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Key-Programmable Control Microcontrollers are everywhere: in household devices, in devices of entertainment electronics, in meters and even in unmanned space vehicles. Everywhere, they do things that a program tells them. It is very exciting to generate simple control programs yourself as well.

The first step always is choosing a microcontroller or processor that matches your desired task as precisely as possible. You can choose between a number of types from different companies. You can also choose your programming language. Assembler and C are offered most often; in many cases, so is Basic or another high language. Usually, programming requires elaborate software and a programming unit. In addition to the financial effort, the familiarization time is quite considerable.

The microcontroller used is entirely different. You can program it with only two pushbuttons. The button - programmable control (tastenprogrammierbare Steuerung; TPS) knows only relatively few commands that can be learned easily and that can be programmed into the controller with the buttons. The program can be changed at any time and without any special aids.

The system is particularly suitable for compact applications in the areas measuring, controlling and regulating. Many tasks can already be completely solved with this system. Additionally, you can install the microcontroller into circuits of your own after successfully programming it. Basic knowledge in the electronics area is required for this.

At the same time, the system is suitable for training and the first steps in microcontroller programming. Success will occur faster than in other systems. The structures are, however, very similar to other programming languages, so that the later transfer is made easier.

Table of Contents

1 Introduction

The principle of the TPS controller is simple. You have four digital inputs E1 to E4 and four digital outputs A1 to A4. There are also two analogue inputs AD1 and AD2 and a almost analogue PWM-output. A reset input with a connected reset button resets a program to the start. The controller is supplied with three AA cells with approx. 4.5 V and can work in a range of 2.2 V to 5.5 V.

Technical Data:

Microcontroller: HT46F47

Clock frequency: 2 MHz

Internal EEPROM: 128 Bytes

Power supply VCC: 2.2 V to 5.5 V

Current consumption: 1 mA at 4.5 V

4 output ports: resilient until 10 mA

1 PWM output: resilient until 10 mA

4 input ports: Quiescent condition 1

2 analogue inputs: 0 V ... VCC

2 key inputs: Quiescent condition 1

Components in the learning package:

Breadboard

Battery compartment 3 * AA

Wire

HT46F47 with TPS-firmware

3 Pushbuttons

4 LEDs 5 mm, red

1 LED 5 mm, green

1 LDR

3 disc capacitors 100 nF

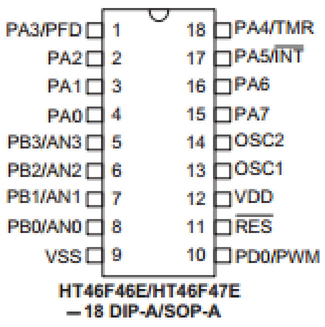
1 electrolyte capacitor 47 µF

5 resistors 2.2 kO

1 resistor 10 kO

1 resistor 27 kO

2 resistors 100 kO



For programming, you need the two buttons S1 and S2 and a simple LED display of four LEDs at the outputs A1 to A4. There is a total of 14 simple commands with associated data or subcommands. Commands and data are each encoded as 4-bit binary numbers from 0000 to 1111 (decimal 0 to 15) and are directly visible at the display LEDs. The respective number is programmed to S1 by pushing buttons when programming. S2 switches between command and data and increases the address in the command line. The entire program structure is so simple that you will know it by heart with a little practice.

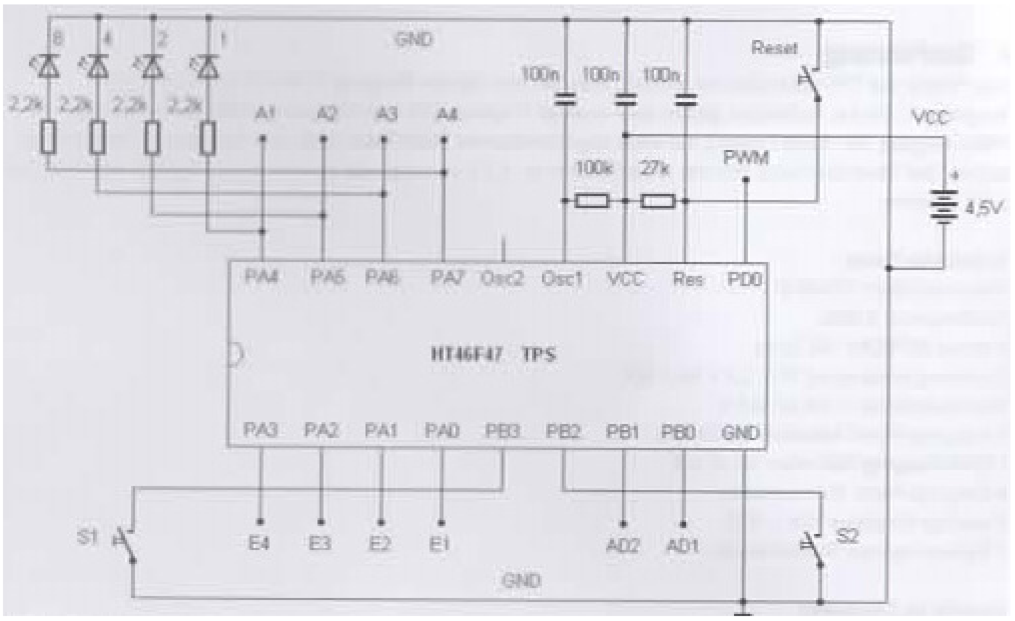


Fig. 1: Basic circuit of the system

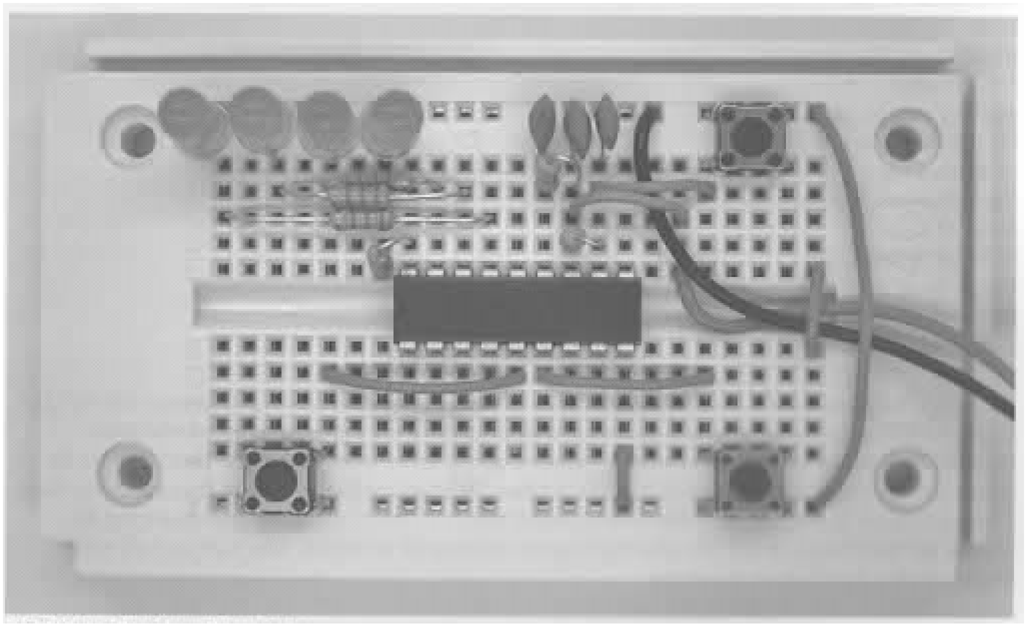


Fig. 2: Standard setup with pushbuttons

Some basic programs are already present in the delivery condition of the TPS-controller (default) and can be started directly. Therefore, it is possible to take the controller into operation step by step. First, familiarize yourself with the hardware functions and start your own programs only after this.

In the first test, you will start small programs that are already finished in the controller. The associated program lists provide an initial impression of the options. They are only briefly explained. The precise explanation of the individual commands follows in the next chapter.

For the first test, set up only the basic configuration with the controller and the required additional elements on the Breadboard. You need:

• Connection of the voltage supply at GND (minus) and VCC (plus)

• A blocking capacitor 100 nF between VCC and GND

• Reset resistor downstream of VCC and reset capacitor downstream of GND

• Oscillator resistor 100 kO downstream of VCC and capacitor downstream of GND

The microcontroller HT46F47 is operated with its internal RC-oscillator. The resistor at the Osc1 input specifies the cycle frequency. 100 kO sets a frequency of approx. 2 MHz. On demand, you can work with lower or faster speeds. The connected capacitor serves only to block and has no influence on the cycle frequency. The connection Osc2 remains free. On demand, you can connect an additional resistor against VCC here and disconnect impulses with a quarter of the cycle frequency.

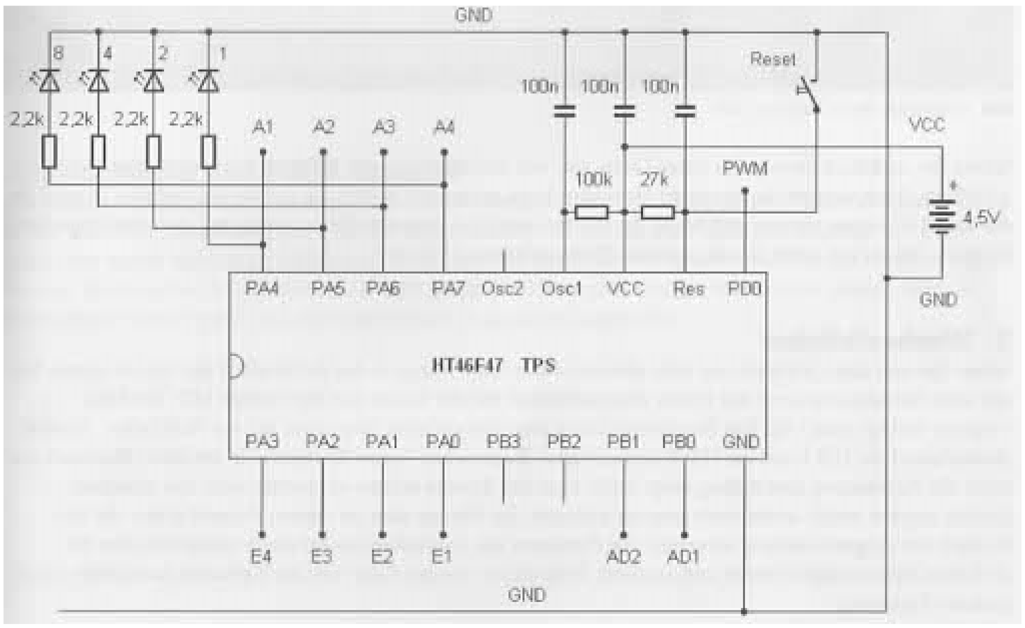


Fig. 3: For LEDs at the outputs

Use the upper and lower supply rails on the Breadboard as ground connection GND. Here, the black cable of the battery compartment, i.e. the minus pole, is connected. The plus line VCC is connected to the red connection cable of the battery compartment. Wrong polarity must be avoided

under all circumstances, since it may destroy the controller. Install a brief wire piece as tension relief. Once the voltage connection has been established, it should remain connected continually if possible. To deactivate it, take one of the batteries from the compartment.

