fischertechnik®

Electronics

The following are needed for building the models: Start 100, Motor + gears, Electromechanics.
Most of the introductory experiments can be done with the fischertechnik transformer unit.

Electronique

Les modèles se construisent avec les boîtes: Start 100; Moteur + engrenages; Electromécanique.
La majeure partie des expériences initiales peut se faire en utilisant uniquement le transformateur fischertechnik.

Elektronika

De modellen kunnen met de bouwdozen Start 100, Motor + aandrijving en Elektromechanika worden gebouwd.
Het merendeel van de inleidende experimenten kan alleen met een transformator-moty van fischertechnik worden doorgevoerd.

Electronics

fischertechnik

The following are needed for building the models: Start 100, Motor + gears, Electromechanics.
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Contents

Introduction

Dear fischertechnik modeller!

Modern components with integrated circuits or "IC's" have transformed the worlds of work and technology. And of course fischertechnik Electronics has not been left behind by this development:

The contact system now used throughout electronic engineering has radically altered the appearance of the new electronic modules.

The use of IC-components has not only made the modules more versatile – they are also more economically priced than the former ec-components.

■ The main application of the new ft-Electronics (ft stands for fischertechnik) naturally remains model-making. Examples are given in this book.

Models from "Motor & Gears" and "Statiks" kits can be controlled with the circuits described here.

And of course the construction model railway too!

■ You can have lots of fun with the new loudspeaker box. The growing and squawking of a dragon-cow, the chirping of birds, a police siren, an alarm siren and the puffing of a steam locomotive – all these sounds can be made with the new ft-Electronics.

■ No electronics engineer can get far without electro-mechanical components. For the ft-modelmaker too, switches and push buttons are just as important as reed contacts, electromagnets and permanent magnets. Highly interesting examples are contained in this book.

Beginners should "play their way through" the sections of the introductory book in the order in which they appear, rushing nothing and leaving nothing out, because each section is built up on the one before it. It's more fun to progress step by step, because this is the sure way to success.

By the way: ■ before a paragraph means "Here you must do something" or "This is important".

But not only beginners will have fun with the new electronics. Even experts will find a number of "choice morsels" that are sure to amuse them.

Page 4

The new contact system

The pin and crimp sleeve together form the new contact system as shown in figure 4–5 (meaning figure 4 on page 5). This page and the next one show how it can be combined with the former plug-socket system and what points you should pay attention to.

Fitting the plugs

- First fit two plugs on the electronic component "output stage" shown in fig. 1–4. A red plug goes on the left pin of the upper pin row "5 ..... 10 V", and a green plug goes on the corresponding pin of the lower row "0 V". Place the plug on the pin and press down gently. Loosen the screw until the plug slides onto the pin; tighten screw. If the screw cannot be done up, try another plug – there is always one that will fit.
- Fit red plugs on the free ends of all red leads and on the one grey lead with only one crimp sleeve as shown in figs. 2–4 and 3–4.

  Fit green plugs on the blue leads.

Important

In order to ensure that the circuits function perfectly, the following instructions must be observed:

- When pushing a crimp sleeve onto a pin, never press the lead against the sharp edge of the sleeve (fig. 5–5). This can damage or even nip off the thin wires inside the insulation.
- Do not push new sleeves too far onto the pin. It is then difficult to get them off again.
- To undo the push-fit connection, never pull on the lead or the connecting wire of a component. Always grip only the crimp sleeve!
- If a lead wears through or is torn off despite these precautions, a replacement sleeve from the kit can be crimped as shown in fig. 6–5. For this you need a fine pair of pliers.

Page 5

Contact pins

The little tubes (fig. 7–5) are indispensable for lengthening leads or the connecting wires of components.

Figs. 8–5 to 10–5 show some examples.

For instance, the push-fit connection shown in fig. 9–5 will already be needed in the first experiment on page 7 if you do not have an electromechanics kit with *2-plug leads.*

Light modules

A light module that is not needed elsewhere can be used to provide a two-core lead with crimp sleeves (fig. 11–5).

Crococlip

This is the short name we have given to the crocodile clip shown in fig. 12–5. It is needed whenever no free pins are left on an electronic building component and a connection still has to be made.

Another use is shown in fig. 6 on page 11.

Page 6

The fischertechnik transformer unit

The transformer unit shown in fig. 1–6 is *our* source of energy. If a model railway transformer or other unit is used, the function of the components in this kit cannot be guaranteed. We shall take a closer look at the transformer unit on the following two pages. Here the loudspeaker will come in handy.

Important

Fig. 1–6 shows the new transformer unit. The experiments and circuits in this book have been designed in such a way that the older transformer unit can also be used.

Both fischertechnik transformer units are protected against short circuits by a built-in fuse.

The voltage at the front output
can be varied with the knob. This applies to both the level and the polarity of the output voltage. We shall come back to this shortly.

The voltage at the side output
is not variable. In the older NG an alternating-current (AC) voltage is supplied at this output, whereas in the new unit a direct current (DC) voltage is supplied.

Abbreviations

In the remainder of this book the transformer unit is referred to simply as NG.

NG[v] means: front output sockets of the NG.

NG[s] means: side output sockets of the NG.

Page 7

The DC voltage of the transformer unit pulsates

We already found this out in "Electromechanics", and used it to produce the growling of the dragon-cow.

- The DC fluctuates between zero and maximum 100 times per second – and the diaphragm of our loudspeaker moves with it. We can try this out by connecting it as shown in fig. 2–7, with the lens lamp "in series" to prevent damage due to overheating.

  The "hum" is unmistakable at both NG outputs. On the side output of the older NG it sounds different because of the AC voltage.

  As a rule electronics engineers have no use for pulsating DC. But on page 44 we can get to know a very interesting circuit for us modelmakers which works only with a pulsating DC voltage.

Output voltage level

We measure distances in metres (m). The unit for measuring electric potential or pressure (voltage) is the volt (V).

- In the experimental arrangement shown in 2–7 we can see that the voltage at the front output of the NG, when turned up to maximum voltage, must be higher than at the side output: the lens lamp clearly gives a brighter light. In fact the voltage at NG[v] in this arrangement is around 8 V, while at NG[s] it is only about 7 V. In the older NG the voltage difference is smaller.

Polarity of the output voltages

In contrast to "Electromechanics", the polarity of the supply voltage – that is the position of the poles on the sockets of the NG – is very important. Later, if a circuit does not work, you must first check if it has been connected up with the right polarity (also see page 91).

- At the front NG output the negative (–) pole is always at the socket to which the tip of the knob points.

  This applies to all fischertechnik transformer units.
- In the new NG the position of the poles (= polarity) at the side output is marked with + and – on the cover plate.

In the case of AC no polarity is indicated because the voltage reverses its polarity 50 times per second.

Current path and direction of current

If you have the "Electromechanics" kit you already know: the source voltage forces the current through the leads and load resistances such as lamps, motors, etc. – provided there are no interruptions in the "current path" shown in fig. 3–7 and the source (our transformer unit) is switched on.

- *Important: The current flows from the (+) pole of the source to the (–) pole.*

Page 8

Symbols and circuit diagrams

You need no plan to find your way round a village. But in a big town you must have a street plan. The same is true for the electronics engineer: The simple circuits shown in 2–7 or 3–9 can be assembled just with the aid of photos. But only a few more components or cables are needed to confuse the picture.

Our circuits too will soon become more complicated, so that we shall need the symbols and circuit diagrams described below.

The *hum circuit* 2–7 which we have just tried out is shown in the form of a circuit diagram in fig. 1–8. The symbols used in the diagram are explained in figs. 2–8 to 5–8.

"Why so complicated?" you may well ask. You're right! The NG symbol is unnecessary if we just label the output as in fig. 6–8. Satisfied?

Wiring plan and current flow diagram

These are the names given to the different ways of drawing a circuit. The circuit diagrams in this book serve both purposes. This is illustrated by a very simple example:

- Wiring instructions; *please carry out:*
  - The symbol 7–8 indicates that the lamp used in circuit 8–8 is a plain one and not a lens one.
  - The lamp is to be connected to NG[v], or in other words to the front NG output.
  - To allow this to be done with the leads from our kit, in each case two leads must be joined together with a contact pin as shown in fig. 9–5. This is indicated by the pairs of rings (see fig. 4–8).

When the circuit is wired up correctly, the lamp will light up brightly.

- Current flow path; *please read diagram:*
  - The plus sign in front of NG[v] and the ground symbol in diagram 8–8 have the following meaning:

    The current is to flow through the lamp from the top (+) to the bottom (–). The knob must therefore be set accordingly.
  - This instruction is naturally unnecessary here because the lamp lights up irrespective of the current direction. For this reason the polarity symbols have already been left out in circuit diagram 6–8.

Page 9

The photoconductive cell

Start 100

Now we can get to know the electronic components in our kit. The extra kits, buttons or switches needed to build experimental circuits or models are listed under the appropriate headings. If the names of the parts are in brackets, this means you can manage without them if necessary.

The best place to start is with the photoconductive cell. We shall soon find out for ourselves where its name comes from.

The photoconductive cell 1–9 is already permanently mounted on a light module. The whole thing is simply referred to as FW. This abbreviation is also used in the circuit symbol for photoconductive cell (2–9).

- Let's begin by building the simple experimental construction 3–9. Building component 15 should be changed to Building Block 15, with red pins allow the FW to be moved in all directions.
- The FW and lamp are *wired in series* in exactly the same way as for the hum circuit 2–7. The circuit diagram 4–9 gives no polarity details; so you can turn the NG up full in either direction – or can you?
- An now try out our little toy and watch the lamp:
  - If it is daytime slowly turn the FW towards the window and away again. Move closer to the window with the construction or away from it.
  - In the evening we use a bright torch or table lamp for the same experiment. Naturally the FW must not come into contact with the hot bulb.

As we can clearly see, the brighter the light falling on the FW, the more brightly the lamp lights up.

In other words, the more strongly the FW is illuminated, the better it *conducts* current – and vice versa. We can clearly see this from the lamp.

Or to put it another way, the *resistance* of the FW to the flow of current is *light-dependent* (which is why it is called a *photo*conductive cell). The more strongly the FW is illuminated, the lower its *resistance* becomes.

By the way: The polarity of the voltage applied to the circuit is unimportant for the FW. So circuit diagram 4–9 is correct.

Page 10

The self-holding trick

Start 100

These first experiments are enough to give us an idea of the enormous scope of the FW. Here is a striking example.

- For the following experiment, instead of the plain lamp we take the so-far unused lens lamp from our kit. We mount it on the building block 15 with red pin as shown in fig. 1–10.
- Despite the somewhat different arrangement, the wiring of the series circuit shown in fig. 2–10 should be no problem for us now.
- Now we direct the lens lamp on the centre of the FW. Distance between the two about 1 mm. We turn up the NG to the maximum – and nothing happens.
- Now shine a bright light (e. g. a torch) on the NG from the side so that the lens lamp lights up brightly (orange arrows).

Switch off the torch – and the lens lamp will remain alight. In a manner of speaking we have switched on the lens lamp with light. Right?

We switch it off again by turning it away from the FW.

Optical self-holding

is the name we give to this. The trick behind it is that the indicator lamp of experiment 3–9 is directed onto the FW. That's all!

If the FW is now made sufficiently "conductive" with an outside light source (e. g. a torch) to make the lamp directed upon it burn sufficiently brightly, the lamp *itself holds* the resistance of the FW low enough to keep it alight when the outside light is switched off.

To ensure that the FW is illuminated brightly enough, we have to use the lens lamp. Everything clear?

By the way: We shall soon come across optical self-holding again. But then only a faint light beam will be sufficient to induce self-holding.

Page 11

Fixed resistors

Start 100

There is hardly any electronic circuit that does not incorporate resistive components – or, more briefly, "resistors" – with a fixed resistance value. We have eight of them in our kit. The general symbol for "resistor" is shown in fig. 1–11.

The unit of electrical resistance is the *ohm* (Ω = Greek Omega). 1000 Ω are known as 1 kiloohm (kΩ), just as 1000 metres are 1 kilometre (km).

Since we have only one resistor in the ohm range (table 3–11) for the sake of simplicity we write only Ω in the circuit symbol of the 100 Ω resistor.

Table 3–11

Quantity	Coloured rings			Resistance	Symbol
	1.	2	3		
1	br	bl	br	100 Ω	Ω
2	br	bl	r	1 kΩ	
1	y	v	r	4,7 kΩ	
2	br	bl	or	10 kΩ	10
1	r	r	or	22 kΩ	
1	br	bl	y	100 kΩ	

br = brown : bl = black : r = red
y = yellow : v = violet : or = orange

As shown in table 3–11, all other resistors are in the kΩ range. This saves us using the unit kΩ so that we need put only the number in the circuit symbol.

The coloured rings indicate the *resistance value.* They are read in the order shown in fig. 2–11. The fourth ring (gold or silver) does not concern us. Table 2–11 shows the meaning of the colour combination made up rings 1, 2 and 3.

And now a brief experiment:

- We connect the lamp in series with the 100 Ω resistor (brown-black-brown) instead of with the FW (fig. 2–7) and connect the circuit to the front NG output (figs. 4–11 and 5–11).
- Turn up NG to maximum: the lamp lights up on faintly.

From this we can conclude that the *resistance* of the FW when strongly illuminated must be considerably less than 100 Ω, since the lamp then lights up much more brightly.

Page 12

The output stage component

The first electronic component we shall deal with is the output stage component, or "LST-component" for short. We have already fitted it with plugs for connection to the transformer unit. Now let's take a closer look at this component.

- The LST-component incorporates two completely identical electronic circuits – *the output stages* (fig. 1–12).
- The central part of every circuit is the black component with three connections marked *TIP 110.* (The photos show the number 111, but this is immaterial.)

The "black box" contains a *special transistor.* All we are interested in is how it works. However, we should carefully note the connection designations given below. They apply to all transistors.

B = base
C = collector
E = emitter

- The component with the red knurled knob is a *potentiometer.* We call it a "potmeter" for short.
- The "connection plan" 2–12 includes all pins (= connecting pins) of the block. A line between two or more pins means that there is an electrical connection between them. For instance, two pins belong to the base connection of the upper output stage.

Page 13

Connecting the supply voltage

- Like every other circuit, the LST-component must naturally be *supplied* with a voltage. This is done by connecting the upper and lower rows of pins to one of the NG outputs (e.g. as shown in fig. 13–3).

  This cannot be done so simply with the AC output of the older NG because then the component does not work properly. Page 23 tells you how this problem can be solved.

- *Important:* The LST-component must be connected with the *correct polarity!*

  This means: The upper row of pins (+ 5 ... 10 V) must be connected to the (+) pole of the source and the lower row (0 V) must be connected to the (–) pole. We therefore call the upper row of pins the "positive bar" and the lower one the "negative bar".

Representation in circuit diagram

The connection plan 2–12 is too complex to use in larger circuit diagrams. For circuit diagrams we therefore use the simplified connection plan shown in fig. 4–13.

- Here the connection bars have been taken out of the box around the component. As we shall see shortly, only the pins we actually need are shown in the connection plan.
- The (+) bar is labelled with the source and polarity. In example 4–13, + NG means "connect to the (+) pole of one of the two NG outputs.

Page 14

If you have looked closely you are sure to have noticed that the lower output stage has three pins more than the upper one, namely two pins for the *emitter* connection and one pin for the *potmeter* connection (see. fig. 2–12). Does that mean it is not true that "both stages are identical"?

Output stage LST-1

To enable them to be distinguished, a number (= index) is placed after each connection designation: 1 for LST-1 (above) and 2 for LST-2 (below).

- Connect a lens lamp between the (+) bar and one of the C_1 pins as shown in figs. 5–14 and 6–14.
- Check that the polarity is correct: red plugs of double lead to (+) socket of NG[s] and to red plug on the (+) bar of the component!
- Turn the potmeter knob to the right-hand limit (indicated in the plan by a dot).

