

# **Protokoll zum Praktikum Programmierbare Schaltkreise**

**Fakultät Informatik  
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## Aufgabe 1 - Binär-Dekoder

### 1.1 Entwurf

**Input** 4-Bit Binärzahl durch Schieberegister SW3 ... SW0

**Output** 7-Segmente Darstellung einer Hexadezimalziffer (8 Einzelsignale = 7 Segmente + 1 Punkt)

Input				Output								
SW3	SW2	SW1	SW0	HEX	A	B	C	D	E	F	G	DOT
0	0	0	0	0	0	0	0	0	0	0	1	1
0	0	0	1	1	1	0	0	1	1	1	1	1
0	0	1	0	2	0	0	1	0	0	1	0	1
0	0	1	1	3	0	0	0	0	1	1	0	1
0	1	0	0	4	1	0	0	1	1	0	0	1
0	1	0	1	5	0	1	0	0	1	0	0	1
0	1	1	0	6	0	1	0	0	0	0	0	1
0	1	1	1	7	0	0	0	1	1	1	1	1
1	0	0	0	8	0	0	0	0	0	0	0	1
1	0	0	1	9	0	0	0	0	1	0	0	1
1	0	1	0	A	0	0	0	1	0	0	0	1
1	0	1	1	b	1	1	0	0	0	0	0	1
1	1	0	0	C	0	1	1	0	0	0	1	1
1	1	0	1	d	1	0	0	0	0	1	0	1
1	1	1	0	E	0	1	1	0	0	0	0	1
1	1	1	1	F	0	1	1	1	0	0	0	1

5.1 Decoder.vhdl Code

### 1.2 Auswertung

**Ressourcenbedarf**

- 7 Logik-Elemente
- 12 Pins

## Aufgabe 2 - Hamming-Distanz

### 2.1 Entwurf

**Input** 2 4-Bit Werte

- 1.Wert: 4-Bit Binärzahl durch Schieberegister SW3 ... SW0
- 2.Wert: 4-Bit Binärzahl durch Schieberegister SW7 ... SW4

**Output** 7-Segmente Darstellung einer Hexadezimalziffer (8 Einzelsignale = 7 Segmente + 1 Punkt)

**Ansatz** SW3 ... SW0 und SW7 ... SW4 logisch xor verknüpfen und Ergebnis direkt auf 7-Segmente Anzeige mappen

5.2 Hamming.vhdl Code

### 2.2 Auswertung

**Ressourcenbedarf**

- 9 Logik-Elemente
- 16 Pins

## Aufgabe 3 - Modulo-n-Zähler

### 3.1 Entwurf

- a) Der Zähler ist nach 50 Millionen Schritten zurückzusetzen (50 MHz Takt entspricht 50 Millionen Taktperioden pro Sekunde)
- b) Für das Schieberegister ist der Zählerzustand ein Enable-Signal

- c) **Input**
- 50MHz Takt
  - Reset (Schiebeschalter SW0)

**Output** LED-Zeile

**Ansatz** 2 Komponenten Schieber und Zähler

**Zähler** gibt alle 50-Millionen Taktperioden einen Takt lang ein enable-Signal aus. (5.3 Zaehler.vhdl-Code)

**Schieber** beinhaltet den Zähler als Komponente und verschiebt bei dessen enable-Signal die LED-Anzeige um eine Stelle pro Takt. (5.3 Schieber.vhdl-Code)

### 3.2 Auswertung

#### Ressourcenbedarf

- 60 Logik-Elemente
- davon 38 dedizierte Logik-Elemente
- 12 Pins
- maximale Taktfrequenz von 250 MHz

## Aufgabe 4 - Entprell-Automat

### 4.1 Entwurf

#### State-Machine-Charts

**LED** enthält die Komponente Entprellung und verbindet die Ein- und Ausgangssignale. (5.4 LED.vhdl-Code)

**Entprellung** enthält die Komponente Zaehler, der bei der Veränderung des Eingangssignals gestartet wird und für 3ms weitere Änderungen ignoriert. (5.4 Entprellung.vhdl-Code)

