ECE 445 SP24

Project Proposal

Team 3: Dough Monitor

Team

Jake Hayes (jhayes@illinois.edu)

Abhitya Krishnaraj (abhitya2@illinois.edu)

Alec Thompson (alect3@illinois.edu)

TA

Tianxiang Zheng (tz32@illinois.edu)

February 8, 2024

Contents

Introduction

Problem

Making bread at home, especially sourdough has become very popular because it is an affordable way to get fresh-baked bread that's free of preservatives and other ingredients that many people are not comfortable with. Sourdough also has other health benefits such as a lower glycemic index and greater bioavailability of nutrients.

However, the bulk fermentation process (letting the dough rise) can be tricky and requires a lot of attention, which leads to many people giving up on making sourdough. Ideally, the dough should be kept at around 80 degrees F, which is warmer than most people keep in their homes, so many people try to find a warm place in their home such as in an oven with a light on, but it's hard to know if the dough is kept at a good temperature. Other steps need to be taken when the dough has risen enough, but rise time varies greatly, so you can't just set a timer, and if you wait too long the dough can start to shrink again. In the case of activating dehydrated sourdough starter, this rise and fall is normal and must happen several times; and its peak volume is what tells you when it's ready to use.

Solution

Our solution is to design a device with a distance sensor and temperature sensor that can be attached to the top and underside of most types of lids, using magnets. The sensors will be controlled with a microcontroller; and an LCD display will show the minimum, current, and maximum heights of the dough along with the temperature. This way the user can see at a glance how much the dough has risen, whether it has already peaked and started to shrink, and whether the temperature is acceptable or not. There is no need to remove it from its warm place and uncover it, introducing cold air; and there is no need to puncture it to measure its height or use some other awkward method. A typical use case will proceed as follows:

1. The device is attached to a container’s lid with the sensor enclosure on the underside and the display and buttons on the topside, and the lid is placed on the container.
2. The button to set container height is pressed. The device measures the distance to the bottom of the container and temporarily displays the result so the user can confirm.

3. A ball of dough that needs to rise is placed in the container, and the button to set dough height is pressed. The device records and displays the current height as both starting height and maximum height.
4. The container is placed in a warm location so the dough can rise. The device periodically updates the temperature, current height, and peak height on the display. The starting height continues to be displayed unchanged.
5. When the dough reaches the desired height, or when the user sees that the current height is lower than the peak height, then the dough is removed.

A similar process can be followed for sourdough starter, except that the starter will peak and fall after every feeding, and the user can optionally press the set dough height button each time. The user will decide when the starter is ready based on the peak height rather than the current height. The device will not attempt to tell the user when the dough/starter is ready because that is a judgment call that depends on the type of bread, the recipe, and the baker's personal preference. Instead, the device makes it easy for the user to see the information they need to make their decision.

Visual Aid

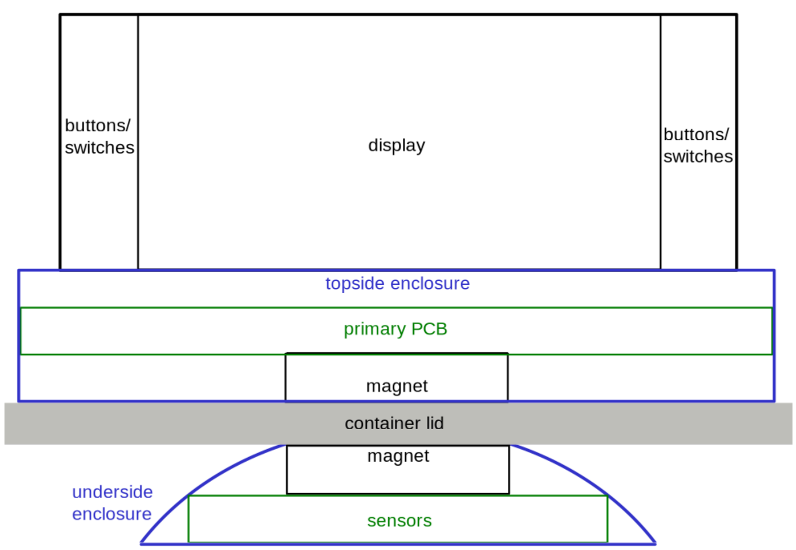

Figure 1: Device Front

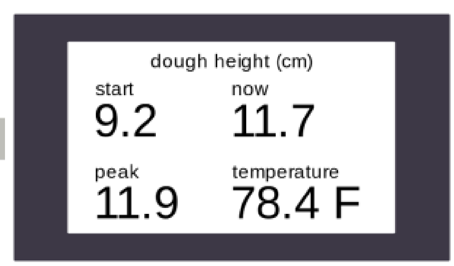

Figure 2: Display layout

High-level Requirements List

- Charge the battery and operate on battery power for at least 10 hours, but ideally a few days for wider use cases and convenience.
- Accurately read and store distance values (+-10% of total height, minimum height 3 centimeters) and temperature values (within 3°C).
- Display the minimum height, maximum height, current height, and current temperature values on a display, updated at least once every five minutes.

