fischertechnik® fischer®

Electromechanics

It is sufficient to have Start 100,
Motors + gears,
Transformer mot. 4
in order to build the models

Electromécanique

Les modèles se construisent avec:
Start 100, Motor + engrenages,
Boîtier d'alimentation mot. 4

Elektromechanika

Je kunt alle modellen bouwen met:
Start 100, Motor + aandrijving,
Transformator mot. 4

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Electromechanics

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Transformer mot. 4 in order to build the models

Contents

Introduction

Dear fischertechnik fans,

At first glance you will recognise old friends in the new em-construction set "Electromechanics"; viz. flat hubs, connecting elements, shafts. However, on closer inspection two shafts are seen to have special features, apart from their unusual lengths: a plug at one end and a socket at the other end. These "plug shafts" can also undertake electrical tasks.

The apparently unaltered hinge blocks also have this capability because of their internal springs:

■ Please take out a hinge block, bend it straight and let go! The "spring hinge blocks" will still provide us with good service.

Then there are the many other electromagnetic components, contact elements, contact terminals, spring contacts, spring feet, reed contacts . . .

Stop! No one can know what everything in the construction set is called!

■ Don't worry – we'll soon get the hang of it! Open the book at the last page. Every component in the em-construction set is listed there with description and quantity – OK?

By the way: A ■ in front of a paragraph always means "Something to do here!" or "This should be remembered".

The instruction book is written primarily for the electronics beginner. He should go through the chapters one after the other, not jumping any or totally omitting any, since one chapter builds on another. The stepwise procedure is much more fun since it ensures success.

■ Keys, switches, slip rings, magnets, electromagnets, vibratory springs, thermal bimetallic strips, etc. will all be investigated, tried out, and explained in sequence and used in one or more models.

In this way one obviously acquires the knowledge necessary to read circuit diagrams and to construct a circuit. Also a little theory does no harm.

He who investigates and attempts everything and successfully completes the models will have much more than just the contents of the book. He will be able to invent new circuits himself and realise them in his own models.

Even the "experts" will have fun playing with the em-construction set and find that they get their money's worth. Care to wager?

Page 4

Our electrical power sources

"Nothing runs without juice" says the engineer. By this he means that each electrical device must be connected to a suitable electrical source which delivers the energy required for operation. The energy from the wall socket is obviously much too great for our lamps, motors and the other fischertechnik devicec – they would be immediately destroyed. Moreover it's dangerous! Thus we only use suitable fischertechnik sources for our purposes; viz. power pack and battery block (or the previous battery stick).

The battery block shown in figure 1–4 (that is figure 1 on page 4) is contained in the new large Motor construction set. It's four baby cells deliver a voltage of 4 times 1.5 V = 6 V. The previous battery stick delivered only 4.5 V. (V stands for "Volts": this is the unit of electrical potential). Unfortunately batteries are so devious that they are often used up just when no replacement can be found. In addition they are expensive!

Thus it always pays to purchase the power pack "mot. 4" (figure 2–4).
It is connected via its mains cable and a plug to the 220 V a. c. mains. The dangerous high voltage is converted by the power pack into the completely safe d. c. voltage of 7 V suitable for our purposes. This is available even on Sundays and holidays and is never empty!
The power pack has two "outputs." This is the short name for the front and side pairs of sockets on the device. Both outputs deliver d. c. voltage. The front output voltage can be reversed or varied between 0 and ca. 7 V using the rotating knob. The side output delivers a constant voltage of about 7 V. (The earlier power packs with an a. c. voltage of about 7 V at their side outputs can also be used.)

Page 5

Wires first!

Obviously! Without wires it's impossible to connect an electrical device! So we have to provide the "leads" in our construction set with plugs. No problem if one follows the following assembly instructions.

Plug assembly

All single-core lead lengths are provided with green plugs at both ends.

- Pull off the pre-notched insulation, twist the bare copper wires and bend them back as shown in figure 1–5.
- Release the plug screw with a screwdriver, push in the wire end (figure 1–5) and tighten up the screw – but not so tight as to crush the lead!
- We will need the long green lead for an important and very interesting experiment on page 62. The blue double-cored wire will be used later.

Continuity test

We now want to check whether current passes through the finished lead. This only happens when the bare wire end is pressed firmly against the metallic part of the plug.

- Connect the light module and its lamp to the front output of the power pack as shown in figure 2–5 and turn up the voltage. The lamp should light.
- If it doesn't check whether all 4 wire ends are screwed correctly into the plugs and whether the lamp is located correctly in the light module. If this doesn't work try another lamp.
- Thus all leads can be checked for "continuity" as the expert says.

Page 6

Plugs for the double-cored lead

The double-cored lead consists of two single-cored leads isolated from each other. One should have green plugs at its ends and the other should have red plugs at its ends. This is important so that the leads cannot be mixed up later.

- Remove the pre-notched insulation. Connect one green and one red plug to only one side of the double-cored lead as in figure 3–6.
- First connect a light module and its lamp to the power pack with any assembled lead and switch on.
- Plug for example the red plug of the double-cored lead in the other light module socket (figure 4–6).

Now how can we discover which bare wire end belongs to which plug? Very simple. We use the previously tried continuity test. That is as follows:

- Touch the free socket of the power pack with one of the bare wire ends.
  - The lamp lights! This means "current is flowing". Thus this end belongs to the red plug which we plugged into the light module. So a red plug should be attached to this bare wire end.
  - The lamp doesn't light! This means "no continuity". Thus this bare wire end belongs to the green plug which is not plugged into the light module and should be inserted in a green plug.

Page 7

Current only flows in a circuit

Current flows extremely well through metallic materials such as the thin copper wires in the leads, the tinned brass of the terminal contacts and contact components or the chrome-plated shafts. Such materials are called electrical conductors. When two conductors touch the current can flow from one to the other through this contact point. We will often make use of this fact. Wires are different. Here accidental contact between each other or with current carrying metal parts is totally undesirable. Hence wires are "insulated" with plastic. This is decidedly a non-conductor – so are air, glass, wood and most non-metallic materials which also do not conduct current.

The source pump

The electrical source operates like a pump. Figure 1–7 explains this.

The source pump drives the current through the red conductor to the consumer: thus the description "outward conductor". The current then flows through the consumer (lamp or motor).

The current returns to the source pump through the blue "return conductor".

This again drives the current into the outward conductor and the cycle begins again – providing of course that the source pump is not switched off or the circuit is not broken at any point!

The metallic circuit

In our continuity test the circuit consists of all sorts of metal bits: lead wires, sockets, plugs, light module parts, lamp filaments. This metallic circuit is only "closed„ when all the matal parts firmly touch each other. As the expert says"... when they are in fixed contact with each other".

- If a circuit does not work one should check all the contact points first. For example loosely fitting plugs cause much annoyance. How this can be remedied is shown on page 20.
- With frequent usage the wires can become loose in the plugs. The plug screw must then be ge-tightened.

Circuit Diagrams

The photograph 2–5 shows how to connect a lamp to the power pack in order to produce a circuit as shown in figure 1–7. Soon however, we shall meet much more complicated circuits and one would hardly be able to recognise from a photograph how the components are connected to each other. For this reason it is preferable to use clear drawings to represent circuits: the "circuit diagrams". In these the electrical components and devices are represented by generally recognised (standardised) circuit drawings or specially agreed symbols as can be seen on the next page. Wiring is very simple using such circuit diagrams. We can immediately try this out on the next page.

Page 8

Lamps and ligth modules

On this page we learn the symbols for the previously employed elements and the fischertechnik power pack. The connecting leads are represented by straight lines. It is easy to wire an experiment or a complete model using such a circuit diagram.

Figures 1–8 and 2–8 show the spherical lamp and the lens lamp with their respective symbols. The lamps are inserted in plug holders which are plugged into the light modules. They can easily be removed again. When the holder is plugged in, the thin connecting wires of the lamp are pressed firmly against the socket tubes producing conducting connections.

In the light module symbol 3–8 the sockets are represented by small circles – exactly like the output sockets in the power pack symbol 4–8.

By the way: For simplicity we will in future use only the abbreviation NG for "power pack".

Figure 5–8 shows the previously encountered lamp circuit (figures 2–5 and 1–7) in the new form of representation. Here as in figure 1–7 the outward and the return wires are also drawn in red and blue respectively.

- Since one can wire the socket tubes from both sides the light module and the lamp can also be connected as in figure 6–8. Make sure that you try this out!
- Under no circumstances should the outward and return wire plugs be inserted in the same socket tube as shown in figure 7–8. This produces a short circuit! This occurs when both connecting sockets (or poles) of one source are connected directly together.

Short circuits in a plug or an electrical device cause considerable banging and sparking. Nothing appears to happen in our NG. This is ensured by the built-in "thermal fuse".

We will discover right at the end of the book how this is possible. In order to understand this we must first study and try out a few more things. Understood?

Page 9

Two lamps at one source

The lamp stand 4–9 carries two light modules with spherical lamps and light caps. Lens lights are brighter but the light caps would be damaged by the heat produced by them. The red hole cap is used for lens lamps.

Both spherical lamps should light together. How could they be connected?

- Firstly let's try the circuit 1–9. Each lamp is connected directly to the NG (double-cored leads and 2 long leads). The task of "connecting two plugs to one socket" is solved in figure 2–9.
- Switch on NG. Both lamps light ... or?

Each lamp has its own circuit in this configuration. For this reason both lamps light as brightly as one lamp in the circuits 5–8 or 6–8.

However, we can simplify the wiring.

- The experienced man wires as in figure 3–9. Thus the outward and return leads for one lamp are simply used in the circuit of the other lamp. The lead length common to both circuits is drawn thicker in figure 3–9.
- The simplified circuit works just as well – agreed?

There is however another way of connecting two lamps to one source. But we will investigate that later (page 46).

By the way: For simplicity we will eliminate the black plug symbols from future circuit diagrams.

Page 10

The ON-key

We can also use the lamp stand 3–9 to send flashing signals to a friend next door; e.g. 3 short "come and play cards", or 3 long "stay there – trouble!".

In this case the signal light must be switched on and off very quickly. This is not possible with the rotating knob on the NG. What shall we do?

To solve this task we need a device with which one can abruptly close or open the circuit – a key. Figure 1–10 shows the symbol for it.

