

# System Design

## Basic Heater Control System

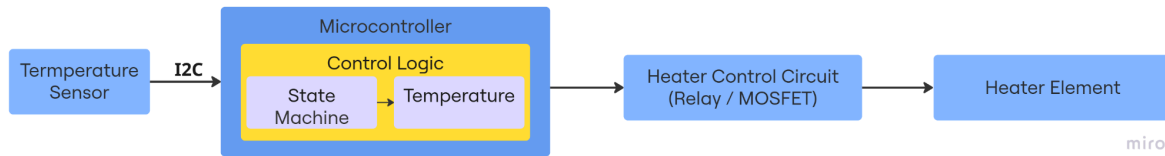


Fig: Basic heater control system without the practical usage components that provide safety, usability, expandability

## Basic Heater Control System (practical usage)

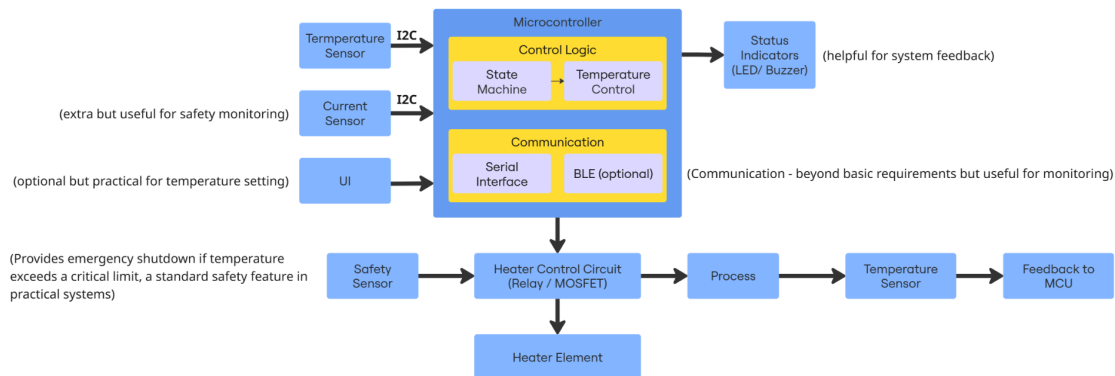


Fig: Basic heater control system with the practical usage components

## Explanation of Components in the Basic Heater Control System

- **Temperature Sensor:**  
Measures the temperature of the environment or object being heated ("process"). It sends this data to the microcontroller, allowing the system to monitor real-time temperature and make control decisions.
- **Current Sensor (optional):**  
Monitors the electrical current flowing to the heater element. This is an extra safety feature: it can detect abnormal current draw, which may indicate faults like a short circuit or heater failure.
- **UI (User Interface, optional):**  
Allows the user to set or adjust the target temperature or other parameters. This can be a simple knob, buttons, or a digital display.

- **Microcontroller:**  
The brain of the system. It processes sensor inputs and user settings, runs the control logic (state machine and temperature control with hysteresis), and manages communication and outputs.
  - **Control Logic:**
    - **State Machine:** Manages the system's operational states (e.g., idle, heating, fault).
    - **Temperature Control:** Compares the measured temperature to the setpoint and decides when to turn the heater on or off.
  - **Communication:**
    - **Serial Interface:** For wired communication with external devices (e.g., for debugging or monitoring).
    - **BLE (optional):** For wireless communication, allowing remote monitoring or control.
- **Status Indicators (LED/Buzzer):**  
Provide visual or audible feedback about the system status, such as power on, heating, or fault conditions.
- **Safety Sensor:**  
A dedicated sensor (like a thermal cutoff or secondary temperature sensor) that triggers an emergency shutdown if the temperature exceeds a critical safety threshold-an essential feature for preventing overheating.
- **Heater Control Circuit (Relay/MOSFET):**  
Acts as a switch, controlled by the microcontroller, to turn the heater element on or off based on the control logic.
- **Heater Element:**  
The actual device that generates heat to raise the temperature of the process.
- **Process:**  
The environment or object being heated (e.g., air in a room, water in a tank). The system's goal is to maintain this at the desired temperature.
- **Temperature Sensor (Feedback Loop):**  
Measures the process temperature and sends this information back to the microcontroller, closing the feedback loop for continuous control.

### Flow Summary:

User sets a target temperature via the UI → Temperature sensor monitors the process →

Microcontroller processes inputs and runs control logic → If heating is needed, microcontroller activates the heater via the control circuit → Status indicators provide feedback → Safety sensor ensures emergency shutdown if needed → Current sensor monitors for electrical faults → The process temperature is continually fed back for ongoing regulation.