

Automated Spice Mixer

ECE4011 Senior Design Project

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Executive Summary

Household kitchen appliances have historically seen improvements in areas such as ergonomics, aesthetics, materials, and mechanical design. However, in order to enhance the user experience with kitchen appliances, improvements can be made to components of the system by adding the Internet of Things (IoT) aspect. The Automated Spice Mixer Team will design a device that will automatically retrieve and weigh the powders of various recipes. The system will include an algorithm that can perform unit conversions between various mass and volume metrics. To make a “smart” device, internet connection will be used to download recipes and display real-time data regarding the amount of the remaining ingredients. The system will have a weighing mechanism on the bottom of each container for measuring the remaining mass. The design will include a credit-card sized computer, the Raspberry Pi, that will perform all the data processing as well as controlling the motor and process of dispensing. In addition, the computer will be responsible for retrieving recipes from the Internet, which fulfills the IoT aspect. In addition, the product will have a touch screen Liquid Crystal Display (LCD) display that can extend the user experience and provide a conceptual model similar to smart phones. The Automated Spice Mixer device can be applied in the commercial food industry, where major fast food restaurant chains can use it to create mixtures automatically as orders are being received. This will help improve efficiency within these restaurants. The expected outcome of the design is a fully functional prototype that will cost less than 200 USD.

Automated Spice Mixer

1. Introduction

The Automated Spice Mixer Team will design a device that will automatically retrieve and weigh the powders conforming to various recipes. Another design specification is to provide easy unit conversions between various mass and volume metrics. Furthermore, the device will have internet connection for downloading recipes and interacting with cloud resources. Real-time data concerning the remaining ingredients can be displayed locally and pushed to a server. The team is requesting 200 USD to develop a prototype of the system.

1.1 Objective

The team will design and prototype a system that is able to automate the extraction and mixing of various powdered ingredients. The prototype will have internet access for uploading and downloading data. Downloading will be used for retrieving spice recipes online and uploading will be used for updating the amount of remaining spices in the device. The user will be able to convert between measurement units of mass and volume to prominent units including but not limited to kilograms, pounds, cups, teaspoons, and tablespoons. Data regarding densities of various spices will be stored on the system for unit conversion.

1.2 Motivation

Cooking is heavily influenced by both the use of pre-made spice mixture as well as the use of ingredients such as flour and sugar in recipes. For both of these use cases, a mixture is required, taking a precise amount of each of the ingredients. In the first case, a mix of spices that is bought in stores cannot be reused in other recipes. Money invested in pre-made mixtures cannot be utilized

efficiently. In the second case, significant time is spent measuring the exact amount of an ingredient, especially when a recipe is followed frequently.

In addition, people often lose track of their kitchen inventory which can lead to disorganization and inefficient planning of grocery shopping as well as unnecessary stress in households. Keeping individuals informed is important and requires an efficient responsive data-collection and visualization system. Overall, the user can better utilize both the resources of spices and time, which saves money. Currently, there are no product in the market that automate spice mixing. The device can be used by people who occasionally mix spices or restaurants that are required to mix spices fast and frequently.

1.3 Background

Embedded systems have been utilized in industry to dispense mixtures of liquids in the past. For example, a soda dispenser machine has successfully been able to mix syrup in the correct proportions to create custom recipes of soft drinks [1]. Additionally, a mix of IoT appliances are entering the market, resulting in a large amount of smart devices. No previous work on powder dispensers for this category of use has been found.

Regarding data visualization, a similar product that uses data visualization to inform users is commercially available. LG Electronics produces a smart fridge equipped with a HomeChat application that lets people receive real-time food status updates from their refrigerators directly on their smartphones. The device provides added data visualization by providing information on what items are reaching their expiration dates. Users can request recipes based on the ingredients they already have. No pricing information is available for this product [2].