Design

Block Diagram

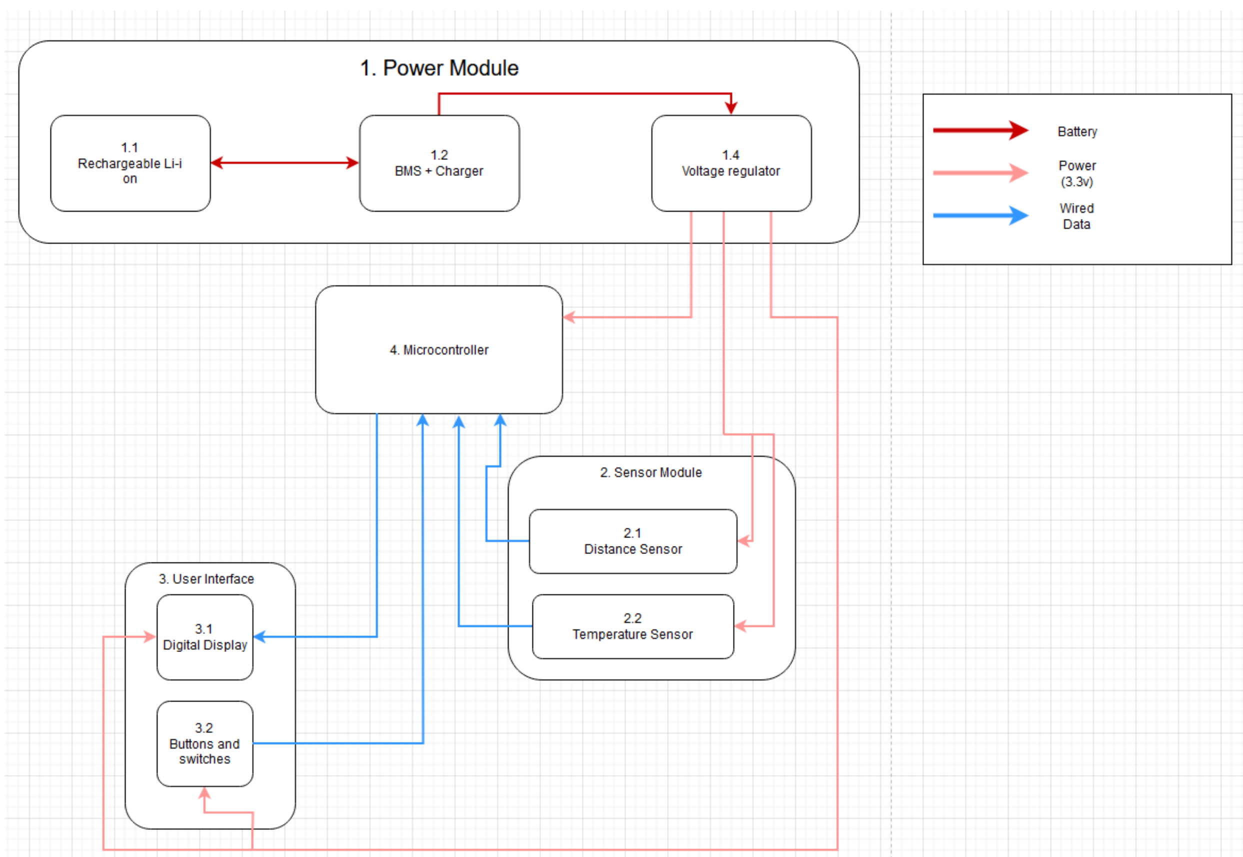

Figure 3: Block Diagram

Subsystem Overview

1. Power Subsystem

Rechargeable Lithium Ion battery capable of staying on for at least one batch of dough (at least 200 mAh) along with a USB charging port and the necessary circuitry to charge the battery. The two halves of the device (top and underside of lid) will be wired together to share power and send and receive data.