**Zaehler** implementiert einen Zähler, der durch ein Signal definierte Schritte zählt. Ausgegeben wird der aktuelle Zustand des Zählers. Eingegeben ein Reset-Signal. (5.4 Zaehler.vhdl-Code)

### 4.2 Auswertung

#### Ressourcenbedarf

- 86 Logik-Elemente
- davon 79 dedizierte Logik-Elemente
- 44 Register
- 3 Pins
- maximale Taktfrequenz von 178 MHz

## Anhang

### 5.1 01-Aufgabe Code

Listing 1: VHDL-Code Decoder.vhdl

```

1
2 library ieee;
3 use ieee.std_logic_1164.all;
4 use ieee.numeric_std.all;
5
6 entity Decoder is
7
8     port (
9         sw : in std_logic_vector(3 downto 0);
10        cc : out std_logic_vector(7 downto 0));
11
12 end Decoder;
13
14 architecture Dec1 of Decoder is
15 begin -- rtl
16
17     -----
18     -- Outputs
19     -----
20
21     with sw select
22         cc <= "00000011" when "0000",
23             "10011111" when "0001",
24             "00100101" when "0010",
25             "00001101" when "0011",
26             "10011001" when "0100",
27             "01001001" when "0101",
28             "01000001" when "0110",
29             "00011111" when "0111",
30             "00000001" when "1000",
31             "00001001" when "1001",
32             "00010001" when "1010",
33             "11000001" when "1011",
34             "01100011" when "1100",
35             "10000101" when "1101",
36             "01100001" when "1110",
37             "01110001" when "1111";
38
39 end dec1;

```

## 5.2 02-Aufgabe Code

Listing 2: VHDL-Code Hamming.vhdl

```

1
2 library ieee;
3 use ieee.std_logic_1164.all;
4 use ieee.numeric_std.all;
5
6 entity Hamming is
7
8     port (
9         sw1 : in std_logic_vector(3 downto 0);
10        sw2 : in std_logic_vector(3 downto 0);
11        cc : out std_logic_vector(7 downto 0));
12
13 end Hamming;
14
15 architecture ham1 of Hamming is
16     signal xo : std_logic_vector(3 downto 0);
17 begin
18
19     xo <= sw1 xor sw2;
20
21     with xo select
22         cc <= "00000011" when "0000",
23             "10011111" when "0001",
24             "10011111" when "0010",
25             "00100101" when "0011",
26             "10011111" when "0100",
27             "00100101" when "0101",
28             "00100101" when "0110",
29             "00001101" when "0111",
30             "10011111" when "1000",
31             "00100101" when "1001",
32             "00100101" when "1010",
33             "00001101" when "1011",
34             "00100101" when "1100",
35             "00001101" when "1101",
36             "00001101" when "1110",
37             "10011001" when "1111";
38 end ham1;
    
```

## 5.3 03-Aufgabe Code

Listing 3: VHDL-Code Schieber.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.numeric_std.all;
4  use Ieee.std_logic_unsigned.all;
5
6  entity Schieber is
7
8      port (
9          clk : in std_logic;
10         rst : in std_logic;
11         ld : out std_logic_vector(9 downto 0)
12     );
13
14
15 end Schieber;
16
17
18 architecture schieb1 of Schieber is
19     component zaehler
20         port (
21             clk : in std_logic;
22             clk_out : out std_logic
23         );
24     end component;
25     signal state : std_logic_vector(9 downto 0) := "0000000001";
26     signal shift : std_logic;
27
28 begin
29     custom_clk : zaehler PORT MAP (clk => clk, clk_out => shift);
30
31     process(clk)
32     begin
33
34         if rising_edge(clk) then
35             if rst = '1' then
36                 state <= "0000000001";
37             elsif shift = '1' then
38                 state <= state(8 downto 0)&state(9);
39             end if;
40         end if;
41     end process;
42
43     ld <= state;
44
45 end schieb1;

```

Listing 4: VHDL-Code Zaehler.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.numeric_std.all;
4
5  entity Zaehler is
6
7
8      port (
9          clk : in std_logic;
10         clk_out : out std_logic
11     );
12
13
14 end Zaehler;
15
16 architecture zael of Zaehler is