2. Project Description and Goals

The fundamental goal of the Automated Spice Mixer Team is to create an internet of thing device enables users to extract precise measurement of powdered spices as well as the ability to access internet to download recipes. Reporting the amount of spices left will be done by the device in the background. The features of the system include:

- The ability to extract precise measurement of powder required
- Automating the mixing of various recipes from unmixed powdered ingredients such as flour and sugar
- Simplifying unit conversions between mass and volume in different unit systems
- Connecting to the Internet to download recipes
- Connecting to the Internet to upload the remaining amount of spices in the system

3. Technical Specifications

There are two major parts to the Automated Spice Mixer: the device and the server. Table 1 has the specifications for the Smart Insole. The technical specification is set to provide a user-friendly system for the end users. Table 1 shows the mechanical and electrical technical specifications for the device. A software related component of the system is data visualization. The data needs to be processed before it can be used for visualizing. A common algorithm used for data processing is called Data Abstraction [3]. It allows summarizing and reducing large amounts of data by grouping them into intervals or patterns. This allows faster processing with lesser required data storage space. Table 2 provides the software technical specifications for database storage and operating system.

Hardware Feature	Specification
Number of containers	8 containers
Speed of Carousel Rotation	1.2 s/360°
Minimum Torque of Carousel	5 kg/cm
Volume of individual containers	300 cm ³
Dimension	40cm × 40cm × 40cm
Computer Power	6 VDC / 1000 mA
Motor Power	6 VDC / 800 mA
Weight Measuring Method	Electronic Scale
Weight Measuring Tool	Point Load Sensor - SEN-10245
Weight Limit Per Sensor	50 kg

Table 1. Mechanical/Electrical Technical Specifications

Software Feature	Specification
Operating System	Ubuntu 14.04 LTS
Memory	At least 1.5 GB of dedicated RAM
CPU	At least 1 core
Data Storage	MongoDB Database at least 500 MB
Other Requirements	Domain, SSL Certificates

Table 2. Software Specifications

4. Design Approach and Details

4.1 Design Approach

System Overview

Figure 1 shows the block diagrams of the main components of the design for the Automated Spice Mixer.

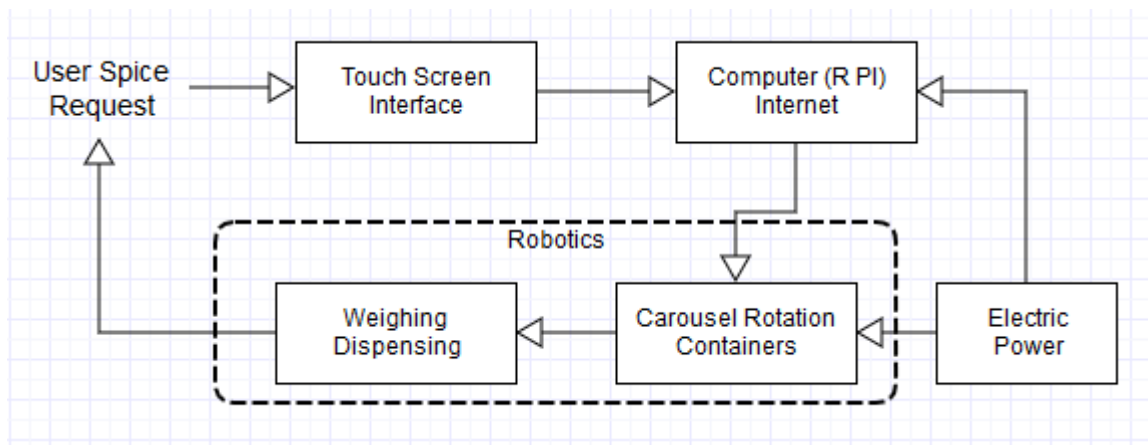


Figure 1. Block Diagram of overall system

Computing Resources

The computing platform for the spice mixer will need enough computing resources to manage network connectivity, robotics control, and any analytics which may be leveraged for higher accuracy such as computer vision or machine learning. The first two requirements call for a powerful processor. Analytics are often highly parallelizable and would benefit from a GPU. Additionally, low power consumption would be a benefit and small size is a must.

The Raspberry Pi B+ was chosen for the spice mixer. It is a 35 USD board with a Quad-core ARM Cortex A7, 1GB RAM, a Broadcom VideoCore IV GPU, and basic peripheral support with a camera port [4]. ARM processors have taken over the market for mobile and embedded

devices, with a high market share in IoT applications [5]. Of the ARM series, the A-series cores have the highest performance and are meant for applications which require a robust OS and networking support, without the need for real-time applications as found in the M-series [6]. The GPU on the Raspberry Pi would be a powerful accelerator for any signal processing or analytics which may be needed. The dimensions of the board are shown in Figure 2 [7].

