Lightweight Enterprises

March 10, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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RE: ENSC 440W Design Specifications for **Bartini Drink Dispensing System**

Dear Dr. Rawicz,

The attached document, *Design Specifications for Bartini Drink Dispensing System*, provides an overview of the design aspects of our capstone project. The goal is to design a software controlled drink dispensing system using electronic control, mechanical design, and software design techniques.

The design specifications will outline how the project will accomplish the specified functionalities of the various subsystems that compose our design. This design specification will present a detailed description of all technical aspects of the product including hardware, software, mechanical, and electronic aspects of the design. A practical test plan will also be provided so that the hardworking team at Lightweight Enterprises can produce a product of higher quality

Lightweight Enterprises consists of 3 talented senior design students: Noel Barron, Luke Mulder, and Ben Hieltjes. If you have any concerns or inquiries related to our design specifications, please do not hesitate to contact our Head of Communications, Noel Barron, by email at nbarron@sfu.ca.

Sincerely,

Luke Mulder
CEO
Lightweight Enterprises

Enclosure: Design Specifications for Bartini Drink Dispensing System

Bartini Drink Dispensing System

by

Lightweight Enterprises

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Abstract

This document describes the design specifications and details for the *Bartini* Automated Drink Dispensing System along with the individual components used in the final product. A detailed look at each subsystem is included in this document in order to help readers understand Lightweight Enterprise's design choices and justifications. Preliminary design thoughts for future versions of the *Bartini* are also explored.

The *Bartini* system is a device servicing the entertainment and amenities industry, consisting of intuitive graphic software control for mechanical dispensing of mixed beverages. The *Bartini* is a fully autonomous machine which can perform the majority of a bartender’s basic duties. A Raspberry Pi is used to control a variety of peripherals including solenoid valves to regulate fluid flow, DC motors, pumps, and a stepper motor system. This project will provide a consistent, entertaining experience to its end users while reducing operating costs and increasing efficiency for its clients. We differentiate ourselves from the scarce competition with our relatively inexpensive, modular, and scalable design.

This design document focuses on the technical details of hardware, software, control, electrical, and mechanical components along with justification of chosen parts and other design decisions. Software architectures, electrical schematics, and other technical details are provided in the design specifications. A high-level test plan is also presented in order to comprehensively test different components of the *Bartini* system and ensure the project’s success. A fully functional proof-of-concept system is to be delivered by April 22nd, 2016.

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Glossary

AC	Alternating Current.
CPU	Central processing unit.
DC	Direct current.
GND	Ground. Electrical reference point.
GPIO	General purpose input and output. Refers to configurable general use ports used to send or receive electrical signals.
GUI	Graphical user interface. A means of interaction with electronic devices through graphical icons and other visual indicators.
HDMI	High-Definition Multimedia Interface
PSI	Pounds per square inch.
RAM	Random access memory.
Raspberry Pi	A small computer containing a low-power microprocessor, various inputs/output devices, expandable memory, and capabilities of running an operating system.
Servo	A miniature rotary actuator consisting of a motor driving a train of reduction gears.
Solenoid Valve	A mechanical value used to control fluid flow. Operated by electrical signals.

1.0 – Introduction

The *Bartini* automated drink dispensing system is an entertaining solution in the amenities industry that will automatically pour a mixed beverage based on input from a user. By use of a graphical user interface (GUI) a user can request any number of predefined drink recipes or create their own based upon the liquids available in the machine. Valves, motors, and the software-based GUI are controlled by a single embedded processor system and work together to produce the end product. The requirements and design details for the *Bartini* system, as proposed by the creating company, Lightweight Enterprises, are outlined in this design specification document.

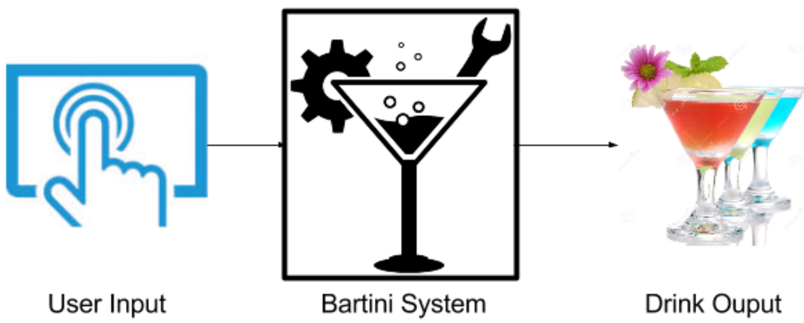

Figure 1: Bartini Concept

1.1 – Scope

This document describes the design specifications of the *Bartini* automated drink dispensing system. The requirements of each subsystem are outlined to provide sufficient details pertaining to the engineering and design aspects. The final product must uphold strict standards, meeting both legal and sustainability requirements. This document will serve as a reference which will be used extensively in the following stages to ensure a fully functional product has been designed and tested in a proper manner.

1.2 – Intended Audience

This document will be used as a guide for all team members of Lightweight Enterprises during the design and testing phases of development. As the team works on the design of the project, these specifications will be used to keep track of design goals and restrictions. During the testing phases it will be used to verify that our goals and sustainability targets have been met and that all specifications outlined in the previous “functional specifications” document have been followed.

2.0 – System Overview

The *Bartini* has been designed to perform most of the functions of a bartender. First the user will select from a list of possible drinks displayed on a graphical user interface. Then the machine dispenses the appropriate amount of each ingredient into a mixing chamber where the liquids are mechanically combined. The finished drink is dispensed into a glass. Finally, the chamber is rinsed of the previous drinks remnants and the remaining ingredients are updated.