Important: If the lens lamp lights up, the plugs on the NG must be changed over.

- Connect LST-1 to the side output of the new NG as shown in diagram 6–14. (In the case of the older NG simply use the front output.)
- We connect a lead on a base pin B_1 as shown in fig. 5–14. We touch a plug against a pin of the (+) bar and then against a pin of the (–) bar. How does the lens lamp respond to this alternate touching?

We find that:

- The lens lamp lights up only when the base pin of LST-1 is connected to "plus".
- If the base is "open" (= connected to nothing) or connected to "negative", the lens lamp does not light up.

We should take careful note of this important finding.

Page 15

Output stage LST-1

- First we connect the bridging wires (shown in heavy black in circuit diagram 8–15) as in fig. 7–15. For this we use short blue leads with two crimp sleeves.
- Repeat the experiment described on page 14. Also turn potmeter P_2 to the right as fas as it will go.

  Is there any difference between this experiment and the last one?

- Now remove the bridging lead beween E_2 and the (–) bar. What is the difference when you touch the (+) or (–) bar with the base lead?
- Replace bridging lead and remove the other "potmeter bridge". What changes now?

This is what we find:

- When the emitter bridge is in place, LST-2 behaves in exactly the same way as the LST-1. No wonder. In LST-1 the potmeter and emitter connections are already permanently connected to (–) on the back of the printed circuit (= internally) by copper strips.
- If the emitter bridge is not in place, LST-2 does not operate – at any rate not in this circuit. We shall see later why the Br and E_2 connections are external in one case and not in the other. For the time being the bridges are placed in position.

Wrong polarity – *please try out:*

- If the LST component is connected with the wrong polarity, nothing is damaged but the circuit goes haywire. The lamp remains continuously alight, irrespective of whether the base is connected to (+) or (–). (See page 93.)

Page 16

Control by light

A small rudder steers a considerably bigger boat such as a barge. *Small cause – big effect:* Our LST-component behaves in a similar way if we connect the photoconductive cell and lamp together via a LST instead of directly (as in the experiment on page 9). The effect is astonishing:

- Connect the FW between the base B_1 and the (+) bar as shown in fig. 1–16 (shown in red in the circuit diagram 2–16). As in the last experiment, the lens lamp is connected to the collector C_1 and the (+) bar.

  Turn knurled knob to right as far as it will go.

- Connect the circuit to the side (or front) NG output. The lens lamp will light up brightly even if the FW is illuminated only weakly.

- We can influence the *sensitivity* of the circuit with the "stray light shields" shown in fig. 1–16. The smaller the diameter of the hole, the more strongly the FW must be illuminated to make the lens lamp light up fully.

  Please try out!

Page 17

Small cause – big effect

In the experiment on page 9 the FW had to be illuminated very strongly to make the lamp light up fairly brightly, and now a very weak light is enough to *cause* a still greater *effect*. The reason for this is the "transistor effect". A weak *base current* makes a *collector current* flow which is many times stronger than itself. "Base current" is the name given to the current flowing from the (+) bar through the FW into the base. The collector current flows from the (+) bar through the lens lamp into the collector. Both currents are "processed" inside the transistor and flow together from the emitter down to the (–) bar. This is why it was essential for the emitter bridge to be in place in LST-2.

The weak base current is known as the "control current", while the much stronger collector current is known as the "load current" (fig. 3–17). And that brings us back to our comparison with the rudder and the barge.

In this case we can also say "The output stage is a *current amplifier*".

Once again: Optical self-holding

Start 100

- We use the trick we already tried on page 10 and position the lens lamp controlled by the FW via the transistor so that it shines on the FW as shown in figs. 4–17 and 5–17.
- In a darkened room the lamp 5–17 now can be switched on from a considerable distance with the aid of a torch, provided no stray light shield is fitted on the FW.

  To switch off the lamp, simply shade the FW with your hand.

Page 18/19

Controlling a conveyor belt

Start 100 Motor + gears Key component

Without electronics it would be completely impossible to build the following model control system! The conveyor belt 6–19 transports fragile goods (e. g. porcelain horses) to the packaging station. Such objects must be placed carefully on the belt and removed from it. For this the belt must naturally stop. The solution to the problem is a "self-holding light barrier".

Figs. 1–18 to 3–18 explain the new symbols used in the circuit diagram 4–19. ("Electromechanics" already know them.)

- "Light barrier" is the name given to an arrangement with a FW and an *associated* light source as shown in fig. 6–19. In this light barrier the lamp controlled by the FW itself acts on the FW as shown in circuit diagram 4–19 – the *self-holding trick* we already know!
- To ensure that the FW really is controlled only by the light barrier lamp and not by "stray light" from its surroundings, we fit the 1 mm stray light shield over it.

And this is how the belt control system works:

- The resistance of the unilluminated FW with the 1 mm shield in place is much too high to allow an adequate base current to flow into the transistor. Therefore no load current can flow through the motor and the light barrier lamp. Nothing happens.

  As a make-believe porcelain horse we can now place a building block 15 on the belt.
- In order to start the belt we must apply a current pulse to the base B_1. This is done by briefly pressing the starting key T (shown in blue in the circuit diagram; if you have no key component, you can also use the bar touching method shown in fig. 6–14):

  The motor starts immediately and the lens lamp lights up brightly. Because of the amplifying action of the LST its light is sufficient to ensure self-holding after the key is released.
- The belt now runs until the transported material *interrupts* the light beam and shades the FW. As we have already found, this cancels the self-holding effect, the lens lamp goes out, and the motor stops. The object can be removed from the belt at leisure. Start again with the key T.
- We use LST-2 for the warning hooter – "attention – belt running". We do this by connecting together the bases B_1 and B_2 with a short red lead as shown in plan 4–19. Via this lead the base of B_2 also receives sufficient current when the FW is illuminated. As we have already found, a strong pulsating load current then also flows through the loudspeaker (not shown in fig. 6–19). To protect the loudspeaker we connect it in series with the 100 Ω resistor (brown-black-brown). The NG hum can be clearly heard – but only when the emitter bridge is in place.

Size control

Another application for the light barrier is the size control of building blocks:

- The distance between the light barrier and the belt can be varied by any amount. In this way we can determine the size of the building components that can fall unhindered into a collecting basket. An oversize building component is "intercepted" by the light barrier and can be removed by hand.

Page 20

Lighting control device

Start 100

With the simple model 1–20 we can not only switch a lamp on and off, but can also make it light up and go out again gradually – in a similar way to the lights in the cinema.

- To prevent interference by stray light, it is best to place the 1 mm shield on the FW and also cover it with a building block 15 (fig. 1–20).
- We connect the "control lamp" on the hinged arm with long leads to the (+) and (–) bars of the LST-component. We fit the white light cap on the lamp.

- The FW and lens lamp are connected up as before, but must not *face each other directly.* Turn potmeter knob to right-hand limit.
- Connect the whole assembly to the front NG output as shown in diagram 2–20: Turn NG (with correct polarity!) up full.
- Move the hinged arm quickly to and fro. How does the lens lamp react?
- Now move the hinged arm extremely slowly inwards from its outer limit and back again. There is a small range in which the lamp is not switched fully on or fully off, but lights up more or less brightly. Correct?

This range, in which the lamp changes from its OFF to its ON state, is known as the "transition range". It is shown in the circuit diagram 2–20 by blue dotted lines and the letter ü.

As indicated in circuit diagram 2–20, we can naturally connect a motor in place of the lens lamp. This enables us, for instance, to control the fischertechnik construction model railway or a model from the "Motor + gears" instruction book by means of the light control device instead of the knob of the NG.

Page 21

Control by potentiometer

Now let's take a look at an important component of the output stage – the potentiometer, or "potmeter" for short. In doing so we get to know another interesting means of control.

A staircase is divided into steps so that a difference in height can easily be overcome in a series of stages. In a similar way the electronic engineer divides large circuits into smaller, easily manageable *stages.*

Our output stages consist of the transistor, which we have already partly tried out, with a protective resistor (1 kΩ) for its base and the potmeter. Now let us take a look at its function whithin the LST (also see page 93).

- First connect the base B_1, as in fig. 1–21, to the (+) bar by means of a red lead with a crimp sleeve. We connect up the lamp in the usual way.
- After connecting the LST-component to the NG with the correct polarity, we turn the potmeter knob very slowly and carefully from right to left through its full range – and back (shown in circuit diagram as arc of circle with arrowheads).

  As in the lighting control device, in doing so we pass through a very narrow *transitional range.*

  From this we can conclude that the potmeter is a resistor whose value, in contrast to the FW, can be varied *mechanically* with the potmeter knob.

  Carry out the same experiment with LST-2 with the bridges leads in place (shown as dotted lines in circuit diagram 1–21). The result will be no different from that of the first experiment – or will it?

  We now remove the left-hand bridge lead between the Br pin and the (–) bar, the "potmeter bridge". The lamp will now remain constantly alight whatever way we turn the potmeter knob. Correct?

We have evidently blocked the potmeter by removing the bridge – only the connection between the base pin B_2 and the (+) bar is effective.

From the result of the *bridge experiment* we can conclude that the potmeter resistance must be connected between the base connection and the Br pin. This is exactly what is shown by the internal wiring plan 2–22 of the LST-2 with the dotted connection lines. (In LST-1 the lower potmeter terminal is already connected internally with the (–) bar.)

Page 22

The symbol for the potmeter with its three connections is shown in blue inside the *circle representing the potmeter knob.* The arrow through the resistor symbol indicates that it is mechanically variable.

We cannot go into the potmeter circuit in detail here. To simplify greatly, we can say the following about the potmeter function in the LST:

- When the Br pin is "open" the potmeter is ineffective. (This, of course, is not the case in the LST-1.)
- When the potmeter bridging lead is in place:
  - With the potmeter knob in its extreme left position the base is effectively connected to (–): nothing now happens.
  - When the potmeter knob is in its extreme right position the effect of the (–) bar is virtually eliminated – the base can be fully "controlled" (e.g. via a FW according to fig. 2–22).
  - The transition range lies somewhere between the left and the right limit of travel.

Widening the transition range

Now we come to an extremely useful trick which we shall often use:

- We connect a 1 kΩ resistor between C_1 and B_1 according to plan 4–22 and fig. 3–22. The lamp remains as it is.
- Connect the LST-component to the NG and slowly turn the potmeter through its full range in both directions.
- We call the base pins the "input" and the collector pins the "output" of our LST, as in fig. 3–22.
- The trick of our circuit is that the *control current* for the input of the LST (diagram 4–22) is obtained from its output.

  Electronics engineers call this trick "feedback". We shall hear more about it soon.

With this circuit we can control all motor-driven models, and also the construction model railway, much more precisely than with the knob of the NG.

Page 23

The diode

The "polarity-dependent" action of the diode was discovered as early as the 1920's and used for the first "cat's whisker" radios. Today diodes are used throughout control and telecommunications engineering. Our kit contains two diodes type 1N 4001 which we shall find extremely useful.

Fig. 1–23 shows the symbol for a diode with the names of its connections. The line placed crosswise corresponds to the ring on the *diode body*. The ring side of the diode should be marked with a tag as shown in fig. 4–23, because the ring will soon wear off. You can also file a notch at this end of the diode body.

We call the ring side the *negative* side of the diode, while the other side is known as the *positive* side.

Conducting direction

- *Wire up* the input and output of LST-1 as shown in plan 3–23. We then connect a diode with the indicated polarity between the front NG output and the (+) bar of the LST-component in accordance with fig. 4–23.
- Turn up NG (with correct polarity!). The lamp lights up. With the NG voltage in this polarity the diode *lets current through* to the LST: It is in the "conducting direction" and acts like an ordinary connecting wire. This is always the case when the diode is connected in a circuit with the correct polarity. The arrow of the diode then points in the *direction of the current* (from positive to negative).

Blocking direction

- Now we reverse the polarity with the NG knob. The lamp does not light up.

The (+) side of the diode is now connected to the (–) pole of the source. The diode arrow therefore points *against the* flow of current. In this polarity the diode *blocks* the current. The diode is in the "blocking direction".
It is as if the *lead* between the (+) bar and NG were *cut*.

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The diode as a rectifier

- If we connect circuit 3–23 to the side output of the *older* NG, the lamp also lights up and goes out as expected when the potmeter is turned to the left limit.

The AC voltage *reverses* its polarity 50 times per second, but the diode allows current to pass only in a given direction – according to the polarity with which it is connected.

- If the diode is connected the opposite way round as shown in diagram 3–23, the current also flows in the opposite direction, namely from the (–) to the (+) bar. The LST then behaves as if it were connected to the NG with the wrong polarity (see page 15).

Because the current is allowed to pass only in the *one direction* despite the alternating polarity, a diode connected like this is known as a "rectifier": it "straightens" the current (Latin: rectus = straight) (also see page 92).

Optical rotation direction indication

Start 100 Motor + gears

With the NG knob or a pole-reversing switch (indicated with PW in fig. 5–24) the polarity of the supply voltage and therefore the rotation direction of the motor are reversed. This change of polarity can be indicated with the aid of our diodes.

- For this we need the pole bars of the LST-component as a *terminal board* for the diode and lamp connections; the LST itself is needed here.
- Connect the diodes on the lower bar with opposite polarities as shown in fig. 6–24. Connect a lamp in series with each diode (diagram 5–24). Connect the bars to the front output of the NG, either via the "pole reverser" or directly.

If, for example, the upper bar is now connected to the (+) pole of the source, the blue diode is in the blocking direction and the red diode is in the flow direction; therefore only the lamp belonging to the *red* diode lights up and the motor turns (e.g.) clockwise.

- After reversing the poles with the switch or NG knob, the *blue* diode is in the conducting direction. The other lamp now lights up so as to indicate "Motor turning anticlockwise".

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"5 V power supply" and threshold switch component

On this page the two other electronic components from the electronics kit are presented together. They are closely linked in their use, as we shall see shortly.

Power supply unit

This is the name we give to the unit shown together with the explanation of the pins in fig. 1–25. The *black component 7805* is a *voltage regulator*. It converts the NG voltage applied according to fig. 2–26 into a non-pulsating (pure) DC voltage of exactly 5 V. It is absolutely essential for the supply to the threshold switch 2–25.

The diode 1N 4001 with which we are already familiar is responsible for ensuring the *correct polarity* of the supply voltage. If the polarity is wrong it is in the blocking direction – and then, as we know, nothing happens.

The "7805" may become quite warm in operation, but this is nothing to worry about.

The circuit of the power supply unit (SPV) is shown and explained on page 92.

The threshold switch shown in fig. 2–25 is called "SWS-component" for short – in the same way as the output stage is known as the "LST-component".

Threshold switch component

At first sight it looks rather like a fakir's bed of nails. But when we take a closer look we see that like the PS module, it contains two circuits of the same type. And when we have seen the familiar potmeters with the associated bridging (Br) pins, we can confidently make our entry into the field of "higher electronics".

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The SWS-component

Connection to the power supply unit

- First transfer the NG connection plug from the LST-component to the power supply unit as shown in fig. 1–26. By means of the diode the SPV can also be

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connected to the side output of the old-type NG (see page 24).

- *The SWS-component must never be connected directly to the NG, but always to the power supply unit.*
- For interconnecting the pole bars of the individual components we use only yellow leads: This is indicated by the orange colour in the circuit diagrams 2–26 and 3–26; the upper bars connected to +5 V are shown in orange throughout, while in the lower (–) bars only the connecting leads are shown in orange.
- For the power supply we need no special connecting plan – the designation "+5 V" in orange is enough.

The threshold switches

Each of the two threshold switches (SWS) is an electronic *switching stage*. Its complex operation is shown and explained on page 94.

