

# MiraTherm Radiator Thermostat

## Software Specification

### Requirement Specification for a Master Project

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## Change Log

Table 1: Document Change Log

Nº	Date	Version	Changed Chapters	Change Type	Editor
1	4.11.2025	0.1	All	Initial version	A. Menzel
2	10.11.2025	0.2	3	Requirements correction	A. Menzel
3	17.11.2025	0.3	1, 2, 3	Amendment of the project context, prototype and target hardware separation, requirements correction	A. Menzel

# 1 Introduction

In this chapter, the purpose of this document and the context of the project are described.

## 1.1 Document Purpose

This document provides a requirements specification for software of a Micro Controller Unit (MCU) based radiator thermostat **prototype<sup>v0.3</sup>**, which will be developed as part of a master project at Fulda University of Applied Sciences. This software should implement basic consumer functions and could be used as a base for research, development and production of smart heating controllers or thermostats.

## 1.2 Project Context

The master project will be realized as part of a bigger interdisciplinary development named “MiraTherm Radiator Thermostat”, which includes the following areas:

- **Mechanics:** Development of the thermostat’s power transmission mechanism for proper function with commonly used radiator valves, followed by the design of an enclosure. **This work is being realized by Anton Surikov and advised by Prof. Dr. Tobias Müller.<sup>v0.3</sup>**
- **Control algorithms:** Engineering of control algorithms to be used by the thermostat. **This work will be realized after the completion of the thermostat’s mechanics development.<sup>v0.3</sup>**
- **Electronics:** Development of the thermostat’s Printed Circuit Board (PCB) and its integration with mechanical components. **It is being realized by Thomas Schneider and advised by Prof. Dr. Daniel Schönherr.<sup>v0.3</sup>**
- **Software:** The subject of this work, development of the thermostat’s software and its integration with PCB components. **It is being realized by Alexander Menzel and advised by Prof. Dr. Uwe Werner.<sup>v0.3</sup>**

## 2 Concept

In this chapter, the overall concept and approach for the development of ~~software of the radiator thermostat prototype~~<sup>v0.3</sup> is described. Additionally, the required hardware for development and testing is outlined.

### 2.1 Solution Approach

In this project, a basic software for a device prototype should be implemented including hardware drivers and general program logic. The description of the eQ-3 eqiva Bluetooth from [1] will be used as a reference for defining the functional scope of the software to be developed.

Due to time constraints, the implementation of control algorithms, wireless connectivity, advanced features, and energy management will be considered out of scope for this project. Instead, the focus will be on developing a solid software foundation that can be extended in the future.

The software should be designed ready for prospective integration of the control algorithms and Matter-over-Thread standard. (For further details about this standard see [2].) The device is supposed to be used for smart home applications, specifically for the integration of the thermostat in Home Assistant, apps like Google Home and/or custom Application Programming Interfaces (APIs).

### 2.2 Required Hardware

To ensure a degree of independence from the PCB design and mechanics, the software will be developed using a prototype hardware set that resembles the ~~target~~<sup>v0.3</sup> thermostat hardware (~~results of the PCB and mechanics development~~)<sup>v0.3</sup> in terms of components and interfaces. This approach enables early software development and testing before all hardware of the thermostat is available.

A block diagram of the prototype hardware ~~for software development and testing~~<sup>v0.3</sup> is shown in Figure 2.1. The following components are required:

- **P-NUCLEO-WB55** - MCU development board with Matter-over-Thread standard support

- **eQ-3 eqiva Model N** - Radiator thermostat for disassembly and reuse of its C300 3V motor, gear box and valve connector
- **DRV8833** - Motor driver module
- **Shunt resistor** -  $1\Omega$  shunt resistor for current measurement of the motor
- **1.3" 128 × 64 Organic Light-Emitting Diode (OLED) Display incl. SH1106**
  - Display with an embedded driver
- **KY-040** - Rotary encoder
- **Connecting wires**
- **Breadboard(s)**
- **Power supply** - laboratory power supply or batteries

