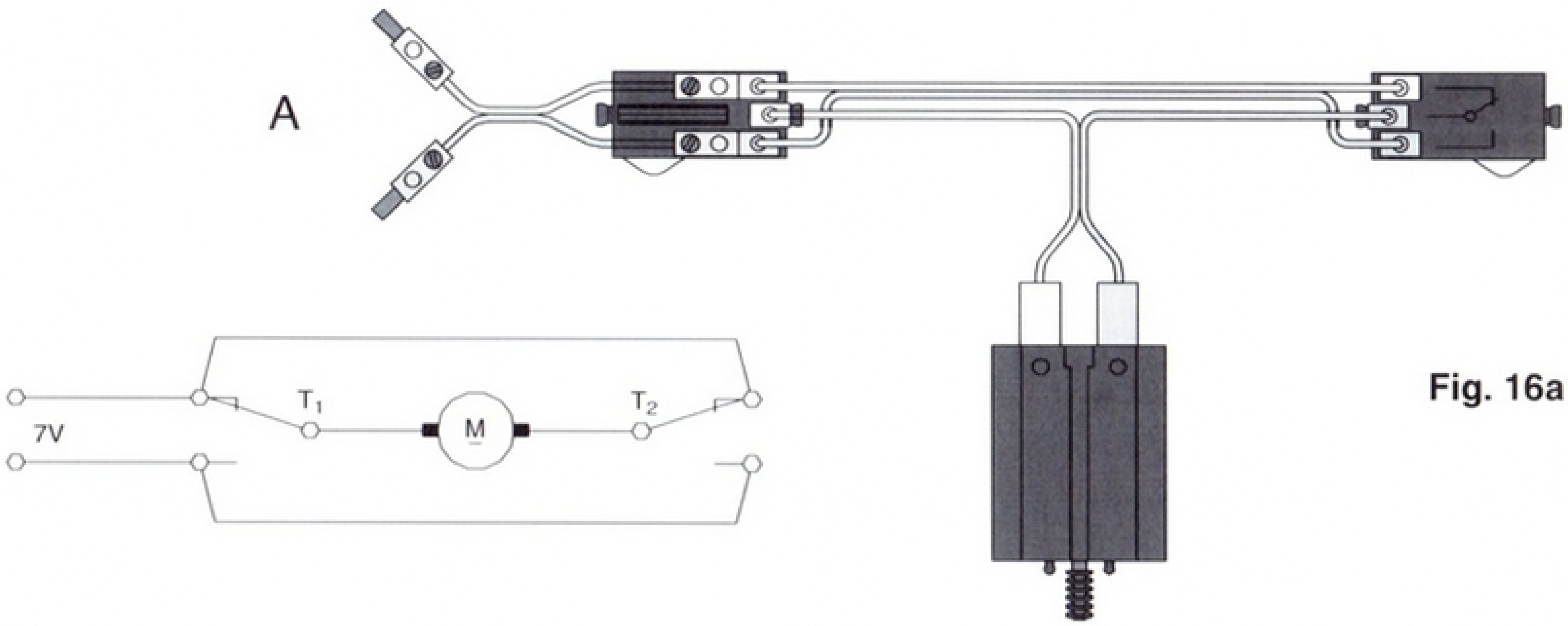


Fig. 16a

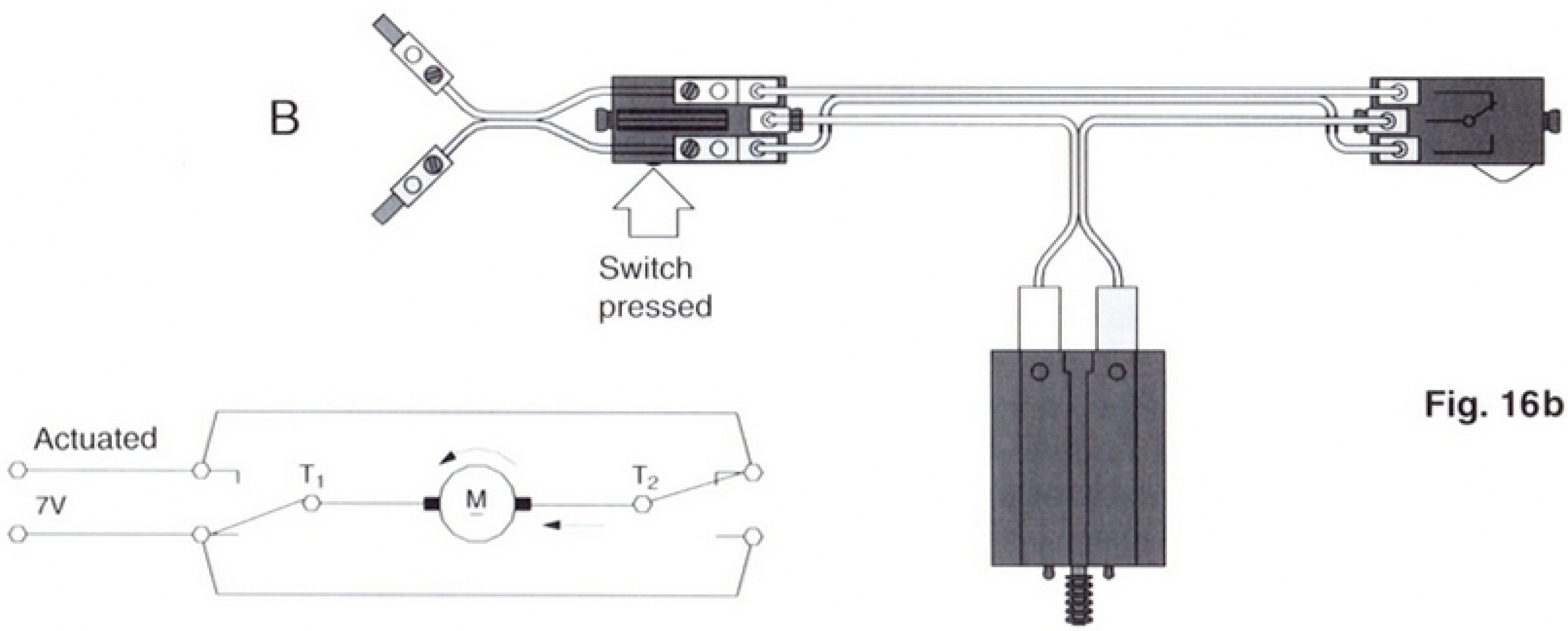


Fig. 16b

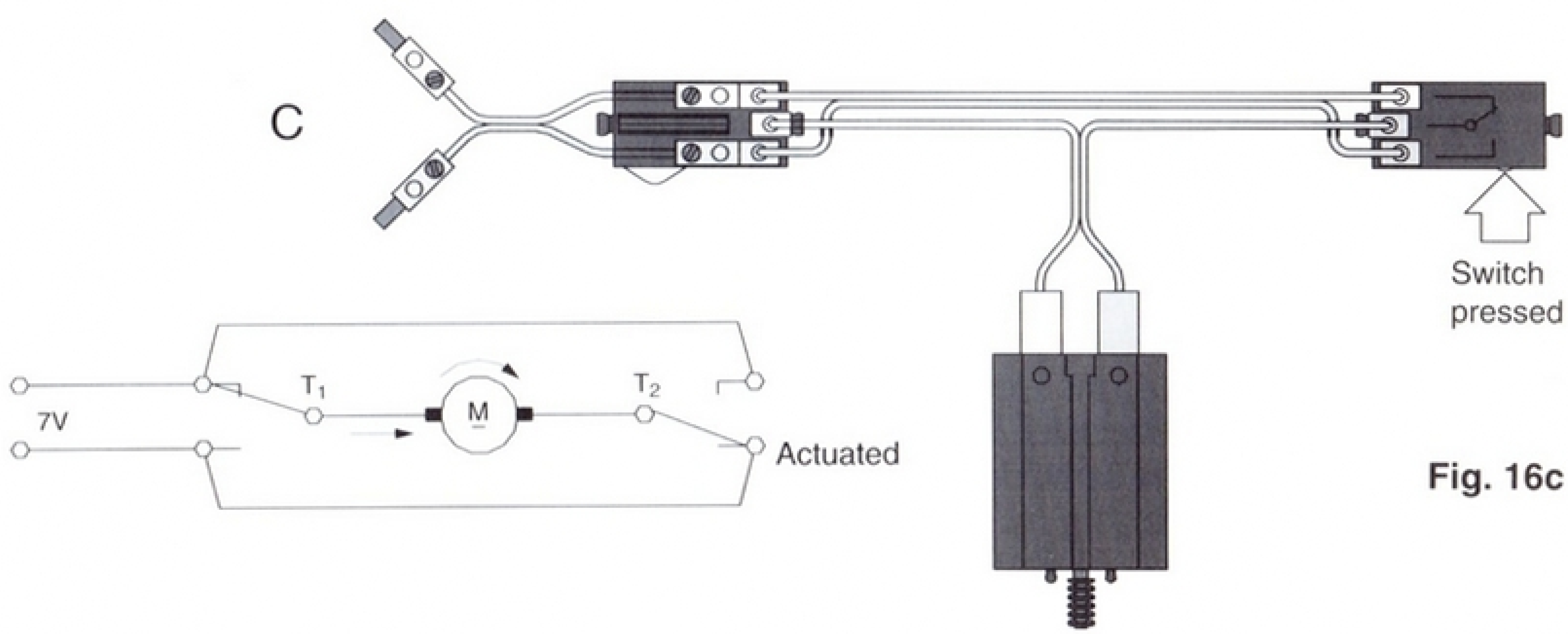


Fig. 16c

Description of components

1. Motor Electric DC motor
Operated with a direct voltage drawn directly from the power supply unit (6-9 V).

2. Gear Reducing gear 65:1
Without the gear, the models would run much too fast and the motor wouldn't be able to produce enough power.

3. Heat sensor NTC resistor
The value of this resistor changes according to the temperature. Its resistance is reduced when the temperature rises - it conducts electricity better when its environment is hot. An engineer would say "The resistor has a negative temperature coefficient" (this is what NTC stands for). The resistance is 60 k_ when the temperature is 20 °C.

4. Light sensor Photo-transistor
The photo-transistor conducts electricity better the more light it has. It is the only component which must always be connected a particular way round. The photo-transistor must also always be connected to the input of the flip-flop, since it cannot provide the high current required by a motor or a lamp. Maximum voltage: 12 V.

5. Magnetic sensor Reed contact
The reed contact is a small tube containing a switch which is sensitive to magnetism. If you move a magnet up close enough to the reed contact, the switch will close. Maximum voltage: 12 V.

6. Switch The switch is used for manual switching functions. It contains a changeover contact.

7. Buzzer DC buzzer, maximum voltage 12 V.

8. Flip-flop Electronic changeover switch with amplifier
The flip-flop contains two input amplifiers for the sensors, an electronic changeover switch and a relay (which is actually an electrically controlled changeover switch) for connecting lamps and motors. The chapter called "Your first experiments with the flip-flop" tells you more about it.

Note: All the electrical components must always be operated using a fischer-technik power supply (power supply unit or batteries), since they may other wise be destroyed if the operating voltage is too high.

Your first experiments with the flip-flop

The flip-flop is the most important component in this fischertechnik kit, since several different electronic functions are all integrated in it. On the other hand, putting all the electronics in the same component makes the circuits for the models all the more simple.

Prepare the experiments described in this chapter by constructing the circuit shown in Fig. 17. Make sure when you connect the flip-flop to the power supply unit that the poles are the right way round - otherwise it won't work.

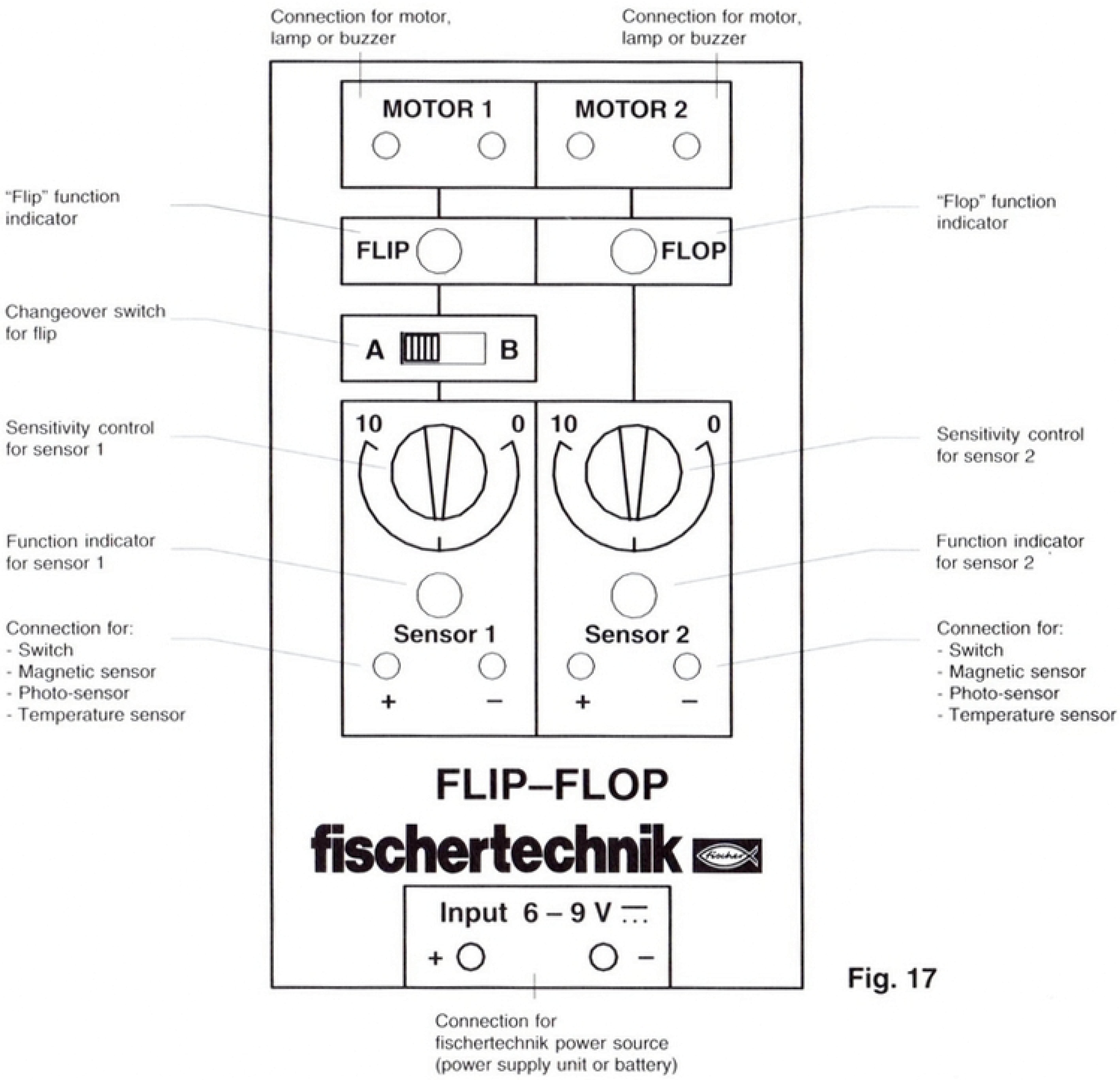


Fig. 17

Adjust the sensitivity controls to the mid-position for the first experiment (the controls should point towards the lamps) and set the switch for the flip-flop to "A" (you will have to wait until the second experiment to find out what this switch does). The sensitivity controls are in fact variable resistors - what the professional would call "potentiometers".