We see that each SWS differs from the LST in having two outputs (Q and $\overline{Q}$ pins) as well as one input (E pins). The individual threshold switches are also designated with A and B as shown in fig. 2–26. It is therefore easy to distinguish the connections of the electronic building components.

Now let's take a look at the meaning of the LED:

- Connect potmeter bridge lead between Br and (–) pin of the upper SWS-A. Turn potmeter P_A to right limit.
- We now connect the input pin E_A to positive or negative by touching the lead against the appropriate pole bar (indicated with a red dotted line in diagram 3–26).

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We find that:

- The LED lights up only when the SWS input E_A is connected to (+).
- It thus indicates that the output Q_A is effectively connected to (+).

- "Then the lamp shown in blue dotted lines in the diagram should also light up?" Try it out:

The threshold switch as a control stage

For this the SWS has insufficient power. It can only act as a "control" stage as connected in fig. 4–27. For the operation of lamps, motors, etc. we need the *output stage*. This stage is *controlled* or *"driven"* by the SWS.

- We connect the LST-component to the "5 V supply" with yellow leads as shown in fig. 4–27 and 5–27. The control output Q_A of the SWS is connected with a short red lead to the control input B_1 of the LST – and now we can use the SWS to control the lamp at the *load output* C_1 of the LST.

When the SWS input is connected to (+), the output Q_A acts like (+) on the input of the LST – so obviously the lamp then lights up.

If on the other hand the SWS input is not connected to (+), then Q_A acts like (–) on B_1 – and, as we know, nothing happens.

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Electronics on wheels

Start 100 Motor + gears

In model 2–28 the "3-component electronic system" we just tried out is mounted on a vehicle. Clever modelmakers will no doubt make it look much smarter. What we shall now do is to use light to control the "electronics on wheels" in various ways.

- In the steering only one wheel is screwed tight, so that the vehicle follows a different curve when it travels forwards from when it moves backwards. This makes the light control more fun.
- We first use the "light snorkel" 4–29 for controlling the vehicle. Wire up as shown in diagram 3–29, keeping the leads as few and as short as possible. Naturally the pole reverser can also be fixed on the LST-component.

Control by darkening

- SWS-A is controlled with the aid of the FW (with 1 mm stray light shield in place) as shown in diagram 3–29. Turn potmeter P_A to left limit. Switch on NG.
- Slowly turn potmeter to right till the LED lights up and the vehicle starts to move. It can be stopped again by shading the FW with the hand.
- The weaker the room lighting, the higher the potmeter must be turned up. Correct?

With the potmeter we adjust the "switching threshold" at the SWS input. If the input level falls below the threshold as a result of shading the FW, the SWS output Q_A instantly "flips" from the (+) *state* to the (–) *state* and the vehicle stops.

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Control by illumination

- Now the other way round: We turn the potmeter so far to the right that the vehicle remains stationary in the existing room lighting.
- With the aid of a torch we can now start the vehicle moving at will.

We have now set the "switching threshold" so that the SWS output instantly flips from (–) to (+) when a light is shone on the FW to put it more briefly.

Reflection light barrier

- Finally we turn the snorkel round as shown in fig. 5–29 and arrange the other lens lamp to shine on the "road". Its light is reflected from a light-coloured table top onto the FW. With P_A we adjust the switching threshold of the SWS so that the LED just lights up and the vehicle starts to move.
- If the vehicle gets dangerously near the edge of the table when travelling in reverse, the lens lamp shines on nothing to reflect its light. The reflected light barrier is interrupted and the intensity of the light falling on the FW drops below the set threshold value at which the SWS output flips over. The electronics on wheels come to a stop. Clever, isn't it!

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Two-source operation

On a 5 V supply the motor runs only slowly. There are two ways of increasing its speed:

- Connecting the (+) bar of the LST-component to the (+) pole of the NG output (shown in blue in diagram 7–30).

  Fig. 8–30 shows the best way to do this.

The motor now runs faster, but the lens lamp lights up too brightly. To protect the lamp it is better to adopt the following method:

- The LST-component continues to be supplied with 5 V, and with it the lamp at the output of LST-1 (diagram 9–30). On the other hand the motor is connected (via the pole reverser) to the output of LST-2 and indirectly to the remaining free pin of the SVP input. Via the lead between B_1 and B_2, shown in red in diagram 9–30, the input of LST-2 is also controlled by output Q_A of the SWS (also see page 19).

  The common (–) pole of both sources are the interconnected (–) bars of the three electronic building components.

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Daylight switch

Start 100

The street lamp 1–31 is to be switched on automatically in the evening and off again in the morning. This is no problem for our threshold switch if we control the output stage not with the Q output as before but with the Q (read $\overline{Q}$-NOT) output.

- Wire up according to fig. 1–31 and diagram 2–32. Fit 1 mm stray light shield on FW, set potmeter P_A roughly in midway position.
- Switch on the NG in "daylight" (it may also be lamplight): the LED lights up, but the street lamp does not.

Obviously $\overline{Q}_A$ acts like (–) on the input of the LST when Q_A is in the (+) state. Does this apply in the reverse situation?

- Let's pretend it is getting dark and shade the FW slowly with our hand.

Yes – when the LED goes out the lamp lights up. Exactly what we wanted.

So the $\overline{Q}$ output acts on the input of the "following" stage in exactly the opposite way to the Q output. Or to put it simply:

$\overline{Q}$ is always in the opposite state to Q. That is why $\overline{Q}$ is read and spoken as "Q-NOT".

- You can determine with the potmeter whether the street lamp is to come on earlier or later.

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Bell pendulum hammer

Start 100 Electromechanics

The pendulum model 5–33 with permanent magnet and electromagnet (diagrams 1–32 and 2–32) is something for the "ft-electromechanic". He will be surprised to see how elegantly a *hammer interruptor* can be made with the aid of a light barrier and the $\overline{Q}$ output of SWS.

- In contrast to the conveyor belt model 6–19 (circuit diagram 4–19) the light barrier lamp shown in blue in diagram 3–32 is connected to the (+) and (–) bars of the LST-component. It therefore remains continuously alight.
- Don't forget the bridging leads when wiring up. Potmeter in midway position.
- If the pendulum does not start to swing when the NG is switched on, the plugs on the electromagnet must be changed over.

And this is how the pendulum works:

- When the NG is switched on, the light beam is interrupted by the permanent magnet. The LED does not glow and nor does the lamp at the output of LST-1.
- On the other hand $\overline{Q}_A$ acts like (+) on the output of LST-2. The electromagnet connected to its output is "excited" and pushes the permanent magnet out of the light beam – provided the polarity of the electromagnet is correct.
- When the light beam is cleared, Q_A flips over from (+) to (–): the electromagnet current is cut off and the pendulum arm swings back to its starting position. This cuts the light beam again and the cycle begins once more.

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- The light barrier must be mounted exactly at the height of the electromagnet.
- The axle-60 acts as a counterweight and prevents the pendulum arm from swinging through in the wrong direction. At the same time it serves as a hammer for the bell. A thin tumbler can also be used as a bell.
- The swing distance of the pendulum can be varied with the potmeter P_A.
- The influence of outside light on the operation of the bell is particularly interesting. The 2.5 mm shield is best suited for this game.

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Alarm system

Switch

You can do some surprising things with experimental arrangement 3–35. For instance, it enables you to light up an ft-lamp with a match – but you can also use it as an alarm system which can be set off by even a very faint light. These experiments are therefore best done in the evening when it is easy to darken the room.

And an alarm system must naturally produce an ear-piercing signal. We make this sound with the "tone generator". Its circuit will not be explained until later, but it is so easy to build that for once we need have no qualms about jumping ahead. Agreed?

Response sensitivity

- We first build circuit 1–34 in such a way that the FW cannot be influenced by the lamp at the output of LST-2. The diode shown in blue together with the "clip lead" (= lead with crocodile clip) is left out for the time being. Maximum sensitivity is obtained when the FW is not fitted with a stray light shield and P_B is at its right limit of movement.
- Turn room lighting off and switch on NG. Strike a match about 2 m away.

  The threshold switch "amplifies" quite well, doesn't it? (Compare with experiments 1–10 and 4–17.)

The self-holding diode

Unfortunately the alarm lamp goes out when the match does. This can easily be altered:

- Switch off NG. Connect blue diode with correct polarity between output and input of SWS-B as shown in diagram 1–34. Finished!
- Darken room and switch on NG again. Now we can light up the lamp with a match. This will amaze anyone who doesn't know the *feedback* trick.

We feedback the required control current from the output via the "self-holding diode" to the input of the SWS.

When the FW is illuminated, Q_B flips from (–) to (+). The diode is then in the flow direction and acts like a connecting wire (page 23); therefore it can *maintain* the (+) supply from the output to the input *itself* even when the "light impulse" of the flaring match has long been forgotten.

- There are two ways in which the visual alarm signal can be *extinguished* – naturally only in a darkened room. (Why?)

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- Switch NG off and on again, or
- Briefly connect E_B to (–) with the *clip lead* as shown in diagram 1–34: Q_B then automatically flips over from (+) to (–), the feedback ist interrupted and the self-holding is therefore cancelled.

The tone generator

- The continuous alarm sound is generated with condenser-47 (see page 40) and the 1 kΩ resistor shown in blue in diagram 2–35. These are fitted on SWS-A as shown in fig. 3–35: the (+) lead of the condenser must be connected to E_A.
- The 1 kΩ resistor, which is not shown in fig. 3–35, conducts the electric sound signal to LST-1. There it is amplified by the transistor and converted into sound waves by the loudspeaker – a sound you cannot fail to hear!
- Switch on NG and test: The pitch of the continuous tone is set with P_A and its volume is set with P_1 within the range indicated by the arrows (diagram 2–35). The LED glows when the generator *is operating*. (For possible sources of trouble see page 91.)

The control diode

The alarm circuit on SWS-B remains unchanged. Its output Q_B controls the alarm signal via the diode shown in red in diagram 2–35:

- With Q_B (–) it is in the conducting direction and therefore acts like a connecting wire: B_1 is therefore connected to (–) and LST-1 is *blocked*.
- Opening the switch or disconnecting the clip lead takes the "safety catch" off the system.
- When the FW is illuminated Q_B flips over from (–) to (+) and SWS-B goes into its self-holding state. The control diode is now in the blocking direction and effectively cuts off LST-1 from SWS-B. LST-1 can now process the sound signal without hindrance: the "nerve rasp" goes into action.

Keep tone generator for next model!

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Finish indicator

Start 100 Switch

The circuit on the back of the instruction book has already been tried out in practice and explained in the "alarm system". The only thing new for us is the function of the light barrier.

In contrast to the alarm system, in the finish indicator the loudspeaker must remain silent when the photoconductor is illuminated (by the light barrier lamp). The loudspeaker may sound only when a racing car passes through the finish. Let us now see how this works.

- We first mount the electronics, together with the tone generator which is still assembled, on the finish gate as shown in fig. 3–37.
- Complete the circuit shown in diagram 1–36 (except for the *self-holding diode*) and mount the indicator lamp which is to be connected to LST-2 on the model wherever you consider best. The lamp lights up when Q_B flips from (–) to (+).
- Switch on NG. Set the switching threshold of SWS-B so that when the FW is illuminated the LED just goes out and the loudspeaker is silent.
- If we now interrupt the light barrier with our hand as a test, the finish indicator will go into action with light and sound. When the light barrier is cleared, the indicator signal stops.

How is this possible?

- To find this out, we need only to remove the FW connection from the Br pin. The LED lights up immediately and the finish indicator signal is switched on.

  This stands to reason SWS input is now connected to (+) only via 22 kΩ so that Q_B flips over from (–) to (+).

With the FW connected up and illuminated, the situation is different. In a similar way to LST-2 the potmeter resistance is connected between the input pins E_B and the Br pin (see page 94).

Therefore the SWS input is also connected with (–) via the potmeter and FW. At the set threshold value the output Q_B acts like (–) on the following output stage. If the resistance of the FW is now greatly increased by shading it, the switching threshold is exceeded and Q_B flips over from (–) to (+).

- We now replace the self-holding diode as shown in diagram 1–36 – and the "finish indicator with continuous signal" is complete. The signal is cancelled either with the *touch-contact lead* as shown in diagram 1–34 or by actuating the switch S according to diagram 2–35.

By the way: In the language of electronics the connection of the PC between the input and (–) bar is known as "signal inversion at the input of a stage" – and self-holding is known as "storage of an input pulse". With the light barrier we have been experimenting with, a "dark pulse" is stored.

- An ft racing car speeding in from a sloping ironing board will be safely guided through the finish by the building plates.

■ For the construction modelrailway model 3–37 can also be used without the racing car guide.

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Melo-Tron

Start 100 Electromechanics

Model 3–39 is for "playing" – for playing real *melo*dies. Naturally the sounds are generated elec*tron*ically. You can also produce a realistic vibrato effect – although only by hand. And if you have a strong heart, you can make your pulse audible with the *Melo-Tron*.

■ Here the tone generator we have already tried out is best mounted on SWS-B – you can then manage with shorter leads.

For reasons of sound quality the loudspeaker is connected in series with a lamp as shown in diagram 1–38.

■ The 1 kΩ resistor previously used between $\overline{Q}_B$ and Br is replaced with the FW shown in blue in diagram 1–38. With the key T connected in series with it we can cleanly key in the individual tones – unless we want to imitate a "musical saw".

■ A lens lamp can be pushed to and fro on slide rail 2–39, which is aligned to point it precisely at the 2.5 mm shield of the FW.

With this *light control device* the effective resistance between the input and output of the SWS can be varied at will. This is the *Melo-Tron* trick, which we shall use quite often.

■ We should avoid stray light from electric lighting. The FW notices the variations in brightness due to the AC of the mains – and the Melo-Tron becomes hoarse!

The effect of pulsation (electronic engineers say "ripple") in our NG voltage sounds even worse if we connect the control lamp to the input pin of the power supply unit: the mixture of the generator tone and NG hum make the musical tone into a real nerve-grater. Try it! (Also see page 61.)

■ The Melo-Tron must now be "tuned".

– Set desired pitch range (between smallest and greatest distance from FW to control lamp) with P_B.

– A scale made as shown in fig. 3–39 helps to find the exact pitch of the individual tones – provided the tone range is not subject to alteration by factors such as changes in the daylight intensity.

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Pulse indicator

Our blood is pumped through our veins according to the rhythm of our heartbeat. This "pulse" can clearly be felt in the wrist.

The FW "feels" the pulse in the fingertip. The fingertip becomes a little more "opaque" each time the blood is forced through its fine vessels by the heart. We make use of this fact:

■ To produce a constant tone, transfer the plug from socket 3 to socket 2 of the key. Turn P_B to its left limit and remove the stray light shield from the FW. The tone is now so high-pitched as to be inaudible.

■ Place the tip of the index or middle finger of your left hand *very gently* and *without pressing* (important) in front of the FW; lightly touch the fingernail with the lens lamp. The constant tone returns.

■ If the influence of outside light has been eliminated as fas as possible, a strong pulse can be clearly heard in the loudspeaker. As a result of the blood rhythmically passing through the fingertip the light falling on the FW becomes slightly weaker; the constant tone becomes somewhat deeper each time. Correct?

Page 40

The condenser

Condensers (also known as capacitors) are components with very special properties. They can be "charged" with electrical energy from a power source – and they can release the stored energy again when they are "discharged"; on discharging they themselves act like a source. We shall shortly see for ourselves how this works.

These properties of the condenser can be used to do an amazing variety of things. We have already sampled them with the tone generator. We shall get to know more applications later.

Figs. 1–40 and 2–40 show the *electrolytic condensers* in our kit.

The hollow rectangle in the electrolytic condenser symbol corresponds to the (+) sign on the *condenser can*. Electrolytic condensers are "polarity-sensitive" and must therefore be connected the right way round. Otherwise they can be damaged. They then have a soapy, slippery feel.

