1. Executive Summary

The project chosen upon for this subject is an Arduino-based grocery weighing scale used for the registration and monitoring of items stored in a refrigerator. This detailed design report focuses on a theory demonstration of the prototype's details.

This includes a detailed introduction, a flowchart of step-by-step functionalities of the prototype with a brief description of the working, a state diagram mapped out with the state machine equations along with explanations of the inputs and outputs and a block diagram describing all the components going into the Arduino circuit. A timing diagram will also be shown with respect to all forms of inputs and outputs. A brief alignment will be available explaining the relationship between the project and the motto of the subject to be followed, along with explaining how it aligns with all requirements set out by the subject teachers. This report will also include a comparison of the prototype to what was originally planned during the brainstorming phase, pointing out any changes made with reason. A testing section is also shown, describing all possible inputs entered into the prototype with all expected outcomes. A detailed plan section will show how this project is going to play out deliverable by deliverable, along with a Gantt chart to map out the timeline and a Work Breakdown Structure clearly showing what has to be done in each section of the remainder of the time to be spent on the project. There is a short section on risks to be looked out for and how they could be prevented with care. A clear budget plan has been laid out in the form of tables, equally distributed amongst all sections required. The team's marketing angle with respect to the prototype is also explained, showing the potential advertising to be made at the Innovation Fair.

All referenced and the appendix are both neatly listed out towards the end of the design report for this deliverable.

Table of Contents

Table of Figures

2. Introduction

Almost all buyers or consumers at this point are conscious of the world's major food waste problem. Food wastage contributes to greenhouse gas emissions, other environmental issues, and wasting an immense number of valuable products or food. As people are very busy in their day-to-day lifestyle, they usually do not really have the time to follow after the amount of food kept or bought which leads to forgotten expired products left in the refrigerators which eventually are thrown away after being unnoticed. These products need to be monitored. To tackle this issue, we have designed an Arduino based scale system that helps us sustain and reduce the risk of negative effects to the environment by reducing the food wastage due to forgotten expired food.

Nowadays, with our enhanced technology, smart refrigerator is being used to increase the use of appropriate storing of food. Although, this device is not economically friendly because it is not cost effective. Thus, this project presents an IoT-based scale using Arduino. The proposed system is an Arduino based scale which allows the user to register both the weight and the expiration date of a newly bought grocery item before storing it in the refrigerator. All this is done remotely in his/her mobile. The information taken in by the Arduino board is then transferred to an app which displays the expiration date of the entered product and the last registered weight. This then gives notifications to the user through the app when the expiration of a registered product is approaching. Also, the user will be able to update a product which has been registered previously.

The biggest advantage of our product? It minimizes food wastage. It is an organized method of having awareness of the availability of edible food, restricts the amount of food products that have to be thrown out once they cannot be eaten and reduces the expenditure to buy food due to wastage as they expire. This in turn reduces pollution and promotes waste management.

Our vision targets a wide variety consumer use case. Some of it includes people who have a busy life and want to keep track of the items kept, the consumers who are lethargic to be concerned if the product is out of date which increases the amount of waste created, and people who would like to reduce the expenditure on food bought because of wasted food.

3. Design

3.1 Working of the Product

The product will start off with being in a state of 'Low power mode' where it will be waiting to detect a proximity input. The proximity acts as an on button to make it easier for the user to turn on the product. Once the proximity sensor detects an input the motorized hatch opens revealing the food scale, waiting for a weight to be kept. Once the user keeps an object the user needs to open the app and will be presented with two options, either 'Set' or 'Update'. If the product was never registered in the database, the user will be given the option to set a product name/ ID. The app will also ask for the expiry date of the product. If the product already exists in the database, the user needs to tap on update and the app will ask/present the names and product IDs in the database. Once the user selects the product the app will display a message asking the user to remove the product from the scale. Once completed the hatch will automatically close and the product will go to the 'Low Power Mode' after a period of time. At any stage of this process if the user hits the OFF button on the scale, the product will turn off and the hatch will close. The flow chart given below (Figure 3-1) is a visual representation of the process.

