March 16th, 2022

Dr. Mike Hegedus
School of Engineering Science
Simon Fraser University
Burnaby BC, V5A 1S6

Re: ENSC 405W Design specification for UpDawg

Dear Dr. Hegedus,

This document describes the design specification for *Doggolicious*, which is an automatic hot dog condiment dispenser targeted for employees working at an office who would like to grab a quick lunch. Our goals are to develop a product that is easy to use and to provide a convenient and mess-free solution to putting condiments on a hot dog.

This document will outline the detailed specifications for the design of *Doggolicious*. It will consist of the following major sections: System Overview, Electric Design, Software Design, Mechanical Design, Appendix A: Design Alternatives, and Appendix B: Test Plan.

UpDawg is a company that is made up of six engineers: Linhan Pei, Mingqi Tian, Jerry Mazurek, Weilong Sun, Tsz Wing (Nicole) Choi and Chi Hong (Happy) Yip. Each team member is well-equipped with different sets of skills gained from previous experiences, which will allow us to succeed in our roles.

Thank you so much for reviewing our design specification. If you have any suggestions or questions, please contact our designated CCO, Jerry Mazurek, at jmazurek@sfu.ca.

Sincerely,

Linhan Pei

Linhan Pei,
CEO
UpDawg

UpDawg

Design Specification:

Doggolicious

Team Members:
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Submitted To:
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Issue Date:
March 16, 2022

Version History

Version #	Version Date	Edited By	Version Description
1	March 10, 2022	Weilong Sun	Added title page, table of content, and headings
2	March 11, 2022	Weilong Sun, Tsz Wing (Nicole) Choi	Edited 3.1 Main Control section, and Introduction/Background
3	March 12, 2022	All team members	Edited Electric Design section, Mechanical Design Section, System Overview section, Software Design section, Design Alternative Section, and Test Plan Section
4	March 13, 2022	Mingqi Tian, Chi Hong (Happy) Yip	Edited Mechanical Design Section
5	March 14, 2022	Jerry Mazurek, Weilong Sun, Linhan Pei	Edited System Overview section, Electric Design section, and Software Design section
6	March 15, 2022	Tsz Wing (Nicole) Choi, Linhan Pei	Edited Letter of Transmittal, Abstract, and Conclusion
7	March 16, 2022	All team members	Edited each section based on TA's feedback, Formatting, Fixing typos, References, Figures and Tables, and Glossary

Abstract

Living in a fast-paced world, people are continuously looking for convenient and time-saving alternatives to assist with their everyday lives. As a result, the team at UpDawg came up with the idea of an automatic hot dog condiment dispenser, *Doggolicious*, that will make the job of placing condiments on a hot dog faster and simpler. The intended user of this product will be employees working at an office looking to have a quick lunch.

This document describes the design specification of the product, *Doggolicious*. It will outline the system overview, the electric design, the software design, and the mechanical design of *Doggolicious*. There will also be two appendices: Appendix A: Design Alternative, and Appendix B: Test Plan that will describe the choice of design with justifications and supporting test plans for testing. The purpose of this document is to provide justifications for the design choices that were made by the team.

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Glossary

CNC	Computer numerical control
I2C	Inter-Integrated Circuit
LCD	Liquid Crystal Display
OLED	Organic Light-Emitting Diode
FDA	Food and Drug Administration
FSA	Food Safety Act

1 Introduction/Background

As the reliance on technology continues to grow, people are always striving for more convenient and time-efficient alternatives. Meanwhile, people are pursuing richer flavours and more refined meals in their diets, but most people cannot make such food conveniently by themselves. Therefore, the team at UpDawg has decided to develop an automatic hot dog condiment dispenser, *Doggolicious*, that will provide a convenient and mess-free solution to putting condiments on a hot dog. Since the top 3 most popular hot dog condiments are mustard, ketchup, and onions [1], those will be the condiment options available to the users. Based on the feedback received from Progress Review Meeting #1 of the targeted audience being too broad, the team has decided to focus on employees working at an office who would like to grab a quick lunch. The team has also narrowed down the scope of the project according to the comment received from Progress Review Meeting #2. Instead of building an automatic hot dog machine that includes cooking sausages and assembling the hot dog, the team has revised the idea to focus solely on the condiment dispenser. A block diagram for the new idea is shown in Figure 1. Since the project scope and idea were changed from an automatic hot dog machine to an automatic hot dog condiment dispenser, requirement references will not be listed.