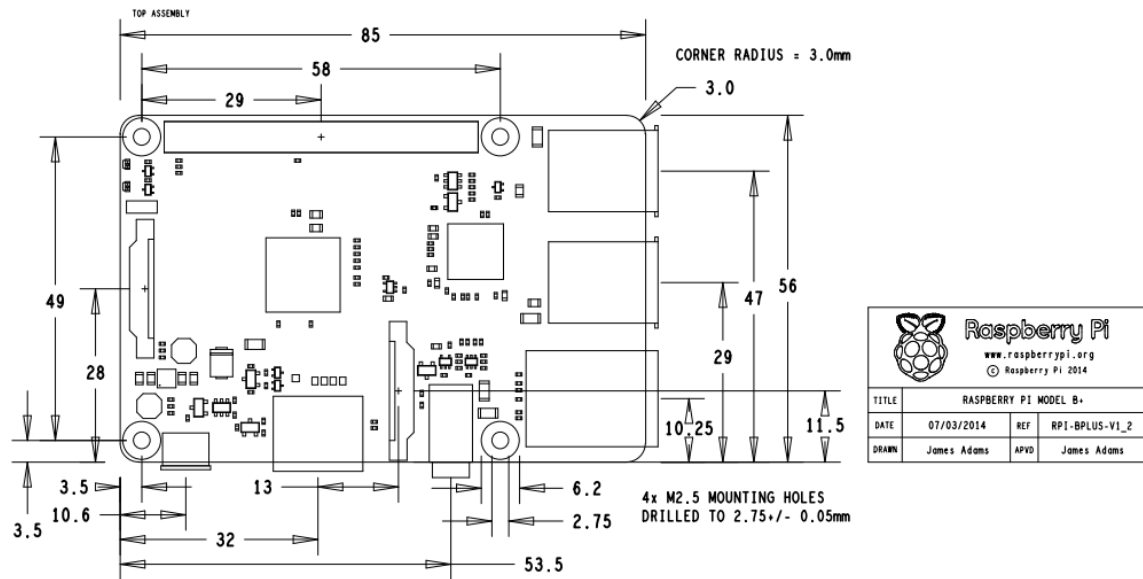


Figure. 2 Mechanical specification of Raspberry Pi B+.

Linux will be used as the operating system for the device. The choice to use the operating system is to better utilize resources and allow device abstraction. Device drivers allow the user to abstract away the hardware details of the specific device the user is controlling. Using the device abstraction allows networking and motor control to be accessed by multiple programs, without duplicating code [8]. Additionally, peripherals such as cameras may be required to use a provided driver. Linux was chosen due to its maturity on embedded devices and the ease of customizability with open-source software.

Storage Container Layout

The Horizontal Carousel (HC) layout is the most advantageous layout for the Spice Mixer application. The advantage of an HC layout is that it only requires one motor for accessing containers, compared to 2 or 3 for a Vertical Lift module layout [9]. The top of the carousel is designed to be a removable lid, which fulfills two design goals: easy access to the containers, and the ability to remove containers from the carousel for cleaning and filling. Figure 3 shows the layout of the horizontal carousel, the containers are clipped to a rail, which is attached to the central motor that enables the rotation of the frame. The radius of the frame is 15 cm.

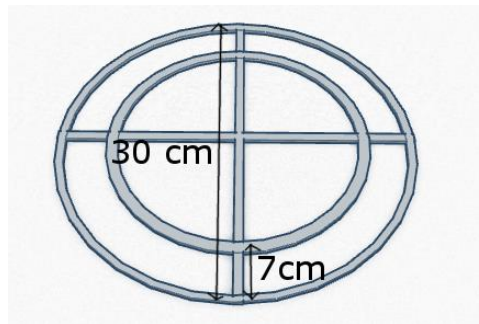


Figure 3. Dimensions of the rails

The HS-805BB Giant Scale Servo Motor [10] was chosen for the central motor that rotates the rails and containers. This motor was chosen for its small size ($66\text{mm} \times 30\text{mm} \times 58\text{mm}$), its appropriate speed (1.2 sec for 360°) and a maximum torque of 24.2 kg/cm. As most of the mass (powders) will be 15 cm away from the central motor (the center of rotation), this allows for 1.5 kg of powder. The containers will be printed in a plastic material, Figure 4 gives a sketch of a single container with its dimensions. The rail will support eight containers, two per quadrant.

