CONTROLLED FRUIT STORAGE WITH ANDROID TECHNOLOGY

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APPROVAL SHEET

This design project entitled "**Controlled Fruit Storage with Android Technology"** prepared by Raymart R. Badillo, Chester Lorenz G. Molina, Sharmaine L. Talento and Jeremiah T. Tricenio of the Computer Engineering Department was examined and evaluated by the members of the Student Design Evaluation Panel and is hereby recommended for oral presentation and approval.

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MAJOR (CAPSTONE) DESIGN EXPERIENCE INFORMATION
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Student/Team	Raymart Badillo / Chester Lorenz Molina / Sharmaine Talento / Jeremiah Tricenio Group 15
Design Title	Controlled Fruit Storage with Android Technology
Program Concentration Area	Embedded Systems
Design Project Objectives	**Project Objectives** The general objective of the project is to design a **Controlled Fruit Storage with Android Technology** that controls temperature and humidity to slow down the ripening process of fruits, particularly bananas, in accordance with codes and engineering standards and consideration of trade-offs based on multiple constraints such as economic, manufacturability and aesthetics. **Specific Objectives** • To design a storage device that would control the temperature and humidity based on the standard requirement of fruits, particularly, bananas. • To develop an Android application that enables the user to monitor the gathered data from the sensor such as temperature and humidity and to view the live streaming. • To test and evaluate the accuracy of the device.
Constraints	
Economic	Generally, one of the largest limiting factors of this design project is the economic constraint. To maintain economic feasibility, the designers considered the orientation, effectiveness and availability of the components. Other costs involved in the project are the developmental costs for the design detailing and testing, resources for labor, machines and materials and the distribution costs for spare parts.
Manufacturability	The designers ensured that the prototype can be manufactured with relative ease at minimum cost. Manufacturability shows how to design for low cost, design in quality, design for lean production, and design quickly for fast production. By considering this constraint, the designers were able to compare the ease of assembly by getting the different effects of the availability of the products, as well as the knowledge of the designers regarding the components or methods that would be used. The designers also prepared for the maintenance of the prototype to ensure its reliability after manufacturing. With this limitation, the design process might be interrupted in case of material failure.
Aesthetics	For the final appearance and kinds of materials that were used on the design, the designers considered storage standards and fruit standards. A design did not just came up, it was specifically designed for the components or materials that were used. The total weight of the prototype, its appearance, as well as its interior setup, were specifically chosen to meet the objectives with high efficiency and accuracy result, in accordance with the constraints and standards.

Standards	
1. IEEE 802.15 The General Bluetooth Wireless Network Standard and Specifications	This standard was used as the main reference for the development of the project in using a Bluetooth module that also uses this standard as its basis for connections and specifications for wireless connectivity between the hardware and a the android application. In accordance with IEEE 802.15, the designers considered the range limit of the Bluetooth which is 10 meters.
2. ISSN: 1011-0518 International Standards for Fruit and Vegetables	The designers used the ISSN: 1011-0518 to determine the standard optimum storage for both fruits and vegetables. The required temperature and humidity range can be found on this standard. (See Appendix A for the range of temperature and humidity to be maintained for fruits, particularly bananas.)
3. ISO 931:1980 Guide to Storage and Transport Standards	The guidance describes methods for obtaining conditions for the successful keeping, with or without artificial cooling, and transporting of fruits. The amount of ethylene production is mentioned here and was taken into consideration of the designers, resulting to the use of ethylene sensor. According to ISO 931:1980, the production rate of ethylene that must be maintained is 1-10 µl/kg*h.
4. ISO 3959:1877 Standards of Ripening Conditions of Green Bananas	This standard is regarding the factors influencing the degree of ripeness when the fruits are placed in the ripening room, the placing of the fruits in the ripening room, the heating of the fruits, the phases of ripening, the action of ethylene, the storage temperature after ripening, the degree of ripeness at the time of supply to the retailer, and causes of defective ripening.
5. ASTM F2520 – 05 (2012) Standard Specification for Reach-in Refrigerators, Freezers, Combination Refrigerator/Freezers, and Thaw Cabinets	This specification covers the basic design and function of temperature regulated, continuous duty commercial, and marine refrigerators, freezers, combination refrigerator/freezers and thaw cabinets. The equipment is stationary and of a vertical or horizontal type. Some equipment covered under this specification are the following: Styrofoam, reflective metallic sheet insulator, fiberglass, Thermal energy always flows from warm objects to cold ones. All materials, even good conductors like metals, offer some resistance to the flow of heat. Insulation, however, is any material that offers high resistance to the flow of energy.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADT	Android Developer Tools
ASTM	American Society for Testing and Materials
AVR	Alf and Vegard's RISC Processor
DC	Direct Current
DFD	Data Flow Diagram
GUI	Graphical User Interface
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IPO	Input Process Output
ISO	International Organization for Standardization
ISSN	International Standard Serial Number
KG	Kilogram
LED	Light Emitting Diode
MAC	Media Access Control
MIPS	Microprocessor
OECD	Organization for Economic Cooperation and Development
PHY	Physical Layer
PIC	Peripheral Interface Controller
PPM	Parts Per Million
RAD	Rapid Application Development
RH	Relative Humidity
RISC	Reduced Instruction Set Computer
SDLC	Systems Development Life Cycle
SI	System Information
UV	Ultraviolet
WIFI	Wireless Fidelity

TABLE OF CONTENTS

CHAPTER 1: PROJECT BACKGROUND

The Project

Fruits constitute a commercially important and nutritionally indispensable food commodity. Being a part of a balanced diet, fruits play a vital role in human nutrition by supplying the necessary growth regulating factors essential for maintaining normal health. Fruits are widely distributed in nature. One of the limiting factors that influence their economic value is the relatively short ripening period and reduced post-harvest life.

According to the World Economic Forum 2013, it is estimated that one-fourth of the harvested fruits are spoiled before consumption. Spoilage of fresh fruits usually occurs during storage and transport. Fruits reach the consumer as fresh, dried, frozen, fermented, pasteurized, or canned. Contamination may take place during harvesting, handling, transportation or storage unless proper hygienic conditions were not maintained. Mechanical damage may increase the susceptibility to decay and the growth of microorganisms may take place. Washing process in contaminated water may moisten surfaces enough to permit entry and growth of organisms. Storage in contaminated containers, use of contaminated dressing materials, possible contact with decayed products, unhygienic handling, fly infestation etc. also cause an accelerated rate of spoilage.

As of the year 2014, controlled atmosphere and chemical application are the most common ways done which are used to slow down the ripening process of fruits while on transport. First, there are the refrigerated trucks or road, rail or sea containers are used for long journeys, but the cost of such transport makes it uneconomical for small-scale operations. Second, the post-harvest application of fungicides or chemicals to control decay which is used on several major crops which are either stored or undergo long periods of transport to distant markets (citrus, bananas, apples, etc.). These chemicals are normally used only on produce which is washed and drained dry before packing. However, if the chemicals were used in excess, it drains off the nutrients from the fruits.

With this in mind, to minimize the fruit spoilage being encountered, the designers came up with the Controlled Fruit Storage with Android Technology. In order to do this, temperature and humidity would be controlled, while following the standards of cooling.

To extend the shelf life of a fruit, its ripening process and agents were greatly considered and was monitored for the designers to achieve the desired result, which is to slow down the ripening process of the fruit, prevent spoilage and damage whether on transportation or on stock.

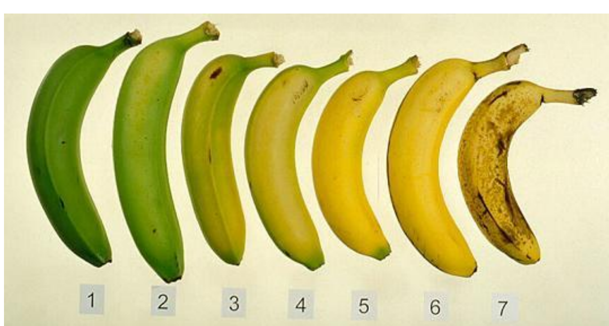


Figure 1.1 Ripening Process of Bananas

Figure 1.1 shows the ripening phases of a banana. It is represented by seven pieces to represent the gradual change in color of the fruit. The first piece is the appearance of an unripe banana and the seventh piece represents an over ripened banana that is near spoilage.

The project is a storage box where humidity and temperature is controlled resulting to slowed ripening process of the fruits, particularly bananas, keeping it from being spoiled. An IP camera is installed inside the storage which is connected to an Android device with application specifically made for the project. The exact values gathered by the sensors can be viewed on the Android application as well.

Project Objectives

The general objective of the project is to design a **Controlled Fruit Storage with Android Technology** that controls temperature and humidity to slow down the ripening process of fruits, particularly bananas, in accordance with codes and engineering standards and consideration of trade-offs based on multiple constraints such as economic, manufacturability and aesthetics.

Specific Objectives

- To design a storage device that would control the temperature and humidity based on the standard requirement of fruits, particularly, bananas.
- To develop an Android application that enables the user to monitor the gathered data from the sensor such as temperature and humidity and to view the live streaming.
- To test and evaluate the accuracy of the device.

The Client

The design project is intended for fruit growers, particularly banana farmers, and transporters which are located at the Philippines

Project Scope and Limitation

The project is a storage device designed for controlling the temperature and humidity. Clearly, fruit ripening is a natural process that could not be stopped, for this reason, the project focuses on controlling the temperature and humidity, resulting in slowed ripening process of fruits, particularly bananas.

The project is only limited to 14.6 ºC as it is the lowest temperature it can reach due to the materials that were used by the designers.

Project Development

Project development is an imperative part of this project, because this is what the designers used as their guide to the development of the project. It establishes guidelines for increased involvement of all the designers in the project lifecycle, with the goals of improving project coordination and communication, and ultimately improving the quality of the design-construction process.

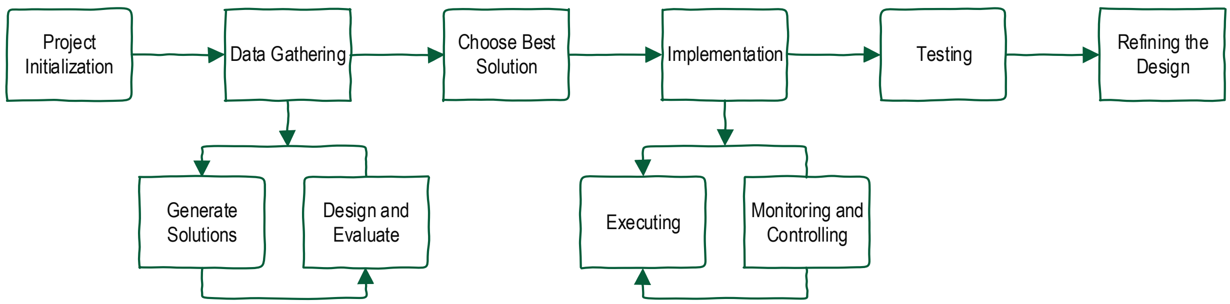


Figure 1.2 Project Development

Figure 1.2 shows the flow of the Project Development. The designers started by defining the problem. Next, data were gathered to generate solutions and evaluate possible designs. After gathering solutions, the designers chose the best solution based on computations and constraints. Once it was decided, the project was implemented right away and it undergone the testing phase. After multiple tests, the designers ended on refining the design to continuously improve the project.

1. **Project Initiation**
   The first phase is starting up the project. The designers started the project by defining its objectives, scope, purpose and deliverables to be produced. The designers also started the research regarding the target client for the project.

2. **Data Gathering**
   This phase started when the designers have finalized the problem to tackle and roles and responsibilities were designated. The designers studied the existing solutions to the problem which is fruit spoilage, finding out both advantages and disadvantages of the solutions present.

   a. Generate Solution
      In this phase, the designers brainstormed about all the possible solutions based on what the team had researched from the previous phase. The solutions are all listed for consideration which was then organized on the next phase.

   b. Design and Evaluate
      In this phase, three most feasible solutions were selected and placed into focus. The materials, circuit designs and proposed prototypes were generated and compared based on the criteria and constraints in its scope.

3. **Choose Best Solution**

Upon the selection of the best possible solution and after weighing all the factors affecting the solution, it was then finalized and prepared for another set phases. The designers set an attainable objective for the spoilage problem which was to design a controlled fruit storage.

4. **Implementation**

The team built the components from scratch and some by composition. The designers had built exactly what had been researched.

   a. Executing

   During this phase, the designers executed the tasks described in all of the plans, processes, and procedures summarized.

   b. Monitoring and Controlling

   This process involved tracking, reviewing, and reporting project progress. The designers performed evaluation of the design, keeping in mind the standards that were set, to be mentioned on Chapter 2.

5. **Testing**

Testing exercised the system in all possible ways. The designers performed a) unit testing which is tested piece by piece, b) integration testing which is testing two or more components that work together, c) system testing where all the pieces or components are tested, d) and lastly, alpha acceptance testing which is the testing phase of the in-house users.

6. **Refining the Design**

The last phase was the part where the designers identified the ambiguity of the design project in which lead to have some improvements of the prototype. The designers also reviewed the outcome of the project, thus being able to monitor and modify.

CHAPTER 2: DESIGN INPUTS

Design Constraints

In every design attempt, there are limitations or constraints that affect the design process that should be properly addressed along the project development. The possible constraints that were considered are listed below:

- Economic (Development). Generally, one of the largest limiting factors of this design project is the economic constraint. To maintain economic feasibility, the designers considered the orientation, effectiveness and availability of the components. Other costs involved in the project are the development costs for the design detailing and testing, resources for time, labor, machines and materials and the distribution costs for spare parts.

- Manufacturability (Availability of Materials). The designers ensured that the prototype can be manufactured with relative ease at minimum cost. Manufacturability shows how to design for low cost, design in quality, design for lean production, and design quickly for fast production. By considering this constraint, the designers were able to compare the ease of assembly by getting the different effects of the availability of the products, as well as the knowledge of the designers regarding the components or methods that would be used. The designers also prepared for the maintenance of the prototype to ensure its reliability after manufacturing. With this limitation, the design process might be interrupted in case of material failure.

- Aesthetics (Materials Used). For the final appearance and kind of materials that were used on the design, the designers considered storage standards and fruit standards. A design did not just came up, it was specifically designed for the components or materials that were used. The total weight of the prototype, its appearance, as well as its interior setup, were specifically chosen to meet the objectives with high efficiency and accuracy result.

Design Standards

The design standards used are taken from the following codes and standards:

1. IEEE 802.15 / Bluetooth – The General Bluetooth Wireless Network Standard and Specifications.

   This standard was used as the main reference for connections and specifications for wireless connectivity between the hardware and the android application. In accordance with IEEE 802.15, the designers considered the range limit of the Bluetooth which is 10 meters.

2. ISSN: 1011-0518 – International Standards for Fruit and Vegetables.

   The designers used the ISSN: 1011-0518 to determine the standard optimum storage for both fruits and vegetables. The required temperature and humidity range can be found on this standard. (See Appendix A for the range of temperature and humidity to be maintained for fruits, particularly bananas.)

3. ISO 931:1980 – Guide to Storage and Transport.

   The guidance describes methods for obtaining conditions for the successful keeping, with or without artificial cooling, and transporting of fruits. The amount of ethylene production is mentioned here and was taken into consideration of the designers, resulting to the use of ethylene sensor. According to ISO 931:1980, the production rate of ethylene that must be maintained is 1-10 μl/kg*h.

4. ISO 3959:1877 – Casing Standard for Ripening Bananas

   This standard is regarding the factors influencing the degree of ripeness when the fruits are placed in the ripening room, the placing of the fruits in the ripening room, the heating of the fruits, the phases of ripening, the action of ethylene, the storage temperature after ripening, the degree of ripeness at the time of supply to the retailer, and causes of defective ripening.

5. ASTM F2520 – 05 (2012) – Standard Specification for Reach-in Refrigerators, Freezers, Combination Refrigerator/Freezers, and Thaw Cabinets

   This specification covers the basic design and function of temperature regulated, continuous duty commercial, and marine refrigerators, freezers, combination refrigerator/freezers and thaw cabinets. The equipment is stationary and of a vertical or horizontal type. Some equipment covered under this specification are the following: Styrofoam, reflective metallic sheet insulator, fiberglass, Thermal energy always flows from warm objects to cold ones. All materials, even good conductors like metals, offer some resistance to the flow of heat. Insulation, however, is any material that offers high resistance to the flow of energy.

Hardware Requirements

The design project has input, process, and control functions. The input comes from the sensors that monitor the data measurements of the humidity and temperature inside the prototype. The sensors focus on the gases, temperature and humidity of the prototype. While the process depends on what the sensors' gathered data is, that triggers the controller to open the air flow of the system and other feature that depends on what the fruit subjects need. The controller has many parts, such as, the airflow, vacuum and ultraviolet light which are all very necessary for the maintenance of the fruits' measures.

The components below have been considered for the development of this project:

1. **Bluetooth Module** – this module receives information from an Android-based device, which consists of information needed to be processed by the PIC Microcontroller to control and monitor the temperature and humidity inside the storage.

2. **ATmega328** – the ATmega 328 is an AVR RISC-based microcontroller which can be programmed like the PIC microcontroller and serves as the controller of the whole system. The limitations on temperature are programmed on this microcontroller and it automatically turn of the cooling system once the selected minimum temperature is achieved.

3. **Temperature and Humidity Sensor** – this sensor monitors the temperature inside the storage and triggers the Cooling system to be turned on or off.

4. **Peltier Tile** – this component is responsible for the cooling of the storage. One side of it is cold, and the other is the hot side. When DC current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter.

5. **Heat Sink** – the heat sink is responsible for dispersing both the heat and cold caused by both sides of the Peltier tile. It draws the heat and the coldness away from the Peltier and with fans attached to it, the coldness is scattered inside the box, as well as the heat being dispersed outside of the storage.

6. **Fan** – the fans placed inside and outside the storage are both used for active cooling. One expels warm air from the heat sink outside and the other, provides air towards the cold side of the heat sink to promote cooling inside the storage.

Software Requirements

1. **Eclipse 4.3 (Kepler) & ADT (Android Development Tool)**
   The Eclipse and ADT are the software used to develop the android application of Controlled Fruit Storage with Android Technology, where the sensors readings are monitored and set.

2. **Arduino software**
   Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. The Arduino software was used by the designers to program the ATMEGA microcontroller.