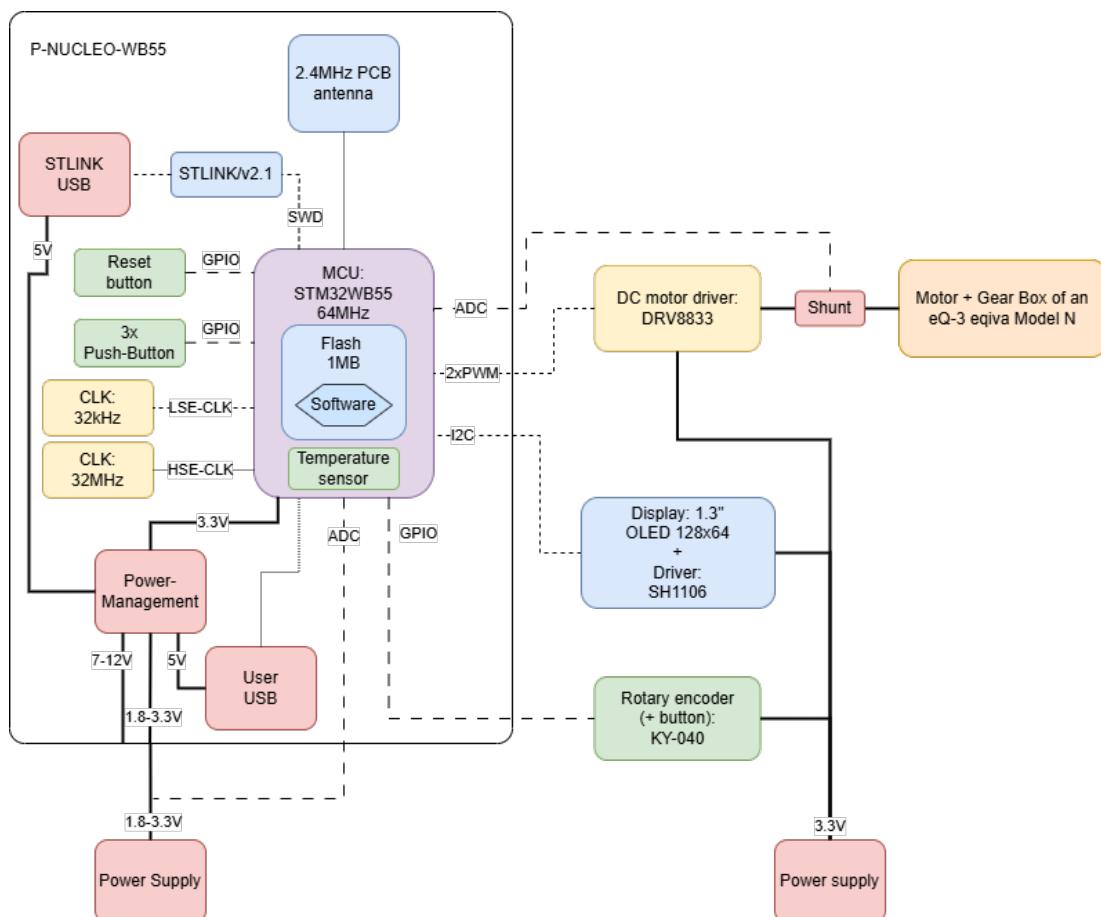


Figure 2.1: Block diagram of the **thermostat's<sup>v0.3</sup>** prototype hardware ~~for software development and testing<sup>v0.3</sup>~~

## 3 Requirements

### 3.1 Functional Requirements

#### **NOTE 2: Prototype Requirements<sup>v0.3</sup>**

The requirements mentioning a prototype (REQ 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 8.1) could be subject to change or removal in the final product version. They are included to define the initial hardware and software setup for prototyping and testing purposes.<sup>v0.3</sup>

#### **REQ 1: Display**

The softwaresystem<sup>v0.3</sup> shall integrate a display.