Drink selection is done through a GUI. A list of drinks composed of the available ingredients is displayed for selection. In addition, the software supports the ability to make a custom drink. The user submits their order, places an appropriate glass into the dispensing chamber and the *Bartini* system will begin to dispense.

Pouring is performed from in two different ways depending on whether a base liquid or an alcohol is needed. A base liquid is any liquid that does not typically have a brand attached to it such as water, tonic, lemon juice, and lime juice. These are stored in reservoirs contained within the device and dispensed into the mixing chamber internally through valves and tubes. Alcohols are external to the device so that they can be seen when poured. A carousel will rotate a selection of alcohols so that the needed alcohol can be released by a valve directly into the mixing chamber from above.

Mixing is done inside of an aluminum chamber. Contained within the mixing chamber is a paddle-wheel driven by a DC motor. The DC motor is outside of the mixing chamber to prevent electrical problems and connected to the paddle-wheel by an axle.

Rinsing must occur after the drink has been dispensed so that there is no contamination between orders. After the drink has been poured the mixing chamber is rinsed with clean water. The water is agitated briefly by the mixer and then dispensed into the waste chamber.

The *Bartini* implements a data collection service, storing the ingredient and recipe usage. This is done to keep vital statistics for serving and long term sales tracking. When an order is placed the statistics are updated for number of orders placed and for which recipes. This intelligence feature is to be implemented in the later stages of the prototype designs.

2.1 – High Level System Specifications

The *Bartini's* functionality is accomplished by a series of parts including a microcomputer, sensors, servos, motors, and an LCD display. For a high level perspective, the *Bartini* can be broken up into multiple subsystems, namely, the hardware-based controls, firmware, and software application. An overview of the system's inputs and outputs is given below in figure 2.

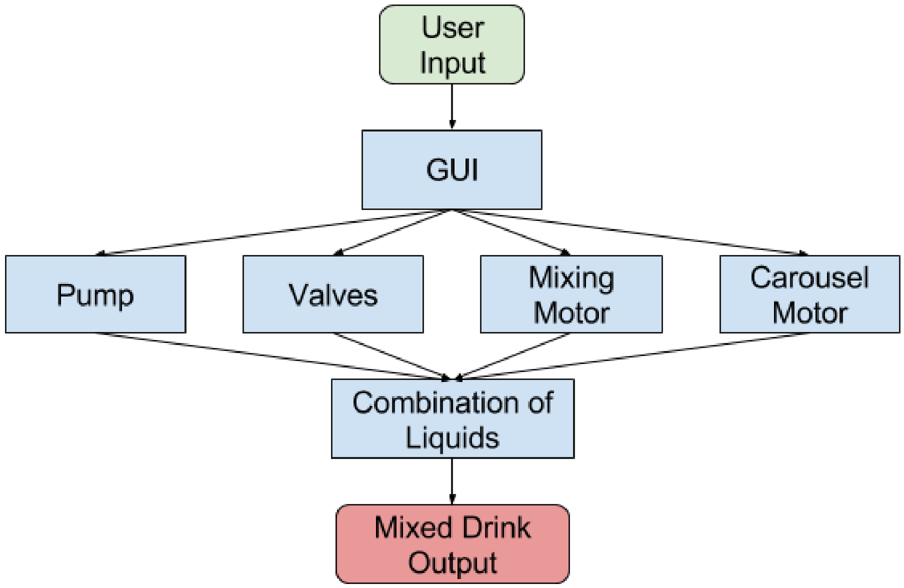

Figure 2: Bartini I/O Processing Overview

The hardware system consists of various components including servos and motors to mechanically move the system, valves and pumps to control liquid flow, mixing chamber, and enclosure. This is the physical entity of the system.

The firmware of the system resides in the Raspberry Pi. Use of the Raspberry Pi meets [Req 3.3.3 - PC] and [Req 3.3.6 - PC]. The firmware is the heart of the control system, regulating the timing and movement of the hardware components mentioned above. Firmware will allow for precise operation of valves, motors, and other electrical components.

The software application is the 3rd vital component of the *Bartini* system. Its purpose is to bridge the gap between the user and the device in a natural and intuitive way. At the highest level of abstraction in the context of the project, the software application will use the firmware that in turn will work with the hardware to create a fully-functional system.

Table 1: Raspberry Pi Specifications

Board	Raspberry Pi 2 Model B
Frequency	900 MHz
Memory	1 GB RAM
GPIO Pins	40
Display Output	Full HDMI