CHAPTER 3: PROJECT / SYSTEM DESIGN

Input-Process-Output

The input-process-output (IPO) model is a functional model and conceptual schema of a general system. An IPO chart/table identifies a program's inputs, its outputs, and the processing steps required to transform the inputs into the outputs. (Gutenberg, 2012)

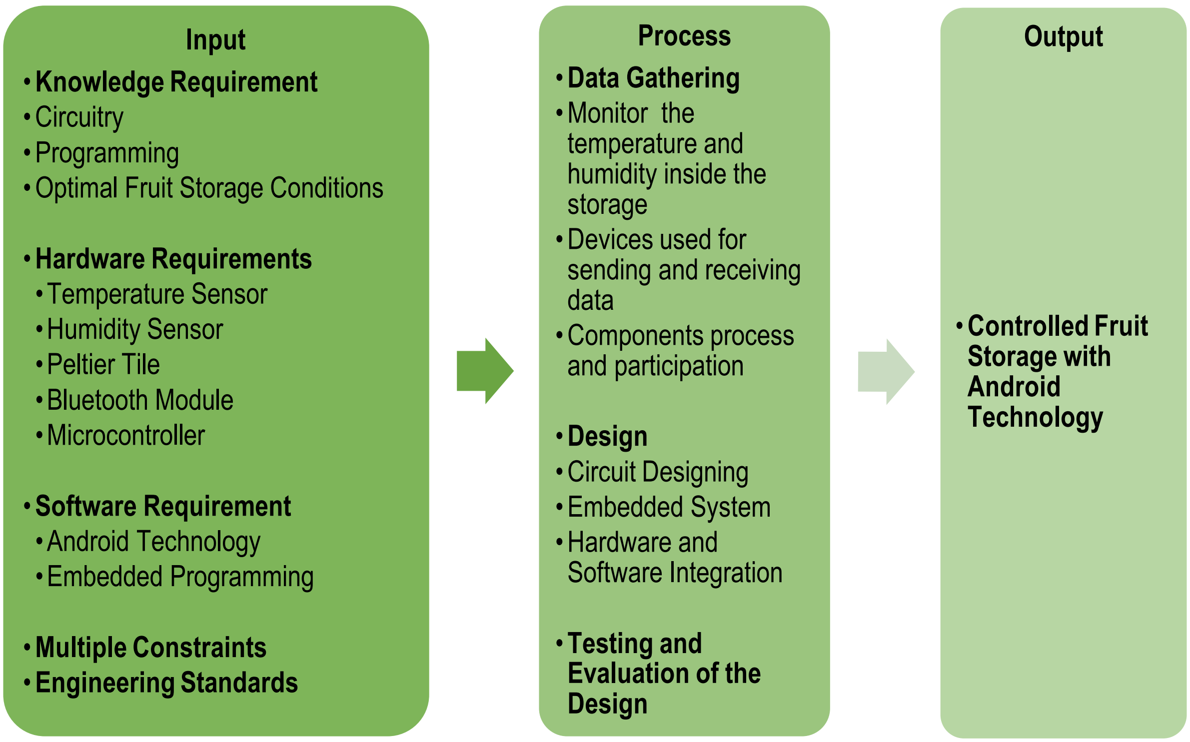


Figure 3.1 Input-Output-Process Model

Figure 3.1 shows the Input-Process-Output of the system which identifies the input, process, and output of the system. The model identifies the input in making this project and the process that were performed in order to develop the output which is the Controlled Fruit Storage with Android Technology.

System Flowchart

The system flowchart shows the key inputs and outputs associated with the program. It displays how data flows in the system and how decisions are made to control events.

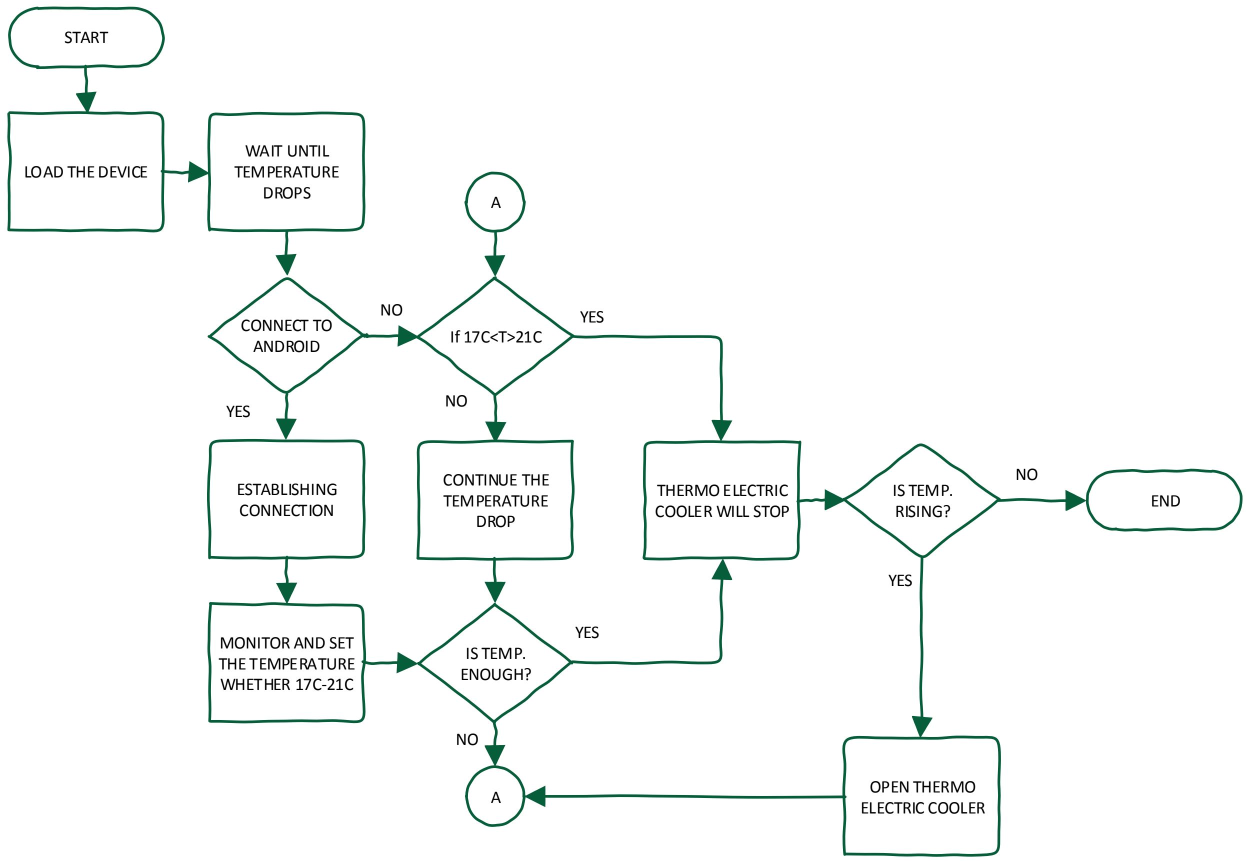


Figure 3.2 System Flowchart

As Figure 3.2 shows, the system starts when it is turned on. Upon turning the device on, the user must wait for the temperature to drop. While waiting, the user may open and connect the Android application to the fruit storage. Once the user has connected the application, the readings of the temperature and humidity can then be monitored and set the range of temperature that was kept by the device. If the temperature is not enough, the user must still wait for the temperature to drop, once it is in the range selected, it would be kept because of the program embedded on the microcontroller. If the temperature reading reaches the minimum temperature on the selected range, the cooling system automatically turns off and only turns on once the temperature is back on the selected range.

Illustrative Diagram

The illustrative diagram is a method used by the designers to obtain assembly information. It shows the connection of the mechanical parts of the project.

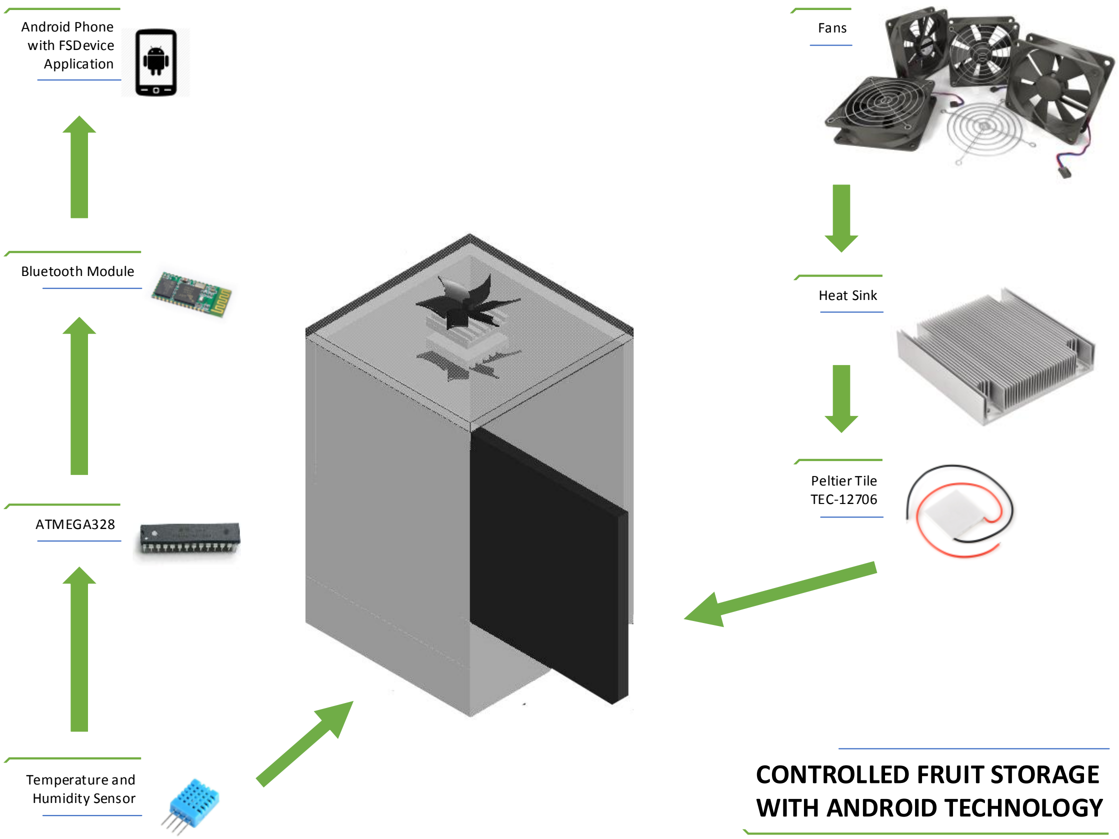


Figure 3.3 Illustrative Diagram

Figure 3.3 shows the illustrative diagram of the system. The arrows show where a component is attached or where it gives feedback.

Description of each component

- **Android Application** – this application displays the temperature and humidity reading from the sensor inside the storage device and send it to the mobile phone via Bluetooth technology.

- **Bluetooth Module** – this module serves as the connection of the Android-based device to the Microcontroller to control and monitor the temperature inside the storage.

- **Microcontroller (ATmega328)** – the ATmega328 was used as the microprocessor of the prototype. It performs the execution of instructions as set by the designers in a single clock cycle. This device also process throughputs approaching 1 MIPS per MHz, balances power consumption and process the speed.

- **Temperature and Humidity Sensor** – this sensor monitors the temperature and humidity inside the storage and triggers the Cooling system to be turned on or off.

- **Peltier Tile** – this component is responsible for the cooling of the storage. One side of it is cold, and the other is the hot side. When DC current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter.

- **Heat Sink** – the heat sink is responsible for dispersing both the heat and cold caused by both sides of the Peltier tile. It draws the heat and the coldness away from the Peltier and with fans attached to it, the coldness is scattered inside the box, as well as the heat being dispersed outside of the storage.

- **Fan** – the fans placed inside and outside the storage are both used for active cooling. One expels warm air from the heat sink outside and the other, provides air towards the cold side of the heat sink to promote cooling inside the storage.

Hardware Design

The designers prepared three designs for the project development of the Controlled Fruit Storage with Android Technology. For the microprocessor, ATmega328 was used in all of the designs prepared. As for the sensors, the designers considered an ethylene or temperature and humidity sensor (DHT11) or both to be present on the device.

The economic constraints, manufacturability and aesthetics, as well as the standards mentioned earlier on Chapter 2, were considered in every design constructed by the designers to ensure that the objectives were met.

Design 1: Storage Device with Air Ventilation and Ethylene Sensor

Design 1 depends on an ethylene sensor and an air ventilation system. It follows the standards of IEEE 802.15 / Bluetooth, ISO 931:1980 and ISSN 1011-0518.

The ISO 931:1980 are the standards followed by the designers regarding the amount of ethylene production that must be maintained in order to slow down the ripening process of the fruits, as well as the storage and transport conditions for the fruits. According to the ISO 3959:1977, the production rate of ethylene that must be maintained is 1-10 μl/kg*h. The designers used the ethylene sensor to monitor this standard.

The ISSN 1011-0518 is the standard followed by the designers regarding the optimal storage conditions of fruits and vegetables. The safe range of temperature and storage life are all listed on this standard. For the bananas, according to the ISSN 1-11-0518, green bananas must be kept at 17ºC – 21ºC. For the ripe bananas, it must be kept at 14ºC - 16ºC.

Aside from considering the standards that were followed for Design 1, the designers also put in consideration the constraints for the designs. These constraints are the economic for the developmental cost, manufacturability and aesthetics.

Economic. The ethylene sensor is easy to use and reliable, yet the price is expensive. This affects the economic constraint being considered in the project. The ethylene sensor is not available locally, in result, it is expensive. The shipping fee, actual fee of the component and the tax greatly affects the cost of the overall project.

Table 3-1 Total Cost of Design 1

Components	Price	Quantity	Cost
ATmega328	158.00	1	158.00
Ethylene Sensor	16,980.00	1	16,980.00
220v Metal Fan	375.00	6	2,250.00
Bluetooth	520.00	1	520.00
Casing Materials (Wood)	3,000	-	3,000.00
		Total	22,908.00

On Table 3-1, the total cost of Design 1 was shown. It is the main focus of the economic constraint, the developmental cost.

Aesthetics. By using the ethylene sensor, the designers were able to keep the design simple and lightweight. Since it is intended for transporting fruits, light-weight storage would be highly beneficial and very suitable for the objectives mentioned on Chapter 1. For the casing of the Controlled Fruit Storage, the designers used wood, as it is a material that would deflect any form of light coming through. For the storage, the designers followed the standards ISO 931:1980 and ISO 3959:1877, Guide to Storage and Transport and Ripening Conditions of Bananas, respectively.

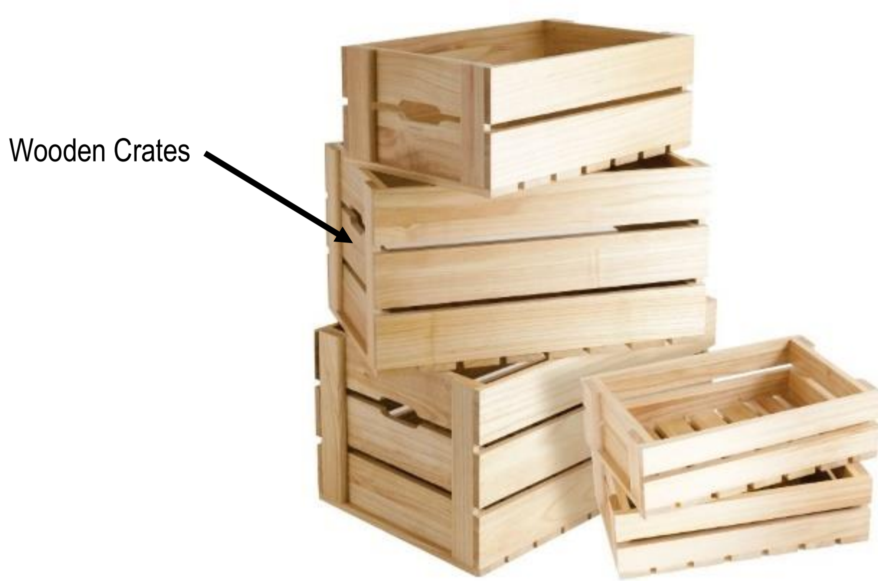


Figure 3.4 Wooden Fruit Boxes

Figure 3.4 shows the most commonly used fruit storage when importing or exporting fruits. Since it is lightweight and it protects the fruits from any form of light or heat, the designers were able to follow the standard materials for storage of fruits for transport, as mentioned in the ISO standard 2959:1877.

Manufacturability. The ethylene sensor would be ordered from China and all other components are available locally. The shipment of the main component, the ethylene sensor, highly affects the time frame intended for the creation of the project. This is a disadvantage for the designers.

Prototype Design

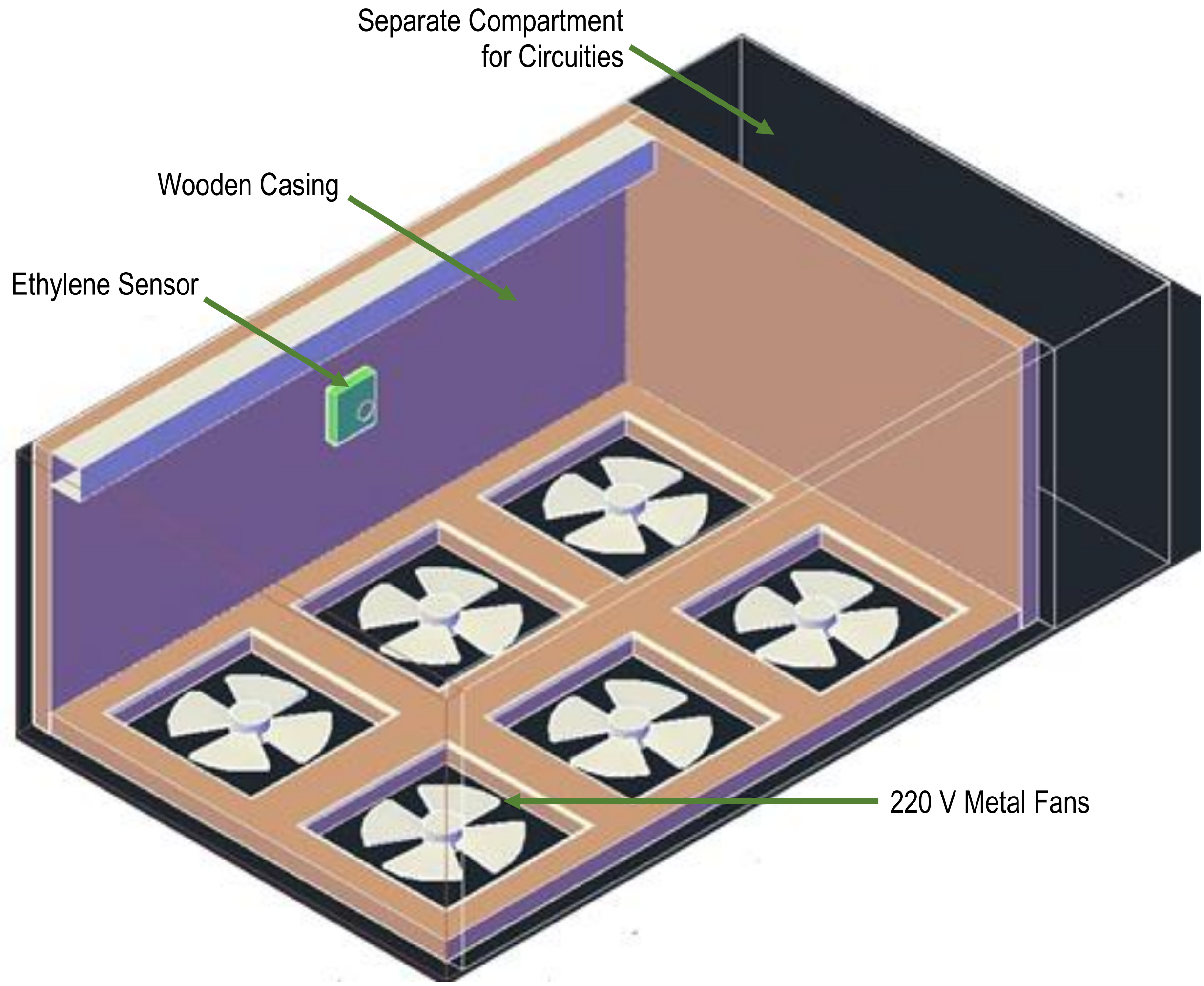


Figure 3.5 Prototype Design using Air Ventilation

Figure 3.5 shows Design 1, where the ethylene gas level is monitored closely. Fans are placed on the bottom of the container and is synced with the sensor. The circuitry is kept on the right side of the division to keep it safe and neat with thick division from the fruit compartment. This position also prevents the fruit from being heated due to the components, as heat causes the fruit to secrete ethylene.

