**THE UNIVERSITY OF TEXAS AT ARLINGTON**

**COMPUTER SCIENCE AND ENGINEERING**

**EMBEDDED SYSTEMS II**

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**Brew Buddy Project Report**

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# **Abstract**

BrewBuddy is a smart coffee heater designed to maintain beverages at the perfect drinking temperature with precision, convenience, and safety. By combining accurate temperature sensing, configurable heating control, and robust safety mechanisms, BrewBuddy solves the common problem of coffee cooling too quickly while offering users precise control over their experience.

The device utilizes an embedded system to detect and regulate the coffee's temperature, displaying real-time temperature readings for added clarity. Users can set highly configurable target temperatures to match their preferences, ensuring a personalized and enjoyable coffee-drinking experience. The heating plate operates efficiently, activating only when necessary to conserve energy, while integrated safety features prevent overheating for peace of mind.

BrewBuddy delivers a reliable and precise solution that transforms how users enjoy their coffee. It showcases the potential for embedded systems to enhance daily convenience, with opportunities for future upgrades like smart connectivity and expanded user customization.

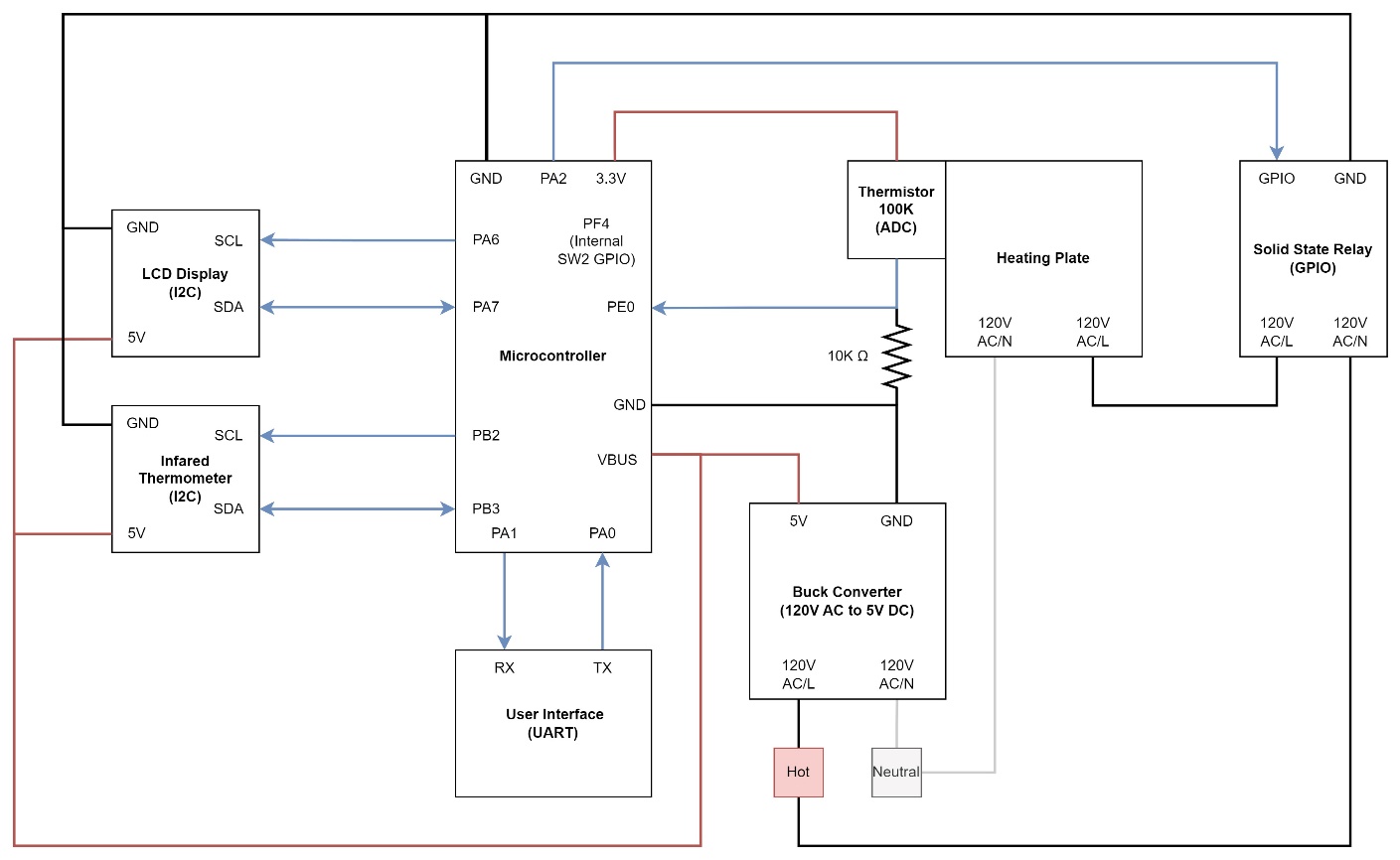
# **System Design and Architecture**

## **High-Level Description**

The BrewBuddy coffee heater is designed to ensure that coffee remains at a user-configurable, ideal drinking temperature. The system accomplishes this by detecting the presence of coffee, measuring its temperature, and regulating heat output precisely.

* System Functionality
  + Measure the coffee’s temperature using an infared thermometer.
  + Display the temperature of the coffee with an LCD display.
  + Heat the coffee to a user-specified temperature via a heating plate controlled by a solid state relay.
* Key Features
  + User Configurability: Temperature can be set in increments of 10 by holding a push button or precise increments over UART.
  + Safety Mechanism: A thermistor-based temperature monitor ensures that the heating plate doesn’t exceed safe operating limits, triggering a safety shutdown if necessary.
  + Energy Efficiency: The heater only activates when coffee is detected and the temperature is below the desired threshold, minimizing power usage.

## **Block Diagram**



## **Components**

* **Sensors**:
  + **Infrared Thermometer (I2C)**: Measures coffee surface temperature accurately without physical contact.
  + **100K Thermistor**: Integrated with a voltage divider circuit to monitor heating plate temperature and prevent overheating.