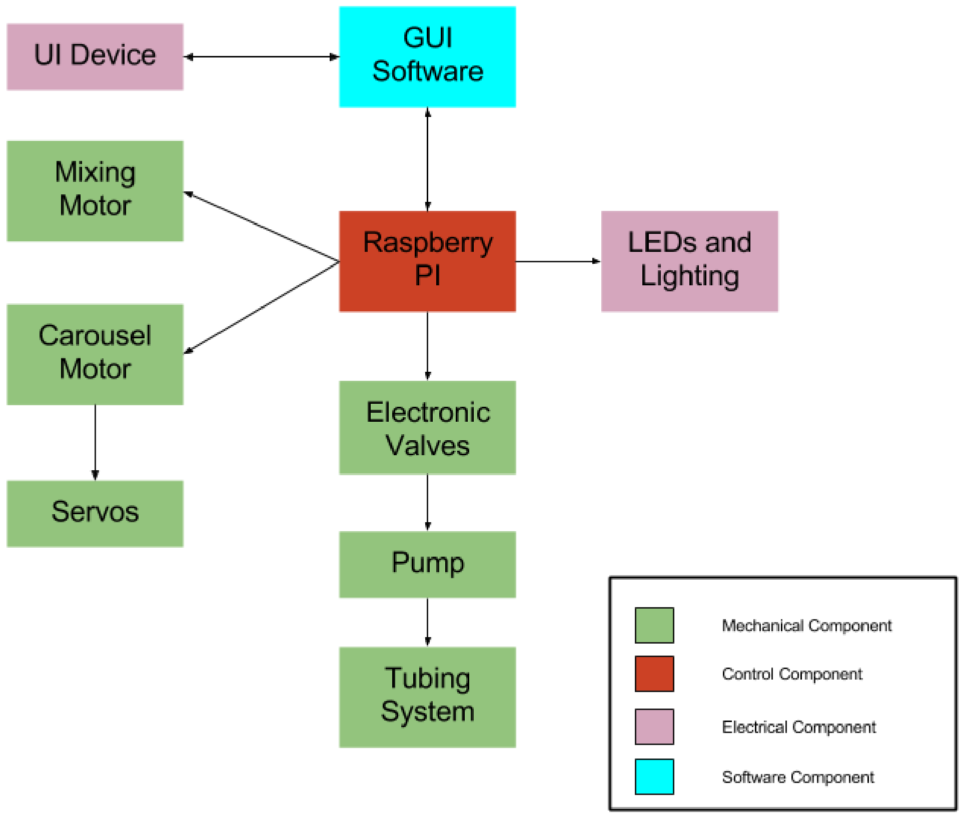

Figure 3: High-level System Overview

2.2 – Non-Alcoholic Liquid Control Specifications

The control of liquids is the core problem in the design of the *Bartini* system. The alcohol system and mixer system differ slightly in the way they are dispensed.

The mixer (or base) drinks refer to all the liquids which are not alcoholic. They include liquids such as soda and juices. The mixer liquids will be dispensed using a pressurized system composed of an aquarium-grade air pump, electrically actuated solenoid valves, and tubing network. The pump and valves are controlled using the Raspberry Pi.

The pump is used to pressurize bottles containing fluid by adding air into the environment. As a consequence of the increased pressure, liquid will be driving out of the bottle. This configuration is achieved by tubing the system according to figure 4.

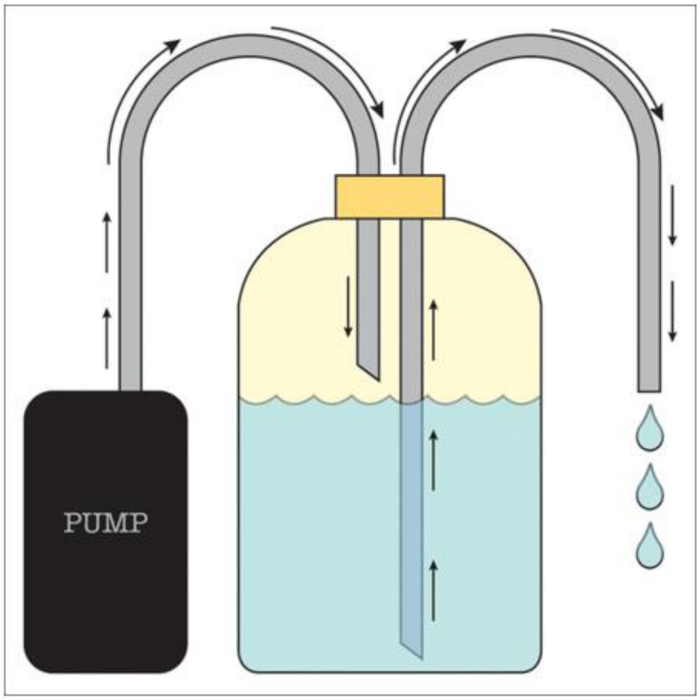

Figure 4: Pressurized Tank System [1]

This principle has been applied to an entire system of mixers by valves which control the pump's output airflow directing it into the bottle containing the liquid to be dispensed. The control software will allow only one of the valves to be open at any time. With the appropriate valve actuated, the pump will be turned on, driving the liquid from the desired bottle into the mixing chamber.

A schematic diagram of the tubing, pump, and valve system is given below in figure 5.