```



```

17
18
19     signal counter : unsigned(26 downto 0) := (others => '0'); -- Zaehler mod 50.000.000
20     signal state : std_logic := '1';
21 begin
22
23     process(clk, state, counter)
24     begin
25
26         if rising_edge(clk) then
27
28             state <= '0';
29             if counter = to_unsigned(50000000, counter'length) then
30                 counter <= (others => '0');
31                 state <= '1';
32
33             else
34                 counter <= counter + 1;
35             end if;
36
37         end if;
38     end process;
39
40     clk_out <= state;
41 end zael;

```

## 5.4 04-Aufgabe Code

Listing 5: VHDL-Code LED.vhdl

```

1
2 library ieee;
3 use ieee.std_logic_1164.all;
4 use ieee.std_logic_unsigned.all;
5 use ieee.numeric_std.all;
6
7 entity LED is
8
9     port (
10         clk : in std_logic;
11         btn : in std_logic;
12         ld : out std_logic
13     );
14 end LED;
15
16 architecture led1 of LED is
17
18     component Entprellung
19     port (
20         clk : in std_logic;
21         btn_in : in std_logic;
22         btn_out : out std_logic
23     );
24 end component;
25
26 signal led_sig : std_logic := '0';
27 signal btn_led : std_logic;
28 signal btn_out : std_logic;
29 signal btn_out_d : std_logic;
30 signal btn_in_d : std_logic := '0';
31 signal btn_in : std_logic := '0';
32
33 begin
34     custom_entpreller : Entprellung PORT MAP (
35         clk => clk,
36         btn_in => btn_in,
37         btn_out => btn_out);
38     process (btn_led)
39     begin
40         if btn_led = '0' then
41             led_sig <= not led_sig;
42         end if;
43     end process;
44
45     process (clk)
46     begin
47         if rising_edge(clk) then
48             btn_in_d <= btn;
49         end if;
50     end process;
51
52     process (clk)
53     begin
54         if rising_edge(clk) then
55             btn_in <= btn_in_d;
56         end if;
57     end process;
58
59     process (clk)
60     begin
61         if rising_edge(clk) then
62             btn_out_d <= btn_out;
63         end if;
64     end process;

```

```

65
66 process (clk)
67 begin
68     if rising_edge(clk) then
69         btn_led <= btn_out_d;
70     end if;
71 end process;
72
73 ld <= not led_sig;
74 end led1;
    
```

Listing 6: VHDL-Code Entprellung.vhdl

```

1
2 library ieee;
3 use ieee.std_logic_1164.all;
4 use ieee.std_logic_unsigned.all;
5 use ieee.numeric_std.all;
6
7
8 entity Entprellung is
9
10     port (
11         clk : in std_logic;
12         btn_in : in std_logic;
13         btn_out : out std_logic
14     );
15
16 end Entprellung;
17
18 architecture entprell of Entprellung is
19
20     signal btn_old : std_logic := '0';
21     signal state : std_logic := '0';
22
23     signal zaehler_state : std_logic := '0';
24     signal zaehler_state_d : std_logic := '0';
25     signal zaehler_reset : std_logic := '0';
26
27
28
29
30     component Zaehler
31     port (
32         clk : in std_logic;
33         count_steps : in unsigned(31 downto 0);
34         counter_reset : in std_logic;
35         counter_state : out std_logic
36     );
37 end component;
38
39 begin
40     custom_zahler : Zaehler PORT MAP (
41         clk => clk,
42         count_steps => to_unsigned(150000, 32),
43         --count_steps => to_unsigned(100000000, 32),
44         counter_state => zaehler_state,
45         counter_reset => zaehler_reset);
46
47 process(clk)
48 begin
49     if rising_edge(clk) then
50         if state = '0' then
51             if btn_in /= btn_old then
52                 zaehler_reset <= '1';
53                 btn_old <= btn_in;
54             end if;
    
```

```

55     else
56         if zaehler_reset = '1' then
57             zaehler_reset <= '0';
58         end if;
59     end if;
60 end if;
61 end process;
62
63 process (clk)
64 begin
65     if rising_edge(clk) then
66         state <= zaehler_state_d;
67         zaehler_state_d <= zaehler_state;
68     end if;
69 end process;
70
71 btn_out <= btn_old;
72 end entprel1;