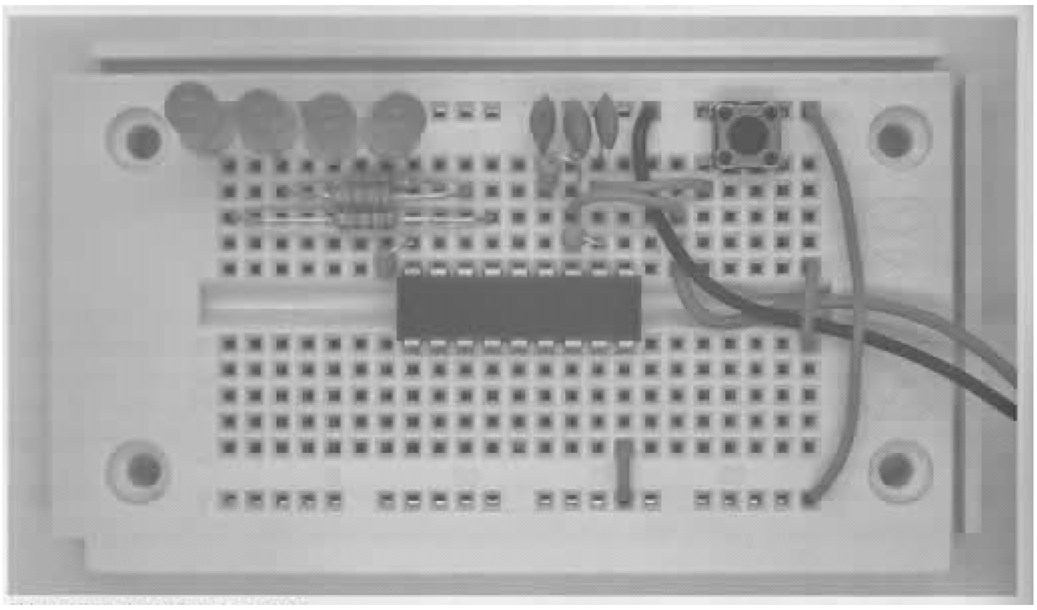


Fig. 4: Minimum application with LEDs

Already use the reset button additionally and connect four LEDs to dropping resistors of 2.2 kO. They are needed for the first hardware tests. Observe the order. A1 is connected to the left LED and A4 to the right one. The binary display with the highest-value bit is on the left. This is helpful particularly during later programming.

2 Alternating Flash

Now insert three 1.5-V batteries or alternatively three NiMh rechargeable batteries into the battery compartment. This starts the first example program with an alternating flash with the left and right LED. the flashing frequency is approx. 1 Hz. The program listing shows the simple program with only five lines. Alternating, LED 1 and LED 8 are switched on. Between them there are waiting commands with a waiting time of 0.5 s. Jumping back to the beginning ensures that flashing is continued forever. The individual commands are explained in more detail below. You can see how simple the programming is by this example. The firmware of the controller has an interpreter that recognizes and executes the simple commands. Programs therefore are much more compact than in other systems.

The example occupies the address range from 20h onwards (decimal 32). Several programs in the upper address range can be started later from dedicated applications. The addresses can also be overwritten with your own program code. On demand, the controller can also be reset to the basic condition, which resets the original example program.

Address	command	Data	Comment
20	1	1	LED1
21	2	8	Wait for 500 ms
22	1	8	LED8
23	2	8	Wait for 500 ms
24	3	4	Jump -4

Listing 1: Alternating flash

If the desired result does not occur, check proper polarity of the LEDs first. It is also helpful to measure some voltages. Always use, e.g., a digital multimeter in the 20 V range and leave the minus connection at GND. All voltages are thus measured against GND:

VCC: 4.5 V

Reset: 4.5 V

Osc1: 1.5 V

E1 to E4: 4.5 V

A1: Alternating

A2, A3: 0V

A3: Alternating

3 Binary counter and PWM Output

All digital inputs are pulled up with an internal resistor against VCC (pull-up resistor) and have a quiescent voltage at the amount of the operating voltage. However, you can put each of the inputs to GND with a wire or contact. When starting, the default program reads the port condition and evaluates it. Individual connections can be put on GND so that a zero condition is read here. Depending on the result, different programs are called.

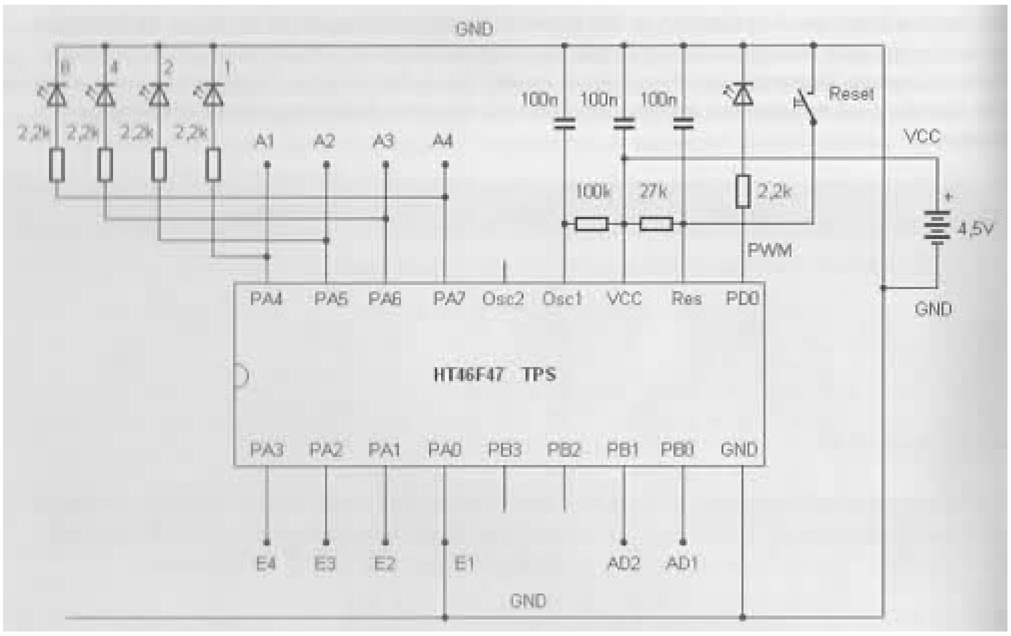


Fig. 5: Use of the PWM-LED

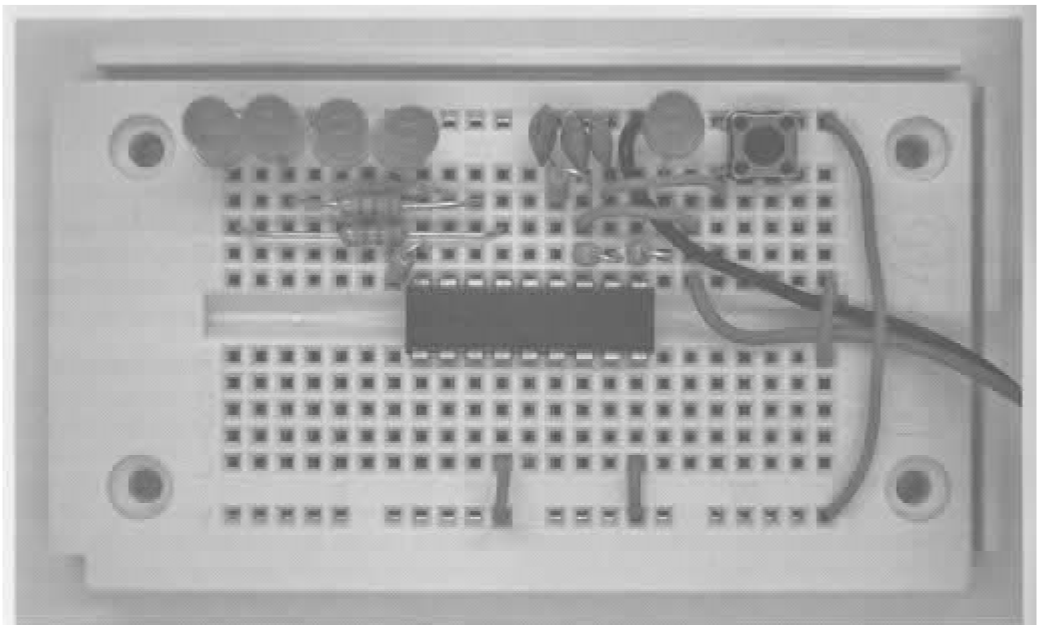


Fig. 6: Starting the binary counter

Apply E1 to GND. This starts the second example program after a reset. It counts up the output conditions binary. The conditions 0000 (decimal 0) to 1111 (decimal 15) are continually gone through. The program uses variable A for a simple addition and for output to the digital outputs as well as the PWM-output. Commands 7 and 5 have sub functions that are written as data.

Address	command	Data	Comment
25	7	1	A=A+1
26	5	4	Port = A
27	5	9	PWM = A
28	2	6	Wait for 100 ms
29	3	4	Jump -4

Listing 2: Binary counter with LEWD and PWM output

The counting program can be used as a practice program for reading binary counters that you must master for your own programming. Each of the four LEDs represents one bit. All in all, a 4-bit number can therefore be displayed. The LEDs are called 8, 4, 2 and 1 according to their value in the circuit diagram. Addition of the respective values results in the decimal figure. Written hexadecimal, the numbers 10 to 15 are represented by capital letters A to F.

Value				Decimal	Hex
8	4	2	1		
0	0	0	0	0	0
0	0	0	1	1	1
0	0	1	0	2	2
0	0	1	1	3	3
0	1	0	0	4	4
0	1	0	1	5	5
0	1	1	0	6	6
0	1	1	1	7	7
1	0	0	0	8	8
1	0	0	1	9	9
1	0	1	0	10	A
1	0	1	1	11	B
1	1	0	0	12	C
1	1	0	1	13	D
1	1	1	0	14	E
1	1	1	1	15	F

The program can be used as a flashing encoder for different frequencies as well.