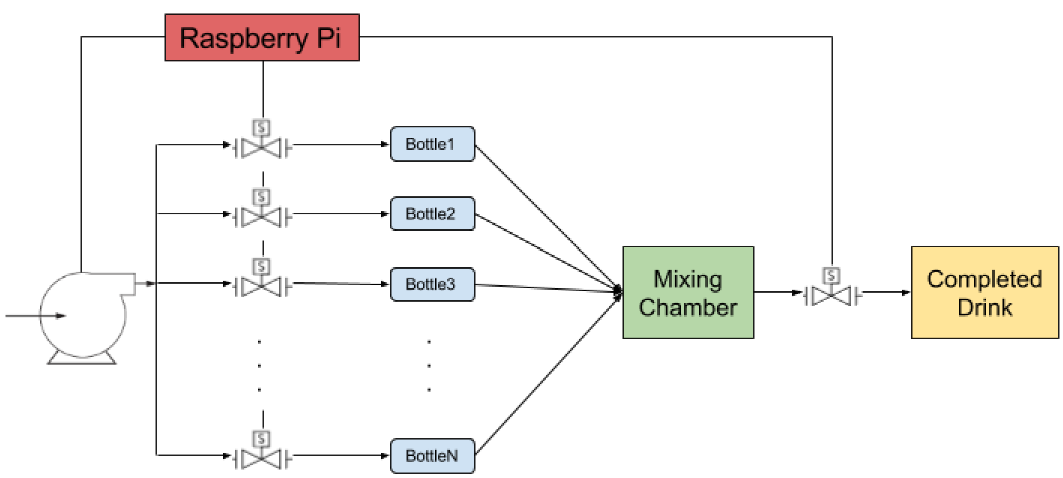

Figure 5: Pump System Schematic

2.3 – Alcoholic Liquid Control Specifications

The second mechanism for dispensing the liquids is the carousel. The purpose of using a second method of dispensing is to create a more visually appealing experience during the creation of a drink. All the brand name alcohols are mounted onto the carousel so that as each ingredient is dispensed the carousel will rotate to that bottle and the customer will see what brands are actually being added.

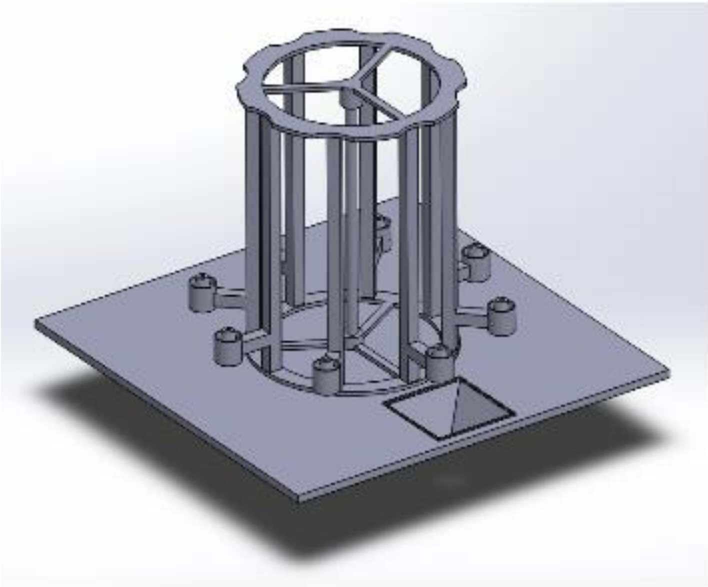

Figure 6: Bartini Carousel

The described function creates many constraints on the design of the carousel. In order to mount up to eight bottles the carousel is designed to support eight full alcohol bottles [Req 3.1.10 - PC]. To hold the inverted bottles securely onto the carousel, tubes of several different sizes are held out by aluminum arms. The sizes of these tubes vary to accommodate different types of bottles and are as follows:

Table 2: Bottle Sizing

Type	Maximum Neck Size	Number on Carousel
Large Base Alcohol	2.00 in	4
Medium Base Bottles	1.75 in	2
Bitters/Liqueurs	1.25 in	2

To hold the bottles against the aluminum struts, a strong elastic ribbon is mounted half way up in loop so that the bottle can slip through and be held tight. On the bottom of these mounting tubes, water cooler dispenser valves are mounted which are actuated by a lever-servo mechanism. When a given bottle is directly over the mixing-chamber funnel, a servo, mounted inside the *Bartini*, pulls a lever which extends out of the enclosure and pushes on the valve handle. Pressing the handle opens the valve and dispenses liquid.

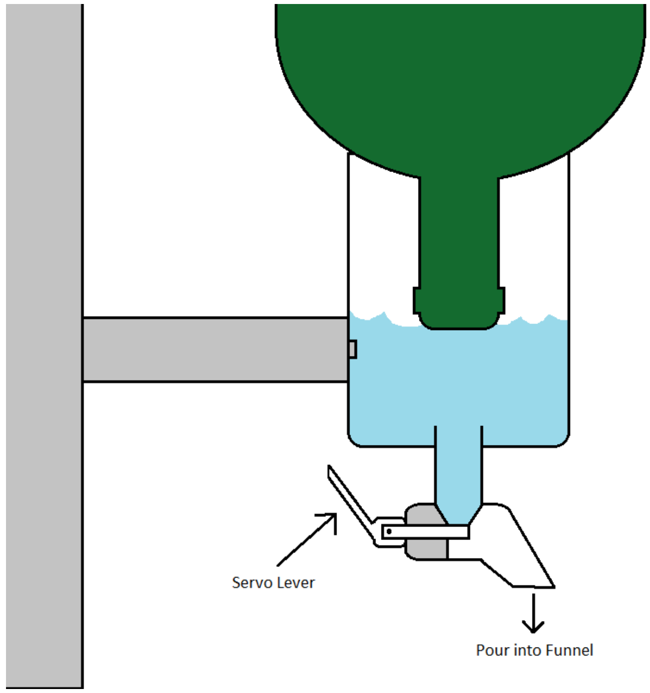

Figure 7: Alcohol Dispensing Mechanism

Water cooler valves were chosen because they are cheap and require a small amount of torque to actuate. As the carousel is rotating it is easier to actuate the valves by mechanical force rather than have wires coming up through the enclosure and attached to the rotating mechanism, possibly leading to tangled wires. A servo was chosen for pressing the valve because its angle could be controlled precisely and it can deliver a high torque for its relatively low cost.