```

Listing 7: VHDL-Code Zaehler.vhdl

```

1
2 library ieee;
3 use ieee.std_logic_1164.all;
4 use Ieee.std_logic_unsigned.all;
5 use ieee.numeric_std.all;
6
7 entity Zaehler is
8
9     port (
10         clk : in std_logic;
11         count_steps : in unsigned(31 downto 0);
12         counter_reset : in std_logic;
13         counter_state : out std_logic);
14
15
16 end Zaehler;
17
18 architecture zael of Zaehler is
19
20     signal reset : std_logic := '0';
21     signal reset_d : std_logic := '0';
22     signal state : std_logic := '0';
23     signal counter : unsigned(31 downto 0) := (others => '0');
24 begin
25
26     process(clk)
27     begin
28
29         if rising_edge(clk) then
30             if reset = '1' then
31                 counter <= (others => '0');
32             end if;
33
34             if counter < count_steps then
35                 state <= '1';
36                 counter <= counter + 1;
37             else
38                 state <= '0';
39             end if;
40         end if;
41     end process;
42
43     --d-ff1 for reset
44     process(clk)
45     begin
46         if rising_edge(clk) then

```

```

47     reset_d <= counter_reset;
48     end if;
49 end process;
50
51 --d-ff2 for reset
52 process(clk)
53 begin
54     if rising_edge(clk) then
55         reset <= reset_d;
56     end if;
57 end process;
58
59 counter_state <= state;
60 end zael;

```

## 5.5 05-Aufgabe Code

Listing 8: VHDL-Code hallo.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.std_logic_unsigned.all;
4  use ieee.numeric_std.all;
5
6  entity Hallo is
7
8      port (
9          clk : in std_logic;
10         rst : in std_logic;
11         seg1 : out std_logic_vector(7 downto 0);
12         seg2 : out std_logic_vector(7 downto 0);
13         seg3 : out std_logic_vector(7 downto 0);
14         seg4 : out std_logic_vector(7 downto 0));
15
16 end Hallo;
17
18 architecture hello of hallo is
19
20     component Multiplex
21     port (
22         clk : in std_logic;
23         rst : in std_logic;
24         led_out : out std_logic_vector(11 downto 0)
25     );
26 end component;
27
28     component Decoder
29     port (
30         clk : in std_logic;
31         code : in std_logic_vector(2 downto 0);
32         decoded : out std_logic_vector(7 downto 0));
33
34     end component;
35
36     signal dig : std_logic_vector(11 downto 0);
37     signal dig0 : std_logic_vector(2 downto 0);
38     signal dig1 : std_logic_vector(2 downto 0);
39     signal dig2 : std_logic_vector(2 downto 0);
40     signal dig3 : std_logic_vector(2 downto 0);
41
42 begin
43
44     mult : Multiplex PORT MAP( clk => clk, rst => rst, led_out => dig);
45     dec0 : Decoder PORT MAP(clk => clk, code => dig0, decoded => seg4);
46     dec1 : Decoder PORT MAP(clk => clk, code => dig1, decoded => seg3);
47     dec2 : Decoder PORT MAP(clk => clk, code => dig2, decoded => seg2);
48     dec3 : Decoder PORT MAP(clk => clk, code => dig3, decoded => seg1);
49
50
51     dig0 <= dig(11 downto 9);
52     dig1 <= dig(8 downto 6);
53     dig2 <= dig(5 downto 3);
54     dig3 <= dig(2 downto 0);
55
56 end hello;
    
