Design Document - Spoiled Milk Detector by FreshGuard Inc.

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I. Client Definition

The citizens of Dufferin County will be our client.

Geographic Attributes: Dufferin County is geographically located in Central Ontario; Dufferin encompasses an area of land of about 1,500 square kilometres, 100 km northwest of Toronto [1].

Demographic Attributes:
The population of our client is around 66,000 and the average number of children per family is 1.8 from a surveyed census in [2]. According to [3], these are the people who often buy milk and store it in the fridge with children being more susceptible to the effects of food poisoning and forgetting to put the milk back into the fridge.

Economic Attributes:
The unemployment rate of Dufferin County is 10% with the average household income being $108,000 before taxes [2][4]. That means the majority of people in Dufferin County should be able to afford to purchase and drink milk regularly.

II. Client Challenge

The challenge that the client is facing is the severe illness caused by food poisoning that can lead to hospitalization [5]. [6] reports that in April 2023, Dufferin County experienced a severe case of food poisoning involving 88 people in the town of Orangeville. However, for this project, we are focusing specifically on food poisoning caused by spoiled milk. Milk is spoiled when it is left outside or in the fridge for an extended period of time. Illness caused by consuming spoiled milk is characterized by diarrhea, vomiting, nausea, and stomachaches [7]. This has a serious effect on personal health.

III. Competitive Landscape

1. <u>Social System:</u> Before the implementation of this spoiled milk detecting device, humans have developed tactics to determine whether or not milk has gone bad. According to [8], some of these methods include smelling the milk for an unpleasant odour, and looking for chunks or lumps when pouring the milk out of the container. As these tactics work and are often already used by humans, some might continue to use this tactic which would replace the purpose of purchasing this device. However, these human-dependent tests are not always fully accurate or reliable, which still poses the risk of drinking spoiled milk and potentially getting food poisoning [9].

2. <u>Technological System #1:</u> The use of antibiotics can suppress the symptoms caused by the bacteria in spoiled milk [10]. By taking antibiotics before or after drinking spoiled milk, the spoiled milk detector becomes obsolete as there are little ill effects of drinking the milk. Despite this, it is not sustainable nor healthy to always consume antibiotics in the long term. According to [10], the body will develop a resistance to the antibiotics over time, rendering them inefficient for more serious use cases.

3. Technological System #2: With the development of a sensor that can detect the volatile gasses and colour change of spoiled milk by researchers of the Department of Biological Systems Engineering at Washington State University [11], this sensor directly competes with our device. Due to the similarities in the purpose of both devices, clients will pick one over the other. This is direct competition to our spoiled milk detection device as clients have an alternative product to choose from. Despite the similarities, according to [11], this sensor is intended to be implemented within the packaging process of milk, whereas our device is intended to be used in households by the end user.

IV. Requirements

- According to [12], outside of a refrigerator, milk spoils in about 2 hours. Thus, if a bag of milk is taken out of the fridge for 2 or more hours, the device must alert the user.

- [13] explains that after 1 hour, people have a 50% chance of remembering a fact after it is learned. Therefore, our device will not be effective if it only alerts the user once; instead, it must do so at least once every 1 hour until the milk bag is changed, since the user is more likely to have forgotten to change the milk than to have remembered.

- [14] states that it is critical for milk to be stored under 4.4 ℃, otherwise it will "begin to develop signs of spoilage". This means our device should indicate to the user if the temperature of the refrigerator it is in is higher than 4.4 ℃.

- [15] states that sounds exceeding 70 dB are annoying to the average person. Therefore, the sound produced by the buzzer alarm must not exceed 70 dB; this way, the buzzer will only be a way of conveying information to the user rather than an annoyance.

V. Design

Design Overview

The product consists of three open-topped containers, C1, C2, and C3. C2 and C3 hold 1.33 L milk bags that are standard in Ontario (sold in bigger bags of 3 small bags each), while C1 holds a milk pitcher that in turn has the third milk bag inside. C1 and C2 have flaps on the inside that press on buttons when a bag is placed into them. C3 has a force sensing mechanism inside on the bottom to determine the weight of the milk bag (see Force Sensing and Button section). Each container has an indicator LED on it (see External Wiring section). Beside C1 is an electronics compartment with our microcontroller, 9V battery, temperature indicator LED, ambient light sensor, temperature sensor, and buzzer (see Electronics section). The device is powered with a 9V battery with a clip-on connector.

For the installation and operation of the device, refer to chapters IX and X of this document.

Detailed Description of All Product Functions

When 3 full milk bags are placed in the compartments, a 7-day timer starts on all of them. C1 with the pitcher is the currently opened bag of milk, and its timer counts down faster when the pitcher is removed (out of the fridge). The rate at which the timer counts out of the fridge is the speed at which a fresh bag would count down in 2 hours. When C1's timer counts down, a buzzer tone will ring once every hour, and when the fridge is opened (as detected by the ambient light sensor), C1's indicator LED will turn on and the buzzer will beep again. These warnings will also trigger if C2 and C3's timers run out.

When C2 or C3's bags are replaced, their timers reset to 1 week. When C1's bag is replaced, if the final weight of the milk bag is less than the bag's weight when it was removed, it's the same bag so the timer keeps counting down. If the final weight is higher, then it means the bag was replaced, and the timer is set to the timer value of whichever of C2 or C3 previously had a bag removed within a minute. If neither C2 or C3 had a bag removed in the last minute, C1's timer resets to 1 week. When any bag is placed or removed from a container, the buzzer quickly plays a notification tone.

The intent is for the user to place newly bought bags of milk into the containers, then as C1 gets used up, bags from C2 and C3 are moved into C1 and used until one full set of 3 milk bags are finished. To reset all timers, there is a reset button on the side that is connected to the reset button on the microcontroller (from here on referred to as the MCU).

Finally, there is a temperature sensor that makes sure the fridge's temperature is suitable for milk storage (less than 4.4 degrees Celsius) [14]. If the temperature is above this threshold, the temperature indicator LED beside the MCU on the front will light up.

NOTE: ALL LENGTH DIMENSIONS ARE IN MILLIMETERS (MM).

Container Dimensions

Figures 1 and 2 show the dimensions of the main frame box, including the 3 containers, the compartment for electronics, and gaps in the frame for other parts. The box is constructed from 5mm-thick foam boards.

