Heater Control System - System Design Document

Introduction

This document outlines the design for a Heater Control System implemented using an ESP32 microcontroller and the ESP-IDF framework. The system reads temperature values from a digital TMP117 sensor connected via I^2C and controls the heater ON/OFF state based on predefined thresholds. It also logs system states via UART for monitoring. The design prioritizes scalability and reliability with digital sensing and structured communication.

1. Sensors

- *Digital Temperature Sensor: TMP117 (I^2C)*
  - Provides high-accuracy temperature readings with minimal noise.
  - Communicates with the ESP32 via I^2C for robust and scalable integration.
  - The sensor is placed close to the heater element to provide real-time temperature feedback for precise control.

2. Communication Protocol

Communication in this system occurs in two parts:

2.1 Sensor to MCU (ESP32)

- *Protocol Used: I^2C*
  - TMP117 uses I^2C for reliable digital data exchange.
  - Supports multiple devices on the same bus (scalable in future).
  - Ensures noise immunity and accuracy over analog voltage-based methods.

2.2 MCU to External System (Logging and Monitoring)

- *Protocol Used: UART (Serial)*
  - Transmits temperature readings and system state logs to the PC.
  - Simple and efficient for real-time logging.
  - Easily supported in Wokwi and ESP-IDF.

3. System Overview, Block Diagram and States

Key Modules:

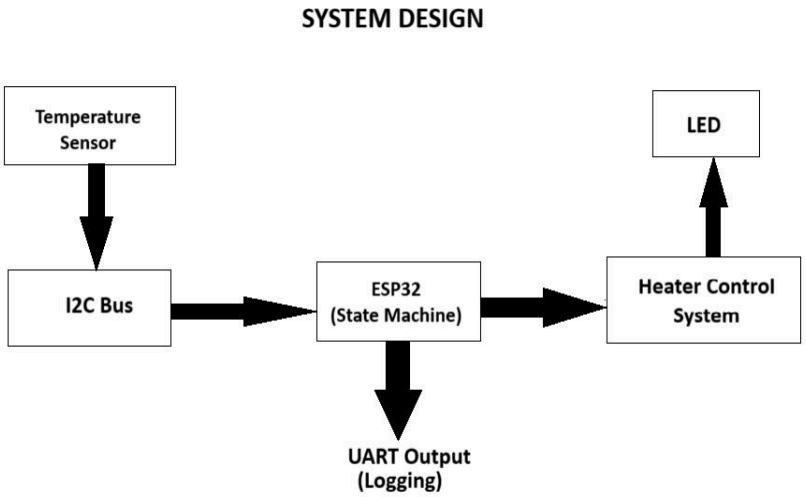
- ESP32 Microcontroller for processing and control

- TMP117 Digital Temperature Sensor via I^2C

- Heater Simulation (LED) to represent ON/OFF operation

- UART Logger for transmitting logs to PC

Block Diagram:



Block Diagram

System States:

State	Condition	Action
Idle	Temperature > 52°C	Heater OFF
Heating	Temperature < 48°C	Heater ON
Stabilizing	48°C ≤ Temperature ≤ 52°C	Toggle to maintain temperature
Target Reached	Stable around 50°C for 5 seconds	Heater OFF
Overheat	Temperature > 60°C	Heater OFF (safety shutdown)

4. Future Roadmap

Multiple Heating Profiles

- Define selectable profiles with varying target temperatures (e.g., Low: 40°C, Medium: 50°C, High: 60°C).
- Allow switching profiles via UART commands or mobile app (future BLE integration).
- Software logic dynamically adjusts control thresholds and behavior for each profile.
- Profiles can be tuned for different environmental or application needs.

Overheating Protection Enhancements

- Implement dual sensor setup: one sensor close to the heater, one at a safer distance for ambient monitoring.
- If the temperature exceeds a safety threshold (e.g., 60°C), disable the heater instantly.
- Add fail-safe cutoff via software and optionally hardware (relay or safety circuit).
- Integrate user alerts using buzzer or flashing LED in overheated condition.

BLE Integration (Optional Future Scope)

- Use ESP32 BLE capabilities for wireless control and mobile app connectivity.
- Enables wireless monitoring of temperature, heater state, and profile switching.

Conclusion

This design provides a robust and scalable Heater Control System. The current implementation uses a digital TMP117 sensor with I^2C communication and UART-based logging for monitoring. An LED simulates heater ON/OFF states. The system is well-positioned for upgrades including multiple heating profiles, BLE control, and smart safety mechanisms.