Project:

Timing Thermometer for Food Industry – Prototype 0

Client:

SD Restaurant Solutions, Inc.

October 30, 2020.

Introduction

The present document includes results obtained in the project development for a proof of concept of a tool that ensures meat products are properly handled. An opportunity to solve a problem was detected: food service providers lack a tool that allows them to monitor proper food handling within "Danger Zone" limits. The "Danger Zone" refers to an internal temperature between 135 °F to 41 °F. Hazardous limits in the Danger Zone are: no more than 6 hours, specifically for temperatures that range between 135 °F to 70 °F for 2 hours, 70 °F to 41 °F for 4 hours. This results in inability to assure product's safety when food providers consider donating it, which results in food waste. The aim is for the tool to help providers ensure that protein meat products are monitored for exposure *(temperature and time)* in the "Danger Zone". Success means the tool allows no meat product to be wasted due to inadequate monitoring practices.

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0.Project Definition

0.1 Project objectives

Project objectives have been established as follows:

- Develop a proof of concept design for a temperature sensing device that monitors food conditions.

- Develop appealing prototype for future investment which helps further define considerations for functionality for future implementations.

- Prototype development that includes first approach to housing design, electronics integration, and interfacing.

- Prototype design development for probe with housing design.

0.2 Project requirements and considerations

The initial guidelines provided by the client for the future vision for the device were established as follows:

General Considerations

1. The tool is intended for catering operations because restaurants often prepare food in advance and lack the means to monitor the internal food temperature.
2. The tool will benefit recipients of donated food.
3. The tool will promote sustainable practices and benefit the environment.
4. The tool will benefit the immunocompromised by improving food handling practices.

Design + Usability requirements

1. The tool must be suitable for different kinds of meat products including fish, poultry, bovine, and pork.
2. The tool must not sacrifice the esthetics of the product being poked.
3. The tool should be stable in position through its use.
4. The tool must provide an audial and or visual alarm to notify staff when a meat product has been exposed to temperatures between 135 °F to 70 °F for 1.5 hours.
5. Tool must provide a reference to assure companies that food was handled properly.
6. Tool should not be easily powered on and off to prevent shutoff during service.
7. The tool must be visible to prevent it being served.
8. The tool must visually fit in a kitchen environment.

0.3 Project Scope

Parting from the previous requirements, CICEII provided the following feedback to ensure the “Prototype 0” proof of concept scope was fully defined for the initial activities. The project scope was defined and agreed by all parts at the beginning of the project. During execution, most heavily on the design phase, the client solicited some changes to be made to the original scope in order to better define the vision for the first proof of concept.

The final scope for project execution is presented below:

1. SUCCESS CRITERIA

1.1. GOALS:

1.1.1. Develop a proof of concept design for a temperature sensing device that monitors food conditions
1.1.2. Create an appealing design for future investment.
1.1.3. Further define de functionality and general considerations for future implementations.

1.2. OBJECTIVES:

1.2.1. Develop shell and housing design.
1.2.2. Integration of electronics and interfacing for simulating operation.
1.2.3. Develop embedded software and debugging.
1.2.4. Fabricate shell and housing.
1.2.5. Assemble and integrate components.
1.2.6. Test device according to scope.
1.2.7. Generate technical, use, and reference documentation.

2. SCOPE

2.1. SCOPE DESCRIPTION

The project presents the development of the proof of concept for a temperature sensing device that simulates the temperature sensing by software and includes simulation for the alarm system to warn the user of the decay of food along its retirement process.

2.2. PROJECT ITEMIZATION

The Project with its different functional systems is described in the following diagram *(Figure 2.2)*:

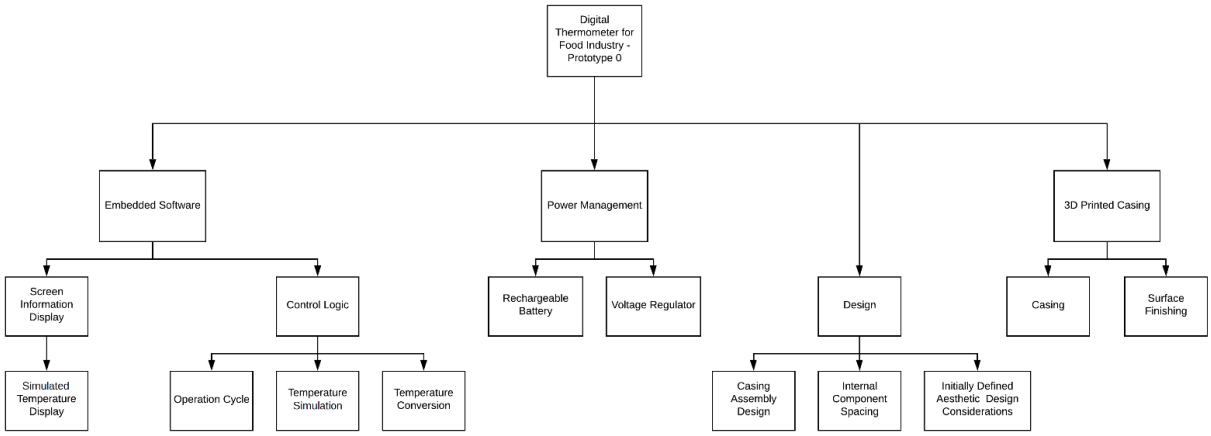


Figure 2.2. Project Itemization

According to the project itemization shown before (figure 2.2), the following requirements are defined.

2.3 FUNCTIONAL REQUIREMENTS

2.3.1 POWER MANAGEMENT

2.2.1.1. Rechargeable Battery. Powers the device through 3.7 V.

2.2.1.2. Voltage Regulator. Smoothens the voltage delivered to components.

2.3.2 EMBEDDED SOFTWARE

Embedded software contemplates libraries for character display on screen and temperature simulation.

2.3.2.1. Screen Information Display

2.3.2.1.1 Simulated Temperature Display

2.3.2.2 Control Logic

2.3.2.2.1 Operation Cycle. Continuously display simulated temperature in an infinite loop. Continually decrease temperature values until a set point is reached.

2.3.2.2.2 Temperature Conversion. Options to switch temperature units (Fahrenheit, Celsius).

2.3.3 3D PRINTED HOUSING

2.3.3.1 Casing. External shell to case the components of the device.

2.3.3.1.1 Mounting Plate. Component that functions as the main mounting surface for internal electronic components. It attaches to back case.

2.3.3.2 Probe. Probe used to be inserted on food. The probe will only be demonstrative, will not include any real functionality.

2.3.3.3 Surface Finishing. Housing final detailing for product appeal.

2.3.4 DESIGN

2.3.4.1 Casing Assembly Design. Design for shell components for device assembly (2 main components).

2.3.4.2 Probe Concept Design. Design custom probe design.

2.3.4.3 Internal Component Spacing. Considerations to organize components internally (MCU, Display, Temperature Module).

2.3.4.4 Initially Defined Aesthetic Design Considerations. The CAD designs for components will be based on initial design considerations and sketches agreed by parts (CICEII-Client).

2.4 NON-FUNCTIONAL REQUIREMENTS

2.4.1.1 Neither the device nor the probe should be placed under extreme conditions (high temperature, pressure, or radiation exposure).

2.4.1.2 All temperature display will be software simulated, neither the device nor the probe will have any real temperature sensing capability.

2.4.1.3 The device and probe are not splash proof or immersive.

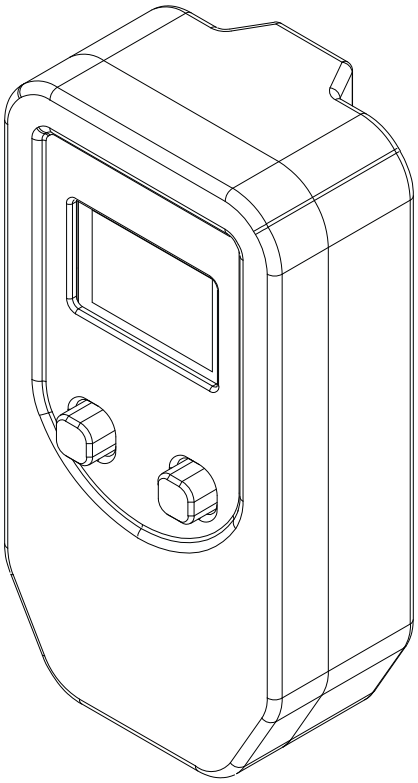
2.2.1.3. The screen is sensible to rupture; it is not a touch indicator. It should not be continually touched. When cleaned, it should be treated very gently to avoid damage.

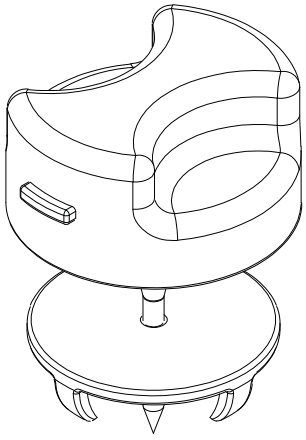
2.4.1.4 The device should be charged with a 5V micro USB regulator.