##### **REQ 1.1: Prototype Display**

AIn the prototype version, a<sup>v0.3</sup> 1.3" 128×64 OLED display with SH1106 controller over the Inter-Integrated Circuit (I2C) protocol shall be integrated used<sup>v0.3</sup>.

#### **REQ 2: Rotary Encoder**

The softwaresystem<sup>v0.3</sup> shall integrate a rotary encoder as a control wheel via Quadrature Decoder (QDEC) interface.

##### **REQ 2.1: Prototype Rotary Encoder**

AIn the prototype version, a<sup>v0.3</sup> KY-040 rotary encoder module shall be integrated as the control wheel.

## REQ 3: Push Buttons

The **softwaresystem**<sup>v0.3</sup> shall integrate the following push buttons via GPIOs:

- **Mode** button
- **Centered** button
- **Menu** button

### REQ 3.1: Prototype Push Buttons

The **In the prototype version, the**<sup>v0.3</sup> push buttons SW1 and SW3 from the P-NUCLEO-WB55 and KY-040 shall be used:

- SW1 as **Mode** button
- KY-040 push button as **Centered** button
- SW3 as **Menu** button

## REQ 4: Motor Control

The **softwaresystem**<sup>v0.3</sup> shall support control of motor driver hardware.

### REQ 4.1: Prototype Motor Control

The **softwaresystem**<sup>v0.3</sup> shall support control of the eQ-3 eqiva Model N C300 3V motor through a DRV8833 motor driver module **using two Pulse Width Modulation (PWM) signals**<sup>v0.3</sup>. (E.g., using two GPIO or Pulse Width Modulation (PWM) signals.)<sup>v0.3</sup>

## REQ 5: Motor Current Measurement

The **softwaresystem**<sup>v0.3</sup> shall measure motor current consumption.

### REQ 5.1: Prototype Motor Current Measurement

The **software****In the prototype version, the system**<sup>v0.3</sup> shall measure motor current consumption using an Analog-to-Digital Converter (ADC) channel connected to a  $1\Omega$  shunt resistor in series with the motor circuit.

## REQ 6: Power Supply Voltage Measurement

The software system<sup>v0.3</sup> shall measure the power supply voltage. The measured voltage shall be used to calculate the battery charge level as a percentage.

### REQ 6.1: Prototype Power Supply Voltage Measurement

The software In the prototype version, the system<sup>v0.3</sup> shall measure the power supply voltage using an ADC channel.

## REQ 7: Motor Current Extremes Definition

During the software development phase, the motor current extremes shall be defined to detect maximal and minimal valve pin positions. This definition shall be based on empirical measurements and analysis of the motor's current consumption during operation.

## REQ 8: Temperature Measurement

The software system<sup>v0.3</sup> shall measure the ambient temperature using a digital temperature sensor.

### REQ 8.1: Prototype Temperature Sensor

The software In the prototype version, the system<sup>v0.3</sup> shall use a temperature sensor integrated into the STM32WB55 MCU of the P-NUCLEO-WB55 development board.

## REQ 9: Configuration Routines

The software system<sup>v0.3</sup> shall provide the following configuration routines for initial setup:

- **Configuration on Device (COD):** Manual configuration via buttons on the device without wireless connectivity.
- **Configuration via App (CVA):** Partially automatic, wireless configuration via Matter standard and/or Thread protocol<sup>v0.2</sup>

The setup process shall run after battery insertion if no complete configuration exists in persistent storage. Otherwise, the **softwaresystem<sup>v0.3</sup>** shall resume normal operation with existing settings.