3.2 Flow Chart

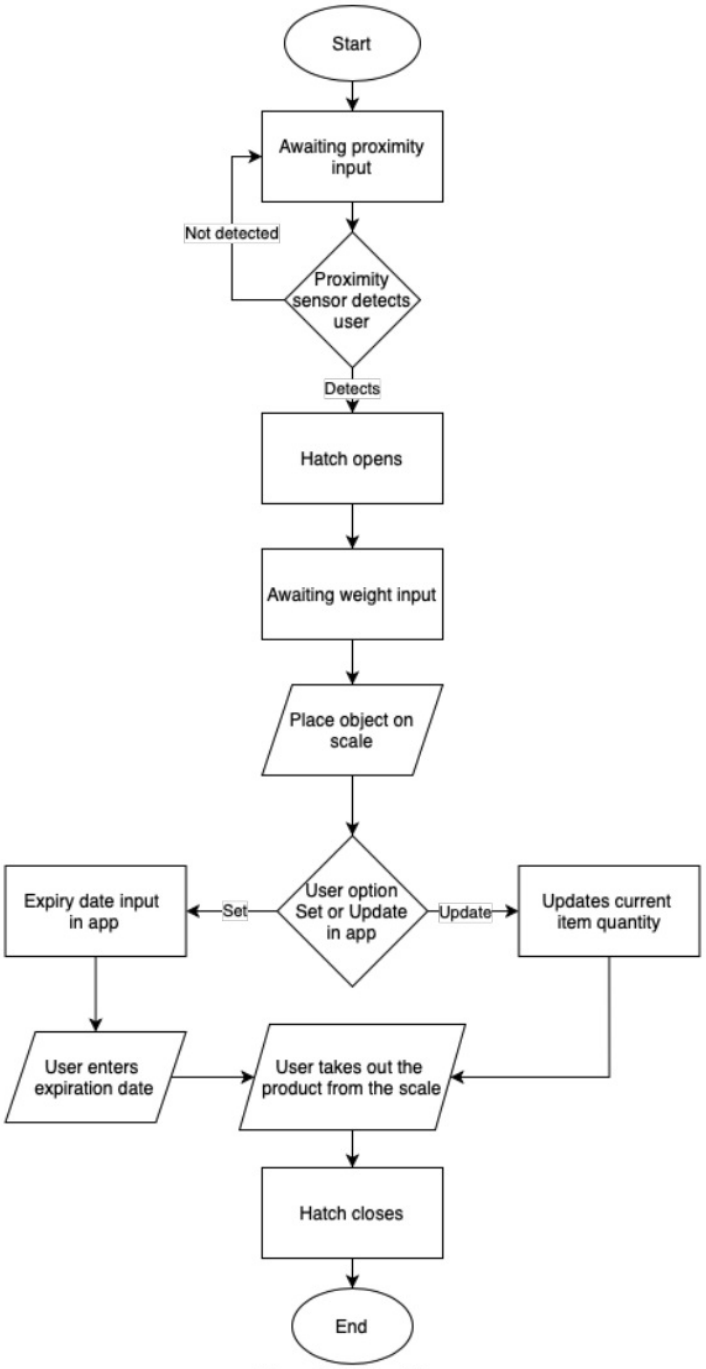

Figure 3-1: Flow Chart

3.3 State Diagram:

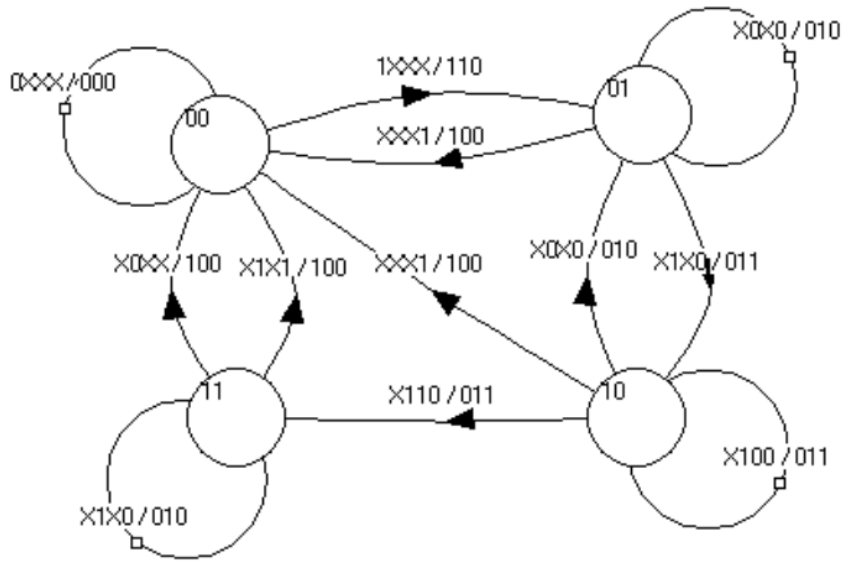

Figure 3-2: State Diagram

The state machine for our project has 4 states which in their respective order are as follows:

- 00 – hatch closed
- 01 – hatch open awaiting input
- 10 – hatch open weight kept
- 11 – data recorded

3.3.1 Overview of the inputs:

The state machine has 4 input as follows:

- A – Proximity Sensor
- B – Weight Input
- C – App
- D – BUTTON

The state diagram inputs are read in the following order:

$$ABCD$$

3.3.2 Explanation of the inputs for each state:

3.3.2.1 State 00-hatch closed:

In this state the machine is ON and is awaiting input from the Proximity Sensor (A), the other inputs do not matter since the machine turns on only if the proximity sensor is ON. Therefore, the input for this state is 1XXX and conversely if there is no input it will be 0XXX(LOOP) for the state 00.