2.4.1.5 The internal battery should be replaced every year.

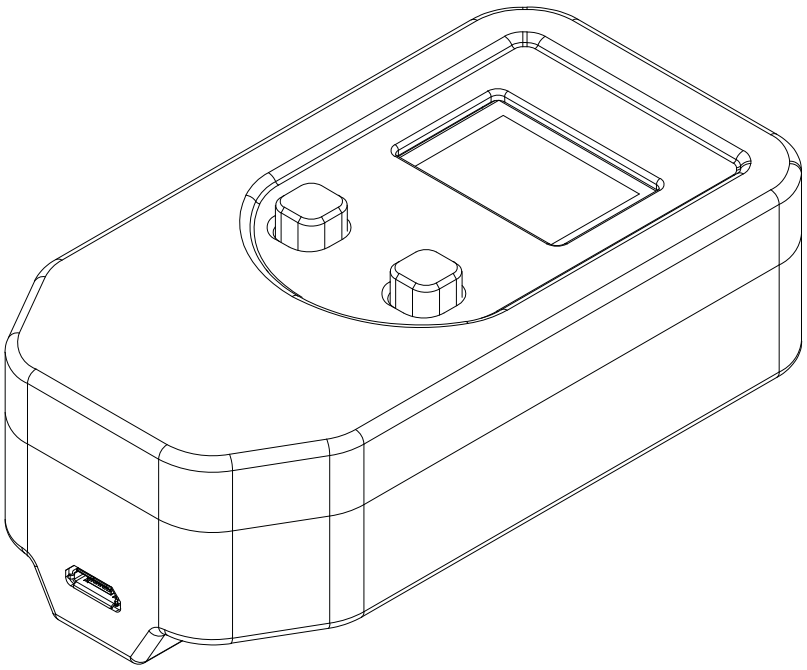
1. Project Results

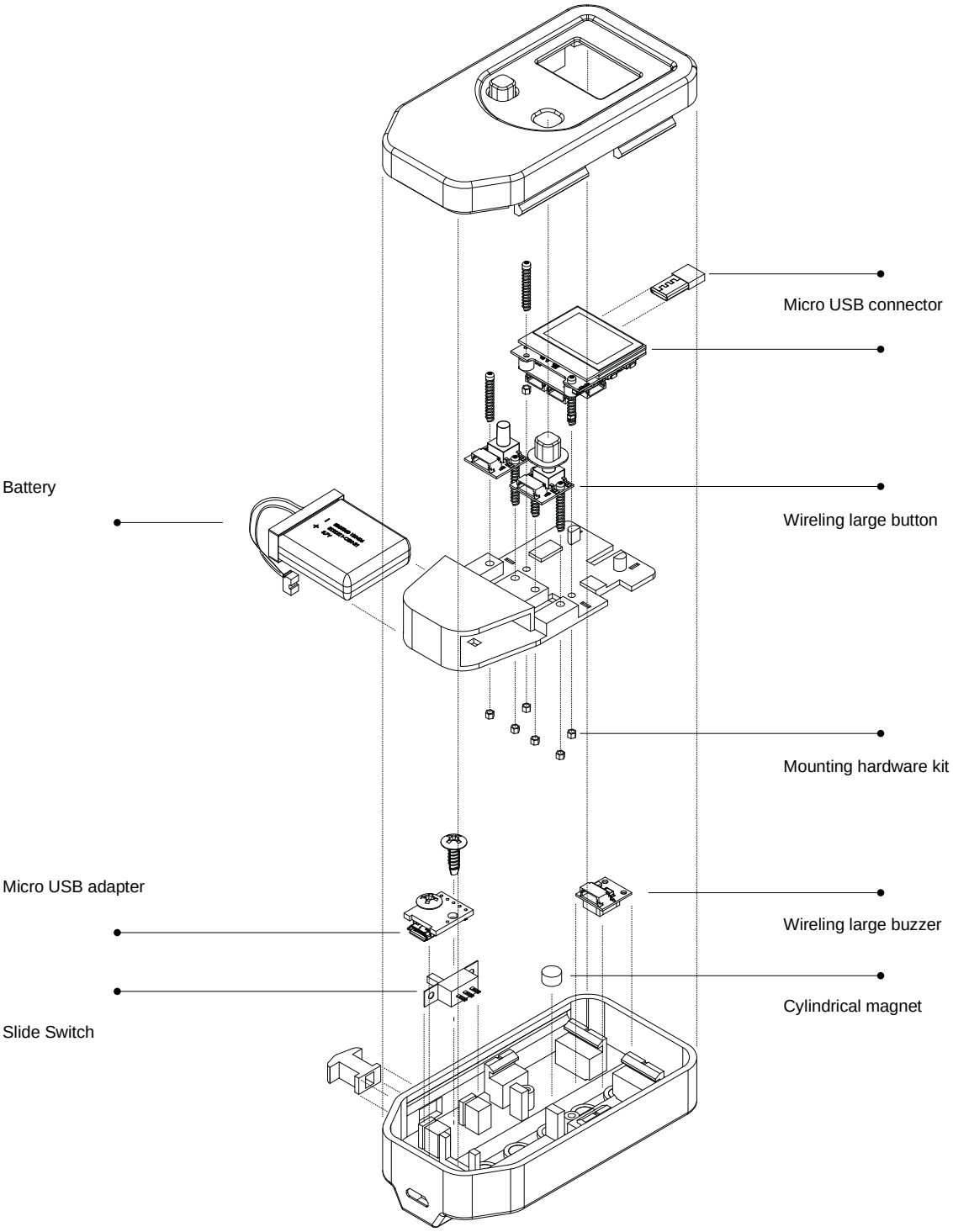
1.1 Design activities results



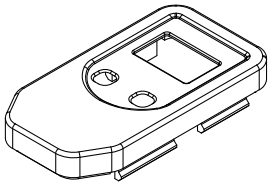
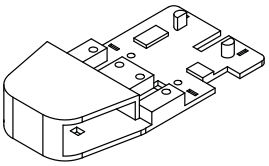
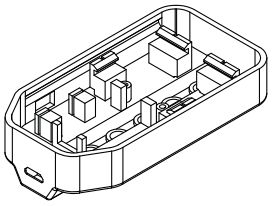


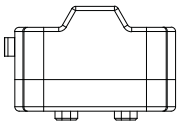
1.1.1 Device casing



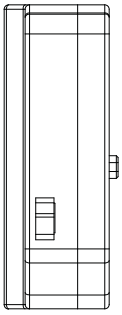

Micro USB connector
Battery
Wireling large button
Mounting hardware kit
Micro USB adapter
Wireling large buzzer
Cylindrical magnet
Slide Switch

Casing Components

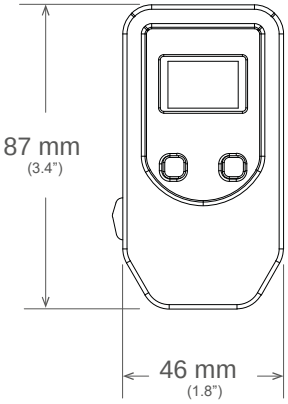
#	Component Name		Description	Specifications
1	Front Case		Front part of electronic component housing. Shows screen and front push buttons.	
2	Push button		Push buttons for navigation in screen.	
3	Mounting Plate		Component which holds most electronic components and is positioned inside of the housing.	Materials: FDM 3D printed in composite based material; micro carbon fiber filled with nylon.
4	ON/OFF Switch		Switch for activating and deactivating the device.	
5	Back Case		Back part of housing, holds	