```

Listing 9: VHDL-Code Decoder.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.std_logic_unsigned.all;
4  use ieee.numeric_std.all;
    
```

```

6
7 entity Decoder is
8
9     port (
10         clk : in std_logic;
11         code : in std_logic_vector(2 downto 0);
12         decoded : out std_logic_vector(7 downto 0));
13 end Decoder;
14
15 architecture decoder1 of Decoder is
16
17     signal decoded_out : std_logic_vector(7 downto 0) := (others => '0');
18
19     begin
20
21     process (clk)
22     begin
23         if rising_edge(clk) then
24             case code is
25                 when "000" => decoded_out <= "11111111";
26                 when "001" => decoded_out <= "10010001";
27                 when "010" => decoded_out <= "00010001";
28                 when "011" => decoded_out <= "11100011";
29                 when "100" => decoded_out <= "00000011";
30                 when others => decoded_out <= "11111111";
31             end case;
32         end if;
33     end process;
34
35     decoded <= decoded_out;
36
37 end decoder1;
    
```

Listing 10: VHDL-Code Multiplex.vhdl

```

1  --
2  -- Copyright (c) 20013
3  -- Technische Universitaet Dresden, Dresden, Germany
4  -- Faculty of Computer Science
5  -- Institute for Computer Engineering
6  -- Chair for VLSI-Design, Diagnostics and Architecture
7  --
8  -- For internal educational use only.
9  -- The distribution of source code or generated files
10 -- is prohibited.
11 --
12
13 --
14 -- Entity: Example
15 -- Author(s): Martin Zabel, Matthias Haesing
16 --
17 -- Simple example for the Terasic DE0 board.
18 --
19 -- Revision: $Revision: 1.1 $
20 -- Last change: $Date: 2013-10-09 12:49:38 $
21 --
22
23 library ieee;
24 use ieee.std_logic_1164.all;
25 use ieee.numeric_std.all;
26
27
28 entity Multiplex is
29
30     port (
31         clk : in std_logic;
32         rst : in std_logic;
    
```

```

33     led_out : out std_logic_vector(11 downto 0)
34 );
35
36 end Multiplex;
37
38 -- 000: _
39 -- 001: H
40 -- 010: A
41 -- 011: L
42 -- 100: 0
43
44 architecture multi of Multiplex is
45 -- _ _ _ _ H A L L 0 _ _ _
46     signal tex : std_logic_vector(35 downto 0) := "00000000000000010100110111000000000000";
47     signal counter : unsigned(24 downto 0) := (others => '0');
48     signal mul : unsigned(3 downto 0);
49
50 begin
51
52     process(clk)
53     begin
54         if rising_edge(clk) then
55             if(rst = '1') then
56                 counter <= (others => '0');
57                 mul <= (others => '0');
58                 elsif(counter = "10111110101111000000111111") then
59                     -- elsif(counter = "00000000000011000000111111") then
60                         counter <= (others => '0');
61                         mul <= mul + 1;
62                         if(mul = "1000") then
63                             mul <= "0000";
64                         end if;
65                     else
66                         counter <= counter + 1;
67                     end if;
68                 end if;
69             end process;
70
71             with mul select
72                 led_out <= tex(35 downto 24) when "0000",
73                     tex(32 downto 21) when "0001",
74                     tex(29 downto 18) when "0010",
75                     tex(26 downto 15) when "0011",
76                     tex(23 downto 12) when "0100",
77                     tex(20 downto 9) when "0101",
78                     tex(17 downto 6) when "0110",
79                     tex(14 downto 3) when "0111",
80                     tex(11 downto 0) when "1000",
81                     (others => '0') when others;
82
83 end multi;