Flip-flop with switch

If you now connect the circuit shown in Fig. 18 to the power supply, none of the lamps at the sensor inputs should light up (if they do, the experiment will not work). The flip-flop must be set to the "flop" position and the red lamp must be lit. Then press the flip switch briefly. What happens?

The electronic changeover switch changes to the "flip" position, the red lamp goes out and the green lamp comes on. At the same time the motor starts up. Even if you release the switch, the flip-flop will remain in this position. This is what the engineer calls "setting the flip-flop". You will probably already have guessed how to turn the motor off again. Right first time! If you press the flop switch, the electronic switch will change back to "flop" and the motor will come to a standstill. The engineer says that the flip-flop has been "reset". Something to remember:

Press flip switch = Set flip-flop Press flop switch = Reset flip-flop

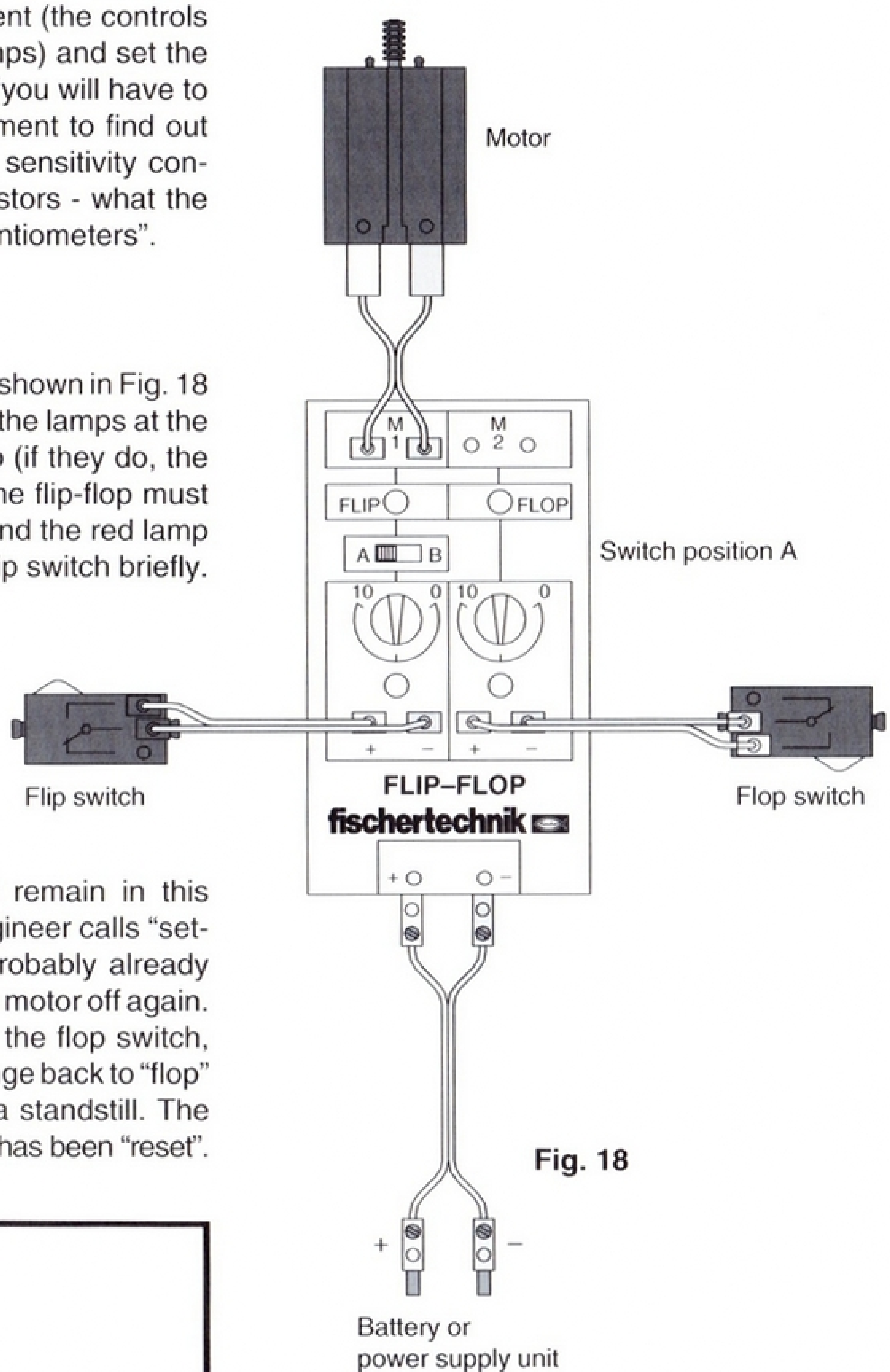


Fig. 18

Now try pressing both switches at once. Both the lamps light up and the motor starts running. This is known as a "prohibited" condition (don't worry - you won't break anything!). It is only called that because it is not "stable". Depending on which of the two switches is released again first, the flop-flop remains set either to the "flip" condition or to the "flop" condition.

Now connect the motor to the "motor 2" output instead. Doing this reverses everything: "flip" stops the motor and "flop" starts it - as you have probably guessed! Connect the motor back to the "motor 1" output and continue with the next experiment.

Flip-flop with photo-sensor

The switch allows you to invert the function of the connected sensor; if you use a photo-sensor, for example, the flip-flop can be set either by dark (switch position B) or by light (switch position A).

Now connect the photo-sensor in place of the flip switch, as shown in Fig. 19.

> Make sure that the polarity of the photo-sensor is correct when you connect it - the "sensor 1" (+) terminal must be connected to the marked side of the photo-transistor.

Set the flip-flop switch to the "B" position. This causes the photo-sensor to be illuminated by the light in the room (either sunlight or a lamp), and the lamp at the "sensor 1" input should light up. If you then cover over the photo-sensor with your hand, the sensor lamp will go out and the flip-flop is set. It can be reset again with the flop switch. If this experiment doesn't work properly straight away, try adjusting the switching threshold with the sensitivity control (if you turn the knob towards "10", the sensitivity to light is reduced, while if you turn it towards "0", the sensitivity is increased). The first model demonstrates one of the things you can do with the photo-sensor.

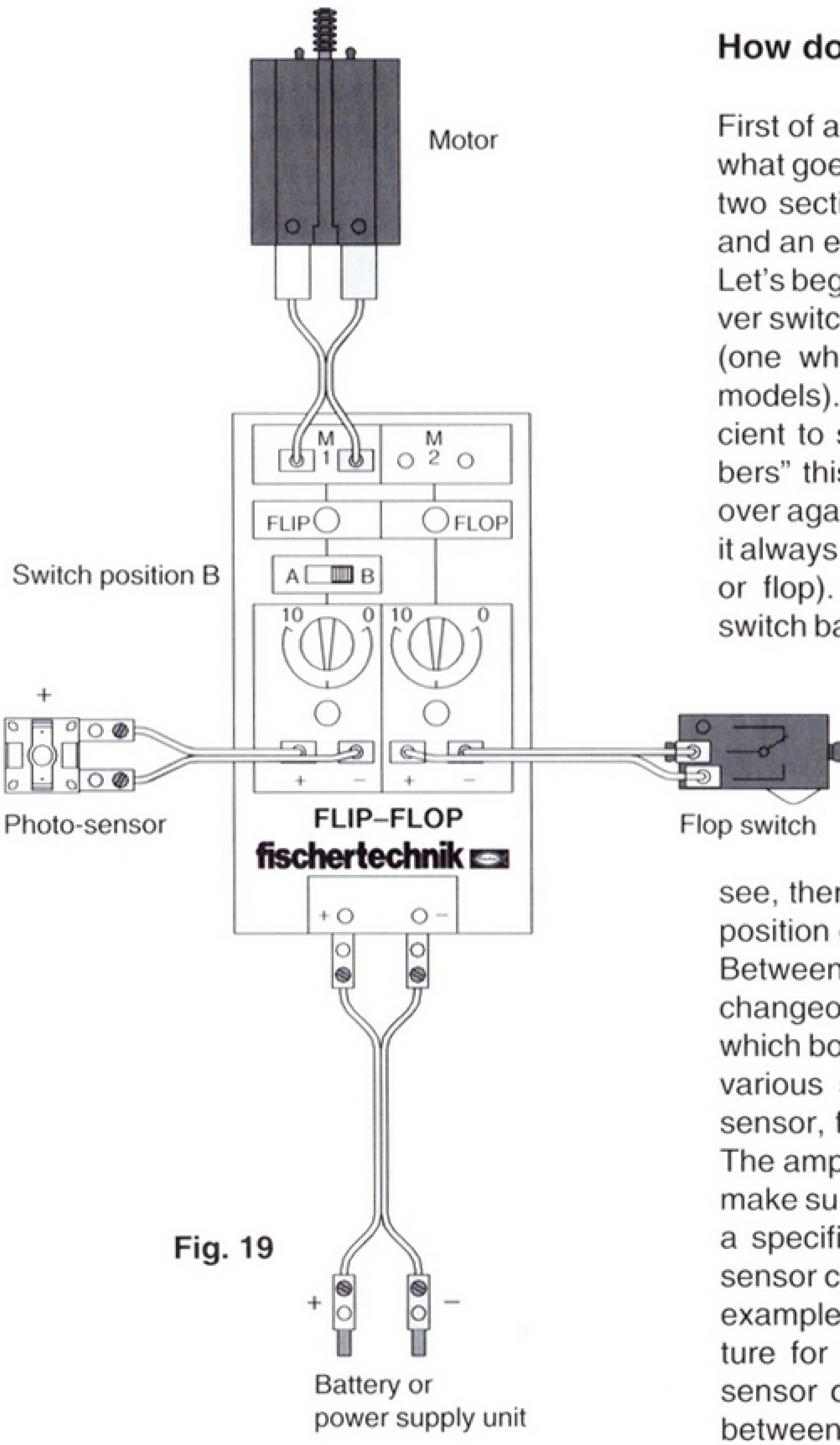


Fig. 19

How does it work?

First of all, however, you need to learn about what goes on inside the flip-flop. It consists of two sections: two amplifiers for the sensors and an electronic changeover switch.
Let's begin with the section with the changeover switch, which has a special characteristic (one which is extremely important for the models). A very short current surge is sufficient to switch the flip-flop. It then "remembers" this switch position until it is switched over again (this is the reason for its name, i.e. it always stays in one of the two positions - flip or flop). The flip-flop needs two inputs to switch back and forth; they are called "sensor 1" and "sensor 2". You can tell the position of the flip-flop from the two lamps in the "flip" and "flop" fields, and of course from whether or not the motor at output 1 is running. As you can see, there is also a different output for every position of the electronic switch.
Between the sensor inputs and the electronic changeover switch there are two amplifiers, which boost the weak current supplied by the various sensors (light sensor, temperature sensor, for example) to the necessary level. The amplifiers also have a second task; they make sure that the flip-flop is only switched at a specific sensor current. You can set this sensor current with the sensitivity control, for example in order to set a particular temperature for the "egg cooler" model. When the sensor current is sufficiently high, the LED between the control and the output jacks lights up as well.

Building the models

The models themselves must be constructed step by step, as shown in the assembly diagrams. Each time you proceed to the next step, the new components are illustrated in color. If they must be built onto a part which is already assembled, this part is shown in white. Before you begin a new step, sort out all the components you need and then build them onto your model. The next step never starts until you have used up all the parts. Make sure that you fit the building blocks the right way round, so that you don't get stuck later on.
It's also very important to tighten the axle screwings (e.g. hubs) properly.
That's all the preparation you need. You are now ready to read through this instruction manual at your leisure, and to stop to browse every now and then if you find something interesting. Since the flip-flop is the component which controls all the Sensoric models, it is best to start with the chapter entitled "Your first experiments with the flip-flop", and then to choose your first model to build.

Hand drier

If you wash your hands at home, you use a towel afterwards to dry them. If you use the toilet in a hotel or a restaurant, along with a lot of other people on the same day, things aren't quite as simple, as one towel between all the guests very soon becomes wet and dirty. A hand drier is often used instead; it works like a hair drier and dries your hands with warm air. You switch it on by pressing a button. The drier then switches itself off again after a fixed time by means of a built-in time-delay switch.

The principle of the fischertechnik model is similar - it also dries your hands with an air stream - except that you switch it on with the photo-sensor rather than having to press a button. This is so that you don't have to fiddle around with wet hands. There is a switch to turn the drier off again (when your hands are dry).
The model doesn't use any form of heater, because the power supply would be much to weak to provide the high current needed by the electric filaments. You will discover, however, that the air still has a good drying effect at room temperature.
The hand drier can of course also be used to dry other things, for example a picture that you have painted in water colors or a photo you have enlarged yourself, though you may have to adapt the model slightly. For now, we shall stick to building the basic model.

The model's "fan" is not terribly complicated; it simply consists of a motor with a propeller, which is mounted leaning slightly forward on a column made of fischertechnik building blocks. The photo-sensor is used as a light barrier to turn it on automatically. At the bottom of the round frame of the propeller is a light holder with a plug-in lens bulb, while at the top is the photo-sensor in a yellow light holder with a masking light cap.
After you have built the model (the various steps are described on pages 25-27 of the German manual), you must wire up the electrical components - but don't worry, it's not too difficult if you follow the circuit diagram.

> Make sure you connect the photo-sensor the right way round, i.e. with the correct polarity, or the hand drier will not work.