The next-higher output has half the frequency or twice the period duration each:

A1: 200 ms

A2: 400 ms

A3: 800 ms

A4: 1,600 ms

Additionally, the rising numerical values are also output to the PWM output (pulse width modulation) . The PWM signal is a rectangular signal with a frequency of approx. 16 kHz. The pulse length is controlled so that the pulse-pause ratio determines the average activation duration and thus the brightness of the LED. The brightness of the connected LED is controlled in 15 levels between zero and full brightness.

A PWM signal can be smoothed to a direct voltage with an RC low-pass filter. The PWM-output thus becomes an analogue output. With this program, you will receive a direct voltage that increases gradually from 0 V to 4.5 V. Track the voltage progress with a meter or an oscilloscope.

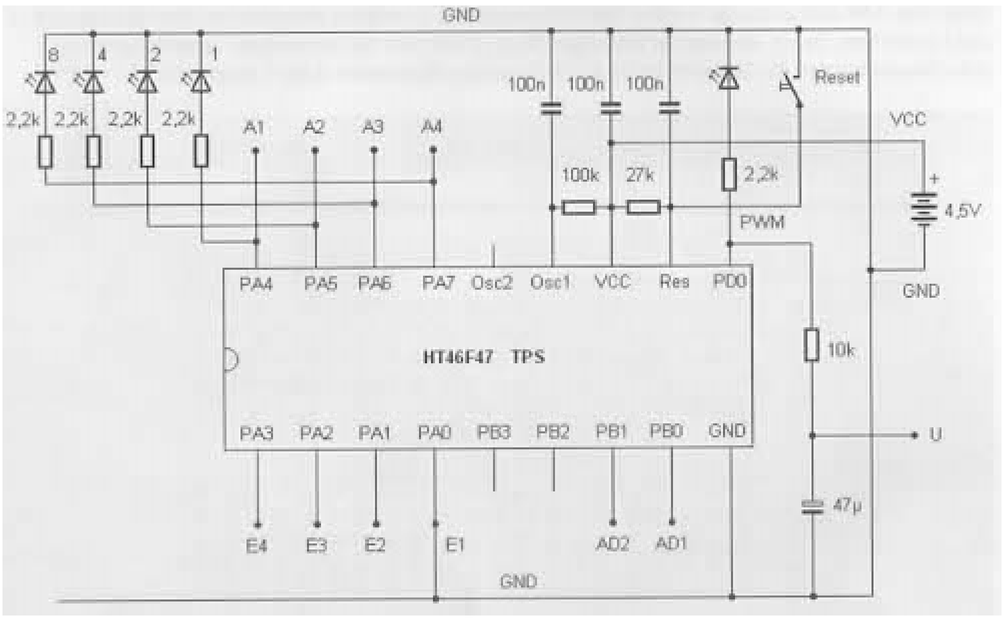


Fig. 7: Low-pass filter at the PWM output

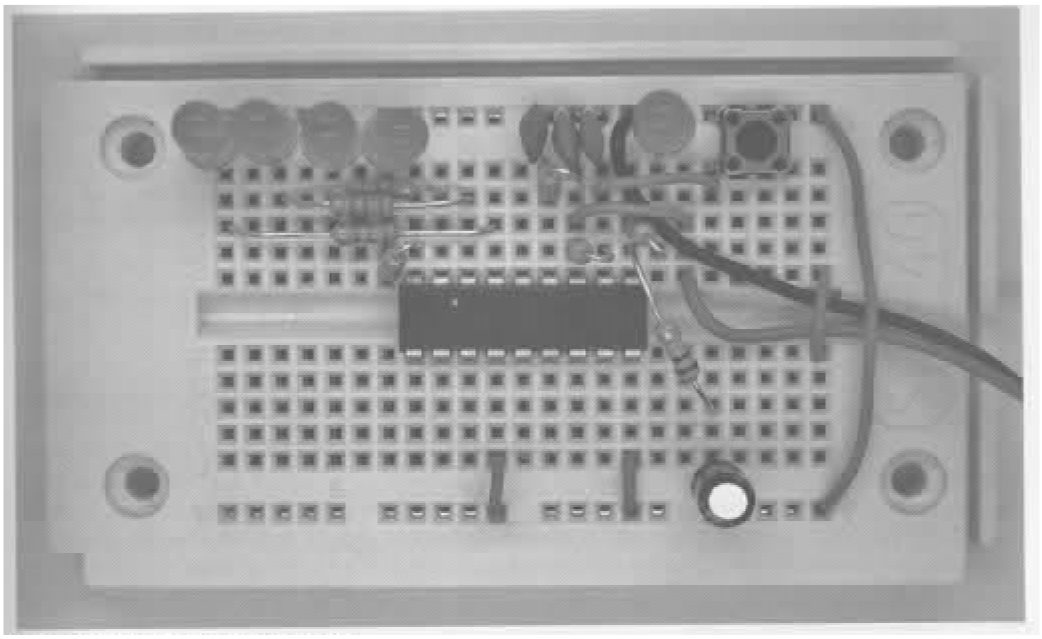


Fig. 8: Smoothed PWM output voltage

4 Analogue-Digital Converter

A connection E2 to GND and pushing the reset button will start a small example program for the analogue-digital converter (AD-converter). The analogue voltage at the analogue input AD1 is measured and converted to a digital numeric value. Because the TPS controller works with 4bit values continually, the result of the analogue-digital conversion is a number from 0 to 15. The result 0 represents the input voltage 0, the result 15 for a voltage that corresponds to the operating voltage, i.e. e.g. 4.5 V. The AD-value is output as a binary number at the four LEDs and additionally handed over to the PWM-output. Connect a voltage divider from a fixed resistor and a light-dependent sensor resistor (LDR) to the analogue input AD1.

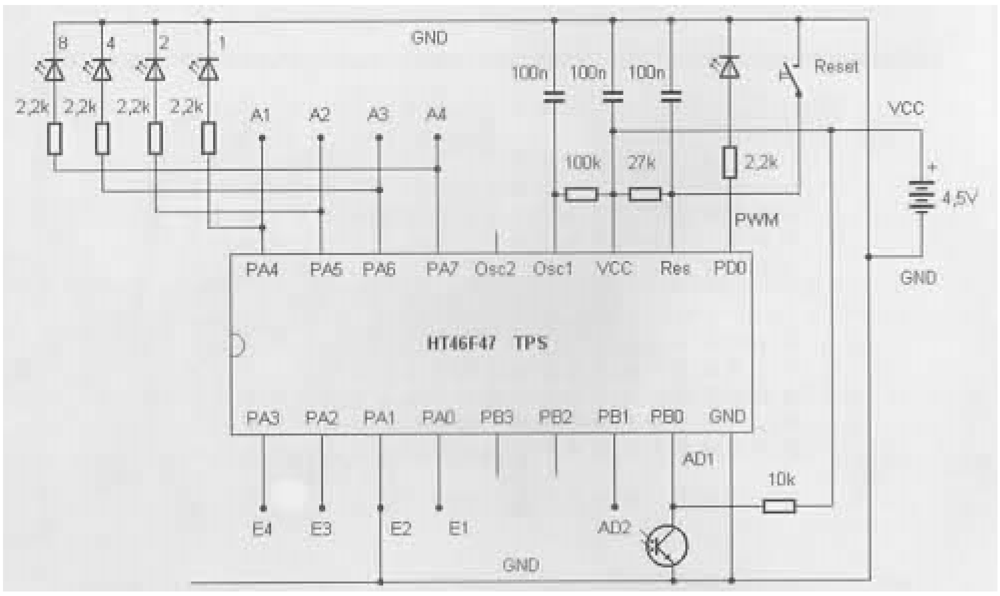


Fig. 9: Connection of the light sensor

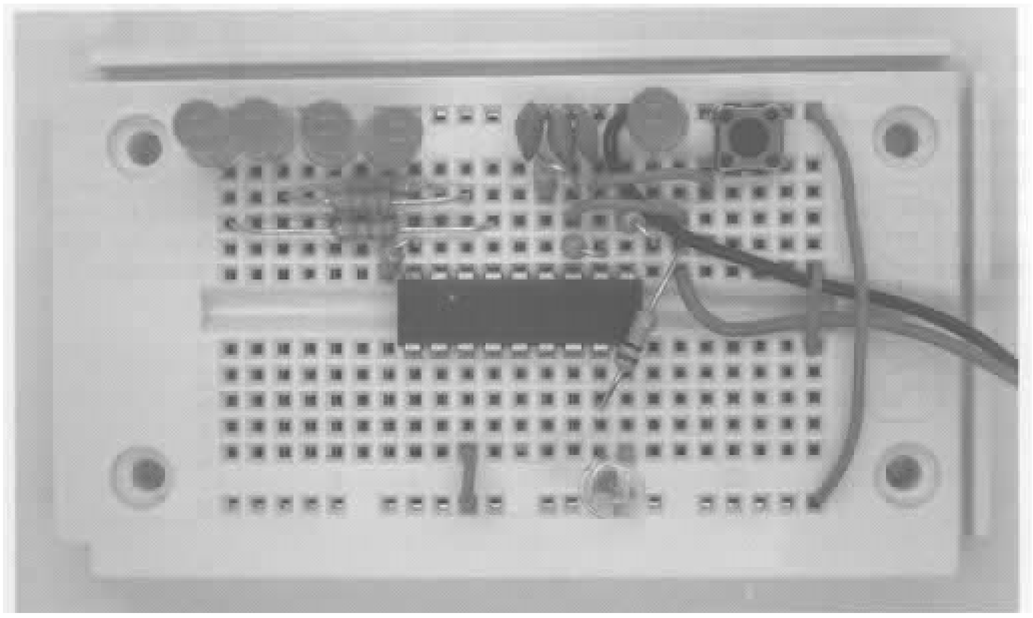


Fig. 10: The LDR at the AD1-input

The example program is very similar to the program from the last section because of the output to the digital outputs and the PWM-output. The first line has the command to convert an analogue value, however.

Address	command	Data	Comment
2A	6	9	A=AD1
2B	5	4	Port = A
2C	5	9	PWM = A
2D	2	6	Wait for 100 ms
2E	3	4	Jump -4

Listing 3: AD converter and PWM output

Test the program with different sensor light exposure. The more light on the LDR, the lower the voltage at AD1. Vice versa, darkness leads to maximum AD-values and thus maximum brightness of the LED at the PWM output. Read the binary lines from the LED display and try to adjust the brightness, e.g. to precisely half the range. The digital value then is at 0111 or 1000. Flickering artificial lighting may cause the result to switch between two levels.