"*Electrical capacity*" is measured in microfarads (μF, pronounced mew-F). The value is printed on the condenser: 470 or 47 (μF).

For the sake of simplicity the unit of measurement is left out in the circuit diagram and the condenser required in each case is indicated only with the appropriate number as in fig. 1–40 and 2–40.

Charging – discharging

■ For the following experiments we use the LST-component only as a *terminal board* for the condenser-470 as shown in fig. 3–41.

Fig. 4–41 shows the circuit diagram for the charging and discharging experiments.

Turn NG up full with correct polarity.

■ First touch the red plug against the (+) connection of the condenser (shown in red in diagram). The loudspeaker will sound.

■ Then touch the end of the lead shown in blue against the (–) connection of the condenser. The lamp must now flash.

Repeat the experiments a number of times, also keeping the *charging lead* in place for a longer time. What does the loudspeaker say to this?

We find that:

– On touching the (+) bar with the red lead the condenser is charged from the NG as in fig. 5–41. The progressively fainter humming sound after the loud click indicates that a *charging current* is flowing in the *charging circuit* but growing rapidly weaker.

■ If the charging cable is held in place for a longer time, a continuous, very faint hum is heard – a sign that in this case the condenser must be acting like a *resistor*. To check this, replace the condenser with a 1 kΩ resistor. The same faint hum is heard.

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– On touching (–) with the blue cable the condenser acts like a very "short-lived" source. The lamp gives a brief flash of light due to the sudden surge of the *discharge current* through the *discharge circuit* as shown in fig. 6–41.

For the sake of interest let's now try feeding the experimental arrangement shown in 3–41 with the *pure* DC voltage of our SPV-component. You should be able to do this without a circuit diagram and photo.

■ Try the touch-contact experiments again.

– On charging, the loudspeaker gives only a clear click – without the slightest hum afterwards. Correct?

This means: Pure DC cannot pass through a charged condenser!

– However, the amount of energy that has been stored is now insufficient to make the lamp flash on discharging.

Result:

From a *comparison of the charging experiments* we can draw the following conclusion: The behaviour of the condenser with a pulsating DC voltage is different from its behaviour with pure DC.

Comparison of the discharge experiments shows that the higher the supply voltage the greater the quantity of energy absorbed – and vice versa.

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Charging and discharging through a resistor

In the previous experiments the condenser-470 was charged and discharged instantaneously. If the charging or discharging current is reduced with the aid of a resistor, the condenser takes longer to charge or discharge fully. It is not only we who are going to make extensive use of this fact: it is indispensable for much of the world of electronics. So now let us take a closer look at these processes from the practical angle without spending too much time on theory.

■ The LST-component is connected to the voltage supply unit in the usual way. For the sake of simplicity it has been left out in figs. 8–42 and 9–42.

■ We now connect up only the emitter bridge as shown in diagram 7–42, set P_2 at its right-hand limit and turn the NG up to maximum with the correct polarity.

■ Now connect the (+) side of the condenser-470 to the (+) bar as shown in fig. 8–42 and its lengthened (–) lead to a B_2 pin.

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■ The lamp lights up immediately, thus showing that the charging current is flowing. It goes out after about 3 seconds although the charging process is not yet completed. Towards the end of the charging process the current becomes so weak that it no longer has a sufficient influence on the base of the transistor.

■ So we wait for about half a minute more and then change over the connection of the *charged* condenser on LST-2 as shown in fig. 9–42 and diagram 7–42.

■ The condenser now acts as a source and makes the lamp light up by its discharge current – again for about 3 seconds. Before recharging we again wait for half a minute, because the same applies for the discharge process as for charging.

The charging/discharging resistor

The resistor which so clearly lengthened the charging and discharging time is the 1 kΩ resistor shown in the full LST circuit diagram on page 93. It is connected between the B pins and the actual base connection of the LST transistor – and therefore lies on the path of the control current from the (+) bar to the (–) bar described on page 17.

■ We now replace the extension lead on the (–) connection of the condenser with the 4.7 kΩ resistor (y-v-r). The charging and discharging currents now have to "force their way" through the 4.7 kΩ and 1 kΩ resistors *one after the other* (diagram 7–42). Repeat the connection changeover experiments with the condenser.

The lamp will light up for longer – provided we wait longer before changing over the connections of the condenser and resistor.

■ And with 10 kΩ in place of 4.7 kΩ the charging and discharging times are doubled – correct?

■ *By the way:* In circuit 7–42 the same effect is achieved by turning the potmeter to the left limit.

The supply voltage

■ We shall now charge the condenser-470 directly from the NG. For this purpose we connect its (+) side to the remaining free pin of the SPV input.

Turn potmeter P_2 to left limit (= charging resistance of 10 + 1 = 11 kΩ).

The lamp glows brightly for a time and then gradually becomes dimmer. About 20 seconds (!) passes before it goes out completely.

■ Change over connection as before. The lamp takes about 17 seconds to go out completely, and becomes dim more quickly.

Capacity

To conclude our investigations, we replace the condenser-470 with the condenser-47.

■ If you find experimenting fun, you can go through the whole series of experiments with the small condenser. For our purposes it is quite enough just to charge the condenser from the NG source and discharge it again.

The result is sure to be no surprise. A condenser with a 10 times smaller capacity will naturally charge and discharge much faster.

To sum up:

The charging and discharging times depend on:

- the capacity of the condenser and
- the value of the charging and discharging resistor.

The quantity of energy absorbed and released depends on the supply voltage.

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Soft start and stop

Start 100 Motor + gears

Passengers in a train or on a roundabout would certainly not be pleased if they were always started and stopped with a jerk. The special stirrer in the new "ft-Electromechanics" must also get up speed slowly so that the magnetic coupling does not break away.

With the following "simple" circuit we can gradually start and stop the model carousel 3–45 – and still better, of course, the construction model railway.

We don't want to spoil the fun of this circuit with long-winded explanations. That belongs to higher electronic theory. The circuit works only with a pulsating DC voltage.

Note:

By now we are so familiar with the technique of wiring-up that we can do without the connection photos. Agreed?

- When the NG is switched on, the motor immediately starts to run at full speed. Wait till it stops and the lens lamp goes out completely. Not until then is the circuit ready for operation.
- Shortly after the switch is pressed, the motor starts and gradually runs up to full speed. On switching off, the motor gradually runs down.
- By connecting the switch to the Br pin the starting and running-down times are made somewhat longer still. Here again the potmeter P_2 should be turned to its right-hand limit.

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Timer

We are sure to be familiar with timer models from "Electromechanics". As electronics engineers we can do without models with motors, cogs and cam discs. In addition to the electronic building components all we need is a condenser and a switch module – and the latter can be replaced with our well-tried touch-contact lead.

"Timer" or "Monoflop" is the name electronics engineers give to a circuit which switches on for a given time after an *input pulse* and then automatically returns to its *quiescent state.* This is exactly how circuit 1–46 works.

- We produce the input pulse by *briefly pressing* the button T.

  "Triggering" is the technical term for this. The indicator lamp at the output of LST-1 is switched on immediately.
- The length of the "on time" after which Q_A flips back from (+) to (–) so that the lamp goes out depends on the setting of the potmeter P_A. *Try it out!*
- The on times are considerably lengthened if the Monoflop 1–46 is triggered with approximately + 10 V instead of with + 5 V. In order to do this we make the connection shown as a blue dotted line to the (+) pole of the NG.
- So that we do not have to determine the on times for each model application, it is best to carry out a "measuring series" according to table 2–46 and enter the results in the table.

Important: The on time of the Monoflop does not begin until the key is released, i.e. at the end of the input pulse.

Table 2–46

Condenser	Potmeter bridge	On time in seconds for: P_A = at left limit, 5 V	P_A = at left limit, NG	P_A = at right limit, 5 V	P_A = at right limit, NG
470	with				
	without				
47	with				
	without				

Table 4–47

Condenser	On time in seconds for: P_A = at left limit, 5 V	P_A = at left limit, NG	P_A = at right limit, 5 V	P_A = at right limit, NG
470				
47				

Page 47

And this is how the circuit works:

- The input (+) pulse has two effects:
  The output Q_A flips over from (–) to (+); the condenser is fully charged in an instant.
- After the disappearance of the input pulse the condenser acts as a source: the on time of the Monoflop begins now.
- The discharge current of the condenser maintains Q_A in the (+) state until it falls below the threshold value of the SWS and the on time is ended; Q_A flips from (+) back to the (–) quiescent state.
- The on time of the Monoflop therefore depends on

the variable threshold level of the SWS and the discharge time of the condenser (see pages 42 and 43).

- In Monoflop 2–47 the condenser is connected to the Br pin so that the potmeter is used as an *additional discharge* resistor (see page 94). This enables the on times to be lengthened considerably.

By the way: The well-tried Monoflop circuits are "re-triggerable". This means the on time can be extended at will by triggering again before it ends. The partly discharged condenser is fully charged again by each triggering pulse. *Try it out!*

Time switches of this kind are used for such purposes as controlling stair lighting in blocks of flats and offices. But they cannot be used for traffic lights at pedestrian crossings. Why is this?

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You have one minute, starting ... now!

Start 100 Motor + gears

"You have one minute starting ... now!" says the quizmaster to the contestant as he starts the timer. TV viewers can see how the time runs away. A timer of this kind is what we are now going to build – and we can see how the time ticks away on the "time" gearwheel 3–49. Perhaps the quizmaster will be kind and "put in an extra tooth".

- Fig. 1–48 shows the circuit diagram of the timer circuit. For pure experiments all you need are the indicator lamp and a clip lead.
- For the construction of the model, the lamp is replaced by the motor of the time gearwheel. Complete the construction in 3–49 with a loudspeaker and switch.

This is how the timer is operated:

- Place switch (symbol in fig. 1–48) in the zero position, or do not yet connect up the clip lead (on the NG pin of the power supply unit).
- After switching on the NG set the pitch and volume of the signal tone.

  Switch off the loudspeaker with the switch or by clipping the lead to E_B. The timer is now ready for operation.
- On "You have one minute" place switch in zero position or unclip lead.

  On "Now!" quickly move the switch lever forward and back again or touch the clip lead against the (+) connection of the condenser.

  The indicator lamp lights up or the time gearwheel rotates.
  At the end of the running time the motor is stopped and the "time up" signal sounds.

  In contrast to the "alarm circuit" 2–35, here the sound signal is controlled not by the Q output but by the Q-NOT output of the appropriate SWS.

This is logical: The timer signal has *not* to sound when the SWS input is connected to (+). So the position is the reverse of that in the alarm circuit. Clear enough?

To allow the contestant to judge how much time he has left, a trial run should be made with the time gearwheel before the start of the game.

- Position the time and zero marks to coincide with each other according to fig. 3–49.
- Trigger timer and count how many teeth pass by the zero mark during its running time.

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The time factor

Start 100 Motor + gears Key component

Games of skill, dice games, lotto – you can play all these with the simple model 3–51. No doubt you can also find other applications. The Monoflop is again the most important part of the circuit.

The circuit contains nothing new. Only the application has been changed. The rotation of the pointer can now be influenced during the on time of the Monoflop.

Game of skill

- The indicator lamp at the output of LST-2 is mounted on the model or on the LST-component according to preference.
- With P_B set the switching threshold of the SWS so that the LED just lights up.
- The on time of the Monoflop should be about 10 seconds. It can naturally be triggered with a touch-contact lead instead of with the switch.
- Any sector of the disc between two numbers is taken to be the target. If there are no numbers, fix a building block on the disc.
- When the referee has triggered the Monoflop, the player must try to stop the running motor so that the rotating pointer comes to a stop over the target by repeatedly covering the FW.

Dice

- For this game you can manage without all the components and connections shown in blue in circuit diagram 1–50.
- Each "throw" is made by triggering the Monoflop. For this there are two possibilities:
  - For each throw the player may "re-trigger" twice while the motor is running.
  - The player may trigger only once – but it is up to him to determine how long the input pulse is to be, or in other words how long he holds down the key or keeps the touch-contact lead in place. The on time does not begin until after this.
- The players must naturally agree beforehand as to how a throw is to be counted when the pointer comes to a stop between two figures.

"Bingomat"

- By dividing the wheel into areas numbered from 0 to 9 you can make the dice into a "bingomat". If you don't win you have got the wrong numbers.

Page 52

Wheel of fortune

Start 100 Motor + gears Electromechanics

In model 4–53 the motor is controlled by the hand-spun disc. With the aid of a few building plates on the disc, you can even start the "wheel of fortune" by blowing. For this "magic" we need a little electronics from the more advanced box of tricks, namely a *non-retriggerable Monoflop*. Let's skip any further explanations and see how this works in practice.

- For the circuit of the new Monoflop we need both SWS as shown in diagram 1–52. It is triggered by a (+) pulse on its input E_B. (In order to prevent unintentional triggering, the (–) bars of the LST and SPV-components are connected directly to each other. (Also see pages 61 and 91.) The LST which follow are controlled via its $\overline{Q}_A$ output.
- Insert a 10 kΩ resistor for R (R = general sign for resistance) in circuit 1–52.
- Close switch S and wait and see what happens. After the lamp goes out, open switch and close again.
- Does the on time change as a result of pressing the switch before it comes to an end?

We find that:

The new Monoflop has the following in common with the old one:

Trigger with (+). The on time depends on the value of the discharge resistor (R) and also on the capacity of the condenser.

There are the following differences between them:

The on time of the new Monoflop begins at the start of the triggering pulse (and not at its end). Retriggering during the on time is impossible, and you can only trigger again after the time has run out.

Page 53

- As shown in diagram 2–52, the motor of the wheel of fortune is controlled via LST-2 from the $\overline{Q}_A$ output of the new Monoflop. On the other hand LST-1 is connected to the Q_A output. For this reason the lamp lights up when the motor is at a standstill.
- Triggering is done by the magnetically actuated reed contact: When the spinner disc is started, the motor also runs until the end of the on time – even if a magnet of the slowing disc "holds on" to the reed contact, which is something that may also happen.
- The spinner disc, which continues running for longer, triggers the Monoflop again. The lamp indicates this with a brief flash.
- Each player may spin the disc once at his discretion. The marker belonging to one of the players – or possibly no marker at all – will come to a stop in front of the "pointer".

  The players must agree among themselves whether this means a win or a loss for them. There are many possibilities – and there are no limits to imagination.

Page 54

Cadence generator

This is an extremely important basic electronic circuit, also known as a multivibrator. In taking a closer look at it, we shall come across a property of the threshold switch that we have not met before.

"Just a moment – haven't we already had circuit 1–54 in the alarm system and the finish indicator?"

That's right. As we shall hear for ourselves in a moment, the "tone generator" we used then is nothing other than a very fast multivibrator.

- For R, first insert the 100 kΩ resistor. Potmeter at right-hand limit.
  Switch on NG and wait.
  Soon after switching on, the loudspeaker clicks and the lamp blinks *in synchrony* with the light-emitting diode which alternately lights up and goes out again. The circuit operates as a *cadence generator*.
- If we turn the potmeter to the left the lamp blinks somewhat faster – correct?
- Try out all the resistors listed beside diagram 1–54 and the cable connection shown in red in the diagram.

  Now it's clear: A multivibrator with a small resistor in the *feedback line* – that's obviously what we have here – acts as a tone generator.
- If we use condenser-47 the changeover from cadense generator to tone generator is still faster. Try that out too!

  If on the other hand we want a still slower rhythm than in the first experiment, we must increase the capacity by connecting our condensers *in parallel* as shown in diagram 2–55.
- First try with 100 kΩ for R and without the *blue* diode.
- The rhythm becomes still slower if the diode is connected in series with the 100 kΩ resistor. We shall make use of this several times more.

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To sum up:

The speed at which the generator circuit "vibrates" depends on

– the capacity of the condenser;
– the value of the resistors in the feedback circuit: High values for cadence generator; small values for tone generator.