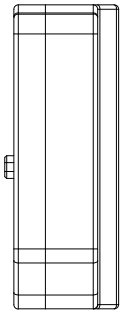
Top View



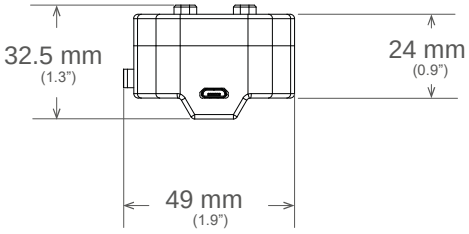
Left Side View



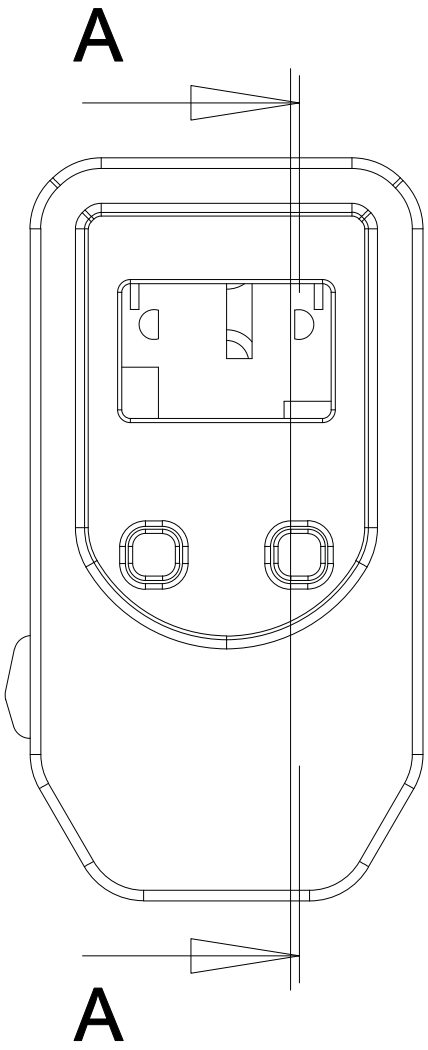
Front View

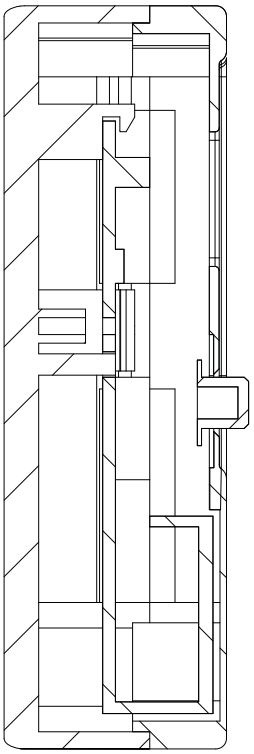


Right Side View

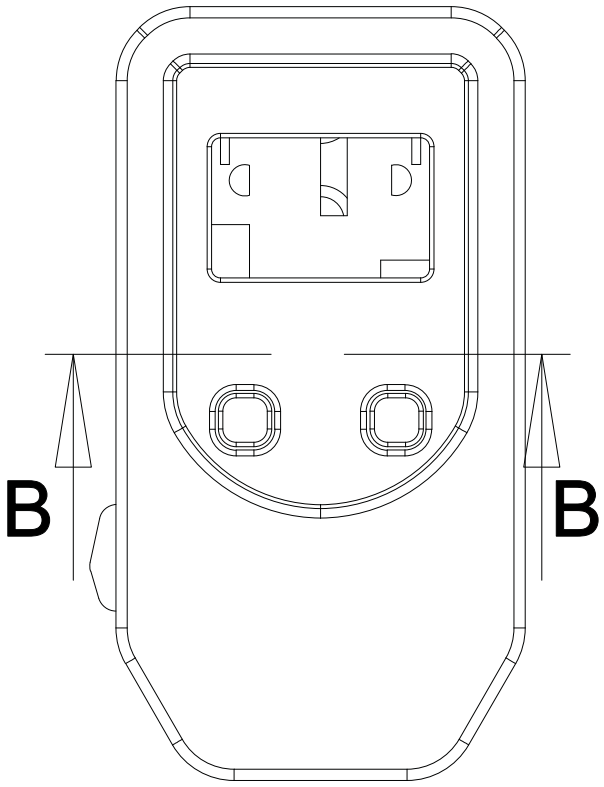


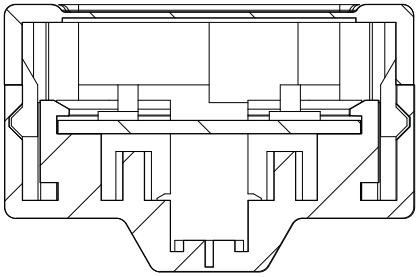
Bottom View





SECTION A-A





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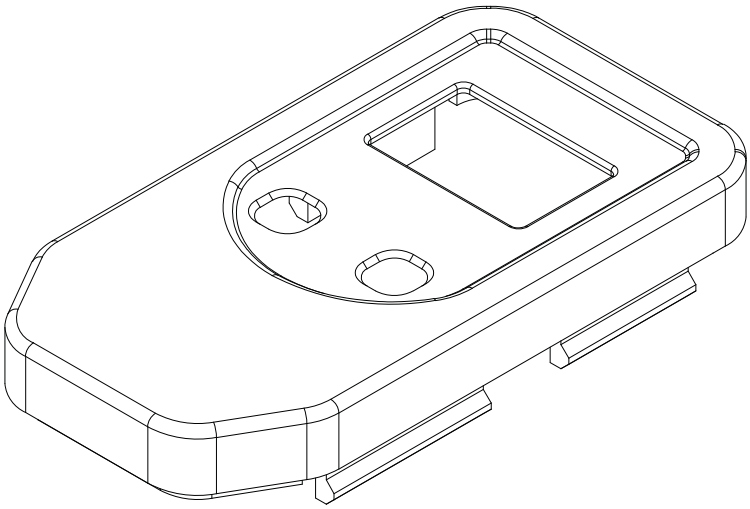
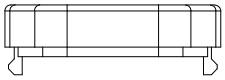
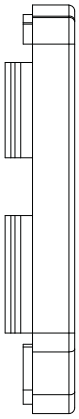


1

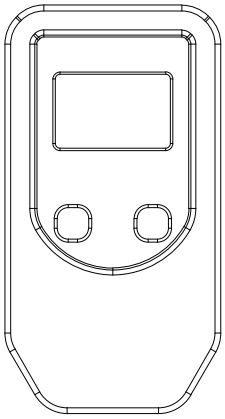
Front Case



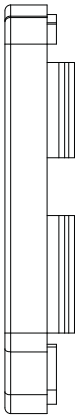
Top View



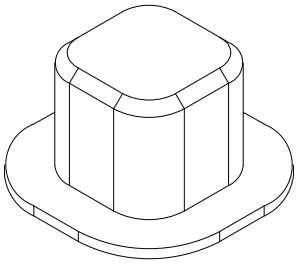
Left Side View



Front View

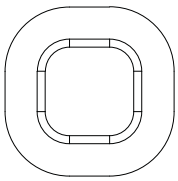


Right Side View

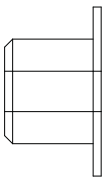


2

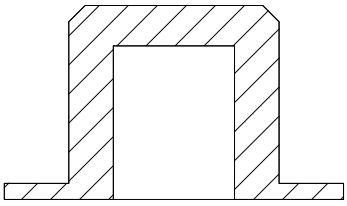
Push Button

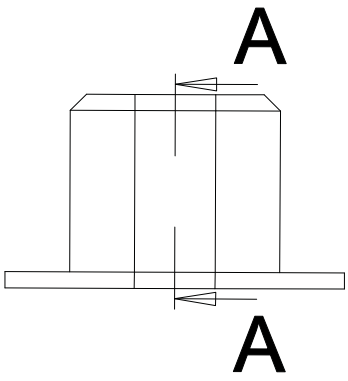


Top View



Side View





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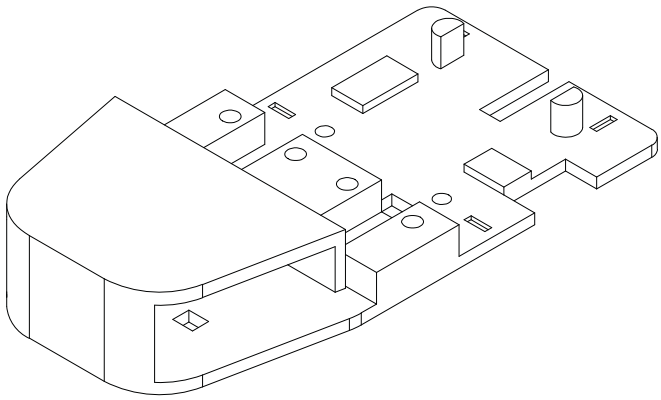
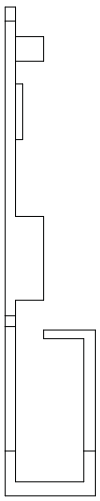
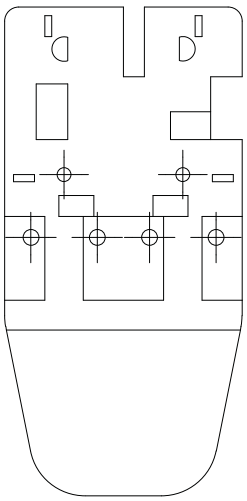