2. Sensor Subsystem

Sensors will be placed on the part of the device that attaches to the underside of a lid. A temperature sensor will measure the ambient temperature near the dough to ensure the dough is kept at an acceptable temperature. The temperature sensor will be an analog sensor that sends its measurements back to the MCU via a wire as a voltage value that scales with temperature changes. A proximity sensor or sensors will first measure the height of the container, and then begin measuring the height of the dough periodically. We believe we can achieve acceptable accuracy with one distance sensor; otherwise, we will use multiple sensors if needed. The distance sensor will communicate with the MCU via a wired I^2C interface.

3. User Interface Subsystem

The UI will attach to the top of the lid and consist of several simple switches, push buttons, and a display to control and monitor the device. For example, a switch to turn the device on and off, a button to measure the height of the container, a button to reset the minimum and maximum dough height, a confirm button, a cancel button, a display to show important data to the user (current height, max height, current, temperature), etc. See **Figure 4** for an example of what this might look like.

4. Microcontroller Subsystem

The microcontroller subsystem will collect data from the sensor subsystem at a regular interval (every five minutes or less) and store this data for a short period of time to display to the text display. The microcontroller will also take input from the buttons and switches in the user interface subsystem, which will be essential on the startup of the device to make sure the output on the display is accurate. A typical user control scenario might work like the following:

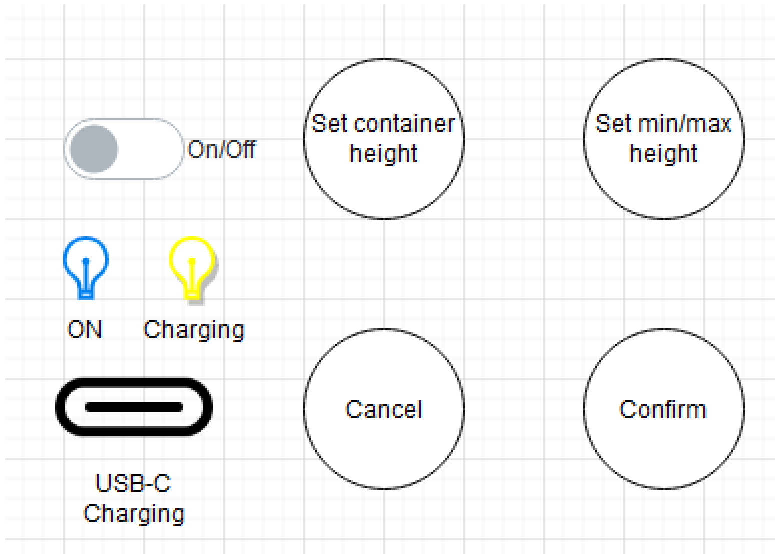

Figure 4: Example UI

The device and MCU would not have power when the switch is in the off position. Once powered on, the device will be waiting on user input for the container height and the starting dough height. To set the container height, the user would press “Set Container Height” and then “Confirm.” This tells the MCU to store the distance value it gets when “Confirm” is pressed as the distance to the bottom of the container. A similar process can be done for the min/max height, but once “Confirm” is pressed, both the minimum and maximum height are recorded by the MCU. The minimum height will stay the same until set again, but the maximum height will change based on what the sensor records periodically, now. Should the user accidentally press a set button when not meaning to, they can press cancel to go back to the prior state. The user will be able to tell the device is on by an “ON” LED (the MCU has power) and that it is charging by a ‘Charging” LED (the USB charging module is being supplied power).

Subsystem Requirements

1. Sensor Subsystem

- Measure the ambient temperature inside a container with an accuracy of ±3°C and transmit the data to the MCU at a rate of at least 1 reading/second.
- Measure the distance from the sensor to the bottom of an empty container and the distance to an object inside the container with an accuracy of of ±1 cm at distances below

10 cm and ±10% at distances from 10-20 cm and transmit the data to the MCU at a rate of at least 1 reading/second.

2. **User Interface Subsystem**
    - Turn the device on and off with a switch on top of the device.
    - Measure or reset the starting height of dough with a button (potentially one button for both measure/reset).
    - Measure or reset the container height with a button.
    - Display the minimum height, maximum height, current height, and current temperature values on a display, updated at least once every five minutes.
3. **Power Subsystem**
    - Supply 5.0V ±10% to the LCD display and 3.3V ±10% to the other subsystems under at least a 400 mA continuous load.
    - Recharge the battery through a port that is exposed to the user.
4. **Microcontroller Subsystem**
    - Store the recorded values from the sensor subsystem for the current "rise", specifically distances (container, dough starting, dough max, and dough current) and the temperature.
    - Compute the average of several consecutive readings to reduce the effect of noise.
    - Use the recorded distance values to calculate dough height (container floor distance minus dough distance).
    - Update the values on the display at least once every five minutes or within 5 seconds of the user pressing a measure/reset button

Tolerance Analysis

One important aspect of the project that poses a risk to successful completion is power, especially power dissipated by the voltage regulator, and ensuring a safe operating temperature. Overheating and causing damage to the components, the dough (or starter), or increasing the overall temperature of the dough beyond what is desired would be detrimental to the project and the safety of the device. We will be looking at the upper bound on the power consumption to determine if our voltage regulator will be within a safe operating range.