By the way: If the Q-NOT output is used for feedback to the input of the *same* SWS we have a device known as "negative feedback" which is very widely used in electronics.

For the curious

This generator circuit works roughly as follows:

– After switching on, the LED does not glow, i. e. $\overline{Q}_A$ is in the (+) state. We make use of this to charge the condenser via the resistor in the feedback line (and the potmeter resistance between the Br and E_A pins). As we have seen, this takes quite a while the first time.
– When the *switch-on* threshold of SWS_A is reached

(by the condenser voltage), $\overline{Q}_A$ flips over from (+) to (–) and the LED lights up.

– The condenser now discharges via the input transistor of the SWS (see page 94) and the feedback resistors until the *switch-off* threshold is reached. $\overline{Q}_A$ promptly flips over from (–) to (+) and the cycle begins again.

"So the SWS has two switching thresholds – correct?"

– That's right. But the difference between the two threshold levels has not been noticeable before. And because it is so small the condenser needs to be charged or discharged only by a very small amount to make the circuit flip over one way or the other. This is why the rhythm is relatively fast despite the large size of the charging and discharging resistors.

– But if the feedback line is blocked for the discharge current with a diode – as shown in diagram 2–55, the discharge takes longer and the rhythm becomes slower, as we have seen and heard.

Page 56/57

Automatic flashing warning light

Start 100 Construction model railway Electro-mechanics

Flashing lights are used to warn of breakdowns, road works or level crossings, or to indicate left or right turns on vehicles. Today they are almost always controlled by an electronic multivibrator. But after the experiments we have already done, a flashing-light circuit of this kind is too simple for us. It is more interesting if the flashing light operates automatically only when it is needed. We can equip the drive-in gateway or the tracks of the construction model railway with such an "automatic warning light".

This is a clear-cut case: For this application the multivibrator must be controlled by a Monoflop. Circuit diagram 1–56 shows how this is done:

- We already know the Monoflop – shown in red – by heart. It is triggered by the light of the car headlamp shining on the FW at the gateway 2–57.

The blue components belong to the multivibrator circuit whose output Q_B controls LST-1 via the 1 kΩ resistor.

The function of the red control diode has already been explained in detail on page 35.

- Unfortunately we need the condenser-470 to give the Monoflop a reasonably long on time. So for the multivibrator there remain only the two condensers-47.
- To make up for the small capacity, the resistance for the feedback must be made correspondingly large. That is the reason for the "sausage string" of resistors shown in blue in diagram 1–56.

A clever trick here is the inclusion in the "string" of the internal potmeter resistor of LST-2. As a result we need only a single contact pin for the series connection of three resistors.

- We control the model railway with the transformer unit. The electronics are connected to the side output of the NG.
- The loco triggers the monoflop via the reed contact by means of the permanent magnet incorporated as shown in fig. 3–57. (Shown in black in diagram 1–56.)
- Of course the warning flasher 4–57 must be placed a suitable distance from the reed contact – otherwise the "train approaching" warning light probably will not light up until it is almost past.

Page 58

Sounds and noises

Switch

Now we shall put the tone generator through its paces: For this we control it with a cadence generator – in effect, from threshold switch to threshold switch. The noises that come out of the loudspeaker are sure to be fun for us. But innocent bystanders may have other views.

- Diagram 1–58 shows the circuit of a "cadenced tone generator". Its output Q_B controls LST-2 with the loudspeaker via the 1 kΩ resistor. The 100 Ω resistor also protects the environment – from pollution with noise!
- Connect the (–) bars of the SPV and LST-components *directly* together. This is dealt with in very interesting notes on page 61.
- The value of the resistor R shown in red determines the "sound picture" after the multivibrator has been started up. The *sound pitch* is adjusted as usual with P_B.
- The loudspeaker can be switched on and off with the switch S.

Bleeping sound

- This is produced by circuit 1–58 with R = 4.7 kΩ as a "linking resistor" between cadence and tone.

  $\overline{Q}_A$ (+) influences the input E_B of the tone generator so strongly that the generator is no longer able to oscillate. It operates only when $\overline{Q}_A$ is in the (–) state. This is indicated by the LED's of the threshold switch.

"Hee-haw" siren

- If R is increased to a larger value such as 10 kΩ or 22 kΩ, the influence of $\overline{Q}_A$ becomes smaller and the tone does not disappear – it only becomes lower-pitched. This gives a "two-tone generator", the well-known sound of the police, fire or ambulance siren.
- Because the cadence generator does not operate uniformly, here it is better to connect the resistor R to Q_A than to $\overline{Q}_A$ (shown in diagram 1–58 by a red dotted line).
- The blue warning light can also be connected via LST-1.

Page 59

Whining instead of bleeping

- First we slow the cadence generator with the diode shown in blue in diagram 2–59. We already know the trick.

- And now we connect the condenser-47, which is shown in red, in series with the "connecting resistor 4.7 kΩ".
- Try out both cadence generator outputs for the control of the tone generator; other values can also be used for R. Here experiment is more important than study.

  The condenser has made the bleeper 1–58 into a whiner. This change is naturally connected with the charging and discharging of the condenser. But instead of making a detailed study of these somewhat complex processes, let's go on to the next circuit.

Twittering birds and chirping crickets

- On the circuit you have just tried, make the changes shown in blue in diagram 3–59.
- By skilfully shading the FW, which should not be covered by a stray light shield, you can produce various sounds such as the twittering of birds and the chirping of crickets.

All one can say is: "Melo-Tron you *have* changed!" (Compare with 1–38.)

Page 60

The light-shy dragon-cow

Start 100 Electromechanics

As we all know, dragons live in caves. The dragon-cow 4–60 must live in a very dark cave, because the slightest ray of light irritates it. In strong light, particularly with rapid changes of intensity, it goes completely wild.

- The electromagnet and "dragon lamp" are supplied separately with the pulsating voltage of the front NG output (shown in heavy black in diagram 5–60).
- The control of LST-1 by output Q_A of the fast-running multivibrator depends on the illumination of the FW (without stray light cap). Set P_1 so that the beast either
  - stays quiet in the existing lighting and must be excited with a torch, or
  - behaves wildly in the existing lighting and is calmed by shading (stroking).
- The lens lamp ensures maximum sound volume.
- The connection of the output of LST-1 via 10 kΩ and 4.7 kΩ with the input of the tone generator ensures that the dragon-cow eventually stops squawking and cackling – although it always has the last word.

Page 61

Little green gremlins or spook effects

If a circuit does not work, a quite definite reason can usually be found; the various causes of trouble are summarised on page 91.

But sometimes it really is almost as if "little green men" were at work – for instance, when a Monoflop triggers itself (?) or music and news suddenly come out of the loudspeaker. Electronics engineers call this kind of thing a "spook effect", and this is what we shall now take a look at.

The "oversensitive" threshold switch

Spook effects occur primarily in SWS circuits in which no potmeter bridging leads are connected. The input sensitivity is then enormous. Here is an example:

- In experimental arrangement 4–27 shown in diagram 5–27, no lead is needed to flip over the SWS if the potmeter lead is disconnected: moist fingers on the input pin and the (+) bar are quite enough – correct?
- The Monoflop 1–52 (no connections on Br pins) can also be triggered with moist fingers – just by grasping the contact pin connection.

By the way: If this connection is not making absolutely firm contact, a light tap with the finger is enough to effect triggering (see page 91).

A gremlins' paradise...

... that's what the tone generator circuits are. This is a result of the notorious "ground leads" as electronics engineers call the (–) bars.

- Construct only the tone generator of the alarm circuit 2–35 together with LST with loudspeaker, and connect to the side NG output.
- Transfer the long yellow lead from the SPV to the SWS-component. Exceptionally the sound volume is *somewhat* higher than usual.
- An absolutely pure tone – or not? Just move the yellow lead to and fro a little between the bars; with one of them (at least) the sound will also move to and fro (see page 91).
- We now remove the (–) connection of the condenser-47 from the ground pin of the SWS-A and hold it against the (–) plug on the SPV bar: the crackling sound is a result of the small contact resistance between the plug contacts. This spook effect is also obtained with the pins on the SPV busbar.
- Now we touch the (–) connection of the condenser successively against all pins that can be reached on the (–) bars of the SWS and LST. We cannot fail to hear the changes in pitch.
  - For this reason condensers in a tone generator circuit should always be connected only to the (–) bar of the SWS-component and not just anywhere in the vicinity. And connecting leads should always be kept as short as possible!
- These an other spook effects are reduced or completely prevented if the LST bar is connected directly to the SPV bar (by means of the long yellow cable). This bypasses the "oversensitive SWS-component".
- For example, the dragon-cow makes ghastly croaking noises if the "interference pulses" produced by the electromagnet are able to act upon the SWS via the ground lead. Then the only solution is to divert the ground line with the long yellow lead.

A "magic" effect

If you live near to a transmitter, you can listen to the radio with the SWS.

- For this you need only to connect a feedback resistor of 100 kΩ between the input and the Q output of one SWS. The SWS then "resonates" – the LED lights up moderately brightly – in a similar way to a "tuned circuit" in a radio set.

- Connect LST with loudspeaker to the Q output. Touch the SWS input with a "moist finger antenna" and adjust for optimum reception with the SWS potmeter.

Not quite HiFi reception, but not bad – agreed?

Page 62

Electronic special switch

Start 100 Construction model railway

Something new once in a while: We have already tried electronic self-holding by feedback several times. In the next circuit we use a dual version of it. The result is an interesting switch that we shall try out and use in the signal installation 3–63. If you do not have a construction model railway, you can go on to page 64. O.K.?

- The special switch is made as shown in diagram 1–62 by "crosswise feedback" from the $\overline{Q}$ output of one SWS to the input of the other via a 1 kΩ resistor.
- Connect potmeter bridging lead and set both potmeters in roughly the same position as shown in diagram 1–62.

  After switching on, one of the two LED's will light up. If it is LED_B of the lower SWS, the lamp naturally does not light up.
- In order to switch on the lamp, we trigger the input E_A of the upper SWS by touching the lead onto the (+) bar. LED_A lights up as well as the lamp. Correct?
- In order to switch off the lamp, input E_B is triggered with (+) according to diagram 1–62.
- How does the "switch" behave when both of its inputs are connected simultaneously with (+)? And what happens when one input is permanently connected with (+) and the other is triggered with (+)? Try it!

How the switch works:

- Again assume that LED_B lights up on switching-on: Q_B than acts like (–) on the input E_A of the upper SWS; the output $\overline{Q}_A$ of the latter therefore also acts like (+) on the input E_B of the lower SWS.

In other words $\overline{Q}_A$ helps to maintain the (+) state of E_B via the *feedback* system.

- If the other switch input E_A is now automatically connected to (+) by triggfering, $\overline{Q}_A$ flips over from (+) to (–); E_B is "pulled along with it", so that at the same time $\overline{Q}_B$ flips over from (–) to (+) and itself helps, by *feedback*, to maintain the input E_A in the state induced by triggering.
- This type of feedback is therefore also known as "positive feedback". Feedback via a "self-holding diode", such as in the alarm circuit on page 34, is also an example of positive feedback.

Page 63

Signal with optical remote control

- For the "remote control" we need a torch. With this we trigger the switch input E_A via the FW according to diagram 2–63: Q_A (+) *switches LST-1 to conduct through*, the green signal lamp lights up, and the train starts to move.
- When the loco with the permanent magnet (see fig. 3–57) passes the signal post, E_B is triggered via the reed contact:

  Q_A flips from (+) to (–) and blocks LST-1; the train stops and the signal changes from green to red. (Why?)
- We can now make the signal change back from red to green by remote control and start the train off on another circuit of the track.
- How can the "switching distance" be increased? (Study diagram carefully.)

By the way: The diode between C_1 and the green lamp ensures that the (+) pole of the front NG output is separated from the +5 V busbar (also see page 91).

Page 64/65

Between start and stop

Start 100 Motor + gears Electromechanics

You can bet that nine out of ten people will answer this question wrongly: which pulley will reach the bottom first – the light one in fig. 2–65 or the heavy one in fig. 3–65? We are not going to give the answer here. We shall first find out exactly for ourselves with the aid of the timer gearwheel, used here as a "cog stopwatch". The special switch we have just tried will help us.

- The special circuit with the typical "crossover resistors" is shown in heavy black in diagram 1–64.
- The *blue* components belong to the *start* device for the cog stopwatch in fig. 2–65. The light barrier is connected in exactly the same way as in the "finish indicator" 1–36. Signal inversion at the input!
- On switching on, the pulley is at the bottom of the bar and interrupts the light barrier.

  $\overline{Q}_B$ therefore acts like (–) on B_2, and the cog stopwatch does not run. On the other hand Q_B acts like (+) on B_1, and the electromagnet is *excited.*
- With the special switch in this state and the potmeter in the indicated position nothing changes when we "fix" the pulley to the electromagnet with its backplate.
- Set the time marker of the stopwatch at zero as shown in fig. 2–65.
- To release the pulley, briefly press the button: both switch outputs immediately flip over to their alternative state. The power to the electromagnet is cut off and the pulley is released. *At the same time* the cog stopwatch begins to run.
- When the pulley passes through the light beam, the switch outputs instantaneously return to their original state.

  The cog stopwatch indicates the time between "start and stop" of the pulley in teeth (instead of seconds); the electromagnet is ready to hold the pulley in preparation for a new start.

  As a check, measure a few times how long the unweighted pulley takes to travel from top to bottom.
- And now do the same with the pulley weighted as in fig. 3–65.

  If we compare the number of "time teeth" that pass the zero mark during each run from top to bottom, we clearly see that:

The weight of the pulley has no influence on its speed – provided the angle of the "inclined plane" has not been altered.

By the way: The explanation for this fact can be found in any school physics book.

Page 66

The transistor resistor

In the following generator circuits the transistor of LST-2 is used as a resistive component. We shall soon see how this works.

Fig. 1–66 shows the symbol for a transistor which we already know from page 17. The path taken by the load current, which is shown in blue, is known as the collector-emitter path or "CE path" for short. Its resistance can be altered by the strength of the base current. We shall now make use of this fact in a new way:

- Fig. 2–66 shows the circuit diagram of the experimental arrangement. For this we need no model. The condenser shown in blue dotted lines is left out for the time being.
- We connect the CE path of the LST transistor between the Br input and the $\overline{Q}_B$ output of the cadence generator with the leads shown in red.

  Thus the CE path of the transistor is used as a *feedback resistor.*
- In order for this to function, however, a control current must flow from (+) into the base through the lead shown in heavy black – and the potmeter bridging lead must be in place.
- After the start of oscillation, LST-1, fitted with the loudspeaker an lens lamp, is audibly and visibly controlled by the Q_B output of the cadence generator.
- The cadence can be varied with P_B in the usual way.

  With P_2 we control the base current and thus alter the resistance of the CE path. Thoroughly try out the effect of the two potmeters on the multivibrator.
- For comparison replace the CE path by the FW (as in the Melo-Tron 1–38): We shall see that the multivibrator is controlled by covering the FW in exactly the same way as when the "CE resistance" is altered by moving the potmeter.
- By means of condenser-47 the capacity is increased and the cadence is slowed.

Page 67

Conveyor belt with start – stop cycle

Model 6–19 is now used not as a continuously running conveyor belt but as a production line belt in a china factory. It stops for a time according to the programmed cycle and then moves on a little further. It is again transporting porcelain horses, to which skilled workers apply dabs of paint during the stops in the cycle.

- Our familiar multivibrator circuit, together with the CE control, is shown in heavy black in diagram 1–67.
- The belt motor controls the Q_B output of the multivibrator via LST-1.
- The belt is switched off in the usual manner when the "reversal light barrier" is interrupted.

The self-holding resistor of 4.7 kΩ ensures that the belt cannot start moving again by itself after the removal of a "porcelain horse 15"; it must be started again with the key as required.