To drive the carousel, the whole assembly will be mounted on a swivel plate for a Lazy Susan and driven by shaft running into the enclosure. The end of the shaft is attached to a bicycle gear which is then connected to a smaller bicycle gear with a chain. This smaller bicycle gear is then driven by the stepper motor which provides power to the whole assembly. A stepper motor was chosen because of its ability to control its position precisely in software compared to a DC motor whose position is unknown without separate feedback systems.

2.4 – Electrical Design Specifications

The automation aspects of the *Bartini* can be attributed to using electrically actuated and controlled components in tasks that are typically performed manually by humans. The system is composed of mostly on/off based control elements. The Raspberry Pi is used in conjunction with diodes, transistors, and resistors for these switch-like electromechanical elements. All electrical components are in compliance with [Req 3.5.4 - FP] and [Req 3.7.3 - FP] and will be mounted in a single prototyping board which will adhere to [Req 3.5.1 - FP]. The wiring of a single solenoid valve is shown below in figure 8 using a single transistor, diode, and current-limiting resistor. This same wiring scheme is replicated over all components in the system requiring on-off signal control from the GPIO ports of the Raspberry Pi.

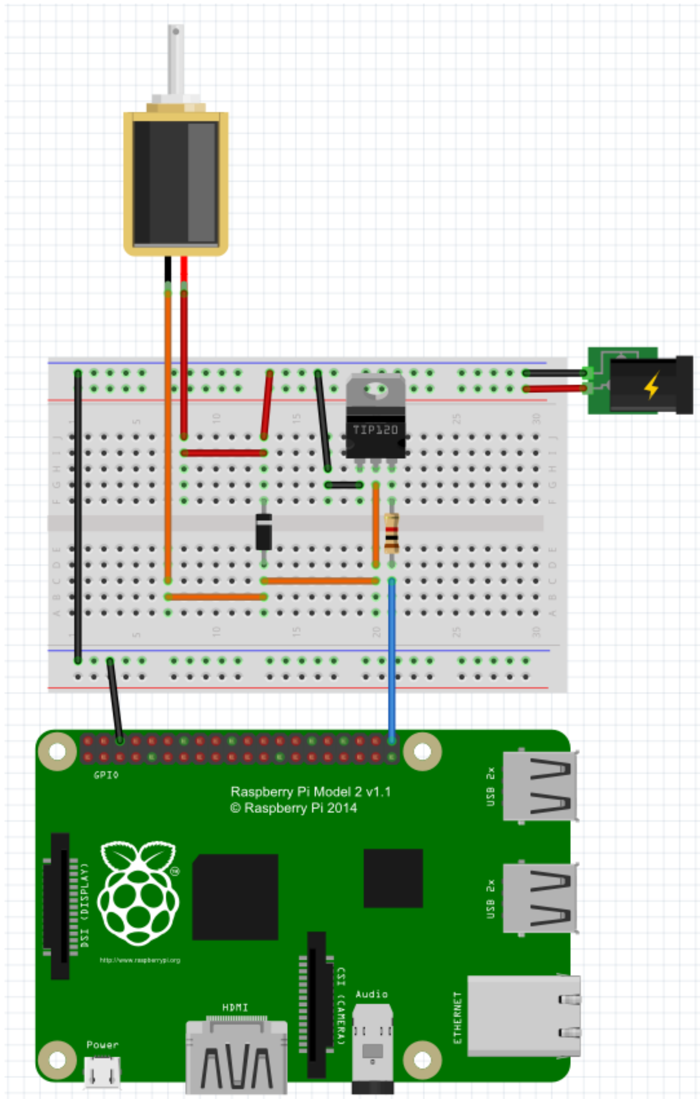

Figure 8: Wiring of a Solenoid Valve

The solenoid valves' specifications are given in table 3. There were chosen based upon the availability, controllability, and operating conditions [Req 3.2.8 - PC], [Req 3.8.7 - FP].

Table 3: Solenoid Valve Specifications

Valve Type	Unidirectional Normally Closed
Diameter	½"
Current Draw @ 9V	240mA
Current Draw @ 12V	320mA
Minimum Pressure Requirement	3 PSI

The DC motor driving the mixing mechanism and the servomotor are also wired in a similar fashion as they are controlled with on-off behavior. A stepper motor controls the rotation of the carousel. These components satisfy [Req 3.6.1 - PC], [Req 3.6.2 - PC], and [Req 3.6.3 - PC].The specifications for the mixing motor, the servomotor, and the stepper motor are given in tables 4, 5, and 6 respectively.

Table 4: Mixing Motor Specifications

Motor Type	DC
Maximum Current Draw @ 12V	1.1 A
Maximum RPM	60

Table 5: Servo Specifications

Motor Type	DC Servomotor
Operating Voltage	6V
Gear Type	Metal
Maximum Torque	12 kg-cm

Table 6: Stepper Motor Specifications

Motor Type	Bipolar DC Stepper Motor
Count Number	200 Steps / Revolution
Degrees per Count	1.8 degrees
Maximum Current Draw @ 12V	2.0 A
Holding Torque	45 N-cm

An electronic air pump is used to drive the mixer liquids. The specifications of the air pump are given in table 7.

Table 7: Pump Specifications

Pump Type	AC/DC
Maximum Output Pressure	3 PSI
DC Operating Voltage	3.3V
Maximum Flow Rate	2.5L/min

The Raspberry Pi GPIO pins were assigned according to the physical numbering shown in figure 9 [2].