* **Microcontroller (TM4C123GH6PM):**
  + Reading sensor data from the I2C infrared thermometer.
  + Retrieving voltage data from the thermistor ADC.
  + Controlling the heating plate via GPIO and solid-state relay.
  + Handling user input from the GPIO button and UART communication.
  + Driving the I2C LCD display for real-time updates.
* **Heating Element and Control System**:
  + **Solid-State Relay**: Provides reliable and efficient control of the 120V AC heating element using a GPIO signal from the microcontroller**.**
  + **Heating Plate**: Directly warms the coffee cup with regulated energy output.
* **User Interface**:
  + **LCD Display (I2C)**: Provides real-time updates on temperature and user settings for an intuitive experience.
  + **GPIO Button**: Enables users to set broad target temperatures.
  + **UART Interface:** Allows external devices to configure safety parameters, set precise temperature levels, and monitor system performance.
* **Power Supply**:
  + **120V to 5V DC Buck Converter**: Converts high-voltage AC to low-voltage DC for powering the microcontroller and auxiliary components.

## **Design Decisions**

1. **Infrared Thermometer (I2C)**
   1. **Why Chosen**:
   * **Non-Contact Measurement**: The infrared thermometer provides accurate surface temperature measurements without physical contact, which is essential for maintaining the purity of the coffee and preventing interference.
   * **I2C Communication**: This interface allows for easy integration with the microcontroller, minimizing the number of pins needed for communication. It also supports multiple devices, making it a flexible solution for future expansions.

* **Trade-offs**:
  + **Cost vs Accuracy**: Infrared thermometers are typically more expensive than simple thermocouples or thermistors. However, the non-contact nature and greater accuracy justify the cost, especially since precision is a key requirement for this project.

**2. 100K Thermistor with Voltage Divider**

* **Why Chosen**:
  + **Cost-Effectiveness**: Thermistors are affordable and readily available, making them an ideal choice for monitoring the heating plate’s temperature without adding significant cost to the overall system.
  + **Simplicity**: Using a voltage divider circuit to convert the thermistor’s resistance to a readable voltage ensures simple and effective temperature detection. The ADC on the microcontroller can easily process this signal.
* **Trade-offs**:
  + **Accuracy vs Complexity**: While thermistors provide good accuracy for the application, they are less precise than more expensive temperature sensors (e.g., RTDs). However, the cost savings and simplicity of implementation outweigh the slight reduction in accuracy for this application.