#### **REQ 9.1: Configuration Routine Choice<sup>v0.2</sup>**

~~The user shall be able to choose between the CVA (“Configuration via App”) and COD (“Configuration on Device”) before the initial setup process.~~<sup>v0.2</sup>

#### **REQ 9.2: Prototype Configuration<sup>v0.2</sup>**

~~In the prototype version of the thermostat software, only the COD shall be implemented. Wireless connectivity and the CVA shall not be supported.~~<sup>v0.2</sup>

#### **REQ 9.3: Configuration Via App Blocking<sup>v0.2</sup>**

~~The system shall block access to the CVA in the prototype version of the thermostat software.~~<sup>v0.2</sup>

### **REQ 10: Date and Time Configuration**

The **softwaresystem<sup>v0.3</sup>** shall request date and time configuration as the first step in the COD, or each time if no wireless connection is configured. The user shall be able to set the year, month, day, hour, and minute through the control wheel interface with confirmation capability via the centered button. After setting the date and time, the **softwaresystem<sup>v0.3</sup>** shall ask whether the user wants to enable automatic summer/winter time switching.

### **REQ 11: Installation Command**

The **softwaresystem<sup>v0.3</sup>** shall wait for an installation begin command from the user as the second step in the COD. The text “Begin Installation?” shall be displayed. The user shall initiate the installation by pressing the centered button, which will start the valve adaptation procedure.

## NOTE 1: Pin Position Extremes Definition

After a successful **valve<sup>v0.2</sup>** adaptation procedure described in **REQ 12<sup>v0.2</sup>**:

- The maximal **movable<sup>v0.2</sup>** valve pin position corresponds to the fully open valve position.
- The minimal **movable<sup>v0.2</sup>** valve pin position corresponds to the fully closed valve position.

## REQ 12: Valve Adaptation

The **software<sup>v0.3</sup>** system shall perform an automatic adaptation run as the third step in the COD to detect and adapt to specific valve characteristics. The adaptation procedure shall:

1. Display “Adaptation...” indicator page during the procedure.
2. Move the motor to the maximal valve pin position.
3. Move the motor to the minimal valve pin position.
4. Incrementally move the motor to the maximal valve pin position.
5. Calculate the valve stroke range.
6. Validate that the measured travel distance matches the expected 4.3mm linear travel.
7. If valve characteristics are outside acceptable ranges, display the following error messages:
  - **F1:** Valve drive sluggish (motor movement is impeded or extremely slow).
  - **F2:** Actuating range too wide (measured valve stroke exceeds expected parameters).
  - **F3:** Adjustment range too small (measured valve stroke is below acceptable minimum).
8. If an error occurs, allow reversal of the adaptation run by pressing the centered button, returning to the waiting state for the installation command.

### REQ 13: Daily Schedule Configuration

The **softwaresystem<sup>v0.3</sup>** shall request daily schedule configuration as the fourth step in the COD. The user shall be able to set three time slots with corresponding target temperatures for the day using the control wheel interface with confirmation capability via the centered button. The first time slot shall always start at 00:00 and the last time slot shall always end at 23:59. After completing the daily schedule configuration, the **softwaresystem<sup>v0.3</sup>** shall proceed to the main display page.

### REQ 14: Main Display Page

On the main display page, the **softwaresystem<sup>v0.3</sup>** shall display at least the following information:

- Current time in hours and minutes.
- Current temperature.
- Target temperature.
- Current time slot.
- Operational mode indicator.
- Battery charge as a percentage.

### REQ 15: Configuration Menu

The **softwaresystem<sup>v0.3</sup>** shall provide a configuration menu page accessible from the main display page by pressing the menu button. The menu shall list the following configurable options:

- Temperature offset configuration.
- Factory reset function.

### REQ 16: Inactivity Timeout

If no user interactions occur for 30s, the **softwaresystem<sup>v0.3</sup>** shall turn the display off. The **softwaresystem<sup>v0.3</sup>** shall return to the currently active page upon the next user interaction via any button.