You can now connect the power supply unit and start the first test. As soon as you put your hands in the space between the light holder and the photo-sensor, the flip-flop is set and the motor starts up automatically. You must adjust the sensitivity with the knob for the flip-flop in order for the light barrier to function correctly. If the motor rotates in the wrong direction, the propeller will "suck" instead of "blowing". In this case you must reverse the poles of the motor. When your hands are dry, press the switch to reset the flip-flop, and the

motor will stop again.
If the drier doesn't work straight away, check the circuit: Is everything the way it should be according to the circuit diagram? Is a plug loose anywhere? Are all the cables conducting properly? Is the polarity correct? Is any voltage being supplied at all by the power supply unit?

How does it work?

The photo-sensor (light sensor) is used as a light barrier in this model. A light barrier always consists of a light source (lamp, LED, etc.) and a photo-sensor (photo-transistor, photo-diode, photo-resistor, etc.). The light source and the photo-sensor are always located in a direct line, in other words with direct "visual contact" (Figs. 20, 21). You can also arrange the light source and the photo-sensor adjacent to one another if the light beam is reflected by a mirror. A special reflector, like the one you have on your bicycle (at the front), is normally used for this purpose, so that minor inaccuracies in the setup do not matter.

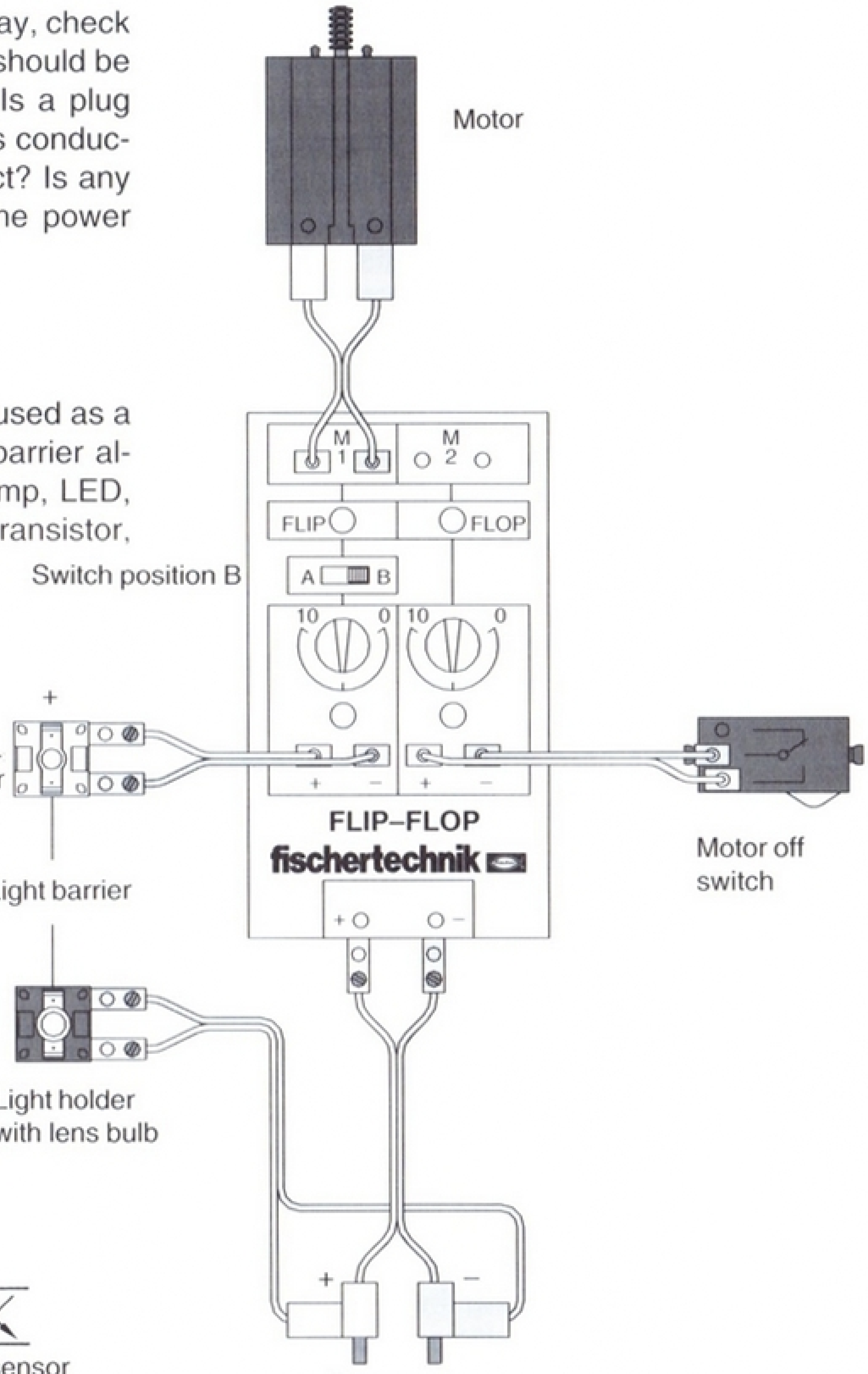


Fig. 20

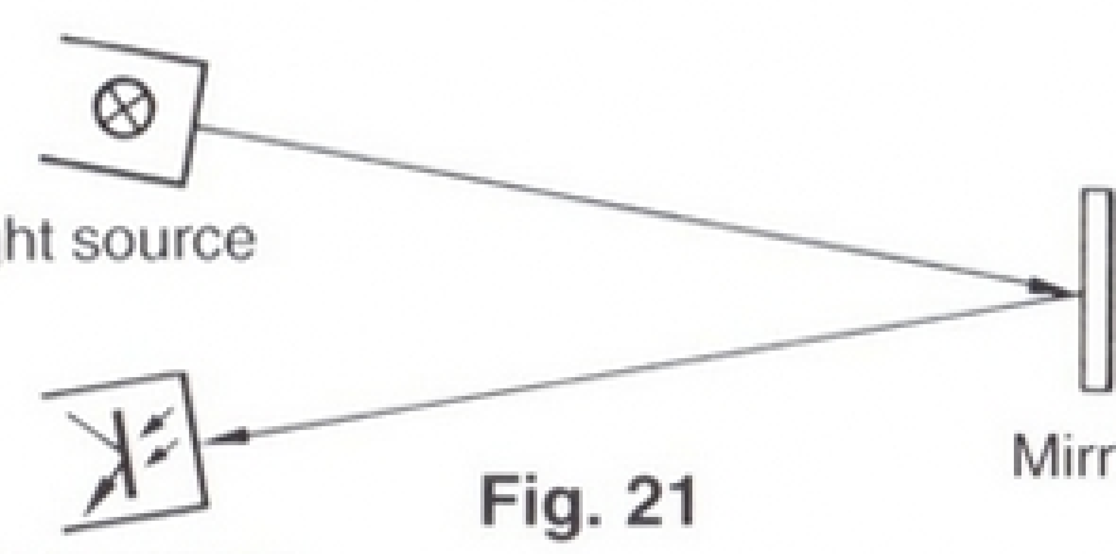


Fig. 21

Note on page 26, Fig. 4 in the German manual:
To avoid any risk of injury, never touch the rotating propeller while playing with your model.

The fischertechnik photo-sensor is a photo-transistor, which conducts electricity better the brighter its surroundings. Thus, when it is illuminated by the lamp, it conducts particularly well; in technical terms, it is said to have a low internal resistance. As soon as anything interrupts the light beam, the internal resistance is increased and the flip-flop connected to the sensor is set. The knob for the sensitivity at the input of the flip-flop should be adjusted so that the flip-flop is set properly, in other words when there is a continuous light beam,

everything stays as it is and when the light beam is interrupted, the flip-flop is set. You may have to try this out a few times until you find the right adjustment.
Light barriers are also used in lifts (so that nobody gets stuck in the automatic door), in garage entrances (so that the barrier remains open until the car has passed through), in automatic door openers and in alarm systems (the alarm is set off if a burglar interrupts the light beam).
The resistance of the photo-transistor is of course also low if sunlight or the light from a lamp shines on it (this is why it is fitted at the top of the model). Professional systems consequently work with infrared light, which is invisible to the human eye, and do not emit light the whole time, but instead send out short flashes in rapid succession (up to 40 000 flashes per second; an engineer would say that "the light has a clock frequency of 40 000 Hertz). Upstream of the photo-sensor is a filter, which only lets through infrared light, and the amplifier circuit only responds to flashes at the correct frequency.

Cash dispenser

Everybody knows the cash dispensers to be found at many banks, where you can withdraw money if you have a cashpoint card or cheque card and know the secret code number for it. All you have to do is insert the cashpoint card in the machine, key in your personal identification number and the amount of money you want to withdraw, and the money is ejected into the tray.

You don't need a real cheque card to be able to use the fischertechnik model. You can make your own "cashpoint card" from cardboard. But first of all you must build the model. The various steps are described on pages 31-34 of the German manual. Make sure that the tube is not directly touching the plate underneath; you must leave sufficient space for a coin to be able to slide out horizontally.
Fill the tube with coins. If you then insert the cashpoint card in the slot to start a payment (by setting the flip-flop), the motor begins rotating and the crank drive moves the slide forward. This causes the bottom coin to be pushed forward out of the tube and to drop into the tray. The motor carries on turning until it actuates the switch with the cam, thereby resetting the flip-flop and cutting off the motor current (assuming you have already removed the card again after releasing the reset switch).
You can test the mechanics of the dispenser without the flip-flop by connecting the motor directly to the power supply unit. Then connect the electrical components together exactly as shown in the circuit diagram. A useful tip: Connect the motor cables before you install the motor, since the terminals will not be as easily accessible afterwards.

> Make sure you connect the photo-sensor the right way round, i.e. with the correct polarity, or the cash dispenser will not work.

The "cashpoint card" is detected by a light barrier, the same as the one used for the hand drier in the previous chapter. You can "code" the card by cutting out a notch at a particular point along the edge, so that when you insert the card, the light beam from the lamp has a direct path to the photo-sensor and the payment operation is set off. Any notches elsewhere in the card have no effect (the position of the light barrier serves as the so-called "code"). The position of the notch is shown in the diagram on page 33 of the German manual. To make the card, simply cut out the shape from a piece of dark cardboard (it should be the same size as the phonecard illustrated at the top right on page 35 of the German manual) and then cut a notch at the point shown. (Please don't use your parents' cheque card or credit card to do this!)
Hang on a minute! If there is no card in the slot, can't the light beam also shine directly on the sensor, so that the machine dispenses money the whole time without a card at all? The answer is no - the switch at the end of the slot stops it from doing so. The light barrier is

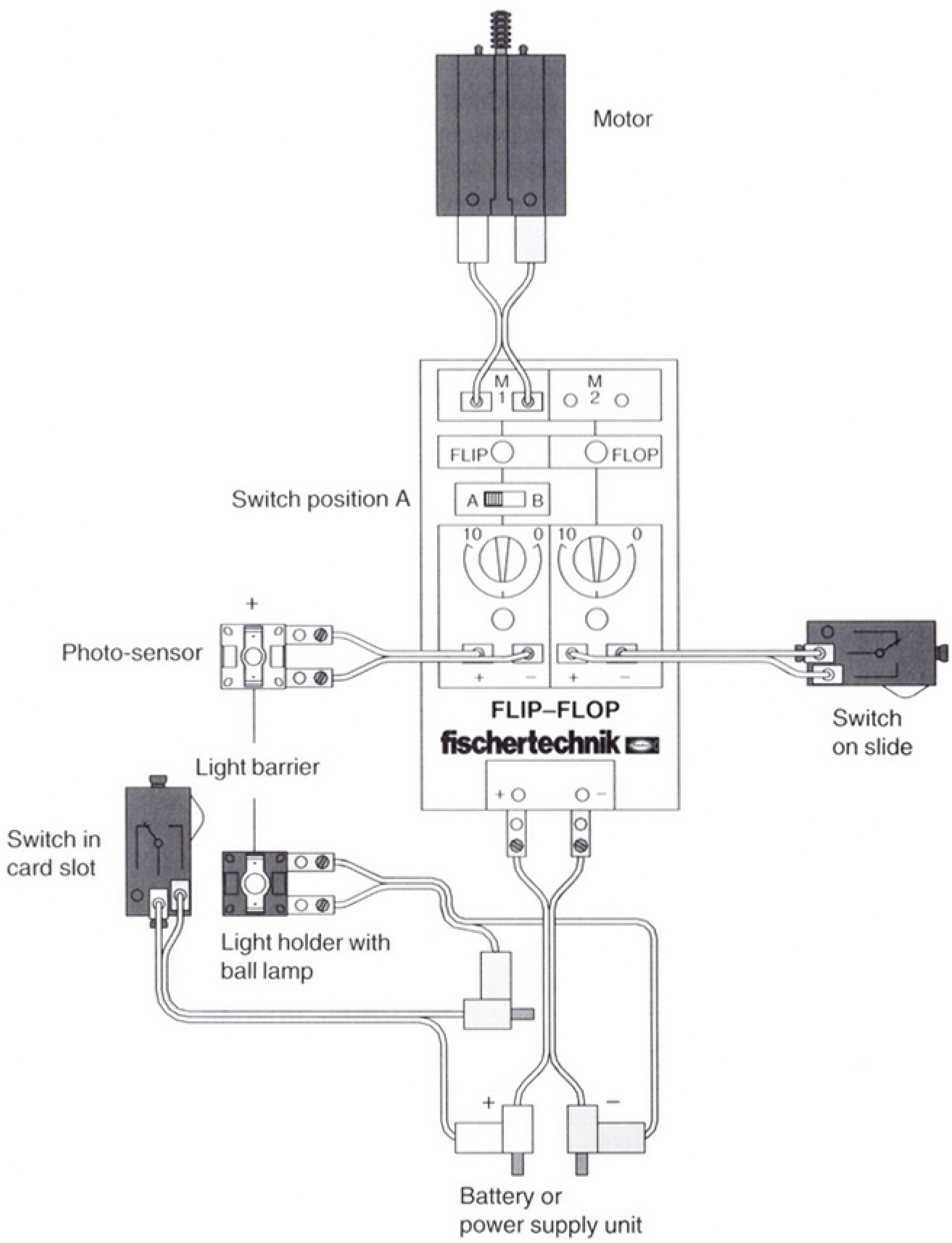
not taken into account until the inserted card actuates the switch. There are thus two conditions which must be satisfied before money is paid out:

Switch pressed AND notch in the right place in the card

The switch and the lamp are in other words connected in series (one after the other). A current cannot flow through the lamp unless the switch is pressed (the photo-sensor cannot "see" anything as long is it is not pressed).