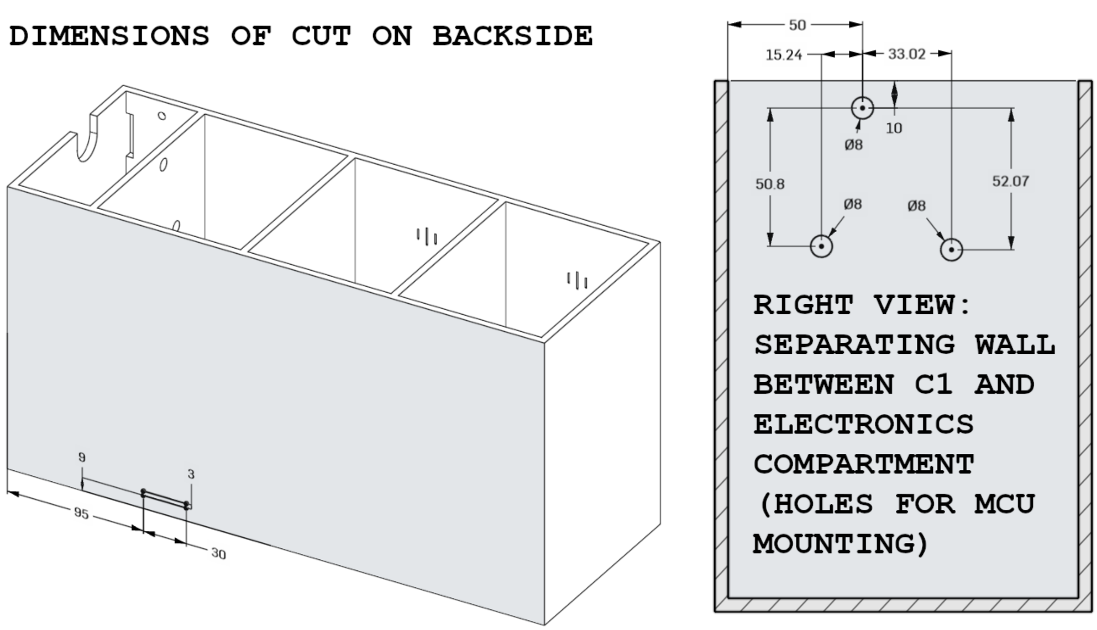


Figure 1: Back-left-top view (left) and MCU mounting hole dimensions (right)

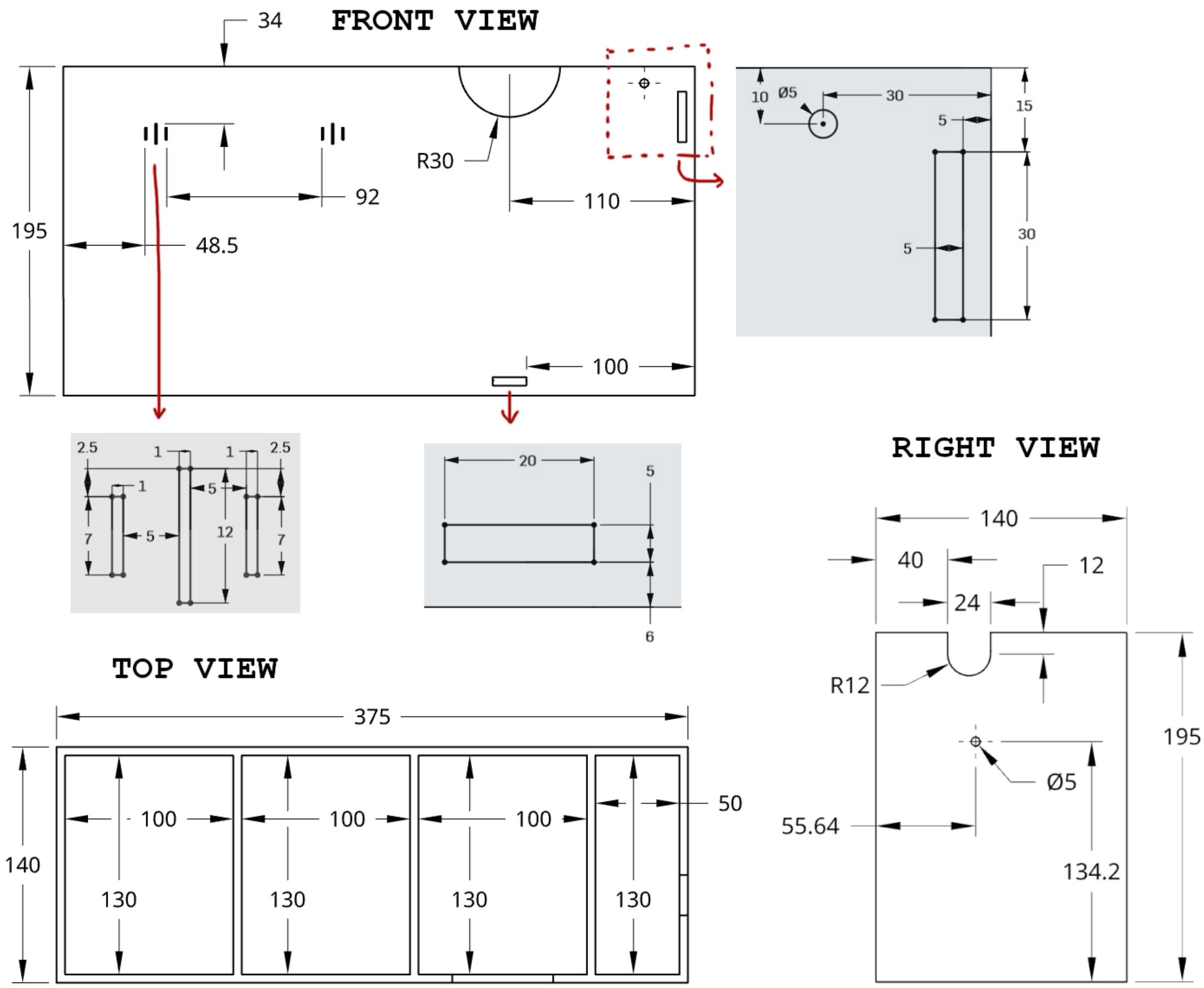
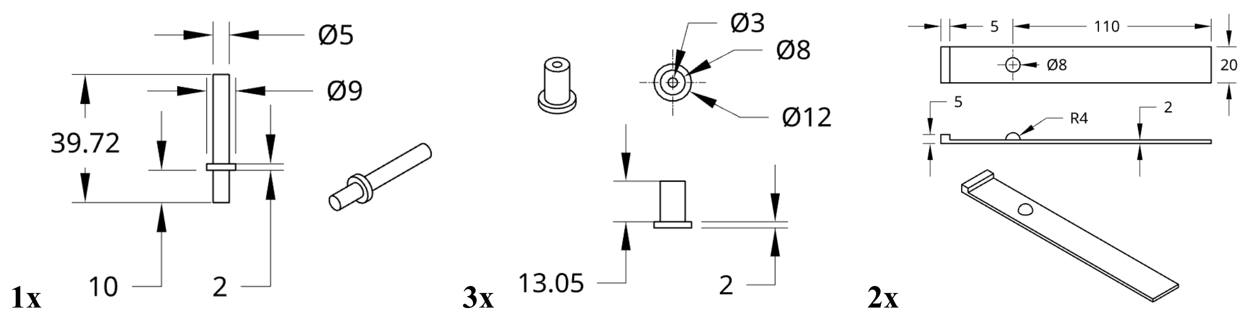