5 Random Generator

Use a jumper E3 against GND to start a basic program for random generator. The button S1 is evaluated here. The associated input has an internal pull-up resistor that pulls the voltage to VCC-level. The button is connected against ground. Pushing the button pulls the input S1 to zero.

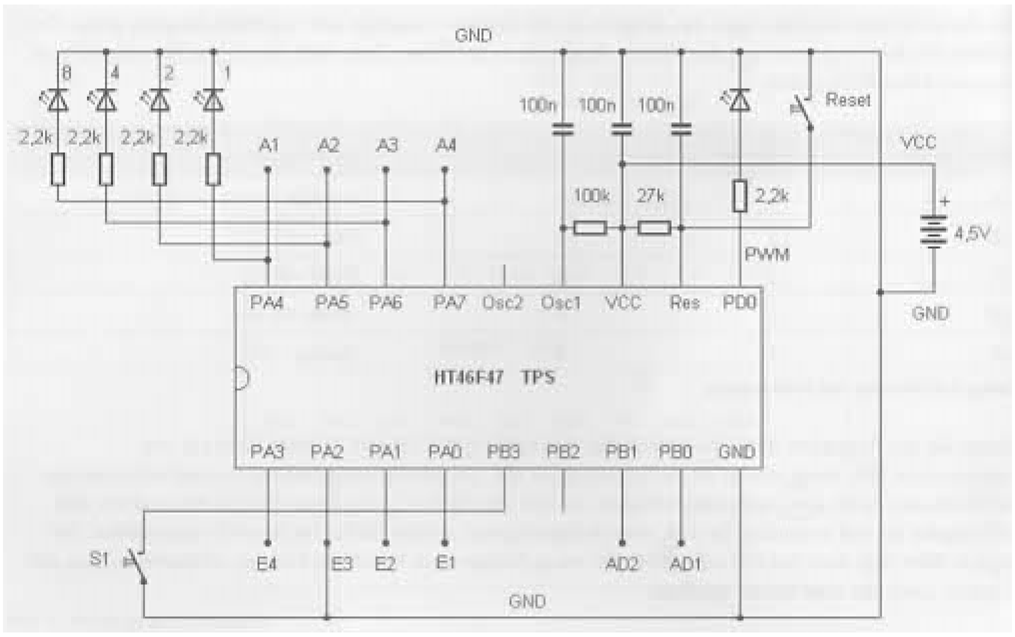


Fig. 11: Start of the random switch

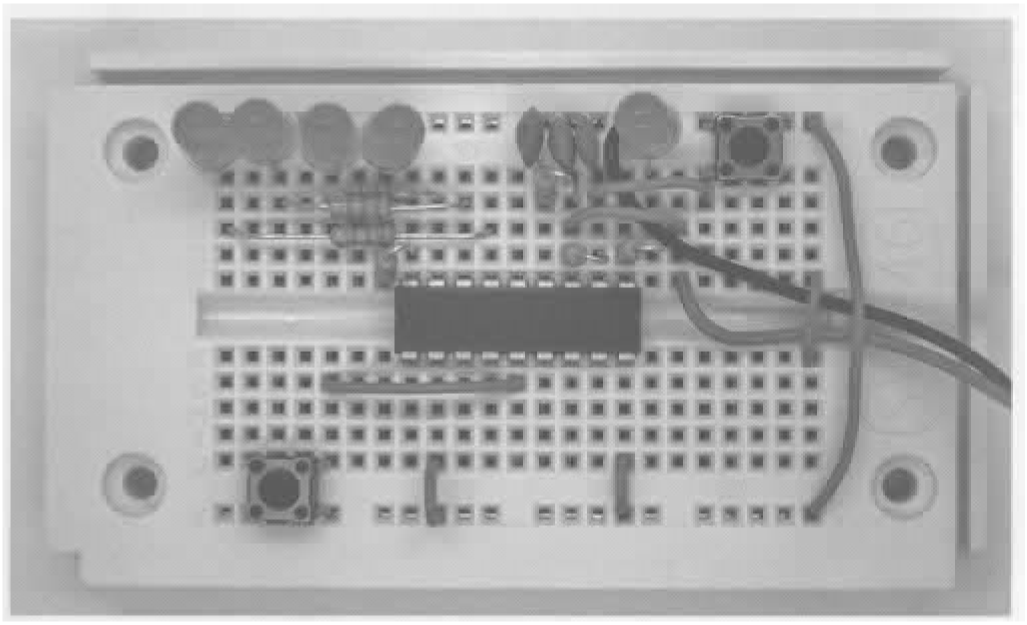


Fig. 12: Jumper between E3 and GND

The program uses a conditional jump command. When the S1 input condition is one, the following command is skipped. Pushing the button makes the condition zero, and thus increases the variable A. This leads to quick counting up of the starting condition. When releasing, the last counter reading is retained. Due to the high counting speed, you have no influence on the result, which therefore is random.

Address	Command	Data	Comment
30	5	4	Port = A
31	C	E	S1 = 1?
32	7	1	A = A + 1
33	3	3	Jump –3

Listing 4: Random generator

Briefly push the button to reactivate a new random result. Test the random function by generating a statistic of the results. After a sufficient number of runs, it should be clear that all results are about equally frequent. The program is also suitable as a game where you need to try to get, e.g., 1111.

At the same time, the program is a counter with the maximum possible working speed because no waiting command is used. Therefore, you can use this example to examine the working speed of the TPS controller. While the button is pushed, the output A1 shows a rectangular signal with a frequency of approx. 133 Hz and a period duration of 7.5 ms. The port changes its condition after 3.75 ms each. The program goes through four commands in the counting loop. About one millisecond is required per command. The last output A4 shows a frequency of 16.6 Hz, which is still visible as a flicker.

If time-critical tasks require higher working speeds, you can increase the cycle speed of the controller by reducing the resistance at Osc1. 100 kO provides a cycle rate of 2 MHz. Replace the resistor with a 27 kO one. This will lead to an almost four times higher cycle rate and a command time of approx. 0.25 ms. In the usual case, however, the controller should run at 100 kO at Osc1. Thus, a low current intake and safe work are also ensured at a low operating voltage down to 2.2 V.

6 Impulse Length Measurement

E4 at GND starts an example program to measure an impulse length after a reset. Again, the condition at the input S1 is evaluated.

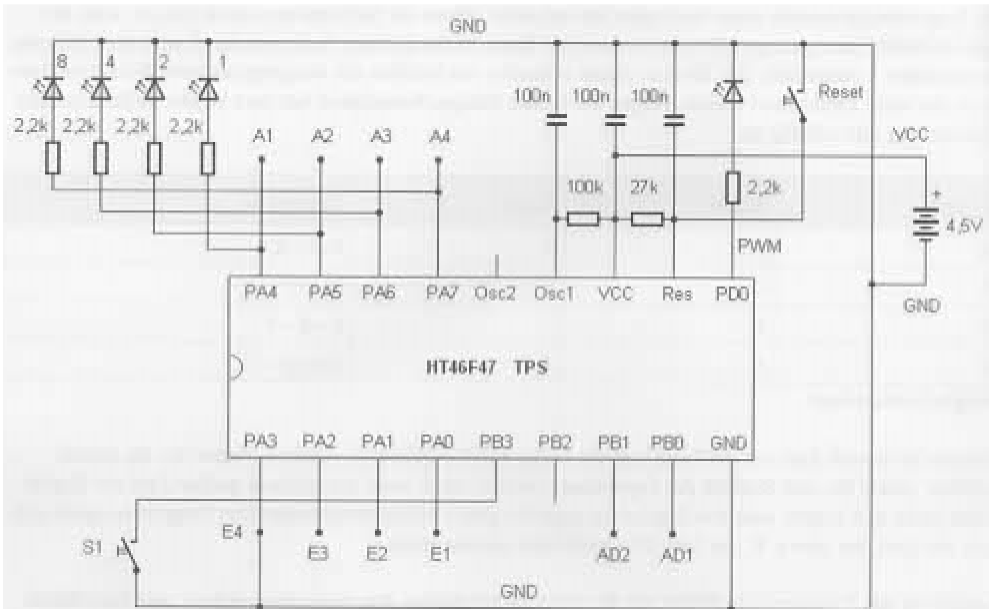


Fig. 13: E4 at GND

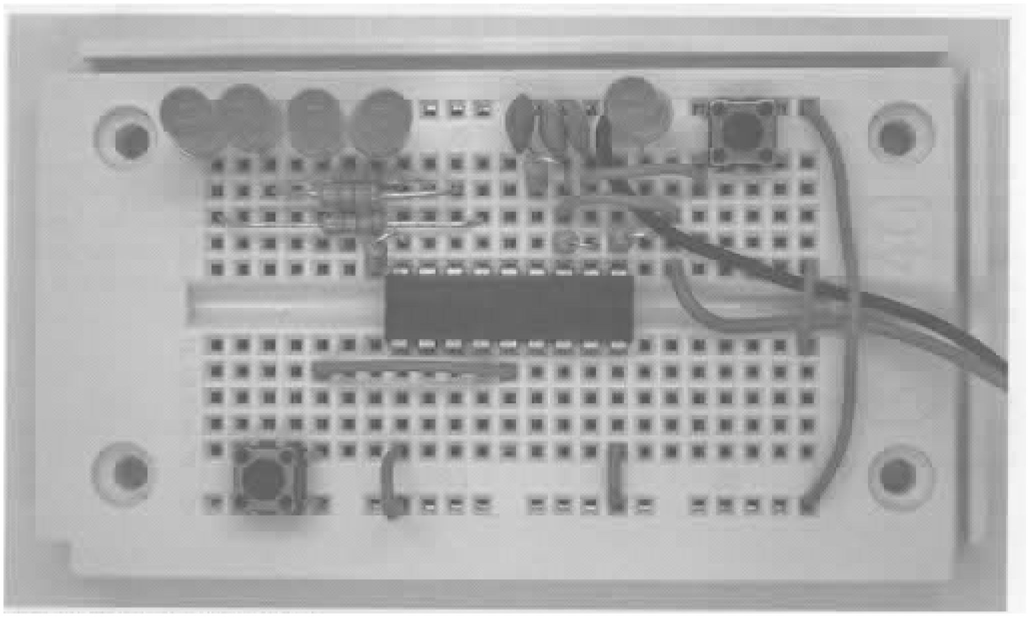


Fig. 14: Start of impulse length measurement

A time measurement runs in condition S1 = 0, i.e. with the button pushed. Another approx. 5 ms are added to the waiting time of 5 ms for execution of a total of five commands in the counting loop. Therefore, the time unit of the measurement is 10 ms.