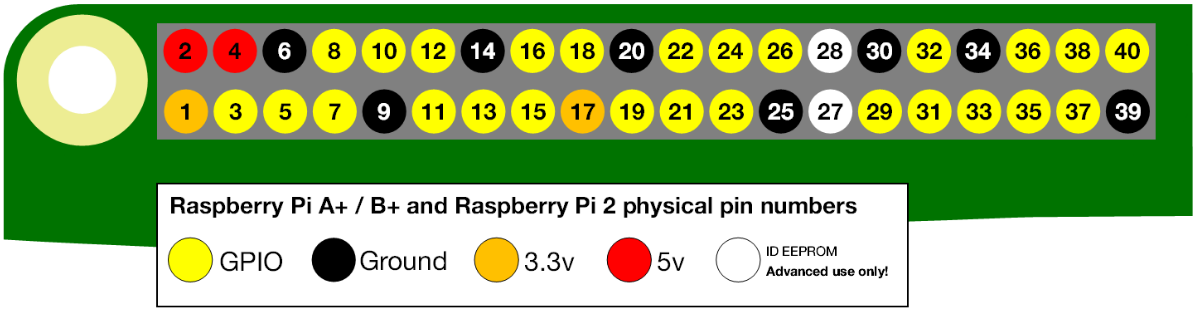

Figure 9: Raspberry Pi GPIO

A partial summary of the GPIO connections on the raspberry pi is given in table 8. These may be subject to change when the electronic and mechanical components are integrated.

Table 8: Raspberry Pi GPIO Assignments

Pin Number	I/O Peripheral
39	GND
40	Solenoid Valve in Mixer System
38	Solenoid Valve in Mixer System
36	Solenoid Valve in Mixer System
32	Solenoid Valve in Mixer System
26	Solenoid Valve in Mixer System
24	Solenoid Valve in Mixer System
32	Solenoid Valve above Dispensing Chamber
37	Servomotor
8	Mixing Motor
5	Air Pump

2.5 – Graphical User Interface Software Design Specifications

The graphical user interface is an important component of the *Bartini* system as it serves as the interface between the product and the user. It exists at a high level of abstraction and must be able to successfully work with all underlying technical components of the drink dispensing system. The GUI also serves as a major selling point as it is largely representative of the customer's experience with the *Bartini*. An intuitive GUI will satisfy [Req 3.1.6 - PC] and [Req 3.2.1 - PC]. The GUI has been designed to operate within the resolution and aspect ratio of a standard 7" display in accordance with [Req 3.2.2 – PT]. For the proof of concept system, the software has been divided into 3 main files: one for GPIO control, one for the recipe database, and one for the GUI which takes user input and sends commands to the control software. The hierarchy of the code is shown in figure 10.

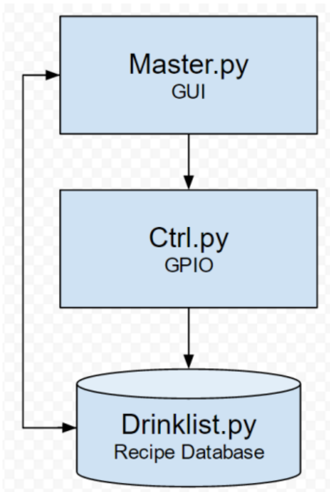

Figure 10: Software File Hierarchy

Python was chosen as a development language for our proof of concept system as it allows for rapid prototyping and has many modules and libraries that are useful when prototyping a system. A production level model may possible move to another language depending on the production-level design of the GUI and the database structure. The GUI is designed so that the user can choose from a list of predefined drinks or create their own based upon the liquids available in the machine [Req 3.2.3 - PT]. A user may choose a drink by selecting an associated button, labelled with both the drink name and a photo [Req 3.2.7 - PT].

As of March 9th, 2016, the GUI software flow functions as shown in figure 11.