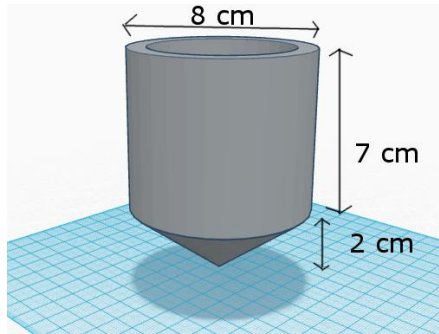


Figure 4. Dimensions of a container

Weighing and Dispensing Mechanism

The system is using a Raspberry Pi, which makes the electronic scale the best option because it allows the data to be processed by it and uses data visualization for interpretation. The electronic scale can be small enough to fit within the layout of the Spice Mixer. Using the strain gauge with the dispenser, underneath the container in use, will allow the Raspberry Pi to track the current weight of the container. Because it can constantly check the weight, it allows the system to track when spices are low in quantity and when the weight falls below a certain threshold. When this occurs, the user is notified on the LCD screen on which spices are low in quantity. When the user refills the spice, the weight will be above the minimum threshold. The SEN-10245 point load sensor can measure up to about 110 pounds, which satisfies the technical requirement [11]. The SEN-10245 will be connected to a load cell amplifier called the HX711. This component extracts the measurable data and makes it accessible by the computer [12].

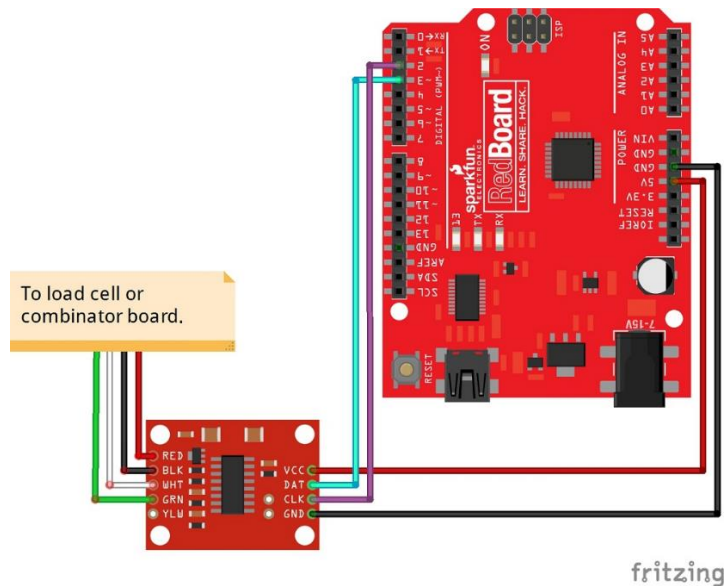


Figure 5. HX711 amplifier connected to a RedBoard

As seen in Figure 5 [13] the HX711 amplifier is connected to a RedBoard, but can also be connected to a Raspberry Pi. Because these components are smaller, the measurements can be off by +/- 5% due to many variables such as temperature, creep, vibration, drift, and other interferences [14]. This weighing of the container enables control over the quantity that is dispensed, and the computer controls when the tube is open (and dispensing), once the appropriate quantity of powder has been dispensed, the computer can remove the dispenser from the container.

Electric Power

There are several devices that require powering: the computer, the rotational motor, the weighing and movement motors. The device will have two power supplies, one that will provide power for the Raspberry Pi, which will be connected to the sensors, and the other for the motors. The AC Power Supply Adapter Charger 6V DC 1500mA, sold by Metroaccess, transforms 240V AC to 6V DC power that can be used for the computer as well as the motors.