Address	command	Data	Comment
34	2	2	Wait for 5 ms
35	C	C	Skip if S1 = 0
36	3	2	Jmp -2
37	4	0	A = 0
38	2	2	Wait for 5 ms
39	7	1	A = A + 1
3A	5	4	Port = A
3B	C	E	Skip if S1 = 1
3C	3	4	Jmp -4
3D	3	9	Jmp -9

Listing 5: Time measurement

Push the button S1 as briefly as possible. You will receive, e.g. the result 1010, i.e. decimal 10. Since the time unit of the program is 10 ms, the display means 100 ms. With a little training, you can reach short times down to 50 ms.

7 Reading Programs

For programming, you need the buttons S1 (data input, left) and S2 (programming, right). The reset button is required as well. These buttons alone can be used to read programs and enter any programs. With a little practice, you can enter new programs very quickly and modify present ones.

To enter programming mode, perform a reset with the programming button S2 pushed, and release S2 only about half a second after the reset. Now you can use the button S2 to scroll through the present program and view the commands and data. Each address requires two button pushes at S2 for this. This switches between display of the command and the data. The current address is also briefly displayed.

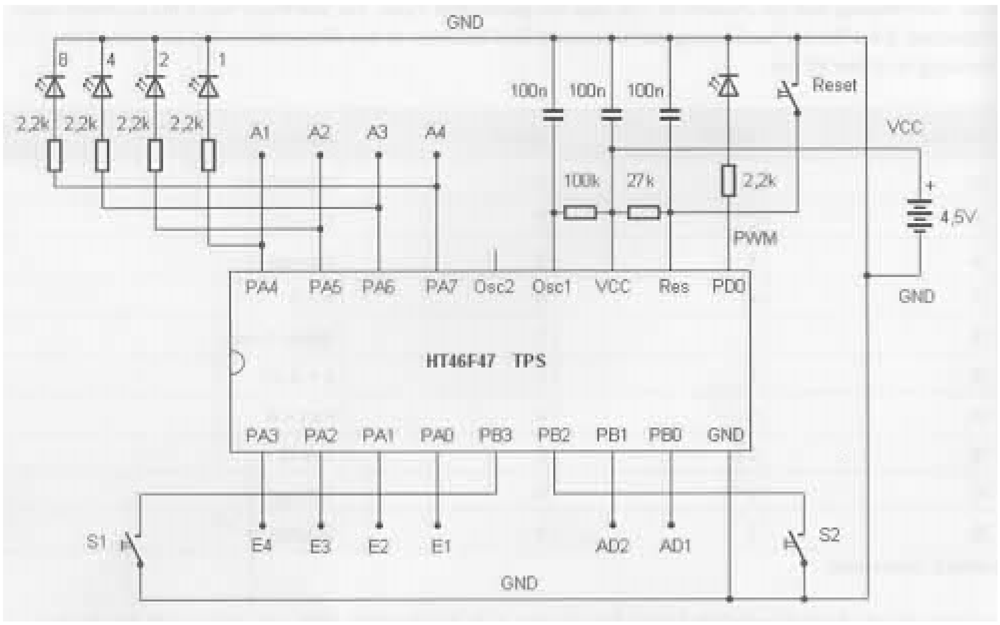


Fig. 15: S1 and S2 for programming mode

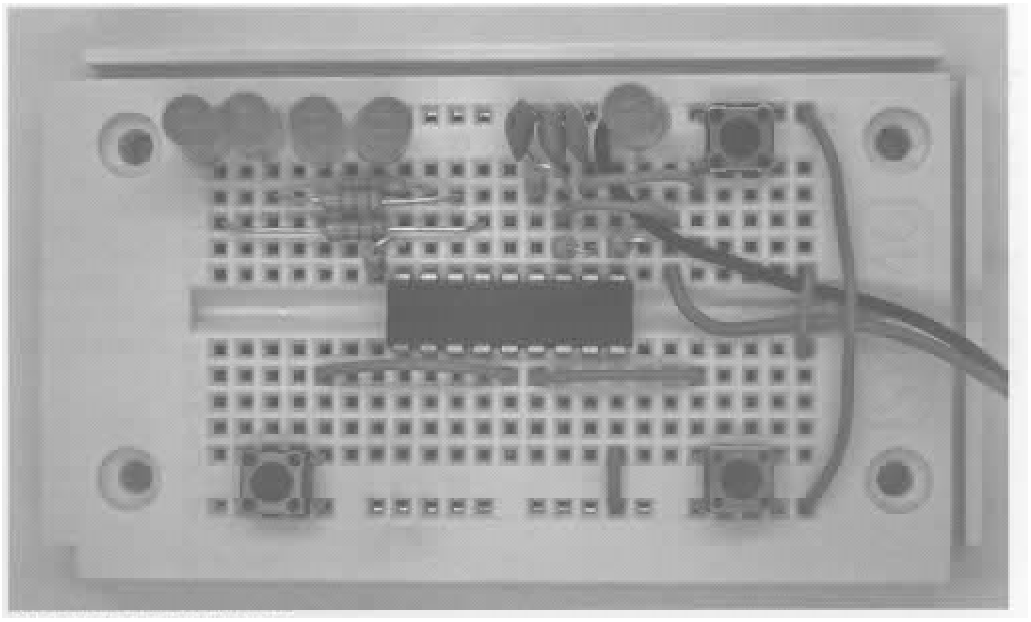


Fig. 16: Three buttons and LED displays

• First push of a button S2

• Display address (lower four bits), 300 ms

• Display off, 300 ms

• Show command

• Second push of button S2

• Show data

• Third push of button S2

• Display next address, 300 ms

• etc.

If you want to view only a present program with five steps, for example, without changing it, a total of ten pushes of S2 takes you to the end. Because the current address is displayed briefly, orientation is easy. You will always know if the display is currently showing a command or data. In the delivery condition, the following commands are found in the first five addresses. This is the start of the selection programme to start the individual example programs.

Address	command	Data	Comment
0	6	4	A = Din
1	5	1	B = A
2	4	E	a = 14
3	B	0	Addr Hi = 0
4	C	3	Skip if A = B

Listing 6: Program code in the basic condition

A 4-bit command and the associated 4-bit data together form one byte, i.e. an 8-bit number. A half byte is also called a "Nibble". The higher-value nibble forms the command, the lower-value nibble the associated data. The EEPROM of the controller includes a total of 128 bytes. Therefore, a program can hold up to 128 commands. This is enough for most applications, since the program code is extremely compact. Many useful programs can get by with fewer than ten commands.

Display the individual commands and data and compare the content of the memory. Then push the reset button again. The old program will start unchanged.

8 Entering Programs

The button S1 is used only if a command or its data are to be changed or entered anew. Generally, only numbers between 0 and 15 can be entered. With the first push of S1, 0 is set. Every following push of a button increases the number by 1. The current status is displayed binarily with the four LEDs. If you want to enter 4, push S1 five times: 0, 1, 2, 3, 4. The binary display then is 0100.

Once you have entered either the command, the data or both in this manner, the second push of S2 programs this byte into the EEPROM. To clarify this, the LED display for 600 ms is switched off before the next address and the next command is displayed. This brief pause is to be intuitively understood as programming. You can imagine that the system saves energy for

display and uses it for programming the EEPROM. You know this from the car: When you activate the starter, the light and radio will go out for a brief moment.

You can change the already-present program in a single location as well. Use S2 to scroll to the desired location and change the command or data with S1, to save them with S2.

For the first part, a program with only two commands is entered. It switches on three LEDs and leads into an endless loop.

Address	command	Data	Comment
0	1	7	A1 - 4 = 0111
1	3	0	Jmp 0

Listing 7: Switching on LEDs

Instead of a detailed listing, you can choose an abbreviated form as well. The two bytes are summarized in hex numbers: 17h, 30h. Below, the hexadecimal way of writing is used. The programs are therefore written in the short version without the hex mark: 17 30

You need to type the following for input:

S2 + Reset

2 x S1

S2

8 x S1

S2

4 x S1

S2

1 x S1

S2

If you have pushed the button S1 once too often by accident, you can still reach the right number. Go to above 15, which is followed by the value 0.

After complete input, the new program is started again with the reset button. You can see that three LEDs are connected. Nothing else happens. The controller will no longer react to the conditions at the inputs E1 to E4 anymore, since the original program has been partially overwritten. The example program cannot be started anymore either.

Since you have only changed the first two memory addresses, you can easily start the original program again. For this, just enter the first two commands (64 51) anew according to the listing from the last section.

Test the original function of the example programs. Best enter the new exercise program again. You will quickly gain security in handling the program input.

9 Recovery of the Example Programs

If you want to restore the controller's original condition after some time, this can be done by entering two bytes FF. In fact, this corresponds to the condition of the unwritten EEPROM. The firmware of the TPS controller contains a start function that initially reviews the first two addresses to recognize an empty memory. If two FF-bytes are read here, the controller assumes that no program has been entered yet. In this case, the EEPROM is automatically filled with the example software. This function actually serves to apply the controller with the example program in the EEPROM at the first start. However, it can be used at any time to restore factory settings.

Address	command	Data	Comment
0	F	F	
1	F	F	

Listing 8: Return to the factory condition

Start programming mode by resetting with the S2 button pushed. Enter the value F (decimal 15) four times then, where all LEDs A1 to A4 are on. Complete the last input with S2 as well.

Then push reset.

The controller needs just a moment longer than usual to reprogram all bytes from the example programs. This restores the original condition. Test, e.g., the alternating flash from page 8 without the jumper at the inputs.

10 TPS Basic Commands

The key-programmable control knows a total of 14 commands (1–14). Many of these commands have a parameter in the form of a 4-bit number 0000 to 1111 (0–F), i.e. with a number range to 15 (decimal). Other commands know sub functions that are indicated as a parameter. A command code may therefore contain up to 16 subcommands. For example, command 7 means "Compute A = ...". The parameter indicates which computation function is to be performed.

Below, the commands and data are written together in hexadecimal code as one byte. Command 1 together with parameter 4 thus becomes the command 14h. The hex sign is left out because all commands and addresses are generally written in hexadecimal code.

The first three commands are:

10–1F: Direct port output at A1–A4, 0–15, binary 0000 to 1111

20–2F: Waiting time 0–15 (1, 2, 5, 10, 20, 50, 100, 200, 500, 1,000, 2,000, 5,000, 10,000, 20,000, 30,000, 60,000 ms)

30–3F: Jump back 0–15

Command 1 is used for port output of a constant number. This permits outputting any bit pattern and e.g switching on several LEDs at the same time.