Circuit Design

Figure 3.6 shows the circuit diagram of Design 1. This diagram contains the major components of the design and its connection to the microcontroller used.

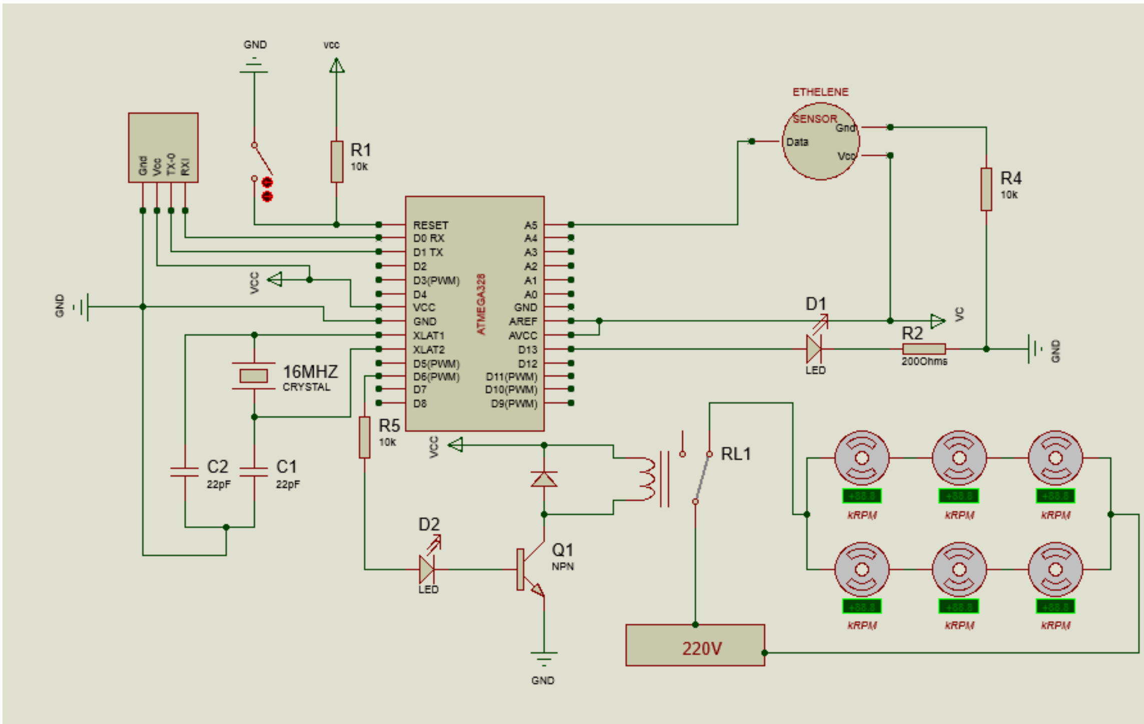


Figure 3.6 Circuit Diagram of Design 1

Power Computation for Design 1

The total power consumption of the storage device is necessary for the designers to know how much power supply is needed. Aside from the total supply needed, knowing how much current is flowing to the load is very important in selecting the correct wire for the components to the circuitry.

$P = V \ x \ I$ Equation 3.1

Dorf, R.C. (1993). Pocket *Book of Electrical Engineering Formulas.* Sacramento: CRC Press.

Where power P is in watts, voltage V is in volts and current I is in amperes (DC).

For ATmega328:
Input Voltage = 12v
Input Current = 200 mA

$$Power \ of \ Microcontroller = 12 \ v \ x \ 200mA = 2.4 \ watts$$

For Fan (6 pieces):
Input Voltage = 220 v
Input Current = 0.40A

$$Power\ for\ fan = 220\ v\ x\ 0.40\ A = 88\ watts$$
$$Power\ for\ 6\ fans = 88\ watts\ x\ 6 = 528\ watts$$

$$Total\ power\ consumption\ for\ Design\ 1 = 2.4\ watts + 528\ watts = 530.4\ watts$$

Specifications and Cost of Materials

The total cost of Design 1 is 22,908.00 as shown on Table 3-1. It includes shipping fee and tax of the ethylene sensor, its main component, as well as the cost for the material used for the case which is wood.

Table 3-2 Component Specification of Design 1

Components	Specifications
ATmega328	• Flash (Kbytes): 32 Kbytes • Pin Count: 32 • Max. Operating Freq. (MHz): 20 MHz • CPU: 8-bit AVR • # of Touch Channels: 16 • Hardware QTouch Acquisition: No • Max I/O Pins: 23 • See Appendix C for more information
Ethylene Sensor	• Measurement ranges - 0-3% Volume Ethylene (CH_2CH_2) • Reduced gas response time (< 20secs) compared with earlier versions • Low Power (15mA) versions available • EN 50271 / SIL1 SIRA Certified versions available • Combines all the features of the well-proven range of Premier sensors • Operating voltage 3 to 5 volts dc, standard nominal current = 80mA • Wide operating temperature range of -20 to +50 deg. C as standard • Output format options - Digital, Analogue or Pellistor Replacement • Instantly converts existing compatible pellistor-based instruments to infrared • Sensors can be factory configured to customer specifications • User configurable via a configuration unit available from Dynament

Components	Specifications
	• Internal 'Flash' memory enables firmware updates via the configuration unit • Industry standard size - 20mm diameter x 16.6mm high (excluding pins) • 3-pin (pellistor replacement) or 5-pin versions available • Optional replaceable, self-adhesive micro porous 14 micron filter
220v Metal Fan	• RoHS: Yes • Greenguard: Yes • Mounting Points: 2 • Volts: 220 • Finish Type: Black Brushed and Anodized • Component Type: active
Bluetooth	• Radio Chip: CSR BC417 • Memory: External 8Mbit Flash • Output Power: -4 to +6dbm Class 2 • Sensitivity: -80dbm Typical • Bit Rate: EDR, up to 3Mbps • Interface: UART • Antenna: Built-in Dimension: 27W x 13H mm • Voltage: 3.1 to 4.2VDC • Current: 40mA max
Casing Material (Wood)	• 6 x 8 2" Wood
	Total Cost: 22,908.00

In Table 3-2, the main components of Design 1 were listed and the specifications are also shown.

Design 2: Storage Device with Air Compressor Cooling System and DHT 11

Design 2 uses air compressor for cooling system and DHT 11 or what is commonly known as the temperature and humidity sensor. The standard cooling temperature for the bananas is 17°C – 21°C while the humidity level must be 80% - 95% for the ripening process to slow down.

Design 2 follows the standards of IEEE 802.15 / Bluetooth, ISSN 1011-0518, ISO 21348 and ASTM F252-05.

IEEE 802.15 was used for the limit of Bluetooth range which is 10 meters. Aside from IEEE802.15 standard, ASTM F2520-05 (2012) for Standard Specification for Reach-in Refrigerators, Freezers, Combination Refrigerator/Freezers, and Thaw Cabinets was considered for the casing materials of Design 2. Following these standards made the designers sure that the users of the Controlled fruit storage would be effective.

The designers came up with Design 2 by considering the constraints set on the previous chapter. These constraints are economic, aesthetics and manufacturability.

Economic. Design 2 uses an air compressor for cooling system and the temperature and humidity sensor for monitoring. It is an advantage for the designers because all the components are available locally.

Table 3-3 Total Cost of Design 2

Components	Price	Quantity	Cost
ATmega328	158.00	1	158.00
Air Compressor	3,200.00	1	3,200.00
Bluetooth	520.00	1	520.00
Temperature and Humidity Sensor (DHT 11)	105.00	1	105.00
Casing Materials (Metal Sheet and Plastic)	2,000.00	-	2,000.00
		Total	5,983.00

Table 3-3 represents the table of the main components that were used on Design 2. The designers used a different sensor in Design 2 to monitor the condition inside. By using the temperature and humidity sensor, Design 2 became more cost-effective than Design 1, giving the designers more advantage.

Manufacturability. The temperature and humidity sensor which was used in Design 2 is locally available and very cheap. Aside from the sensor, the air compressor was also easily available, giving the designers less time in completing the components of the Design 2 for construction. Compared with Design 1, Design 2 is more feasible because of the availability of its components, locally.

Aesthetics. Design 2 is made up of metal sheet with layers of Styrofoam and plastic to ensure that there's no hole or crack for the cold air to escape. The materials used are heavier than the Design 1 because of the compressor and the thick layer of metal sheet. Though there is a disadvantage in terms of the weight, the thick layer of the Design 2 is beneficial because it ensures that sunlight won't pass through the walls of the storage. Insects and rats would also be unable to penetrate through the walls of Design 2.

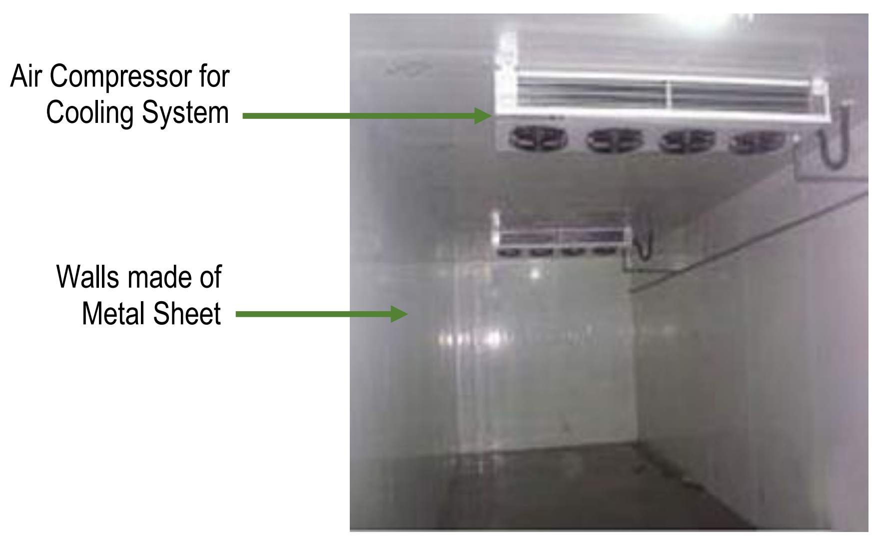


Figure 3.7 Controlled Cooling Room for Fruits and Vegetables

The cold rooms being used today for slowing down the ripening process of fruits are shown on Figure 3.7. Following the standards: ISSN: 1011-0518 and ISO 931:1980 for the required temperature and humidity of the fruits, ISO 3659:1977 for the amount of carbon monoxide to be maintained, and lastly. ASTM F2520-05(2012) for the specifications and materials to be used for a cooling system, such as fiberglass, insulator and Styrofoam. Aside from the standards that were followed by the designers, the use of an air compressor for a cooling system, greatly affected the appearance of the hardware.

Prototype Design

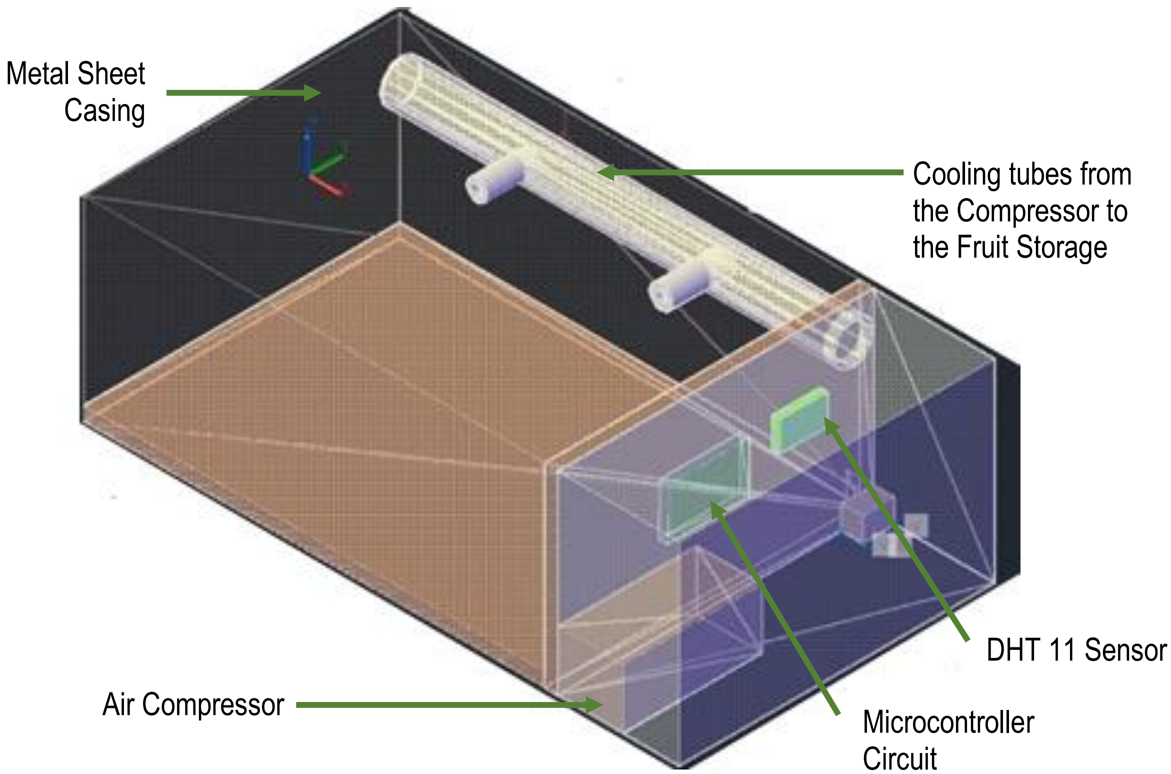


Figure 3.8 Prototype Design using Air Compressor for Cooling

Figure 3.8 represents Design 2 which is made up of metal sheet as its outer most layer, then styrofoam, fiberglass and insulator. It is a thick layer that ensures that there would be no light that can penetrate through the walls of the hardware. The circuitries were placed on the right side of the design with a divider so that the heat coming from the components won't affect the temperature where the fruits are stored. The standard followed to complete the storage is the ASTM F2520 – 05 (2012) which states the materials which can be used on cooling systems to ensure that there would be no form of light that could penetrate on the storage. These materials are the following: fiberglass, styrofoam, polyurethanes and insulators.

Circuit Design

Figure 3.9 is the circuit diagram of Design 2. ATmega328 is the microcontroller used for this design. Only the main components of the Design 2 were shown in this figure.

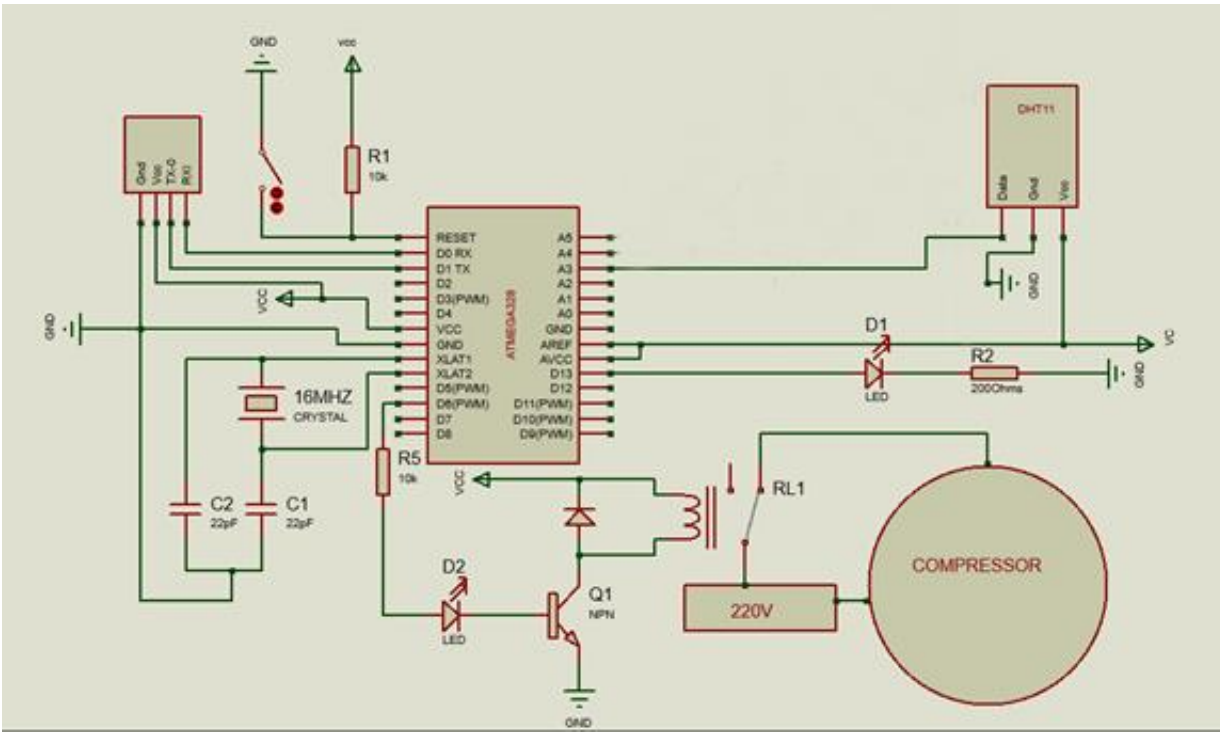


Figure 3.9 Circuit Diagram of Design 2

Power Computation for Design 2

The total power consumption of the storage device is necessary for the designers to know how much power supply is needed. Aside from the total supply needed, knowing how much current is flowing to the load is very important in selecting the correct wire for the components to the circuitry.