How does it work?

With a real cashpoint card, things are more complicated than with the model - after all a lot more money is at stake. A magnetic stripe, in which such information as the bank account number, the transit number (bank code), the date of the last withdrawal and the personal identification number is stored, is adhered to the back of the cashpoint card. The data is stored in the magnetic stripe in the same way as music on a cassette tape, except that the card can be "read" by a computer inside the cash dispenser.



The data is encoded in a cryptic form, so that the personal identification number cannot be read by anyone who happens to find the cashpoint card lying around. Even somebody who has a computer and a reader for magnetic cards cannot get at the personal identification number. The computer inside the cash dispenser reads the card and decodes this number. A person who wishes to withdraw money must key in the number at the machine; the computer then compares it with the number stored on the card. It only produces the cash if the two numbers are identical.

You don't necessarily have to use a magnetic stripe to store the data - there are a number of other ways as well:

The writing on the card is printed using a special type face which can be interpreted by the computer. Sometimes the personal identification number is printed on the card in this special writing. The card is also said to be "machine-readable".

If security is not that important (for example for entrance to a garage or car park), a bar code can be printed on the card instead, such as the ones you often see on food packaging. The lines which make up the codes have different thicknesses and the spaces between them have different widths. Numbers can be represented by the order of the lines and the spaces between them. The bar code is then read using a special type of light barrier. The light beam is concentrated by various lenses and the line thickness determined from the narrow beam which results. Fig. 22 shows an example of a bar code.

You will no doubt often have come across telephone boxes with a narrow slot on the front, rather than a slot for inserting money. These "card phones" are paid for with a "chip card", which you can buy from the Post Office or from certain shops. The card is the same size as a cheque card, but has a field containing contacts, which are used to make an electrical connection (Fig. 23). A small storage chip, only a few hundredths of a millimeter high, is integrated in the card. Every time you spend telephone units, a small section of the memory is erased, and so on until the whole card has been "used up".

For situations where maximum security is necessary, there are chip cards which contain not simply a memory, but a complete miniature computer, which can also perform calculations and store data. In the meantime there are even cards which manage without any contacts at all and which transmit data by radio (though they only have a range of around one meter).

Egg-cooling machine

When the summer gets really hot, you long for a fan to cool yourself down. The water which cools a car engine is cooled additionally by a fan if the head wind is not sufficient on its own. You can probably think of several more examples of things which are cooled by a fan. We want to show you how to build a fully automatic, sensor-controlled egg cooler.

The egg-cooling machine looks similar to the first model - the hand drier - except that it works with a horizontal air stream and no light barrier. Instead a new sensor is used, namely the temperature sensor. There is a base in front of the propeller for the egg which must be cooled. Inside this base is the temperature sensor, which is in contact with the egg above it, and can thus determine its temperature.

The various steps for building the model and the circuit diagram can be found on pages 38-41 of the German manual - so let's get to work.

When the hot egg is placed in the holder, the resistance of the temperature sensor is reduced. First of all, the flip-flop is set with the switch (do you remember? - we explained the principle of an "NTC resistor" earlier). The motor then rotates and the propeller secured to it creates an air stream which cools the egg. When the egg has been cooled to the desired temperature, the flip-flop is reset by the temperature sensor and the propeller stops.

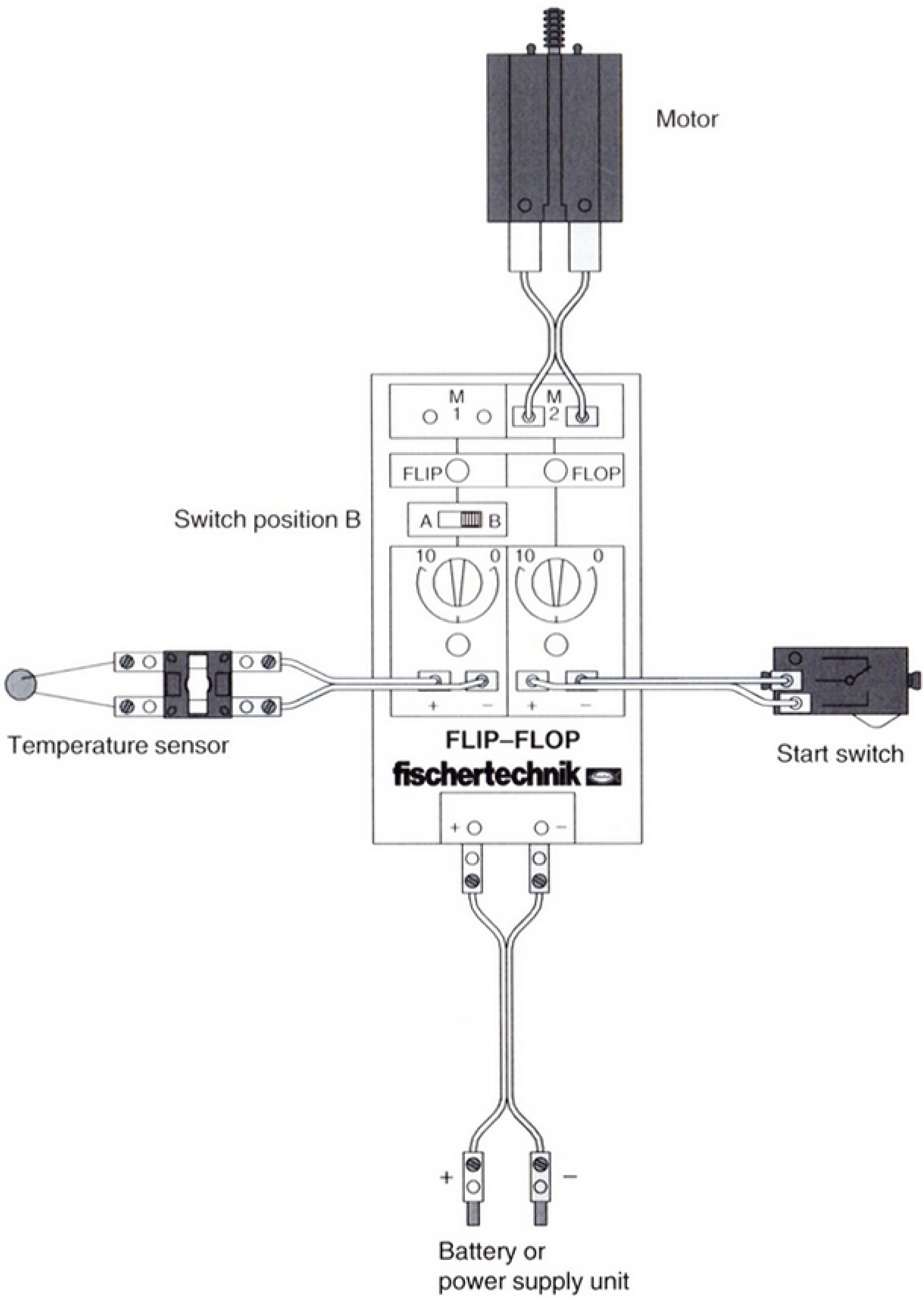
Now try out your model: place a hot egg on the base and press the switch. The motor should start running. Then remove the egg again.

After a short time (the NTC resistor must first cool down), the motor comes to a standstill. You can now adjust the desired egg temperature. First turn the knob for sensor 1 (to which the temperature sensor is connected), so that the motor also starts running if the egg is at room temperature. Then place an egg with the correct temperature on the base and start the egg cooler. Wait a short while for the temperature sensor to reach the egg temperature, then turn down the potentiometer slowly until the motor just about stops. You may have to correct this setting again slightly later on.

To avoid any risk of injury, never touch the rotating propeller while playing with your model.

How does it work?

If you remember back to the description of the components, we mentioned briefly that the temperature sensor is an NTC resistor (or thermistor). An engineer would say that the



resistor has a negative temperature coefficient (this is the meaning of the abbreviation NTC), which simply means that the resistance decreases as the temperature increases (the change in the resistance is considerable). The word "thermistor" comes from "thermal resistor".
In the same way as the photo-transistor can be used as a light sensor (which is a good conductor in bright light), the NTC resistor is a very good temperature sensor (it conducts better at high temperatures). Another use for the temperature sensor is the fan for cooling a car, which is controlled according to the same principle as the egg-cooling machine. It can also be found in heating and air-conditioning systems, where it is used to control the boiler.
When you were trying out the model, you probably noticed that it takes a short while after the hot egg is removed before the electronics respond, since the hot NTC resistor must first cool down itself. In engineering, NTC resistors are said to be "thermally inert".
You can also use the temperature sensor to perform other experiments. If you connect it to the sensor 2 input of the flip-flop (where the start button is now), you can switch on a lamp or a motor by means of heat. If you adjust the sensitivity correctly, you can set the flip-flop by means of your body temperature, just by touching the temperature sensor with your finger.

> Tip:
> If you connect the buzzer to M 1 as well, the egg cooler will buzz as soon as the egg reaches the correct temperature.

Normal metals (iron, copper, etc.) have exactly the opposite temperature coefficient (i.e. positive), in other words their resistance is increased as they heat up. You can however buy special temperature sensors with a positive temperature coefficient which is more pronounced than that of metal - so-called PTC resistors. If very high temperatures are involved, the temperature sensors which are used are made of two different metals welded together at one point. One "thermocouple" is immersed, for example, in iced water (which acts as a 0° reference, while the other element is heated; see Fig. 24). An electric voltage between 7 and 70 millionths of a volt per degree can be measured between the two thermocouples. A complex amplifier is necessary in order to display this value however.

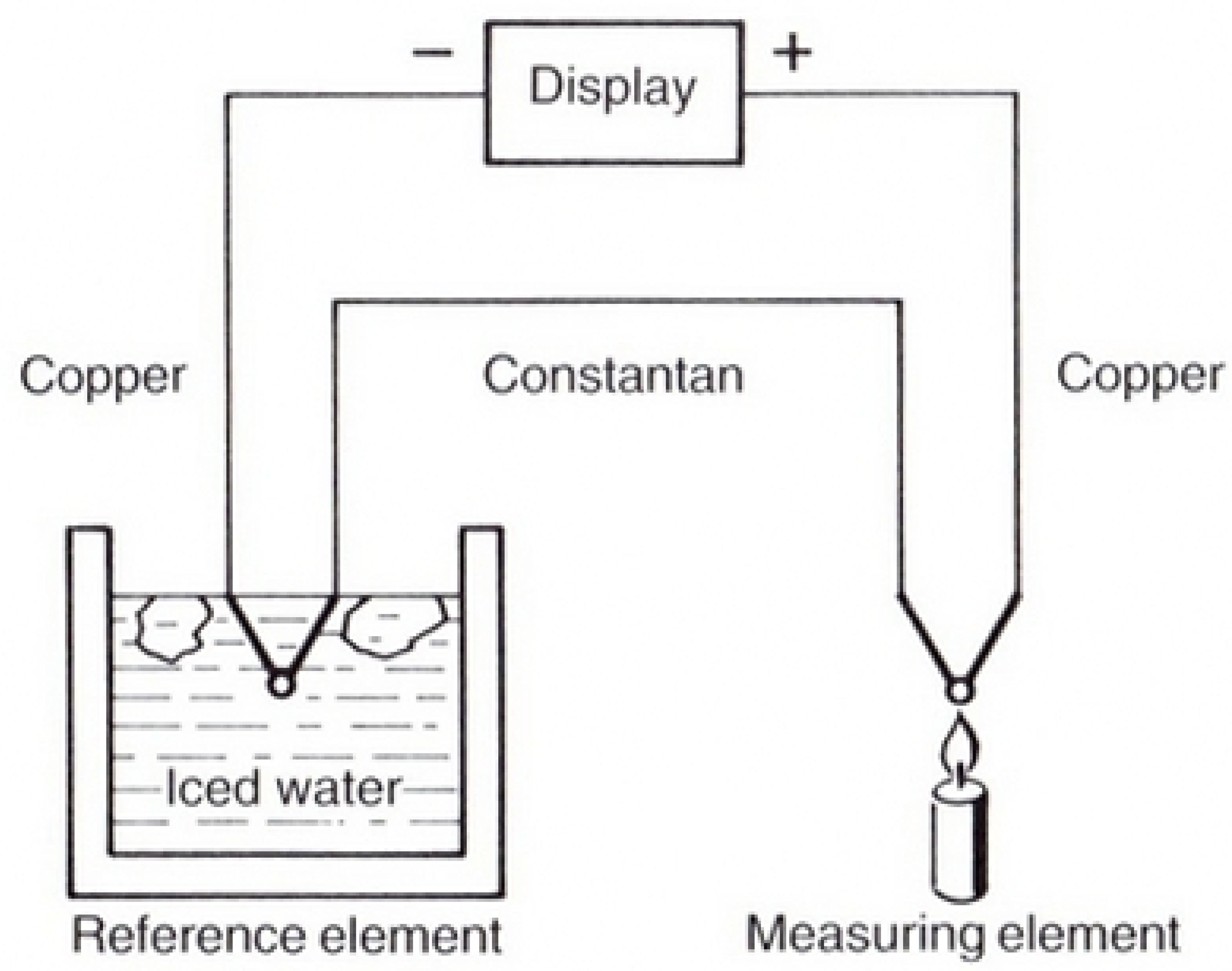


Fig. 24

Treasure chest (safe)