The waiting command 2 uses a parameter that contains the time in milliseconds and a graduation of 1-2-5. In spite of the low number scope from 0 to 15, this permits execution of delay times between one millisecond and one minute. You would have to wait even longer if you were to program execution of the waiting command several times, e.g. in a counting loop.

The return command 3 is particularly simple and is sufficient for any tasks where a process should be repeated endlessly. The jump step is limited to the area up to 15. Since the jump width is relative to the current address, program parts can be moved to any other address with this jump back.

The alternating flash program only needs these three commands. It is written into the address area from 00 here in a slightly modified form. The output bit samples and waiting times are changed as well.

Address	command	Data	Comment
0	1	1	A1 - 4 = 0001 (LED1)
1	2	7	Wait for 200 ms
2	1	4	A1 - 4 = 0100 (LED4)
3	2	7	Wait for 200 ms
4	3	4	Jump - 4

Listing 9: Flashing program

In short hexadecimal form, the program now looks as follows:

11 27 14 27 34

Based on these first three commands, many simple programs can be written. Analyze and test the three following programs. The objective should be to be able to intuitively use these commands. Simple program courses like this can even be programmed by heart and entered directly with a little practice. One example of this is a simple running light with four output patterns:

Address	command	Data	Comment
0	1	1	A1 = 0001 (LED1)
1	2	8	Wait for 500 ms
2	1	2	A1 = 0010 (LED2)
3	2	8	Wait for 500 ms
4	1	4	A1 = 0100 (LED3)
5	2	8	Wait for 500 ms
6	1	8	A1 = 1000 (LED4)
7	2	8	Wait for 500 ms
8	3	8	Jmp - 8

```
11 28 12 28 14 28 18 28 38
```

Listing 10: Running light 1

Expand the program with two more output patterns, so that the light point runs back and forth. Experiment with other output patterns and delay times as well.

Address	command	Data	Comment
0	1	1	A1 = 0001 (LED1)
1	2	8	Wait for 500 ms
2	1	2	A1 = 0010 (LED2)
3	2	8	Wait for 500 ms
4	1	4	A1 = 0100 (LED3)
5	2	8	Wait for 500 ms
6	1	8	A1 = 1000 (LED4)
7	2	8	Wait for 500 ms
8	1	4	A1 = 0100 (LED3)
9	2	8	Wait for 500 ms
A	1	2	A1 = 0010 (LED2)
B	2	8	Wait for 500 ms
C	3	C	Jmp - 12

11 28 12 28 14 28 18 28 14 28 12 28 3C Listing 11: Running light 2, back and forth

A time switch may contain a delay of up to one minute with a waiting command. At the end, there is a jump back with the jump width 0, i.e. an endless loop without content, which serves as the end of the program. Restart is triggered with the reset button. Expand the program into a three-minute kitchen timer. You can display the remaining time by the number of lit LEDs as a light bar.

Address	command	Data	Comment
0	1	F	A1 = 1111 (LED1+2+4+8)
1	2	F	Wait for1000 ms
2	1	0	A1 = 0000 (All LEDs off)
3	3	0	End (Jump 0)

1F 2F 10 30 Listing 12: Time switch for one minute

11 Computing with Variables

Until now, the parameters have used only consistent number values in the parameters of the individual commands. This is sensible when a program is to run the same way every time. More complex programs, however, work with variable data. E.g. a calculation such as A = A + B can be executed. Depending on the content of the variables A and B, something different will result each time. The result could control the LEDs at the outputs as follows, for example.

The control has the four variables A, B, C and D. The most important variable is A. It is also called the accumulator or briefly “Accu” . A is involved in all computing operations and receives the computation result. A is also used for data transport. B is mostly needed for computing operations. C and D can be used as interim memories and are later needed as counters for counting loops.

There also are two analogue inputs (AD1 and AD2) and a PWM-output. The processed data are limited to four bit and only accessible via variable A (A = AD1, PWM = A). Accumulator A can also be loaded directly with a number (commands 40–4F). To fill B, C or D, first load A and then assign the content to the other variable (commands 51–53). A and B permit some computing steps (commands 71–7A).

The commands 40–4F assign A a new value. The command group 51–5A transfers the content of A to a target such as another variable or the PWM output. In this group, there also are commands that set a single bit of the output port.

The other data direction is present in the command group 61–6A, where data from a source are read into A. The command group 71–7A finally performs a few computing operations with the result generally appearing in A. The output port D-out comprises the four outputs A1 to A4, which can be tripped either together or as individual bits D-out.0 to D-out.3. The inputs E1 to E4 are triggered equally as input port Din.

40–4F: A = 0–15

51–5A: Target 1–9 = A

51: B = A

52: C = A

53: D = A

54: D-out = A

55: D-out.0 = A.0

56: D-out.1 = A.0

57: D-out.2 = A.0

58: D-out.3 = A.0

59: PWM = A

61–6A: A = Source 1–10

61: A = B

62: A = C

63: A = D

64: A = Din

65: A = Din.0

66: A = Din.1

67: A = Din.2

68: A = Din.3

69: A = AD1

6A: A = AD2

71 –7A: A = Expression 1–10

71: A = A + 1

72: A = A – 1

73: A = A + B

74: A = A – B

75: A = A * B

76: A = A / B

77: A = A And B

78: A = A Or B

79: A = A Xor B

7A: A = Not A

One example of using the variable A is found in the program examples in chapter 3. The program was set at the address Zero here and slightly expanded. Additionally, there is a defined start with the value 0 in the variable A. Address 01 contains a computing command, here increase by 1. The content of the variables A is then handed over to the PWM-output and the output port.

Address	command	Data	Comment
0	4	0	A = 0
1	7	1	A = A + 1
2	5	4	Port = A
3	5	9	PWM = A
4	2	6	Wait for 100 ms
5	3	4	Jmp -4

40 71 54 59 26 34 Listing 13: Increase by 1

Another example has already been shown in chapter 4. The data come from the analogue input AD1 and are transferred to the output port and the PWM output. The modified program contains an additional computing step, i.e. inversion of the content of the variable A. This way turns the value 0000 into the new value 1111, i.e. 0 becomes 15 and vice versa. The rising input voltage thus leads to a reducing PWM-output.

Address	command	Data	Comment
0	6	9	A = AD1
1	5	4	Port = A
2	7	A	A = Not A
3	5	9	PWM = A
4	2	6	Wait for 100 ms
5	3	5	Jmp - 5

69 54 7A 59 26 35 Listing 14: Invert

12 Jumps and Branches

Up to now, there was only a simple jump back (command 3) that went back up to 15 addresses. Now we add an absolute jump. Since the jump target can only be indicated with 4 bit, there is an additional command that specifies the high nibble of the address. This gives you an address space of 0–255. This is more than you need, since the EEPROM of the controller only holds 128 bytes, i.e. the area 00 to 7F (decimal 0 to 127). The memory is thus virtually divided into eight pages, pages 0 to 7. The page of the jump target must be specified before an absolute jump.

Two counting loops with the variables C and D also perform absolute jumps, with the page of the address having to be specified before here as well.

The conditional jumps work as skip commands. When the respective condition is true, an address is skipped. There, e.g. a jump command or computing command might be written. The conditions can be comparisons between A and B or direct bit queries of the input port.

There also is a subprogram call and the associated return command. While several subprograms are permitted, a subprogram must not call another subprogram, because the interpreter only remembers the return address at a time.

80–8F: Adr-high = 0–15

90–0F: Direct jump to Adr-high, Adr-low (0–15)

A0–AF: Counting loop C-times Adr-high, Adr-low (0–15)

B0–BF: Counting loop D-times Adr-high, Adr-low (0–15)

C1–CF: Conditional jump: if (condition 1–15) then skip

C1: if A > B then Adr = Adr + 1

C2: if A > B then Adr = Adr + 1

C3: if A = B then Adr = Adr + 1

C4: if Din.0 = 1 then Adr = Adr + 1

C5: if Din.1 = 1 then Adr = Adr + 1

C6: if Din.2 = 1 then Adr = Adr + 1

C7: if Din.3 = 1 then Adr = Adr + 1

C8: if Din.0 = 0 then Adr = Adr + 1

C9: if Din.1 = 0 then Adr = Adr + 1

CA: if Din.2 = 0 then Adr = Adr + 1

CB: if Din.3 = 0 then Adr = Adr + 1

CC: if S1 = 0 then Adr = Adr + 1

CD: if S2 = 0 then Adr = Adr + 1

CE: if S1 = 1 then Adr = Adr + 1

CF: if S2 = 1 then Adr = Adr + 1

D0–DF: Subprogram call Adr-high, Adr-low (0-15)

E0–EF: Return from subprogram

One example of using conditional jump commands is found in the example program in chapter 6. Here, it has been slightly modified and put in address 0. Since the upper part of the address (Adr-hi) is in the quiescent condition 0, and the controller starts on page 0, the command 80 does not need to be used here. The length of a push of a button is measured and displayed again. All waiting commands have been removed from the program so that it now works with a higher resolution.

Address	command	Data	Comment
0	C	C	Skip if S1 = 0
1	3	1	Jmp -1
2	4	0	A = 0
3	7	1	A = A + 1
4	5	4	Port = A
5	C	E	Skip if S1 = 1
6	3	3	Jmp - 3
7	3	7	Jmp - 7

CC 31 40 71 54 CE 33 37 Listing 15: Reactions to button S1

The jump command CC in address 00 evaluates the condition at buttons S1. In the quiescent condition, S1 = 1. The condition therefore is not true and the command in address 01 is not skipped. There is a relative jump command to the start. The program repeats the commands in addresses 00 and 01 until the button is pushed. The condition becomes true and address 01 is skipped. This starts the actual measuring process. The accumulator is deleted and then increased by 1 continually and output to the LEDs. Another conditional jump command CE is placed in address 05. Here, the condition for skipping of a command is S1 = 1. Since the button is still pushed at first, the condition is not true. The command in 06 therefore is performed and causes a return to 03. Only when the button is released will the program get to address 07 and thus a return to the start.

Enter the program and test it. The reaction time is no much faster. The time unit is at approx. 5 ms.

The original example program is still in the memory from address 34h onwards, since only the lower addresses have been overwritten. Write a little program that contains only a jump to this address. You first need to indicate page 3. The following absolute jump with the specified address 4 then actually targets the address 34.