- Build a key according to figure 3–10 using a fixed contact element and a flexible spring foot. The two should be separated by an air gap of about 2 mm.
- Now plug a lead plug in the socket hole in the contact element and connect it as shown in figure 2–10 to the NG. The terminal contact is used for connecting the spring foot in figure 3–10. We know the rest of the wiring.
- Switch on NG: The lamps remain dark since the air gap in the key does not pass any current.
- Now "operate" the key by pressing the spring foot onto the contact element. The lamps light up!

This key is called the ON-key since its operation switches on the lamps. The lamps are switched on because operating the key closes the otherwise broken circuit or the "open key contact": hence the description make contact instead of ON-key.

We call the moving part the "contact lever" and the fixed part the "fixed contact".

Typical characteristics of a key: If the spring contact lever is released it springs back to the rest position by itself.

We will meet other types of ON-keys subsequently. There are an amazing number of possibilities!

Page 11

Separate flashing

It is obviously much more fun if one can flash each lamp separately. Naturally each lamp must have its own key!

- Therefore assemble two keys with spring feet and contact elements at the base of the light as shown in figure 4–11.
- The contact elements of the keys are connected together by a short lead as seen in figure 4–11. This is represented by a thin red line (outward conductor) in the circuit diagram 5–11. The spring foot of the left key T_1 (say T-ONE) and the spring foot of the right key T_2 are connected through terminal contacts to the yellow and the green lamp respectively. The remaining free light module sockets are connected together by a lead for the return conductor as in circuit diagram 5–11. Finally the outward and return lines are led to the front output of the NG by the double-cored lead.
- Switch on NG and operate the keys separately or together. Depending on the operation the yellow or the green or both circuits will be closed and the lamps will light up. Agreed?

The trick with the common fixed contact

- The two contact elements which are connected together can be replaced by a "common fixed contact", e.g. the shaft-80 with a terminal contact. This is shown in figure 6–11 and circuit diagram 7–11.
- Make sure that you try this! We will use this trick often since it avoids a cumbersome "cable salad".

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Test scales with indicating light

What is heavier than component-30: a spool of thread, a screwdriver, a light module with lamp, a spring hinge block or what...? This can be found out very simply and accurately using the test scales 4–13. Here we use the previously tried ON-key principle.

- The plug shaft-180 (figure 4–13) serves as the needle for a simple weighing lever with a movable jockey. It is loosely located in its holder (figure 3–13) at right angles to the scale balance.
- Now for the trick! The plug shaft can be connected by its socket end (symbol 1–12) through a plug lead to the indicator lamp (see circuit diagram 2–12). The plug ensures that the plug shaft does not slide through. (The lead must not be too short or the needle motion will be affected!)
- In this way the scale needle and the spring foot become the lever and the fixed contacts respectively of an ON-key.

The weight test using a component-30

- Put a component-30 on the scale pan. Switch on NG. Move the jockey wheels along the shaft-110 until the plug shaft needle just fails to touch the spring foot. The lamp must not light! This is ON-key rest position.
- Remove the module-30 and put a test piece on the scale pan, e.g. a spring hinge block.
  - If it is lighter than the component-30 the needle will move to the left, the lamp circuit remains broken and the lamp does not light.
  - If the spring hinge block is heavier, the needle presses against the spring foot, the circuit is closed and the lamp lights up to show that the hinge block is heavier!

The jockey weights ensure that when the test piece is removed the plug shaft (lever contact) separates from the spring foot (fixed contact) – the typical behaviour of the ON-key!

Page 14

Flashing lights

These operate every night on sea coasts, river banks, islands, and dangerous reefs to warn ships. Each flashing light has a special "character" (flash programme) which is given in the sea chart. Thus the helmsman can determine the exact location of his ship and also avoid dangerous obstructions. We can use the automatic ON-key model 5–15 to imitate such a flashing light.

- This time the ON-key required for flashing is constructed from two spring feet with terminal sockets. It is automatically operated by two "cams". They are the angle blocks on the motor-driven disc in figure 5–15. In this case both contacts are flexible to ensure that the key operates faultlessly. Figure 5–15 shows the completed key. There should be an air gap of about 1 mm between the spring feet.

- The symbols for motors and cams are shown in figure 1–14. The thin double line between them indicates that the motor is driving the cam. The dotted operating line with the small circle at the beginning means that the key is operated by the cam (black square).
- The wiring is in circuit diagram 2–14.

Simplified circuit diagram

Figure 3–14 shows the same circuit diagram as figure 2–14 – but in a much simpler form. The light module symbol is dropped – we are now well aware of how it should be wired. The outward and return leads are no longer coloured and are drawn in black. The large black dots mean that the components should be connected electrically at those points. How and where this should happen is now left to the constructor.

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- The number and position of the cams on the cam disc determines the "character" of the flashing light. The lens lamp (with hole cap!) will flash more or less often, regularly or irregularly depending on the programme.
- The flash length of the flashing lamp can be slightly altered by moving the component-30 having the spring foot lever contact.
- Try other suitable fischertechnik components as cams. The "character" depends on the shape of the cam – agreed?

Page 16

The trick with the second source

The flashing light model 5–15 has an obvious disadvantage. If NG is turned up fully for a fast programme the light shines very brightly. The slower the motor runs the duller the lamp becomes. This is where the often-used trick with the second source comes in handy. That is as follows:

- The trick is to supply the motor and the lamp from separate sources. Thus two separate circuits exist (see figure 1–16). The red circuit is connected to the side output and the black circuit is connected to the front output of the NG.
- Since the voltage at the side output is constantly high the lamp always shines brightly – irrespective of what is happening at the front output.
- Obviously one could also use the battery block or the previous battery stick as the second source.

It can't be simpler!

The simpler the circuit diagram the easier it is to read. So in future we will drop the NG symbol. Instead the output socket circles will be drawn at the start of the connecting lines – see circuit diagram 2–16.

Now if we have to use a particular NG output the following labels will be used between the NG connecting lines:

7 V [v] = front output (adjustable).
7 V [s] = side output (not adjustable).
6 V will be written when the battery block is used as the source (e.g. figure 1–67).

A circuit full of tricks

Both the trick with the second source and the trick with the common fixed contact are used in the circuit 3–16 for the next model 2–17.

- The circuit diagram 3–16 closely resembles the circuit diagram 7–11 of the flashing light model. Only here both spring foot lever contacts of the ON-key are operated by the cam discs rather than manually.
- The 2-source circuit ensures that the lamp brightness remains the same irrespective of the varying motor speed.

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An optical illusion

If the motor in the ON-key model 2-17 is running quickly enough and one stares at the lights for a time it appears as if a point of light is moving in a circle from the back to the front. Thus one only sees the moving light when it appears to move past the front. It shows how one can be deceived – the lamps remain stationary!

Leave this model standing. Figure 4–18 shows an interesting alteration.

Page 18

The OFF-key . . .

is as can be seen from the name: the opposite to the ON-key. Its operation switches off a lamp for example. This type of key has great technical importance as well.

Figure 1–18 shows the symbol for an OFF-key. The "key contact" is closed in its rest position. This is made particularly obvious by the little hook on the fixed contact.

- Figure 2–18 shows two types. The spring foot presses against the contact element in both cases. The OFF-key is operated by lifting the lever contact from the fixed contact. Try out the operation of the OFF-key 2–18 using the simple circuit 3–18.

The key is also called a push-to-break key since its operation opens the otherwise closed contact and breaks the circuit.

Interrupting instead of flashing

- Figure 4–18 shows how one can very simply make an OFF-key model from the ON-key model 2-17. The common fixed contact and the level contacts are raised so that the wing cams of the flat hubs can lift the spring feet off of the shaft-80.
- In this case the cam discs must run in the opposite direction to that in the ON-key model 2–17.

This means the end of the moving light effect since the lamp light is only interrupted for a short time . . . or is it?

By the way: What could the circuit diagram of the OFF-key model look like? If you can't solve it – never mind. We will return to it later.

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The OFF-roller...

is an amusing game where the concept of an opening contact plays a "role" in the truest sense of the word. We can use this model 2–19 to give us a temporary rest from the previous exertions ... agreed?

- Figure 1–19 shows the simple circuit diagram. The lamp circuit is closed when the roller axle touches both plug shafts. If the roller falls off the roller contact and the circuit is opened – the lamp goes out.

Game rules – a suggestion

The plug shaft rails must be raised or lowered using the connecting component-45 until the roller catches on the plug tips of the shafts (figure 3–19). It must not be able to roll back when the shaft rails are raised!

Each player has 30 seconds. The player who succeeds wins and a new round begins. If the roller falls off causing the lamp to go out the player retires until the next game.

Beware interference!

The display lamp flickers when the OFF-roller moves to and fro along the plug shaft rails.

This is a typical loose contact. It does not affect the game but does affect the reception of a neighbouring radio – especially medium wave! The small sparks caused by the opening contact are responsible. We will return to these so-called "sparks at break" later.

Page 20

Wiring tips

Now that we have wired several models it is time to look at some tips for avoiding the cumbersome wiring salad. Loosely hanging strips not only interfere with the model operation but they also look messy.

① Light modules should be wired from the side to which the lead is taken. Beware: avoid short circuits (see page 8).

② Space can be saved by leading wires between the pegs and slots without clamping them.

③ The individual link elements in the basic set-200 or

④ the component-5 units can fix the leads into the slots of the fischertechnik components.

⑤ The short connecting component-15 is also well-suited to this purpose.

⑥ Obviously before pulling a lead through a link element the plug must be unscrewed and subsequently screwed back on again. In the case of the double-cored lead this should be completed for each plug separately. Otherwise the continuity test on page 6 must be repeated.

⑦ Using corner angle blocks under the base plate is a favourite way of leading supply and other long leads under the model to avoid interference.

⑧ The light module is excellently suited as a socket on the model for NG supply leads.

⑨ Leads which are too long and cannot be attached should be wound round a shaft to produce an elegant spiral.

⑩ Plugs which slide out of sockets should be opened out a little using a knife.

Page 21

The make-break key

The ON-key consists of a lever contact and a make fixed contact. In the OFF-key a break fixed contact is used. The make-break key consists of a lever contact, a make and a break fixed contact as shown in figure 1–21. During operation the lever contact alternates between one fixed contact and the other. Let's have a go.

Figure 2–21 shows two types of make-break key. They are the previously encountered OFF-keys 2–18 each extended by a spring contact for use as the make fixed contact.