$P = V \ x \ I$ Equation 3.1

Dorf, R.C. (1993). Pocket *Book of Electrical Engineering Formulas.* Sacramento: CRC Press.

Where power P is in watts, voltage V is in volts and current I is in amperes (DC).
For ATmega328:
Input Voltage = 12 v
Input Current = 200 mA

$Power \ of \ Microcontroller = 12 \ v \ x \ 200mA = 2.4 \ watts$

For Compressor:
Input Voltage = 220 v
Input Current = 2.27 A

$$Power\ for\ compressor = 220\ v\ x\ 2.27\ A = 499.4\ watts$$

$$Total\ power\ consumption\ for\ Design\ 2 = 499.4\ watts + 2.4\ watts = 501.8\ watts$$

Specifications and Cost of Materials

The total cost of Design 2 is 5,983.00 as shown on Table 3-3. It includes shipping fee and tax of the ethylene sensor, its main component, as well as the cost for the material used for the case which is wood.

Table 3-4 Component Specification of Design 2

Components	**Specifications**
ATmega328	• Operating Voltage: 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P • Temperature Range: 40°C to 85°C • Speed Grade:0 - 20 MHz @ 1.8 - 5.5V • Speed Grade: 0 - 20 MHz @ 1.8 - 5.5V • See Appendix C for more information
Temperature and Humidity Sensor	• 3 to 5V power and I/O • 2.5mA max current use during conversion (while requesting data) • Good for 20-90% humidity readings with 5% accuracy • Good for 0-50°C temperature readings ±2°C accuracy • No more than 1 Hz sampling rate (once every second) • Body size 15.5mm x 12mm x 5.5mm • See Appendix B for more information
Bluetooth	• Radio Chip: CSR BC417 • Memory: External 8Mbit Flash • Output Power: -4 to +6dbm Class 2 • Sensitivity: -80dbm Typical • Bit Rate: EDR, up to 3Mbps • Interface: UART • Antenna: Built-in Dimension: 27W x 13H mm • Voltage: 3.1 to 4.2VDC • Current: 40mA max
Casing Material (Metal Sheet)	• 6 x 8 ft metal sheet
	Total Cost: 5,983.00

Table 3-4 represents the costing of the components that were used on Design 2. It has 1 sensor, the temperature and humidity sensor.

Design 3: Storage Device with Cooling System Using Peltier and DHT 11

Design 3 uses a Peltier tile for its cooling system. The Peltier tile is a ceramic component which is commonly used and found on water dispensers. One side of it turns hot, and the other turns cold. For Design 3, the designers considered the following standards: ASTM F2520—05(2012) for the materials to be used on the cooling system, ISO 931:1980 and ISSN 1011-0518 for the required temperature and humidity to me kept for the fruits, specially bananas.

With regards to the design, the designers also weighted the effects on the constraints set on the first chapter. These constraints are economic, aesthetics and manufacturability.

Aside from the constraints that were affected, the designers also kept in mind the standard temperature and humidity that must be kept to cool fruits, specifically the bananas.

Temperature:		Humidity:
Green Bananas	17 ºC – 21ºC	80 % - 95 % RH
Ripe Bananas	14 ºC – 16 ºC	

Economic. Design 3 uses Peltier tile as a cooling system. It is cheap and only needs a heat sink and fans. This is a great advantage to the designers because it did not only become cheaper than the rest of the designs; it also gave a benefit to the clients since it provides the same temperature catered by the compressor, but with a cheaper price. The sensor which is the DHT 11 or the temperature and humidity sensor also save a lot of money for the designers and the client as it only cost 120 pesos.

Table 3-5 Total Cost of Design 3

Components	Price	Quantity	Cost
ATmega328	158.00	1	158.00
Peltier Tile	350.00	1	350.00
Temperature and Humidity Sensor	105.00	1	105.00
Heat Sink	150.00	2	300.00
Metal Fan	375.00	1	375.00
Brushless Fan	75.00	1	175.00
Bluetooth	520.00	1	520.00
Metal Casing, Fiberglass, Styrofoam and Insulator	3000.00	-	3000.00
		Total	4,983.00

Table 3-5 represents the cost of the main components which were used on Design 3. The Peltier tile causes the cooling for the storage and the sensor DHT 11 is what monitors the temperature and humidity inside the Controlled Fruit Storage.

Manufacturability. Because all the components are available locally and are cheap, the prototype was finished within 10 days, giving the designers ample time to test the device with different conditions. Through the time saved by the availability of the components, the designers had plenty of time to ensure the reliability and accuracy of the design.

Aesthetics. In terms of aesthetics, the designers became more concerned with the kind of materials used, as well as the health hazard that comes with it, if any. Since the Design 3 was finished in 8 days' time, the designers prove the accuracy and safety of using the device as well.

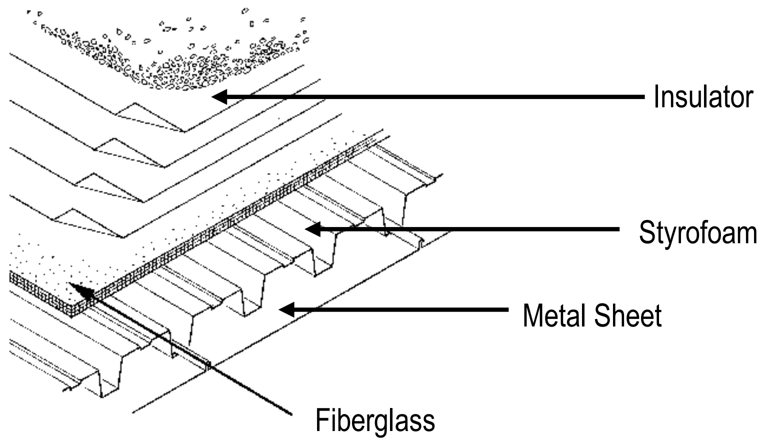


Figure 3.10 Interior Layering for Design 3

Figure 3.10 represents the layers of materials which the designers used for the Controlled Fruit Storage using a Peltier tile. The outer covering is a metal sheet, next to it is styrofoam, then fiberglass and insulator as the inner most layer that touches the fruits inside. It follows the standard ASTM F2520—05(2012) for the materials to be used on the cooling system.

Prototype Design

The intended design for the third prototype is using cooling system which is synced with the temperature and humidity sensor for keeping the required standard temperature to slow down the ripening process of the fruits inside the container. The standard cooling temperature for the bananas is 17 - 21°C while the humidity level must be 80% for the ripening to slow down.

Figure 3.11 is the Design 3 which is rectangular in shape just like the standard refrigerators. It has a fan on top of it and the bottom part has 5 inches space for the power supply. The standard followed to complete the storage is the ASTM F2520 – 05 (2012) which states the materials which can be used on cooling systems to ensure that there would be no form of light that could penetrate on the storage. These materials are the following: fiberglass, styrofoam, polyurethanes and insulators.

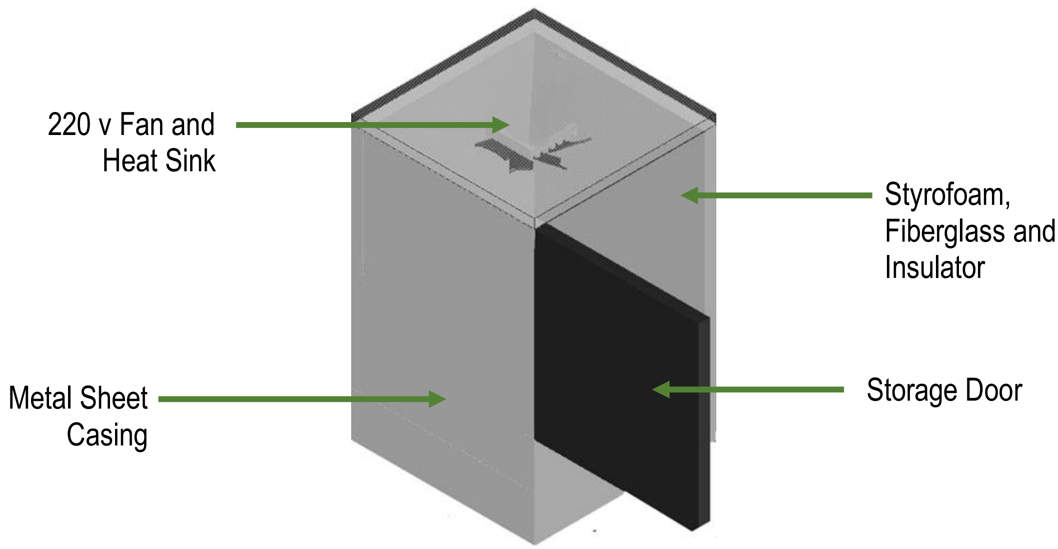


Figure 3.11 Prototype Design using Peltier Tile Cooling System

Circuit Design

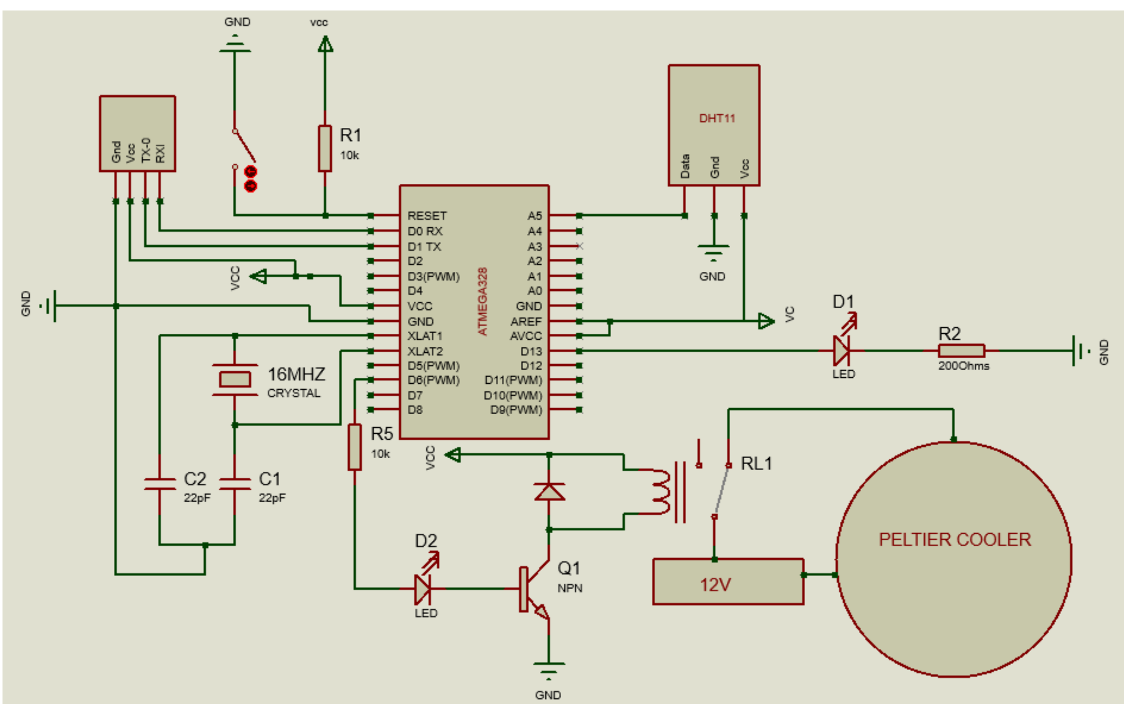


Figure 3.12 Circuit Diagram of Design 3

Figure 3.12 is the circuit diagram for Design 3. ATmega328 was used for its microcontroller and DHT 11 for its sensor. The fan which blows air to the cold plate attached to the Peltier tile is also shown on the circuit.

Power Computation for Design 3

The designers used the Ohm's Law to derive the Resistance Formula. Resistance is very important in a circuit as it reduces the current in the circuit so that the device or components do not get damaged. It is also important to have a variation in current for two different elements of a circuit from a same battery or source. The Resistance formula is necessary for the computation of the Total voltage of the whole design.

$$V = IR$$ Equation 3.2

Boylestad, R., & Nashelsky, L. (1998). *Electronic Devices and Circuit Theory.* New Jersey: Prentice Hall

The Ohm's Law formula was used to derive the needed equation for solving the ideal value of the resistors used on the design.

Note: Each output pin of the Atmega328microcontroller has maximum of 5v, based on the data sheet. For this circuit the designers used the following components: LED, 12V relay and 1N4007 diode.

Compute for the Resistor to be used.

$$R = \frac{V}{I}$$ Equation 3.3

$$V = Vout - Vd(total)$$

Voltage drop of LED	=	0.7v
Voltage drop of relay	=	3v
Voltage drop of N4007 diode	=	0.3 v

$$Vd(total) = 0.70v + 3v\ +\ 0.30v$$

$$V = Output\ V\ of\ microcontroller - Total\ V\ drop$$ Equation 3.4

$$V = 5v - 4v = 1v$$

Total current = current input of LED + current input of Relay + current input of N4007 diode

Where in:

Current of LED	=	20mA
Current input of Relay	=	120mA
Current input of N4007 diode	=	5µA

$$Total\ Current = 20mA + 120mA + 5\mu A$$

$$Total\ Current = 140mA$$

$$R = \frac{4v}{140mA} = 28\ ohms$$

The total power consumption of the storage device is necessary for the designers to know how much power supply is needed. Aside from the total supply needed, knowing how much current is flowing to the load is very important in selecting the correct wire for the components to the circuitry.

$$P = V\ x\ I \qquad \text{Equation 3.5}$$

Where power P is in watts, voltage V is in volts and current I is in amperes (DC).

For ATmega328:
Input Voltage = 12 v
Input Current = 200 mA

$$\text{P}ower\ of\ Microcontroller = 12\ v\ x\ 200mA = 2.4\ watts$$

For Compressor:
Input Voltage = 220 v
Input Current = 2.27 A

For TEC1-12706 Thermoelectric Peltier power:

Note: the input voltage of TEC1-12706 is 12-15v and current input is 6A, based on the data sheet (See Appendix

$$Power = Voltage\ x\ Current$$
$$Power\ of\ peltier = 15v\ x\ 6A = 90\ watts$$

$$Total\ power\ consumption\ for\ Design\ 3 = 90\ watts + 2.4\ watts = 90.4\ watts$$

Therefore the ideal resistor for this circuit must be greater than 28ohms, so the designers decided to use 1kohms.

Specifications and Cost of Materials

The total cost of Design 3 is 4,983.00 as shown on Table 3-3. It includes shipping fee and tax of the ethylene sensor, its main component, as well as the cost for the material used for the case which is wood.

Table 3-6 Component Specification of Design 3

Components	Specifications
ATmega328	• Flash (Kbytes): 32 Kbytes • Pin Count: 32 • Max. Operating Freq. (MHz): 20 MHz • CPU: 8-bit AVR • # of Touch Channels: 16 • Hardware QTouch Acquisition: No • Max I/O Pins: 23 • See Appendix C for more information
Peltier Tile	• Dimensions : 40 X 40 X 3.4 mm • Color : White Couples : 127 • Vmax : 15.2 V Imax : 6 A • Max power consumption : 90 Watts (Max) • Tmax : 67 degree celcius • Resistance : 1.3 - 1.5 ohms • Item Net Weight: 250g 17.5oz • See Appendix E for more information
Temperature and Humidity Sensor	• 3 to 5V power and I/O • 2.5mA max current use during conversion (while requesting data) • Good for 20-90% humidity readings with 5% accuracy • Good for 0-50°C temperature readings ±2°C accuracy • No more than 1 Hz sampling rate (once every second) • Body size 15.5mm x 12mm x 5.5mm • 4 pins with 0.1" spacing • See Appendix B for more information
Heat Sink	• Thermal Resistance: 13.4 º C/W • Material: Anodized • Mounting Style: Bolt-on • Dimensions: 34.92 x 12.7 x 25.4 mm
Metal Fan	• 220 v • 5 x 5 in

Components	Specifications
Brushless Fan	• 9 v • 3 x 3 in
Bluetooth	• Radio Chip: CSR BC417 • Memory: External 8Mbit Flash • Output Power: -4 to +6dbm Class 2 • Sensitivity: -80dbm Typical • Bit Rate: EDR, up to 3Mbps • Interface: UART • Antenna: Built-in Dimension: 27W x 13H mm • Voltage: 3.1 to 4.2VDC • Current: 40mA max
Casing Material (Metal)	• 6 x 8 ft metal sheet
	Total Cost: 4,983.00

Table 3-6 represents the cost of the main components used on Design 3. All materials were bought locally and the miscellaneous fee which is included on the table was the cost for the labor of creating the storage using metal sheet because the designers had it done on a workshop.

Software Design

The Android application specifically created for the Controlled Fruit Storage is used for monitoring and controlling the temperature and humidity inside the storage. Through the application, the user can also view the live stream of the storage.

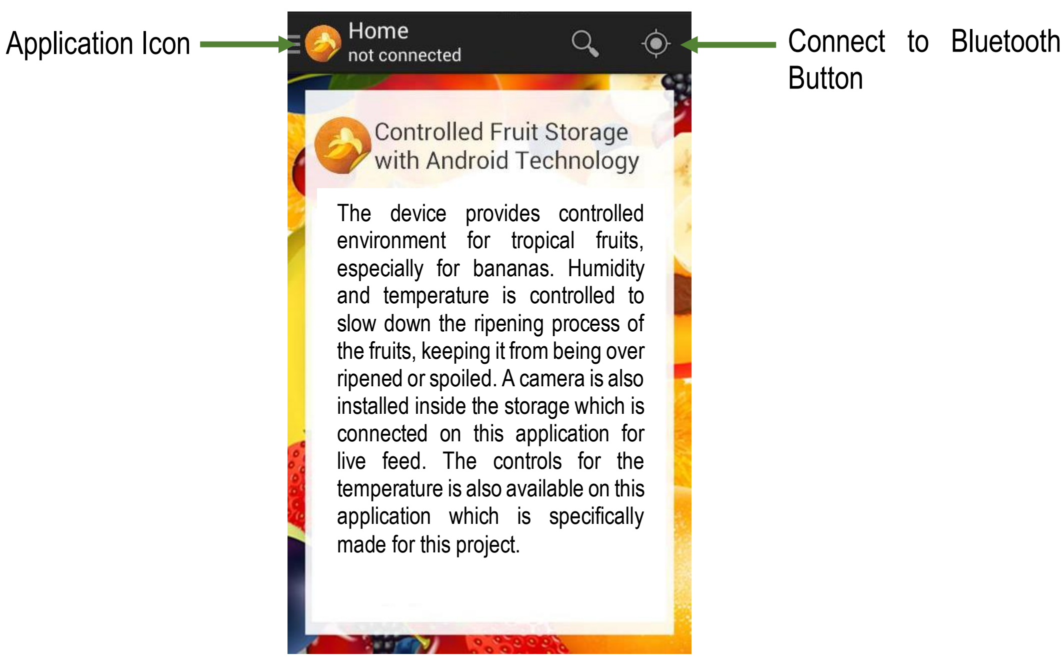


Figure 3.13 Home Screen of the Android Application

Figure 3.13 shows the content of the home screen of the Android application for the Controlled Fruit Storage. It contains a brief description of the project. Once the Android application is run, it will be the first screen to appear.