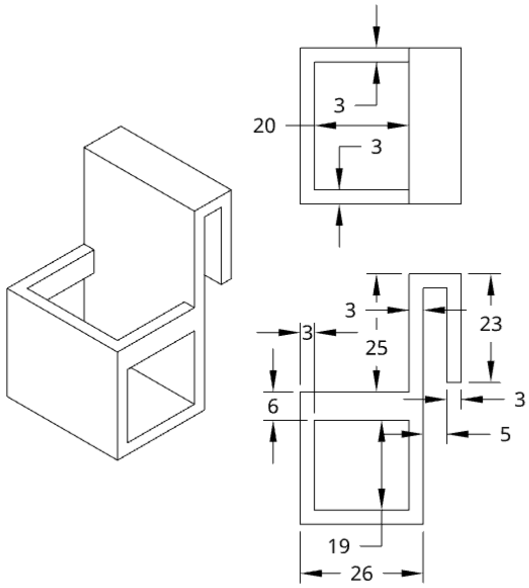
Figure 2: Front, top, and right view with annotated dimensions

3D Printed Parts

Figures 3 to 8 show the dimensions of all 3D Printed parts. Parts are printed with 0.2 mm layer height, 1 mm wall thickness, 30% cubic infill, and PLA filament. The function of these parts will be shown later.



Figures 3, 4, 5: Reset button (print x1), MCU mounting standoff (print x3), and button lever (print x2)



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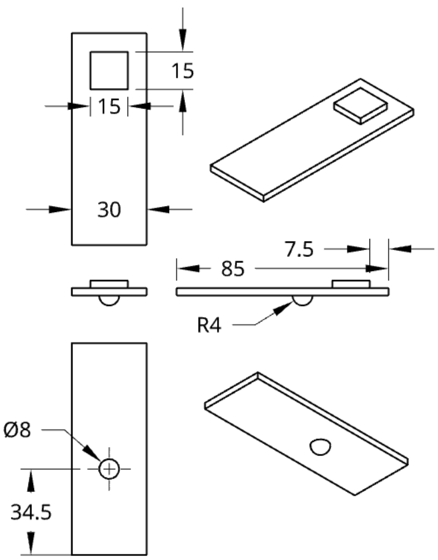

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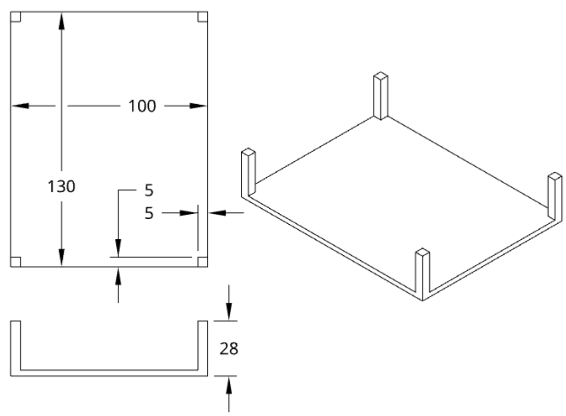

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Figures 6, 7, 8 (print x1 each): 9V battery holder, force sensor lever, and pitcher platform

Pitcher Dimensions

Figure 9 depicts the dimensions of the milk pitcher that comes with the product. Most milk pitchers in Canada have similar dimensions and can also be used in place of the one provided. The milk pitcher lets the user easily pour milk with one hand.

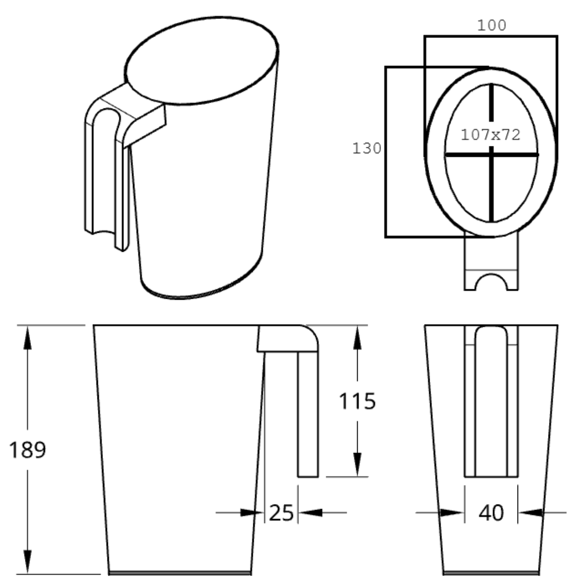
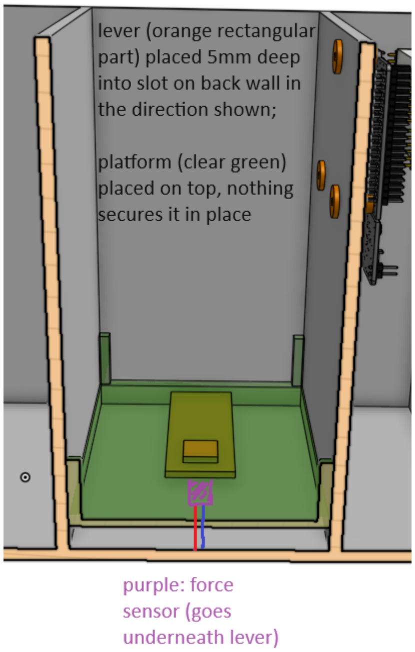
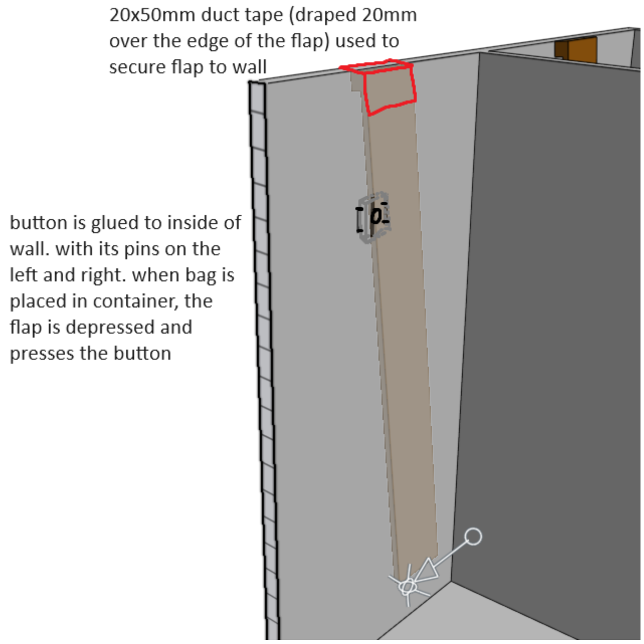


Figure 9 (right): The milk pitcher





Figures 10 (left) and 11 (right)

Force Sensing and Button

Figure 10 shows the front view of C1 with its front face removed to show the force sensing mechanism. The platform gives the pitcher a stable place to sit on, the force sensor detects when the bag is replaced rather than just used, and Chapter VI explains the function of the lever. Figure 11 shows a cross-section from the back-right side of C2 and explains the button mechanism. The button lever makes the button more sensitive to bags being placed. The same mechanism exists in C3. C2 and C3 do not need a force sensor since bags are always assumed to be replaced when they are removed from C2 and C3.