- Try out the make-break key using circuit 3–21. Only the break contact 1–2 works in the rest position. The green lamp lights when NG is switched on.
- Operate the key by pushing the spring foot against the spring contact. This closes the contact 1–3 and the red lamp lights.
- Thus one can light and extinguish two lamps alternatively using a make-break key.

By the way: Slow operation produces a dead point – no lamp lights. Correct?

The key module

A make-break key is installed and wired up in key module 4–21. The numbers on the back side correspond to the socket descriptions in symbol 1–21.

- Try out the module using circuit 3–21 again! Because of the built-in "toggle" there is no dead point even under slow operation. An important advantage!

N.B. We will abbreviate the key module 4–21 to ft-key (ft: fischertechnik). In circuit diagrams it will be represented by a framed T (see circuit diagram 5–24).

Page 22

An illuminating eye-catcher

The model 4–23 could be put in the display window of a toy shop as an "eye-catcher" to attract attention. The yellow lamp glides to and fro behind a screen with the fischertechnik-fish for example. Everyone will look!
The advertising effect of the model will be markedly increased on the next two pages by using the ft-key.

The light moves to and fro

- The electrical part of the circuit diagram 1–22 is easily understood. Advertising lamp and motor are connected together to NG – like both lamps in the lamp stand 2–9.

  This means that the lamp lights when the motor is witched on.

Page 23

- The advertising lamp is mounted on a sled (component-30 with hole) as shown in figures 3–23 and 4–23. This is moved to and fro on the shaft rails-110 by the rotating disc which drives the struts-120 (figure 4–23). The "mode of operation" is also indicated in circuit diagram 1–22.

Page 24

The light goes to or fro

The eye-catcher would be more fun if the lamp appeared to be travelling from only one side behind the transparent screen instead of simply moving to and fro. This is another type of moving light effect.

- To achieve this we will use the ft-key as an ON-key in figure 5–24. It is operated by a switching disc whose cam runs around half its circumference as shown by the symbol in the circuit diagram. The general symbol for our adjustable "switching cam disc" is shown in figure 6–24.
- Construct a switching cam disc using the two simple switching discs as shown in figure 7–24. The completed disc with the 180° cams is shown in figure 8–24.
- Now mount the ft-key and the switching cam disc on the drive shaft between the bearing block and the rotating disc as shown in figures 10–25 and 11–25. Do not use the green lamp in figure 11–25 for the moment.
- Finally the switching cam disc is fixed on to the shaft so that the cam operates or releases the ft-key at the reversing point of the lamp.

Page 25

Yellow to – green fro

The eye-catcher has more variety if a yellow light shines in one direction and a green light shines in the other direction.

- Mount the green lamp in the lamp holder (figure 11–25).
- Obviously the ft-key must be inserted and wired as a make-break key as shown in figure 12–25. In order to make the lamp brightness independent of the motor speed we will use the side NG output as a separate source for the lamp circuit. We've used this trick before!

Page 26

Timing device

This is an assembly which automatically switches an electrical device on or off after a defined time. Using the simple model 5–27 we can quickly discover how such a "time switch" works and page 28 explains how it works electrically. Later we will change and improve the model.

- Wire using figure 1–26. The dotted "operating line" is bent at right angles for clarity. This doesn't alter its meaning, i.e. cam disc operates key just as in the flashing light on page 14.
- When NG is switched on the motor will run and the green lamp will light provided that the ft-key is not operated by the corner stone cam (figure 4–27). In that case the motor stops and the yellow lamp lights. Agreed? This is the "start position" of our time switch.
- The yellow light is now to be switched off and the green light to be switched on for a defined time. Press key T and release it again when the cam has released the ft-key. The time switch will run until the motor is automatically stopped after one revolution by the cam disc.
- This "switching time" can be varied between approximately 1 and 10 minutes by using the NG rotating knob.

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- The worm section in figure 3–27 is contained in the large new Motor set. However, one can use the earlier mot-construction set. Of course the model must be altered somewhat. No problem for fischertechnik experts!

Page 28

The time switch operation

The time switch operation relies on the fact that the motor is no longer connected directly to the NG but has a break contact 1–2 of a ft-key in its supply lead. Thus the motor switches itself off when the key is operated by the cam disc. The details are as follows.

- Figure 6–28 shows the operational status "ready to start". The circuit of the motor and the green lamp is broken by the operated ft-key; the red circuit of the yellow lamp is closed causing the yellow lamp to shine.
- Operating the key T (figure 7–28) connects the motor and the green lamp to the NG (blue circuit). The time switch starts and the green lamp lights. The yellow lamp still lights for a short while until the cam releases the ft-key (figure 7–28).
- The large blue circuit for the motor and the green light in figure 8–28 is only closed by the ft-key contact 1–2 and then the yellow lamp circuit is broken. Only then can the key T be released. The time switch continues to run until it is automatically stopped again as in figure 6–28. Is everything clear?

One of the best known uses of the timing switch is the stairwell illumination – represented by the green light in the model. It is switched on by hand and switches itself off. However, our circuit is not suited to this purpose. The longer the switch time the weaker the lamp-light. It's not surprising – the motor and the lamps are supplied by the same source. Unfortunately the old trick with the second source is not possible due to lack of a further key for the lamp circuits. However, that shouldn't worry us. There are still many untried components in our set – one of them will surely be able to help us!

Page 29

The ft-mains switcher

A so-called "relay" is installed in the mains switcher 9–29 (not to be confused with the power pack!). Using this we can automatically switch household appliances such as for example table or standing lamps, radios, smaller ovens, etc., on or off in complete safety! The relay operation will be described on page 64.

- The mains switcher 9–29 is connected by its mains cable to a wall socket. The household appliance plug is plugged into the mains switcher socket and the electrical appliance is switched on.

During the ON-period

Saving energy is always important! Thus a standing lamp in front of a book shelf in a dark corner should only light up when we want to remove a book. Naturally it's switched on by hand – but it should go out by itself.

- To this end the lamp is removed from the "green light module" which is then connected to the sockets of one of the two "control inputs" of the mains switcher (figure 9–29).
- The yellow lamp lights to show that the timing device is operational and ready to go. When required the timing switch is switched on, the standing lamp is switched on and goes out automatically when the timing period expires. The expert says that "it is controlled through the mains switcher by the time switch".
- The switching time can be adjusted approximately between 1 and 4 minutes. Longer times are not possible since the relay in the mains switcher will not "energise". Try it! We will discover the reason on page 64.

During the Off-period

The radio is playing music. The telephone rings and we want a few minutes' silence – OR – total silence is required at the start of an OFF-roller round (page 19) and after one minute the end of the round is unmistakably signalled by the automatic switching-on of the radio.

- There is nothing simpler. The mains switcher is connected to the "yellow light module" instead of the green light module and the lamp is removed. Now the radio runs all the time and is silenced only during the switching period of the time switch. OK... Or?

Have you noticed yet? The 2-source problem has been solved in a very elegant way using the mains switcher. We have simply used the mains supply (through the socket) as the second source for the household appliances. This is only possible since the relay in the mains switcher is specially constructed for this purpose. Therefore it pays to use the mains switcher.

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Flashing unit with time switch

The flasher is combined with a time switch in the model 5–31. Both are driven by a motor. The flasher only works during the switching period and must be started by hand as required. Such a system could be installed for example to safequard a concealed gate entrance. In this interesting model we will use the slip ring from the em-construction set for the first time.

- Figure 1–30 shows the circuit diagram of the model. On the left of the motor, corresponding to the position in the model 5–31, the previously encountered time circuit with the cam-operated OFF-key T_1 and the hand-operated start key T_2 are drawn in.
- Both spring foot keys are mounted on the key holder as shown in figures 2–31 and 3–31. The plastic shaft-30 in figure 5–31 serves as the switching cam.
- The flasher circuit on the right of the motor which uses the cam-operated ft-key also has no electrical novelty.

We now use the slip ring as the cam disc. Figure 2–30 shows how the interrupter components are mounted onto the slip ring as cams using a component-30.

The slip ring is drawn as a cam disc in the circuit diagram since, in this model, it has yet to undertake any electrical tasks.

- Very different "flash programmes" can be produced by varying the number and separation of the cams.
- Obviously the cam disc for the time switch must run much more slowly than the "flasher disc". The gear wheel reduction in figure 4–31 achieves this.
- Since two individual "cam keys" are used in this model the flashing lamp is supplied separately from the motor using the NG[s]-source.

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Rotating searchlight

In this model the slip ring is to transfer the current to a rotating lamp. (It is not very practical using leads!) The spring hinge blocks ensure that the contact elements are pressed against the slip tracks. Our symbol for a ring and two slip tracks is shown in figure 1–32.

- Circuit diagram 2–32 shows how the contact elements are connected to the motor and the NG. These slip contacts are pressed against the slip tracks using the spring hinge blocks (figure 3–32) and the tracks are connected to sockets inside the slip ring (figure 4–32).
- The current can now flow to the lens lamp through the plug shafts inserted in the sockets.
- The interrupters used in figure 2–30 turn the searchlight into a flasher.

Page 33

Motor control using make-break keys

It's very tiresome having to reverse the rotating knob of the NG every time that we want to reverse the motor direction. It is much more practical to use two make-break keys. Let's try this now!

- Figure 1–33 shows the experimental set-up using a "homemade" and a ft-make-break key. The reversal of the motor rotation is more easily seen if the gear and the rotating disc are used.
- Wire as in circuit diagram 2–33. Switch on NG and operate the keys alternately. Happy?
- If both keys are either operated or not operated nothing happens. The motor has both its terminals connected to only one "pole" of the NG source.
- However, if only one key is operated the motor runs. Figures 3–33 and 4–33 clearly show that the direction of rotation (drawn at random) depends

upon the side from which the current flows through the motor. We can control this using the cunning make-break key circuit.

We will find our new-found knowledge very helpful in the following crane model.

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Building crane with stick control

The previously used motor control with make-break keys is exceptionally well-suited to the building crane model 5–35. For this purpose we shall build a proper control desk which can be operated independently of the position of the crane.

The two make-break keys in the experimental set-up 1–33 are too expensive to use in the control desk. A much more elegant solution is possible.

- Figure 1–34 shows the simplified circuit diagram whose execution is shown in figures 2–34 and 3–34. The spring feet serve as "control sticks" to control the motor for the rope pulleys.
- Both connecting leads between the make and break fixed contacts are replaced by two shafts-60 acting as "common fixed contacts". This trick has already been used successfully on pages 11 and 17.

