# *Moore machine*

Design a thermostat that stabilizes the temperature to 22°C with a hysteresis of ± 2°C. The circuit should work as follows: when temperature drop below 20°C, the state machine will turn on heating and turn off above 22°C. Next, fluctuation of temperature between 20-24°C shouldn't turn on heating or cooling. When temperature rise above 24°C, the state machine will turn on cooling and turn off below 22°C. And next, fluctuation of temperature between 20-24°C shouldn't turn on heating or cooling. The state machine uses 3 digital 1-bit sensors to measure the temperature. Each sensor on his output sets logic 1 when the temperature is higher than the setting level and logic 0 when the temperature is lower that the setting level. Individual thresholds of temperature for each sensor are set: 24°C (sensor a), 22°C (sensor b) and 20°C (sensor c). System design as a Moore machine.

| **Temperature** | **Sensors indications** | | |
|---|---|---|---|
| | **a** | **b** | **c** |
| | 1 | 1 | 1 |
| 24°C | | | |
| | 0 | 1 | 1 |
| 22°C | | | |
| | 0 | 0 | 1 |
| 20°C | | | |
| | 0 | 0 | 0 |

Sensor indications (a b c):

> 24°C – 111;

22°C ÷ 24°C – 011;

20°C ÷ 22°C – 001;

< 20°C – 000;

In order to test the system, use the ***ThermoObject*** module. ***ThermoObject*** is a control object simulator. The outputs of this object shows the states of sensors a, b and c (HEX5 display diodes). Additionally, the ***ThermoObject*** displays the current temperature on 7-segment displays (HEX2..HEX0). Connect the module as shown in Fig. 2.