External Wiring

Figure 12 shows how the wires for the LED's, buttons, and force sensors will be routed.

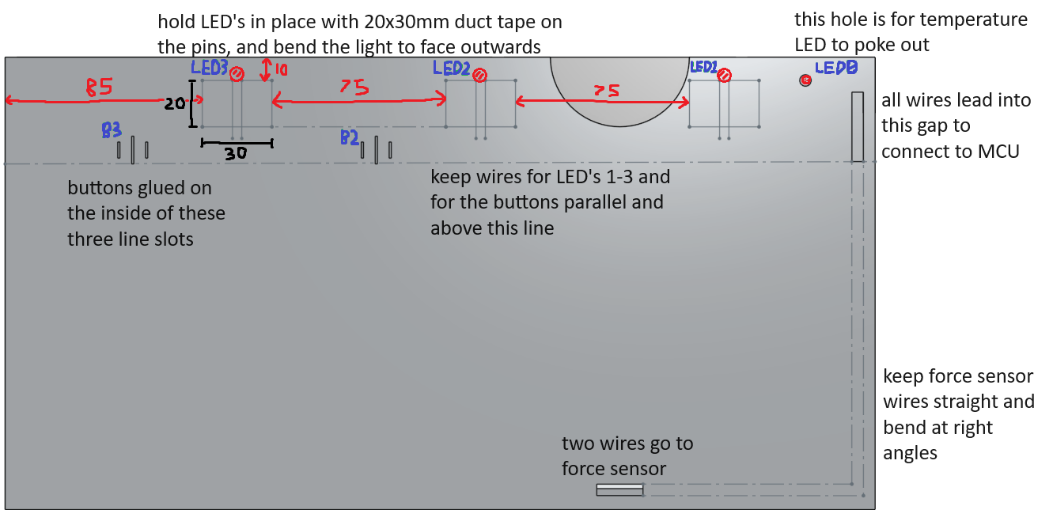
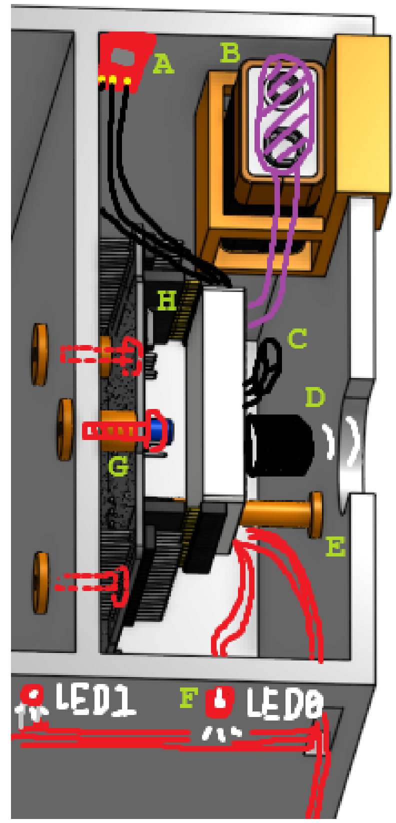


Figure 12: Front wiring

Electronics

Figure 13 (right) explains a few aspects of electronics mounting:

a) The ambient light sensor is glued, wires-down, as shown
b) Battery is held in the 3D print which hangs on the side
c) Temperature sensor is plugged into breadboard and bent up
d) Buzzer is plugged into breadboard
e) Reset button 3D print is placed so that the flange is against the side wall
f) LED0 (temperature indicator) is glued to the hole as shown
g) 3D print standoffs go through the holes in the container wall and 3x 8mm M3 button screws will go through the holes on the MCU into the standoffs for mounting
h) Pin header rows are inserted into the MCU and glued to the sides of the breadboard



Figures 14 and 15 explain wiring and electrical component connections. We use a buzzer and LEDs to provide visual and audio warnings to the user, a temperature sensor to ensure fridge temperature is ideal, a light sensor to detect when the fridge is open to determine when to turn on LEDs, and a 9V battery so that the product is portable yet long-lasting.