3.3.2.2 State 01-hatch open awaiting input:

In this state the machine is awaiting weight input from the user (B) we do not care about the proximity sensor (A) or the app (C) in this state for the inputs. If weight is kept in the machine, then the machine goes to the next state 10-hatch open weight kept X1X0. Conversely if there is no weight input then the input will be X0X0 (LOOP) for the state 01. If the user presses the BUTTON then we do not care about if the weight is kept on the scale and go back to state 00, the input in this case is XXX1. The BUTTON acts like a manual override.

3.3.2.3 State 10-hatch open weight kept:

In this state the machine is awaiting input from the app(C) we don't care about the proximity sensor(A) in this state. If there is app input from the user then we go to the next state 11-data recorded X110. Conversely if no app input is given by the user then it is X100(LOOP). Also, if the weight is removed while in state 10 then we go back to state 01-hatch open awaiting input X0X0, and if the BUTTON is pressed then we go back to state 00 and don't care about any of the other inputs XXX1. The button is a manual override.

3.3.2.4 State 11-data recorded:

In this state we only care about if the weight(B) has been removed or the BUTTON(D) has been pressed. We do not care about the proximity sensor(A) or the App(C). If the weight is removed or the BUTTON is pressed, then we go to the next state 00-X0XX and X1XX respectively. Also, if the weight is not removed then the input is X1X0(LOOP).

3.3.3 Overview of the Outputs:

The state machine has 3 outputs as follows:

- X – MOTOR
- Y – LCD
- Z – App

The state diagram inputs are read in the following order:

$$XYZ$$

3.3.3.1 State 00-hatch closed:

The input/output for this state is 0XXX/000 if there is no input from proximity sensor it stays off. 1XXX/110 when there is an input for proximity sensor, we have output for the hatch mechanism that is driven by a DC MOTOR and the LCD displays a message.

3.3.3.2 State 01-hatch open awaiting input:

The input/output for this state is X1X0/011 to go to the next state 10, the DC motor is OFF, the LCD displays the user a message and the app displays a message to the use as well. If there is no weight input, then X0X0/010 there is only one output that is the LCD which displays the user a message. If the button is pressed XXX1/100 the only output is the DC motor which closes the hatch.

3.3.3.3 State 10-hatch open weight kept:

The input/output for this state is X110/011 which is app input from the user while the weight is kept on the device, the output is DC motor OFF, LCD displays a message, and the app displays a message as well. When weight is removed X0X0/010 LCD displays a message. When BUTTON is pressed XXX1/100 DC motor is ON hatch closes.

3.3.3.4 State 11-data recorded:

The input/output for this state is X0XX/100 when the weight is removed and X1X1/100 when the BUTTON is pressed the outputs for both of the following is DC MOTOR ON and the hatch closes. For state X1X0/010 the output is LCD displays a message to tell the user to remove the weight.