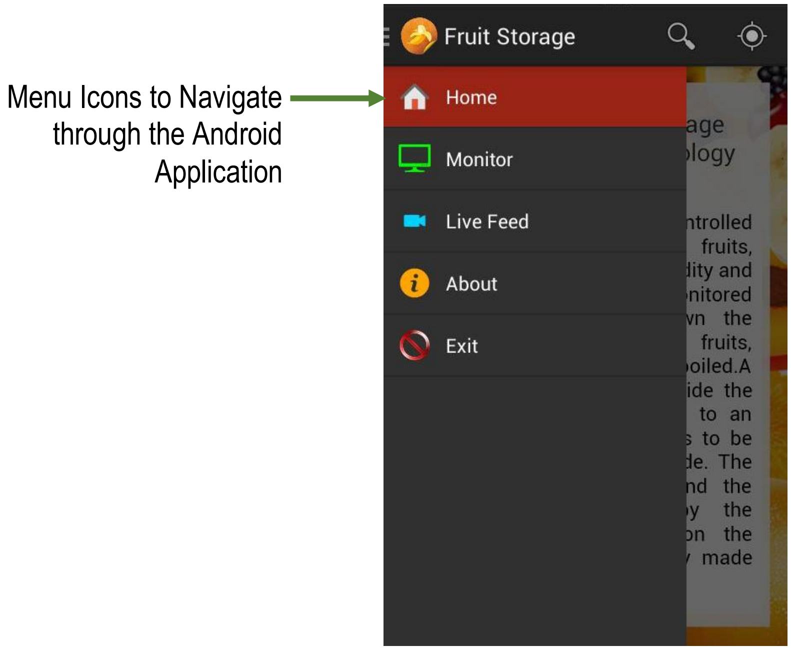
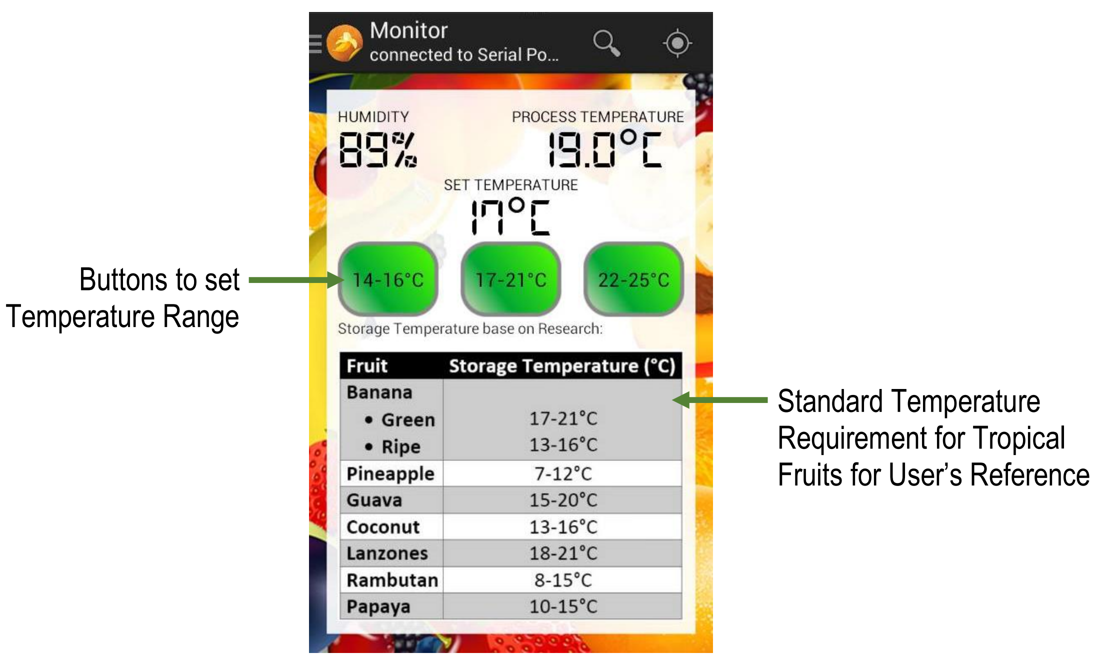


Figure 3.14 Menu of the Android Application

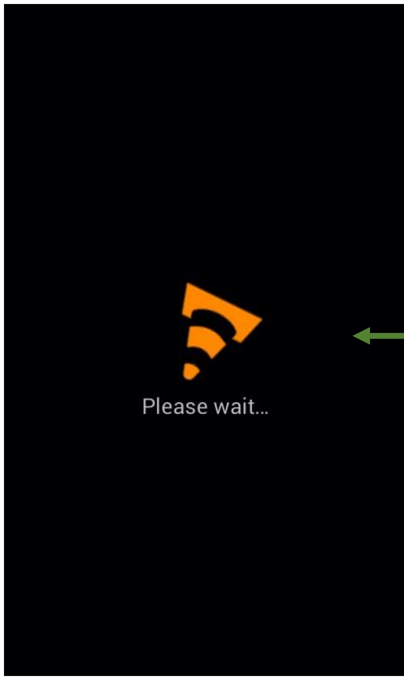
Figure 3.14 is the Menu Bar of the Android application. It represents the available options that can be selected by the user on the Android application.



Fruit	Storage Temperature (°C)
Banana	
• Green	17-21°C
• Ripe	13-16°C
Pineapple	7-12°C
Guava	15-20°C
Coconut	13-16°C
Lanzones	18-21°C
Rambutan	8-15°C
Papaya	10-15°C

Figure 3.15 Monitor Screen of the Android Application

In Figure 3.15, the user would see the available temperature that can be set on the device. The humidity reading is also seen on this screen, as well as the standard temperature for some tropical fruits.



Loading VLC Icon while waiting for the livestream to connect

Figure 3.16 Live Feed from the Camera inside the Storage

Figure 3.16 shows the live feed option of the Android application which is coming from the camera installed inside the Controlled Fruit Storage. The user can connect on it through wireless fidelity.

Description of the Controlled Fruit Storage for User's Reference

Figure 3.17 Description of the Android Application

Figure 3.17 represents the “About” screen of the Android application. The standard followed by the project is also mentioned, the ISSN: 1011-0518.

Software Development Life Cycle

The Software Development Life Cycle (SDLC) is process that ensures good software is built. Figure 3.18 shows every phase of the life cycle. If the functional requirements and objective are met, it provides a structured and standardized process for all phases.

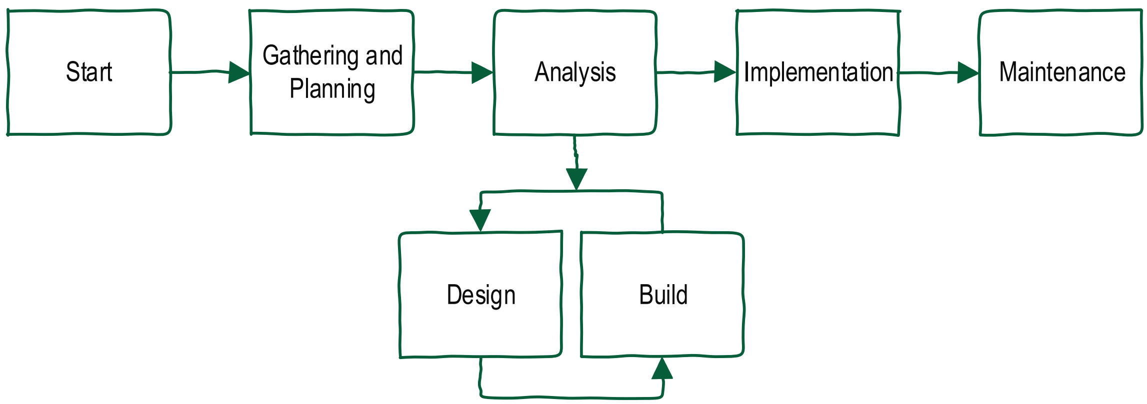


Figure 3.18 System Development Life Cycle

SDLC contains the following phases:

1. **Gathering Data & Planning.** The starting phase of the development, defining the needs, objectives, goals and gathering information regarding the problems. The designers performed research to determine the advantages and disadvantages of the existing solutions to the problem, fruit spoilage.

2. **Analysis.** This is the phase were the possible solutions was presented. It is based on the summarized data of the first phase. The designers formulated a solution based on the disadvantages that were disregarded by the current solutions.

3. **Design.** In this phase, the product was produced based on the analysis. This is where the purpose or intention to the project. With the information that the designers have, the requirement are being translated in to the representation of the project. In this phase also can assess the quality and the insurance of the project.

4. **Build.** This phase is the actual coding of the Android application and the construction of the hardware.

5. **Implementation.** On receiving system design documents, the work is divided in modules/units and actual coding is started. Since, in this phase the code is produced so it is the main focus of the developer. This is the longest phase of the development life cycle.

6. **Maintenance.** Once when the customers starts using the developed system then the actual problems comes up and needs to be solved from time to time.

Use Case Diagram

The use case diagram describes what the system does from the viewpoint of an external observer. The emphasis is on what a system does rather than how.

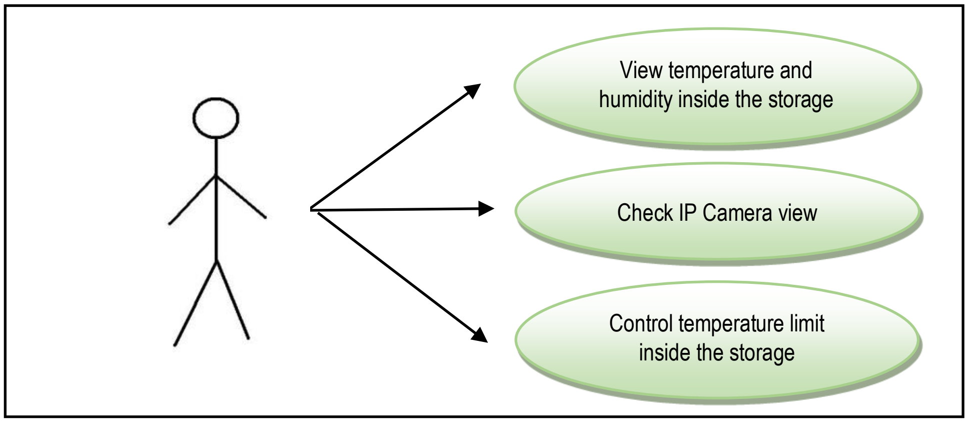


Figure 3.14 Use Case Diagram

In Figure 3.14, the functions of the Controlled Fruit Storage are shown. It includes viewing and controlling of the temperature and humidity inside the storage and live streaming.

System Algorithm

To understand the chemical that produce in the fruits by the computer, some computations were made and comparing of answer to the required parts per million of the gas in the atmosphere of the storage. The required parts per million of ethylene (C_2H_4) is not more than 0.5 ppm in order the design be functional.

Table 3-7 System Algorithm

Initialization	Input	Process	Output

double temp;
(dht_reg[5])
	temp = analogRead(A0);
	[Analog pin 0]
		if (temp<='16' &&
		temp>='14'){
		}
		else if (temp<='21'&&
		temp>='17'){
		}
		else if (temp<='25' &&
		temp>='22'){
		}
			Serial.Print(temp);
			Serial.Print("°C");
			
			Serial.Print(humidity);
			Serial.Print("%");
			
			digitalWrite(9, HIGH);

int humidity;	humidity =
	analogRead(A0);
	[Analog pin 0]
		if(humidity<='95' &&
		humidity>='85'){
		}
		else{
		}
			digitalWrite(9, LOW);
			
			digitalWrite(6, HIGH);
			
			digitalWrite(6, LOW);

int state; int timer;	state = Serial.read();		label.setText(data);

int led;	int led = 9;
	[Digital Pin 9]
		timer.initialize(30000);
		timer.pwm(9, 512);
		timer.attachInterrupt(callback);	

int fan;	int fan = 6;
	[Digital Pin 6]
		timer.initialize(500000);
		timer.pwm(6, 512);
		timer.attachInterrupt(callback);	

Table 3-7 represents the system algorithm of the Controlled Fruit Storage with Android Technology. The system has 3 controls from 14ºC – 16ºC, 17 ºC – 21ºC and 22ºC-25ºC. The temperature and humidity sensor is connected through analog pin 0 of the microcontroller and has 3 processes using if else, and the output will be a text. While the humidity is set on 85-95%, the TEC will stop if it is lower than 85-95%. Also the output will be a text and displayed through the Android application. The LED is open when the button live feed is clicked through the Android application. It is connected to pin 9. While the fan is connected to Peltier, if the Peltier stop through the control the fan will also stop. On the Android application, the tx and rx which is used in order for us to communicate through microcontroller and application.

Data Flow Diagram

The Data flow diagram (DFD) is a graphical representation of the flow of the data through an information system. It represents the processes in the system from the view of the data. A DFD illustrate those functions that must be performed in a system as well as the data that the functions will need.

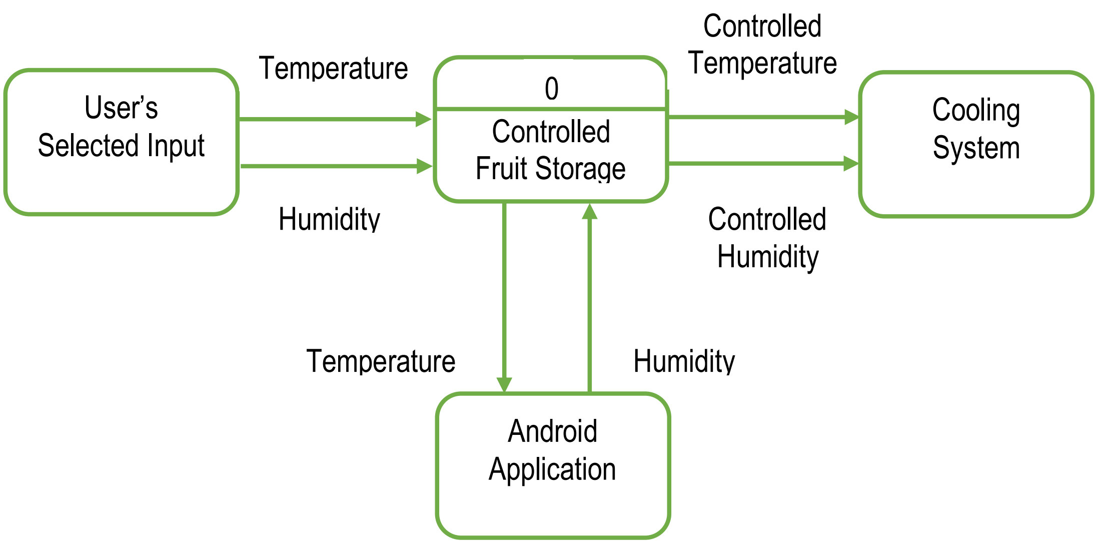


Figure 3.15 Dataflow Diagram

In the Figure 3.15, the dataflow diagram of the automated storage has 3 entities, User's Input, Cooling System and Android Application. The entity user of the storage that has a two access through storing and by viewing the data. When storing, the cooling system is on. It is one of the processes in the diagram; also the sensor value and the time of the system that will process that will save for time to time in to the database. When the user wants to view the system, there are particular processes that will also occur. Also the user can view the system log and will save through the device.

CHAPTER 4: DESIGN TRADE-OFFS

Design Trade-offs

In designing or developing a new technology, there would always be a factor that must be sacrificed in order to achieve the goal of the design project. In this situation, the designers considered a trade off on the cooling system that is used, as well as the sensors that are integrated in the storage to monitor the condition inside.

Multiple kinds of cooling system, ventilation and sensors were being considered for the Controlled Fruit Storage and this ranking would be effective on determining the best approach to complete the system while following the constraints and standards set on the first chapter.

Using the model on trade-off strategies in engineering design presented by Otto and Antonsson (1991), the importance of each criterion (on a scale of 0 to 5, 5 being the highest importance was assigned and each design technology's ability to satisfy the criterion (on scale from -5 to 5, 5 being the highest ability to satisfy the criterion) was likewise tabulated. The designers computed the ability to satisfy the criterion using this procedure.

The designers did the subjective assigning and choosing of the selection and the value of the governing rank respectively. In assigning the value for the criterion's importance and the ability to satisfy the criterion, the designers would subjectively choose any desired value. The subjective values will be gathered based on the initial analysis of the designers. The subordinate rank is computed based on equation 4.2. After considering the design constraints, the designers came up with the initial rankings on the cooling system to be used. The explanations and discussion on how the designers came up with the raw ranking values are shown and computed below.

The governing rank given to the design trade-offs was based on the subjective observation of the designers. The same on how criterion importance and the ability to satisfy the criterion are rated. The subjective values are gathered based on the initial analysis of the designers. The subordinate rank was computed based on Equation 4.2 and presented in Table 4-1.

Table 4-1 Designers' Raw Ranking

Design Criteria	Criterion's Importance (on a scale of 0 to 5)	Ability to Satisfy Criterion (on a scale from -5 to 5)		
		Design 1	Design 2	Design 3
1. Economic	3	-3	3	5
2. Manufacturability	4	1	5	4
3. Aesthetics	5	5	2	3
Over-all Rank		20	39	46

Reference: Otto, K. N. and Antonsson, E. K., (1991). Trade-off strategies in engineering design. Research in Engineering Design, volume 3, number 2, pages 87-104. Retrieved from http://www/design.caltech.edu/Research/Publications/90e.pdf on March 11, 2014.

The designers gave a value of five (5) for the importance of criterion for aesthetic because the project is intended for transporting fruits. In result, the design must be not too heavy for vehicle loading. Manufacturability criterion, in terms of assembly and availability of components, only gained an importance value of four (4) because the client and the designers already agreed on suffering the use of the tested components being used nowadays like the compressor, but rather, to test the Peltier tile being easily available in the market at low cost. Lastly, the designers gave a value of five (3) to the importance of economic because the client is willing to pay for the cost of the project as long as the objective is met of controlling the temperature and humidity, resulting to slowed ripening process of fruits, particularly bananas. This kind of subjects must be taken care of properly because those fruits that would be stored on the fruit storage would then be consumed by the customers.

Computation of ranking for the ability to satisfy criterion of each mechanism:

$$\%\ difference = \frac{(Higher\ Level\ Value - Lower\ Level\ Value)}{Higher\ Value} \qquad \text{Equation 4.1}$$

$$Subordinate\ Rank = Governing\ Rank - [(\%\ difference)\ x\ 10] \qquad \text{Equation 4.2}$$

The discussions on the choice of the governing and the subjective ranking on the ability to satisfy the criterion are as follows:

- Economic. Generally one of the largest limiting factors of this design project is the economic constraint. To maintain economic feasibility, the designers considered the orientation, effectiveness and availability of the components. Other costs involved in the project are the development costs for the design detailing and testing, resources for time, labor, machines and materials and the distribution costs for spare parts.