3

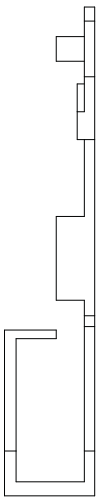
Mounting Plate



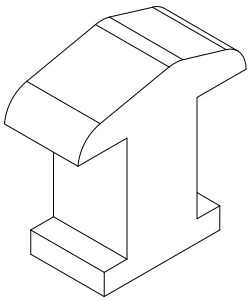
Left Side View



Front View

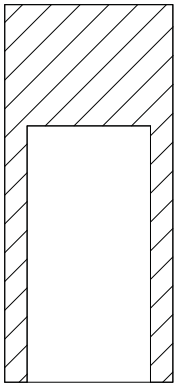


Right Side View

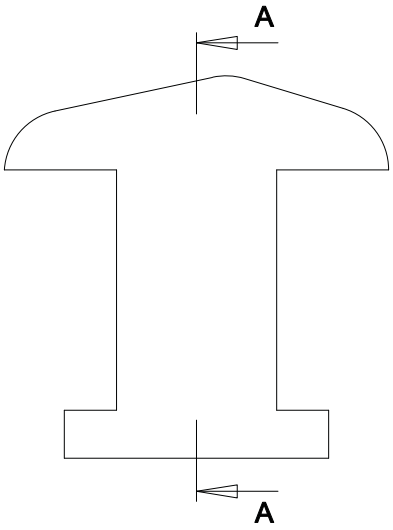


4

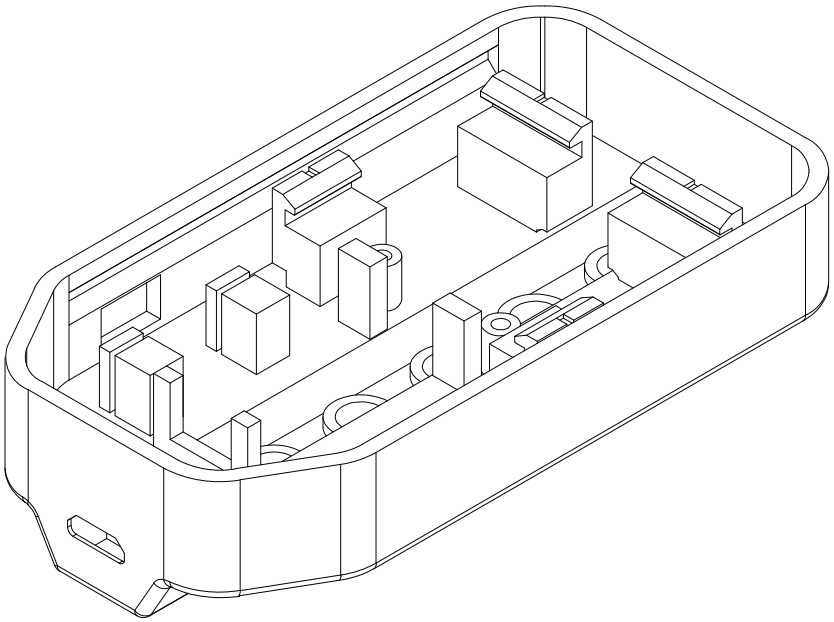
ON/OFF Switch



SECTION A-A

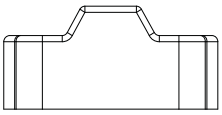


Front View

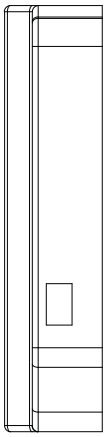


5

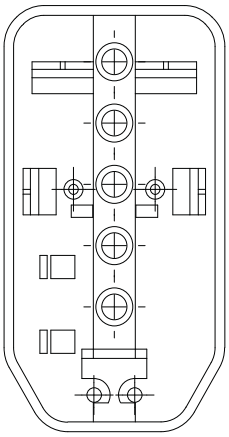
Back Case



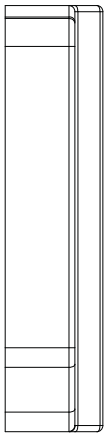
Top View



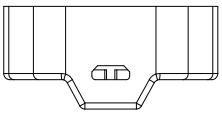
Left Side View



Front View

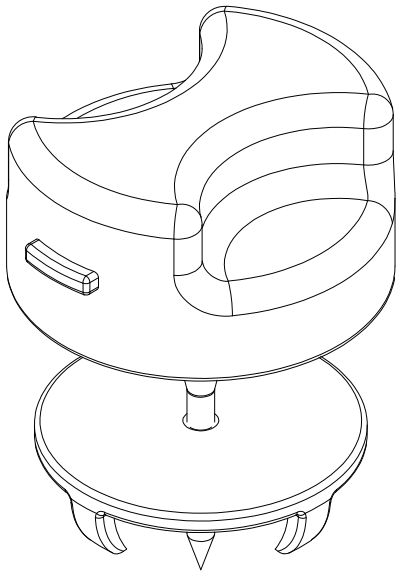


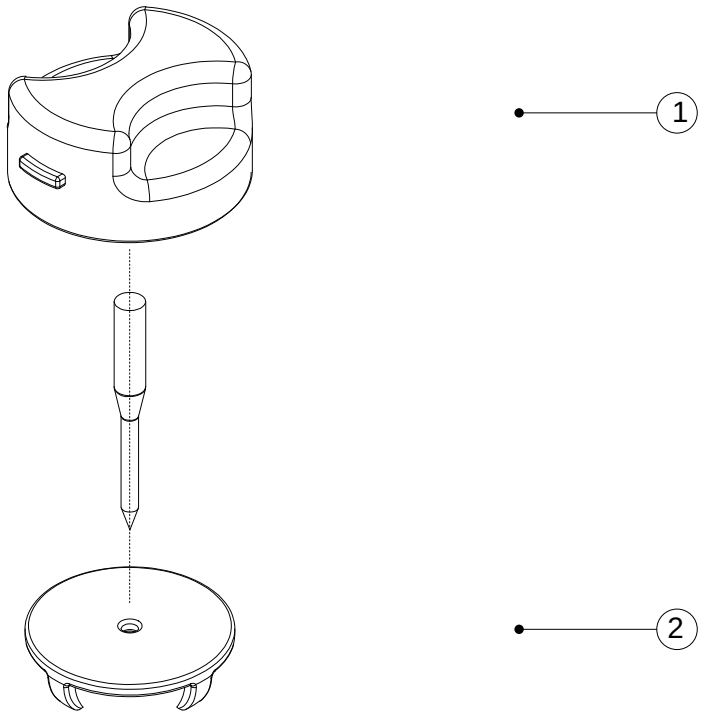
Right Side View



Bottom View

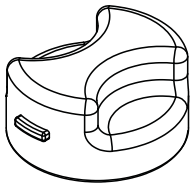
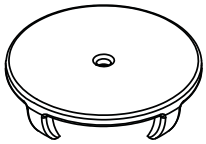
1.1.2 Probe

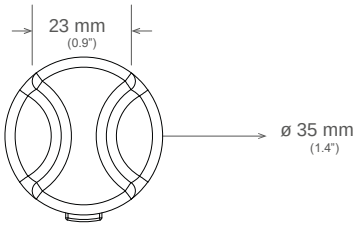




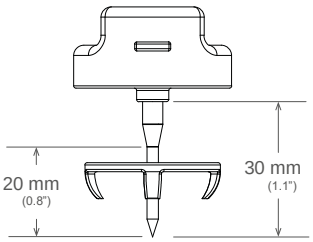
1. Probe 2. Limit Plate

Probe Components

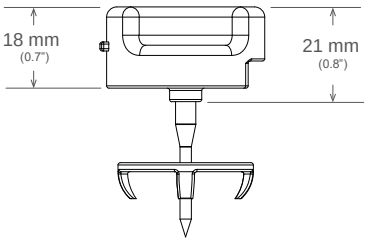
#	Component Name		Description	Specifications
1	Probe		This component would hold electronic components for the probe, it includes a dummy button and area for USB-Connector.	Materials: FDM 3D printed in composite based material; micro carbon fiber filled with nylon.
2	Limit Plate		Helps probe stay upright while positioned in food, helps balance and limits point of insertion.	