Naturally one could also use the change-over switch in the new Motor construction set. In practice however, the stick control has an important advantage. If the crane driver releases the control stick through carelessness or because he suddenly becomes ill, the motor is stopped automatically and an accident is avoided.

Unfortunately the stick control does not prevent accidents caused through overloading the crane. For this we need an "overload protector" in our model (page 36).

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Overload protection

It wouldn't be the first time that a building crane capsized because the load was too heavy or the grab had somehow got caught in the ground. Such accidents are avoided by, for example, the overload protector described here.

- The electrical operation of the protector is very simple. The break contact 1–2 of the ft-key is inserted in the connection between the two make fixed contacts of the make-break keys (see figure 1–36). If this is operated by overload the motor is immediately stopped since its circuit is broken.
- The common fixed contact (shaft-60) in the control desk is replaced by two contact elements (see figure 2–36). The key is connected to the contact elements as shown in circuit diagram 1–36.
- Figure 3–36 schematically shows the mechanical part of the protector. Under overload the lifting cable becomes too tight and pushes a pulley lever assembly against the key thus operating it. The layout is shown in figures 4–37 and 6–37.
- Obviously the "protection switch" will also be operated if the motor is inadvertently left running after the load has been lifted and the crane hook bumps against the "catcher strut" (featured in figure 5–37).

Because of the mechanical construction of our model it requires quite a substantial load on the hook before the protector operates.

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Switches

Principally switches differ from keys in that the moving contact lever does not spring back after operation but "latches" firmly in place. This is shown in the symbol (figure 1–38) as a dotted line with a "latch"; otherwise it does not differ from the key symbol.

On-off switch

- The simplest type of switch has only one fixed contact (figure 1-38). This is a spring foot in switch 2–38: the movable but inflexible contact lever consists of the contact element in the rotatable component-15 with red pins.
- Figures 3–38 and 4–38 show how we can make a switch from the ft-key. The heavy disc or pressure handle of the fixed contact sockets (2 or 3) is used for the ON-OFF switch.
- Try out all the switch types using only one lamp in figure 5–38.

Reversing switch

As in the make-break key this switch has two fixed contacts (figure 1–38). In order to avoid errors the expression "reversing switch" rather than make-break switch is preferred.

- Both fixed contact sockets (2 and 3) are used in figure 5–38 to produce the reversing switch.
- The reversing switch in figure 6–38 has a neutral position (like the switch in the large new Motor construction set). No lamp lights if the spring foot contact lever is not touching a fixed contact shaft – agreed?

Page 39

Two switches for one lamp

In a room with two opposite doors it is obviously necessary to be able to switch the ceiling light on and off from each door. This not so simple task is solved by using two reversing switches.

- Figure 7–39 shows the experimental layout using a "ceiling light", the sliding reversing switch S_1 and the reversing switch S_2 whose neutral position obviously must not be used here.
- Since each reversing switch has two contact positions both switches have four contact combinations. They are shown in figures 8–39 to 11–39.
- Consider a moment before trying it.
  Which of the four switch positions will cause the lamp to light and which will not?

Page 40

Light show with economy circuit

The light show model 4–41 can also be used as an "eye-catcher" in a toy shop display window. Each of its two lamps can be arbitrarily turned on and off for long or short periods either individually or together. After the busy period the "economy lighting" with only one lamp is switched on or the whole system can be switched off.

- Figure 1–40 gives the answer to the question on page 18 "What does the circuit diagram for an OFF-key model with cam-controlled contact levers and a common fixed contact lever look like?"
- The shaft-50 in the spring hinge blocks are used as moving contact levers in figure 2–40. A plug shaft serves as the common fixed contact. Each of the two OFF-keys is operated by an adjustable switching cam disc which extinguishes the relevant lamp (see page 24). This "control section" can achieve a wide variety of programmes for the light show.
- The common fixed contact (the plug shaft) is connected using the socket end to the fixed contact 3 of the previously met reversing switch with neutral position. Operating the 1–3 contact connects the motor and the lamps through the corresponding OFF-key to the NG. The light show begins – OK?
- In contrast the fixed switch contact 2 is connected only to the left-hand lamp in figure 1–40. If contact 1–2 is closed only this lamp lights and it does so continuously: the motor and the right-hand lamp are switched off.
  Hence the operational mode "economy lighting"!

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Light show with ecomomy circuit

- What happens when the reversing switch is put in the neutral position?

By the way! One could also use the new switch in the large Motor construction set instead of the home-made switch S.

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The switch component

The switch component 1–42 is very useful for model building. It only differs from the switch component in the large Motor construction set because of its "snap-action contact" and its handle construction. Like the key component it has no neutral position. Let's look more closely at the switch component's inner workings.

- The switch component has two reversing switches (drawn in blue in figure 2–42) whose lever contacts are joined together (red operating line). Thus both reversing switches are always operated together.
- If only the sockets 1–3 or sockets 2–4 are used (figure 3–42) the reversing switch becomes a normal ON-OFF switch. Figure 4–42 shows the circuit in which the component is inserted as a reversing switch. Try this out thoroughly!

Switch component as pole reverser (PW)

This is the name for a switch whose operation interchanges the electrical connections of an appliance. Figures 5–42 and 6–42 show how this works. Here the outward leads from the NG to the motor are drawn in red and the return leads are in blue – exactly as in the key control diagrams on page 33. Whereas previously two control sticks were used the pole reversing switch only needs one handle to reverse the current through the motor and also – as we know already! – the rotation direction. In future we will use the symbol 7–42 instead of the cumbersome representation 2–42.

The rotating knob on the NG is also a pole reverser which interchanges (reverses) the NG connections (poles).

In contrast to the switch component in the motor construction set which must be operated by hand, this component can also be operated automatically.

This is shown in two examples on the next pages.

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As stubborn as a tank...

which keeps on going in a straight line even if a house is in the way. This certainly isn't the case with this amusing caterpillar vehicle 4–43! It immediately reverses when its "wheel sensors" hit an obstruction.

- The wiring is very simple (figure 1–43) – just make sure that the leads do not go between the caterpillar tracks!
- When the wheel sensors are pushed by an obstacle the locking discs operate the pole reverser. That's all there is to it!
- At the same time the ft-key which controls the lamps used to display the direction, is operated or released by the terminal socket-10.

Page 44/45

Ship's radar antenna

Nowadays almost all ships are equipped with "radar navigation". The radar antenna continously swings first in one direction and then in the other direction to detect ships or other obstacles in its path during the night or foggy conditions. The helmsman uses a screen connected to the antenna to detect obstacles in time and thus avoid collisions. The simple model 4–45 can copy the motion of the antenna using the pole reverser.

- The switching cam disc with the matching switching discs operates the pole reverser after a half a revolution in either direction (figures 2–44 and 3–45). As a result the radar antenna will be rotated to and fro by the interlocking wheel profiles.
- The other switching cam disc controls the "alarm flasher" using the ft-key. The flash programme is determined by the positioning of the switching discs relative to each other and the position of the two cam discs on the drive shaft.
- Wire as in figure 5–45.

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Side by side – one after the other

It has already been hinted on page 9 that there is another method of connecting two lamps to one source. We will compare the two possible circuits with each other and use them in a simple model.

Parallel circuit

This is the name of the circuit previously used on page 9 and repeated again in figure 1–46. Figure 2–46 clearly shows the parallel lines lying side by side and drawn in red. Each lamp lies in its own circuit – as discussed previously – and therefore receives the total operating voltage.

■ Turn the NG on fully. Both lamps light very brightly.

Obviously one can connect other components "in parallel" such as motor and lamp or two keys as in the time switch models.

Series circuit

This is the circuit shown in figure 3–46. Figure 4–46 clearly shows the sequential character of the lines drawn in red.

■ Connect the series circuit to the fully turned-on NG. Both lamps light considerably less brightly!

The reason? The two series connected lamps lie in the *same* circuit. Thus the operational voltage must be "divided" between the lamps. If the lamps are the same each receives half of approximately 7 V, that is a "partial voltage" of about 3.5 V – and that's not much.

Mixed circuit

Both circuit types are used in the following fan model. The circuit diagram 5–46 shows that the parallel circuit of two lens lamps and the break contact 1–2 of the ft-key is connected in series with the motor.

■ Turn up NG fully. The fan runs at full speed. No wonder – the motor is connected directly to the NG source through the break contact (blue circuit) and therefore receives the full voltage.

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■ Operate the ft-key. The lamps and the motor now lie in series in the red circuit and apparently the "parallel voltage" across the motor is sufficient to keep it running slowly.

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Combination lock with key code

Generally safe and strong box locks can be opened using a number key (number code). In contrast our "combination lock" 5–50 only reacts to a particular method of operating the various keys. This game is great fun. "Who will be the first to crack the code?"

Game rules

Each player has for example 3 minutes to operate (or not operate) the three keys of the model 5–50 in such a way that the green lamp lights up to indicate "lock open". However, he who causes the red "alarm" lamp to light has been caught safe-breaking and must retire.

The key code

Naturally there are a few traps built into the code circuit to make life difficult for the safe-breaker!

■ Firstly there is the key T_1 with two fixed make contacts and a neutral position (circuit diagram 1–48) – a so-called "two-way switch". Figures 2–49 and 3–49 show the stages in the construction of this type of key. Obviously one could have used a reversing switch with neutral position but a key makes "breaking" more difficult.

■ When the A–B contact of T_1 is operated the motor is switched on and the slip ring rotates. This time it's slip tracks are connected in series as in figure 1–48; see figure 4–50 for the wiring. Thus two series connected "OFF-keys" (drawn in red in figure 1–48) are formed using interrupt elements (figure 4–50) and slip contacts. The current only has a chance to come through to the green lamp if this key is not operated by an interrupt element.

■ Thus the player has to release the key and stop the motor at the exact moment when both contact elements touch their respective slip tracks at the same time. Clever use of the interrupt elements and a fast motor speed mean that this task is by no means easy!

However, further conditions must be fulfilled before the green lamp can light.

■ After its release T_1 must be operated in the other direction (and remain there!) so that the current can flow through the closed A–C contact of T_1.

■ Finally the ON-key T_2 must be operated. The green lamp circuit is closed at last, the lamp lights and the lock is open. He who decodes this code without a circuit diagram deserves praise indeed!