3.3.4 D-Flip Flop Equivalent Circuit:

3.3.4.1 Output X:

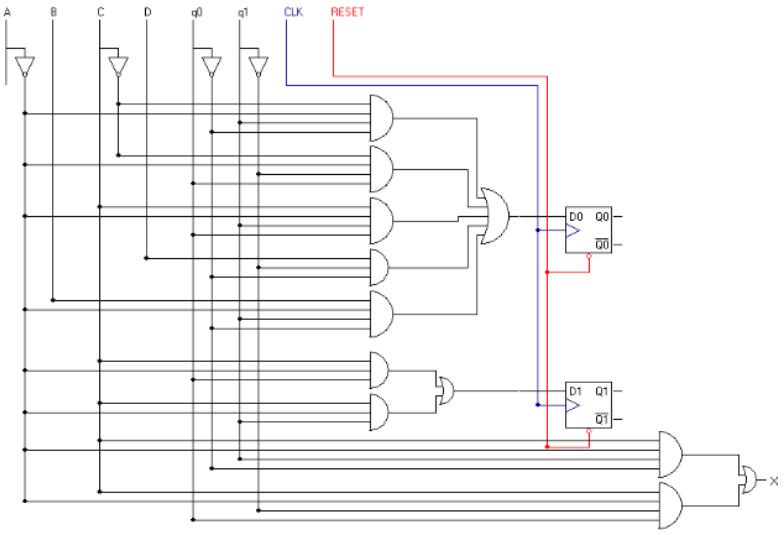

Figure 3-3: State machine output for X

3.3.4.2 Output Y:

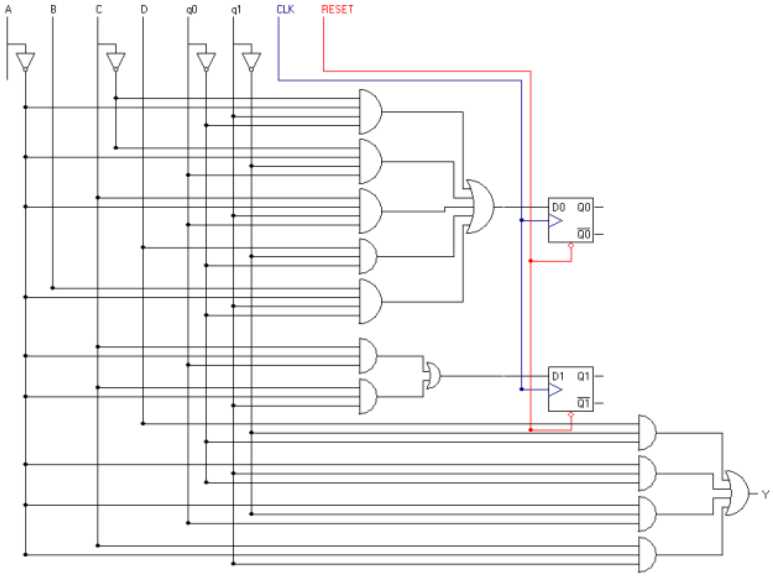

Figure 3-4: State machine output for Y

3.3.4.3 Output Z:

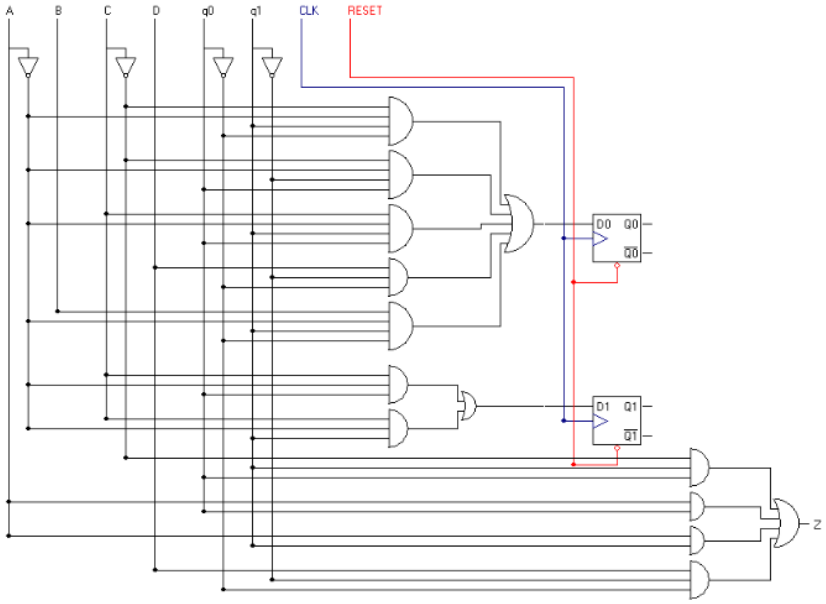

Figure 3-5: State machine output for Z

3.4 Block Diagram

The block diagram (Figure 3-6) visually describes the layout of what the Arduino circuit should contain. The circuitry is clearly labelled and the inputs and outputs are denoted using arrows.