- Manufacturability. The ability of a system to be produced with as few resources possible be it parts, labor, or maintenance alludes to a system’s manufacturability. Since some of the major components of the design are only available abroad, the designers regarded manufacturing, purchase of component, as one of their constraints. With this limitation, the design process might be interrupted in case of material failure.

- Reliability. Repeated tests are conducted using the design to see if it is effective enough to yield the intended results, prolonging the storage life of bananas, and to see if it is in line with the standards that needs to be followed as per fruits. The designers will also be using an external device which is a hygrometer to compare the readings of the sensor that is used to monitor and maintain the needed values of the temperature and humidity needed for each tropical fruit. It must be able to maintain the range set of the determining factors, consistently.

Economic Constraint

Table 4-2 represents the comparison of the total costing of Design 1, Design 2 and Design 3. Upon computing, Design 3 is the cheapest due to the availability of all of its components locally, saving money for the designers.

Table 4-2 Cost Comparison of the Designs

Design Costing	Price
Design 1	22,908.00
Design 2	5,983.00
Design 3	4,983.00

Computation of Ranking for Economic of Design 1:

$$\%\ difference = \frac{[\ 22{,}908 - 4{,}983\ ]}{22{,}908} = 0.78$$

$$Subordinate\ Rank = 5 - [(0.78\ )\ x\ 10] = -\ 2.8\ \approx\ -3$$

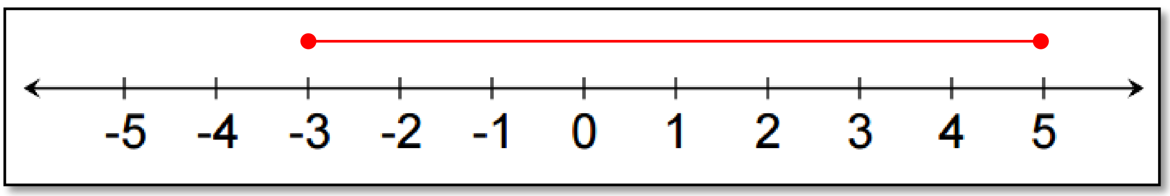


Figure 4.1 Economic Ranking of Design 1 against Design 3

Computation of Ranking for Economic of Design 2:

$$\%\ difference = \frac{[\ 5{,}983 - 4{,}983\ ]}{5{,}983} = 0.17$$

$$Subordinate\ Rank = 5 - [(0.17\ )\ x\ 10] = 3.3 \approx 3$$

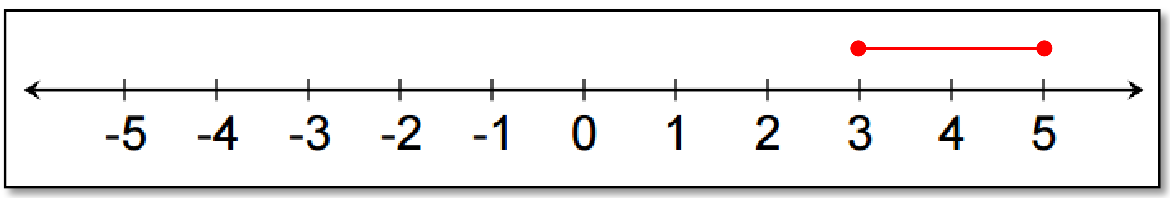


Figure 4.2 Economic Ranking of Design 2 against Design 3

Manufacturability Constraint

Table 4-3 shows the total number of days needed to finish Design 1, Design 2 and Design 3. Multiple factors affected the manufacturability time frame such as the shipping of the components, the labor for the casing and the circuitry of the designs. For the casing, since the designers only had it made from a workshop, the designers had to wait for a multiple days before it is completed. While the casing is still on the workshop, the designers used that time to finish the circuitry so that when the casing was finished, the designers were able to integrate the components into the case.

Table 4-3 Days Acquired by the Designs

Design Manufacturability	Time Consumed
Design 1: Ventilation System	12 Days
Design 2: Cooling System using Compressor	7 Days
Design 3: Cooling System using Peltier Tile	8 Days

Computation of Ranking for Manufacturability of Design 1:

$$\% \, difference = \frac{[\,12 - 7\,]}{12} = 0.42$$

$$Subordinate \ Rank = 5 - [(0.42) \ x \ 10] = 0.8 \ \approx 1$$

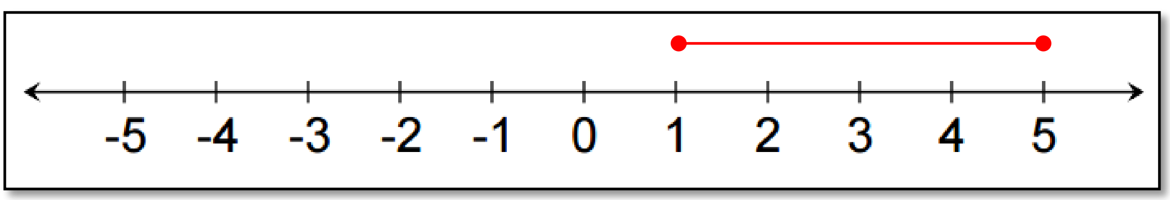


Figure 4.3 Manufacturability Ranking of Design 1 against Design 2

Computation of Ranking for Manufacturability of Design 3:

$$\% \, difference = \frac{[\,8 - 7\,]}{8} = 0.13$$

$$Subordinate \ Rank = 5 - [(0.13) \ x \ 10] = 3.7 \ \approx 4$$

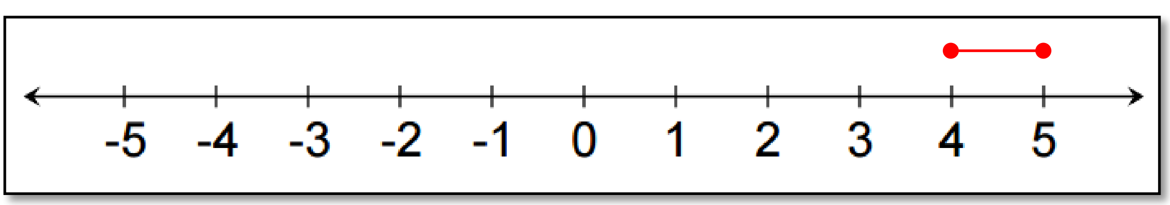


Figure 4.4 Manufacturability Ranking of Design 3 against Design 2

Aesthetics Constraint

For the aesthetic constraint, the designers compared the weight of each design to determine which of the following is more advisable to meet the objective of transportability.

Table 4-4 Aesthetic Design Based on Weight

Design Materials	Weight of Design
Design 1: Ventilation System	5 kg
Design 2: Cooling System using Compressor	7 kg
Design 3: Cooling System using Peltier Tile	6 kg

In Table 4-4, the designers used weight as the factor to be considered in aesthetics; since the design is intended for travel, it must be not too heavy for the vehicle. Aside from the weight, the designers also made sure that the storage device can handle the weight of the fruit to be placed in the storage. As shown on the table, Design 2 is the heaviest, it is because of the compressor. The cooling system of Design 2 is a compressor which can be found on refrigerators. Next on the list was the Design 3, weighing 6 kg. Design 3 is made up of metal sheet and has a thick layer of insulator. It also has metal fans that made it reach the weight of 6 kg. The lightest of the three Designs was the Design 1. It is made up wood and fans, resulting to a weight of 5 kg, unlike the Design2 and 3 which is made up of metal sheets and aluminum frames.

Computation of Ranking for Economic of Design 2:

$$\% \, difference = \frac{[\,7-5\,]}{7} = 0.29$$

$$Subordinate \ Rank = 5 - [(0.29\,)\, x\ 10] = 2.1 \ \approx 2$$

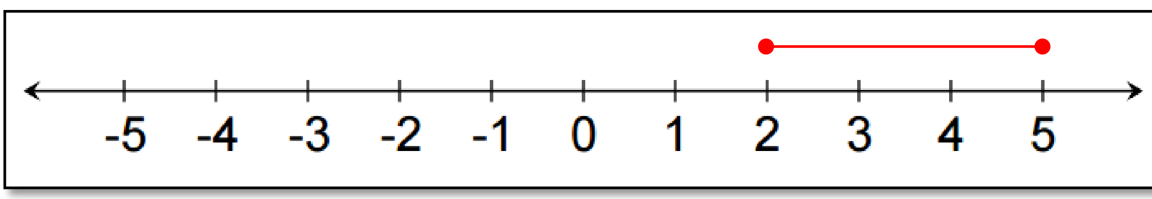


Figure 4.5 Aesthetic Ranking of Design 2 against Design 1

Computation of Ranking for Economic of Design 3:

$$\% \, difference = \frac{[\,6-5\,]}{6} = 0.17$$

$$Subordinate \ Rank = 5 - [(0.17\,)\, x\ 10] = 3.3 \ \approx 3$$

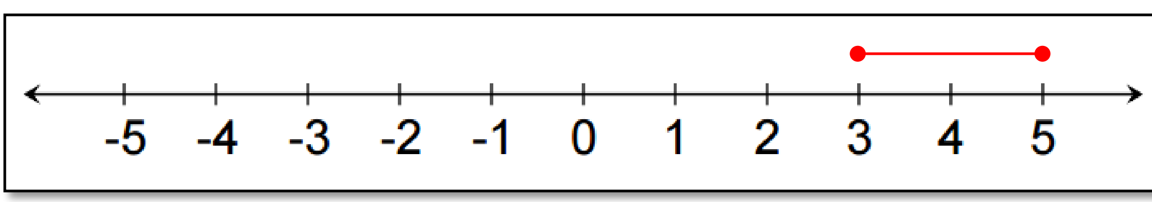


Figure 4.6 Aesthetic Ranking of Design 3 against Design 1

Influence of Multiple Constraints, Trade-offs and Standards in the Final Design

The designers considered different constraints and standards to come up for the ideal design. These constraints were considered to easily identify the factors that will greatly affect the fabrication of the prototype. The constraints extract different trade-offs which will help to differentiate the three designs in terms of economic, aesthetic, and manufacturability. Calculations were used for ranking and to show the differences of each design through the trade-offs (see Table 4-1).

Design Criterion 1: Economic

The first constraint that the designers need to consider is the development cost of the project. Components must be economic friendly and locally available, Design 3 design satisfies the complete components needed for the ideal prototype, and is also the cheapest among the selected designs. Each component affected the rank for the economic constraint, in result, Design 1 and Design 2 would not be able to keep up with the costing when compared to Design 3 because both of the first two designs has an ethylene sensor that costs more than 16,000 pesos and is not available here in the Philippines. The use of PIC16F877A for Design 3 met the same rank as Design 1.

Design Criterion 2: Manufacturability

Due to the unavailability of the primary and the most vital monitoring component of the design locally, the development time increased and the project development was delayed. Moreover, this component does not have a cheap version for testing usage. Due to that information, the designers have come up with a solution to study and focus on the other ripening agents or factors of the fruits. Again, this complexity consumed too much man -hour. Nevertheless, this component was able to reduce the cost of the design.

Design Criterion 3: Aesthetics

Aesthetics concern the appearance and materials used on the design. The impact of aesthetic constraints varies enormously, from negligible to critical. Customer or client appeal is considered in terms of the shape, the functionality, expectations and technologies used for the project. The designers focused on the materials that can be used to make it efficient and reliable. On this project, the designers came up with multiple hardware designs to determine the best appearance to suit aesthetic requirements. One good example is when the designers used the Design 1 or Design 3. The kind of materials used in the project also affected the design.

CHAPTER 5: FINAL DESIGN

Final Design

The designers implemented Design 3 for the project design. Conforming to the standards and constraints mentioned on chapter 2, Design 3's approach was to use the software to support the limitations of the hardware, working on a premise that the hardware is only as good as the application that controls it. Finally, both of the software are working and functions as it was stated and designed for its specified algorithm found previously in Chapter 3, System Algorithm. For the sensor, the designers used DHT11, the temperature and humidity sensor.

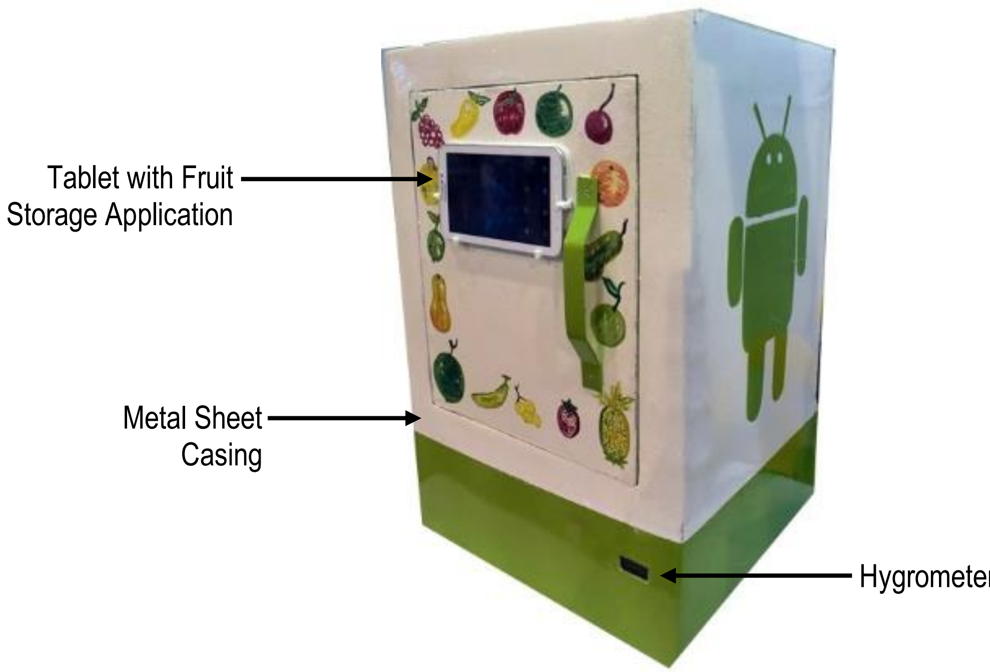


Figure 5.1 Final Design Prototype

Figure 5.1 shows the final project prototype, utilizing everything that has been discussed. The final prototype consists of a cooling system using Peltier tile with live feed inside the storage using a high definition camera connected to the Android application.

The designers also added a hygrometer on the design. The digital hygrometer is a device used for measuring the relative air humidity and temperature by inserting the device's probe into the storage. It is battery operated so there's no need for calibration.

Design 3 uses a Peltier tile for its cooling system. The Peltier tile is a ceramic component which is commonly used and found on water dispensers. One side of it turns hot, and the other turns cold. For Design 3, the designers considered the following standards: ASTM F2520 - 05(2012) for the materials to be used on the cooling system, ISO 931:1980 and ISSN 1011-0518 for the required temperature and humidity to me kept for the fruits, specially bananas and the ISO 931:1977 which also described the optimum conditions inside the cooling storage where the fruits are kept.

With regards to the design, the designers also weighted the effects on the constraints set on the first chapter. These constraints are economic, aesthetics and manufacturability.

Economic. Design 3 uses Peltier tile as a cooling system. It is cheap and only needs a heat sink and fans. This is a great advantage to the designers because it did not only became cheaper than the rest of the designs, it also gave a benefit to the clients since it provides the same temperature catered by the compressor, but with a cheaper price. The sensor which is the DHT 11 or the temperature and humidity sensor also save a lot of money for the designers and the client as it only costs 120 pesos.

Manufacturability. All the components are available locally and are cheap; in result, the prototype was finished within 8 days, giving the designers ample time to test the device with different conditions. Through the time saved by the availability of the components, the designers had plenty of time to ensure the reliability and accuracy of the design.

Aesthetics. In terms of aesthetics, the designers became more concerned with the kind of materials used, as well as the health hazard that comes with it, if any. Since the Design 3 was finished in 8 days' time, the designers prove the accuracy and safety of using the device as well.

Aside from the constraints that were affected, the designers also kept in mind the standard temperature and humidity that must be kept to cool fruits, specifically the bananas. (See Appendix A for more information.)

Temperature:		Humidity:
Green Bananas	17 ºC – 21ºC	80 % - 95 % RH
Ripe Bananas	14 ºC – 16 ºC	

Android Application

The Android application specifically created for the Controlled Fruit Storage is used for monitoring and controlling the temperature and humidity inside the storage. Through the application, the user can also view the live stream of the storage.

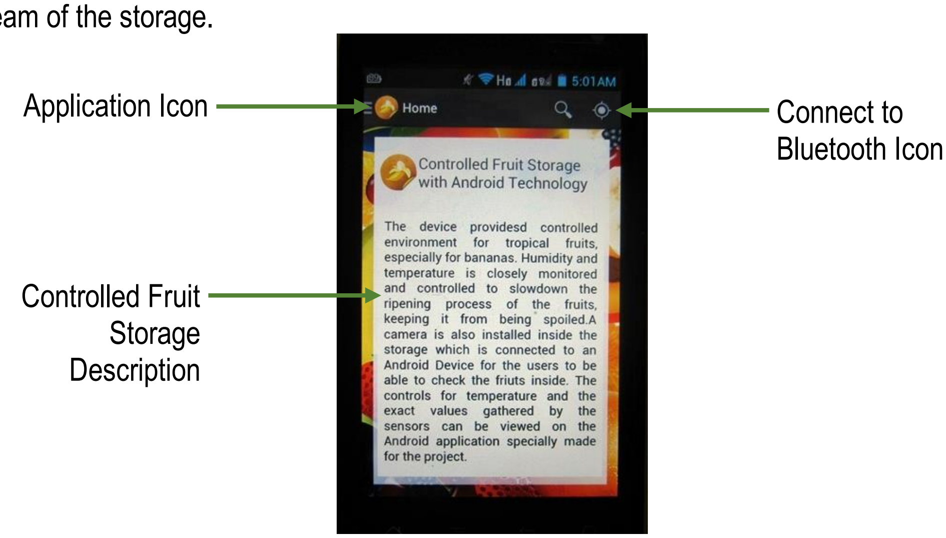


Figure 5.2 Home Screen of the Android Application

Figure 5.2 shows the content of the home screen of the Android application for the Controlled Fruit Storage. It contains a brief description of the project. Once the Android application is run, it will be the first screen to appear.