```



## 5.6 06-Aufgabe Code

Listing 11: VHDL-Code Stoppuhr.vhd

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.std_logic_unsigned.all;
4  use ieee.numeric_std.all;
5
6  entity Stoppuhr is
7
8      port (
9          clk : in std_logic;
10         rst : in std_logic;
11         onoff : in std_logic;
12         seg1 : out std_logic_vector(7 downto 0);
13         seg2 : out std_logic_vector(7 downto 0);
14         seg3 : out std_logic_vector(7 downto 0);
15         seg4 : out std_logic_vector(7 downto 0));
16
17 end Stoppuhr;
18
19 architecture uhr of Stoppuhr is
20
21     component Zaehler
22     port (
23         clk : in std_logic;
24         zaehler_time : in unsigned(31 downto 0);
25         zaehler_on : in std_logic;
26         peak_out : out std_logic
27     );
28 end component;
29
30 component EntprellAutomat
31 port (
32     clk : in std_logic;
33     btn : in std_logic;
34     btnout : out std_logic
35 );
36 end component;
37
38 component Decoder
39 port (
40     clk : in std_logic;
41     code : in std_logic_vector(3 downto 0);
42     decoded : out std_logic_vector(7 downto 0)
43 );
44 end component;
45
46 signal timer_on, peak : std_logic := '0';
47 signal min, sec1, sec2, ms : unsigned(3 downto 0) := (others => '0');
48 signal running, onoff_db, onoff_old : std_logic := '0';
49 signal segMin, segSec1, segSec2, segMs : std_logic_vector(7 downto 0) := (others => '0');
50
51
52 begin
53
54     zaehl : Zaehler PORT MAP (clk => clk,
55                             zaehler_time => to_unsigned(5000000, 32),
56                             zaehler_on => timer_on,
57                             peak_out => peak);
58
59     prell : EntprellAutomat PORT MAP (
60         clk => clk,
61         btn => onoff,
62         btnout => onoff_db);
63
64     dec0 : Decoder PORT MAP(clk => clk, code => std_logic_vector(min), decoded => segMin);

```

```

65 dec1 : Decoder PORT MAP(clk => clk, code => std_logic_vector(sec1), decoded => segSec1);
66 dec2 : Decoder PORT MAP(clk => clk, code => std_logic_vector(sec2), decoded => segSec2);
67 dec3 : Decoder PORT MAP(clk => clk, code => std_logic_vector(ms), decoded => segMs);
68
69
70 process(clk)
71 begin
72     if rising_edge(clk) then
73         if(rst = '1') then
74             running <= '0';
75             timer_on <= '0';
76             min <= (others => '0');
77             sec1 <= (others => '0');
78             sec2 <= (others => '0');
79             ms <= (others => '0');
80         else
81             onoff_old <= onoff_db;
82             -----
83             -- on/off umschalten wenn btn gedrueckt
84             -----
85             if(onoff_db = '1' and onoff_db /= onoff_old) then
86                 running <= not running;
87                 timer_on <= not timer_on;
88             end if;
89
90             if(running = '1') then
91                 if(peak = '1') then
92                     if(ms = to_unsigned(9, 4)) then
93                         if(sec2 = to_unsigned(9, 4)) then
94                             if(sec1 = to_unsigned(5, 4)) then
95                                 if(min = to_unsigned(9, 4)) then
96                                     min <= (others => '0');
97                                     sec1 <= (others => '0');
98                                     sec2 <= (others => '0');
99                                     ms <= (others => '0');
100                                else
101                                    min <= min + 1;
102                                    sec1 <= (others => '0');
103                                    sec2 <= (others => '0');
104                                    ms <= (others => '0');
105                                end if;
106                            else
107                                sec1 <= sec1 + 1;
108                                sec2 <= (others => '0');
109                                ms <= (others => '0');
110                            end if;
111                        else
112                            sec2 <= sec2 + 1;
113                            ms <= (others => '0');
114                        end if;
115                    else
116                        ms <= ms + 1;
117                    end if;
118                end if;
119            end if;
120
121        end if;
122    end if;
123 end process;
124
125 seg4 <= segMin and "11111110";
126 seg3 <= segSec1;
127 seg2 <= segSec2 and "11111110";
128 seg1 <= segMS;
129
130 end uhr;
    