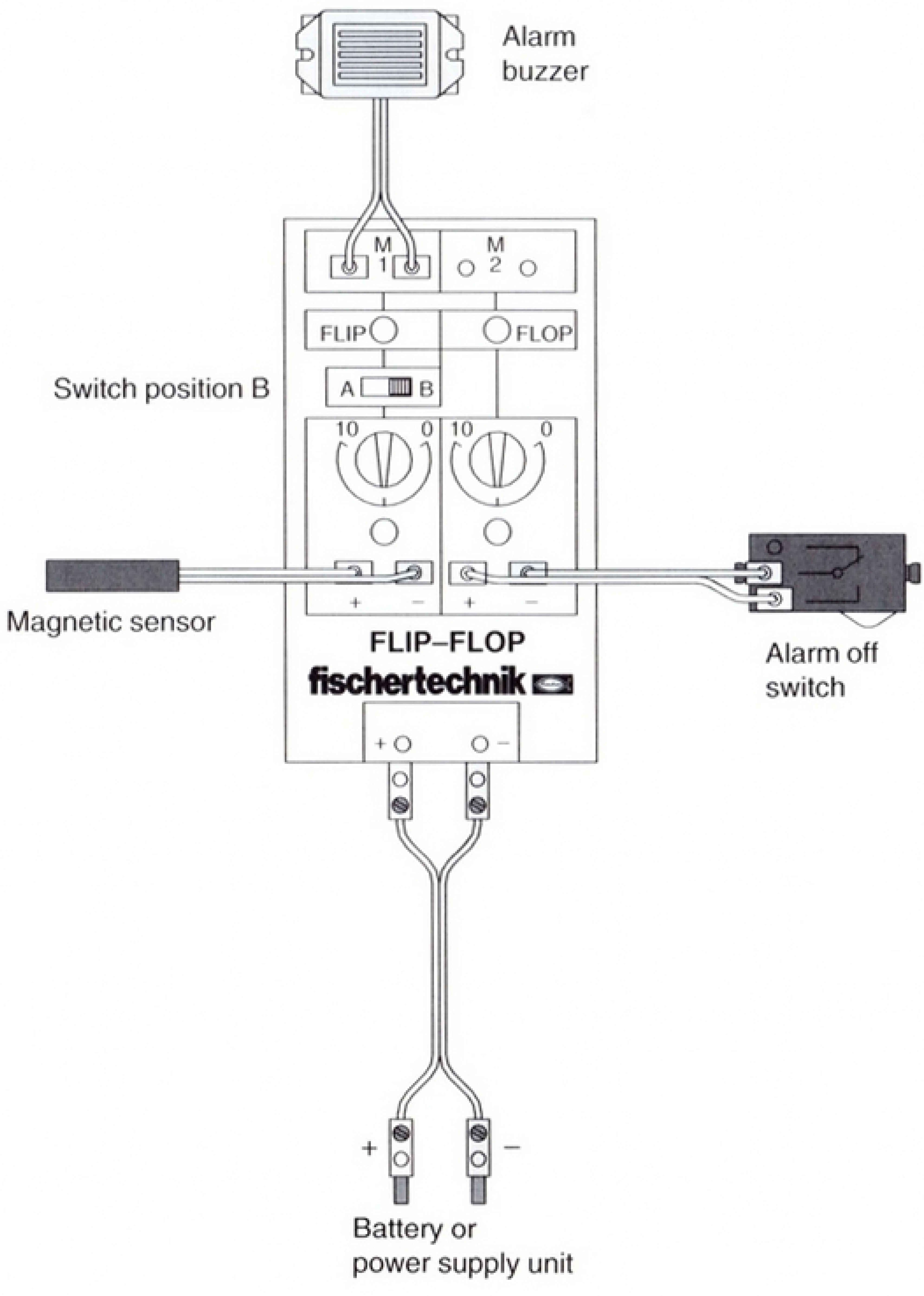
Valuable objects are often kept in a locked case or in a safe. Or alternatively an alarm is set to go off as soon as a thief opens the lock. In order to set off an alarm, you need a mechanism to actuate a switch.
This model shows you how you can actuate the switch without actually touching it directly. To do so, you need a magnetic sensor, which is switched even if the control magnet is several millimeters away from it.

Magnetic sensors are often used wherever it is not possible to install a switch (e.g. to protect windows and doors as part of an alarm system), or in places where a switch would

not work on account of the wet or dirty environment (e.g. in a factory shop or in a car wash). The magnet is not bothered by dirt or water, and the magnetic sensor is enclosed in a waterproof, airtight casing.
The electronic treasure chest can be used, for example, as a "toffee safe", to catch anyone trying to get at your sweets. As soon as the lid of the model is lifted, an alarm buzzer sounds and the culprit is caught red-handed. A magnetic sensor is used this time to determine when the lid is opened; it is secured to the lid itself, while the magnet is inside the chest. When the lid is closed, the sensor and the magnet are close together, so that the sensor closes the circuit. If the lid is opened, the magnet is moved away from the sensor, the circuit is interrupted, the flip-flop is set and the buzzer connected to the output of the flip-flop betrays the thief. The alarm can be turned off again by pressing a switch. Now you are ready to build the model and start the first test (the various steps and the circuit diagram can be found on pages 44-46 of the German manual).

How does it work?

The magnetic sensor is a so-called reed contact, with two switching reeds made of a magnetic material sealed air-tight in a little glass tube (Fig. 25). If you move a magnet close to the



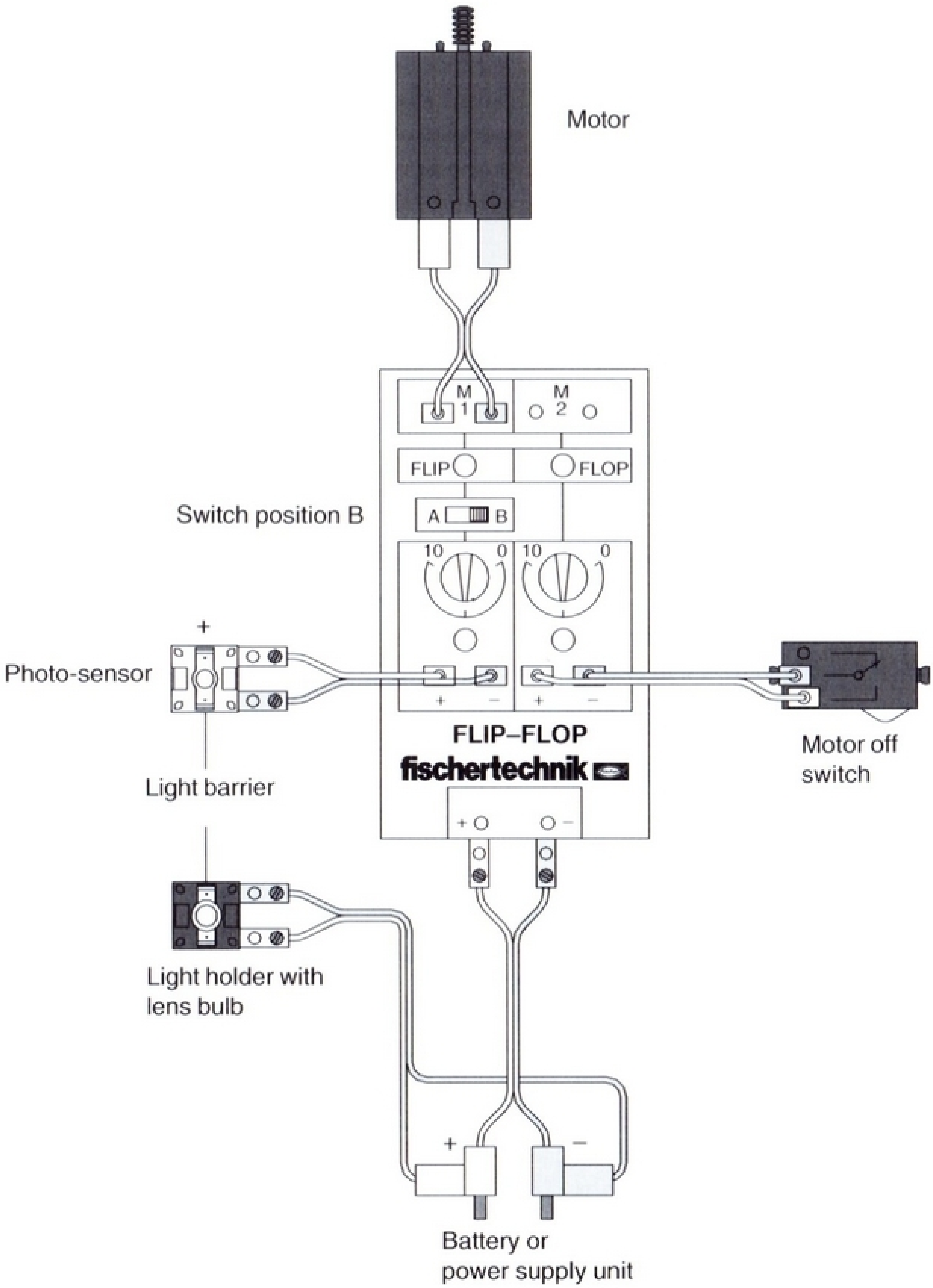
tube, the circuits attract each other and close the contact. The glass tube is encapsulated in plastic for additional protection. The advantage of the magnetic sensor is that it is contactless, in other words it is sufficient for the magnet merely to be close to the sensor.
A magnetic field builds up around the magnet; you can make it visible using iron chippings (Fig. 26). The magnetic field penetrates the switch and magnetizes the contacts (Fig. 27), which close as a result. There is consequently no mechanical wear on any moving parts.
You can however also invert the function of the reed contact. If you insert a piece of sheet iron between the magnet and the reed contact, the field lines will no longer pass through the reed contact, but will run instead through the iron - like a sort of short-circuit - and the contact will be opened.
There is another type of magnetic sensor, which is made like a transistor from semiconductor materials. These sensors have a wider range (they are more sensitive), but they almost always need a complex, electronic amplifier circuit - the reed contact is therefore the most suitable type for our purposes.

Press or stamping machine

The majority of ticket-stamping machines used in buses, trams or underground trains are automatic. You simply insert your ticket in a slot and the machine stamps it for you. Once again, a light barrier is often used inside the machine to set off the stamp.

The light barrier function is inverted in the large presses used for industrial purposes: the press cannot be started up as long as the operator is loading a workpiece (and working underneath the press in doing so). Several light barriers are often used together in such situations to form a "light curtain", to ensure that nobody can be injured. The press can only be operated if the light curtain is not interrupted at any point.
Our fischertechnik model functions as a ticket-stamping machine, in other words it stamps automatically if a card or a sheet of paper is inserted between the lamp and the photosensor. (When you have finished building the model, you can have a think about how the protection function would have to be wired up for a press - the light barrier would of course have to be located ahead (upstream) of the press.)
The motor moves the wheel in a circle over the gear. The stamp is moved up and down on the guiding axles by means of the connecting rod on the wheel. If the paper interrupts the beam of the light barrier, the flip-flop is set, causing the motor to start turning and the stamp to be lowered onto the paper. The stamp is then raised again until the flip-flop is reset by means of the cam on the wheel and the switch; the motor then stops. When you build the model by following the steps described on pages 51-53 of the German manual, install the switch so that the wheel turns sufficiently for the connecting rod to be at a slight angle. If the connecting rod is exactly perpendicular (at the "top dead center"), the motor requires a great deal of power at first and you may even find that the model refuses to start up at all.

> Tip:
> You can use picture stamps from a toy shop (roughly 2 mm thick) for your machine and stick them underneath the transverse girder of the press.


Motor
M
1
M
2
FLIP
FLOP
Switch position B
A
B
10
0
10
0
+
Photo-sensor
+
−
+
−
Motor off
switch
FLIP–FLOP
fischertechnik
Light barrier
+
−
Light holder with
lens bulb
+
−
Battery or
power supply unit

Sorting machine

Recycling materials found in rubbish for re-use is nowadays very common practice in many towns and districts. Collecting glass, paper, plastic and metal separately saves both raw materials and energy. A number of car manufacturers are currently researching methods of processing scrap cars better than in the past. The results of their investigations will later be applied to the cars at the manufacturing stage.

Just as product manufacturing processes are controlled automatically, recycling methods must also be automated, so that reutilizing valuable materials ends up being no more expensive than using new materials. The recycling process almost always starts with sorting and separating the different materials. Iron can be separated from other metals, for example, by exploiting its magnetic properties. This chapter tells you how to build a sorting machine for such purposes (the assembly drawings and the circuit diagram can be found on pages 47-49 of the German manual).
Useful tip: Connect the motor cables before you install the motor, since the terminals will not be as easily accessible afterwards.

The parts which must be sorted drop onto the sloping feeder and slide down by the force of gravity until they reach the light barrier. The light barrier realizes that a new part has arrived, and starts up the motor for the conveyor belt via the set input of the flip-flop. The part is then conveyed to the sorting station. If the belt moves in the wrong direction, you must connect the motor the other way round.

> Make sure you connect the photo-sensor the right way round, i.e. with the correct polarity, or the sorting machine will not work.

We must cheat a little at this stage, since the magnetic sensor is not sensitive enough to distinguish iron from other materials (we discussed the different types of magnetic sensor earlier on in conjunction with the treasure chest model). Instead of ordinary iron parts, we shall therefore use fischertechnik building blocks with a magnet attached to them, which the magnetic sensor can easily distinguish from other building blocks without a magnet. What do you think happens next at the sorting station?
If a building block with a magnet passes by the magnetic sensor, the belt stops and a signal lamp is switched on, so that the "valuable" magnet can be removed from the belt. If a non-magnetic building block arrives instead however, the belt continues and the part drops into the scrap bin at the end of the belt. Your sorting machine is thus semiautomatic. You must press the stop button to stop the belt when it is empty.

How does it work?