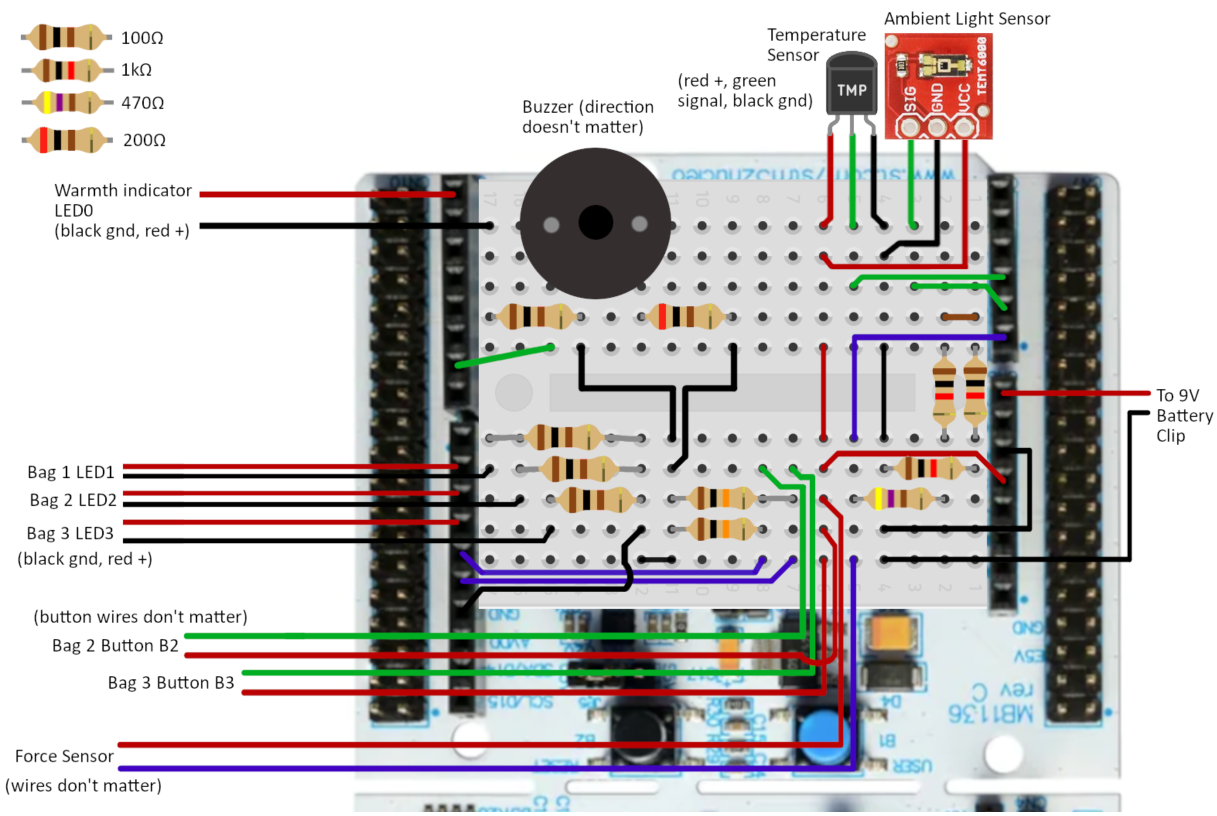


Figure 14: MCU wiring diagram

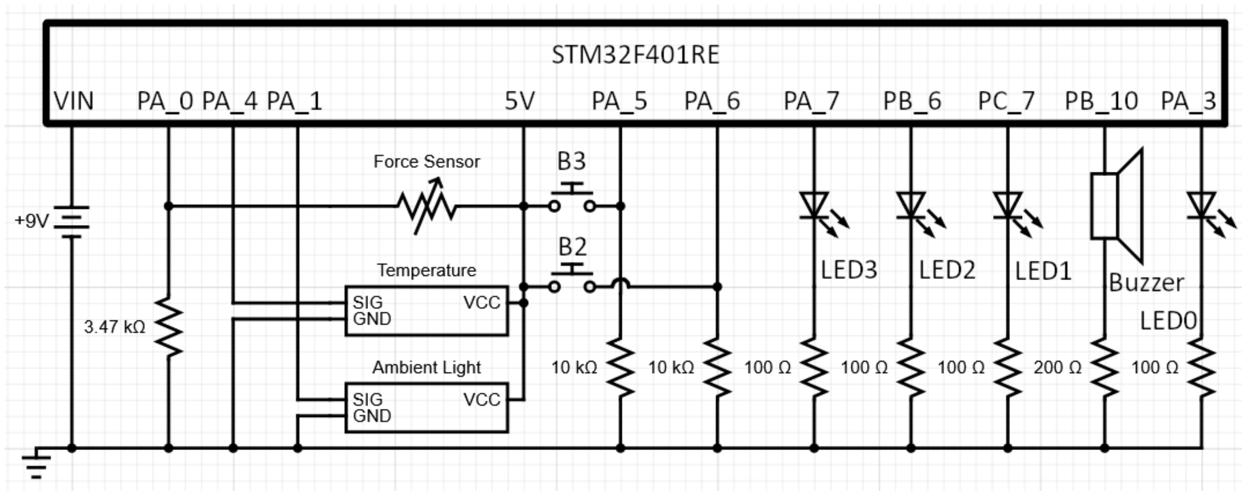


Figure 15: Schematic

Programming the Device

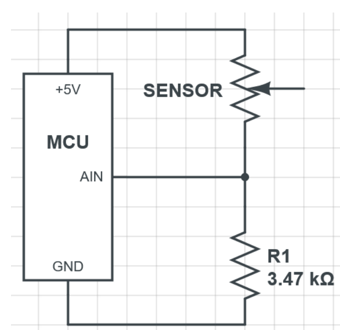
Provided below is some "pseudocode" (not real code, but provides a concise summary of the program) for the MCU logic. Time units are all in milliseconds in the code since the Hardware Abstraction Layer (HAL) on the microcontroller provides a function to get the current runtime in milliseconds.

```
void run_every_loop() {
        if (temp_sense_ADC > 751) { // value from TMP36 datasheet
                setPin(LED0, 1);
        } else {
                setPin(LED0, 0;
        }

        if (B2_pressed) { // just pushed down last loop
                C2_timer = 604800000; // milliseconds in a week
                play_buzzer_tone;
        } else if (B2_released) { // just released last loop
                play_buzzer_tone;
                last_removed = HAL_GetTick(); // time at which C2/C3 last removed
                last_removed_timer = C2_timer; // timer value when C2/C3 last removed
        }
        // loop_time is duration of one loop in milliseconds
        if (B2_held) { C2_timer -= 1 * loop_time; }

        // repeat above for C3 and B3

        // see pseudocode in Chapter VI for how we obtain moving_average
        if (C1_placed) { // just placed into container last loop
                play_buzzer_tone;
                if (moving_average > prev_weight) {
                        if (HAL_GetTick() - last_removed) > 60000 {
                                C1_timer = 604800000;
                        } else {
```

```
                    C1_timer = last_removed_timer;
                }
            }
        } else if (C1_removed) { // just removed last loop
            play_buzzer_tone;
            Prev_weight = old_weight; //old_weight is weight recorded 10 loops ago
        }
        if (C1_in_container) {
            C1_timer -= 1 * loop_time;
        } else {
            C1_timer -= 84 * loop_time; //outside of fridge, counts down faster
        }

        is_alarming = C1_timer < 0 || C2_timer < 0 || C3_timer < 0;
        // prev_alarm is the time at which the alarm previously rang
        if (is_alarming && HAL_GetTick() - prev_alarm > 3600000) { // ring once per
        hour
            play_buzzer_tone;
            prev_alarm = HAL_GetTick()
        }
        // fridge_opened if current ambient light is significantly higher than ambient
        light value 10 loops ago
        if (fridge_opened && is_alarming) {
            // turn on warning LEDs
            setPin(LED1, C1_timer < 0);
            setPin(LED2, C2_timer < 0);
            setPin(LED3, C3_timer < 0);
            // ring buzzer
            play_buzzer_tone;
        }
}
```

VI. Principles

1. Voltage Divider



Our force sensor will output its readings as resistance; the amount of resistance across the sensor's terminals will change depending on how much force is on the sensor. We need a way to read these resistances. This can be done using a voltage divider: a power pin is connected through our sensor and another fixed resistor to the ground. Then the analog input pin will be connected between the sensor and the fixed resistor. This can be done with the circuit in Figure 16 (right).

The equation for voltage readings in the analog input pin is $V_{out} = V_{in} \frac{R_1}{R_1+R_2}$ [16], where V_{in} is the input/power voltage, R_1 is the resistance of the fixed resistor, and R_2 is the resistance of the sensor.