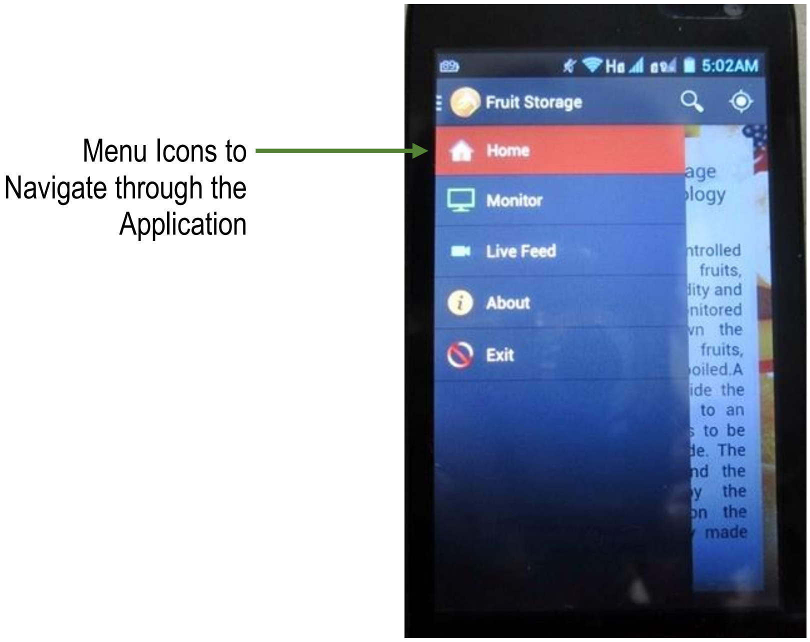


Figure 5.3 Menu of the Android Application

Figure 5.3 is the Menu Bar of the Android application. It represents the available options that can be selected by the user on the Android application.

Figure 5.4 Monitor Screen of the Android Application

In Figure 5.4, the user would see the available temperature that can be set on the device. The humidity reading is also seen on this screen, as well as the standard temperature for some tropical fruits.

Loading VLC Icon while waiting for the livestream to connect

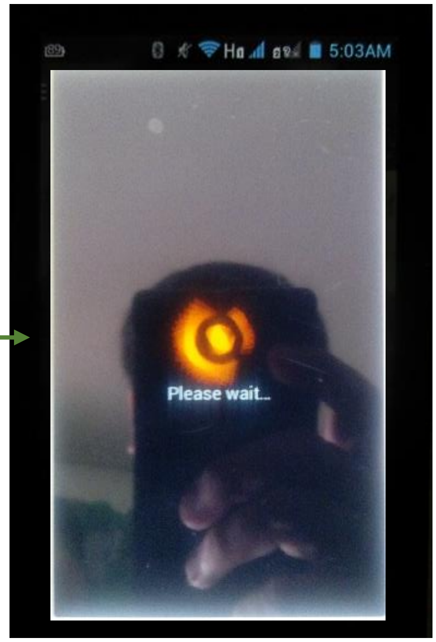


Figure 5.5 Live Feed from the Camera inside the Storage

Figure 5.5 shows the live feed option of the Android application which is coming from the camera installed inside the Controlled Fruit Storage. The user can connect on it through wireless fidelity.

Description of the Controlled Fruit Storage for User's Reference

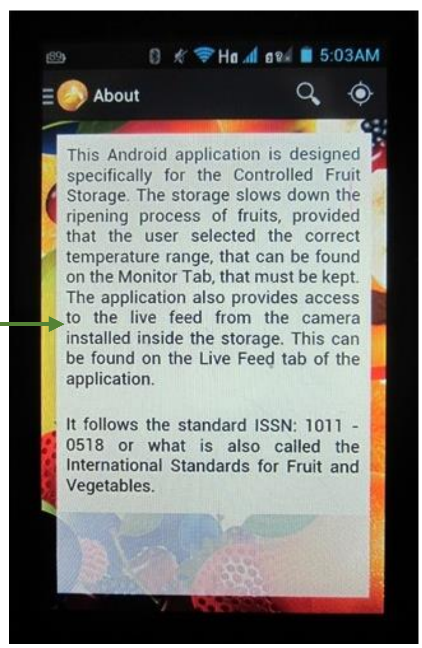


Figure 5.6 Description of the Android Application

Figure 5.6 represents the “About” screen of the Android application. The standard followed by the project is also mentioned, the ISSN: 1011-0518.

Figure 5.7 Fruit Storage Android Icon

Figure 5.7 shows the actual icon of the Fruit Storage Icon on an Android phone.

Test Procedures and Evaluation

Test Procedures

The designers prepared multiple testing processes to ensure that the objectives were met. The device used by the designers as basis of the reading is a digital hygrometer. A hygrometer accurately measures relative humidity and temperature through a probe that the user has putting inside the storage or room.

For the testing, three cases were prepared. Case 1 was to compare the temperature reading of the Controlled Fruit Storage and the hygrometer. Case 2 was to compare the relative humidity reading of the design and the hygrometer. Lastly, Case 3 was to compare both the temperature and humidity of the room where the test was made, the temperature inside the Controlled Fruit Storage and the temperature and humidity inside the box with ventilation. Three cases were prepared in order to test the accuracy of the design.

The margin of error is ±5% for both temperature and humidity. The hardware is considered accurate if the gathered sensor readings are within the range set by the designers.

Accuracy Test

In testing the accuracy of temperature and humidity, the designers conducted a day and night testing in accordance with the standard for Banana International Standards for Fruit and Vegetables as discussed in Chapter 2.

1. Based on the standard mentioned, the prototype should maintain a standard temperature of 17°-21°C.
2. With for the compliance of the standard, the prototype should maintain a standard humidity of 85% - 95%.

In determining the percentage of accuracy, the designers compared the reading of digital hygrometer a temperature and humidity sensor to the output provided by the system. The formula for percentage of accuracy is:

$$Percentage\ Error = \frac{[\,measured\ value - actual\ value\,]}{actual\ value}\ x100 \qquad \text{Equation 5.1}$$

$$Accuracy\ Percentage = 100 - Percentage\ Error \qquad \text{Equation 5.2}$$

$$Accuracy\ Percentage\ Average = \frac{a1+a2+a3+a4+a5+\cdots}{a*x} \qquad \text{Equation 5.3}$$

The sensor readings being displayed at the Android application and the hygrometer were compared and computed to check for the accuracy percentage.

The margin of error is ±5% for both temperature and humidity. The hardware is considered accurate if it is within the range set by the designers.

Test Evaluation

The evaluation process is given upon the client's discretion. The client rated the device according to some important factors; concerns mainly on the prototype's accuracy and reliability of the gathered result.

Table 5-1 Evaluation Procedure

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?				
Accurate Is the measured value of prototype accurate?				
Reliability Was the objective met?				

In this Table 5-1, each performance of the prototype should be rated from Poor, Fair, Moderate and Excellent. The client will fill-up the information to support the test evaluation table check (√) the rate of performance that has been chosen.

Testing and Evaluation Results

Test Results

Case 1: Accuracy Test Result for Temperature Compared with the Values Measured by the Hygrometer with controlled range of 17 ºC – 21 ºC.

Table 5-2 Temperature Test Results

	Controlled Prototype (Measured Value)	**Hygrometer** (Actual Value)	**Accuracy Percentage**	**Remarks**
10:00 PM	20.4 ºC	20.1 ºC	98.53 %	Accurate
12:00 AM	17.6 ºC	17.2 ºC	97.73 %	Accurate
2:00 AM	17.4 ºC	17.3 ºC	99.43 %	Accurate
4:00 AM	17.6 ºC	17.6 ºC	100 %	Accurate
6:00 AM	17.5 ºC	17.5 ºC	100 %	Accurate
8:00 AM	17.8 ºC	17.8 ºC	100 %	Accurate
10:00 AM	17.9 ºC	17.7 ºC	98.88 %	Accurate
12:00 PM	18.0 ºC	18.1 ºC	99.44 %	Accurate
		Average	99.25 %	Accurate

Table 5-2 represents the result from the test made every 2 hours on the temperature reading. The controlled prototype is the reading from the sensor and the actual value is the reading from the hygrometer.

Based on the standard mentioned, the prototype should maintain the temperature in the range of 17°-21°C to slow down the ripening process of the bananas or to lengthen its storage life.

The designers have compared the values generated seen in the prototype to the values measured by the hygrometer. The comparison of the said values have been taken through the percentage error formula and will only be considered accurate once the value for the average accuracy is more than 95%.

The Average of the Accuracy Percentage is 99.25 %, meaning that the temperature readings of the prototype are accurate.

Case 2: Accuracy Test Result for Humidity Compared with the Values Measured by the Hygrometer

Table 5-3 Humidity Test Results

	Controlled Prototype (Measured Value)	**Hygrometer** (Actual Value)	**Accuracy Percentage**	**Remarks**
10:00 PM	85 %	86 %	98.82 %	Accurate
12:00 AM	89 %	89 %	100 %	Accurate
2:00 AM	90 %	88 %	97.78 %	Accurate
4:00 AM	91 %	89 %	97.80 %	Accurate

	Controlled Prototype (Measured Value)	**Hygrometer** (Actual Value)	**Accuracy Percentage**	**Remarks**
6:00 AM	92 %	90 %	97.83 %	Accurate
8:00 AM	92 %	91 %	98.91 %	Accurate
10:00 AM	90 %	90 %	100 %	Accurate
12:00 PM	88 %	89 %	98.86 %	Accurate
		Average	98.75 %	Accurate

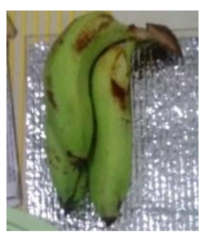
Table 5-3 represents the result from the test made every 2 hours on the humidity reading. The controlled prototype is the reading from the sensor and the actual value is the reading from the hygrometer.

With for the compliance of the standard, the prototype should maintain a standard humidity of 85% - 95%. The designers have compared the values generated seen in the prototype to the values measured by the hygrometer. The comparison of the said values have been taken through the percentage error formula and will only be considered accurate once the value for the average accuracy is less than 5%.

The Average of the Accuracy Percentage is 98.75%, meaning that the temperature readings of the prototype are accurate.

Case 3: Accuracy Test Result for both Temperature and Relative Humidity Compared with the Values Measured by the Hygrometer with Live Stream

Table 5-4 Accuracy Test of Temperature and Humidity with Live Stream

<table>
<tr><th></th><th colspan="2">Condition 1
(Controlled Fruit Storage)</th><th colspan="2">Condition 2
(Storage with Fan for Ventilation)</th><th colspan="2">Condition 3
(Room Temperature)</th></tr>
<tr><td rowspan="2">10:00 PM</td><td rowspan="2"></td><td>19.2 ºC</td><td rowspan="2"></td><td>28.3 ºC</td><td rowspan="2"></td><td>29.2 ºC</td></tr>
<tr><td>90 % RH</td><td>70 % RH</td><td>40 % RH</td></tr>
<tr><td rowspan="2">12:00 AM</td><td rowspan="2"></td><td>18.1 ºC</td><td rowspan="2"></td><td>25.2 ºC</td><td rowspan="2"></td><td>27.8 ºC RH</td></tr>
<tr><td>91 % RH</td><td>72 % RH</td><td>43 % RH</td></tr>
</table>

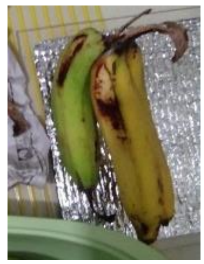
	Condition 1 (Controlled Fruit Storage)		**Condition 2** (Storage with Fan for Ventilation)		**Condition 3** (Room Temperature)	
2:00 AM		17.2 ºC 92 % RH		23.4 ºC 72 % RH		24.8 ºC 42 % RH
4:00 AM		17. 1ºC 92 % RH		24.6 ºC 73 % RH		26.4 ºC 43 % RH
6:00 AM		17.4 ºC 90 % RH		25.3 ºC 72 % RH		26.8 ºC 44 % RH
10:00 AM		17.7 ºC 90 % RH		26.7 ºC 71 % RH		27.5 ºC 45 % RH

Table 5-4 shows another accuracy test made by the designers. The storage's objective is to control the temperature and humidity which results in slowing down the ripening process of the fruits, specifically the bananas. To show the effects on the banana, the picture of the bananas before and after the test was also shown. Condition 1 is the Controlled Fruit Storage with Android Technology, condition 2 is the fiberglass box with fan for ventilation and condition 3 is by exposing the banana on normal room temperature. The designers started the testing at 10 PM and ended it at exactly 10 AM the next day.

Evaluation Results

The evaluation procedure depends upon the criteria that were given to the client. The client should rate the survey form regarding on the performance of the device and if the device met the objectives of being accurate.

The designers used three graphs to represent the result of the surveys. One graph is for the result of the ease of use, one for accuracy and another one for reliability. For the options, the designers prepared excellent, being the highest, second, moderate, third, fair, and lastly, poor for the lowest satisfaction catered by the project. (See Appendix G for the survey forms.)

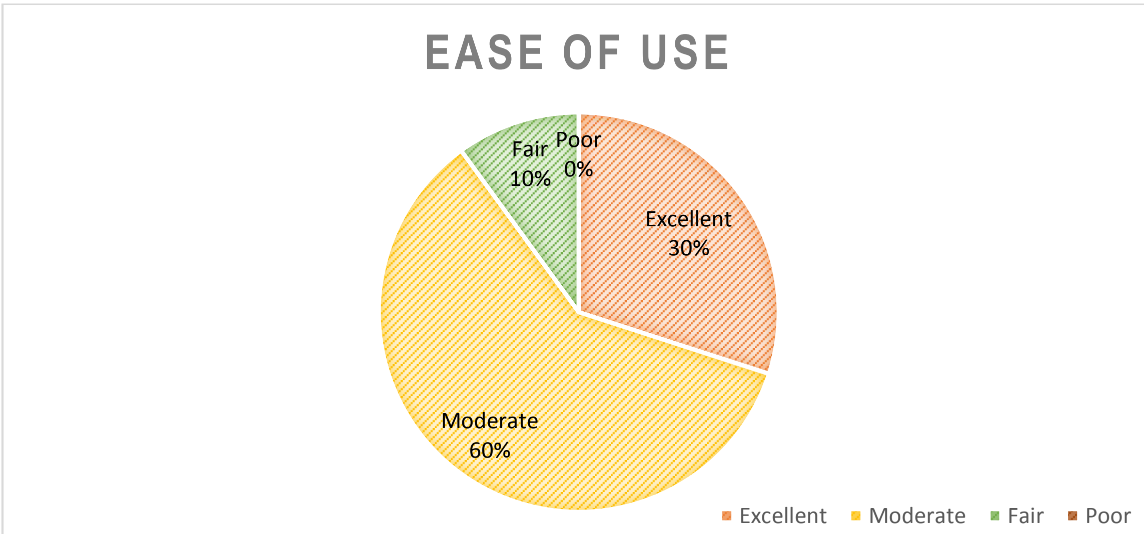


Figure 5.8 Ease of Use Result Chart Representation

Figure 5.8 represents the graph used in the ease of use criteria of the design. The figure below shows the result of the first question, "Is the Android application easy to use?" As illustrated below, majority of the participants answered that the android application is moderately efficient to use. This proves that the software would be useful and convenient for the users.

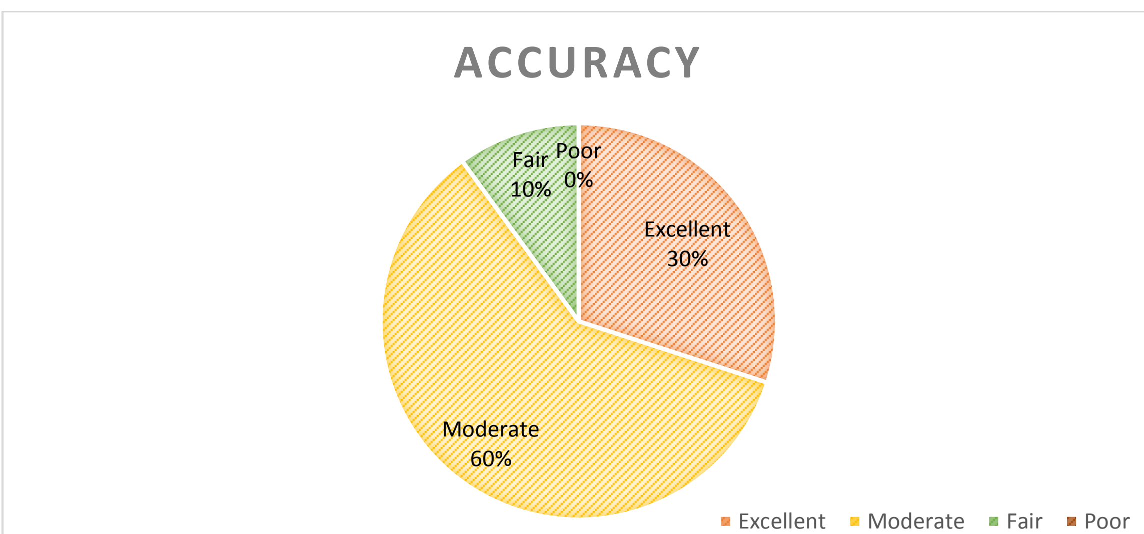


Figure 5.9 Accuracy Result Chart Representation

Figure 5.9 represents the graph used in the accuracy criteria of the design. The figure shows the result of the second question, “Is the measured value of the prototype accurate?” As illustrated below, majority of the participants answered that the accuracy of the project is moderate. In result, the designers concluded that the project is accurate.

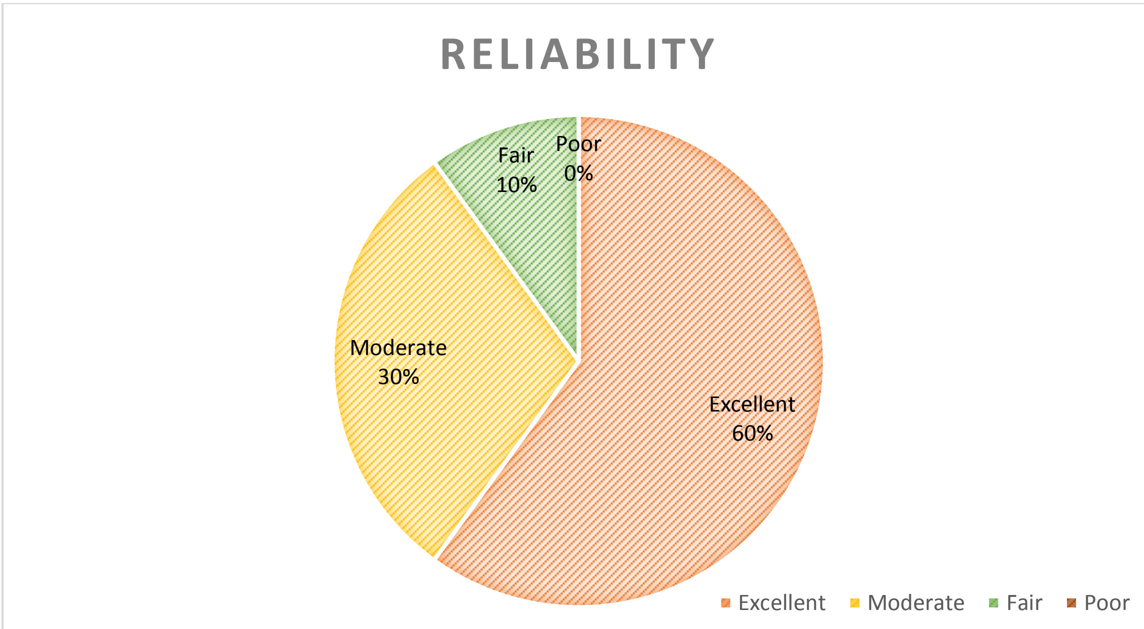


Figure 5.10 Reliability Result Chart Representation

Figure 5.10 represents the graph used in the accuracy criteria of the design. The figure below shows the result of the second question, “Is the measured value of the prototype accurate?” As illustrated below, majority of the participants rated the project “excellent” for meeting the objectives. In result, the designers concluded that the project Controlled Fruit Storage with Android Technology met the objectives by controlling the temperature and humidity, resulting to slowed ripening process of fruits, particularly bananas.