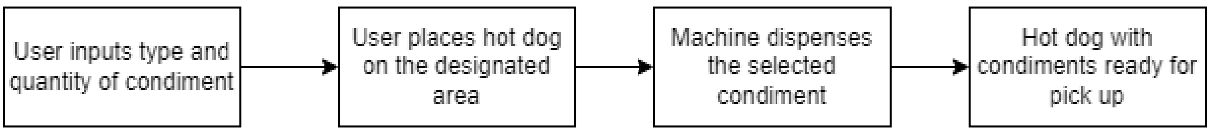

Figure 1: Block diagram for *Doggolicious*

Some challenges are expected to be tackled during the development of the project and can be divided into two parts: technical design challenges and project planning challenges. For technical design challenges, the condiments will be difficult to be dispensed since ketchup and mustard have a higher viscosity than water [2]. Furthermore, diced onion is solid and cannot be squeezed out, so another approach for dispensing the onions will be needed. For project planning challenges, the time it takes for 3D printing may be underestimated. The team will have to start working on 3D printing early so that there will be enough time to make another one in case something goes wrong. Additionally, the COVID-19 pandemic is an unforeseeable factor that may negatively impact the project progress and timeline.

In the following requirements part, each requirement specification will be defined as the following labelling schema:

[Des. S. SS. N - ProjectStage]

- S = Section
- SS = Subsection
- N = Requirement number

Where the different project stages will be represented as the table below:

Encoding	The stage of development
A	Proof-of-concept
B	Engineering Prototype

Table 1.1 - Representation of different stages

2 System Overview

The Doggolicious is an automatic condiments dispenser for hot dogs. The user can place a hot dog on the tray near the base of the machine, select their desired condiments, and have them dispensed evenly on the hot dog. The underlying system can be divided into 3 parts: the UI layer, the electronics layer, and the dispensing mechanism.

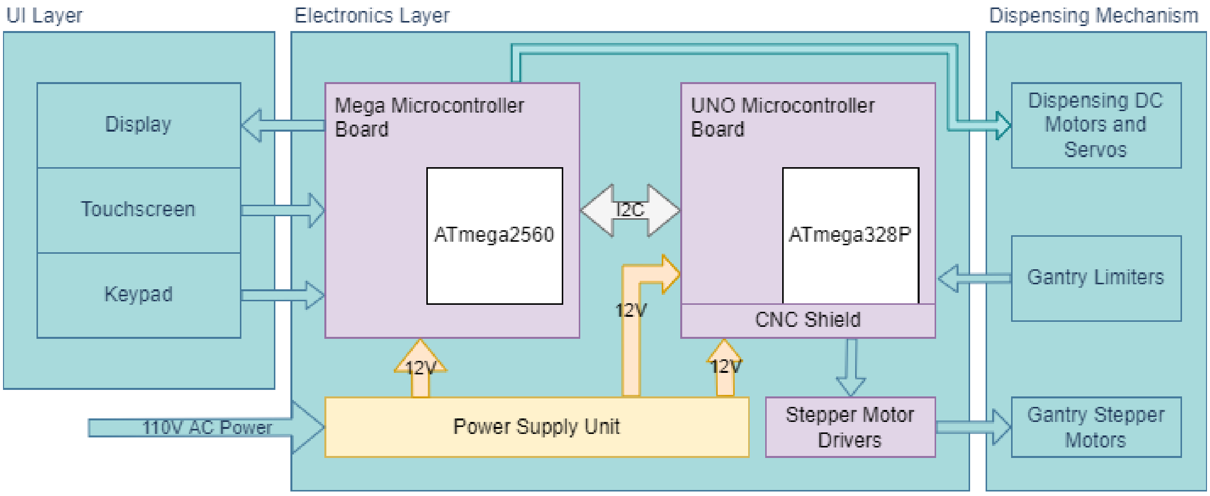

Figure 2: *Doggolicious* System Block Diagram

The UI Layer includes a display, keypad, and touchscreen to aid the user in operating the machine. The dispensing mechanism is the output layer, consisting of a CNC gantry on the x-y plane as well as DC motors for dispensing various condiments. The electronics layer is a bit more complicated, including two microcontroller boards that communicate via I2C. The MEGA board has more GPIO pins so it was chosen to facilitate IO with the UI layer as well as the additional signals needed for dispensing DC and servo motor control in the dispensing mechanism. The board will serve as the master in I2C communication and will manage the orders received from the user. The secondary UNO Microcontroller board will control the CNC components of the machine. A CNC shield will be mounted on the board that will accept supplementary 12V DC power for driving the stepper motors. A pair of stepper motor drivers will be used for the x and y axes and gantry limiters switches will feedback to the UNO board. Additionally, the Power Supply Unit will convert 110V AC Power into 12V DC for each of the microcontroller boards and the supplementary stepper motor power on the CNC shield.