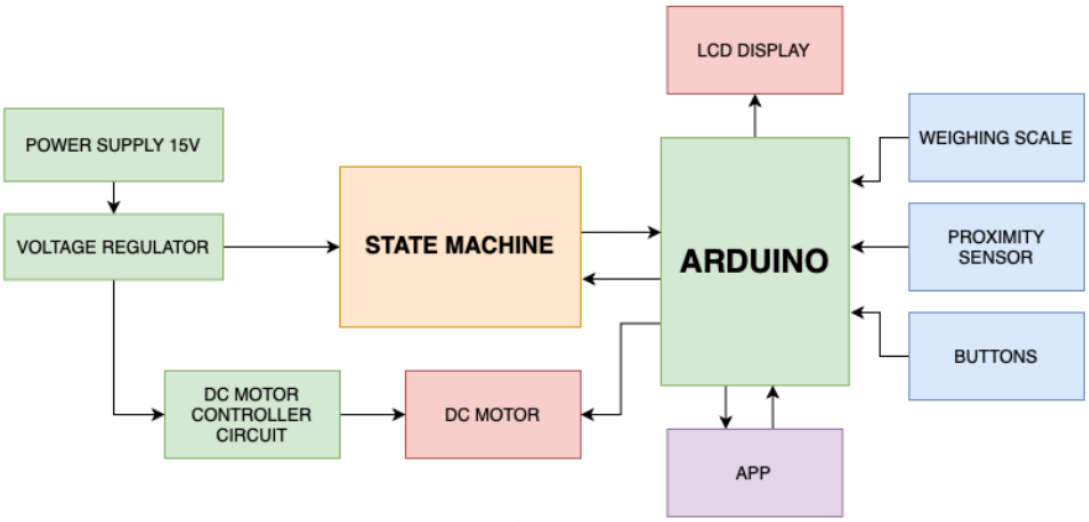

Figure 3-6: Block Diagram

3.5 Timing Diagram

The timing diagram shows the changing of signals in the time domain, showing the input and output details of the state machine with respect to time. The values in the timing diagram is taken from the Timing diagram truth table (Appendix: Table 4).

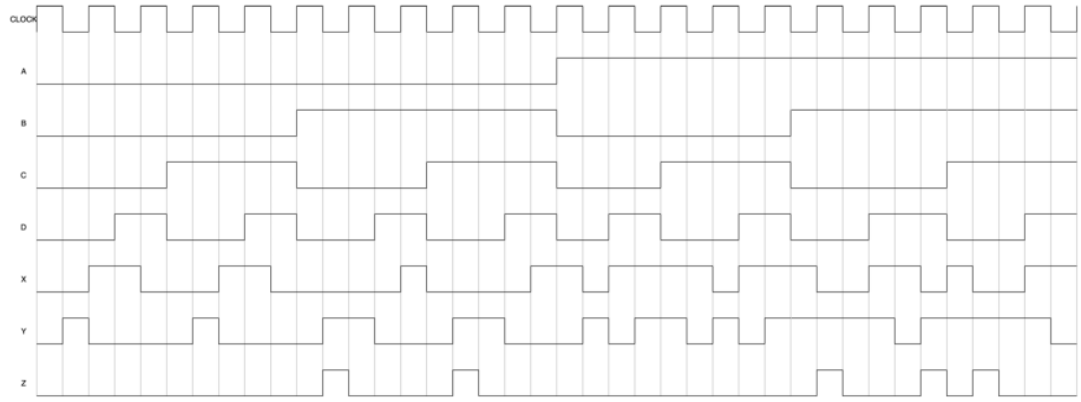

Figure 3-7: Timing Diagram

4. Alignment

Our proposal meets all 9 requirements which are the state machine, the DC motor, the push button, the transferring of weight from the Arduino based scale to the app using the internet, the LCD display to show data, the NE555 timer, the power supply, the four 7805 voltage regulators and the measurement of the total power consumption over the representative operational cycle. The proposal meets the main theme of the project which is Reduce Reuse Recycle, focusing mainly on reducing and meets the IoT requirement.

The only constraint shown by the Arduino scale was that the user will have to update the product after each use for the accurate percentage remaining and the expiration date when an item is bought again before storing it back into the refrigerator.

According to our design we will be using one infrared proximity sensor, one push-button to switch on or off the scale and the design of the app is once the product has been detected there will be two options shown to the user. The first option is called “set” for setting up the data of the product like the product ID, name, and the expiry date. The second option is called “update” for updating the data of a product which has been recorded previously after being used or bought, after selecting this option it requests you to enter the product ID or scroll through the list of items in order the update any detail of a specific product.

According to the original plan, the idea was to have a keypad on the scale device prototype itself to register the product by entering its name ID using the keys. But due to the unavailability of keypads, the team was allowed to replace that particular part with a numpad. With the numpad, the expiration date can be entered either through it or by the app. Another issue was when the limitations of the buttons were pointed out. Because of this, three buttons were included in the updated design, one to switch on or off, one to set a product to register and one to update an already registered product. The second button is to be used whenever a new product is registered, and the third to be used to update a registered product. All of these functions could also be carried out through the mobile app.

5. Testing

The testing of the project will be done by breaking down the components of the project and testing them first then incorporating them in the final testing phase.

The Hatch: The hatch mechanism and the opening and closing of the hatch with the proximity sensor will be tested first. The outputs being the motor is also checked.