Data Visualization

The most common way of handling data is by binding it to a Data Object Model (DOM) that would enable quick access to various sets of data [15]. This model clusters related data together and allows them to share common attributes. Once the data is bounded to a DOM, various data-driven transformations can be applied to it which would enable generating a wide variety of visualizations. Since the data is bounded to a DOM, the representation for the data can be quickly switched from one form to another without requiring to reprocess the data [16]. A well-known algorithm, Spatial Layout, produces the logic and mechanism for positioning a data element in a spatial substrate [17]. This allows generation of visuals such as scatter plots, bar graphs, stacked graphs, various sorts of maps and theme river graphs.

4.2 Codes and Standards

Food Codes and Standards

- FDA Food Code 4-201.11 Equipment and Utensils

Regarding durability and strength, the equipment shall be designed and constructed to be durable and to retain their characteristic qualities under normal use conditions [18].

- FDA Food Code 4-202.11 Food-Contact Surfaces

Regarding cleanability, the nozzle shall be smooth, free of breaks, open seams, cracks, chips, inclusions, pits, and similar imperfections. Free of sharp internal angles, corners, and crevices [18].

Computing Codes and Standards

- IEEE 802.11

This is a standard for wireless local area connection communication. It will be used with the device and a router supporting the 802.11b/g standard will be required to form the wireless network [19].

- LCD Interface

Several interfaces exist to connect monitors to embedded device including the prominent LVDS, and VGA connectors. Additionally, touch screen sensors require a controller which typically interfaces with the embedded device through a Serial/COM or USB port. Even though different controllers are required for the different touch sensors, the computer connections are standardized [20].

- Zero Indication

On a scale equipped with indicating or recording elements, provisions shall be made to either indicate or record a zero-balance condition. On an automatic-indicating scale or balance indicator, provision shall be made to indicate or record an out-of-balance condition on both sides of zero [21].

Engineering and Safety Codes and Standards

- Design

The surface of a weight shall be smooth and shall not be coated with thick, soft, or brittle material. A ring on a weight shall not be split or removable [21].

- Gross Capacity

An indicating or recording element shall not display nor record any values when the total platform load (not counting the initial dead load that has been canceled by an initial zero-setting mechanism) is in excess of 105 % of scale capacity [21].

- FCC Declaration of Conformity

Electronic devices must be checked to ensure that they do not radiate excessive amounts of radio signal if they are to be sold in the US [22].

4.3 Constraints, Alternatives and Tradeoffs

Alternatives

Alternatives for the computing include choice of embedded platform as well as operating system. Two alternative platforms are the Beagleboard Black [23] and the Qualcomm Dragonboard [24]. According to ARM product descriptions, the DragonBoard has the most powerful processor, followed by the Beagleboard Black, and Raspberry Pi [25].

Alternatives to the weighing mechanism include the choice to use a bar load sensor instead of a point load sensor. The bar load sensor is larger than the point load sensor, which may have an issue with the size of the Spice Mixer, but it can give more accurate measurements for containers that are large [26].

Constraints

The size of individual containers is a constraint as each container can hold at most 200 g of powder, assuming a density similar to flour density. The number of containers held by the machine is also a constraint as some users might have more spices than the eight available containers.

The size of the containers directly affects the size of load sensors that can be used for the weighing mechanism. If the containers are too large, the point load sensors will not be accurate. Depending on the container size, the size of the load sensor can be determined for greatest accuracy.

Trade-offs

There is a trade-off between the speed of delivery of the machine and the accuracy of the amount dispensed by the machine. Another trade-off exists between the size of the motor and power required. A larger central motor can be used instead of the HS-805BB Giant Scale Servo Motor, to improve the number and size of the containers, but will take up more space and require more power.

5. Schedule, Tasks and Milestones

The project will be developed over 3 months. **Appendix A** contains the list of all major milestones, the person(s) assigned to those tasks, and their relative risk levels. **Appendix B** contains the Gantt chart giving the timeline and ordering of the different tasks, with start date and end date. **Appendix C** contains a PERT (Program Evaluation and Review Technique) chart with specific tasks, milestones, and critical paths in red and the timeline for accomplishing them. The degree of difficulty for each task corresponds to the risk involved for each task, and the tasks are divided up to each member of the team by the initials of their names.