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■ If the player operates the ft-key instead of the ON-key T_2 then . . . he is out of luck. Why?

Think about the following:

- Can the lamp light while the motor is running?
- Can both lamps light at the same time?
- Can one of the lamps light if the two-way make key T_1 is not operated?

Do you understand the key code now? Then build the model, wire it correctly and . . . have fun with the code game!

Page 51

Our permanent magnets

The magnet plates stuck onto a coloured holder consist of ferrite powder, which was pressed (sintered) at high temperature and subsequently magnetised. Such materials which retain their magnetic force after being magnetised are termed "magnetically hard". Figure 1–51 shows the symbols used for our permanent magnets.

The magnetic poles

Each magnet always has two poles; a North and a South pole. Single pole magnets do not exist! The magnet plate with the red holder is glued on the South pole side: the gray-black front side is its North pole (see figure 2–51). The magnet plate with the green holder is the exact opposite of this.

- Lay both permanent magnets in the plastic shaft frame as in figure 3–51. Do the magnets attract or not?
- How do the magnets behave when they are layed in the frame as in figure 4–51?

This small experiment impressively confirms:

The fundamental laws of magnetism

- Unlike poles (North-South and vice versa) attract.
- Like poles (South-South or North-North) repel.

By the way: It is interesting to note that the magnetic force of the lower magnet in figure 4–51 passes undiminished through the plastic holder! We will use this immediately in the next model.

Page 52/53

Special stirrer

In some laboratories stirrers are used in special cases where the stirring vane must rotate in a totally airtight vessel – because, for example, no oxygen may penetrate or no dangerous gas may escape. The model 5–53 shows the trick which is used in these cases: the "magnetic shaft coupling".

- Figure 1–52 shows how the magnet is fixed onto the shaft with the stirring vanes using a pulley. This shaft-50 must be secured by a terminal socket under the base plate (figure 2–52), otherwise it would be pulled against the upper plate which represents the "vessel cover", by the magnet on the drive shaft (figure 5–53).
- Mount the component-30 with the "leading magnet" on the plastic shaft with the rectangular attachment as shown in figure 4–53.
- We have already discovered that plastic does not obstruct the magnetic force. Thus the stirring shaft will be "lead" by the drive shaft providing that the motor is not brought up to full speed too quickly. This would lead to the "breaking" of the magnetic coupling.

By the way: The instruction book for the new fischertechnik ec-construction set "Electronics" describes a clever circuit which enables the motor to start very slowly and gradually work up to full speed even with the NG turned on fully! More about the ec-construction set on page 87!

Page 54

Magnets make things magnetic

It's true! Many materials, our ft-shafts for example, turn into magnets when they are brought into contact with a magnet – but only when they are touching the permanent magnet. We will now investigate this amazing fact.

- The shaft-50 hanging from the permanent magnet in figure 1–54 is magnetised and in its turn attracts the paper clip.

  Try it. Will the shaft attract several paper clips or even a screwdriver?
- Pull the shaft with its "hangers-on" off the magnet. The screwdriver remains attached. Shake it slightly, it falls off as do the paper clips. The shaft no longer attracts anything – it is as unmagnetised as before. Agreed?

Materials which subsequently lose their magnetism are "magnetically soft". (The so-called "magnetic remanence" has no effect here.)

- Two shafts are magnetised by the same magnet in figure 2–54. As a result the shaft ends appear to have the same poles which repel in accordance with the fundamental laws of magnetism.
- If the shafts are hung from two dissimilar magnets as in figure 3–54 the unequal poles of the "shaft magnets" attract.
- The small truck-trailer model in figure 4–55 shows how strong the magnetic force at the shaft ends is. The "magnetic coupling" consists of two shafts loosely laid on the permanent magnets and fixed solely by locking discs. It takes quite a jerk to break the coupling!
- For fun let's clamp the two permanent magnets into the frame as in figure 5–55. The shafts-110 which are held by the magnets are strongly magnetised in opposite directions.

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- This produces a magnet which works using both its poles together – like a horseshoe magnet. Obviously this produces much more force!

  Will it still hold the shaft when two hubs and profiled tyres are attached?
- Now lay the magnet frame on the table as in figure 6–55, fix the two shafts in position using a second terminal socket-5 and... the magnet roller is ready! In contrast to the OFF-roller on page 19 doesn't fall off when the shaft rails are held at an angle. On the contrary: it even climbs a bit up the underside of the rails! However, tire wheels are a little too heavy for this game.

Magnets attract iron in particular but also nickel and cobalt. However, copper and its alloys, e.g. brass are not attracted.

- Silver is also non-magnetic. In spite of this some "silver" coins, 10 and 5 pfennig pieces, as well as "copper pfennigs" are attracted. A sure sign that such coins contain iron to a greater or lesser extent!

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The reed contact

Light module attachment for the reed contact

Before we try out the reed contact and use it in a model we must first insert it in a "light module attachment". This is absolutely necessary because the ends of the glass tube which contain the sealed-in connecting wires are very sensitive to mechanical treatment. The glass can shatter making this important, frequently used component useless.

- The connecting wires, which are already inserted into plugs (figure 1–56), are bent using the bending device in figure 2–56 in order to prevent damage to the glass tube.
- Using one hand press the wire against the shaft-50 so that it cannot be bent at the end of the tube. Using the other hand bend the plug end of the wire around the shaft as shown in figure 2–56.
- Then plug the finished end into the light module as shown in figure 3–56 and slide the whole unit along until the other wire end can be bent exactly as the first.
- Finally carefully plug the two plugs of the reed contact into the light module (figure 4–56).

Never remove the reed contact from this "mounting". Connections will now be made solely through the light module sockets, see for example figure 6–57!

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A magnetically operated contact

The reed contact sealed into the glass tube consists of two, very thin spring "reeds" of iron-nickel metal. One can see the small air gap between the reed ends. This is represented by the symbol 5–57. This make contact can only be operated using a magnet. Its action will now be investigated.

- First build the simple experimental assembly 6–57. The picture shows the wiring for the reed contact and the light module attachment.
- Figure 7–57 shows that the lamp and the reed contact are connected in series. Thus the lamp will not light when the NG is switched on. However, if a magnet is brought close to the reed contact the reeds are magnetised and attract each other – the contact is closed and the lamp lights.
- Figure 8–57 shows some of the ways in which the "switching magnet" can approach, leave or pass by the contact. Try out these and other possibilities thoroughly and take your time!

In most cases the contact switches only once as the magnet passes by – however in some cases it shuts and opens twice!

- How close must the switching magnet come to the contact before it closes? And how far must it be removed from the contact before it opens again? It is important for the correct insertion in the model to know these *different* distances!

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Stop the conveyor belt

Figure 1–58 shows a schematic diagram of the use of a proximity "contact maker" in the model of a filling plant with a conveyor belt and automatic filling scales (figure 6–60). In this model the weighing skip always tips forward when a particular load is reached and automatically stops the conveyor belt. The procedure is only repeated when the empty skip has tipped back to its original position. These plants are used widely, e.g. in the packaging industry.

- The switching magnet is rigidly fixed to the skip plate as shown in figures 1–58 and 5–60. The magnet operates the reed when the skip is empty or not full enough (figure 1–58).
- The position of the reed contact holder should be adjusted accordingly (figure 4–60). If everything is wired according to circuit diagram 1–58 the conveyor belt will run when the NG is switched on.
- The switching magnet must be positioned under the skip plate in such a way that when the skip tips it does not strike the supporting assembly (figures 3–59 and 4–60).
- The "full" weight which should tip the skip can be varied by sliding the end plate counterweight (figure 5–60).
- On tipping the switching magnet passes behind the reed contact and releases it. The belt immediately stops. It's that simple!

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Time switch with reed contact

We solved the "two source problem" very elegantly using the mains switcher 1–29 in the time switch 5–27 – but this only applies to "heavy current appliances". In contrast the reed contact also permits a separate supply for our ft-lamps.

- The circuit 7–57 just used is drawn unaltered in blue in the circuit diagram 1–61. We have already met the timing circuit with the motor, cam discs and parallel connected keys.
- We only need to make sure that the reed contact and the ft-key are operated at the same time. Here we use a very simple trick. We use a magnet as a switching cam! This requires that the model 5–27 be altered somewhat as in figure 2–61. The reed contact is inserted in such a way that it is operated by the magnet at the same time as the ft-key (figure 2–61).

The reed contact only permits the operation mode "OFF during the switching time" – the magnet is underway during this time. The switching time can be extended up to 10 minutes without decreasing the lamp brightness. If the mains switcher is used instead of the lamp the household appliance can be stopped automatically for between 1 and 10 minutes. We will soon build and test an electromechanical device (page 64) which will permit the operation mode "ON during the switching time" as well. Until then leave the model standing. Just remove the reed contact holder and the three components-15 with lamps – we will need them earlier.

Page 62

Current also magnetises

We know that a magnet can magnetise a ft-shaft (page 54). As unlikely as it may seem – the current flowing through a wire can also do this! The following experiment proves this.

- We will now use the 1 meter long green lead. It is wound firmly around the pulley (see figure 1–62). Both lead ends are stuck through a locking disc and inserted into plugs which are plugged into the light module holder. Stick the shaft-50 (the iron core) through the spool and assemble the complete unit into the holder as shown in figure 3–62.
- Connect the pulley through the make contact of the ft-key to the NG and turn on fully.
- Hold some paper clips near to the iron core and operate the key. Try the same with a shaft-30 and a shaft-50. A good strong magnetic force ... or?

When the current flows through the spool a "magnetic field" is produced which magnetises the control shaft exactly like a permanent magnet. When the current flow is broken the magnetic force in the spool disappears – the shaft-50 falls off. Lighter iron bits, such as paper clips in figure 3–62 remain hanging. We have already met this on page 54.

The "magnetic effect" of the electric current was discovered in 1870 by the Danish physicist Ørsted and this led to the rapid development of electrotechnology.

Page 63

The electromagnet

Electromagnets (or E-magnets for short) not only play an enormous role in technology they are also very important in model construction! The next 16 pages will introduce E-magnet applications which will be great fun for the fischertechnik expert – care to bet? However, we must first get to know our E-magnet. We use the symbol in figure 1-63.

Magnetic force on tap

The E-magnet has a decided advantage over a permanent magnet. Its magnetic force can be switched on or off and increase or decrease in strength.