In our case, R_1 will be 3470 Ω and V_{in} will be 5 V. V_{out} is read by the MCU, which is converted into a number between 0 and 4095 [17, p. 106]:

$$d = round(V_{in}\frac{R_1}{R_1+R_2} \times \frac{4095}{V_{in}})$$

$$d = round(4095\frac{R_1}{R_1+R_2})$$

$$d = round(4095\frac{3470}{3470+R_2})$$

Now, we have an equation that converts the resistance of the force sensor into the Analog-Digital Converter (ADC) reading that the program will read and use for future decisions.

2. Moving average

We must filter our force sensor data with a moving average. The data could be inconsistent depending on the quality of the sensor, and there may be occasional jumps or other anomalies. Therefore, we will use the moving average to "smooth out" our stream of sensor data values to ensure a consistent force/weight reading. The moving average of *k* data points at point *t*, where y_n is the data value at point *n*, is:

$$\frac{1}{2k+1}\sum_{j=-k}^{k} y_{t+j} \quad [18]$$

We can put this in C++-like pseudocode, with a slight modification in that it takes the *k* points before the current point rather than the *k* points nearest to the point, as we can't poll sensor readings in the future:

```
int moving_average;
int prev_values[5] = {0, 0, 0, 0, 0};
// this code runs periodically
void run_every_loop() {
	int reading = poll_ADC();
	// remove first element, shift elements left, replace last element with reading
	shift_prev_values(reading);
	// calculating sum of elements in prev_values
	int value_sum = 0;
	for (int i = 0; i < prev_values.length; i++) {
		value_sum += prev_values[i];
	}
	// calculating average of elements by dividing sum by number of elements
	moving_average = value_sum / prev_values.length;
}
```

3. Torque in levers

Torque is $\vec{r} \times \vec{F}$ [19] where $\vec{r}$ is the displacement vector from the fulcrum to the point at which the force vector $\vec{F}$ is applied. When a lever has no angular acceleration, the sum of torques is equal, and we can use this to scale up the weight range to the force sensor's detection range. We want to do this because we want to utilize the full precision of the sensor.

Also, the magnitude of the cross product is equal to the product of the magnitudes if the vectors are perpendicular (which, in our case, is true), so we will simplify this equation to L * F, where F is positive if pushing clockwise about the fulcrum and negative if pushing counterclockwise.

We are required to measure from 0 to 1,377 g, or 0 to 13.50 N. The sensor measures from 0.196 to 19.6 N. Having a lever mechanism can only scale the input forces and not shift them; we must add a "dead weight" (the platform) equivalent to 0.196 N to the force sensor to shift its range to 0 to 19.40 N. Next, we need to scale up 13.50 to 19.40. If the weight of the milk is scaled by 1.43, the range of forces on the sensor will be from 0 to 19.29 N which is just within the force sensor's range.

We will apply levers with the design in Figure 17:

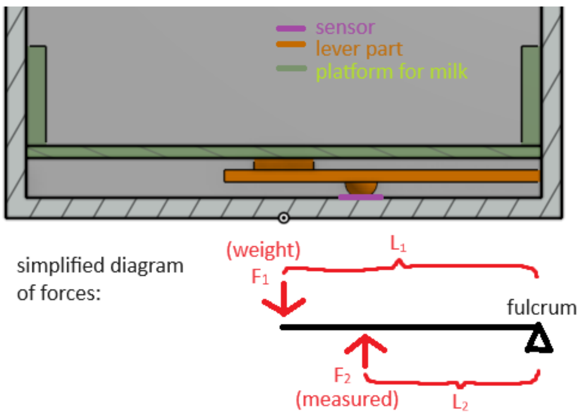
$$\Sigma\tau = 0$$

$$\tau_1 + \tau_2 = 0$$

$$-L_1F_1 + L_2F_2 = 0$$

$$L_2F_2 = L_1F_1$$

$$\frac{F_2}{F_1} = \frac{L_1}{L_2}$$



The ratio of F_2 / F_1 is 1.43, so the ratio between L_1 and L_2 must be 1.43. For L_1 = 65 mm in our design, L_2 must equal 45.5 mm, and any measured force F will be 1.43*w* where *w* is the weight of the milk.

4. Ohm's Law + Kirchhoff's Laws

We will use these laws to find the value of the resistor put in series with the buzzer to ensure it operates at its rated voltage of 1.5V:

- Ohm's law is a relationship between current, resistance, and voltage: V = IR [20]
- Kirchhoff's voltage law states that the sum of voltages in a closed loop is zero, or $\Sigma\Delta V = 0$ [21]
- Kirchhoff's current law states that the sum of currents entering and exiting any point is equal [22]

In our circuit, going clockwise, the voltage drop across the buzzer must be -1.5 V, the voltage across the MCU is +5 V between the GND pin at 0 V and the +5V pin, so we have, by Kirchhoff's voltage law:

$$-1.5\text{ V} + V_{R1} + 5\text{ V} = 0$$

$$V_{R1} = -5\text{ V} + 1.5\text{ V}$$

$$V_{R1} = -3.5\text{ V}$$

So the voltage drop across the resistor is -3.5 V. In other words, 3.5 V is passing through the resistor. The mean operating voltage of the buzzer is 15 mA, so by Kirchhoff's current law, the current across the resistor will be 15 mA too. We have now, by Ohm's law:

$$V = IR$$

$$3.5\text{ V} = 0.015\text{ A} * R$$

$$R = 3.5 / 0.015\ \Omega$$

$$R \approx 233\ \Omega$$

Therefore, for the buzzer to operate at its intended voltage, we must hook up a resistor in series with it that is around 233 Ω. This explains the use of a 200 Ω resistor with the buzzer in the Electronics section of the previous chapter.

VII. Manufacturing Costs

Materials required for manufacturing: Cardboard/foam boards, duct tape, hot glue, solder, milk pitcher, wires, and components specified below. Very little glue, wires, solder, and tape are used for the prototype, and costs are negligible (less than $1 combined). We need 745x510mm of 5mm thick foam boards, which will cost around $5 CAD. The milk pitcher costs $2 CAD from Canadian Tire, any milk pitcher works.

Technologies: Hot glue gun, 3D printer, Onshape CAD software, Cura (3D model slicing software), soldering iron, STM32CubeIDE, laptop with Windows 11. All the software is free, and the tools used for the prototype were personal or borrowed. The cost of electricity used for the prototype is insignificantly small.