## REQ 17: Operational Modes

The **softwaresystem<sup>v0.3</sup>** shall support the following operational modes:

- **Manual Mode:** The user can manually set the target temperature.
- **Auto Mode:** The **softwaresystem<sup>v0.3</sup>** follows the heating program and sets the target temperature according to the current time slot.
- **Boost Mode:** Described in REQ 19.

## REQ 18: Switching Operational Modes

The **softwaresystem<sup>v0.3</sup>** shall allow switching between Manual Mode and Auto Mode using the mode button.

## REQ 19: Boost Mode

The **softwaresystem<sup>v0.3</sup>** shall provide a boost mode that immediately opens the heating valve to 80% for 5min after double-pressing the control wheel button. Then the **software system<sup>v0.3</sup>** shall display the remaining time instead of the target temperature on the main display page. The remaining time shall be displayed as a countdown in seconds. The function shall be deactivatable at any time by pressing the control wheel button.

## REQ 20: Temperature Range and Resolution

In Manual Mode, the **softwaresystem<sup>v0.3</sup>** shall allow setting target temperatures in the range of 5.0°C to 30.0°C in increments of 0.5°C. The **softwaresystem<sup>v0.3</sup>** shall support the following special states:

- **CLOSED state:** When the user sets a target temperature below 5.0°C, the valve shall be fully closed. Then the **softwaresystem<sup>v0.3</sup>** shall display “CLOSED” instead of the target temperature on the main display page.
- **OPEN state:** When the user sets a target temperature above 30.0°C, the valve shall be fully opened. Then the **softwaresystem<sup>v0.3</sup>** shall display “OPEN” instead of the target temperature on the main display page.

## REQ 21: Temperature Offset Configuration

The **softwaresystem<sup>v0.3</sup>** shall allow setting a temperature offset between  $-3.5^{\circ}\text{C}$  and  $+3.5^{\circ}\text{C}$  in increments of  $0.5^{\circ}\text{C}$ . The default value shall be  $0.0^{\circ}\text{C}$ . The offset shall be applied to the measured temperature to calculate the effective temperature.

## REQ 22: Automatic Summer/Winter Time Switching

The **softwaresystem<sup>v0.3</sup>** shall automatically switch between summer and winter time.

## REQ 23: Persistent Settings Storage

The **softwaresystem<sup>v0.3</sup>** shall persist all user-configured settings in non-volatile memory. These settings shall survive battery removal and replacement.

## REQ 24: Factory Reset

The **softwaresystem<sup>v0.3</sup>** shall provide a factory reset function that clears all user settings and returns to default configuration. A confirmation prompt page (“Confirm Factory Reset?”) shall be displayed to prevent accidental data loss.

## REQ 25: Automatic Descaling Routine

The **softwaresystem<sup>v0.3</sup>** shall perform an automatic descaling routine once a week on Saturday at 12:00 to protect against calcification of the valve. The descaling procedure shall:

- Display “Maintenance...” indicator page.
- Ignore any user inputs during the routine.
- Move the motor through its full stroke range at maximum speed.

The calcification protection routine shall continue running in all operational modes except Boost Mode. If Boost Mode is active, the **softwaresystem<sup>v0.3</sup>** shall wait until it is deactivated before beginning the descaling routine.

### **REQ 28: Deep Sleep Mode<sup>v0.2</sup>**

The softwaresystem<sup>v0.3</sup> shall enter a deep sleep mode to minimize power consumption when no user interactions occur for 3s30s<sup>v0.3</sup> after an inactivity timeout (described in REQ 16) and no tasks are being executed (e.g., Boost Mode). In deep sleep mode, all non-essential functions shall be disabled, and the softwaresystem<sup>v0.3</sup> shall only wake up upon user interaction or scheduled tasks (e.g., Descaling Routine).<sup>v0.2</sup>