- Figure 2–63 shows the experimental set-up which is connected as in figure 3–63 to the front output of the NG.
- A thin self-adhesive strip is stuck onto the "pole piece" in order to avoid the tiresome "caking" of metal bits onto the E-magnet. The "pole pieces" are the rings screwed onto the end of the U-shaped iron core.
- Now play with it a little.

– How many plug shafts can the magnet hold when the key is operated? Try it with the NG fully on and only half on. What happens to other shafts?

– How should the NG be set in order for the E-magnet to pick out paper clips from an assortment of paper clips and shafts?

– Does the E-magnet pull more strongly than the permanent magnet?

– Press your fingers against a shaft which is being held by the E-magnet. Do you feel anything? (We will deal with this on

The E-magnet poles

The iron core of the E-magnet is bent into a U-shape so that the pole ends lie next to each other. We have already seen that two poles together are stronger than one single pole (page 55). The effect is improved by using pole pieces.

- The shafts hanging from each pole in figure 4–63 are magnetised exactly as in the experiment on page 54. If the shafts are nudged slightly the ends stick together!
- The North and South poles of the E-magnet can be determined using the permanent magnets as in figure 5–63. This depends on whether the rotating knob on the NG was turned to the left or the right. Try it for fun! However, the location of the poles is of no importance to model construction using the em-construction set.

Page 64

An electrically operated key

This is the plain and simple description of the operation of a "relay". Our relay model 4–65 consists of a reversing switch with a spring contact lever (key!) which is operated magnetically when the E-magnet is "controlled"; i.e. electrically switched on or off. Using this model we will soon discover how the relay operates.

- We will use the vibratory spring as the contact lever. On one side it is held by a notch onto a com-

switch component. A component slid down on top of the spring ensures that it is firmly clamped.

The relay control circuit

This is the term for the E-magnet circuit drawn in red in figure 1–64. It is switched on and off (controlled) using the switch.

- We want to discover the smallest current neces-ponent-15 using a connecting element-30 (see figure 3–65). The other side is taken care of by the the end of the spring and the upper fixed contact must be set so that the relay does not vibrate when switched on at low NG output. If the current is too small the E-magnet pulls so weakly that nothing happens any more.

Now we know why the mains switching device would not work correctly or at all if the NG was turned down too much (page 29).

The relay load circuit

The two lamps which are to be switched lie in the circuit drawn in blue (figure 1–64). The scientist calls them the "load" (more exactly "load resistance"): thus the name "load circuit". However, ordinary mortals call the lamps "consumers" just as we did at the beginning of this book. Why this is not scientifically correct will not be discussed here.

- The load circuit is supplied by the side NG output (figure 1–64). The hole in the spring serves as a socket for the plug connection (figure 3–65).

When the magnet is switched off the lamp which is connected to the spring contact (break key) lights up – agreed? If it flickers the fixed contacts must be changed (beware: interference transmitter!).

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- Control the relay using the ft-ON/OFF switch S. The lamps in the load circuit light up alternately depending on whether the relay is "energised" or de-energised. Everything OK?

Thus the relay has two prominent characteristics:

- Two source circuits are easily realised. The relay in the mains switching device has already shown us this (page 29). However, that only possessed a make contact instead of a make-break contact.
- A relay is not operated mechanically using a make-break key: it is operated electrically using an E-magnet.

We will now complete the time switch model using the relay.

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Time switch with relay

- Here the ft-key controls the E-magnet instead of the yellow lamp as in circuit diagram 1–26. The control lines are drawn in red in circuit diagram 2–66.

  In this case the switch only controls the load circuit.

  Now we can select both operational modes: OFF or ON during the switch time. The switch time can be varied up to 5 minutes without reducing the lamp brightness.

  For the pro! How can one use the relay to achieve a switch time of 10 minutes? (Solution page 80.)

Page 67

Why does the spring buzz?

Shafts vibrate, the spring buzzes and chatters when they are attracted by the E-magnet but are not firmly held on to the pole pieces. Perhaps the E-magnet isn't working properly or is there another reason for this occurrence which is very disturbing for the engineer? The following experiment should clarify this.

- In order to make the spring buzz decently it is mounted on the holder together with the E-magnet (figure 2–67). The coupling element-30 serves as a stop for the vibratory spring.
- First use the battery block from the new Motor construction set as the source (6 V –, see figure 1–67). The previous battery stick or a flat battery also suffice. Hold the key down. Can you feel the spring vibrate or hear a noise?
- How does the spring behave when the battery circuit is closed and broken by operating the key as fast as possible?
- When the NG is used as the source – it doesn't matter which output – the spring buzzes, or can be felt to vibrate by depressing it slightly with a finger, when the key is operated. The noise can be altered by moving the magnet or the stop.

The experimental result clearly shows that the E-magnet isn't at fault: it's the source! Why?

Pure direct current

The battery voltage drives the current in the same direction (direct current) and without interruption through the E-magnet. Thus the spring is constantly held by the E-magnet and does not flutter when the key is operated.

Pulsing direct current

If the "pure" direct current is broken up into a series of "current impulses" by rapidly operating the key the spring obviously vibrates. It's attracted by each current impulse and released by each "current pause". Short current impulses in a continuous series are called "pulses".

In the case of the NG no key is needed for "pulse generation" – the NG voltage does this by itself. It alternates 100 times per second between zero and its maximum value. This pulsing is indicated by a broken line in the direct current symbol (-----). It's not surprising that the spring buzzes or that a shaft vibrates if it's attracted and released 100 times each second.

Page 68

A comical beast

This would appear to be a good description when one glances at this mixture of cow and dragon (figure 2–68)! The head on a vibrating spring neck which carries an E-magnet would suggest that it can nod and make noises. Judging from the single lamp the monster only has one eye. The tail appears to have no electrical importance and is probably only for decoration. The "automatic" 5–70 brings the beast to life. We will then discover whether our assumptions are correct.

- The spring is clamped by two "bones-30" (a very graphic description of the connecting elements in fischertechnik circles) as in figure 1–68. The head is fixed in the two notches at the freely vibrating end of the spring using two bones-15 (figure 1–68). Nothing prevents the addition of further embellishments to the dragon-cow!

Page 69

- The figures 3–69 and 4–69 show the first and second construction stages, and figure 6–70 shows the completed model of the "drive automatic" for the beast. The spring hinge blocks are provided with two components-5 each on the inside which assist the switching discs to operate the "shaft keys" (for construction see page 24).

Page 70

- The motor is supplied by the variable NG source (see figure 5–70). Thus the beast can react sluggishly or rapidly as desired.

- The lower, more slowly rotating, switching disc shaft is driven by the gear block (figure 4–69). It controls the shaft keys in the usual way.

  The top shaft with the switching magnet rotates considerably faster because of the gear wheel drive (figure 6–70).
- The "organs" of the beast – the lamp and the E-magnet – are supplied separately by the side NG output. The plug shaft is used as a common return line for this purpose. It is connected by the firmly attached spring foot to the source (figures 4–69 and 6–70).
- The E-magnet, which is responsible for the head nodding and the noises, is switched on as long as the shaft key touches the plug shaft. This switch time can be varied by adjusting the switching disc. (The spring is not shown in circuit diagram 5–70 since it has no electrical task.)
- The same applies to the lamp-eye. However the reed contact in series with the lamp must also be closed. The beast can only blink because the switching magnet rotates quickly and works with both sides!
- The behaviour of the dragon-cow can be "programmed" quite differently by adjusting the motor speed, the switching discs and the reed contact. An evening's occupation which is great fun!

Page 71

Crane with lifting magnet

The crane model 5–73 displays an important and very useful use of the E-magnet (schematic diagram figure 1–71). Instead of a crane hook it uses a lifting magnet. Such cranes are used for the loading and sorting of scrap. It easily transports bulky materials and the magnet does not pick up non-ferrous metals, plastic, sand or refuse – only steel and iron pieces are held. This "magnetic separation" can also be undertaken by our model.

- The current is fed to the E-magnet through connecting leads, drawn in blue on the circuit diagram 1–71, using the slip ring. A double-cored lead from the Motor construction set ist used for this. It serves simultaneously as the lifting cable for the lifting magnet (figures 4–72 and 5–73). However, in practice the load has its own steel cable for safety reasons.
- The best way of controlling the raising and lowering of the lifting magnet is to use the stick control described on page 34 (figure 4–72). The circuit for this is shown in figure 1–71.
- The ft-switch S is used to switch on the E-magnet for lifting and to switch it off for depositing a load. Contacts 1–3 or 2–4 of the switch component are used for this.

Page 72/73

- *Important!* During the lifting of a load the current must not be interrupted – even for a short time – as the load will immediately fall off (and in practice this would cause damage or even an accident)! For this reason the slip shafts in the spring hinge block must be set very accurately on their slip tracks (figures 3–72, 4–72 and 5–73)! If necessary bend the terminal contacts together slightly – they must sit tightly on the shafts.

Page 74/75/76/77

Morse telegraph

One of the oldest applications of the E-magnet which is still used today is the Morse telegraph. Our model on page 77 consists of a "transmitter" 6–77 and a "receiver" 7–77. The two are connected by wires as was the case in our great-grandfather's time. Naturally we don't use wires nowadays. The Morse code is given on page 86.

Let's try for once to read the circuit diagram 1–74 before we build the model using the pictures on the following pages. To this end cross off the answers which appear to be correct in the following test, OK?

Transmitter

The ft-switch S is installed as a:

Pole changer ☐ Reversing switch ☐

ON/OFF switch ☐

We will use the ft-key sockets:

1–2 ☐ 1–3 ☐ 2–3 ☐

Receiver

The motor which drives the roll of paper (drawn red in the circuit diagram) is switched ON/OFF by the:

Switch S ☐ Key T ☐

The E-magnet energises the recording arm (with felt pen) when: –

- the motor runs ☐
- the motor runs and the key is operated at the same time ☐
- only the key is operated ☐

One of the E-magnet connections is connected directly to the NG. This connection is on the:

left-hand side ☐ right-hand side ☐

of the circuit diagram.

Now that we have of course crossed the right answers we can build the model, wire it and put it into operation. We shall quickly discover that we have, perhaps, not got all the answers quite right!

By the way: How would the circuit diagram look if the E-magnet was to be supplied from a separate source? (Solution on page 80.)