Although we have yet to identify exactly which sensors and parts we will be using, these are our current anticipated selections, along with the LT1117-3.3 as our linear voltage regulator.

Part (Operating at 3.3V)	**Max Current Draw at 3.3V**	**Comments**
ESP32-S3	340 mA (1)	Need ESP32 for wifi capabilities for stretch goal. Average case is much lower than the worst case.
VCNL3020-GS18	4 mA (2)	IR Proximity Sensor
LM61BIZ/LFT3	10 mA (3)	Temperature Sensor
NHD-0416BZ-NSW-BBW	22.5 mA (4)	LCD Display
Total	376.5 mA	

This current draw is less than the 800mA max for the LT1117-3.3 (5).
Using $T_j = i_{out}(v_{in} - v_{out})(\Theta_{jc} + \Theta_{ca}) + T_a$ to estimate the junction temperature of the voltage regulator:

Variable	**Value**	**Comments**
$max(T_j)$	125 C	Max operating temperature of LT1117-3.3
i_{out}	376.5 mA	Max current draw @ 3.3V
v_{in}	5.5 V	Max input voltage from USB charging port
v_{out}	3.3 V	Operating Voltage
Θ_{jc}	15° C/W	Junction-to-case thermal resistance of LT1117-3.3
Θ_{ca}	44° C/W	Max Junction-to-ambient was 59° C/W for LT1117-3.3
T_a	38 C	Assume around 100F if a really warm dough environment

With the above values, our T_j = 86.87 C, which is less than the max of 125 C, meaning temperature and power risks are likely, not high for our circuit.

Ethics and Safety

IEEE Code of Ethics

We will uphold the standards of ethical and professional conduct throughout this project as listed in the IEEE Code of Ethics. We commit ourselves to avoiding conflict, offering honest criticism, and communicating with each other if any problems arise. We will treat each other fairly and respectfully, being non-discriminatory, and refraining from harassment and injury of group members.

We strive to support each other throughout this project, maintaining and improving our technical competence while holding ourselves to the highest standards for the delivery of this endeavor.

Food Safety Requirements

Our product falls under the category of food storage, as the dough may come into contact with the system when rising. The NSF/ANSI 2 documentation establishes food protection and sanitation standards for any equipment that comes into contact with food. There are 4 primary standards that we will need to follow to ensure compliance with these standards (6).

- Material Safety: The parts of the system that can potentially come into contact with the dough must be made of materials that are non-toxic and can't migrate chemicals into food upon contact
- Cleanability/Sanitization: The product should be designed to be easily cleaned and sanitized to reduce possible contamination
- Durability: The product should be durable enough to withstand deep cleaning and continuous use without affecting the food involved
- Documentation: The materials used in the product should be properly documented and to ensure compliance with state and federal standards

Safety Concerns

The major safety concerns with our project concern food contamination, the materials we utilize throughout the exterior of the product cannot have any toxic materials or have a possibility of contamination. The product must also be able to withstand a general cleaning and sanitation process if any contaminants do come in contact with it or if any non-food product is found on its surface. There are also some electrical safety concerns regarding the wiring between the top and bottom halves of the solution which will need to be able to withstand some external factors and pressures so that they pose no harm to the user.

Sources

1. https://www.espressif.com/sites/default/files/documentation/esp32-s3_datasheet_en.pdf
2. https://www.vishay.com/docs/84150/vcnl3020.pdf
3. https://www.ti.com/lit/ds/symlink/lm61.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-wwe&ts=1707339882603&ref_url=https%253A%252F%252Fwww.ti.com%252Fgeneral%252Fdocs%252Fsuppproductinfo.tsp%253FdistId%253D10%2526gotoUrl%253Dhttps%253A%252F%252Fwww.ti.com%252Flit%252Fgpn%252Flm61
4. https://newhavendisplay.com/content/specs/NHD-0416BZ-NSW-BBW.pdf
5. https://www.analog.com/media/en/technical-documentation/data-sheets/1117fd.pdf
6. https://blog.ansi.org/nsf-ansi-2-2022-food-equipment-standard/