The belt in this model is controlled by two different units, namely by the light barrier and by the switch.
The principle on which it works is as follows:

> Motor stopped when magnetic sensor responds OR switch pressed

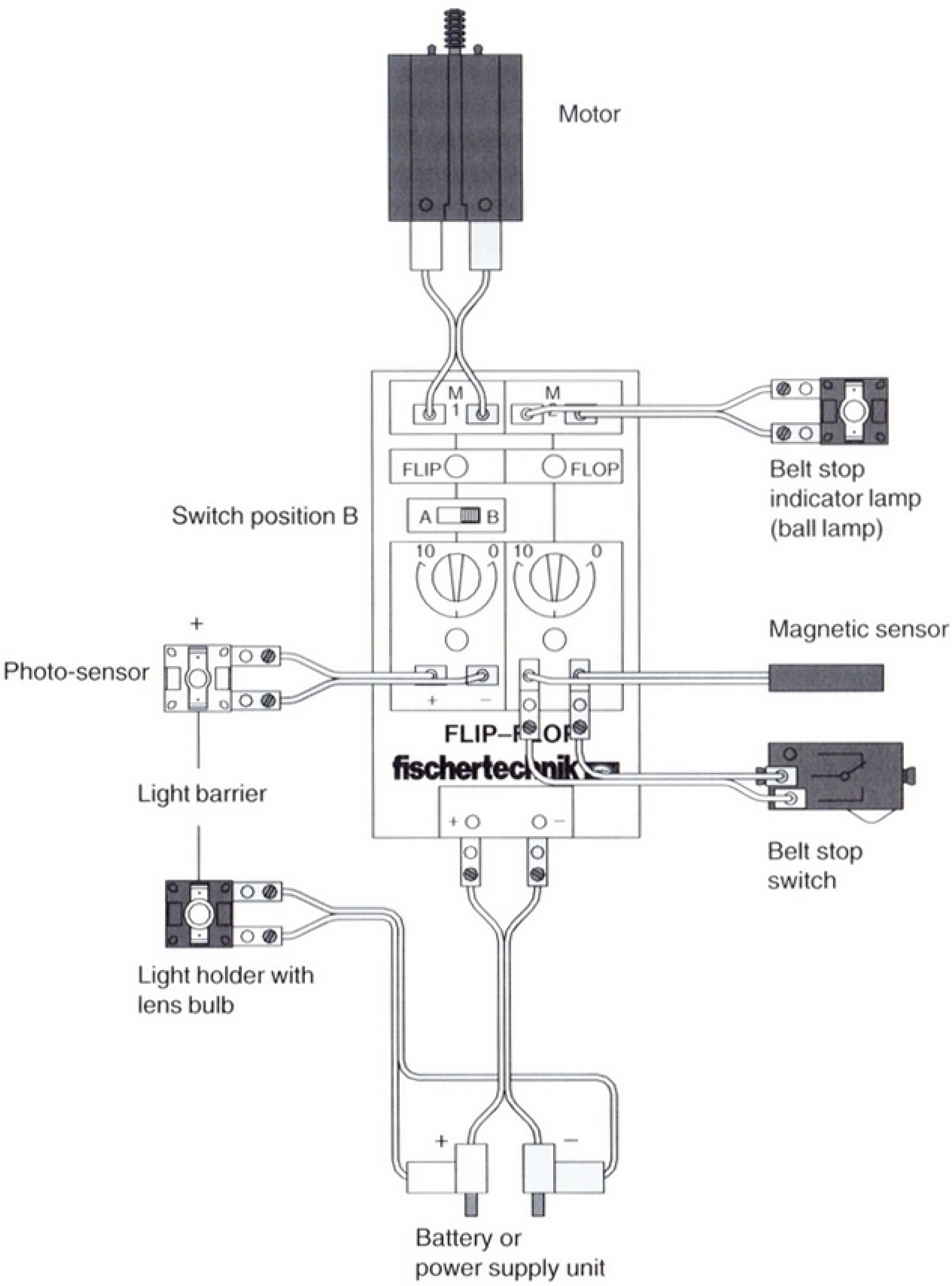
Principle of the cash dispenser:

> Motor started when light barrier free AND switch pressed

Principle of the hand drier:

> Motor started when light NOT shining on photo-sensor

These three basic functions, by the way, are combined millions of times to control what goes on inside a computer - not in the form of switches and lamps of course, but as tiny transistor elements which nevertheless work in exactly the same way. A computer uses hundreds of thousands of flip-flops, which are also constructed from transistor elements, to store information.

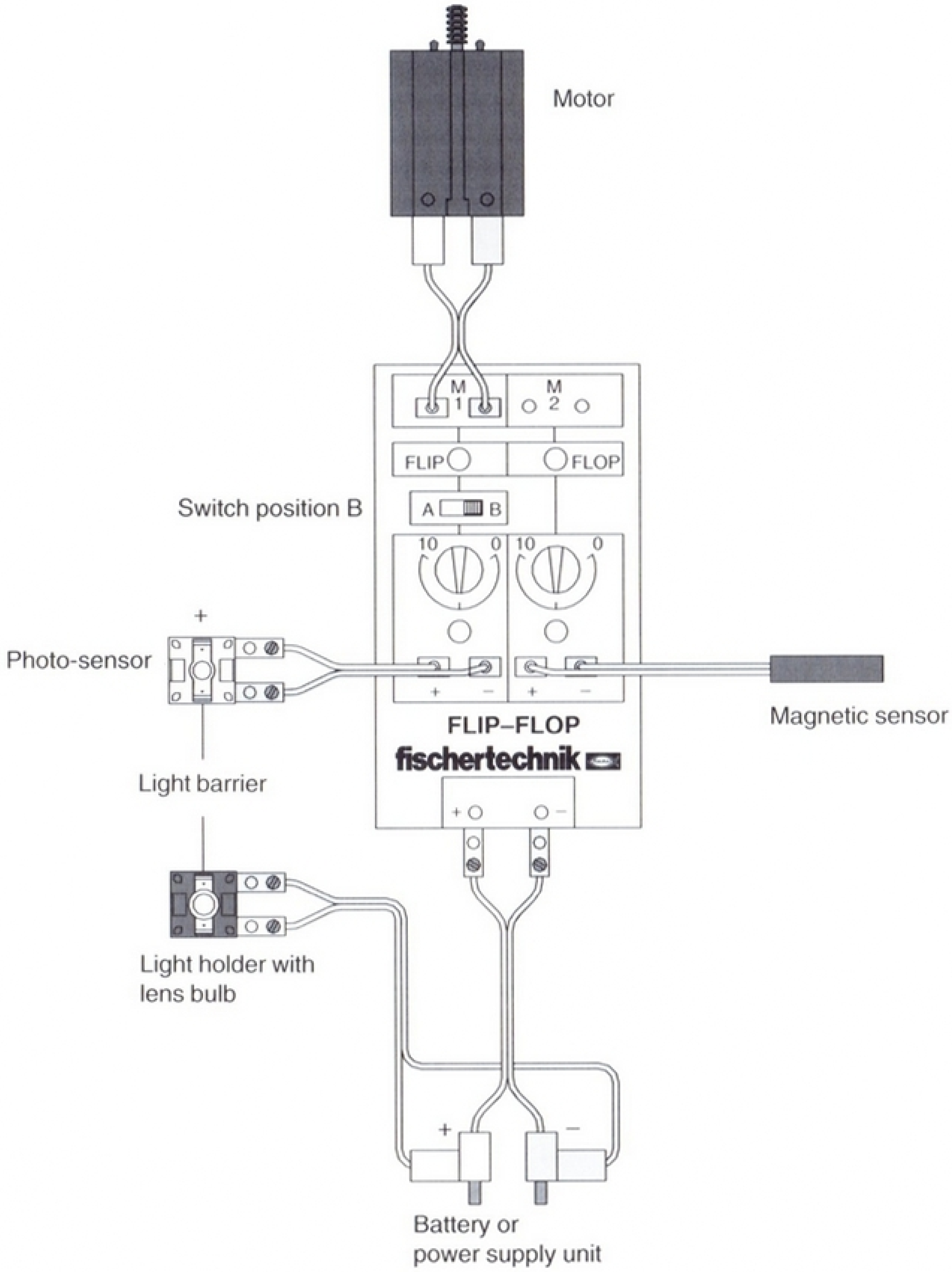

Motor
M
1
M
2
FLIP
FLOP
Switch position B
A
B
10
0
10
0
Belt stop
indicator lamp
(ball lamp)
Magnetic sensor
+
Photo-sensor
+
−
FLIP–FLOP
fischertechnik
Light barrier
+
−
Belt stop
switch
Light holder with
lens bulb
+
−
Battery or
power supply unit

Reflex game

Fast reflexes are not something that are only useful for sports or in traffic situations. This model enables you to test your own reflexes and those of your friends - it is so clever, however, that even the fastest of them will find it very difficult to beat it at its own game. And yet it is built extremely simply.

At the front, above the table, is a light barrier, which switches on the motor via the flip-flop when interrupted. The motor winds up the cord and retracts the magnet at lightning speed. The magnetic sensor is located underneath the table a little way behind the light barrier. When the magnet is retracted, it switches the motor off again by means of the magnetic sensor. You can "arm" your model again by lifting the lid and pulling the magnet forward once more. You can use it either to test your reflexes or as a game of skill.
If you use it to test your reflexes, the light barrier must be installed roughly level with the magnetic building block, and the block placed behind the barrier. If you try to grab hold of it, your fingers will interrupt the light barrier and the magnet will jump back. The greater the distance between the light barrier and the magnet, the more difficult it becomes.
To use the model as a game of skill, you must reposition the light barrier higher up and place the magnet underneath it. The light barrier should be just above the magnetic building block. As soon as you try to remove the magnet and lift it even slightly, the motor will start up and the magnet will disappear. The various steps for building the model are described on pages 63-65 of the German manual.

Note:
If you actually succeed in grabbing the magnet away, don't hold on to it too long, because you will be blocking the motor in doing so.


Motor
M 1
M 2
FLIP
FLOP
Switch position B
A
B
10
0
10
0
+
Photo-sensor
+
−
+
−
Magnetic sensor
FLIP–FLOP
fischertechnik
Light barrier
+
−
Light holder with
lens bulb
+
−
Battery or
power supply unit

Dosing machine

How does the sugar get into the bag or the juice into the bottle? There are lots of industries where loose bulk material must be filled. The principle is always the same - whether a box must be filled with cornflakes or a truck with gravel. The purpose of a dosing machine is to make sure that the same quantity of bulk material is filled every time. Weighing and filling by hand is often practiced in small businesses, for example, but is much too slow and much too expensive for mass production.

Our dosing machine consists of a conveyor belt, on which the fischertechnik building blocks are delivered as bulk material. Below the end of the conveyor belt is a collecting pan secured to a balance beam (scales). A magnet, which also controls the dosing machine, acts as a counterweight. The scales work like a rocker: if the pan is empty, the magnet will touch the ground. When the bulk material is loaded, the weight ratio changes, the pan is lowered and the magnet is raised. When the prescribed weight is reached, the magnet will be next to the sensor and the belt is stopped. The contents of the pan can then be removed and the belt started again with the switch. If the belt moves in the wrong direction, you must connect the motor the other way round.

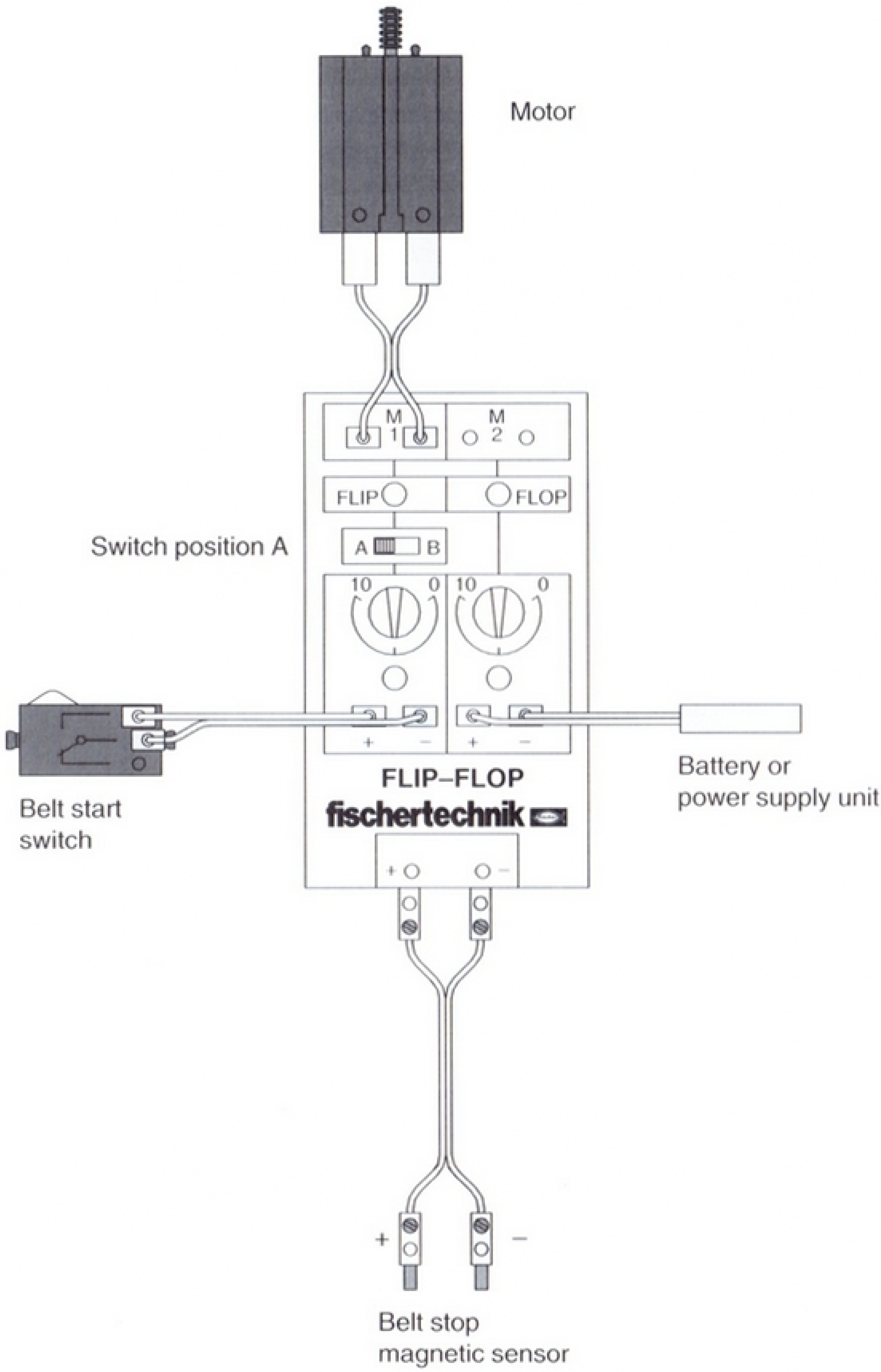
The various steps are described on pages 69-71 of the German manual.

How does it work?

You now know how to dose bulk material using a balance. If your product has an irregular shape (e.g. potato crisps) and therefore does not always take up the same amount of space (= volume), this is also the most reliable method of getting the same quantity every time. If the bulk material has a relatively regular shape (e.g. balls, sand, cement) or if the exact quantity is not quite as important (e.g. a truck full of gravel), there are other methods that can be used instead. Here are two examples:

Scanning the level with a light barrier (e.g. a liquid level).

Measuring the conductivity of a liquid. If you immerse two metal rods in the liquid a certain distance apart, you can measure the resistance between them. The higher the level of the conducting liquid rises, the lower will be its resistance.