Page 68

Signals and Sirens

There's lots more fun to be had with the following experimental circuits. With the aid of the transistor resistor you can imitate various types of sirens. But we should now be able to modify the described circuits by ourselves. For instance, we may change condensers, insert resistors or use the photoconductive cell. There are countless ways of making practical use of the knowledge we have acquired. Electronics then really starts to get exciting, as on page 80, for instance.

Circuit 1–68

- By changing the condenser at the input of SWS-B we make the cadence generator into a tone generator. It controls LST-1 with loudspeaker + resistor via 4.7 kΩ.
- As in the previous circuits, the base current flowing from (+) into the input of LST-2 is controlled with P_2.
- An additional control current flows from the $\overline{Q}_A$ output of the generator via the Br input to the base.
- Depending on the setting of the potmeter, one control current or the other is dominant or the currents influence each other:

– *Bleeping sound* with P_2 at left-hand limit.

– *Hee-haw siren* with potmeter in central position; the deeper tone can be exactly tuned with P_2 within the range fixed with P_A.

– *Continuous tone* with P_2 at right-hand limit.

- The condenser-47 is connected directly to the (+) bar and has no appreciable effect on the sound pattern.

Page 69

Circuit 2–69

- Instead of from (+) the base is now supplied with control current solely from the Q_A output of the generator, namely via the *red* control diode.
- The condenser-47 now comes fully into operation as a "gap filler".

– *Condition Q_A (+)*: Control current flows from Q_A to B_2, the sound starts up at full strength – the condenser is charged instantaneously.

– *Condition Q_A(–)*: The diode blocks the control current from Q_A – the condenser fills the gap with its discharge current – a fading howl is produced.

Circuit 3–69

- Do not replace the control diode with the 22 kΩ resistor, but only connect the *blue* 10 kΩ resistor between the (+) bar and the Br input. This is known as "biasing the Br input with 10 kΩ".

This appreciably increases the input sensitivity of LST-2 and thus augments the "howl effect". The sound is now reminiscent of an American *police siren.*

- If the control diode is replaced by the 22 kΩ resistor, the nerve-rasping howl of *an alarm siren* comes from the loudspeaker.

Page 70

Coil and magnet

Start 100 Electromechanics

When a current flows through a coil it becomes magnetic. This is nothing new to us. Now we learn something more: If a magnet is moved past a coil, a voltage is produced in the coil. This is known as an "induced voltage". With the magnetic swing 4–71 we can generate "voltage pulses" in the coil of the electromagnet and use it to control a threshold switch.

- With the arm of the magnetic swing 4–71 the permanent magnet can be moved quickly or slowly past the coil of the electromagnet at a greater or lesser distance from it.
- The electromagnet is connected between the input of SWS-A and its ground pin as shown in diagram 1–70. LST-1 is controlled via output Q_A.
- *Try out:* How do the LED, lamp and loudspeaker react to moving the permanent magnet slowly or quickly past the electromagnet coil at a greater or lesser distance from it?

Page 71

We find that:

In order for the LED to light up and for the loudspeaker to emit a click, the permanent magnet must be moved as closely as possible past the electromagnet – the faster the better.

The lamp does not respond tu such short pulses.

- If we increase the response sensitivity of the SWS with the "bias" trick we have just tried according to diagram 2–70, with P_A in its extreme right position only a small movement of the magnet is enough to bring the SWS into its self-holding state. Correct?

Thus our coil responds with a "pulse" only if the magnet *moves* close by it. The faster the magnet is moved, the stronger the pulse – and vice versa.

We shall now make use of these remarkable "sensor properties" of a coil in order to control a model and the construction model railway.

Page 72

Motor speed regulation

Start 100 Motor + gears Electromechanics

The control of the motor with the LST potmeter is a problem in itself. It is impossible to achieve steady running at a low speed without repeatedly adjusting the potmeter – the motor "keeps running away". For regulating the motor speed the machine 3–73 is equipped with a disc on which a magnet is fitted. If the motor speed increases, the coil of the electromagnet "feels" this and ... but we should best try it out.

- First we make the input of SWS-A (diagram 1–72) insensitive by turning P_A to its left limit. P_1 on the other hand is set at its right limit.
- Turn on NG and ... nothing happens. Only after some time does the motor begin to buzz and jerk until it slowly but surely begins to pick up speed.

  If this does not happen, after a minute replace the 10 kΩ resistor with the 4.7 kΩ resistor and turn P_1 to the left until the motor stops: wait!
- With P_A we can now fix the motor speed at which the coil is to act as a "pulse generator".

  The SWS then goes into its self-holding state: Q_A flips over to (+) and the lamp indicates "fault"; Q_A flips to (–) and blocks LST-1 via the control diode: the motor is immediately stopped.

The motor "running away"

is a result of the heating effect of the electric current. We can visualise this roughly as follows:

- The *blue* 10 kΩ resistor (diagram 1–72) allows so little control current to pass through to the base that the load current is not yet sufficient to set the motor in motion. On the other hand it is sufficient to warm the transistor. This diminishes the resistance of the CE path so that the load current increases. The motor starts to run.
- In this phase a stronger load current generates more heat. The motor runs faster. We now counteract this by reducing the control current with the potmeter.
- The game continues like this until a "thermal equilibrium" is established. The transistor will have grown quite hot.

  Unfortunately the motor will not start again after a pause in operation. As a result of "turning down" the potmeter the control current has become much too weak to make the transistor conduct, since by now it will have cooled down again. So you must "turn up" the potmeter again ... and so on.

Page 73

Motor speed regulation

Speed control is known as *regulation* when the rise in the load current due to the warming of the transistor *automatically* brings about an immediate reduction in the control current so that the speed set with the potmeter is maintained.

This is exactly what is achieved with the 1 kΩ resistor in the feedback line between the output and input of LST-1, which we have already used on page 22 for "widening the transition range".

We shall already make use of this speed regulation system on the next page.

Page 74

Warning, construction works

Start 100 Motor + gears Electromechanics

The model train cannot pass warning signal 3–75 at full speed. The circuit forces it to go slowly until it has passed the "construction works". Slow-moving trains can creep past unhindered – but this need not always be so. This depends entirely on the "traffic controller" who operates the circuit. If he wishes, he can also make each train stop at the signal.

- The "pulse generator" shown in red with its components in diagram 1–74 is now actuated – or not actuated – by the loco fitted with the permanent magnet (as shown in fig. 3–57). Whether or not it is actuated depends on the potmeter setting.
- The pulse originating from Q_A triggers the *blue* Monoflop (via the *red* diode).
- The speed of the train is "regulated" with P_1 (see page 73).
- And now we come to the trick: When the Monoflop is triggered, $\overline{Q}_B$ flips back to (–). Because of the 1 kΩ resistor shown in blue, now LST-1 is not blocked completely but only a part of the control current is conducted away to $\overline{Q}_B$ (–). The train therefore travels more slowly. It stops if it has previously been set at a slow speed with P_1.
- After the end of the switching time the previous condition is restored.
- *Please try out:* What is the effect when:

a. The 1 kΩ resistor on LST-1 is replaced by 4.7 kΩ?

b. The 1 kΩ resistor which is now free is connected in parallel with the blue 1 kΩ resistor between $\overline{Q}_B$ and B_1 (crocodile clip)?

c. The diode is replaced by a lead?

Page 75

Answers and explanations to:

a. The range of regulation becomes somewhat narrower, but the slow speed of the train can be adjusted more sensitively. The explanation for this is too complicated to give here, so we can do no more than take note of this fact.

b. The "effective resistance" is reduced by the *parallel connection* of resistors. LST-1 is therefore blocked by the triggered Monoflop.

In contrast to parallel connection, series connection *increases* the resistance of resistors, as we have found a number of times.

c. When the condenser is charged, the diode is in the nonconducting direction, thus preventing the condenser from discharging instantaneously when Q_A flips over to (–). If the diode is replaced by a lead, the Monoflop cannot exercise its function.

Page 76

Electronic divining rod

Start 100 Electromechanics

There are people who can detect underground water with the aid of a "divining rod". The divining rod 3–76 can be used for locating the invisible "stray electromagnetic fields" which surround a transformer. For instance, if we run the electromagnet over our transformer unit, we can "hear" where the transformer is located in the casing. This works equally well with mains-operated radio sets, cassette recorders, etc.

- Naturally if the LST is to act as a "bloodhound" it must be supplied with pure DC as shown in diagram 1–76, otherwise the hum of the pulsating NG voltage will already be inside our circuit before we start.
- An AC voltage is induced in the coil of the electromagnet if it is brought close enough to the stray field, which oscillates at the frequency of the mains supply.
- This "alternating signal" is fed to LST-2 via the Br input. In order to increase sensitivity the B_2 input is biased with 4.7 kΩ.
- We adjust P_2 so that the lamp just lights up faintly; the "transistor amplifier" then works in the transition range or at the "operating point", as electronics engineers call it.
- The running motor also produces considerable stray magnetic fields, but these sound different from those of a transformer. Correct?

Page 77

The motor as a dynamo

Start 100 Motor + gears Key component

Now for something exciting: We can use our motor to generate electricity. Just like the dynamo on a bicycle or in a car. We shall have lots of fun with the "dynamo model" 6–79.

- With the "cord start" method (figs. 1–77 and 2–77) we turn the motor so that the lamp lights up brightly for a short time.

This works in a similar way to the magnetic swing 4–71, except that in the motor the coil is moved while the magnets are fixed. The principle and effect are the same.

- We can generate a voltage more simply with the circuit in diagram 3–77 with the aid of model 6–79.
- Does it make any difference whether the drive disc is turned forwards or backwards?

  Our dynamo is therefore a DC source with a positive and a negative pole – provided the dynamo is kept turning constantly and at an adequate speed.

As a result of the special coil design and the arrangement of the magnets, a very rapid sequence of pulses is produced. The dynamo therefore produces not a pure DC voltage but a *pulsating* one. This is important for the next circuits.

Page 78/79

Crank-starting the motor

In the old days cars used to be started with a handle. We can still see this from time to time in films. We can imitate this "cranking up" operation with circuit 4–78.

- The input E_A of the SWS, biased with 22 kΩ, is connected to output C_1 of the LST via the condenser-47 shown in diagram 4–78.
- When the NG is switched on, the SWS immediately goes into its self-holding state as a result of a "spook effect", and the motor starts to run. Cancel the self-holding in the usual manner with the push button.

- Now off you go: Turn P_A not quite to its left-hand limit and crank away. The motor will start – right?

  If P_A is turned too far to the right, there is more chance of your arm dropping off than of the motor starting.

This is how the trick works:

- The condenser-47 is fully charged via the motor, which is connected to (+). It therefore lets no control current through to the SWS input (see page 41) and Q_A blocks LST-1 together with the motor.
- However, the "pulses" generated by the ft dynamo are able to pass through the condenser and bring the SWS into its self-holding state. The motor starts up.

This important property by which a charged condenser blocks pure DC while allowing pulses to pass through will be utilized once more in the "handclap switch" later on.

Page 80

Mixo-Tron

This is the name we give to the "instrument" 6–79, because its circuit 7–80 is a mixture of a number of stages. A cadence generator enriched with dynamo voltage – plus a sound generator spiced with light-garnished CE control and condenser sauce to taste. This is the recipe for a "sound salad" à la fischertechnik. Served with humour and wit, it makes an entertaining party dish.

- The Mixo-Tron player has both hands fully occupied. The fun is still greater if the instrument is operated with four hands. Then the potmeters can also develop their full effect.
- Siren-like noises can be mixed into the sound pattern by means of a diode between Q_A and B_2.
- And because the lens lamp cannot grow too hot as a result of being continuously alight, exceptionally it may be fitted with a coloured cap to enhance the general party atmosphere.

Page 81

Handclap switch

Now we are getting near the end of the book we can enjoy some really choice morsels from the electronic cuisine. First let's taste the "handclap switch". This is the name we give to a switch that responds to sound impulses, using the loudspeaker as a microphone.

- In accordance with diagram 1–81 the "amplifier transistor" is brought to its operating point with P_1 so that the lamp lights up only faintly. We are already familiar with this.
- Set P_A so that LED_A just does not light up. The lens lamp is switched on when B_2 is connected to Q_B, whereas with B_2 connected to $\overline{Q}_B$ it is switched off.

The pulse passes through four stages

- The coil which is mechanically connected to the loudspeaker diaphragm must be moved fairly quickly in the magnetic field of the loudspeaker by the sound impulse.
- The very weak voltage pulse which this generates is "passed on" by the condenser-47 to the biased input of LST-1.
- This signal is amplified by the transistor, and travels through the second condenser-47 to the input of SWS-A, which is also biased. P_A is used to determine the "sound level" at which SWS-A flips over and passes on the signal, which it amplifies further, to SWS-B.
- On arriving at SWS-B, the pulse brings it into its self-holding state. Via Q_B or $\overline{Q}_B$, LST-2 is made to conduct through or to block. With the aid of an ft mains switching device connected in place of the lens lamp we can, for example, turn a table lamp on or off by clapping our hands.
- P_2 *regulates* the lamp brightness, motor speed or model train speed.

Page 82

12-minute switch

Start 100 Electromechanics

The second thing we pull from our box of tricks is a very interesting switch with a particularly long running period. We shall assemble it in a series of steps in order thoroughly to try out the individual stages and get to know the way they interact. Agreed?

The hammer interruptor

- This is the nucleus of this neat little timer circuit. This time we assemble it from the electromagnet and the reed contact as shown in fig. 1–82.
- The condenser-47 shown in blue in the circuit diagram is left out for the time being.

  After switching on the NG the lens lamp lights up only faintly, and we hear a faint whirring sound. Correct?
- Now we connect up the condenser. The lamp lights up brightly and the whirring changes into a ticking sound. The setting of P_B has no noticeable influence.

Whirring and ticking

These sounds are produced by the reed contact. How does this take place? Let's take a closer look at circuit 2–82 and imagine the condenser is not there:

- The reed contact is open on switching-on, so that no control current reaches the SWS input and $\overline{Q}_B$ (+) switches LST-2 to conduct through.
- The magnet is excited and closes the reed contact. E_B is thus connected to (+), $\overline{Q}_B$ flips over to (–) and blocks LST-2.
- The current through the electromagnet is thus cut off and the reed contact is released; the current to E_B is also cut off and $\overline{Q}_B$ flips back to (+), etc. etc.

Thus in principle this circuit works in exactly the same way as the bell pendulum 3–32, but much, much faster: The reed contact closes and opens roughly 2500 times per second (!). This accounts for the whirring noise, while such incredibly short pulses are naturally insufficient to make the lamp controlled via Q_B – LST-1 light up brightly.

- Now we come to the *first trick:* By inserting the condenser-47 we obtain the Monoflop with which we are now quite familiar. It is triggered via the reed contact with (+), but as a result of its short discharge time the reed contact is switched on and off only about 20 times per second.
- As a result, we obtain the much slower "ticking" sound and the lamp lights up brightly.

Page 83

3-minute switch

- Add the components shown in red to the circuit as shown in diagram 3–83.
- Turn potmeter P_B to the left-hand limit. Briefly press button: The lamp immediately lights up. It goes out automatically after about three minutes. It flickers a little before going out.
- With P_B at its right-hand limit the lamp flickers considerably more because of the longer on time of the Monoflop. It blinks very markedly towards the end of the running period of the switch. The timer circuit will therefore be used only with P_B at its right-hand limit.

Little sips from the condenser can

- The condenser-470, together with SWS-B, forms the retriggerable Monoflop which determines the running time of the switch. It is triggered with the start key – its on time begins when the key is released. Nothing new for us so far.
- The *second trick* is decisive. The condenser-470 is not discharged "at a single draught" in the accustomed way during the on time of the Monoflop, but only "sip by sip". Thnis is ensured by the *hammer interruptor* connected between the condenser and the SWS input in association with the "small" Monoflop.