Weight Input: The weighing scale will be tested to check if the input is being recognized by the system as to move on to the state 10 which checks if the app is connected.

App Input: The app connectivity will be tested to check if the system recognizes the phone as an input as it is needed to move to state 11. Recording of the inputted values from user: A data sheet is used to manage the data inputted from the user and is verified that these values are also being shown in the app.

LCD Output: LCD output is checked in all states of the machine. Then the above modules are incorporated and are tested in order with our state diagram and the flowchart all inputs and outputs are verified and checked.

Simulation Testing: During simulation since will check the working of the state machine using Multisim and Tinkercad and check if it matches the specification of our project. Since we cannot check if the app works in the simulation, we will have to wait till the prototyping of the project to begin testing the app and the functionality of the app in our system. All voltages and outputs will be marked and noted for the circuitry of the state machine and components of the machine, like sensors, motor etc. During simulation testing we will try to streamline the number of gates required to realise our state machine through rigorous testing and theory crafting.

Prototype Testing: During the breadboard/perfoboard testing we will verify the working of our statemachine and probe and check the voltages and outputs from our state machine and verify the proper working of the components of the machine. During this phase we will also have the app developed and we will be able to test the app in accompany with the state machine and check the function of the app with it.

6. Plan

6.1 Deliverables

Throughout the rest of the course and project timeline, there are up to six deliverables left for project completion. In the first deliverable, the team was to present two or more proposals for the project under the theme "Reduce Reuse Recycle". It was carried out through 18 minutes of two ideas; one being the selected food storage scale system, and the other one being a smart bin used to segregate recyclable and non-recyclable waste. For the division of work between teammates, the proposals were discussed at great length in meetings and parts of each proposal were distributed amongst one another to work on the presentation. This worked seamlessly as all members involved were on the same level of understanding with regards to the topics and how they accomplish the ultimate goal.

Once this was done, the second deliverable was then put to work, where a 4000 – word Detailed Design Report was to be written. This was to be written with the sole intent of targeting the proposal which was selected by the subject teachers. Once the topics were finalized, meetings were then held to appropriately divide the report amongst teammates to promptly finish writing with the highest level of prowess. This deliverable is to be submitted in week 6 of semester 2.

The objective for deliverable 3 is to demonstrate Design Simulation with a short Technical Report. This report should explain the design with the help of schematics, diagrams and tables. This is mainly to target the results of the project in terms of hardware. This should also address the feedback given by the professor from the previous deliverable. The deadline for this deliverable is to be expected on week 10 of semester 2. The reflections from the team members should also be included in this deliverable.

Deliverable 4 requires groups to make a short technical report on a breadboard-based prototype. The objective of this deliverable is to use a breadboard and the parts required for the project to build the circuit that would carry out the functions for the team's ideas. The inputs must be given as predicted to see how the circuit responds in accordance with what is to be expected from the project design. This simulation must be shown by week 4 of semester 3.

The target for deliverable 5 is to present a Perfoboard-based prototype with the help of a short technical report. The tested circuits for the project must be soldered to a perfoboard. The perfoboard should be able to demonstrate all properties of the project with respect to all inputs and outputs. A power analysis must be made based on the observations. The deadline for this proposal is week 7 of semester 3.

Deliverable 6 entails the final design report. This should include design calculations, the breadboard design and the final Arduino circuit design. The testing results, procedures and discussions must also be mentioned in this report. The roles of each team member must be clearly listed along with their key achievements and contributions towards the project. This should be submitted by week 9 of semester 3.

Deliverable 7 should be the presentation of the final prototype design along with testing and implementation. This should be done during tutorial hours in week 9 of semester 3. Illustrations and visuals are highly recommended for this presentation. The performance of the team should also be recorded, along with a comparison of the prototype against the original plans. The marketing strategy and commercializing must also be clearly stated. This must be presented in the duration of 10 minutes with 5 minutes allocated for questions.

Deliverable 8 is the Innovation Fair 2021 which is to be held in week 10 of semester 3. All the team members are required to attend, which allocates to 5% of the final grade based on presentation. A PE session is to be held, which must be submitted by the end of Innovation Fair day. The Innovation Fair is where the groups must present the project prototype.