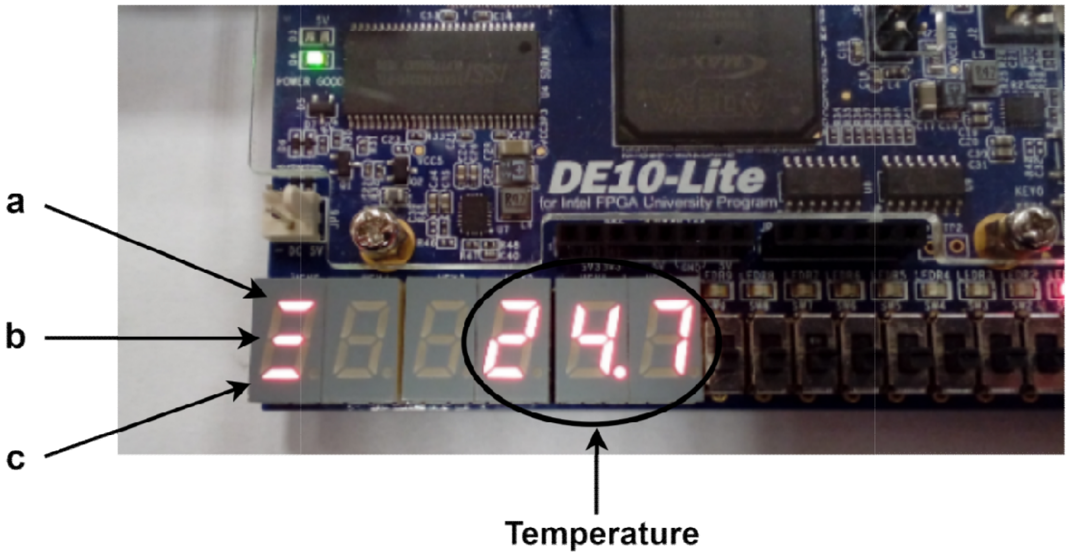


**Fig. 1: LED indications corresponding to sensors a, b and c and current temperature in °C**

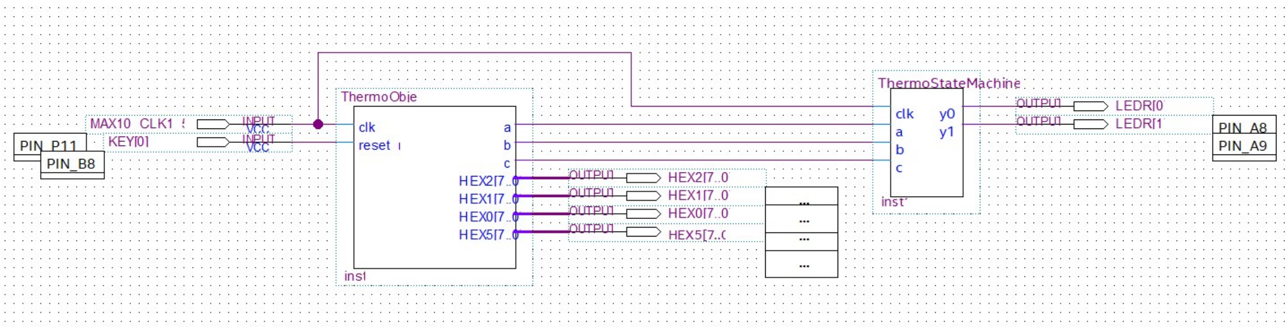


**Fig. 2: Connection of the ThermoObject and Moore machine**

# Synthesis of the Moore machine

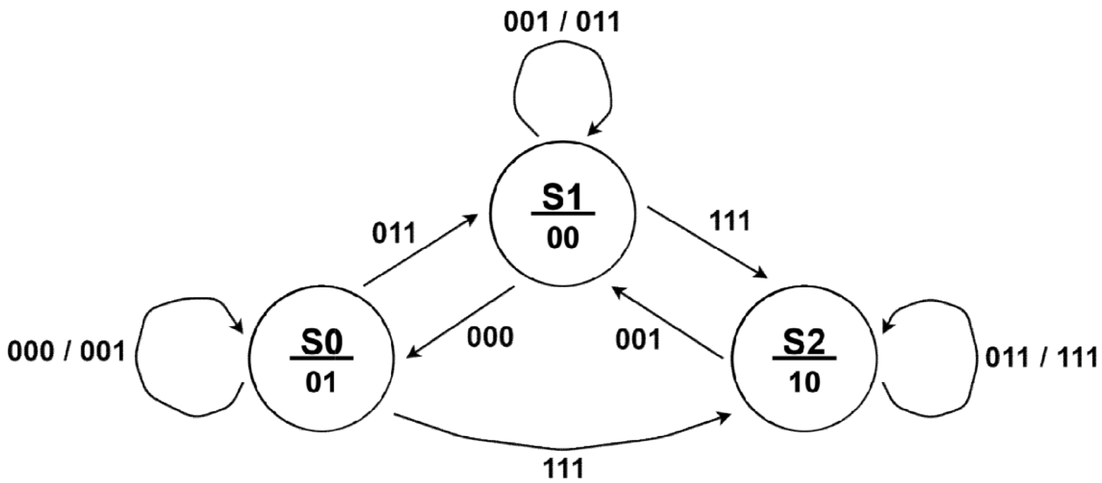


**Fig. 3: The state machine graph**
**(S0 – cooling off / heating on, S1 – cooling off / heating off, S2 – cooling on / heating off)**
**000: temp < 20°C; 001: temp 20°C ÷ 22°C; 011: temp 22°C ÷ 24°C; 111: temp > 24°C;**

State coding (assignment of binary values):

**S0 -> 00**

**S1 -> 01**

**S2 -> 10**

| $S_n$ | | | X | | | $S_{n+1}$ | | |
|---|---|---|---|---|---|---|---|---|
| $S_n$ | $q_1$ | $q_0$ | a | b | c | $q_1'$ | $q_0'$ | $S_{n+1}$ |
| S0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | S0 |
| S0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | S0 |
| S0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | S1 |
| S0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | S2 |
| S1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | S0 |
| S1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | S1 |
| S1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | S1 |
| S1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | S2 |
| S2 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | S1 |
| S2 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | S2 |
| S2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | S2 |

**Tab. 1: The state transition table of Moore machine**

**D flip-flops were selected for the synthesis of the Moore machine.**

| $q_1 q_0$ \ a b c | 000 | 001 | 011 | 010 | 110 | 111 | 101 | 100 |
|---|---|---|---|---|---|---|---|---|
| 00 | 0 | 0 | 1 | - | - | 0 | - | - |
| 01 | 0 | 1 | 1 | - | - | 0 | - | - |
| 11 | - | - | - | - | - | - | - | - |
| 10 | - | 1 | 0 | - | - | 0 | - | - |

$$D_0 = q_1\overline{b} + q_0\overline{a}c + \overline{q_1}\overline{a}b$$

| $q_1 q_0$ \ a b c | 000 | 001 | 011 | 010 | 110 | 111 | 101 | 100 |
|---|---|---|---|---|---|---|---|---|
| 00 | 0 | 0 | 0 | - | - | 1 | - | - |
| 01 | 0 | 0 | 0 | - | - | 1 | - | - |
| 11 | - | - | - | - | - | - | - | - |
| 10 | - | 0 | 1 | - | - | 1 | - | - |

$$D_1 = a + q_1 b$$

| $S_n$ | | | Y | |
|---|---|---|---|---|
| $S_n$ | $q_1$ | $q_0$ | $y_1$ | $y_0$ |
| S0 | 0 | 0 | 0 | 1 |
| S1 | 0 | 1 | 0 | 0 |
| S2 | 1 | 0 | 1 | 0 |

**Tab. 2: The output table of Moore machine**

$$y_0 = \overline{q_1}\,\overline{q_0}$$

$$y_1 = q_1\,\overline{q_0}$$