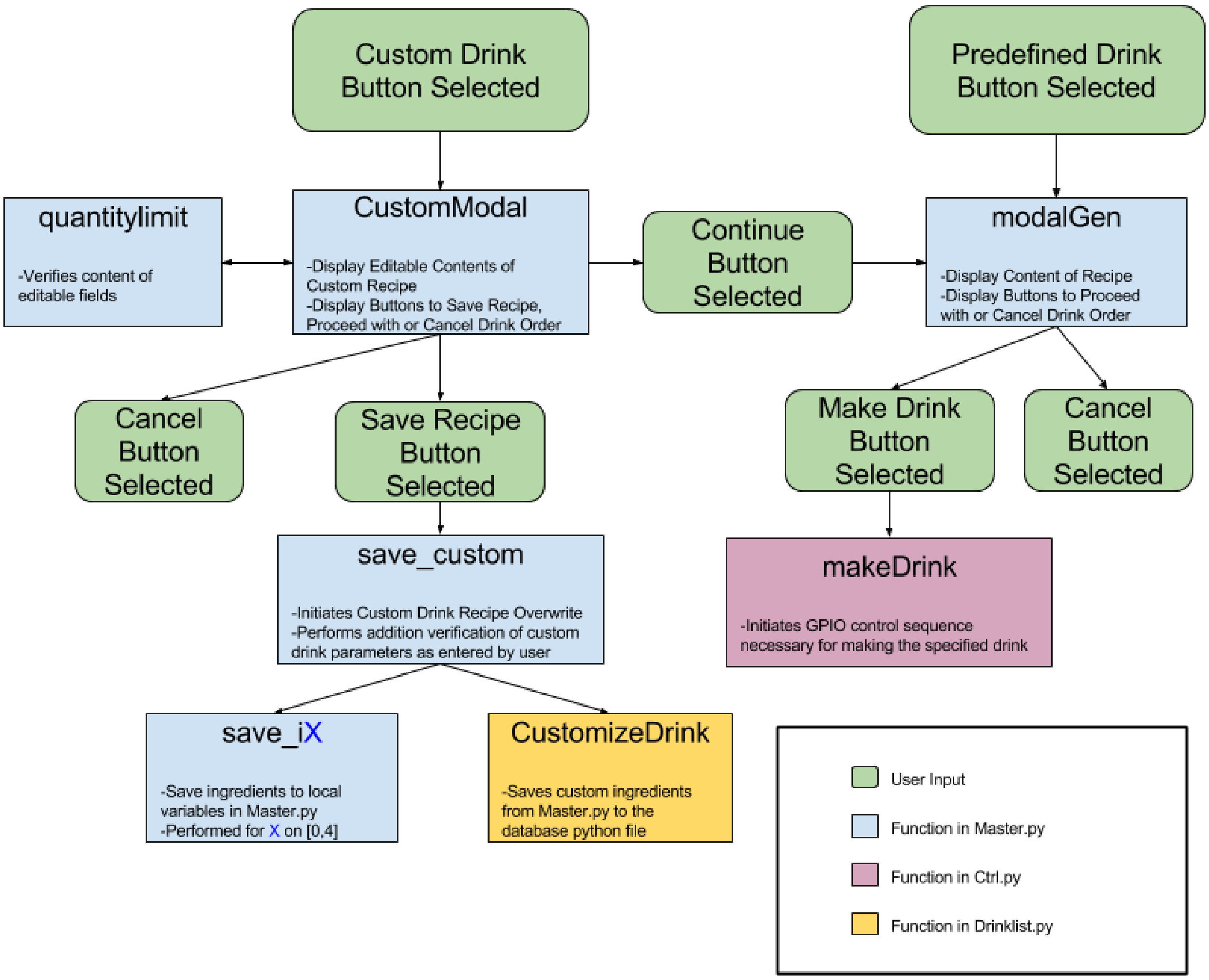

Figure 11: GUI Function Call Structure

2.6 – Control Software Design Specifications

The control portion of the software for the *Bartini* system resides in Ctrl.py. This python file takes input from the GUI and controls the appropriate I/O devices via the GPIO of the Raspberry Pi to correctly operate the automated drink system. Similar to the GUI software, the control software was designed to be modular [Req 3.1.4 - PT] and breaks the functionality required to dispense a drink into smaller, more manageable functions. This practice both improves code readability and allows the team at Lightweight Enterprises to be more efficient in the debugging process. The GPIO pin associations are defined in this file. Functions exists to actuate the pump and the solenoid valves in the mixer system, rotate the carousel of alcohols, actuate the DC mixing motor, and actuate the solenoid valve in the dispensing chamber. Based upon the drink ordered, these functions will be sequentially invoked in varying orders with control signals being sent for an appropriate amount of time to correctly operate the machine [Req 3.2.7 - PC].

2.7 – Enclosure and Construction Materials Design Specifications

Parts of the enclosure, carousel, and dispensing chamber have been water-jet cut from 1/16" aluminum. The metal components are fastened together using welding epoxy in conjunction with [Req 3.4.5 - PC] to prevent leakage and protect the structural integrity of the enclosure and mechanical parts. In conjunction with [Req 3.4.4 - PC], any of the epoxy within the container will be coated with "RTV 120" [3], a silicone caulking that can be used in food contact applications where FDA regulations apply. All the aluminum parts are safe for use with food. "Kerdi-Board" [4] and plywood are available for use in the remaining aspects of the enclosure [Req 3.7.2 - FP]. "Kerdi-Board" is a lightweight substrate material that is extremely useful in prototyping design due to its high strength-to-weight ratio and the ease with which it can be worked. "Kerdi-Board" is also a waterproof material, suitable for use in a system dispensing liquids in the presence of electronics [Req 3.8.4 - PC]. Plywood is used in situations where the "Kerdi-Board" cannot provide sufficient strength.

3.0 – Test Plan

The following sections will provide an overview of the proposed test and quality assurance procedures the team at Lightweight Enterprises will be applying to the *Bartini* system. Reliability [Req 3.5.8 - FP] and predictable behavior are key aspects of a successful engineering project. By following the high-level test plans proposed in these subsequent sections, our engineering team will be able to deliver a final product that better meets the standards an end customer is expecting.

3.1 – GUI Test Plan

The GUI test plan is important as it is the representation of the *Bartini's* software components. This front-facing application is responsible for collecting input from the user and passing it onto the control software in the lower levels. As such, the primary testing for the GUI software will be done through stimulation of input and reading of output. A simple comparison of expected output with actual output will be sufficient for these types of tests. Because the production model of the *Bartini* system is designed to be implemented with a touch screen for user input, a test of various screens is an important step to make sure the aesthetics of the GUI application remain as desired while displayed on the alternate peripheral. All editable fields will be tested with both valid and invalid input. All interactive elements (Buttons, Sliders, etc.) will be included as a part of this plan.

3.2 – Control and Electrical Test Plan

The control and electrical component of the *Bartini* is essential to ensure that each drink is made consistently. The electrical system is what enables the various parts of the *Bartini* to perform its intended functionality. The stepper motor, servos, pumps, and solenoid valves are included in these subsystems. The control system is responsible for ensuring that the liquids are dispensed properly and accurately. As a proof of concept, it will be sufficient to ensure that the drinks are dispensed properly. With the production model, a large amount of remodeling will be necessary to accommodate for a larger array of drinks.