Page 78

This is a hammer

It's true! The model 4–79 which uses a vibratory spring pendulum represents a so-called "Wagner's hammer". The device which is named after its inventor is an electromagnetic "interrupter" which automatically and continuously interrupts and closes its own circuit. Of particular interest is the way that the model sparks (ionises).

Question: Would it be possible to build also an interrupter from the relay 4–65? (Solution on page 80.)

- The vibratory spring and the fixed contact (drawn here as an arrowhead) together form a break contact which lies in series with the E-magnet as shown in figure 1–78.
- The E-magnet is positioned so that the spring is energised when the NG is switched on (figure 4–79). It's clear what happens next. The E-magnet lifts the spring from the contact element (figure 4–79), drawn as a dotted line in figure 1–78, and breaks its own circuit! The spring swings back and closes the break contact causing the E-magnet to re-energise immediately interrupting its own circuit again, etc., etc.
- In which spring position will the lamp shown in figure 1–18 light up?

Contact burning

Sparking occurs when a contact is opened. The sparks are particularly large if a coil lies in the circuit – e.g. the coil of our E-magnet.

- After about 20 minutes our hammer ceases to oscillate. This is due to the harmful "contact burning". The sparking has oxidised the metal. The oxide spots are clearly seen on the spring. Since metal oxide does not conduct current the oscillations cease. If the oxide flakes are ground off the sparking resumes. Try it!

Page 79

Oxidation is avoided by covering sparking contacts with a layer of oxidation resistant noble metal – like the contact ends of reed contacts or the contacts of a house door bell.

The spark gap

- The break spark jumps from the contact element to the spring. Two shafts-110 (figure 6–79) are connected as "electrodes" in parallel with this "spark gap" as shown in circuit diagram 5–79.
- If the interrupter is started up and the two electrodes are grasped in either hand ...

  Well, is it a hammer or isn't it?

Normally current cannot pass through air. Only a very high voltage makes this possible. A voltage of about 3000 V is required to pass current in the form of a spark through the 1 mm air gap! Although our interrupter has a much shorter path it still provides about 1000 V. It's not possible to explain this here.

This high voltage which we "tap" off the electrodes gives quite a jolt. However it's totally harmless since the amount of current driven through the hands is far too small to cause any damage.

Sparks interfere – we discovered that in the OFF-roller (page 19). The break-sparks caused by the relay (page 65) are considerably stronger and the interrupter can be "heard" on a radio in the next romm. Many people don't like this at all! For this reason all spark producers such as motors and ignition systems in cars and motorcycles, etc. must be suppressed!

Electrical sparks transmit "electromagnetic waves". The spark gap was used by Marconi in 1896 as a transmitter in the first experiment with wireless telegraphy.

Page 80

Problem solutions

From page 66

Once again the solution of the 2-source problem must be considered. In order to ensure that the E-magnet still energises even when the motor is running very slowly the red control circuit and the blue load circuit (circuit diagram 1–80) must both be supplied by the side NG output. This is possible without further ado if the E-magnet is controlled using the reed contact. The practical execution has already been encountered.

From page 74

The solution of this simple problem is shown in figure 2–80. There is however another problem. In the Morse telegraph the transmitter and the receiver are close together – one can see and hear immediately if the paper roll motor has been switched on or not. This is not the case if the transmitting station is in another room! For this reason a lamp should be mounted on the transmitter and connected in parallel with the receiver motor using two extra wires. This indicates whether the motor has been switched on before transmission and is switched off afterwards.

From page 78

No problem. You only need to insert the break contact of the relay in the E-magnet circuit and the relay buzzer is complete. (Enjoy listening to the radio!)

Page 81

The bimetallic strip

Only one electromechanical device remains uninvestigated now. This is the metal strip which is printed on one side and has only one socket hole: the "bimetallic strip". The thermal bimetallic strip consists of two different types of sheet metal strips which are so tightly fixed together that we can no longer see the joint. The symbol 1–81 represents the bimetallic strip. The bimetallic strip has a peculiar characteristic which causes it to react in a special way when heated as we will soon discover.

- Clamp the bimetallic strip using two components-15 as in figure 2–81. Now we will light a small fire under it. A so-called "night light" is particularly suited to this since it doesn't smoke like a normal candle. After a short time the "bi-strip" as we will call it in future, begins to bend. Does it bend towards the plain or the printed side?
- If we remove the flame the strip bends back again. However it takes rather a long time before it's straight again – agreed?
- Turn the bi-strip upside down and heat it again. The same thing happens as before. It bends towards the plain side.

This is because the printed sheet expands to a much greater extent than the plain sheet when the bi-strip is heated. For this reason the printed side (black in the symbol 1–81) is called the "active side". (For completeness it should be mentioned that when the bi-strip is cooled substantially – i. e. in the ice-making compartment of a fridge) – it bends a little towards the active side. However, we are only interested in the behaviour of the bi-strip when heated.)

Both metal sheets in the bi-strip conduct current. Thus we can use it as a contact lever in a contact just as we used the vibratory spring. Let's try this out right now ... OK?

Page 82/83

Thermal contacts

We have met manually operated, magnetically operated and electrically operated contacts. Finally we will learn how heat operated thermal contacts funktion and how they can be used.

Thermal make contact

- The bimetallic strip and the contact element (figure 2–83) form the make contact shown in figure 1–82. The bi-strip is straight at room temperature and must not touch the contact element (rest position). The active side must face upwards so that when heated the bi-strip presses against the contact element. The larger the gap between the bi-strip and the contact element the higher the temperature required to close the contact.

A "windy" air conditioner

In hot, humid, tropical climates fans provide draughts to give much-needed cooling in enclosed spaces. Model 2–83 represents a type of air conditioner which could be used for such purposes.

- Naturally the fan should not immediately blow out the candle. The draught should only make the flame flicker and push it to one side so that the bi-strip can cool off and bend back. This opens the thermal contact and switches off the motor. If it becomes too hot again the fan starts up – etc., etc. The exact position of the model parts relative to each other must be discovered by trial and error (figure 2–83).
- We will use here the previously tested model 8–47 without the key and the lamps. The motor is connected is series with the thermal make contact (figure 2–83) so that the fan starts up when it becomes too hot (figure 1–82). The "tropical" heat is provided by the candle (figure 2–83).

Usually in the tropics the fan is allowed to run slowly and continuously. However in particularly oppressive heat the fan should be brought up to full speed.

- No problem! The solution is a fan with a speed changer. For this we only need to replace the manually operated break contact of the ft-key (circuit diagram 5–46) by the heat operated thermal make contact. In practice this means that two lens lamps are connected in parallel to the thermal contact. Is that clear? Now alter the circuit diagram 1–82 accordingly!

Page 84

Thermal break contact

- A thermal break contact is made out of a thermal make contact if the active side of the bi-strip is allowed to rest on the spring contact (figure 1–84).

Temperature regulation

It's rarely too hot in our climate, but it can often be too cold for long periods. So the temperature of an appartment will not be regulated by air forced in draughts but by heating. (The type of heating is of no importance here.) It is represented in model 4–85 by two parallel connected lens lamps (figure 3–85).

- The thermal break contact is connected in series with the heating (figure 1–84). In our model the "heated room" is pitifully small. For this reason we will initially omit the detachable inside wall (figures 3–85, 4–85).
- Clamp the bi-strip using a connecting element-15 (if necessary fix it with thin paper) which is inserted into a rotating holder (figure 4–85). In this way we can vary the "contact pressure" of the bi-strip on the spring contact. The greater the pressure the higher the "room temperature" required to open the thermal contact. The bi-strip serves at the same time as the ceiling for the room.
- The control operates in the opposite way to that of the air conditioner. If the heat is too great the thermal contact switches the "electrical appliance" off; not on.

The thermal fuse in the NG

- Now insert the inside wall as in figure 4–85. This totally enclosed box represents the NG. The lamps correspond to the "transformer" installed in the NG. If this becomes too hot through overload (e. g. because of a short circuit) the spezially constructed thermal breaker in the NG operates exactly like the one in our model.
- This can be beautifully demonstrated in the following experiment. Connect a lamp to the side output of the NG and short circuit the fully-turned up front output using a lead (figure 2–84). Now wait a bit...

  Not bad our NG flasher ... or?

The thermal fuse prevents the NG transformer from scorching during a short circuit by continually switching off and on.

Page 85

Control and regulation

The room temperature can be held at a desired level by using a switch to switch the heating on and off, i. e. controlling it manually. Using a time switch the heating control can take place partially or fully automatically.

In each case the heating must be controlled by a person – either using his heat sensitivity or a thermometer. Even the time switch automatic must be adjusted to suit the weather.

The temperature regulation operates in a completely different manner. Here the temperature itself switches the heating on and off without our help using a "heat sensor". We only need to set the "reference temperature" and the heat sensor does everything else automatically. Our model, the NG and most other current "thermostats" use a bimetallic strip as their "heat sensor".

Thus a control is a system which regulates itself.

Page 86

The Morse code

The code invented by the American Samuel Morse in the previous century only needs two characters: a dot and a dash. These can be written by a device as simple as our Morse receiver 7–77. They can also be heard if a buzzer is used. Because of these advantages the Morse code is still indispensable for communication in today's world. Every radio ham will confirm this.

Table 2 shows how the letters, numbers and punctuation marks are converted into Morse characters. Table 3 shows how the Morse characters can be converted into plain language.

Examble 1: ––·– = ?

The unknown Morse character begins with a dash. Thus we must use the lower half of the table. After the first dash (=t) comes another dash. Follow the "dash" line to m. Then comes a dot – follow the "dotted" line to g. Finally we have another dash – the "dash" line goes from g to q. Thus the Morse character ––·– represents a q.

Example 2:·––· = ?

Start with a dot, i. e. the top half of the table. The "dash" line goes from e to a, the next "dash" line goes to w and the final "dotted" line goes to p. Thus the Morse character ·––· represents a p.

Page 87

The new ec-construction set "Electronics"

Here it is again, the comical beast. However, this time it has a totally different drive automatic: no more motor, no switching cam discs, no shaft keys – the dragon-cow is now brought to life electronically. The drive automatic consists of the three e-components out of the new construction set "Electronics" which contains further electronic elements. The whole thing is not much bigger than the dragon-cow itself.