```

Listing 12: VHDL-Code Decoder.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.std_logic_unsigned.all;
4  use ieee.numeric_std.all;
5
6  -- Decoder bekommt einen 3bit breiten Code fuer ein Zeichen und gibt den 8bit breiten Code
   fuer die 7-Segment Anzeige des Zeichens aus
7
8  entity Decoder is
9
10     port (
11         clk : in std_logic;
12         code : in std_logic_vector(3 downto 0);
13         decoded : out std_logic_vector(7 downto 0));
14 end Decoder;
15
16 architecture decoder1 of Decoder is
17
18     signal decoded_out : std_logic_vector(7 downto 0) := (others => '0');
19
20     begin
21
22     process (clk)
23     begin
24         if rising_edge(clk) then
25             case code is
26                 when "0000" => decoded_out <= "00000011"; -- 0
27                 when "0001" => decoded_out <= "10011111"; -- 1
28                 when "0010" => decoded_out <= "00100101"; -- 2
29                 when "0011" => decoded_out <= "00001101"; -- 3
30                 when "0100" => decoded_out <= "10011001"; -- 4
31                 when "0101" => decoded_out <= "01001001"; -- 5
32                 when "0110" => decoded_out <= "01000001"; -- 6
33                 when "0111" => decoded_out <= "00011111"; -- 7
34                 when "1000" => decoded_out <= "00000001"; -- 8
35                 when "1001" => decoded_out <= "00001001"; -- 9
36                 when others => decoded_out <= "11111111"; -- error
37             end case;
38         end if;
39     end process;
40
41     decoded <= decoded_out;
42
43 end decoder1;

```

Listing 13: VHDL-Code EntprellAutomat.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.numeric_std.all;
4
5
6  entity EntprellAutomat is
7
8     port (
9         clk : in std_logic;
10         btn : in std_logic;
11         btnout : out std_logic
12     );
13
14 end EntprellAutomat;
15
16 architecture prell of EntprellAutomat is
17
18     component Zaehler
19     port (

```

```

20     clk : in std_logic;
21     zaehler_time : in unsigned(31 downto 0);
22     zaehler_on : in std_logic;
23     peak_out : out std_logic
24 );
25 end component;
26
27 type zustaeende is (idle, count); -- 2 Zustaeende, idle = button betaetigen moeglich, count
    = 3ms warten (bis 150.000 hochzaehlen bei 50Mhz)
28 attribute enum_encoding : string;
29 attribute enum_encoding of zustaeende : type is "1 0";
30 signal z_alt, z_neu : zustaeende := idle;
31 signal btn_s, btn_old, timer_on, btn_output : std_logic := '0';
32 signal btn2 : std_logic := '1';
33 signal peak : std_logic := '0';
34
35 begin
36
37     timer : Zaehler PORT MAP (clk => clk, zaehler_time => to_unsigned(150000,32), zaehler_on
        => timer_on, peak_out => peak);
38
39     process(clk)
40     begin
41         if rising_edge(clk) then
42             btn2 <= btn;
43             btn_old <= btn_s;
44             btn_s <= not btn2;
45         end if;
46     end process;
47
48
49     process(clk)
50     begin
51         if rising_edge(clk) then
52             z_alt <= z_neu;
53             case z_alt is
54                 when idle => if(btn_s /= btn_old) then
55                     btn_output <= btn_s;
56                     z_neu <= count;
57                     timer_on <= '1';
58                 end if;
59                 when count => if(peak = '1') then
60                     z_neu <= idle;
61                     timer_on <= '0';
62                 end if;
63             end case;
64         end if;
65     end process;
66     btnout <= btn_output;
67 end prell;

```

Listing 14: VHDL-Code Zaehler.vhdl

```

1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.numeric_std.all;
4
5
6  entity Zaehler is
7
8      port (
9          clk : in std_logic;
10         zaehler_time : in unsigned(31 downto 0);
11         zaehler_on : in std_logic;
12         peak_out : out std_logic
13     );
14

```

```

15 end Zaehler;
16
17 architecture timer of Zaehler is
18
19     signal counter : unsigned(31 downto 0) := (others => '0');
20     signal peak : std_logic := '0';
21
22 begin
23
24     process(clk)
25     begin
26         if rising_edge(clk) then
27             peak <= '0';
28             if(zaehler_on = '1') then
29                 if(counter = zaehler_time - 1) then
30                     counter <= (others => '0');
31                     peak <= '1';
32                 else
33                     counter <= counter + 1;
34                 end if;
35             else
36                 counter <= (others => '0');
37             end if;
38         end if;
39     end process;
40
41     peak_out <= peak;
42
43 end timer;

```