6.2 Work Breakdown Structure

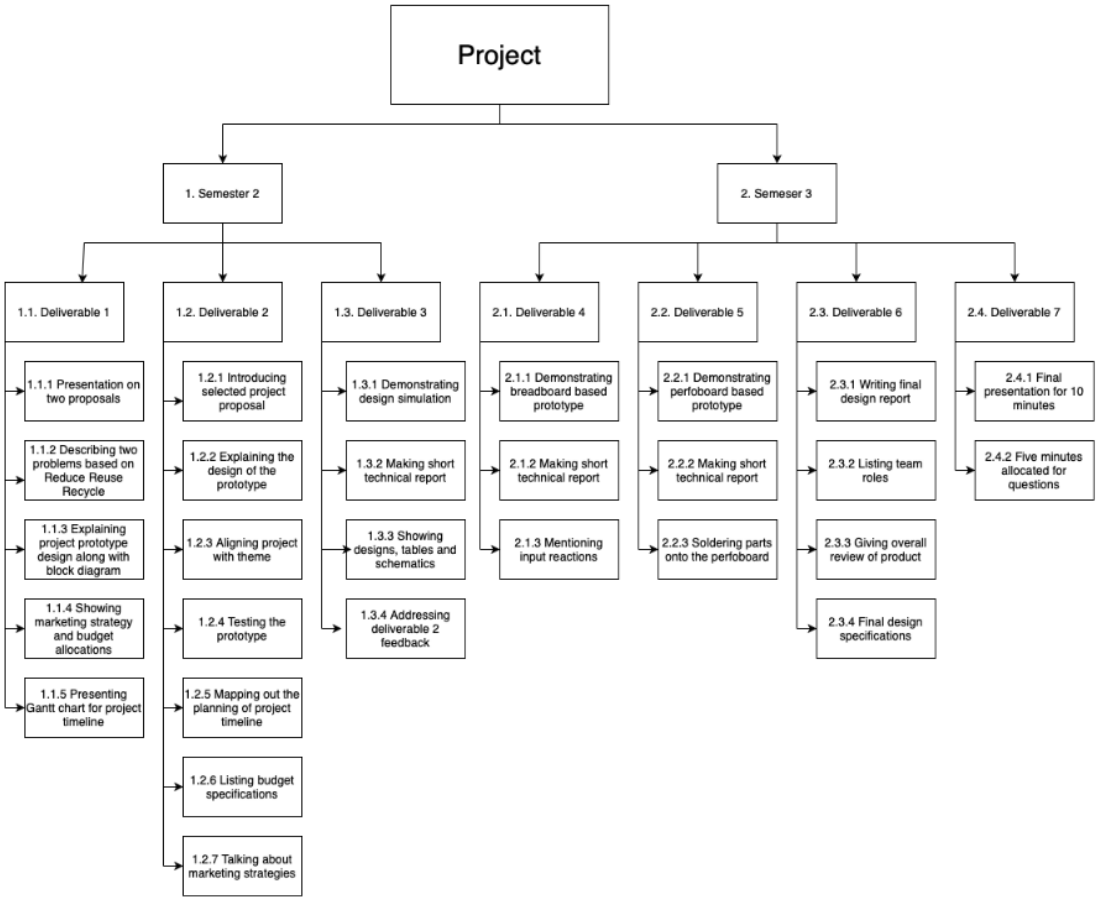

Figure 6-1: Work Breakdown Structure (WBS)

6.3 Gantt Chart

A Gantt Chart was made to map out the timeline in which all these deliverables are due. This just visually clarifies what was explained earlier above. The Gantt chart is as follows:

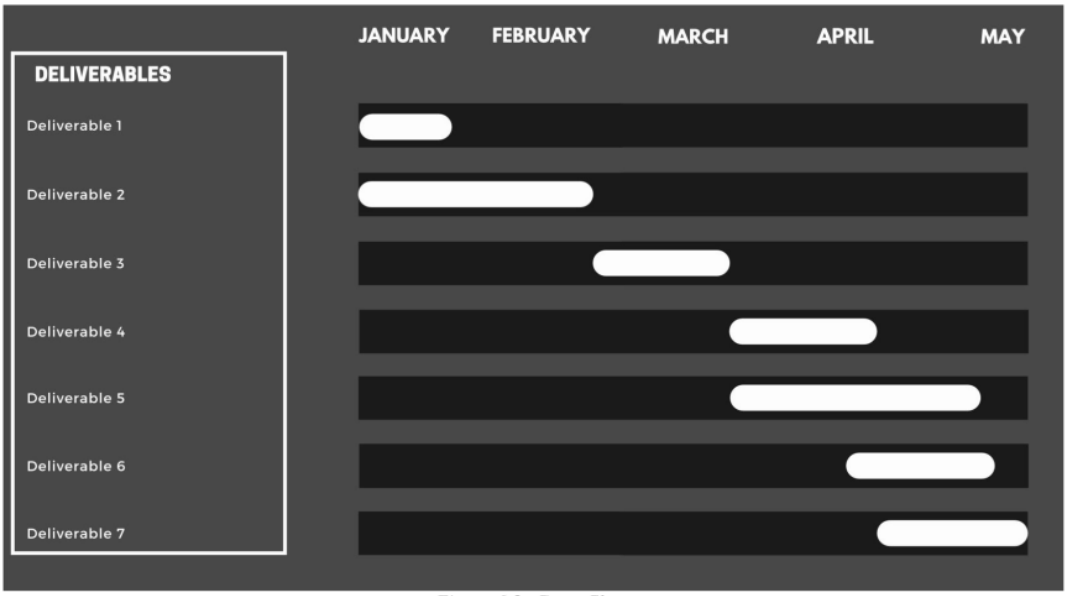

Figure 6-2: Gantt Chart

6.4 Risks

There are a number of potential risks that come with the preparation of our project. One of them is the hazard of working with electric products, which gives the danger of shocks or worse injuries. The same warning can be given when working with soldering. This can easily be managed by taking the necessary precautions such as wearing safety gear when preparing to construct the circuit. One other problem that could be of significance is the technical issues that could be brought upon by the application designed to monitor the registered products in the refrigerator. This could be foreseen and corrected by making sure all functionalities of the app are fully working in terms of its coding and connection to the device prototype.

7. Budget

7.1 Parts

For this project the budget for parts was set to AED 900. The most expensive part of this budget is taken up by the Arduino Starter Kit costing AED 600. The kit comes with the Arduino board as well as most of the basic parts. Apart from this a few other parts listed as seen in Table 1 will be required for making the product prototype. The current parts chosen are based on the team's current understand of what will be needed to create the prototype however some parts might be added or removed. With this, the team is still estimated to be well within budget for the cost of parts. Since certain equipment will be provided to use by the university, it drastically reduces the cost required to create the prototype.

Table 1: Cost list for parts

Sl. No.	Part Name	Cost	Quantity	Total Cost
1	Arduino/Genuino Starter Kit	600	1	600
2	NE555 timers	5	1	5
3	74LS00 (Quad 2-input NAND gate)	4	4	16
4	74HC02 (Quad 2-input NOR gate)	4	3	12
5	74LS08 (Quad 2-input AND gate)	4	4	16
6	74HC74 (Dual D type flip flops)	4	2	8
7	7805 (+5 VDC Voltage regulator, 1 amp)	4	2	8
8	Infrared Proximity Sensor	45	1	45
9	Weighing Scale*	25.8	1	25.8
				735.8

7.2 Labour

The team has created the expected time per spent per deliverable based on how much time was spent thus far and has come up with an estimate of AED 109,200. The cost does account for the consultations which is an added estimate of AED 1,800 for a total of AED 111,000. It should be noted that there is no limit set for budget for this project however the team aims to be as efficient as possible with the time. The wages are subject to change and an accurate representation of the labor wages will be provided by the team in the final report.

Table 2: Cost list for labour

Deliverables	**Expected Time (Hours) (Team)**	**Hourly Wages (Per Person)**	**Hourly Wages (Per Team)**	**Total Wages(Team)**
1	8	300	1200	9600
2	12	300	1200	14400
3	6	300	1200	7200
4	8	300	1200	9600
5	20	300	1200	24000
6	28	300	1200	33600
7	5	300	1200	6000
8	4	300	1200	4800
				109200

8. Marketing

The main goal for the team is for each household to have at least one of our product. We aim to achieve this first for the UAE and then eventually to launch the product globally. We believe the product is a game-changer and something every household would desire for. According to statistics, there are roughly 2.3 mil households in the UAE (WDI, 2021). Initially we plan to cover at least 40% of the households in the UAE. This would equate to about 950k households. At one device per household our team is looking to dell 950k units of our product. This is a 2-year goal set by the team to cover the goal.

To do this, our team is planning on partnering up with existing brands and companies in the food industry to promote our product. Our goal is to partner up with food storage companies and refrigerator brands to promote our product and its usage while selling their product. We will share a percentage of the profits with the companies for them to promote and sell our product.

Another way our team planned on promoting the product is by partnering up with the UAE Government – Waste Department to mandate every household or give incentive to the users to use our product. The Waste Department is actively working on efforts to reduce waste (Waste management - The Official Portal of the UAE Government, 2021) and our team sees this as an opportunity for the department to add our product to their plan on reducing waste which in turn benefits their end goal.

9. References

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- 2019. *Internet of things-based (IoT) inventory monitoring refrigerator using arduino sensor network*. [online] Available at: <https://www.researchgate.net/publication/337560327_Internet_of_things-based_IoT_inventory_monitoring_refrigerator_using_arduino_sensor_network> [Accessed 20 February 2021].