The beast not only wags its head, rattles and blinks in a much more comical fashion but it can also speak. It can growl, whimper, or howl depending on whether the photo-resistor is covered slowly or rapidly, totally or partly by the hand. The dragon-cow is "controlled by light".

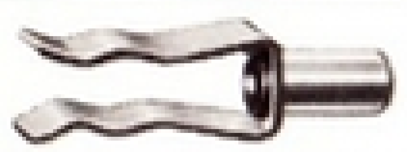
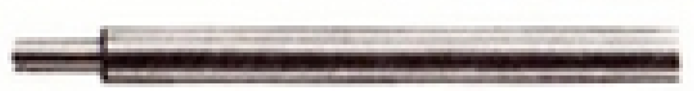
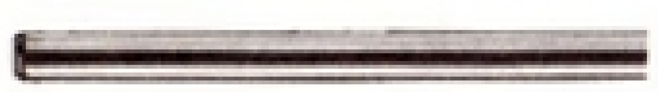
It is quite amazing what one can do with the three E-components, power supply (SPV), threshold switch (SWS) and output stage (LST) and the electronic components in the construction set: electronic time switches, control circuits for models and the construction model railway, versatile applications for barriers – flashers, light shows, optical signal devices – police siren, various siren types and much more.

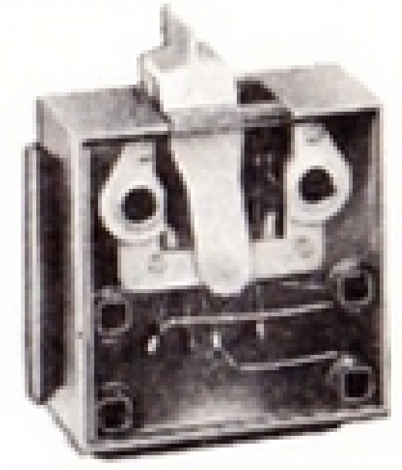
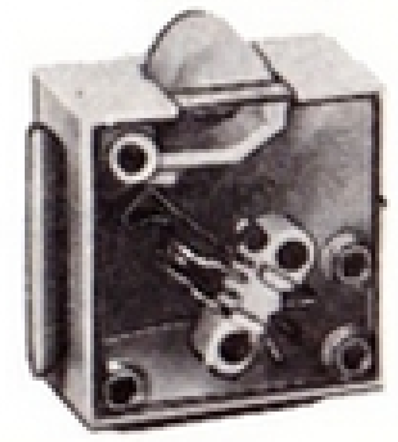
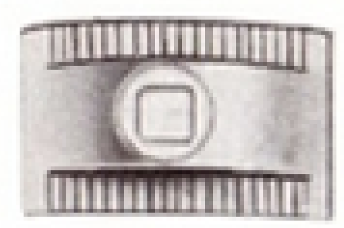
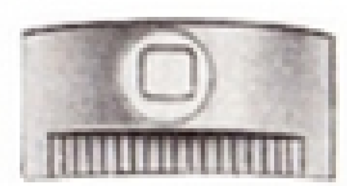
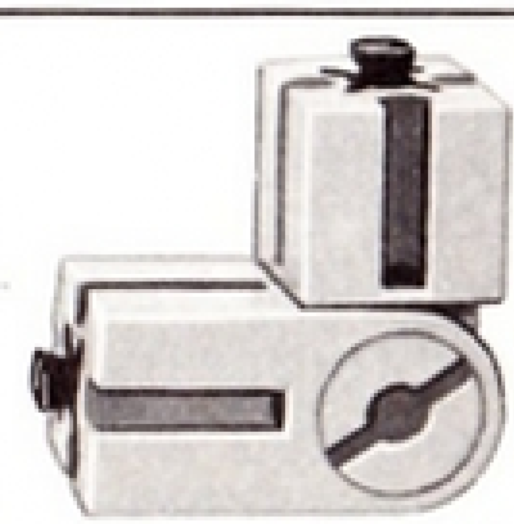
Using the construction set "Electronics" enables the production of many partial and full automatic model controls (see dragon-cow, alarm and signal devices) useful things and playthings. The instruction book is totally unable to exhaust all the possibilities.

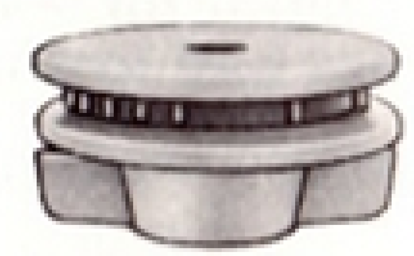
For this reason a special "Model Book" is planned. It not only contains some very interesting new model suggestions, but in addition it has practical tips and suggestions, but in addition has practical tips and suggestions for continuing experiments and for the development of one's own circuit designs.

Finally it should be mentioned that by playing with the "Electronics" construction set the beginner acquires the necessary fundamental knowledge which is indispensable to substantial and successful progress. Also the "expert" will be more than delighted with the simple, but versatile circuit technology which permits the easy construction of ingenuous circuits.

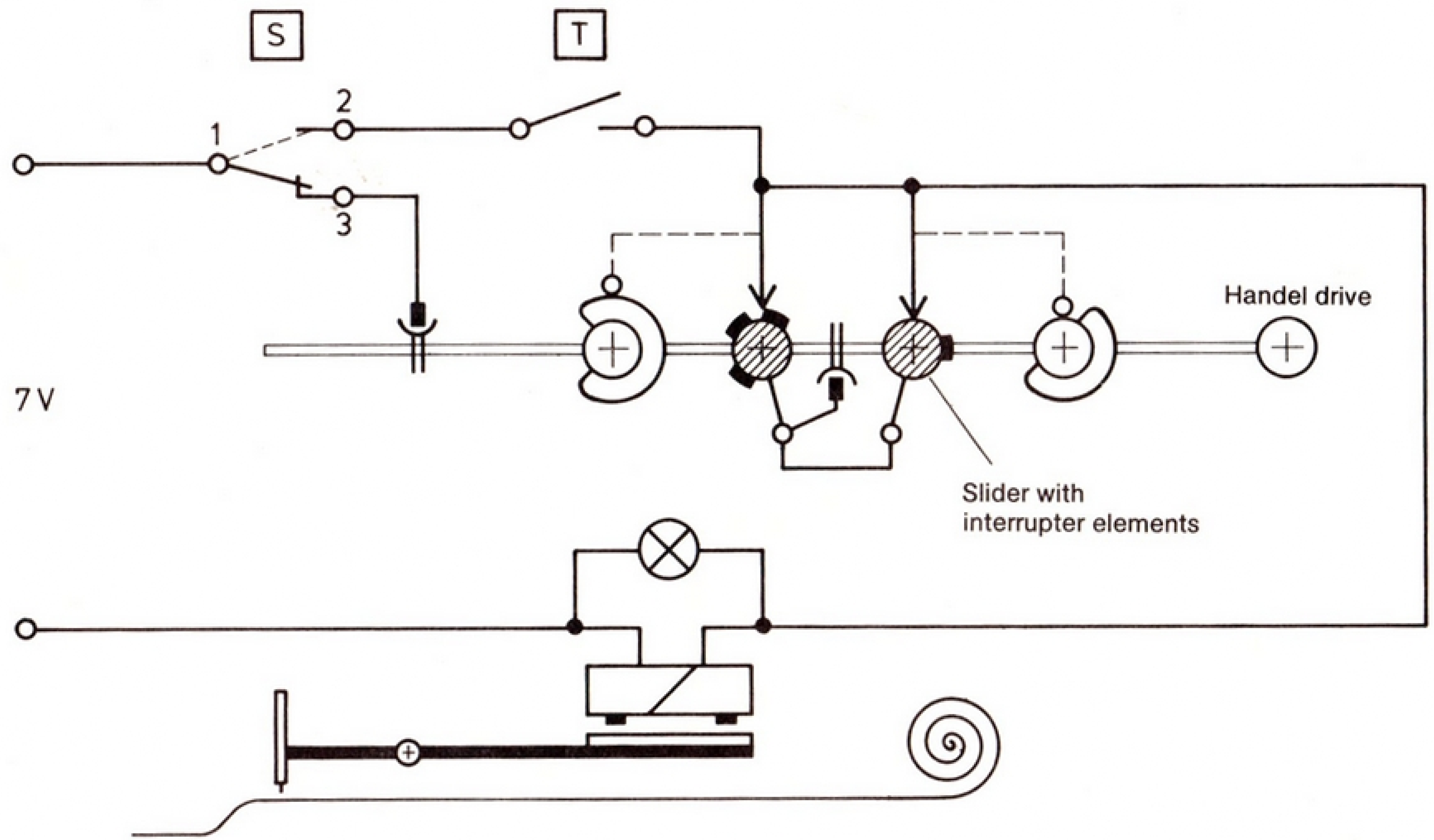
Part list

	Part	Piece
	Flat plugs red green	5 29
	Spherical jack lamps: 6 V; 0.1 A	4
	Lens jack lamps: 6 V; 0.2 A	2
	Light modules with socket	3
	Light caps yellow red green	2 1 1
	Light cap for lens lamp	1
	Spring feet	2
	Terminal contacts	6
	Contact elements	2
	Spring contacts	2
	Plug shafts-180, 4	2
	Shaft-50	1

	Part	Piece
	Switch	1
	Key	1
	Slip-ring with sockets	1
	Double-sided 60° interrupter elements	2
	Single-sided 60° interrupter elements	2
	Spring hinge blocks	2
	Permanent magnet green red	1 1

	Part	Piece
	Electromagnet	1
	End plate	1
	Switching discs	4
	Reed contact	1
	Vibratory spring	1
	Bimetallic strip	1
	Flat hubs	2
	Leads Double core 1000 long Single core 1000 long Single core 300 long Single core 200 long Single core 150 long Single core 60 long	1 1 2 2 4 4
	Connecting elements-15	2
	Mini-screwdriver	1

Morse coder with Morse code transmitter



The picture on the cover illustrates the model of a Morse coder with Morse code transmitter and recording pen. The coder transmitter is used to transmit automatically a call sign both before and after the Morse code message has been relayed.

With the switching arrangement shown in the circuit diagram turning the handel relays the programmed code via a signal lamp and is simultaneously recorded by a electromagnetically motivated recording pen.

The code is programmed with the aid of both cam-switching discs and the interrupter elements on the slip ring.

To sing an actual Morse message the switch contacts 1–2 must be closed and the Morse key used. The Morse code is shown on page 86.