Motor
M
1
M
2
FLIP
FLOP
Switch position A
A
B
10
0
10
0
+
−
+
−
Belt start
switch
FLIP–FLOP
fischertechnik
Battery or
power supply unit
+
−
+
−
Belt stop
magnetic sensor

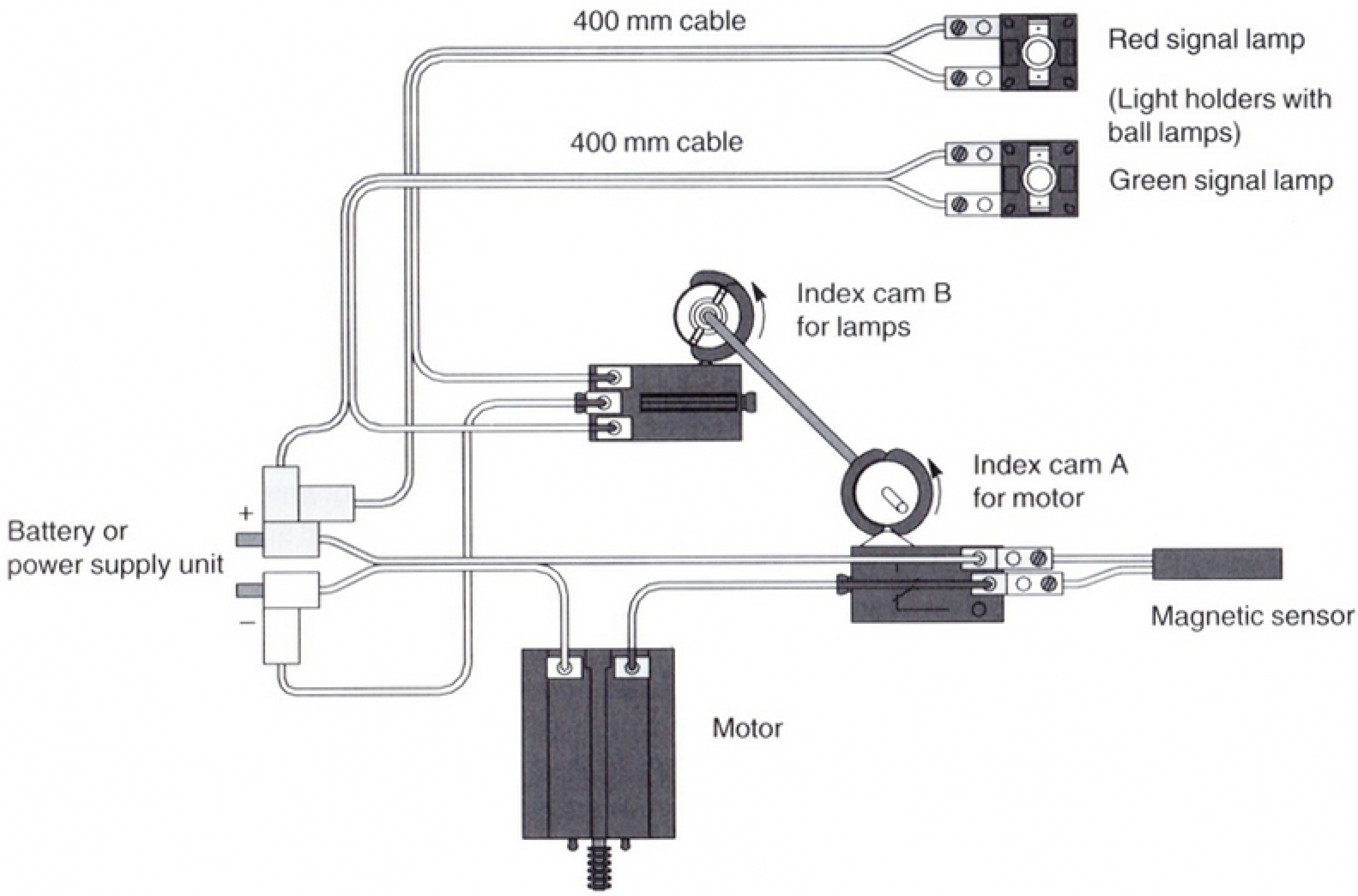
Garage entrance with barrier

In multi-storey car parks and underground garages there is normally a barrier at the entrance and exit. The barriers work in different ways, depending on the nature of the garage. If the garage is a private garage, you need either a key or a card (see "cash dispenser" model) to get in. When you leave the garage, the barrier opens automatically. If the garage is a public garage, the barrier at the entrance is opened automatically, providing there is still room inside. At the exit you must insert your receipt ticket or a coin in order to get out again.

The fischertechnik model demonstrates how an automatic barrier is controlled. It is opened by means of the magnetic sensor. A magnet is secured to the car (e.g. to a model car or to a fischertechnik model) level with the sensor. Double-sided adhesive tape is the best means of sticking the magnet onto the car. As soon as the car stops in front of the barrier, it is opened by means of a mechanical lifting device with an eccentric. When the barrier opens, the traffic light changes from red to green and the car can drive through. The barrier then closes again and the traffic light changes back to red. The various steps for building the model are described on pages 75-77 of the German manual. You are about to make your first acquaintance with index cams; the flip-flop isn't used this time. To make sure that the model works properly, you must take care to fit the index cams onto the axle in the correct positions and to fit them with the right aperture angles. The position of the eccentric lever for moving the mechanical barrier must also be matched to the position of the index cams. The direction of rotation of the motor is likewise important (see circuit diagram - you may have to reverse the motor connections).
The front index cam with the smaller aperture angle (A) controls the motor. The magnetic sensor switches on the motor when a vehicle approaches. The motor turns the index cam, which in turn actuates the motor switch which keeps the circuit for the motor closed. The switch opens again after one complete revolution and the motor stops. The second index cam with the larger aperture angle (B) changes the lamps of the traffic light from red to green and back again with its switch.

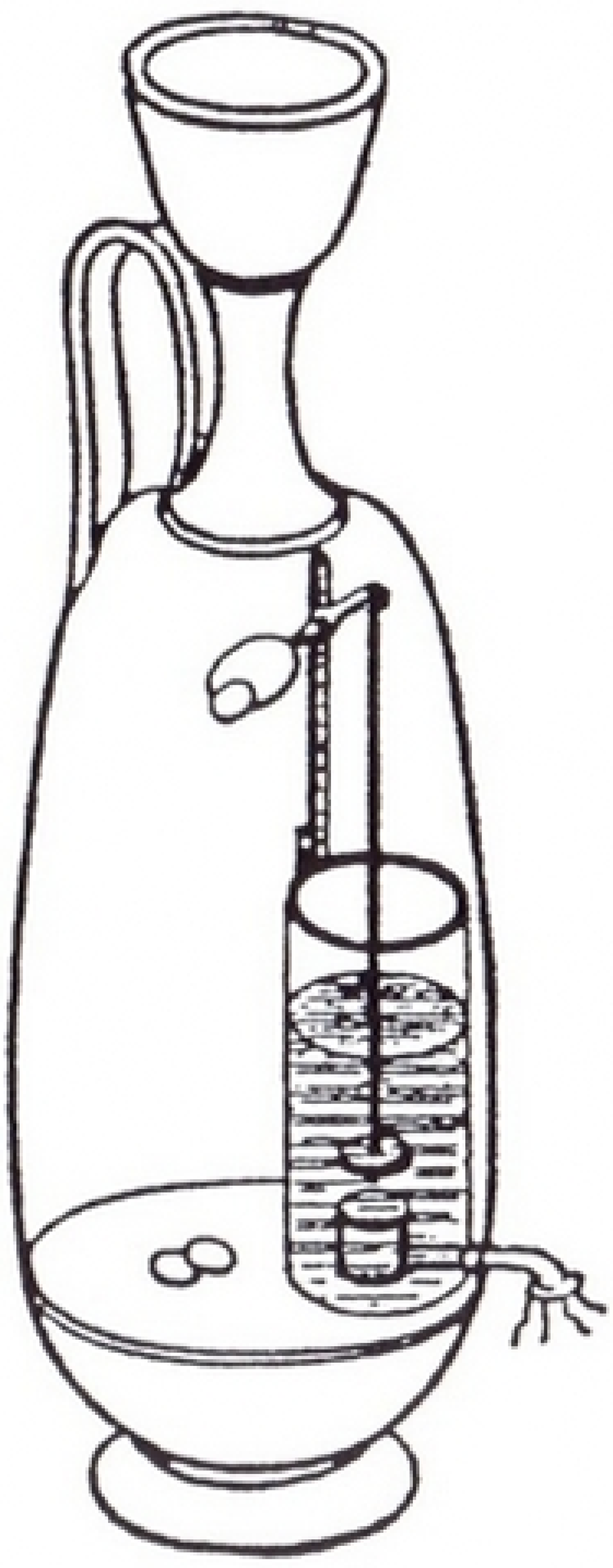
How does it work?

"Large" barriers are somewhat more complicated to control. They are sometimes opened by a light barrier, but more often by means of an induction loop in the ground.
The induction loop consists of a large wire coil (diameter 1 to 2 meters), which is connected to an electronic oscillator or vibration generator (which is basically a type of transmitter). The number of electrical oscillations per second (= frequency) is dependent on the design of the coil. If a car drives over the coil, the metal in the car causes the frequency to change, and the controller can tell that a car is waiting in front of the barrier. The advantage of the induction loop is that there are no moving parts and no optical components to get dirty (or lamps which might blow). A light barrier is normally installed in addition directly at the mechanical barrier, to prevent the latter from closing while a car is still underneath it.
A switch operated by means of a lock can be used to open the non-automatic barrier in the opposite direction. Many barriers however employ magnetic cards or similar systems instead. A lot of firms allow you to open the barrier to the car park with your company ID card. A large number of multi-storey car parks use receipt tickets made of stiff card with a magnetic stripe, in which the date and time of payment are stored. The receipt only remains valid for about a quarter of an hour after payment.
Some car owners have an ultra-luxurious means of opening the barrier in the form of a small remote-control transmitter inside their car or an infrared remote-control unit like the one you use for a TV set.


400 mm cable
Red signal lamp
(Light holders with
ball lamps)
400 mm cable
Green signal lamp
Index cam B
for lamps
Index cam A
for motor
Battery or
power supply unit
+
–
Magnetic sensor
Motor

Sweet-dispensing machine

Coin-operated vending machines were invented as early as the ancient civilizations. Almost 2000 years ago Heron of Alexandria constructed a dispensing machine for holy water (Fig. 28). The first forerunners of our modern vending machines were developed around 100 years ago. And of course, even then there were machines for dispensing sweets. When a coin is inserted, it is checked first, in case someone is trying to fiddle the machine with a metal disk or a foreign coin. The compartment containing the sweets or the other articles is then released. Depending on how the machine has been designed, either you must pull out a drawer to remove the article or else the machine ejects them automatically.



The last model we are going to build is of course a modern type of dispensing machine, which ejects sweets fully automatically. The coin acceptance test performed by our model, on the other hand, is extremely simple. The machine merely checks the diameter of the coin, because the slot for inserting money consists of two fischertechnik building blocks; the coins roll down the grooves in the blocks. On their way down they interrupt the beam of a light barrier and cause the sweets to be dispensed.

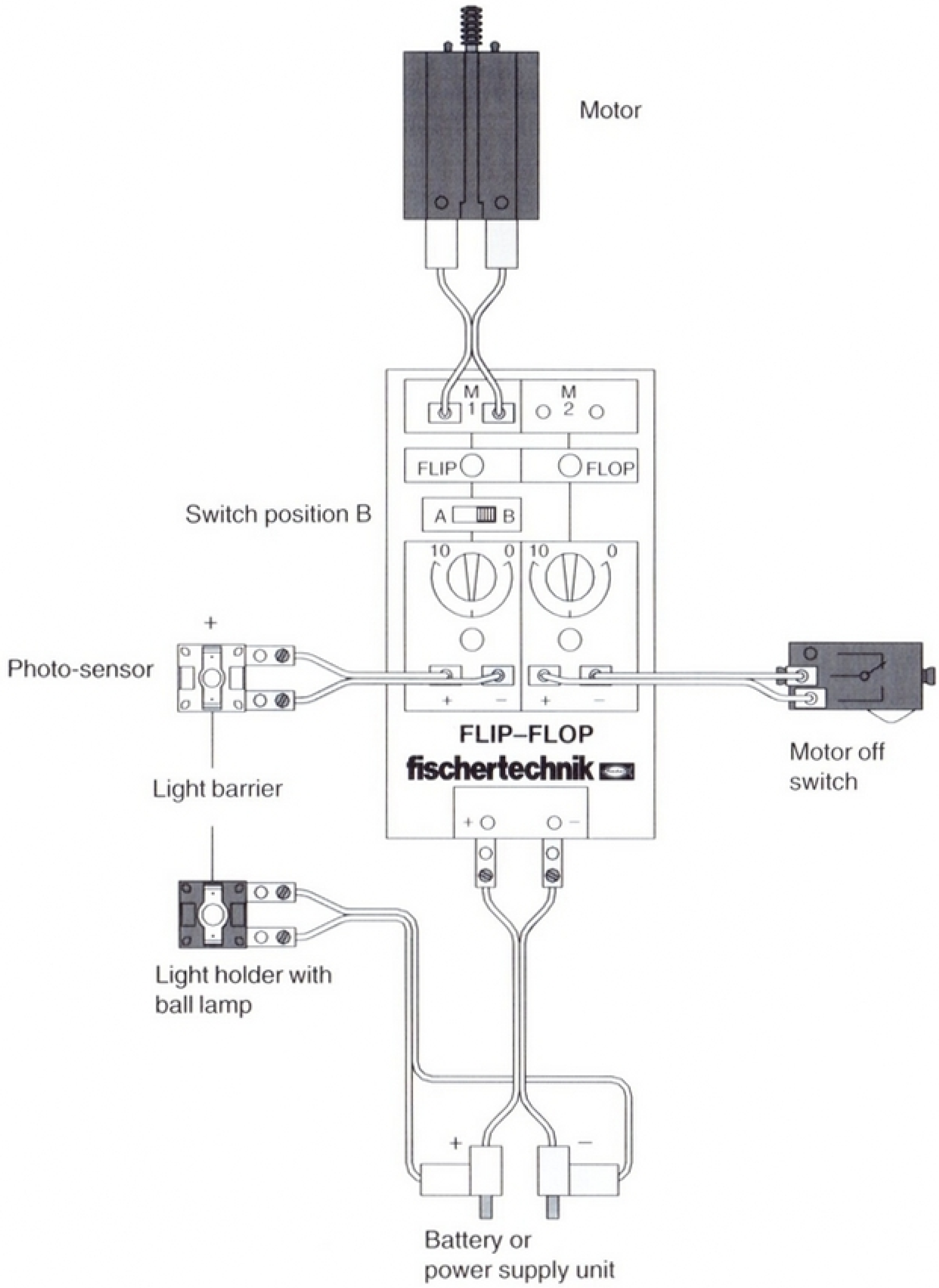
A conveyor belt is used again to dispense the sweets, similar to the one you have already come across in other models. As soon as the light barrier sets the flip-flop, the motor begins to turn and the conveyor belt transports the sweets loaded on it forward. The first sweet in the line drops off the belt and can be removed. The motor is stopped after one sweet by actuating a switch with the crawler track links. The various steps and the circuit diagram can be found on pages 81-83 of the German manual.