Design ID	Design Specification Requirements
Des 2.1 A	The machine will include an LCD and input via keypad.
Des 2.2 A	The machine will be able to dispense ketchup and onions.
Des 2.3 A	The machine will include a power switch.
Des 2.4 B	The machine will include a touchscreen for input.
Des 2.5 B	The machine will accept 110V AC Power.

Table 2.1 - System design requirements

3 Electrical Design

This section will include the details of electric design. The current overall circuit of the *Doggolicious* is shown as Figure 3.

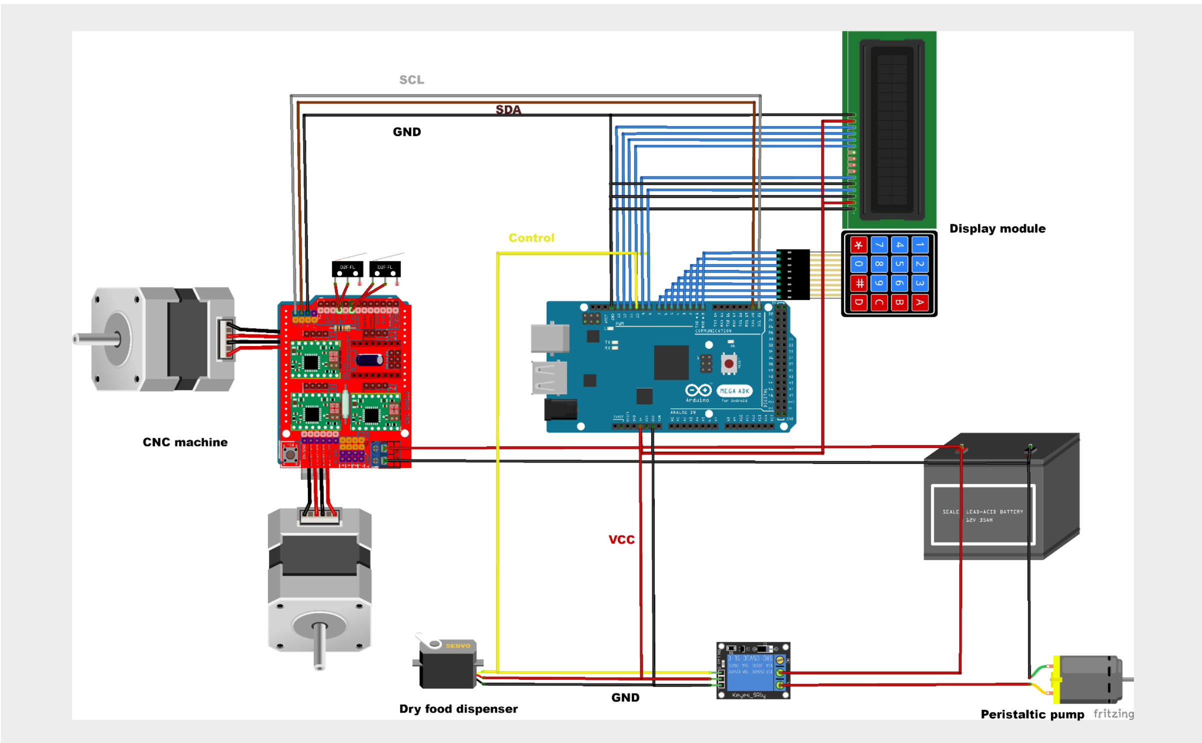

Figure 3: Overall circuit of *Doggolicious*

3.1 Main Control

Design ID	Design Specification Requirements
Des 3.1.1 A	The main control is compatible with the display module.
Des 3.1.2 A	The main control is compatible with the sauce dispenser module, which includes CNC machine, peristaltic pump, and dry food dispenser.
Des 3.1.3 A	The main control works with power control regularly.
Des 3.1.4 B	The main control fits in the *Doggolicious* enclosure easily.