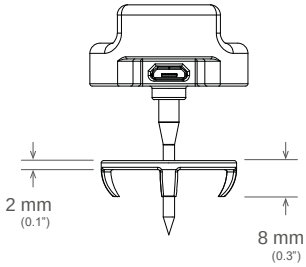
Top View



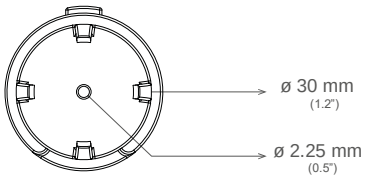
Front View



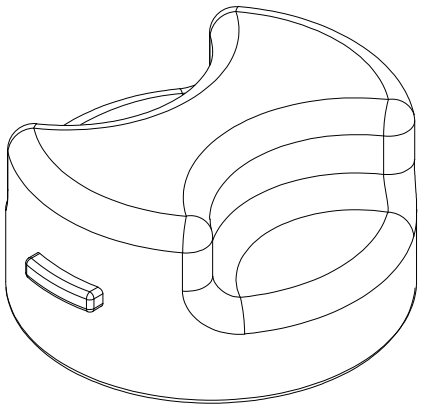
Right Side View



Posterior View

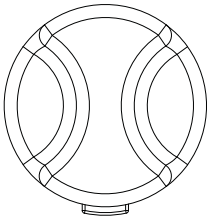


Bottom View

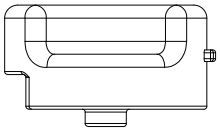


1

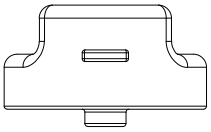
Probe



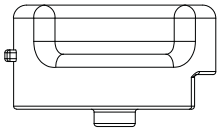
Top View



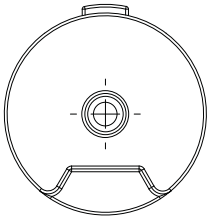
Left Side View



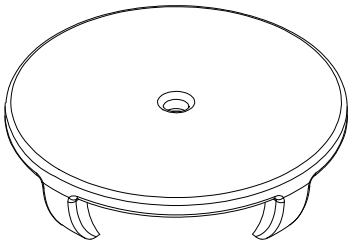
Front View



Left Side View

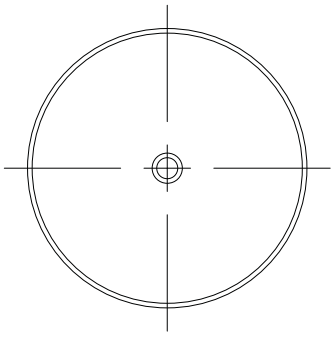


Bottom View

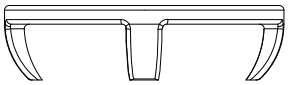


②

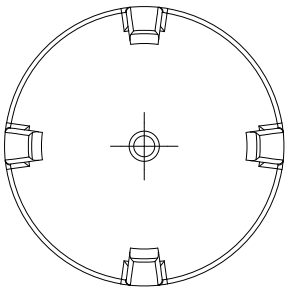
Limit Plate



Top View

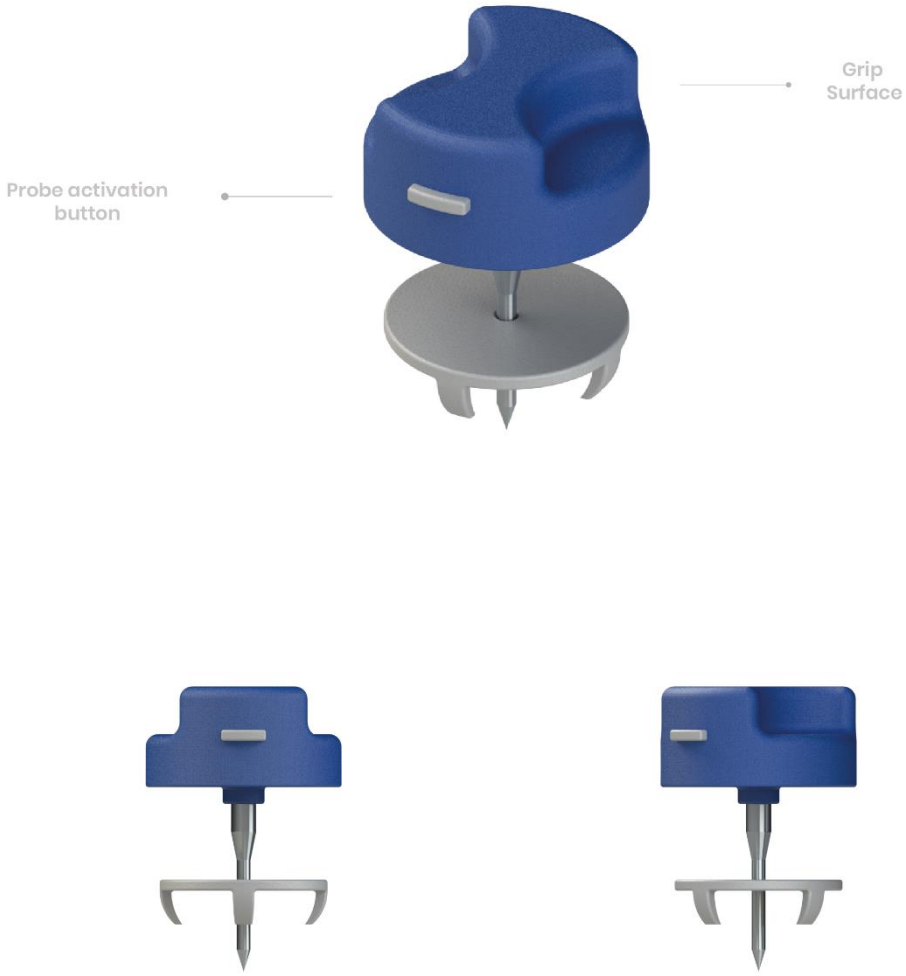


Front View

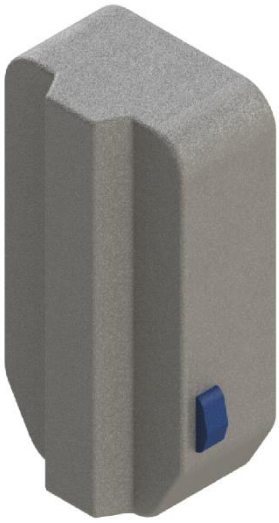


Bottom View

Micro USB
connector


Grip
Surface
Probe activation
button

Front case reveals Tinyscreen
and 2 push buttons

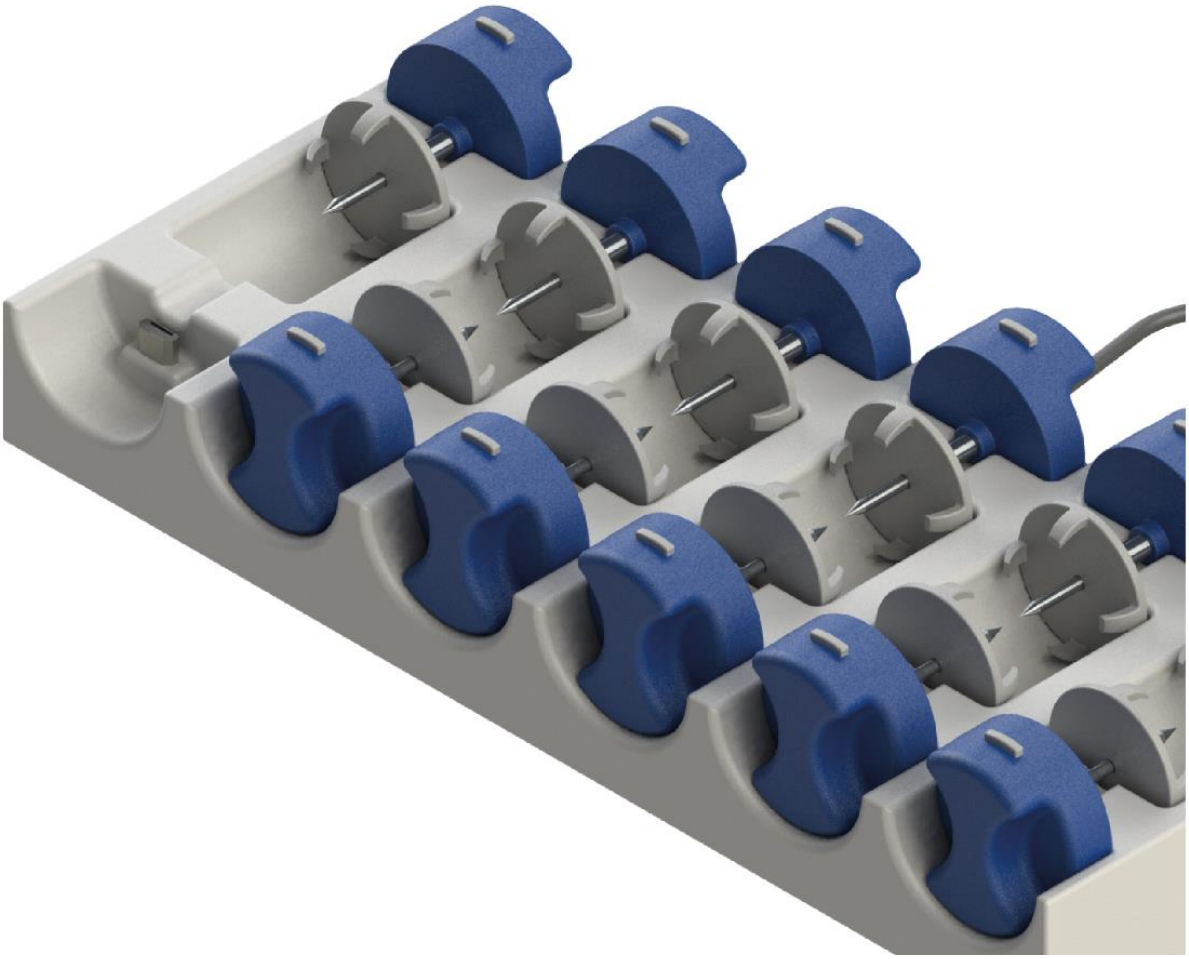


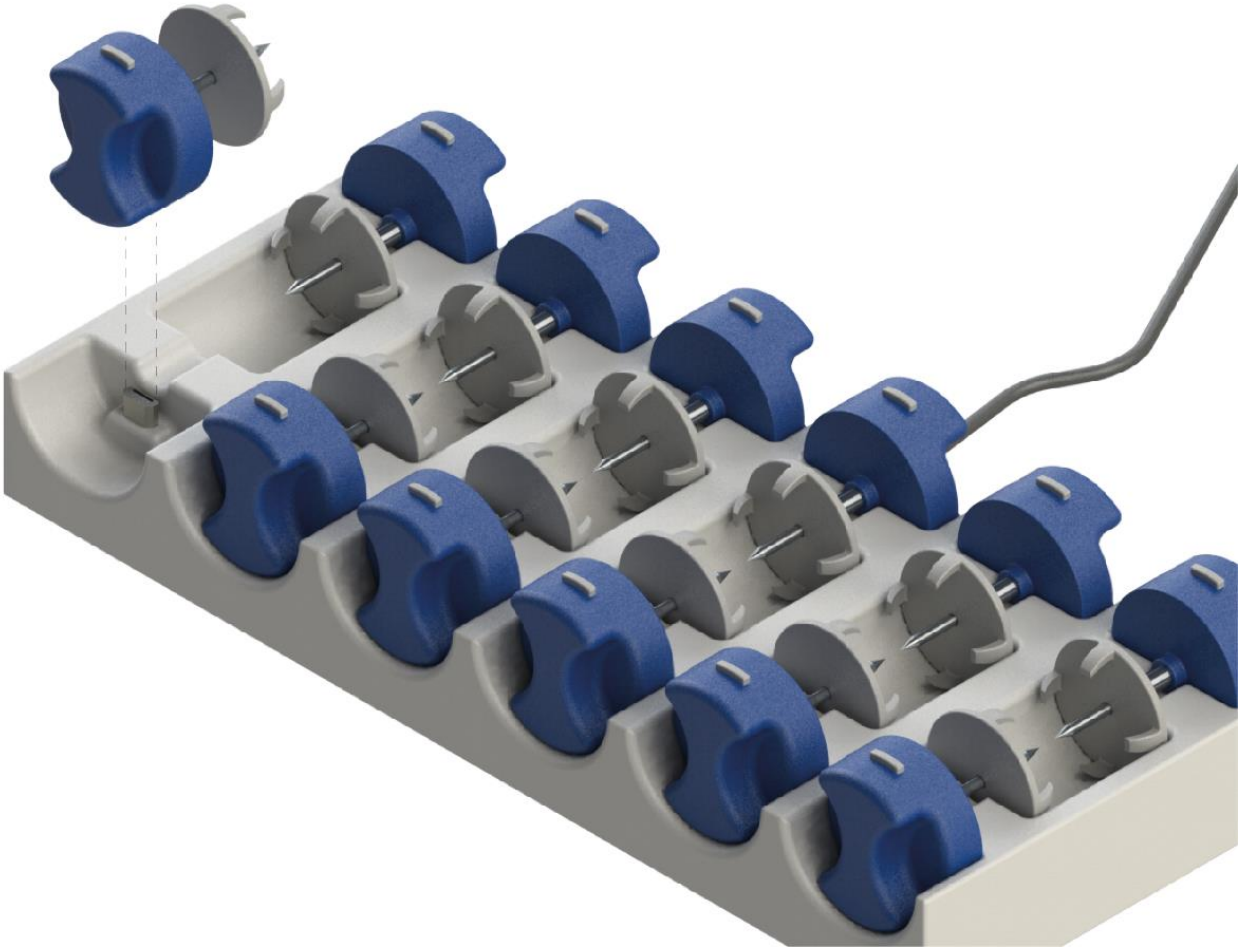
Back case contains 5 magnets
for placement in metal surfaces