### **REQ 30: Control Algorithms Integration<sup>v0.3</sup>**

The software shall make possible the integration of control algorithms (e.g., Proportional-Integral-Derivative (PID) control) to regulate the valve position based on the difference between the target temperature and the effective temperature.<sup>v0.3</sup>

## **3.2 Non-Functional Requirements**

### **REQ 26: Energy Efficiency<sup>v0.2</sup>**

The system shall be designed for low power consumption to maximize battery life. Deep sleep modes and efficient peripheral management shall be implemented to minimize energy usage during idle periods.<sup>v0.2</sup>

### **REQ 27: User Interface Responsiveness<sup>v0.2</sup>**

The system shall provide immediate visual feedback for all user interactions via the control wheel and buttons, with display updates occurring within acceptable latency for user perception.<sup>v0.2</sup>

### **REQ 29: Display Update Latency<sup>v0.2</sup>**

The softwaresystem<sup>v0.3</sup> shall update the display within 150ms after each user interaction or softwaresystem<sup>v0.3</sup> event, provided that these require a display change.<sup>v0.2</sup>

**REQ 30: Hardware Components Replaceability<sup>v0.3</sup>**

The software shall be designed to allow easy replacement of hardware components (e.g., display, driver Integrated Circuit (IC) of the motor, temperature sensor) with minimal changes to the codebase. Hardware abstraction layers shall be implemented to facilitate this replaceability.<sup>v0.3</sup>

## 4 Planning

### 4.1 Time plan

The master project will presumably have the duration of 13 Calendar Weeks (CWs), which are divided into:

- CWs 44-45: Software requirements analysis.
- CW 46: Software architecture design.
- CW 47: Design of software interfaces.
- CW 48: Implementation and tests of software drivers.
- CW 49: Motor Current Extremes Definition.
- CWs 50-52: Implementation and tests of program logic.
- CWs 01-03: Paper writing.
- CWs 04-05: Final review and submission of the paper.

Each calendar week will approximately consist of  $\frac{150\text{h}}{14} \approx 10.7$  hours of work.

### 4.2 Responsibilities

The whole work will be carried out by Alexander Menzel. The advisor for this master project will be Prof. Dr. Uwe Werner.

E-Mails and questions should be answered within 2 working days by both parties. If any problems arise, the advisor has to be informed as soon as possible.

## Bibliography

- [1] eQ-3 AG, *Operating Manual BLUETOOTH® Smart Radiator Thermostat UK eqiva CC-RT-M-BLE-EQ*, May 2018.
- [2] Wikipedia contributors, *Matter (standard)* — Wikipedia, the free encyclopedia, [Online; accessed 28-October-2025], 2025. [Online]. Available: [https://en.wikipedia.org/w/index.php?title=Matter\\_\(standard\)&oldid=1318221979](https://en.wikipedia.org/w/index.php?title=Matter_(standard)&oldid=1318221979)

## List of Figures

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## List of Abbreviations

<b>CW</b>	Calendar Week
<b>MCU</b>	Micro Controller Unit
<b>PCB</b>	Printed Circuit Board
<b>API</b>	Application Programming Interface
<b>COD</b>	Configuration on Device
<b>CVA</b>	Configuration via App
<b>OLED</b>	Organic Light-Emitting Diode
<b>QDEC</b>	Quadrature Decoder
<b>GPIO</b>	General Purpose Input/Output
<b>I2C</b>	Inter-Integrated Circuit
<b>PWM</b>	Pulse Width Modulation
<b>ADC</b>	Analog-to-Digital Converter
<b>PID</b>	Proportional-Integral-Derivative
<b>IC</b>	Integrated Circuit

## List of Symbols

Symbol	Meaning	Units
$D$	Distance	mm
$U$	Electric voltage	V
$R$	Electrical resistance	$\Omega$
$d$	Diagonal	" (inches)
$T$	Temperature	$^{\circ}\text{C}$
$t$	Time	ms, s, min
$v$	Valve position	%