**3. Solid-State Relay (GPIO-Controlled)**

* **Why Chosen**:
  + **Reliability and Longevity**: Solid-state relays (SSRs) provide faster switching times and are more durable than mechanical relays, which would wear out over time. This is essential for ensuring long-term, reliable operation of the coffee heater.
  + **Silent Operation**: SSRs have no moving parts, leading to quieter operation compared to mechanical relays, which is important for consumer products.
* **Trade-offs**:
  + **Cost vs Switching Speed**: SSRs are typically more expensive than mechanical relays. However, their reliability, fast response times, and ability to handle high currents justify the added cost in this context.

**5. LCD Display (I2C)**

* **Why Chosen**:
  + **User Experience**: The LCD display provides an intuitive way for users to monitor the real-time temperature of their coffee and adjust settings. The I2C interface reduces wiring complexity, allowing a more streamlined design.
* **Trade-offs**:
  + **Size vs Cost**: While a larger or more advanced display could offer more features, such as touch functionality or a higher resolution, a simple LCD display was chosen to balance cost and the required functionality, as it provides sufficient feedback for this application.

**6. 120V to 5V DC Buck Converter**

* **Why Chosen**:
  + **Power Efficiency**: A buck converter is a highly efficient solution for stepping down the 120V AC to the required 5V DC for powering the microcontroller and other components. This ensures minimal energy loss, which is important for overall energy efficiency in the system.
  + **Compact and Reliable**: Buck converters are compact, reliable, and readily available, making them a good choice for efficiently powering low-voltage components in a system that operates on high-voltage AC power.
* **Trade-offs**:
  + **Size vs Power Output**: While the buck converter provides efficient power conversion, there is a trade-off in terms of the physical size compared to simpler power supplies. However, the improved efficiency and stability of the system outweigh the slight increase in size.

**7. Heating Plate and Heating Element**

* **Why Chosen**:
  + **Efficiency and Heat Transfer**: The heating plate offers an even and efficient method for warming the coffee, ensuring consistent temperature regulation across the entire surface of the cup. It is crucial to maintain an ideal temperature without causing local overheating.
* **Trade-offs**:
  + **Power Consumption vs Control**: While the heating element provides sufficient power to heat the coffee effectively, there is a trade-off in power consumption. The system uses a solid-state relay and precise temperature regulation to mitigate this, balancing energy usage with performance.

**8. UART Interface**

* **Why Chosen**:
  + **Configuration Flexibility**: UART allows for easy configuration of system parameters, including temperature thresholds and safety limits. It facilitates debugging and external monitoring, making it a valuable tool for future adjustments and integrations.
* **Trade-offs**:
  + **Complexity vs Simplicity**: While UART provides a high degree of flexibility and configurability, it adds complexity to the design and communication. However, the added capability for remote configuration and adjustments makes it a worthwhile trade-off, especially for users who want more control over the system.

# **Implementation**

**System Design and Architecture (20%)**

Detail the structure and functionality of your system:

1. **High-Level Description**:
   * System functionality (detect coffee, measure temperature, heat to the desired level).
   * Key features (e.g., energy efficiency, safety mechanisms).
2. **Block Diagram**:
   * Include a diagram of the system architecture (sensors, microcontroller, heater, power supply).
3. **Components**:
   * Sensors (e.g., temperature sensor, weight sensor to detect coffee presence).
   * Embedded processor (e.g., microcontroller).
   * Heating element and control system (e.g., relay or MOSFET).
4. **Design Decisions**:
   * Why specific components and methods were chosen.
   * Trade-offs in system design (e.g., cost vs performance).

# **Results and Testing**

Describe how the system was tested and the outcomes:

1. **Testing Methodology**:
   * Procedures for verifying sensor accuracy and heating performance.
   * Test cases (e.g., detecting empty cups, varying ambient temperatures).
2. **Results**:
   * Measurements (e.g., time taken to heat coffee to a set temperature).
   * System accuracy (e.g., temperature stability).
3. **Performance Metrics**:
   * Energy efficiency.
   * Reliability and responsiveness.
4. **Graphs and Tables**:
   * Include graphs of temperature over time, test case results, etc.
5. **Limitations**:
   * Identify areas where the system could be improved.

# **Conclusion and Future Work**

1. **Summary of Achievements**:

* How the system met the project goals.
* Key benefits of the design.

1. **Future Enhancements**:

* Ideas for improvement (e.g., adding IoT functionality, advanced sensors, mobile app control).
* Scaling the system for commercial use.