Address	command	Data	Comment
0	8	3	Page 3
1	9	4	Address = 34

83 94 Listing 16: Absolute jump to the time measuring program

The original example program is thus called again. Test this also for other examples. For a complete overview of all possible programs, see the Appendix.

13 Command Overview

All commands at a glance – this simplifies work with the controller. The following table contains the entire command stock in a compact form.

0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
	Port=	Wait	Jump-	A=	=A	A=	A=	Page	Jump	C*	D*	Skip if	Call	Ret
0	0	1 ms	0	0				0	0	0	0		0	
1	1	2 ms	1	1	B = A	A = B	A = A+1	1	1	1	1	A>B	1	
2	2	5 ms	2	2	C = A	A = C	A = A-1	2	2	2	2	A<B	2	
3	3	10 ms	3	3	D = A	A = D	A = A+B	3	3	3	3	A=B	3	
4	4	20 ms	4	4	Dout = A	A = Din	A = A-B	4	4	4	4	Din.0=1	4	
5	5	50 ms	5	5	Dout.0 = A.0	A = Din.0	A = A*B	5	5	5	5	Din.1=1	5	
6	6	100 ms	6	6	Dout.1 = A.0	A = Din.1	A = A/B	6	6	6	6	Din.2=1	6	
7	7	200 ms	7	7	Dout.2 = A.0	A = Din.2	A = A AND B	7	7	7	7	Din.3=1	7	
8	8	500 ms	8	8	Dout.3 = A.0	A = Din.3	A = A OR B		8	8	8	Din.0=0	8	
9	9	1 sec	9	9	PWM = A	A = AD1	A = A XOR B		9	9	9	Din.1=0	9	
A	10	2 sec	10	10		A = AD2	A = NOT A		A	A	A	Din.2=0	A	
B	11	5 sec	11	11					B	B	B	Din.3=0	B	
C	12	10 sec	12	12					C	C	C	S1=0	C	
D	13	20 sec	13	13					D	D	D	S2=0	D	
E	14	30 sec	14	14					E	E	E	S1=1	E	
F	15	60 sec	15	15					F	F	F	S2=1	F	

14 Counting Loops

A process is to be performed, e.g. five times. For this, a count loop is formed. A jump command is performed five times in this case, and then no longer. The count variable is called C. The count value 5 must be loaded in A first, and from there in C. The command A2 performs an absolute count to 02 and at the same time reduces the content of the variable C by 1. When C has reached the value 0, the jump is no longer performed. The absolute jump address refers to the indicated page. For a program on page 0, the page command 80 may also be left out. However, it s necessary when jumping to any other page.

Address	command	Data	Comment
0	4	5	A = 5
1	5	2	C = A
2	1	5	Port = 0101
3	2	8	Wait for 500 ms
4	1	A	Port = 1010
5	2	8	Wait for 500 ms
6	8	0	Page 0
7	A	2	C = C*2
8	3	0	End (Jmp 0)

45 52 15 28 1A 28 80 A2 30 Listing 17: A count loop

Test the program. The LEDs show the patterns 0101 and 1010 at each pass. However, this program part is obviously not gone through five times but precisely six times. The jump command in address 07 is performed precisely five times, but to get to this point for the first time, a flashing process is performed. Therefore, the program will flash six times in total.

Change the count variable to value 4 and test the program again. Now the LEDs will flash precisely five times.

You can also use the count loop so that you will not jump back, but forwards. This time, the process is actually performed five times when C has been loaded with the value 5 in the beginning. The skipped address 04 contains a relative jump to itself and thus an endless loop that serves as the program end.

Address	command	Data	Comment
0	4	5	A = 5
1	5	2	C = A
2	8	0	Addr high = 0
3	A	5	C = C*5
4	3	0	Ende
5	1	5	Port = 0101
6	2	8	Wait for 500 ms
7	1	A	Port = 1010
8	2	8	Wait for 500 ms
9	3	6	Jmp -6

45 52 80 A5 30 15 28 1A 28 36 Listing 18: Five flashes

15 Comparisons

Two number values are to be compared. Depending on the result of the comparison, a jump is performed. The two number values must be in A and B. The following example loads B with the number 5. A receives its result from the analogue input AD1. Here, e.g. a light sensor can be connected as in chapter 4. The program should now perform the following action continually:

If AD1 > 5

then: all LEDs on

else: all LEDs off

All in all, you will receive a twilight switch. Since LDR is connected against GND, more brightness causes a lower voltage at AD1. The LEDs will go out once a certain brightness sis exceeded and a certain voltage therefore undercut. The limit is at 6, since the measuring result must be above 5.

Address	command	Data	Comment
0	4	5	A=5
1	5	1	B = A
2	8	0	Addr high = 0
3	6	9	A = AD1
4	C	1	Skip if A>B
5	9	8	Addr = 8
6	1	F	LEDs = 1111
7	3	4	Addr 3
8	1	0	LEDs=0000
9	3	6	Addr 3

45 51 80 69 C1 98 1F 34 10 36 Listing 19: Simple twilight switch

Test the program by shading the light senor with your hand more or less. You will find that the basic function is met. However, there is usually an unpleasant side effect. Exactly at the threshold between On and Off, the LEDs will flash uncontrolled. Especially in artificial light, the brightness will fluctuate around a certain average quickly. This flickering is correctly evaluated by the program, but the result is not what you would expect of a twilight switch. Chapter 18 shows an improved twilight switch.

16 AND, OR and XOR

Two binary conditions can be linked into a new condition. One example is the AND function: When bit 1 has condition 1 AND bit 2 has condition 1, the output condition is also 1. Binary numbers with several bits can also be linked in this manner. The link "10 AND 3 = 2" becomes understandable when writing it in binary numbers:

1010 AND 0011 = 0010

The following program links the input conditions to the constant number 3. The AND function practically causes the two lower bits to be masked (filtered out). In the quiescent condition, the input port has condition 1111. The AND link with 0011 then delivers the condition 0011 at the LED. If you connect one of the inputs E1 or E2 to GND, however, the 0 condition is also visible at the other outputs. Changes to E3 and E4 have no effects.

0	6	4	A = Din
1	5	1	B = A
2	4	3	A = 3
3	7	7	A = A AND B
4	5	4	Port = A
5	3	5	Jmp -5

64 51 43 77 54 35 Listing 20:Application of the AND function

Change the program and test other logical functions as well. The OR function (78) can be used to generally set specific input conditions to 1: 64 51 43 78 54 35

1010 OR 0011 = 1011

Use the XOR function (exclusive-or, 79) to invert individual bits: 64 51 43 79 54 35

1010 XOR 0011 = 1001

17 Subprograms

When parts of a program are to be reused, write them into a subprogram. This often saves memory space, and sometimes also a lot of typing. The following example shows use of a subprogram that is called in two places in the main program. The subprogram only contains one instruction (A = A-1) and the return jump command here. This does not save memory, but the example is only meant to demonstrate the CALL and RET commands.

Main program:

Address	command	Data	Comment
0	8	0	Addr high = 0
1	D	8	Call 08
2	5	4	Output
3	2	9	Wait for 1 sec
4	D	8	Call 08
5	5	4	output
6	2	8	Wait for 500 ms
7	3	7	Jump -7

Subprogram:

Address	command	Data	Comment
8	7	2	A = A - 1
9	E	0	ret

80 D8 54 29 D8 54 28 37 72 E0 Listing 21: Subprogram calls

The result of the program is a downwards counting binary counter with uneven time delays. Also test other commands in the subprogram.

There are several useful subprograms for general use among the example programs in the delivery condition. They are listed completely in the Appendix. Only the entrance address needs to be known for using them:

50: Subprogram: Long sound

52: Subprogram: Short sound

53: Subprogram: Any sound, length in A

60: Subprogram: Wait for pushed button S1

68: Subprogram: Wait for pushed button S2

70: Subprogram: Number input with S1 and S2

The subprogram from address 60 onwards is only used to set up a counter that is controlled via button S1. The counter reading starts at 0. The main program is relatively short because the complex task of the button queries has been outsourced into the subprogram.

Address	command	Data	Comment
0	4	0	A = 0
1	5	4	Output
2	7	1	A = A + 1
3	8	6	page 6
4	D	0	Call 60 (wait for push S1)
5	3	4	Jump -4

40 54 71 86 D0 34 Listing 22: Counter controlled via S1

Test the program. If you push S1 ten times, the result should be 1010. Change the program so that the subprogram is used from address 68. Now the counter reacts to S2.

18 Twilight

Switch A twilight switch is to switch on the lamp when the ambient brightness drops below a certain limit. When the light grows brighter, the lamp is to go out again. It should be ensured that the light does not flicker on the threshold between light and dark. This is possible with a hysteresis, i.e. a certain distance between the activation and deactivation brightness. The program presented here works with the following rules: • If the voltage at AD1 is not above 5, the lamp is switched off. • If the voltage at AD1 is not below 9, the lamp is switched on.

This provides a middle area in which the output condition cannot change. This gap prevents flickering of the LEDs.

0–5: LEDs off

6–8: LEDs unchanged

9–15: LEDs on

Address	command	Data	Comment
0	1	0	LEDs = 0000
1	4	5	A = 5
2	5	1	B = A
3	6	9	A = AD1
4	C	1	Skip if a>b
5	1	0	LEDs = 0000
6	4	9	A = 9
7	5	1	B = A
8	6	9	A = AD1
9	C	2	skip if A<B
A	1	F	LEDs=1111
B	3	A	Jump -10

10 45 51 69 C1 10 49 51 69 C2 1F 3A Listing 23: Twilight switch with hysteresis

19 LED-Dimmer

The target of this programming example is a controllable LED lamp. The brightness of an LED at the PWM output is to be adjustable via buttons. You can briefly push a button to get to the next brightness stage, or you can keep pushing to change the brightness continually.

In the core of the program, the skip commands that are already known are used. If the respective button is not pushed, the associated command to increase or reduce the accumulator content is skipped. The problem is that this can usually lead to an overrun from 15 to 0 or from 0 to 15. Preventing this overrun requires somewhat more effort. For this, you have to query whether the lower end (0) or the upper end (15) has already been reached. Since the accumulator is always involved in a comparison, its content must be put in interim memory. This is used by setting variable C.