Components:

Component	Part #/Name	Manufacturer	M. Location	Vendor/Distributor	V/D. Location	Cost (CAD)
3D Printer Filament (100g)	Canadian Filaments - Black PLA	Canadian Filaments	Edmonton, AB	Canadian Filaments	Edmonton, AB	$2.50
Temperature Sensor	tmp36gz	Analog Devices	Wilmington, MA	SparkFun	Boulder, CO	$1.85
Red LEDs x5	YSL-R531R3D-D2	Yunsun LED Lighting	Shenzhen, China	SparkFun	Boulder, CO	$2.49
Ambient light sensor	TEMT6000	Vishay Semiconductors	Suffolk, NY	SparkFun	Boulder, CO	$6.84
Force-sensitive resistor	FSR07DE	Ohmite	Warrenville, IL	DigiKey	Thief River Falls, MN	$6.76
Note: in our prototype, we are instead using the DF9-16 force sensor manufactured by Suzhou Leanstar Electronic Technology. We could not find a good industrial supplier other than Amazon for this part number so for the cost analysis we changed the part number.						
Breadboard	170 Points solderless breadboard	CIXI ZHONGYI ELECTRONICS	Zhejiang, China	Adafruit	New York, NY	$3.95
Microcontroller	STM32F401RE	STMicroelectronics	Mississauga, ON	DigiKey	Thief River Falls, MN	$34.99
Buttons x2	B3F-4000	OMRON	Kyoto, Japan	DigiKey	Thief River Falls, MN	$2.00
Buzzer	QMB-01	Star Micronics	Shizuoka, Japan	ABRA Electronics	Montreal, QC	$2.88
Resistors x12	53J1K0E	Ohmite	Warrenville, IL	DigiKey	Thief River Falls, MN	$1.20
Pin headers	PRT-11417	SparkFun	Boulder, CO	DigiKey	Thief River Falls, MN	$2.51

Component	Part #/Name	Manufacturer	M. Location	Vendor/Distributor	V/D. Location	Cost (CAD)
Jumper wires x14	PRT-12796	SparkFun	Boulder, CO	DigiKey	Thief River Falls, MN	$3.01
8mm M3 screws x3	76200-100	Studica	Mississauga, ON	Studica	Mississauga, ON	$0.39
Total (HST+shipping)						$88.65

VIII. Test Plan

Req #	Setup	Environmental Parameters	Inputs	Measurement Standard	Pass Criteria
1	Place a phone against the side of the device with the buzzer, with a sound measurement app (eg. "Sound Meter" on Google Play). Place a full 1.33 L bag of milk into the middle container and measure the peak sound level with the app as the buzzer rings.	Ambient noise is negligible and won't impact buzzer measurement (<20 dB)	Pressing of the button in the container once a bag is placed	Decibels (dB), buzzer loudness measured by app	Peak measured sound < 70 dB
2	Place a thermometer inside of a refrigerator and make sure the temperature < 4.4 ℃. Place the device into the fridge until the temperature indicator LED is off. Slowly raise the temperature of the fridge until it surpasses 4.4 ℃ and monitor the indicator LED.	Initial temperature of fridge < 4.4 ℃ and the fridge must have a temperature dial	Ambient temperature read by temperature sensor	Degrees Celsius (℃), temperature measured by thermometer	LED indicator should turn on once thermometer shows > 4.4 ℃
3	Start with 3 empty containers and press the reset button, which resets all internal timers. Place a full bag into the container closest to the reset button, then remove it within 3 seconds. Wait for a buzzer tone and record the time between removing the bag in and the start of the buzzer tone.	Nothing specific. For general environmental parameters that are necessary, see note below.	Pressure on force sensor detected by MCU when milk bag is placed/removed. This and the internal MCU timer are the only relevant data that is received as input.	Hours, unit of time measured by stopwatch	Buzzer should ring 2 hours (+/- 3 seconds) after the bag is removed
4	Start with 3 empty containers and press the reset button. Place a full bag into the container closest to the reset button. Wait for a buzzer tone and record the time between placing the bag in and the start of the buzzer tone.			Days, measured by stopwatch	Buzzer should ring 7 days after the bag is initially placed
5	Start with 3 empty containers and press the reset button, which resets all internal timers. Place a full bag into the			Hours, measured by stopwatch	Buzzer should ring 3 more times, 1 hour

	container closest to the reset button, then remove it within 3 seconds. Wait for a buzzer tone (after ~2 hours), then start timing and record when future buzzer tones are.				apart, starting 1 hour after the first tone

Notes On Test Plan

Environmental parameters that apply to all tests:

- Device is powered and on
- Ambient temperature is between -40 and 105 ℃ to ensure normal operation, as specified in the datasheet [17]. Ensuring proper operation at fridge temperatures should be tested in a different test for a different requirement.

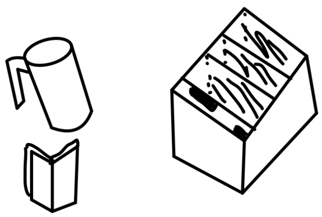
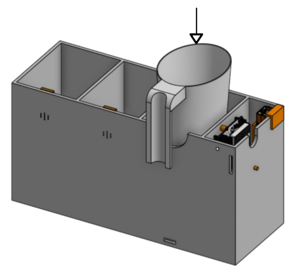
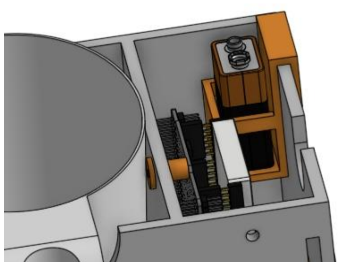
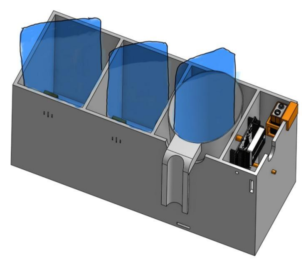
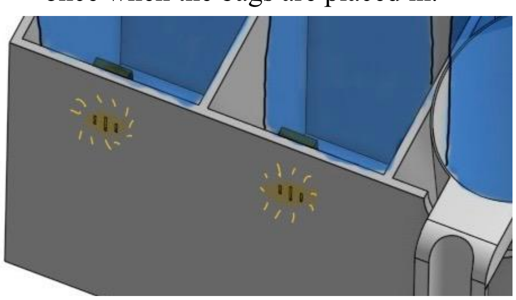
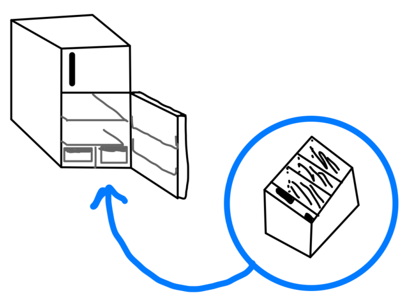
In the implementation demo:

- Water will be used instead of milk. Water is easier to get a hold of and its density is very similar; besides, the accuracy of force measurement isn't tested here so it's ok if the weight of the bag isn't exact
- To test timings during the relatively short implementation demo, we will change the time scale in the microcontroller to 120x normal speed, so that 1 hour becomes 30 seconds and 2 hours becomes a minute. We will not test requirement 4 as 7 days is still too long at 120x speed