To load the dispensing machine with sweets or sugar cubes, open up the cover and place them on the crawler between the track links. Close the cover again and your machine is ready to dispense. If you still have enough fischertechnik components left over (e.g. from the Master), you can build a feeder as well (like the one for the sorting machine), into which you can pour the sweets for loading onto the end of the conveyor belt.

How does it work?

The first vending machines were extremely simple and worked in a similar way to the fischertechnik model. Fig. 29 shows a cigarette machine built in 1883, which operates almost exactly identically - a type of "bucket wheel" is used instead of the conveyor belt. The more modern machines have electric switches for selecting the article instead of drawers; they also use an electric motor to eject them. Gaming machines were developed parallel to the vending machines - they range from simple slot machines to modern computer games.

The coin-acceptor unit is an important feature of all these machines; after all, it stands to reason that if too many "forgeries" end up inside them, it is not worth the owner installing them. These units began as coin slots, which checked the diameter and thickness of the coins. A balance beam was installed behind



the slot, so that the machine wouldn't work with coins that were too small. The valid coins were just heavy enough for the balance beam to tip and the coin to release the drawer. Lighter coins simply rolled back into the "returned coins" tray (basically the same principle as for the dosing-machine model). A second balance was sometimes mounted behind the first one, to eliminate coins which were too heavy. The resulting system was thus purely mechanical, and enabled the thickness and diameter of the coin to be determined accurately - the same principle is still commonly employed today.

Magnets are used to determine the metal from which a coin is made. They are not only capable of distinguishing coins containing iron from other coins, but also detecting "false" metal alloys, in other words the coin material. The conductivity of the coin can be examined by means of a magnetic field, since when a conductor moves through a magnetic field, an "electrodynamic force" is generated inside it (this characteristic is used in generators, e.g. in a bicycle dynamo). The force counteracts the movement of the coin and affects the speed at which it rolls. Since different metals conduct more or less well, the mechanical

design of the coin slideway provides a means of eliminating "bad" coins.
Modern machines use electronic coin-acceptor units, which check the thickness, diameter and material with the aid of sensor coils (Fig. 30). Cheap electronic components have come to replace complex, expensive mechanical parts. The advantage of the electronic coin-acceptor units, which are generally linked up to a small computer, is that they are able to check more than one type of coin. Machines with such units recognize different coins automatically, and can be converted to new coins or to foreign currencies simply by reprogramming the computer, without the need for any mechanical alterations.

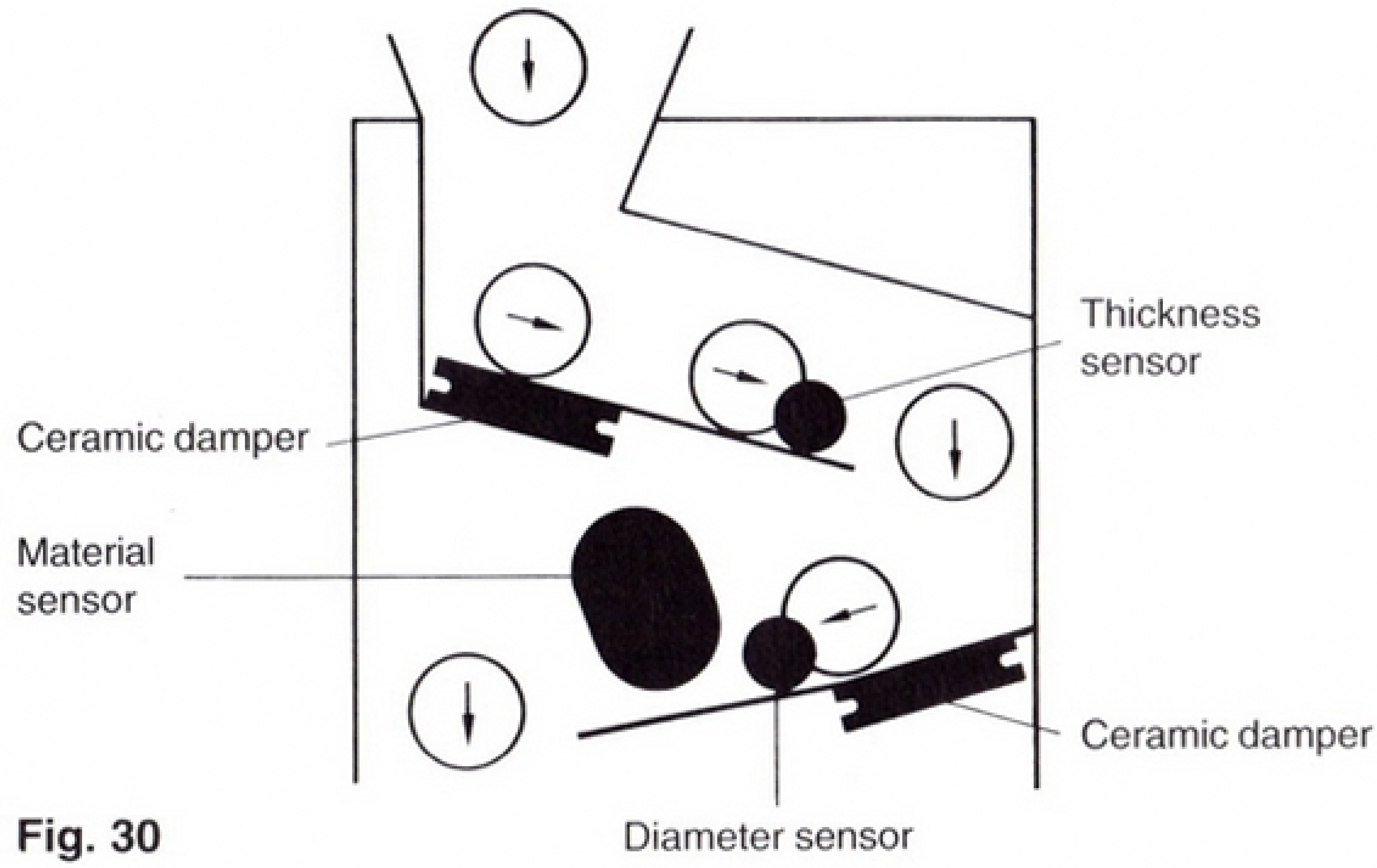


Fig. 30

Parts list for illustrations and article numbers

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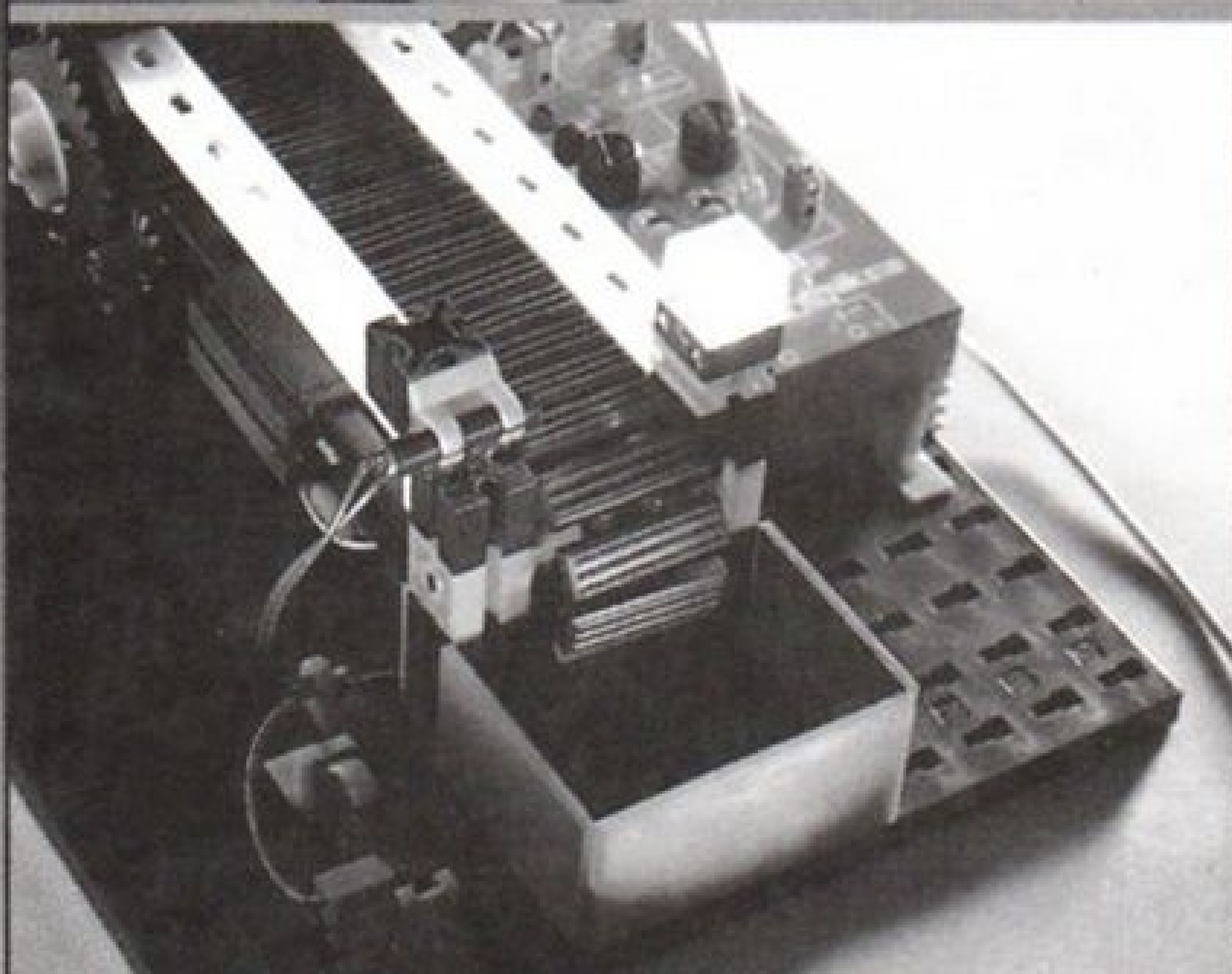

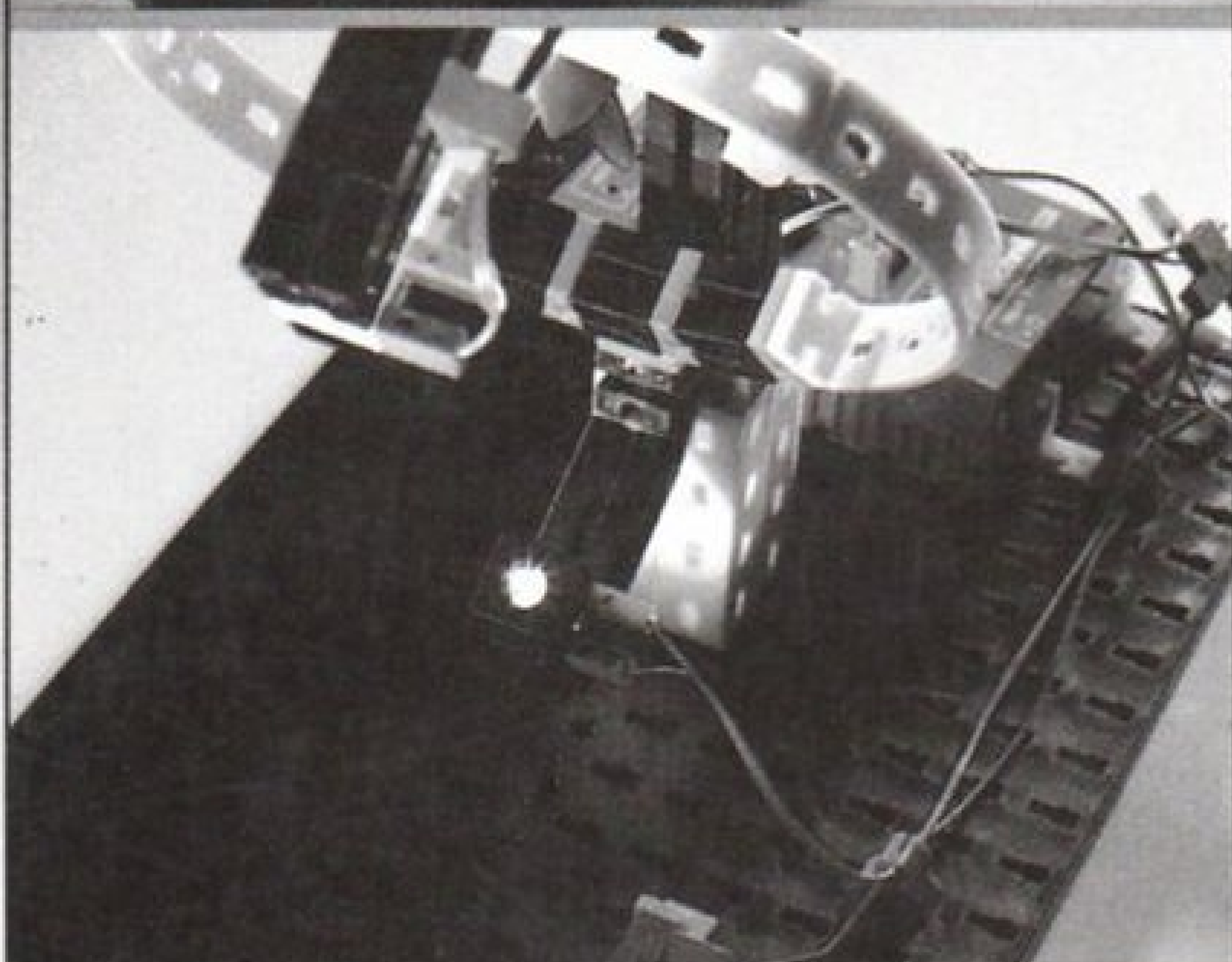

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