6. Project Demonstration

The project will be designed to be portable and will be tested in Van Leer, Georgia Institute of Technology. The formal demonstration will consist of one person doing the following:

1. Fill the machine with spices and powdered ingredients.
2. Choose a recipe available in the machine at random.
3. Request a specified amount of servings through a simple user interface.

The machine will automatically serve the quantity specified, with an error in measurement of less than 10%.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

Even though no spice dispensers have been made commercially available, there are several products that resemble the concept of the Spice Mixer. Equipped with a HomeChat application, LG Electronics smart fridge lets people receive real-time food status updates from their refrigerators directly on their smartphones. Users can also request recipes based on the ingredients they already have.

In the context of spice handling for the kitchen, there have not been any Automated Storage and Retrieval Systems (AS/RS) developed yet. There exist AS/RS systems of the same scale, but they are built for biology and chemistry laboratory settings [27]. These AS/RS systems have a typical minimum cost of 50,000 USD, and have many more features than the Automated Spice Mixer project such as handling temperature, humidity and air quality of the containers.

7.2 Cost Analysis

The total development cost for a prototype of the Automated Spice Mixer is approximately 189.70 USD. Table 3 shows a breakdown of the material costs of the prototype. The most costly equipment is the LCD - 7" Touch Screen at 62.95 USD. For the finished product, a customized Raspberry Pi will be designed to minimize costs and optimize functionality.

Product Description	Quantity	Unit Price (USD)	Total Price (USD)
Raspberry Pi B+	1	35.00	35.00
LCD - 7" Touch Screen	1	62.95	62.95
Giant Scale Servo Motor	1	39.95	39.95
Power Supply	2	9.95	19.90
3D Printed Containers	10	2.00	20.00
Load Sensor Combinator	1	1.95	1.95
Load Sensor	1	9.95	9.95
Total Cost			189.70 USD

Table 3. Equipment costs

The development costs shown in Table 4 were determined with an assumed labor cost of 40 USD per hour. The Python and C programming for drivers portion of the Raspberry Pi will have the highest number of labor hours due to the complexity of the implementation of the motor, nozzle, weighing mechanism, and data visualization.

Project Component	Labor Hours	Labor Cost (USD)	Part Cost (USD)	Total Costs (USD)
Raspberry Pi				
Python Programming	300	12,000	0	12,000.00
C Programming	100	4,000	0	4,000.00
Building/Wiring	120	4,800	35.00	4,835.00
LCD - 7" Touch Screen				
User Interface Design	50	2,000	0	2,000.00
GUI Programming	100	4,000	0	4,000.00
Building/Wiring	10	400	62.95	462.95
Electrical Design				
Building/Wiring	10	400	59.85	459.85
Mechanical Design				
3D Printed Container Design	75	3,000	0	3,000.00
3D Printing Material	100	4,000	20.00	4,020.00
Building/Wiring	10	400	0	400.00
Weighing Mechanism				
Load Weighing Sensors	0	0	11.90	11.90
Building/Wiring	10	400	0	400.00
TOTAL COST	885	35,400	189.70	35,589.70

Table 4. Development costs

The production run will consist of 5000 units sold over a 5-year period at a price of 250 USD per unit. More specialized controllers can be used once the performance requirements of the device are better studied. Most of the components can be integrated into a few packages so that they can be mass produced at a low cost. Assembly will be done manually until it is profitable to fully automate the production of components. The device will be sold to home goods stores with a small sales team. The equipment cost can be purchased at a discount for 100 USD per unit. A group of technicians will be employed at 20 USD an hour to solder the board, perform testing, and assemble the final product. Sale expense in the form of advertising will make up 6% of the final selling price, which will be 15 USD. At 250 USD per unit, the expected revenue is 1,250,000 USD, yielding a profit of 107.8 USD per unit. The production costs, profit, and selling price of the system are displayed in **Table 5**.