This accounts for the amazing running time of the switch. It can be increased to around seven (!) minutes if the condenser is charged via the (+) pole of the front NG output.

- Instructions for setting shorter running times are given on the next page.

Page 84

12-minute switch

- Add to the circuit as shown in diagram 4–84. In order to obtain a running time of 12 minutes, the condenser-470 is charged at the (+) pole of the front NG output.
- Naturally the mains switching device "NSchG" shown in blue in diagram 5–85 can already be used for turning on table lamps, radios or other equipment for a certain length of time. If on the other hand the device is to be turned off for a given period, B_1 must be connected with Q_A.
- Shorter running times can be set as follows:
- The FW is connected in parallel with the condenser-470 as an additional discharge resistor as shown in diagram 5–85. The resistance is altered as desired with the aid of the lamp.
- The "Optocoupler" of the "noise generator" 3–87 is well suited for this purpose.

Pauses between sips

- The third Monoflop (shown in red in diagram 4–84) by itself does nothing to lengthen the time – but it is constantly retriggered from Q_B via the *red* diode. Therefore the lamp controlled via the Q_A output and LST-1 no longer flickers towards the end of the on time.
- The on time is actually lengthened only by the *third trick* with the *blue* control diode. This is in the conducting direction during the on time of the Monoflop-A, so that LST-2 can be blocked by Q_A (–). The reed contact therefore remains open during this time, there is no current at E_B and LED_B does not light up; this can be seen particularly clearly when P_B is at its right-hand limit.
- Not until Q_A flips over to (+) after the end of the on time does the interruptor make contact again so that Monoflop-B can take a new sip from the condenser can and trigger Monoflop-A once more.

  Like a lemonade, a condenser charge lasts longer if you only take an *occasional* sip from the can!

Page 85

From now on it'll cost more

In some countries when you are telephoning the timer gives you this warning with a signal tone after about seven minutes.

- In place of the third Monoflop we now construct the familiar tone generator according to diagram 5–85 on SWS-A and at the same time make the changes with resistors and diodes. We have already discussed the use of the mains switching device and the FW and lamp.
- The loudspeaker may also be connected directly to the output of the loudspeaker with the protective resistor in series; then, however, we cannot vary the volume.
- When the NG is switched on, the signal tone can be heard immediately. It ceases when the start button is pressed, and does not return until the on time of the timer has expired.
- If you want a warning bleep signal shortly beforehand, you need only to set P_B at its right-hand limit.

We already know how the control diodes work – and that brings us to the end of this chapter.

Page 86

Steam locomotive noises

Start 100 Electromechanics Construction model railway

To finish up, let's take a look at the circuit of a "noise generator" with which the typical sounds of a steam-driven machine can be imitated. If you do not have a construction model railway you can use the steam engine cylinder model on page 89. Even an expert will be surprised how this circuit makes use of a notorious purely mechanical spook effect, namely "contact bounce".

- At the same time we control forward and reverse movement and the speed of the train by means of the brightness of the "Optocoupler" lamp, which is controlled by the NG knob.

  The electronics must therefore be supplied from the side output of the NG.
- Don't forget the 1 kΩ resistor shown in blue in diagram 1–86.
- We first leave out the *red* diode and determine by trial and error how and where the reed contact must be located on the electromagnet in order to obtain a pure roaring or hissing sound from the loudspeaker.
- We now connect up the diode. Adjust the distance between the lamp and FW and the potmeter P_A so that the locomotive sound follows a nice slow rhythm as the train starts to move.

Page 87

The Optocoupler

The cadence generator in the SPV current circuit is controlled only by the brightness of the lamp in the NG [v] current circuit.

"The two different circuits are optically coupled with each other" the expert would say. This explains the name "Optocoupler" for this elegant arrangement which is very often used in modern electronic technology.

Page 88/89

- Model 7–89 represents the cylinder of a locomotive or steam engine.

  Because the hissing is controlled by the piston moving back and forth and influencing a light barrier as shown in diagram 4–88, we no longer need a cadence generator or an Optocoupler.

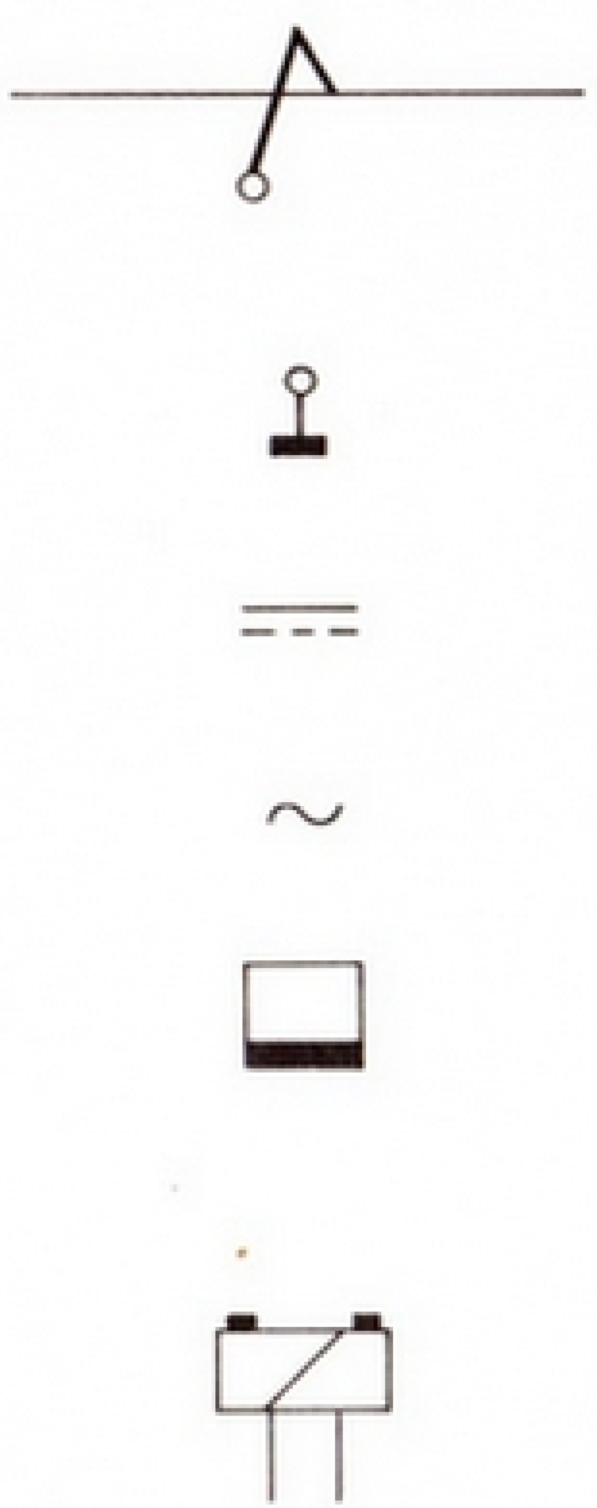
  Since nothing more is altered in the remainder of the circuit, fig. 4–88 shows only the part that interests us here.

The *noise effect* is produced roughly as follows:

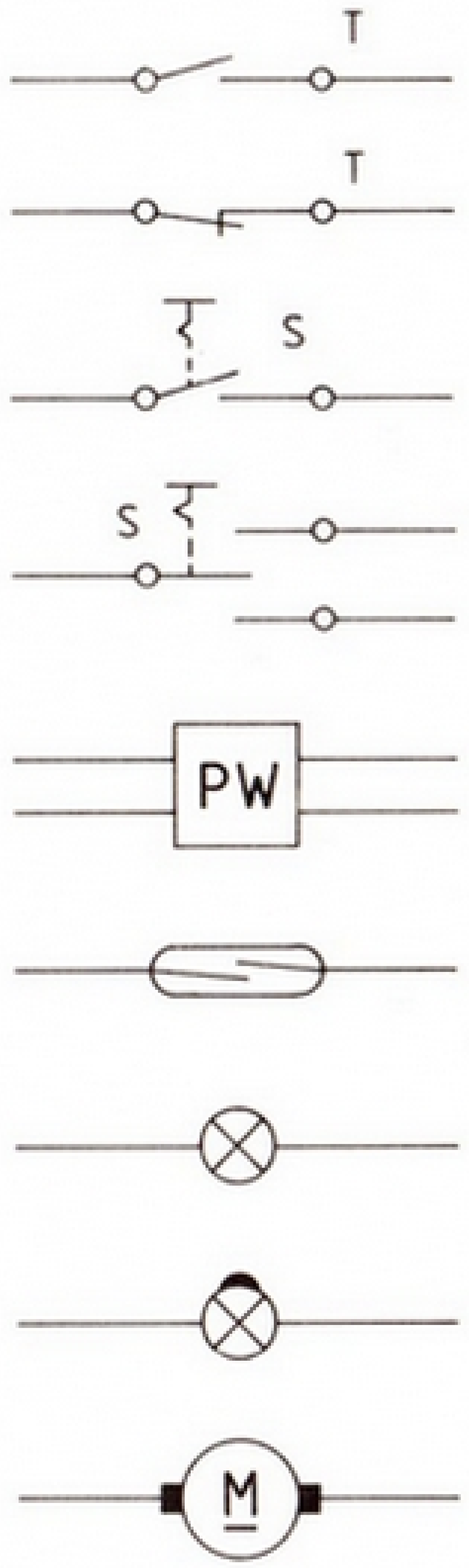
- In the "interruptor circuit" without a condenser at the SWS input, the reed contact is closed and opened approximately 2500 times per second.
- With this "mechanical tone generator" we now drive LST-1 together with the loudspeaker. We obtain a fairly pure and high-pitched tone when the reed contact is brought towards the electromagnet from the side at a somewhat greater distance from it. *Try it out!*
- The situation becomes different when the reed contact rests against both poles of the electromagnet. The reeds are then moved so violently by the electromagnets that they spring back and forth several times when the contact closes. This is known as "bounce". When and how often the contact reeds bounce depends purely on chance, so that this is a somewhat chaotic process. Consequently the tone generator becomes a noise generator.

Overview of circuit symbols

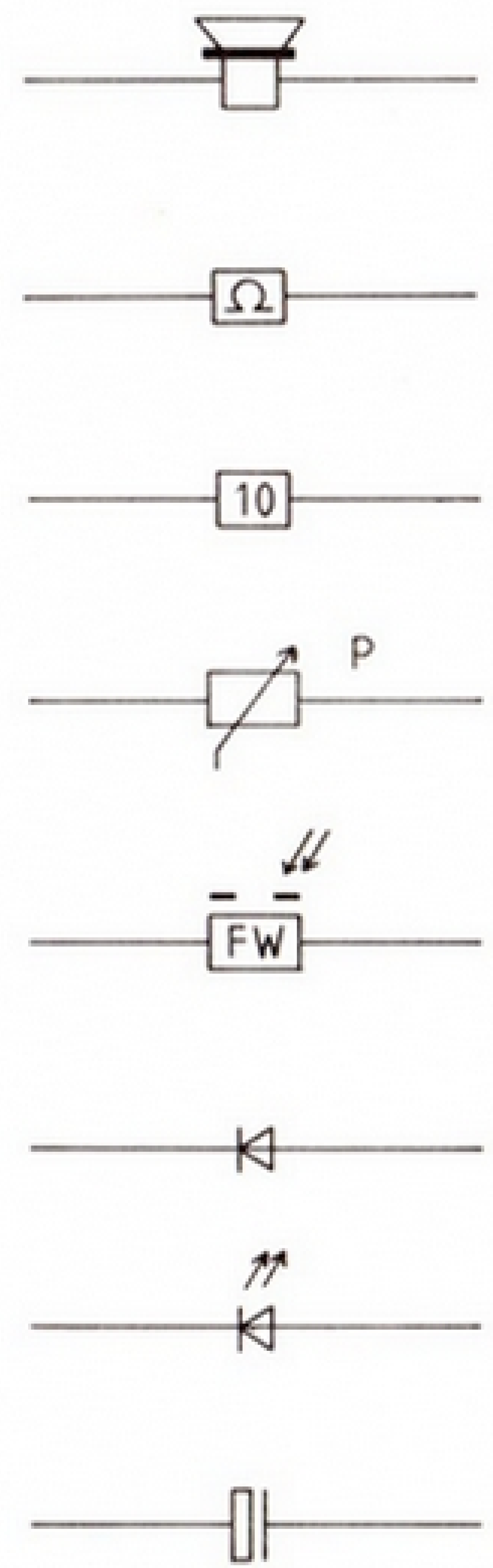
All the signs and symbols used in the circuit diagrams in this book are listed on this page. Some of the symbols do not conform exactly to the standards (DIN) which applied at the time of printing, since they have been adapted to the requirements of the reader of this book. We feel confident that electronics experts will view these changes sympathetically.



- Electrically conducting connection
- Push-fit connections
- Connection with contact pin
- Crocodile clip
- Ground or 0 volts
- Pulsating DC voltage
- AC voltage
- Permanent magnet
- Electromagnet



- Make switch
- Break switch
- Make/break switch
- Two-way switch with zero position
- PW Pole-reversing switch
- Reed contact
- Spherical lamp
- Lens lamp
- DC motor



- Loudspeaker
- 100 Ω resistor
- 10 kΩ resistor
- Potentiometer
- FW Photoconductor with stray light shield
- Diode
- Light-emitting diode
- Electrolytic condenser

Page 91

Sources of trouble

Nothing happens because...

- NG is not plugged into the mains socket;
- NG is not switched on;
- the polarity of the supply voltage is reversed.

Poor contact due to loose...

- crimp sleeves (squeeze together slightly with fine pliers);
- plug (bend out a little with knife);
- contact pin connections.

Other sources of trouble

- Unintentional contact of uninsulated connecting wires with other uninsulated wires, contact pin connections, loose touchcontact leads or the crocodile clip.
- Omission of connecting leads between the (+) and (–) bars of the components.
- Omission of potentiometer or emitter bridging lead(!)
- Wrong resistance values inserted.
- Components wrongly connected.
- Diodes connected with wrong polarity!
- Confusion of ground, Br and (+) pins on the SWS-component (a common occurrence).
- Load connected to wrong C or E pin of a LST.
- Prohibited coupling of (5 V) and NG source; e.g. by connection of motor to C_1 in circuit 9–30 or by omission of diode in circuit 2–63!

Spook effects

See page 61!

Lead check

In tone generator circuits spook effects are generally caused by defective leads. We can take advantage of this fact for testing leads. In order to increase the effect, the condenser-47 should be connected to the (–) bar of the SPV shown in blue in diagram 1–91.

- ■ Connect lead under test between the (–) bars of the SPV and SWS-component. Connect leads with plugs to the crimp sleeve of the condenser with the crocodile clip.
- ■ First we move the other connecting leads about a little. If the constant tone is interrupted, the lead is defective and must be replaced with a new one.
- ■ Only then do we move the lead under test to and fro:
- Small variations in tone: Lead O.K.
- Larger variations in tone: Squeeze together the clips of the crimp sleeve over the lead; in case of plugs tighten screws.
- Squeaking, crackling: It is best to fit new crimp sleeves on the lead or to reconnect the plug.

Page 92

Circuit and testing of the electronic building components

On the following pages the mode of operation of the electronic components is described, insofar as this has not already been done. No explanation is given of the inner circuitry of the IC-components, some of which are highly complex. The function of each electronic module has been tested several times at the factory. The quick tests described here enable any user to check for himself whether a module is still working correctly. Within the guarantee period defective modules can be sent for repair or replacement to:

fischer-werke GmbH – ft-Service-Abt. – 7244 Waldachtal

SPV-component

Circuit

The operation of the protective and rectifier diode shown in red in diagram 1–92 has been discussed on pages 23 to 25.