All electronic peripherals connected to the Raspberry Pi will be tested for accurate actuation based on input from the control software. There are distinct tests that will have to be implemented to cover the different types of peripherals. The first test will involve sending enable signals to the switch circuit found in figure 8 that will ensure that the various components that we intend to control are being turned on or off as we intended.

Lastly, we need to test that the stepper motor positions the carousel properly. This will involve sending the necessary signals from the Raspberry Pi's GPIO pins to actuate the stepper motor so that the drinks align with the funnel to properly dispense onto the mixing chamber.

3.3 – Mechanical Test Plan

The performance of the mechanical aspects of the *Bartini* is what will determine the accuracy and speed at which the drinks are created. The most essential test will focus on the structural integrity. To ensure that the carousel and enclosure do not fail the completed build will be loaded with 1.5 times the maximum expected load of bottles and alcohol. If no physical deterioration is observed the performance testing can start. To test the speed at which the system can pour a drink, the maximum rate of rotation will be determined by rotating the carousel 180 degrees. This is the maximum distance it will have to rotate between any two alcohols. Testing will continue at increasing speeds until the acceleration and deceleration are too jarring for the mechanism.

The pouring speed of the liquid from the taps on the carousel and pumped liquid from the reservoirs will be determined by timing the dispensing of 250ml of fluid into the mixing chamber and directly into a measuring cup. From all these measurements estimations for the mixing time of each drink can be calculated and displayed during mixing.

Reliability tests will be performed on the positioning of the carousel, actuation of the carousel valves, and mixing of large volumes of liquid in the mixing chamber. To test reliability of the carousel a rotation test will be made in software which will rotate the carousel to select random bottles and we will visually inspect each alignment to ensure the carousel is consistently aligning the bottles with the servo-lever and funnel. In addition to the positioning, the water dispenser valve reliability will be tested by repeatedly pressing the valves on and releasing them to ensure that they are properly lubricated and actuate correctly each time without sticking in the on position or jamming in the off position. For the reservoir dispensing, the reliability will also be tested by repeatedly actuating the sequentially for long periods of time and checking for heat buildup and mechanical wear of both the solenoid valves and the air pump. Finally, the mixing chamber reliability will be tested by running the mixing motor with the liquid at maximum capacity and ensuring the wheel does not fail or exceed the yielding point of the metal and that the motor does not wear or heat up past the recommended conditions.

Table 9: High-Level Mechanical Test Cases

Hardware Component	Test Case		
	Reliability	**Speed**	**Accuracy**
Carousel	Test the load carrying capacity by weighing it down with 1.5x the expected load of bottles and liquid. Ensure no heat buildup during repeated rotations	Progressively increase the speed of rotation to the maximum safe speed	Rotate the carousel to random positions and ensure the bottles align with funnel each time
Carousel Valves	Actuate valves on and off many times and inspect for mechanical wear	Measure the flow rate of the valves for all cases of bottle types and levels of liquid in the bottles	Actuate valves with the servo and ensure they open and close without sticking or breaking
Reservoir	Actuate solenoid valves in cycles continuously and ensure no misfires, leaks or wear	Measure the rate of liquid accumulation in the mixing chamber	Test of residual flow after the valve has been shut off and any changes in flow as the reservoir empties
Mixing Chamber	Perform spin cycles with the maximum capacity and ensure no wear on motor or mixing wheel	Test different mixing times for total mixing of the separate liquids	Visually inspect that the mixing wheel spins at the same rate for different volumes in the chamber

4.0 – Conclusion

This document highlights the design specifications of the *Bartini* automated drink dispensing machine. The design specifications work in conjunction with the functional specifications and aid our engineering team in the prototyping process. The *Bartini* is a complex system that interacts with users through a software interface to take drink orders, mechanically dispenses and mixes the drink ingredients, and presents a completed drink to the user. This document separates the design into distinct self-contained parts that allows the various development streams to maintain coherency and meet quality goals.

Lightweight Enterprises acknowledges the need for detailed specifications in all aspects of the product including electromechanical systems, software-based systems, safety, reliability, and sustainability. The modularity of the design aspects allows for unit testing and development without need for integration in many cases. Inclusion of a test plan will be essential in the later stages of development as the proof-of-concept system nears completion.

The *Bartini* system will be developed in the coming weeks to meet the various standards outlined in this specification. A functional system is to be delivered for the project demonstration in April 2016.

References

[1] J. Baichtal, *Arduino for beginners*. Indianapolis: Que, 2014, pp. 165-186.

[2] "GPIO: Models A+, B+ and Raspberry Pi 2 - Raspberry Pi Documentation", *Raspberrypi.org*, 2016. [Online]. Available: https://www.raspberrypi.org/documentation/usage/gpio-plus-and-raspi2/. [Accessed: 07- Mar- 2016].

[3] "RTV 102 | MG Chemicals." [Online]. Available at: http://www.onlinecomponents.com/productfiles/mf-mgc/rtv102-85ml.pdf. [Accessed: 10- Mar-2016].

[4] "KERDI-BOARD Panels | Building Panels | schluter.ca", 2016. [Online]. Available: http://www.schluter.ca/schluter-ca/en_CA/Building-Panels/KERDI-BOARD-Panels/c/BP-KBP. [Accessed: 06- Mar- 2016].