IX. Installation Manual

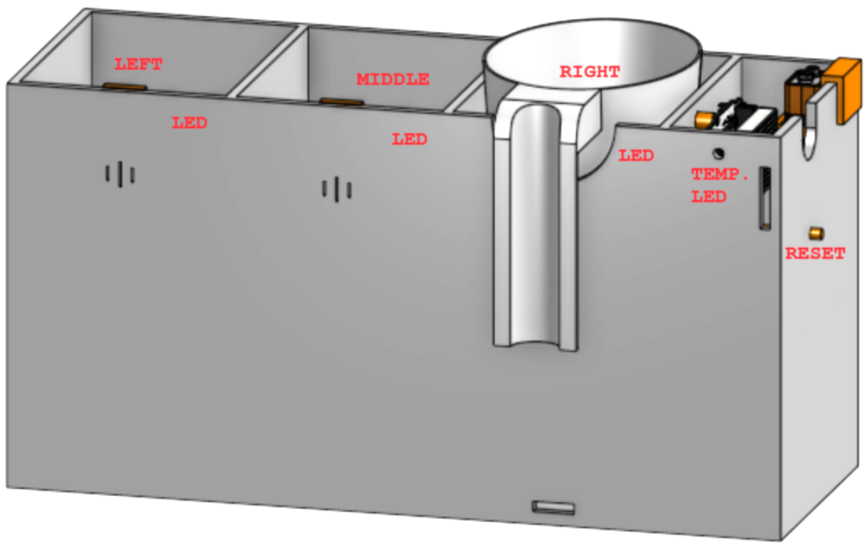
Thank you for purchasing the Spoiled Milk Detector from FreshGuard Inc. This manual will assist in the setup and installation of the device. Upon receiving your device, inspect the product for any noticeable damage that may arise due to shipping and package handling. In particular, inspect the casing of the product for cracks, and look for any loose wires. Should any parts be broken or malfunctioning, please contact Customer Support at **519-420-6969** or send us an email at **support@freshguard.com** with images of the issue if possible. Thank you and enjoy your fresh milk!

<u>Note: A 9V battery is required to operate this product which is not included.</u>

1. Ensure you have the following: ○ Milk Pitcher ○ User Guide ○ Spoiled Milk Detector Device 	2. Place the milk pitcher into the rightmost container with a cutout for the milk pitcher handle. 
3. Connect a 9V battery to the battery clip in the electronics compartment, located on the right of the three milk bag containers, then place the battery in the holder as shown. 	4. Power on the device and place three fresh milk bags into the three compartments with the one currently in use placed into the milk pitcher. 
5. Ensure all three container LEDs blink once when the bags are placed in. 	6. Finally, place the device into the fridge. Enjoy your fresh milk! 

X. User Guide

This user guide contains all the necessary information about the operations and maintenance of the Spoiled Milk Detector device by FreshGuard Inc. Included are common troubleshooting issues, the operational restrictions of the device, and any precautions to take note of. For setup and installation instructions, refer to the Installation Manual.



Instructions:

1. Place a batch of 3 fresh milk bags in the 3 containers.
2. When pouring milk, use the bag in the pitcher.
3. When the bag in the pitcher is empty, move a bag from the left/middle container into the pitcher.
4. Any new fresh bags can be placed into the left/middle containers as well.
5. If any indicator LED light is on, that bag if milk is spoiled; replace as soon as possible.
6. If the TEMP LED light is on, the fridge is not cold enough. Milk should be stored at < 4.4 ℃

Notes:

- Milk lasts about 7 days in the fridge and 2 hours outside of the fridge.
- This device should not be handled/operated by children under the age of 12 due to safety reasons.

Technical Issue Troubleshooting:

When attempting to troubleshoot the device for malfunctions, the following steps should be followed.

1. Check the device for any visible physical damage or loose parts (wires, sensors, etc.).
2. Reset the device by using the reset button located on the side.
3. Switch the 9V battery.
4. Contact our Customer Support line if the issue persists.

Customer Service:

FreshGuard Customer Support 24/7 Hotline:
519-420-6969

Email:
support@freshguard.com

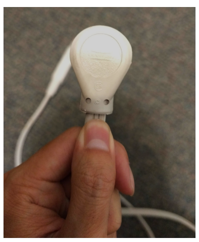
Website:
www.freshguard.com

XI. Energy Analysis

In the actual product, energy will be stored in a 9V battery. However, for our Implementation Demo prototype, we will plug our device directly into an 110V AC power outlet. Since the project safety requirements pertain to the Demo, we will do our analysis with the power outlet rather than the battery.

No significant amount of energy is stored in our prototype, since our circuits have no capacitors/inductors, no chemical changes occur during operation, and we have no parts that deform to store energy. Therefore, the energy stored in our device is negligible and safe, even during operation; certainly under 500mJ.

We will connect our device to a mini-USB to USB-A cable, then a 5V DC adapter, then finally an extension cord that goes into a 110V AC power outlet. The microcontroller will not draw more than 300mA of current through the USB port [23, p. 20], so the max power draw is 5V * 0.3A = 1.5W, well below the limit of 30W. This is the only source of energy for the device. As shown below, the cord that directly connects to the outlet is CSA approved, and the adapter is UL certified and rated for 5V. The CSA approval, 30W limit, and 500mJ limit imposed by the project requirements are all satisfied [24].




XII. Risk Analysis

Using the device for its intended purpose will have very little negative impact on the environment (the device uses a small amount of electrical energy which may come from non-renewable resources), and no impact on safety.

Unintentional use of the device incorrectly may lead to negative impacts on health, since the warnings for when milk bags are spoiled will display at the wrong time. This could lead to the user drinking spoiled milk without realizing, leading to symptoms such as diarrhea, stomachaches, and vomiting [7].

Improper use and abuse of this device can result in negative effects to both the user and environment. Usage outside of household or refrigerator temperatures, or subjecting the device to direct sunlight or fire, may cause the plastic parts to melt, or cause the 9V battery to unsafely expand/explode. This will lead to potential burns to the user. Furthermore, damaging the product purposefully is bad for the environment since the device will need to be disposed of. As this device incorporates electronics, plastic, and a 9V battery, there will be a considerable amount of non-recyclable waste created.

The device can malfunction in a few ways. Programming bugs, restarts due to errors or power inconsistencies, or sensor failure could all lead to incorrect timings. The buzzer/LEDs could also fail to trigger, failing to warn the user.

Incorrect timings or failure to warn the user could lead to the user drinking spoiled milk, which is again a safety hazard. Incorrect timing can also cause the user to throw away milk that isn't spoiled yet, which is wasteful and bad for the environment (considering the production, packaging, processing, and transportation of milk).

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