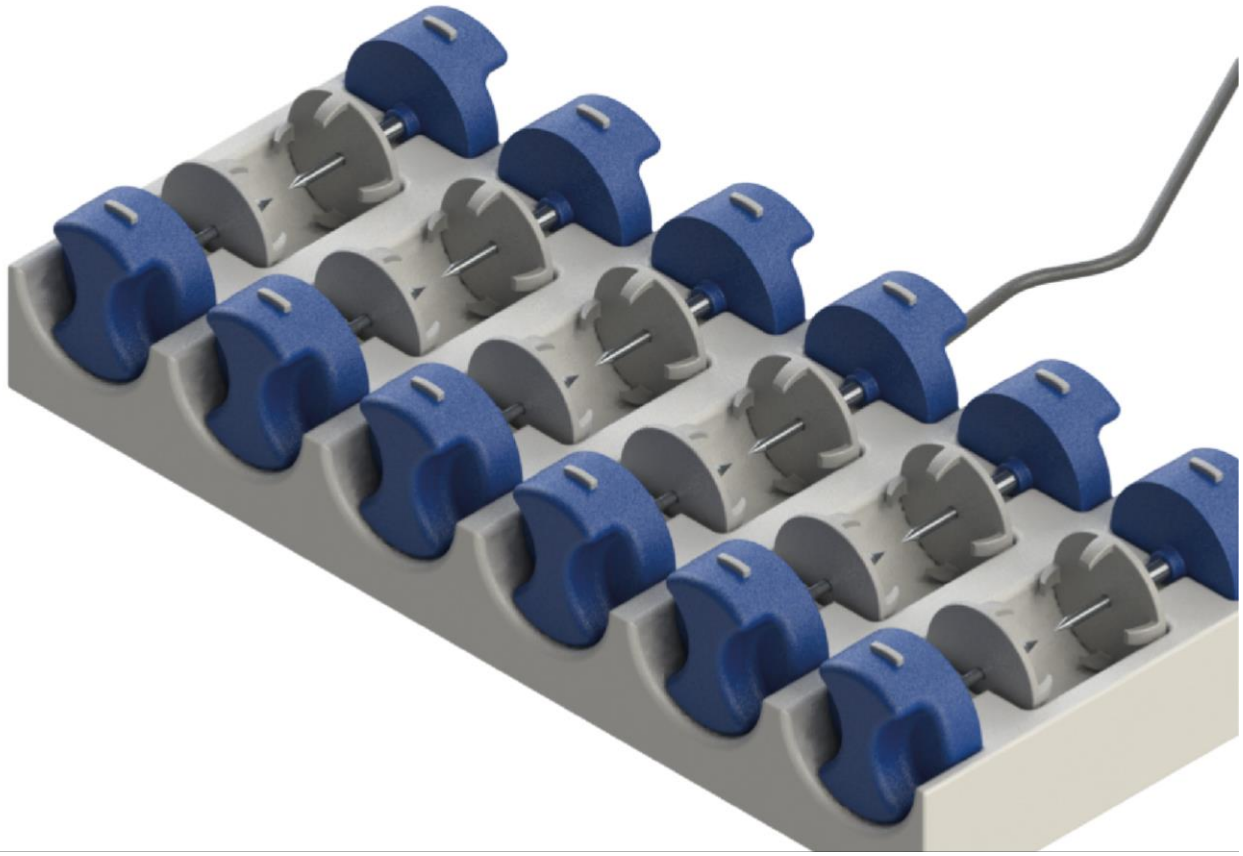
ON/OFF Slide switch

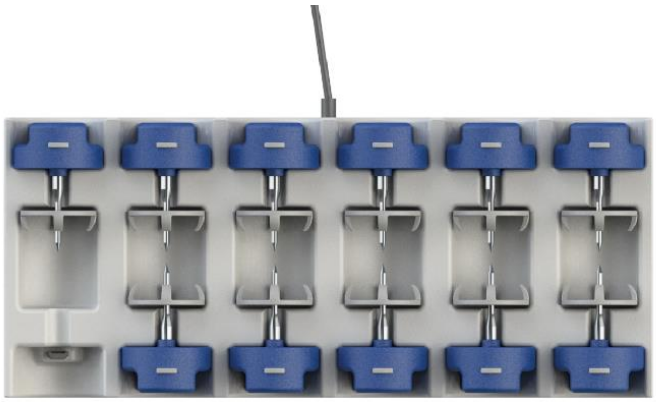
Micro USB connector

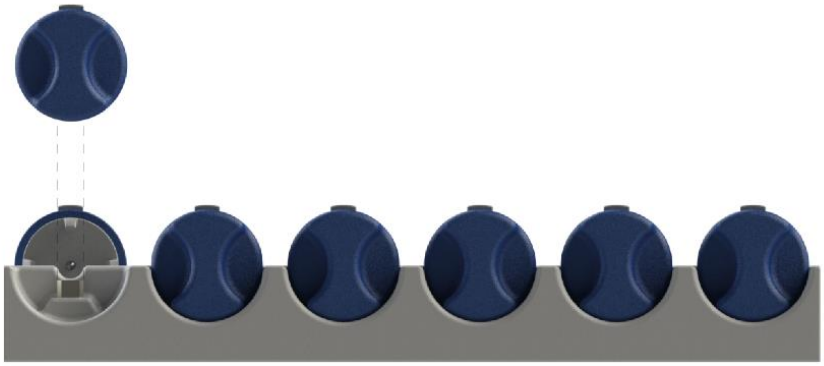
1.1.3 Probe Dock Concept Development

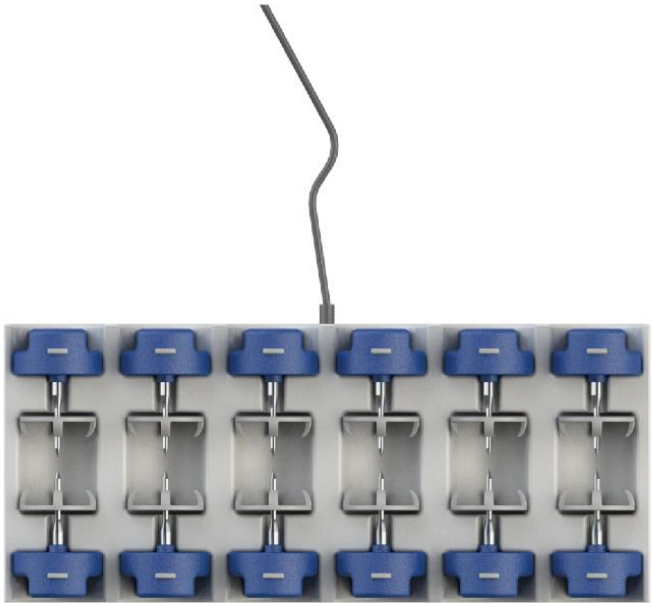


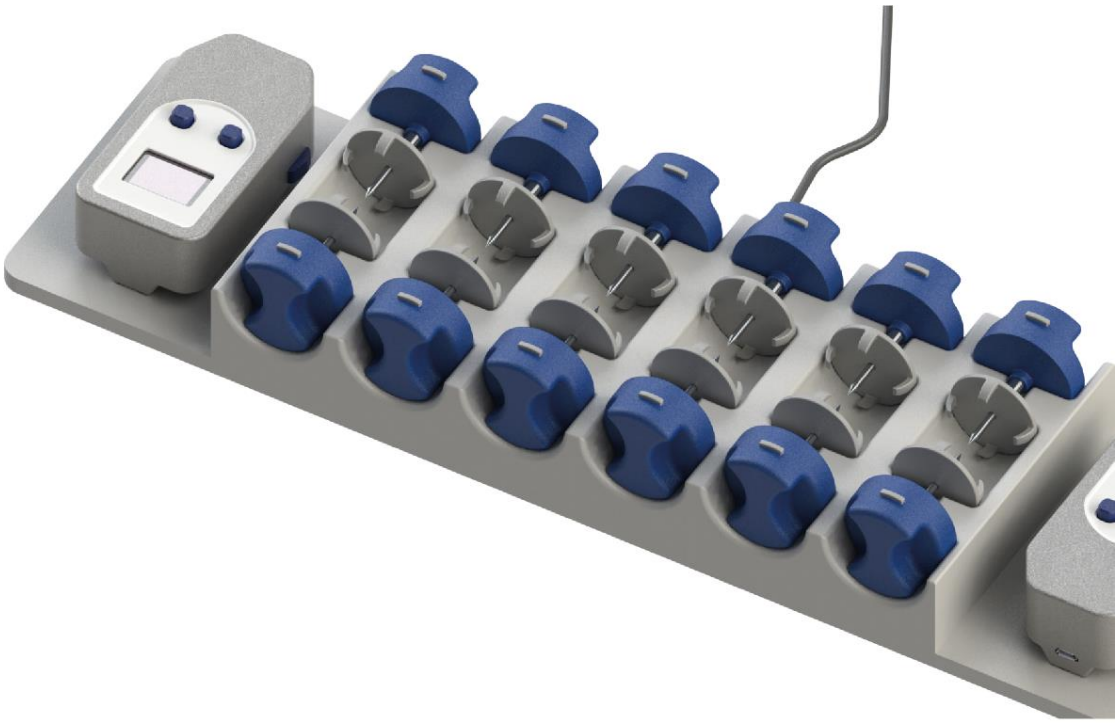


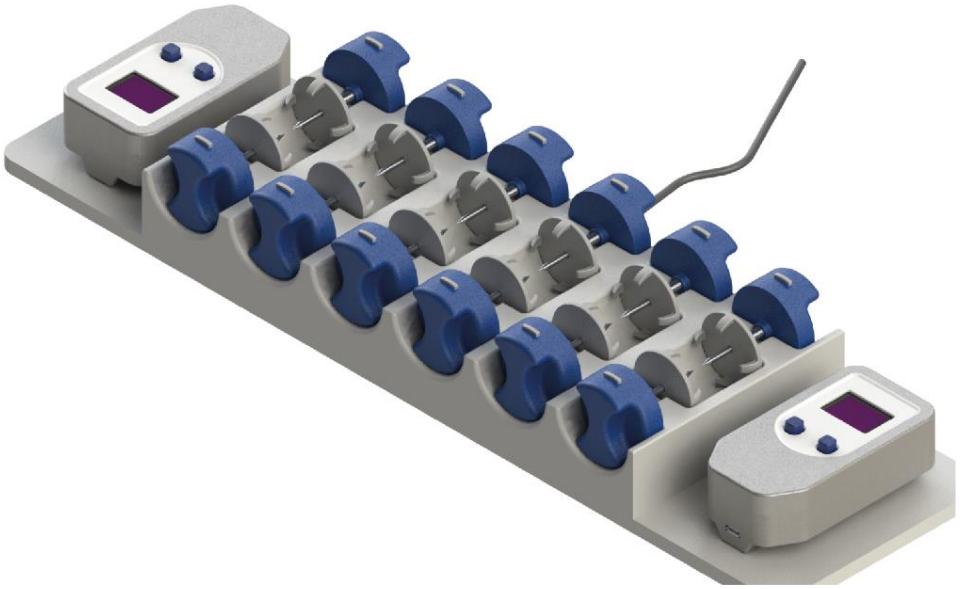












1.2 Software and electronics

1.2.1 Electronic components

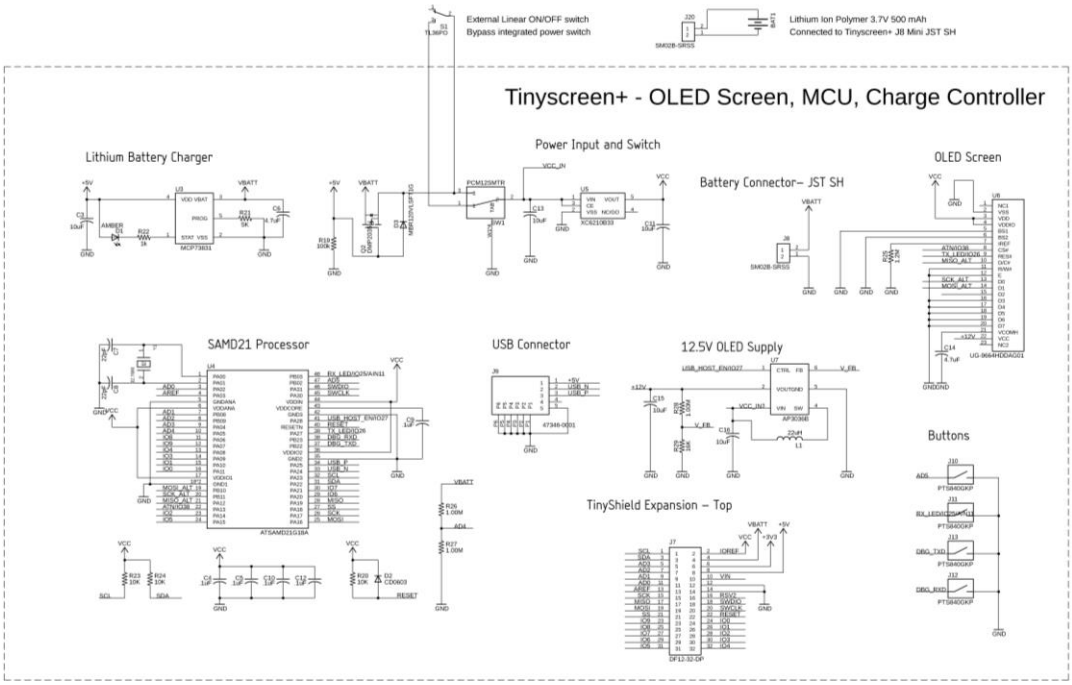
The following table shows all the electronic and commercial components used:

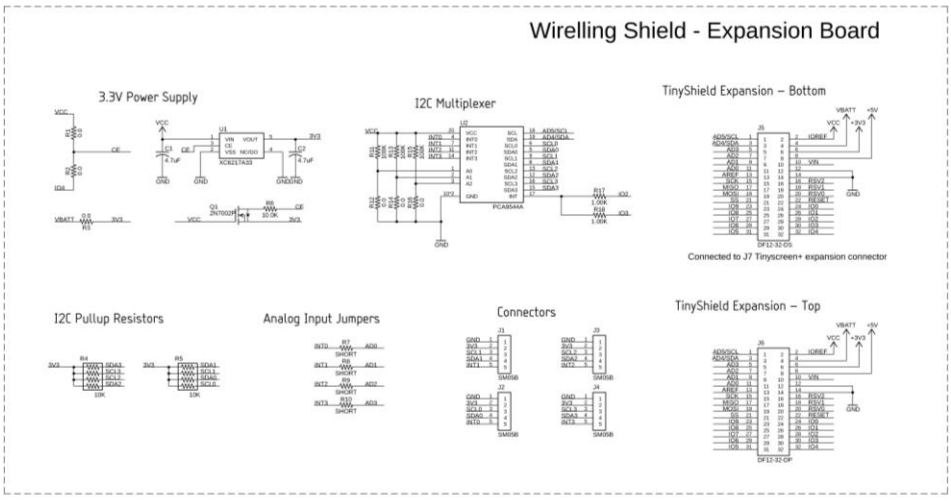
BILL OF MATERIALS

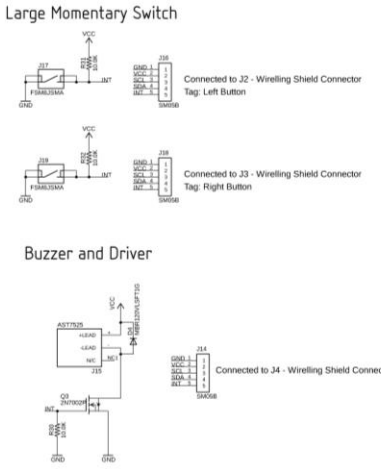
#	Description	
1	Food Cooking Oven Meat Stainless Steel Probe	
2	Micro Usb Male Port Connector	
3	Micro USB To DIP 5-Pin Pin board Power Adapter Board	
4	Tinyscreen+ (Processor, OLED & USB)	
5	Tinyshield Wireling Adapter	
