Software Development for a Smart Radiator Thermostat

Exposé for a Master Project

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1 Problem description

Heating is one of the most CO_2-intensive areas of human life. In Germany, around 210 million tons of $CO2$ of the general total of 762 million tons of CO_2 equivalents emitted in 2021 came from heating private living spaces. [1] [2]

Effective heating control has an average saving potential of between 8 and 19%, which can be achieved through the use of intelligent heating controllers and smart home systems. [3]

Whereas such control systems are sophisticated and widespread in developed countries such as Germany, most of them are fully proprietary. There is currently no project of public domain, which could be used as a base for research, development and production of smart heating controllers or thermostats.

The general aim of this master's project is to develop a modern software for a Micro Controller Unit (MCU) based radiator thermostat and to contribute it to the public domain.

2 Theoretical fundamentals and state of the art

A radiator thermostat is a device, which is mounted on a heating radiator valve to control the flow of hot water through it. This allows the thermostat to regulate the room temperature.

As described in [4] and shown in figure 2.1, a digital radiator thermostat typically consists of the following components:

- PCB with User Interface (UI) including buttons, rotary encoder, display, motor driver, and other components
- Direct Current (DC)-motor
- Gear box with planetary gears
- Valve connector

Most digital thermostats are MCU-based and battery powered. Smart thermostats often include additional features such as Wireless Local Area Network (WLAN) or Bluetooth Low Energy (BLE) connectivity and mobile app integration.

Descriptions of common thermostats such as eQ-3 MAX! from [4] and smart eQ-3 eqiva Bluetooth from [5] can be used as a reference for functional scope of the software to develop. For example they implement following functions:

- Mode selection (Auto, Manual, Boost, Vacation)
- Manual temperature adjustment
- Weekly schedule programming
- Decalcification program
- Open-window function

Commonly the following qualities are expected from digital radiator thermostats:

- Low power consumption to maximize battery life (e.g. 2 years on 2xAA batteries)
- Reliable operation (e.g. operate reliably even on valves with minor calcification)
- User-friendly UI
- Easy installation and setup

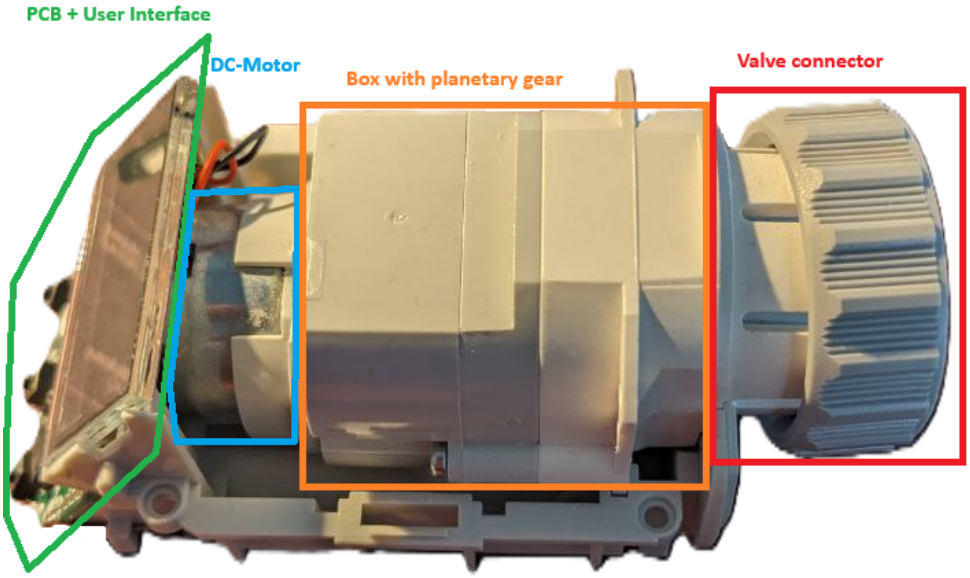

Figure 2.1: Photo of a partially disassembled radiator thermostat eQ-3 eqiva (version without Bluetooth).

3 Objectives and concept presentation

The focus of the presented master project is the development of a modern software for a MCU-based radiator thermostat and its contribution to the public domain. The master project will be realized as a part of a bigger interdisciplinary development, which includes:

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

In the first part of this project, a basic software for the device should be implemented including hardware drivers, main state machines and tasks. At the end of this part a scientific paper will be written as an Institute of Electrical and Electronics Engineers (IEEE) report, describing the developed software architecture and design decisions.

The software should be designed ready for prospective integration of the control algorithms and BLE. The latter feature is supposed to be used for smart home applications, specifically for the integration of the thermostat in Home Assistant and/or for provisioning of a Hypertext Transfer Protocol (HTTP) Application Programming Interface (API) using a gateway.

The following points are consequently objectives of this master project:

- Development or integration of drivers for all radiator thermostat components.
- Design of the software according to basic consumer functions and hardware features.
- Implementation and tests of the designed software.
- Writing of an IEEE report describing program design.

4 Provisional outline

The contents of the feature IEEE paper will presumably be:

I. Introduction

II. Related work

III. Software design

   A. Architecture

   B. Interfaces

IV. Results of Implementation

   A. Drivers

   B. Program Structure

   C. Test Results

V. Conclusion and Outlook

5 Time plan

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

- CWs 43-44: Software requirements analysis.
- CW 45: Software architecture design.
- CW 46: Design of software interfaces.
- CW 47: Implementation and tests of software drivers.
- CWs 49-51: Implementation and tests of main program structure.
- CWs 52-02: Paper writing.
- CWs 03-04: Final review and submission of the paper.

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List of Abbreviations

CW	Calendar Week
MCU	Micro Controller Unit
PCB	Printed Circuit Board
API	Application Programming Interface
UI	User Interface
WLAN	Wireless Local Area Network
BLE	Bluetooth Low Energy
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
DC	Direct Current