The large electrolytic condenser 1000 connected between the (+) and (–) poles of the applied supply voltage is used to "smooth" the pulsating NG voltage. It fills the "gaps" between two peaks (see page 7) roughly as described for circuit 2–69.

The resulting almost pure DC voltage is fed to the "voltage regulator UA 7805" which converts it into a completely pure DC voltage of exactly 5 V. It is taken from the (+) and (–) bars to supply the modules that follow.

The "little egg" on the SPV-component is a "tantalum condenser" – shown as an electrolytic condenser-4.7 in diagram 1–92. This is essential for the smooth operation of the voltage regulator.

By the way: In circuit 7–30 we can also "smooth" the pulsating NG voltage with our condenser-470. The vehicle then travels faster.

- ■ If we do this it is essential to connect the condenser with the correct polarity between the (+) and (–) bars of the LST-component – otherwise it will be damaged, or even destroyed in the case of prolonged operation. It then has a slippery feel.

Quick test

- ■ Connect the loudspeaker and lens lamp (diagram 6–8) to the output of the SPV:

  The building component is O.K. if the lamp lights up brightly and no sound of any kind can be heard after the switching-on click.

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LST-component

Circuit

The part of the circuit which is not accessible from the outside is enclosed in a blue box in diagram 2–93. It is the same in both LST.

With the potmeter bridging lead in place, a "shunt current" flows through the red, illuminated FW through the resistance track of the 10 kΩ potmeter from (+) to (–).

Depending on the position of the "slider" indicated with an arrowhead (third potmeter connection), more or less of this current is diverted off to supply the base with control current. The base is protected from excessive control current by the 1 kΩ series resistor (see pages 17 and 66).

The oversize symbol in the grey field represents a "Darlington transistor" in simplified form; this is all we need to know to understand the operation of the TIP 110.

- With an adequate control current the lamp lights up brightly. The CE path then acts like a lead connecting the C connection with (–); the load current can flow unhindered through the lamp.
- If on the other hand the control current is too weak, the CE path acts like a break in the line – the load current through the lamp is blocked.
- In the narrow transition range (see page 20) the CE path acts like a resistor whose value depends on the level of the control current (pages 66 to 69).

- If the LST-component is connected with the wrong polarity, the *blue* protective diode is in the conducting direction and diverts the load current past the CE path. For this reason the lamp also lights up when no control current flows (see page 15).

If the potmeter bridge lead is not in place, the Br pin belongs to the input of LST-2. A control voltage can also be applied to the base via this pin with the use of the potmeter resistor – as, for instance, in circuit 3–69.

Quick test

The TIP-100 transistors will withstand almost any abuse short of hitting them with a hammer. Only the potmeters may be damaged if treated too roughly:

■ If the potmeter is damaged, the lamp in circuit 4–22 goes out for a short time when the potmeter is slowly turned from one end of its range to the other.

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SWS-component

Circuit

The "little black thing" beside the potmeter is a transistor. In contrast to the TIP 110 it has to handle very little power – it acts only as a link between the outside world and the IC-7414. For this reason only its base connection can be reached from the outside via the 1 kΩ protective resistor. (The internal part of the circuit is enclosed in a blue box in diagram 3–94.)

In contrast to the LST-component, the lower potmeter connections of *both* SWS are accessible from the outside. This is essential for the wide range of control functions it must fulfil. Despite their different connections, the operation of the SWS potmeters is quite similar to that of the LST potmeters.

To enable the transistor BC 238 C to act as a "control element", a "load resistor" of 470 Ω is connected between (+) and the collector.

The IC-7414 consists of six very complex circuits which are independent of each other and are known as "Schmitt triggers" after their inventor. Each SWS contains three triggers – shown in diagram 3–94 as half-moons with an S inside them. The heavy black spot means: This circuit has the property of reversing or "inverting" a "state". It is therefore known as an "inverter".

- In diagram 3–94 the CE path of the transistor acts like a simple connecting wire as a result of FW being illuminated.

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The input of the inverter 1 is therefore connected with (–); this state is inverted inside it so that its output connected with the Q pins acts like (+). This we already know.

- The same also applies to the following inverters 2 and 3: They make the (+) at the input into a (–) at the output. The LED through which current flows via the protective resistor therefore lights up and indicates "Q now acting as (+)".
- On the other hand the output of the inverter 2, which is connected to $\overline{Q}$, acts like (–).

A typical feature of trigger circuits is their instantaneous flipping over even if the input state is altered only very slowly, as for instance in the daylight switch 2–31. Therefore in the SWS there is (hardly) any transitional zone like that of the LST.

The two threshold values (the curious among you have already learnt about these on page 55) at which the trigger flips one way or the other are fixed by the IC-circuit and cannot be altered.

But how and when they are reached depends on the way in which the transistor is controlled.

Quick test

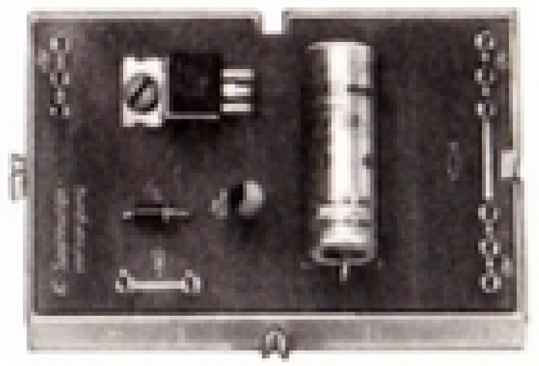
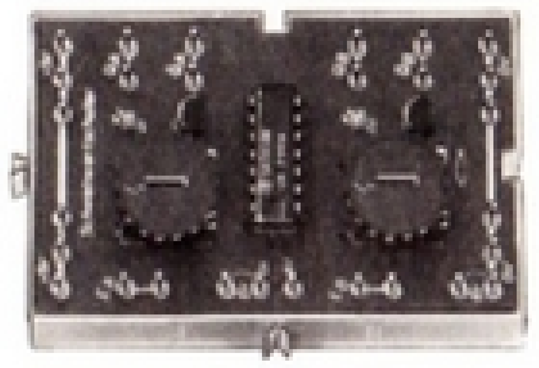
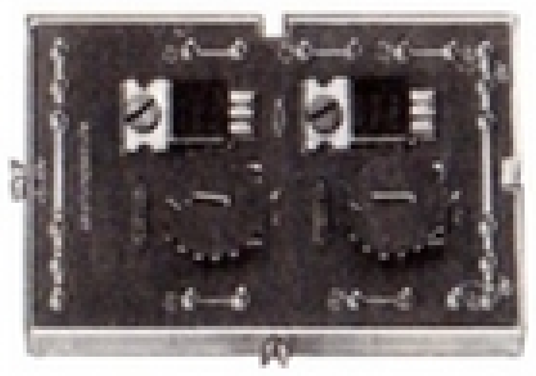
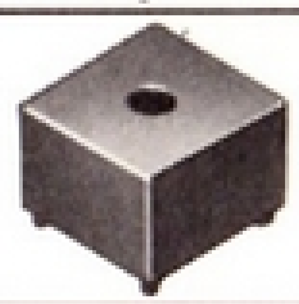
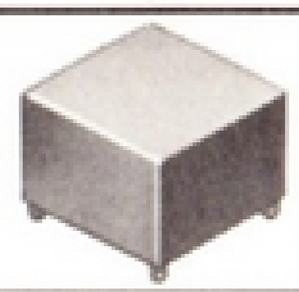
■ The SWS-component is O.K. if in the circuit 1–54, with R = 100 kΩ and with the potmeter at its right-hand limit, the lamp lights up roughly 15 times in 15 seconds, or roughly once per second.

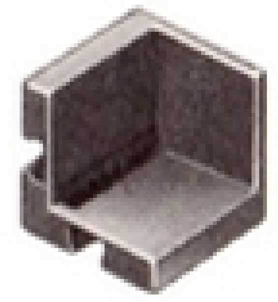
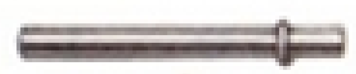
■ If the LED of a SWS does not light up when its input is connected to (+), the IC is "dud". A new IC-7414 can be obtained for a small price from a dealer in electronic components. Thanks to the convenient IC mount we can easily change it ourselves. The correct positioning of the IC is shown in fig. 2–25.

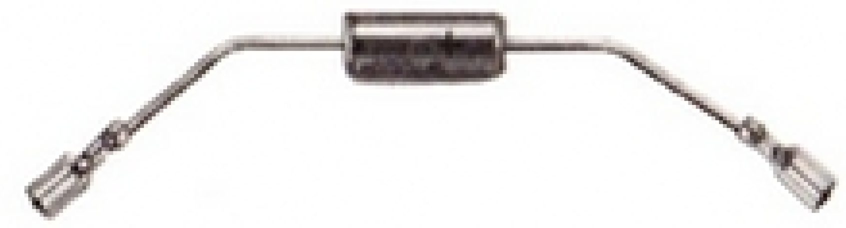
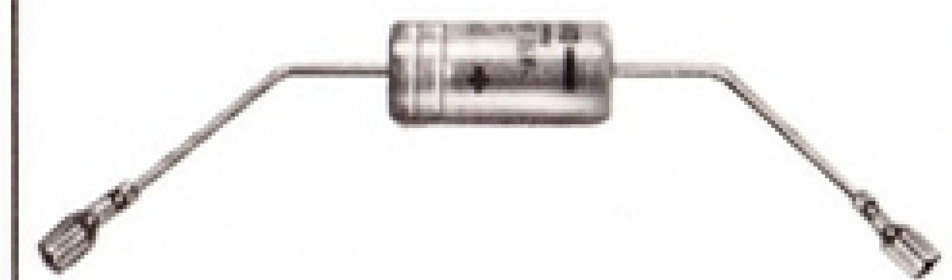
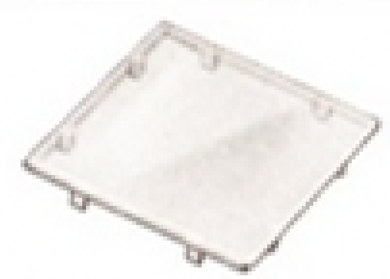
■ If an LED lights up faintly when nothing is connected to the SWS input, then the component is defective and must be returned to the Fischer factory for replacement.

The new fischertechnik Electronics is being expanded. Model and circuit books which follow on from this one are in preparation.

Electronics parts list

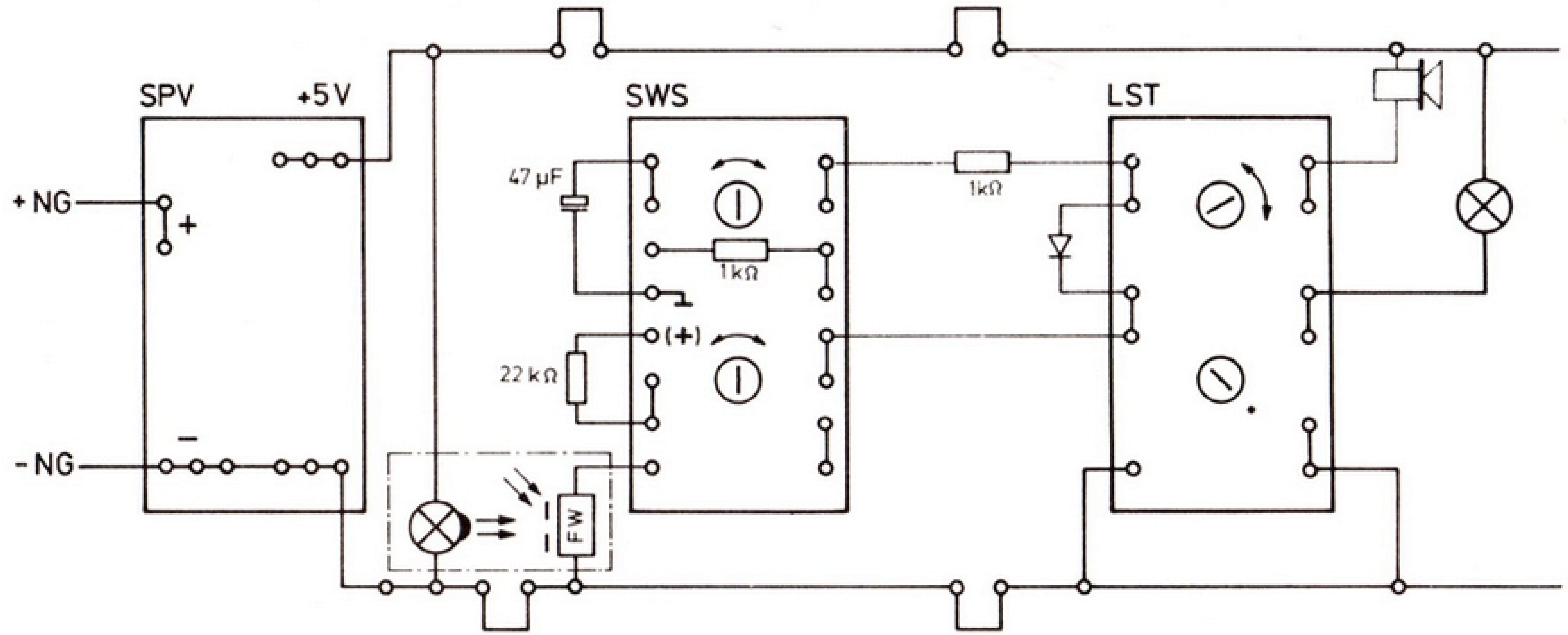
		Quantity
	**Power supply unit** (SPV)	**1**
	**Threshold switch** (SWS)	**1**
	**Output stage** (LST)	**1**
	**Loudspeaker**	**1**
	**Photoconductor cell** (FW)	**1**
	**Stray light shield** Hole dia. 1 mm Hole dia. 2.5 mm Hole dia. 4.0 mm	 **1** **1** **1**
	**Light cap for lens lamp**	**1**
	**Light cap, blue** **Light cap, white**	**1** **1**
	**Light module**	**2**

		Quantity
	**Spherical lamp**	**2**
	**Lens lamp**	**2**
	**Building block V 15 corner**	**2**
	**Building block 7.5**	**1**
	**Joining piece 15**	**1**
	**Crocodile clip**	**1**
	**Contact pin**	**8**
	**Crimp sleeve**	**3**
	**Screwdriver**	**1**
	**2-core lead, 1000 mm long with plugs**	**1**
	**Plug, red** **Plug, green**	**16** **14**

		Quantity
	**Electrolyt. condenser 47 µF**	**2**
	**Electrolyt. condenser 470 µf**	**1**
	**Diode 1N 4001**	**2**
	**Resistor** 100 Ω 1 kΩ 4,7 kΩ 10 kΩ 22 kΩ 100 kΩ	**1** **2** **1** **2** **1** **1**
	**Lead with 2 crimp sleeves** Yellow 60 mm Red 60 mm Blue 60 mm Yellow 100 mm Red 100 mm	 **4** **3** **3** **1** **1**
	**Lead with 1 crimp sleeve** Red 80 mm Blue 80 mm Red 120 mm Blue 120 mm Grey 120 mm Red 200 mm Blue 200 mm Red 300 mm Blue 300 mm	 **4** **4** **2** **2** **1** **2** **2** **2** **2**
	**Case lid**	**1**
	**Case body**	**1**

Finish indicator

with visual and acoustic signals (front cover picture)



The picture on the front cover page shows the model of a finish indicator which could be used for model car or soapbox derby racing.

■ When a contestant passes the finish, the indicator lamp lights up for a moment and a brief bleeping sound is heard.

The pitch of the sound can be varied with the potmeter P_A, and the volume with the potmeter P_1.

■ The loudspeaker is located beside the finish indicator and cannot be seen in the picture.

■ A further development of this circuit, giving a continuous signal, is described in detail on page 36.