Description	USD
Parts Cost	100
Assembly Labor	10
Testing Labor	10
Sales Expense	15
Amortized Development Costs	7.2
Profit	107.8
Selling Price	250

Table 5. Selling price and profit per unit (Based on 5,000 unit production)

8. Current Status

The spice mixer outlined in this document will attempt to solve the problem of the mixture of powders found in recipes. Recipes will be obtained from a server on the internet, and automatic measuring of each powder will be done via a controlled dispensing unit. A preliminary design has been outlined, however, further technical design will be required. Once all the parts for this design have been obtained via purchase or 3D printing, the assembly and integration of the components can proceed. Tools on campus will be used for assembly.

The team is currently purchasing parts to be used in the device. For example, a microcontroller will be purchased to begin communication with the phone to ensure that data transfer can occur. Finally, user interface are being designed for the LCD screen to display.

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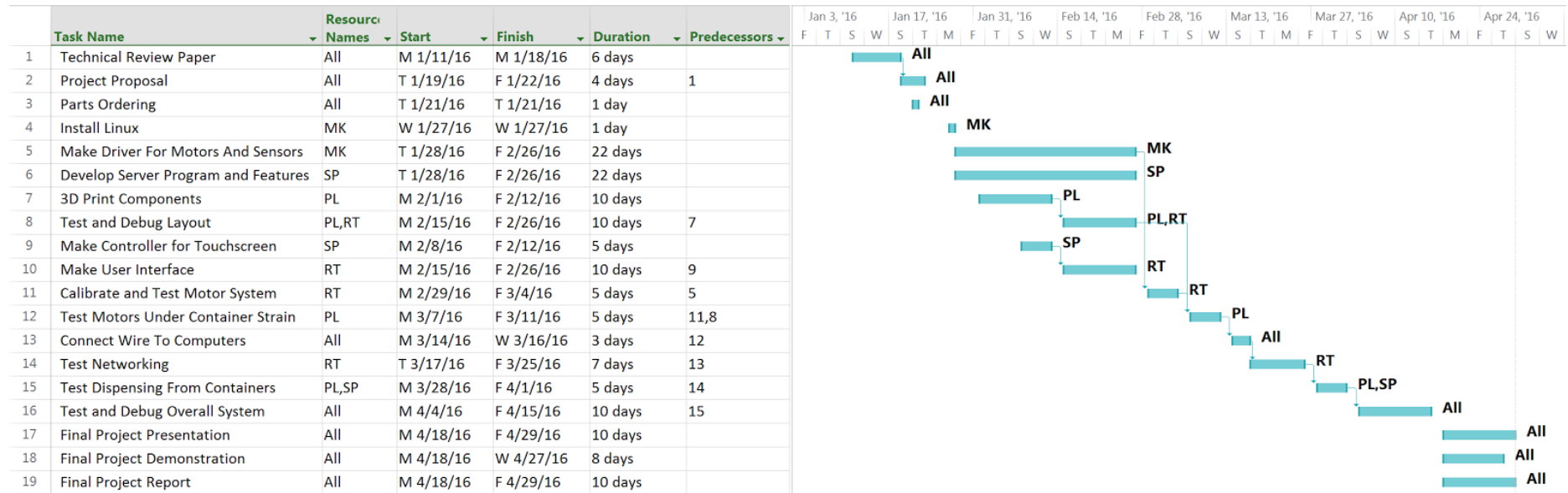
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Appendix A

Task Name	Task Lead	Risk Level
Planning, Presentation, and Documentation	All	Low
Technical Review Paper	All	Low
Project Proposal	All	Low
Parts Ordering	All	Low
Final Project Presentation	All	Low
Final Project Demonstration	All	Medium
Final Project Report	All	Low
Touch Screen - User Interface	SP, RT	Low
Make User Interface	RT	Low
Make controller for touchscreen	SP	Medium
Computing	All	Medium
Connect wire to computers	All	Low
Install Linux	MK	Low
Make driver for motors and sensors	MK	High
Networking and Cloud	SP, RT	Low
Test networking	RT	Low
Develop server program and features	SP	Medium
Mechanical	All	Medium
3D print components	PL	Medium
Test and debug Layout	PL, RT	Medium
Calibrate and test motor system	RT	High
Test dispensing from containers	PL, SP	Low
Test Motors under container Strain	PL	Low

Appendix B



Appendix C