6	Lithium Ion Polymer Battery - 3.7v 500mah	

7	Wireling Large Button	
8	Wireling Buzzer Module	
9	5 Pin Wireling Cables	
12	Tinyduino Mounting Hardware Kit	
13	Cylindrical Magnets 4 mm.	
14	Eg1201a Slide Switch	

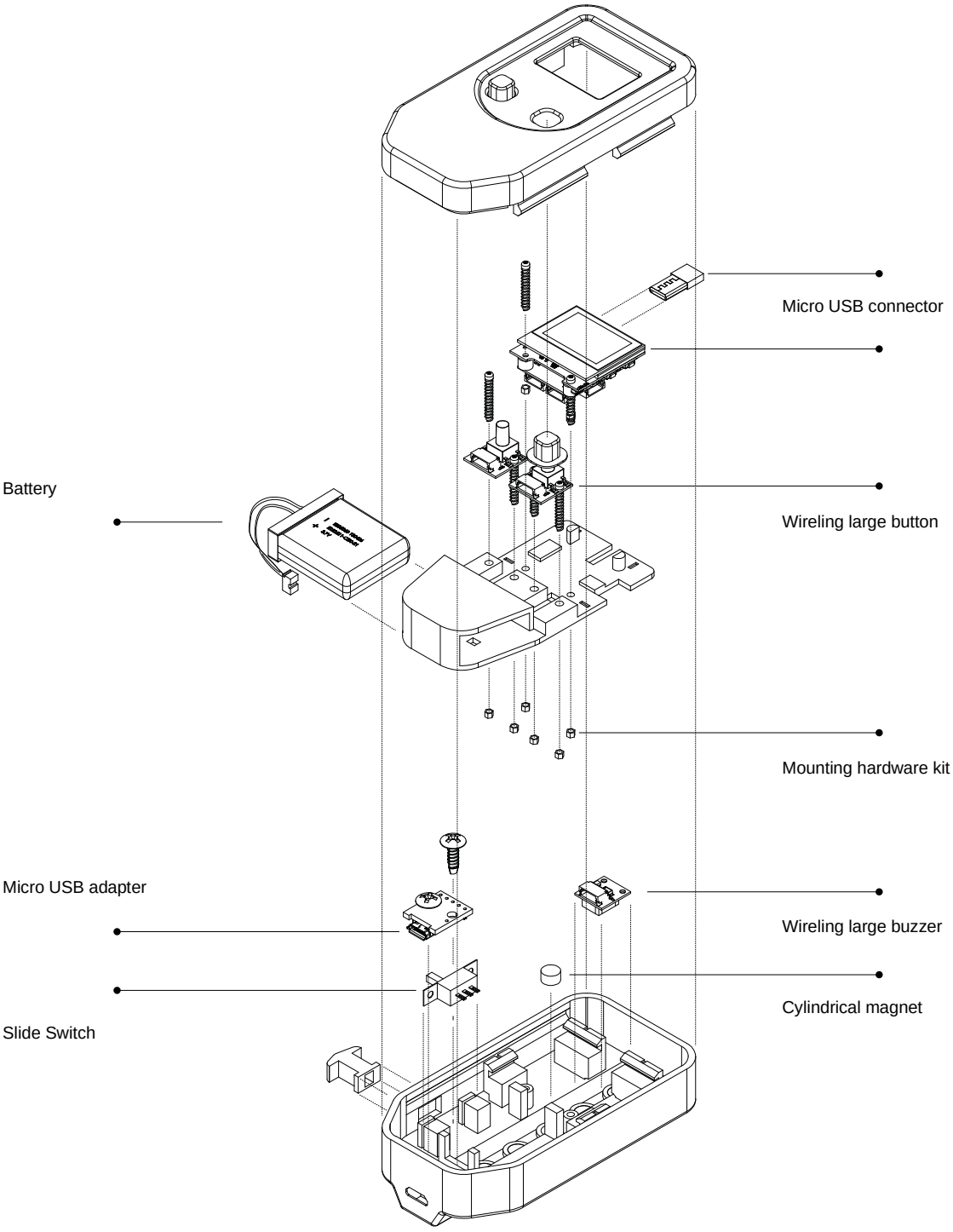
1.2.2 Connections Diagram:







Food Thermometer Prototype 0 - Electronic Connections Diagram


Micro USB connector
Battery
Wireling large button
Mounting hardware kit
Micro USB adapter
Wireling large buzzer
Cylindrical magnet
Slide Switch

1.2.3 Software Methods:

The software works as a simulation of an interface that displays the temperature and time in range for two probes. It consists of 4 screens, dividing two screens for Probe 1 and two for Probe 2. One screen for simulated temperature display, and one screen for simulated time in range display.