The participants of the survey are fruit vendors. From the survey, as shown on the graphs, the design proves to be accurate and the objectives were met.

This gives the designers a good look on the results of the project and considers that there have been a lot of positive responses given by the client. This showed that the project’s objective with regards to the client was successfully and excellently met.

Conclusion

Finally, the general and specific objectives and the full functionality of this project that were stated in Chapter 1 have already been sufficed. The designers were able to suffice them considering the codes and engineering standards, trade-offs based on multiple constraints such as economic, manufacturability and aesthetics.

To reiterate, the general objective of this project is to slow down the ripening process of the fruits to help the farmers and vendors. It aims to provide them an access to an affordable fruit storage that gives them greater opportunity to earn more through minimizing or eliminating the spoilage problem that they are encountering. The designers were also able to cater additional features such as the live feed monitoring inside the storage for checking the contents of the storage without opening the door to prevent the cold air from the storage to escape. The designers have successfully made it "low-cost" without neglecting its functionality but made it more efficient by utilizing their resources well. Upon various condition testing, it also proved that it is capable to prolong the storage life of fruits, slow down the ripening process or maintain its freshness, specifically the bananas without making the client spend more on the hardware as well as for the power it consumes.

Humidity test was 98.75% accurate and 99.25% accurate for temperature. It passed multiple and repetitive testing and evaluation procedures that had taken place. The results can be seen on Table 5-2, Table 5-3 and Table 5-4.

In conclusion, the project design is fully functional and working as expected. The Android application can connect to the hardware, provide live feed, and control humidity and temperature, and furthermore, the fruit storage can efficiently maintain the quality of fruits while slowing down the ripening process. Based on that, the designers concluded that the fruit storage and the Android application are all working and functional as planned. Therefore, the project design of a Controlled Fruit Storage with Android Technology was a successful and innovative one.

CHAPTER 6: BUSINESS MODEL

<table>
<tr><th colspan="5">CONTROLLED FRUIT STORAGE WITH ANDROID TECHNOLOGY</th></tr>
<tr><th>Partner Network</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationship</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">• Department of Science and Technology (DOST)
• Igloo Supply Chain Philippines, Inc.
• Royal Cargo Philippines</td>
<td>• Gathering Materials
• Researching for the target Market
• Monitoring current trends
• Analyzing advantages and disadvantages of the design and continuous improvement</td>
<td rowspan="3">• Controlled Fruit Storage with Android Technology
• Slow down fruit ripening through temperature and humidity control
• Sensor readings and live stream using Android application for the users</td>
<td>• Updates on temperature and humidity readings through the Android application used by the client
• Live stream through the Android application</td>
<td rowspan="3">• Fruit Farmers and Vendors
• Household</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>• Engr. Alonica Villanueva (Adviser)

• Engr. Maria Cecilia Venal (CPE Department Chair)</td>
<td>• Posting Videos Online
• Company Blog
• Posters
• Flyers</td>
</tr>
<tr><th colspan="3">Cost Structure</th><th colspan="2">Revenue Streams</th></tr>
<tr>
<td colspan="3">• Developmental Cost
• Energy Cost
• Casing materials (Metal Sheets, Styrofoam, Fiberglass and Insulator)</td>
<td colspan="2">• Longer Shelf Life of Fruits
• Reliable Design
• Low-cost yet efficient device</td>
</tr>
</table>

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APPENDICES

Appendix A

Fruits and Vegetables – Optimal Storage Conditions

Product	Optimal Storage Temperature		Chill Point		Freezing Point	Optimal Humidity	Ethylene Production	Sensitive to Ethylene	Approximate Storage Life
	(°F)	(°C)	(°F)	(°C)	(°F)	%			
Apples	30-40	-1-4			29.3	90-95	High	Yes	1-12 months
Apricots	31-32	-1-0			30.1	90-95	High	Yes	1-3 weeks
Artichokes	32-35	0-2				90-95	No	No	
Artichokes, Jerusalem	31-32	0-2			28.0	90-95	No	No	4-5 months
Asparagus	32-35				30.9	95-100	No	Yes	2-3 weeks
Avocados, ripe	38-45	3-7	36	2		85-95	High	Yes	
Avocados, unripe	45-50	7-10	45	7		85-95	Low	Yes, Very	
Bananas, green	62-70	17-21	56	13		85-95	Low	Yes	
Bananas, ripe	56-60	13-16	54	12		85-95	Medium	No	
Basil	52-59	11-15	50	10		90-95	No	Yes	
Beans, dry	40-50					40-50			6-10 months
Beans, green or snap	40-45				30.7	95			7-10 days
Beans, sprouts	32	0				95-100			7-9 days
Beans. Lima	37-41	0			31.0	95			5-7 days
Beets	32-35	0-2				90-95	No	Yes	
Beets, bunched	32	0			31.3	98-100			10-14 days
Beets, topped	32	0			30.3	98-100			4-6 months

Blackberries	32-33	0-1			30.5	90-95	Very Low	No	2-3 days
Blueberries	32-35	0-2				90-95	Very Low	No	
Bok Choy	32-35	0-2				90-95	No	Yes	
Broccoli	32	0			30.9	95-100	No	Yes	10-14 days
Brussels Sprouts	32	0			30.5	90-95	No	Yes	3-5 weeks
Bunched Greens	32	0				90-95	No	Yes	
Cabbage, Chinese	32	0				95-100	No	Yes	2-3 months
Cabbage, early	32	0			30.4	98-100	No	Yes	3-6 weeks
Cabbage, late	32	0			30.4	98-100			5-6 months
Cantaloupe	36-38	2-3	34	1		90-95	Medium	Yes	
Carrots, bunched	32	0				95-100	No	Yes	2 weeks
Carrots, immature	32	0			29.5	98-100			4-6 weeks
Carrots, mature	32	0			29.5	98-100			7-9 months
Cauliflower	32	0			30.6	95-98			3-4 weeks
Cauliflower	32-35	0-2				90-95	No	Yes	
Celery	32	0			31.1	98-100	No	Yes	2-3 months
Celeriac	32	0			30.3	97-99			6-8 months
Chard	32	0				95-100			10-14 days
Cherries	32-35	0-2				90-95	Very Low	No	
Cherries, sour	32	0			29.0	90-95			3-7 days
Cherries, sweet	30-31				28.8	90-95			2-3 weeks
Chicory	32-35	0-2				90-95	No	No	
Chicory, witloof	32	0				95-100			2-4 weeks
Chinese Pea Pods	32-35	0-2				90-95	No	No	
Coconuts	55-60	13-16				80-85	No	No	

Collards	32	0			30.6	95-100			10-14 days
Corn, sweet	32	0			30.9	95-98	No	No	5-8 days
Cranberries	38-42	3-6	36	2		90-95	No	No	
Cucumbers	50-55		40	4	31.1	95	Very Low	Yes	10-14 days
Currants	31-32				30.2	90-95			1-4 weeks
Eggplant	46-54		45	7	30.6	90-95	No	Yes	1 week
Elderberries	31-32					90-95			1-2 weeks
Endive	32	0			31.9	95-100	No	No	2-3 weeks
Escarole	32-35	0-2				90-95	No	No	
Escarole	32	0			31.9	95-100			2-3 weeks
Figs	32-35	0-2				90-95	Low	No	
Garlic	32	0			30.5	65-70	No	No	6-7 months
Ginger Root	60-65	16-18	55	13		65-70	No	No	
Gooseberries	31-32				30.0	90-95			3-4 weeks
Grapefruit	55-60	13-16	50	10		90-95	Very Low	No	
Grapes	31-32				29.7	85	Very Low	Yes	2-8 weeks
Green Beans	40-45	4-7	38	3		90-95	No	Yes	
Green Peas	32-35	0-2				90-95	No	Yes	
Greens, leafy	32	0				95-100			10-14 days
Guavas	45-50	7-10	40	4		90-95	Medium	Yes	
Herbs	32-35	0-2				90-95	No	Yes	
Horseradish	30-32				28.7	98-100			10-12 months
Jicama	55-65					65-70			1-2 months
Kale	32				31.1	95-100			2-3 weeks

Kiwi, ripe	32-35	0-2				90-95	High	Yes	
Kiwi, unripe	32-35	0-2				90-95	Low	Yes, Very	
Kohlrabi	32	0			30.2	98-100	No	No	2-3 months
Leeks	32	0			30.7	95-100	No	Yes	2-3 months
Lemons	52-55	11-13	50	10		90-95	Very Low	No	
Lettuce	32	0			31.7	98-100	No	Yes	2-3 weeks
Limes	48-55	9-13	45	7		90-95	Very Low	No	
Lychees	40-45	4-7	36	2		90-95	Very Low	No	
Mangos	50-55	10-13	50	10		85-95	Medium	Yes	
Melons, Casaba/Persian	50-55	10-13	45	7		85-95	Very Low	Yes	
Melons, Crenshaw	50-55	10-13	45	7		85-95	Low	Yes	
Melons, Honey Dew	50-55	10-13	41	5		85-95	Medium	Yes	
Mushrooms	32	0			30.4	95	No	Yes	3-4 days
Napa	32-35	0-2				90-95	No	Yes	
Nectarines	31-32				30.4	90-95	High	No	2-4 weeks
Okra	45-50		45	7	28.7	90-95	Very Low	Yes	7-10 days
Onions	32-35	0-2				65-75	No	No	
Oranges	40-45	4-7	38	3		90-95	Very Low	No	
Oranges	32-35	0-2				90-95	Very Low	Yes	
Papayas	50-55	10-13	45	7		85-95	Medium	Yes	
Parsley	32	0			30.0	95-100			2-3 months
Parsnips	32	0			30.4	98-100	No	Yes	4-6 months
Peaches	31-32				30.3	90-95	High	Yes	2-4 weeks

Pears	29-31				29.2	90-95	High	Yes	2-7 months
Peas, green	32	0			30.9	95-98			1-2 weeks
Peas, southern	40-41					95			6-8 days
Peppers, hot chili	32-50					60-70	No	Yes	6 months
Peppers, sweet	45-55	7-10	42	6	30.7	90-95	No	No	2-3 weeks
Persimmons	32-35	0-2				90-95	No	Yes, Very	
Pineapples	50-55	10-13	45	7		85-95	Very Low	No	
Plums	31-32				30.5	90-95	High	Yes	2-5 weeks
Pomegranates	41-50	5-10	41	5		90-95	No	No	
Potatoes	45-50	7-10	38	3		90-95	No	Yes	
Precut Fruit	32-36	0-2				90-95	Low	No	
Precut Vegetables	32-36	0-2				90-95	No	Yes	
Prunes	31-32				30.5	90-95	High	Yes	2-5 weeks
Pumpkins	50-55		50	10	30.5	65-70	No	Yes	2-3 months
Quinces	31-32				28.4	90			2-3 months
Quinces	32-35	0-2				90-95	High	Yes	
Radishes, spring	32	0			30.7	95-100	No	Yes	3-4 weeks
Radishes, winter	32					95-100			2-4 months
Raspberries	31-32				30.0	90-95	Very Low	No	2-3 days
Rhubarb	32	0			30.3	95-100	No	No	2-4 weeks
Rutabagas	32	0			30.0	98-100	No	Yes	4-6 months
Salad Mixes	32-35	0-2				90-95	No	Yes	
Salsify	32				30.0	95-98			2-4 months
Spinach	32				31.5	95-100			10-14 days

Sprouts	32-35	0-2				90-95	No	Yes	
Squashes, summer	41-50		40	4	31.1	95	No	Yes	1-2 weeks
Squashes, winter	50				30.5	50-70	No	Yes	1-6 months
Strawberries	32	0			30.6	90-95	Very Low	No	3-7 days
Sweet Potatoes	55-60		54	12	29.7	85-90	No	Yes	4-7 months
Tangerines	32-35	0-2				90-95	Very Low	No	
Tangerines	40-45	4-7	38	3		90-95	Very Low	No	
Tomatoes, mature green	55-70				31.0	90-95	Low	Yes	1-3 weeks
Tomatoes, ripe	55-70				31.1	90-95	Medium	No	4-7 days
Turnip greens	32				31.7	95-100			10-14 days
Turnips	32	0			30.1	95	No	Yes	4-5 months
Watercress	32				31.4	95-100			2-3 weeks
Watermelon	55-70	13-21	50	10		85-95	No	Yes, Very	

Appendix B

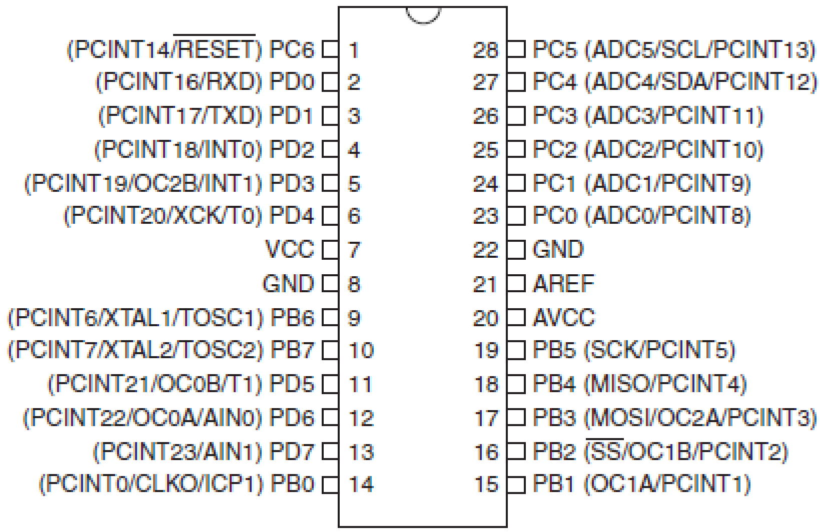
Temperature and Humidity Sensor

This DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.

- Ultra low cost
- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)
- Good for 20-90% humidity readings with 5% accuracy
- Good for 0-50°C temperature readings ±2°C accuracy
- No more than 1 Hz sampling rate (once every second)
- Body size 15.5mm x 12mm x 5.5mm
- 4 pins with 0.1" spacing

Appendix C

ATmega328



The high-performance Atmel 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.

- Operating Voltage: 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P
- Temperature Range: 40°C to 85°C
- Speed Grade:0 - 20 MHz @ 1.8 - 5.5V
- Peripheral Features: Two 8-bit Timer/Counters with Separate Presales and Compare Mode, Real Time Counter with Separate Oscillator, Six PWM Channels, 8-channel 10-bit ADC in TQFP and QFN/MLF package Temperature Measurement, 6-channel 10-bit ADC in PDIP Package Temperature Measurement
- Special Microcontroller Features: Power-on Reset and Programmable Brown-out Detection, Internal Calibrated Oscillator, External and Internal Interrupt Sources, Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- Speed Grade: 0 - 20 MHz @ 1.8 - 5.5V

Appendix D

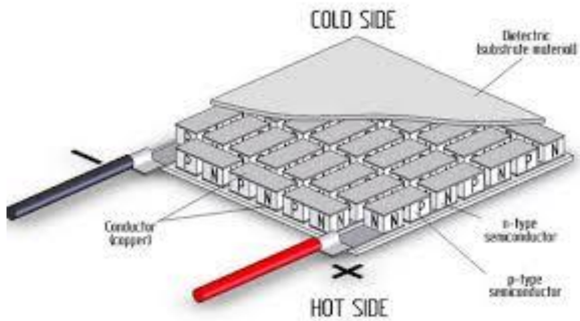
Ethylene Sensor

These Ethylene sensors contain all the necessary optics, electronics and firmware to provide a calibrated and linearized output for the detection of Ethylene gas over the range 0 - 3% volume. Note however that due to the nature of this gas, we cannot guarantee compliance with the temperature performance specification on the hydrocarbon sensor data sheets.

- Measurement ranges - 0-3% Volume Ethylene (CH_2=CH_2)
- Operating voltage 3 to 5 volts dc, nominal current = 80mA
- Wide operating temperature range of -20 to +50 deg. C
- Output format options - Digital, Analogue or Pellistor Replacement
- Instantly converts existing compatible pellistor-based instruments to infrared
- Sensors can be factory configured to customer specifications
- User configurable via a configuration unit available from Dynament
- Internal 'Flash' memory enables firmware updates via the configuration unit
- Industry standard size - 20mm diameter x 16.6mm high (excluding pins)
- 3-pin (pellistor replacement) or 5-pin versions available
- Optional replaceable, self-adhesive micro porous 1 micron filter

Appendix E

Peltier Tile



TE Technology's Thermoelectric, or Peltier Cooling Modules (also known as a TEC or a TEM) come in a wide variety of types and sizes. While typically used for cooling, they can also be used for heating (by reversing the electric current flow) and even power generation. The TEC have two wires coming out of it, if a voltage is applied to those wires, then a temperature difference across the two sides is achieved, if the polarity is reversed on the wires - then the temperature difference is also reversed.

- TEC1-12706 Thermoelectric Cooler Peltier 12V 60W
- TEC1-12706
- Voltage(V): 12V Umax (V): 15.4V Imax (A): 6A
- QMax (W) : 92W
- Dimensions : 40mm x 40mm x 3.6mm

Appendix F

Survey Results

Participant 1

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?				√
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?		√		

Participant 2

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?				√
Accurate Is the measured value of prototype accurate?		√		
Reliability Was the objective met?				√

Participant 3

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?		√		
Accurate Is the measured value of prototype accurate?				√
Reliability Was the objective met?			√	

Participant 4

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?				√
Reliability Was the objective met?				√

Participant 5

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?				√
Accurate Is the measured value of prototype accurate?				√
Reliability Was the objective met?				√

Participant 6

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?				√

Participant 7

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?				√

Participant 8

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?				√

Participant 9

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?			√	

Participant 10

Performance of the Project	**Poor** (Fails to meet the required task)	**Fair** (Performed the minimum objective of the prototype)	**Moderate** (Has perform the task but executed with few errors)	**Excellent** (Successfully executed the task)
Easy to Use Is the software easy to use?			√	
Accurate Is the measured value of prototype accurate?			√	
Reliability Was the objective met?			√	