Address	command	Data	Comment
0	8	0	Addr high = 0
1	5	9	PWM = A
2	2	7	Wait for 200 ms
3	5	2	C = A
4	4	F	A = 15
5	5	1	B = A
6	6	2	A = C
7	C	2	Skip if A<B
8	9	B	Jump 11
9	C	F	Skip if S2=1
A	7	1	A = A + 1
B	5	2	C = A
C	4	0	A = 0
D	5	1	B = A
E	6	2	A = C
F	C	1	Skip if a>b
10	9	0	jmp 0
11	C	E	Skip if S1=1
12	7	2	A = A-1
13	9	0	Jmp 0

80 59 27 52 4F 51 62 C2 9B CF 71 52 40 51 62 C1 90 CE 72 90 Listing 24: Brightness control

20 Number lock

The number lock presented here switches on the PWM output if the user enters the correct number sequence. The number input should be precisely according to the pattern of programming via buttons S1 and S2. The following program demonstrates input of a single number via the button S1. As when programming, the first push of the button leads to result 0000. Any subsequent push of S1 increases output by 1. Pushing S2 ends the input. In this case, the program will end in an endless loop.

Address	command	Data	Comment
0	C	C	Skip if S1 = 0
1	3	1	Jmp -1
2	4	0	A=0
3	5	4	Dout = A
4	2	3	Wait for 10 ms
5	C	E	Skip if S1 = 1
6	3	2	Addr = 4
7	C	F	Skip if S2 = 1
8	3	0	End (jmp 0)
9	C	C	Skip if S1 = 0
A	3	3	Addr = 7
B	7	1	A = A+1
C	2	3	Wait for 10 ms
D	C	C	Skip if S1 = 1
E	3	1	Addr = D
F	3	C	Addr = 3

CC 31 40 54 23 CE 32 CF 30 CC 33 71 23 CC 31 3C Listing 25: Input of a number

The number input is also available as a finished subprogram from address 70 onwards. Instead of the endless loop in line 08, there is a RET command here. The subprogram is left with the result of the number input in A.

The following number lock calls the number input thrice and compares the results to pre-defined numbers. In this example, the correct input is 3, 5, 2. Then the PWM output is fully activated with value 15. Any wrong input, however, leads to an endless loop that can only be left by a reset.

The PWM output is treated like a normal digital port in this example. This is necessary because all four outputs A1 to A4 are needed for number input. After each complete input, the four LEDs are deleted to give the observer as little information about the secret combination as possible.

Address	command	Data	Comment
0	8	7	Page 7
1	4	3	A = 3
2	5	1	B = A
3	D	0	Call 70
4	C	3	Skip if A = B
5	3	0	End (Jmp 0)
6	1	0	LEDs = 0000
7	4	5	A = 5
8	5	1	B = A
9	D	0	Call 70
A	C	3	Skip if A = B
B	3	0	End (Jmp 0)
C	1	0	LEDs = 0000
D	4	2	A = 2
E	5	1	B = A
F	D	0	Call 70
10	C	3	Skip if A = B
11	3	0	End (Jmp 0)
12	1	0	LEDs = 0000
13	4	F	A = 15
14	5	9	PWM = A
15	3	0	End (Jmp 0)

87 43 51 D0 C3 30 10 45 51 D0 C3 30 10 42 51 D0 C3 30 10 4F 59 30 Listing 26: The number lock

21 Appendix

Listing of the example programs

Address	command	Data	Comment
0	6	4	a = Din
1	5	1	B = A
2	4	E	A = 1110
3	8	0	Page 0
4	C	3	Skip if A = B
5	9	8	Jmp 8
6	8	2	Page 2
7	9	5	Jmp 5 (25)
8	4	D	A = 1101
9	8	0	Page 0
A	C	3	Skip if A = B
B	9	E	Jmp 14
C	8	2	Page 2
D	9	A	Jmp A (2A)
E	4	B	A = 1011
F	8	1	Page 1

64 51 4E 80 C3 98 82 95 4D 80 C3 9E 82 9A 4B 81

Page 0: Selection and start of the example programs

Address	command	Data	Comment
10	C	3	Skip if A = B
11	9	4	Jmp 4 (14)
12	8	3	Page 3
13	9	0	Jmp 0 (30)
14	4	7	A = 0111
15	8	1	Page 1
16	C	3	Skip if A = B
17	9	A	Jmp a (1A)
18	8	3	Page 3
19	9	4	Jmp 4 (34 Stopwatch S1)
1A	4	3	A = 0011
1B	8	2	Page 2
1C	C	3	Skip if A = B
1D	9	0	Jmp 0 (20 Alternating flash)
1E	8	4	Page 4
1F	9	0	Jmp 0 (40 Stopwatch S1/S2)

C3 94 83 90 47 81 C3 9A 83 94 43 82 C3 90 84 90

Page 1: Selection and start of the example programs

Address	command	Data	Comment
20	1	1	Port = 1 (Alternating flash)
21	2	8	Wait for 500ms
22	1	8	Port = 8 (1000)
23	2	8	Wait for 500ms
24	3	4	Jmp -4
25	7	1	A = A+1 (Count up)
26	5	4	Dout = A
27	5	9	PWM = A
28	2	6	Wait for 100 ms
29	3	4	Jmp -4
2A	6	9	A = AD1 (AD/PWM)
2B	5	4	Dout = A
2C	5	9	PWM = A
2D	2	6	Wait for 100 ms
2E	3	4	Jmp -4
2F	F	F	

11 28 18 28 34 71 54 59 26 34 69 54 59 26 34 FF

Page 2: Example programs: Alternating flash, counting up, AD/PWM

Address	command	Data	Comment
30	5	4	Dout = A (Random)
31	C	E	Skip if S1 = 1
32	7	1	A = A+1
33	3	3	Jmp -3
34	2	2	Wait for 2 ms (Stop watch S1)
35	C	C	Skip if S1=0
36	3	2	Jmp -2
37	4	0	A = 0
38	2	2	Wait for 2 ms
39	7	1	A = A+1
3A	5	4	Dout = A
3B	C	E	Skip if S1=1
3C	3	4	Jmp -4
3D	3	9	Jmp -9
3E	F	F	
3F	F	F	

54 CE 71 33 22 CC 32 40 22 71 54 CE 34 39 FF FF

Page 3: Example programs: Random, stop watch S1

Address	command	Data	Comment
40	8	6	Page 6 (Stopwatch start/stop)
41	D	0	Call 0 (60 Wait for S1)
42	4	0	A = 0
43	7	1	A = A+1
44	5	4	Dout = A
45	2	3	Wait for 10 ms
46	C	D	Skip if S2=0
47	3	4	Jmp -4
48	D	8	Call 8 (68 Wait for S2)
49	4	0	A = 0
4A	5	4	Dout = A
4B	3	B	Jmp -11
4C	F	F	
4D	F	F	
4E	F	F	
4F	F	F	

86 D0 40 71 54 23 CD 34 D8 40 54 3B FF FF FF FF

Page 4: Example program stop watch start/stop

Address	command	Data	Comment
50	4	F	a = 15 (Long tone)
51	9	3	Jmp 3
52	4	5	A = 5 (Short tone)
53	5	3	D = A
54	1	9	A4 = 1 (Port = 1001)
55	1	1	A4 = 0 (Port = 0001)
56	2	1	Wait for 2 ms
57	1	9	A4 = 1 (Port = 1001)
58	1	1	A4 = 0 (Port = 0001)
59	2	1	Wait for 2 ms
5A	1	9	A4 = 1 (Port = 1001)
5B	1	1	A4 = 0 (Port = 0001)
5C	2	0	Wait for 1 ms
5D	B	4	D = D*4
5E	1	0	Dout = 0
5F	E	0	Return

4F 93 45 53 19 11 21 19 11 21 19 11 20 B4 10 E0

Page 5: Subprogram sound output

Address	command	Data	Comment
60	2	3	Wait for 10 ms (Wait for S1)
61	C	E	Skip if S1=1
62	3	2	Jmp -2
63	2	3	Wait for 10 ms
64	C	C	Skip if S1=0
65	3	1	Jmp -1
66	E	0	Return
67	F	F	
68	2	3	Wait for 10 ms (Wait for S2)
69	C	F	Skip if S2=1
6A	3	2	Jmp -2
6B	2	3	Wait for 10 ms
6C	C	D	Skip if S2=0
6D	3	1	Jmp -1
6E	E	0	Return
6F	F	F	

23 CE 32 23 CC 31 E0 FF 23 CF 32 23 CD 31 E0 FF

Page 6: Subprograms Wait S1 and Wait S2

Address	command	Data	Comment
70	C	C	Skip if S1=0 (Button input)
71	3	1	Jmp -1
72	4	0	A = 0
73	5	4	Dout = A
74	2	3	Wait 10 ms
75	C	E	Skip if S1=1
76	3	2	Jmp -2
77	C	F	Skip if S2=1
78	E	0	Return
79	C	C	Skip if S1=0
7A	3	3	Jmp -3
7B	7	1	A = A+1
7C	2	3	Wait for 10 ms
7D	C	C	Skip if S1=1
7E	3	1	Jmp -1
7F	3	C	Jmp -12

CC 31 40 54 23 CE 32 CF 30 CC 33 71 23 CC 31 3C

Page 7: Subprogram button input

Command table

0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
	Port=	Wait	Jump-	A=	=A	A=	A=	Page	Jump	C*	D*	Skip if	Call	Ret
0	0	1 ms	0	0				0	0	0	0		0	
1	1	2 ms	1	1	B = A	A = B	A = A+1	1	1	1	1	A>B	1	
2	2	5 ms	2	2	C = A	A = C	A = A-1	2	2	2	2	A<B	2	
3	3	10 ms	3	3	D = A	A = D	A = A+B	3	3	3	3	A=B	3	
4	4	20 ms	4	4	Dout = A	A = Din	A = A-B	4	4	4	4	Din.0=1	4	
5	5	50 ms	5	5	Dout.0 = A.0	A = Din.0	A = A*B	5	5	5	5	Din.1=1	5	
6	6	100 ms	6	6	Dout.1 = A.0	A = Din.1	A = A/B	6	6	6	6	Din.2=1	6	
7	7	200 ms	7	7	Dout.2 = A.0	A = Din.2	A = A AND B	7	7	7	7	Din.3=1	7	
8	8	500 ms	8	8	Dout.3 = A.0	A = Din.3	A = A OR B		8	8	8	Din.0=0	8	
9	9	1 sec	9	9	PWM = A	A = AD1	A = A XOR B		9	9	9	Din.1=0	9	
A	10	2 sec	10	10		A = AD2	A = NOT A		A	A	A	Din.2=0	A	
B	11	5 sec	11	11					B	B	B	Din.3=0	B	
C	12	10 sec	12	12					C	C	C	S1=0	C	
D	13	20 sec	13	13					D	D	D	S2=0	D	
E	14	30 sec	14	14					E	E	E	S1=1	E	
F	15	60 sec	15	15					F	F	F	S2=1	F	

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