Each Probe can be alarmed by selecting one of their respective screens and holding both buttons for more than 2 seconds. All internal numeric conversions, data type conversions, pixel refresh, section refresh, sound alarm activations and button detection are managed by control logic, using multiple methods that are called during execution.

The control methods are described below:

setup():

On Arduino IDE, setup() method is used to initialize variables and processes needed only on startup, and it is executed just once per boot.

loop():

On Arduino IDE, loop(), as it's name implies, will execute continuously while the system is operating. Inside, all functions, variable changes and verifications that need to be controlled during execution of the software are included inside of the loop method. It can be considered the "main" method.

Display():

Custom method designed to control all the screen display operations, including screen selection according to button variables, temperature conversion, variable type conversion from numeric to char, time conversion, and line display refresh and clearing, according to screen selection and alarm state.

randomTemp():

This method generates a simulated temperature reading in Fahrenheit, within half a degree approximately. The temperature has a probability to increase or decrease in any scale within half a degree, positive or negative, given that the probability is slightly biased to the negative side, so that each time the temperature is generated and the received value is above 80F, the value has a higher probability to decrease.

Once the received temperature reaches 80F or below, then it will stay within that value +-8 degrees approximately. The real time required to reach 80F starting in 160F will vary depending on the probability of each case, but it has been approximated to 25 minutes.

Pushed_button():

This method's function is to detect if any button is pressed, and selects the action according to the next criteria: right button pressed, left button pressed, right button long press, left button long press, both buttons long pressed. According to the results, the next screen and alarm state are changed, prepared for the next refresh cycle.

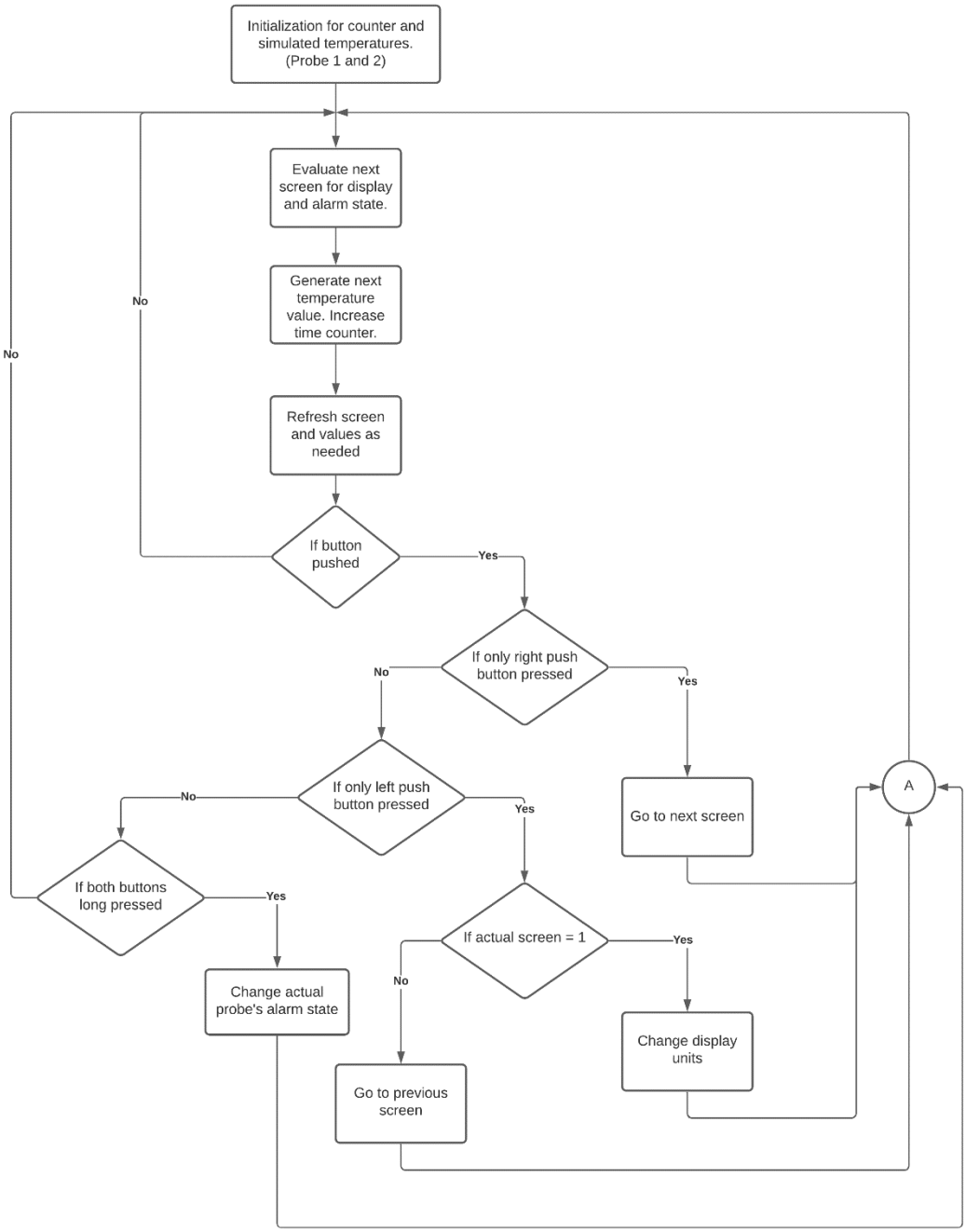
beep()

The method generates a 1000 Hz. sound for 700 milli seconds.

The code file contains specific comments for the main functions and variables for further reference. The complete code file consists of 1175 lines.

1.2.4 Device Use

1.2.4.1 Flowchart



1.2.4.2 Navigation

Sensing Screen
Probe #1

Left single press: Change units (F/C)	**Left + Right Long Press:** Activate/Deactivate Probe 1 alarm	**Right single press:** Next screen

Time in Range Screen
Probe #1

Left single press:
Go back to past screen

Left + Right Long Press:
Activate/Deactivate
Probe 1 alarm

Right single press:
Next screen

Left long press (home):
Go to Probe 1 main screen

Sensing Screen
Probe #2

Left single press:
Change units (F/C)

Left + Right Long Press:
Activate/Deactivate
Probe 1 alarm

Right single press:
Next screen

Left long press (home):
Go to Probe 2 main screen

Time in Range Screen
Probe #2

Left single press:
Go back to past screen

Left + Right Long Press:
Activate/Deactivate
Probe 1 alarm

Right single press:
Go to Probe 1 main screen

Left long press (home):
Go to Probe 2 main screen

1.2.5 Battery Life

According to Tinyscreen+ official site:

"The TinyScreen+ power consumption is determined by what is displayed on the screen. For a normal screen with a black background and white text […] the TinyScreen+ will consume 16-20mA on average - keep in mind that this is when there are no other TinyShields connected to the TinyScreen+. More boards will draw more power."

"If you were […] playing videos from an SD Card, you would have a power consumption range between 40-90mA. This is an absurd range because of the variable pixel colors in different videos. If you were to play a mostly black background video you would be drawing around 40-60mA, whereas a colored background would draw anywhere from 55-75mA, and a white background would draw between 70-90mA. Darker colors draw less current, and lighter/whiter colors draw the most current."

Our implementation does not read data from an SD card or play video, but it does include the wirelling shield adapter and some wirelling components, such as a buzzer and a couple of buttons. So, if we consider a maximum rating of 50 mA average (it is likely much lower, but for the purposes of worst case scenario, let's consider it) when the screen has a black background (normal operations) and the buzzer alarm is off, then the approximate autonomy for a 90% battery capacity would be:

(500 mAh battery rating)*0.9 / (50 mA consumption) = 9 hours of continuous operation.

In the case of an alarmed state, where the alarmed screen is always displayed and the alarm sound is never turned off, then we consider the second parameter, where the background is colored (70 mA average), and we consider an 80 mA average consumption from the buzzer continuous beeping:

(500 mAh battery rating)*0.9 / (70 mA + 80 mA) = (500 mA) / (150 mA) = 3 hours approximately for a continuous alarmed state operation.

- So, in the hypothetical use case that the device is left turned on in a non-alarmed state, the approximate worst-case scenario would be 9 hours.
- For the hypothetical use case that the device is left turned on in an alarmed state, the approximate worst-case scenario would be 3 hours.

Of course, as with any other electronic device, the battery life could be extended depending on the time interval that the device is operating.

1.2.6 Charging the Device

The Tinyscreen+ includes a lithium battery charger that allows a 200mA current rate.

For charging the device:

1. Turn Off the device.
2. Connect the micro-USB cable to the female micro-USB connection port on the bottom of the device.
3. Leave the device connected 3 to 5 hours for a full charge.

Notes:

- Do not leave the device connected for extended periods of time (more than 10 hours)
- Battery life will depend on the charging cycles that the device receives during its lifetime. It is recommended that the battery is changed every 1 – 2 years.
- It is not recommended to use the device (power On) while charging, which could cause higher stress to battery and thus causing the battery life to be highly decreased.

Conclusions

The described project has been successfully finished according to the project scope. The prototype 0 is the proof of concept and first approach to the development of an idea, which serves as the first steps for a future commercial implementation.

The development executed serves as a valuable tool for defining some of the future considerations for the device, establishing the first traits for branding and marketing, and materializing proof of concept elements that can be pitched to possible investors.

Regarding the scope of this project, we believe that all the deliverables are a success according to the client vision, were the best use of CICEII's practices, knowledge and techniques were applied to execute and deliver quality products and services.

CICEII appreciates the confidence on our team, which is proud to contribute in projects that involve the improvement of products and services, as well as positively impacting businesses and society in reducing waste and costs involved in products and services, allowing benefit and support to all the parts involved.