Table 3.1.1 - Main Control design requirements

The main control is made up of two microcontroller boards, which are a UNO and a MEGA board. The positive characteristics of the UNO board are low-cost, flexible, easy-to-use, and open-source [3]. Because of those characteristics and comparison with other boards, the UNO R3 board is chosen to work with a CNC machine to provide pattern style. It operates with 5 volts and its input voltage is under an external supply of 6 to 20 volts [4]. However, the recommended range of voltages is within 7 and 12 [4]. Its microcontroller is Microchip ATmega328P [4]. This board has 14 digital I/O pins, which include 6 PWM pins, 6 Analog input pins, 1 LED, and 1 Ground pin [4]. Also, it has 32 KB flash memory, 2KB SRAM, and 16 MHz clock speed [4]. The basic structure of the UNO R3 board is shown in Figure 4.

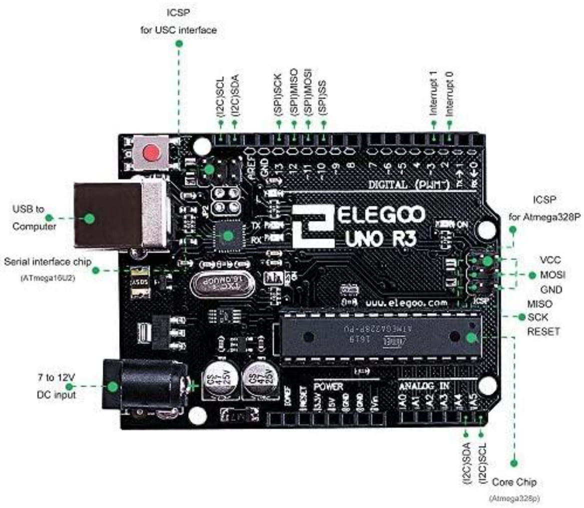

Figure 4: UNO board [5]

The MEGA 2560 board chosen is to work with the display module, peristaltic pump, and servo motor since it has more pins than the UNO board. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [6]. The basic structure of the MEGA 2560 board is shown in Figure 5.

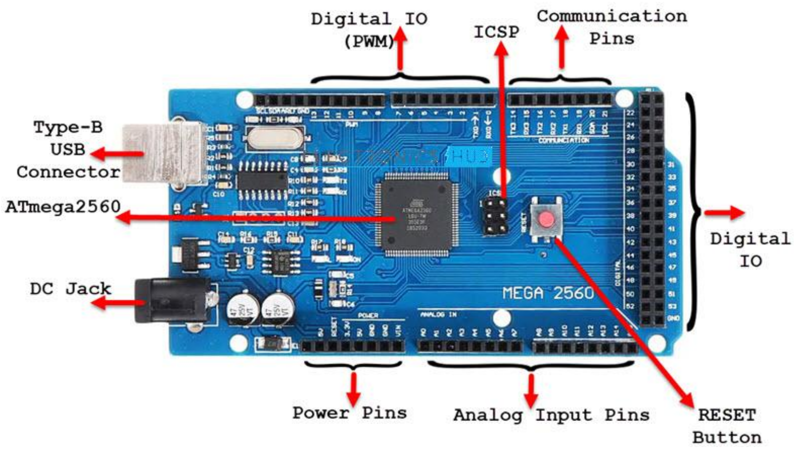

Figure 5: MEGA board [7]

3.2 Display Module

Design ID	Design Specification Requirements
Des 3.2.1 A	The keypad shall have physical feedback (e.g. elasticity) when the key is pressed.
Des 3.2.2 A	The LCD shall be able to display clear pixels.
Des 3.2.3 A	The LCD shall be able to be programmed by the MEGA board.

Table 3.2.1 - Display Module design requirements

This display module includes a 4*4 keypad and a 1602 LCD which are built for main control and allow them to interface with the MEGA board because the keypad provides sufficient actions and LCD satisfies the basic need of resolution at the early-stage design. The LCD, keypad and corresponding port connection are shown in Figure 6.

Figure 6: LCD 1602 (left) [8] & 4*4 keypad (right) [9]

3.3 Stepper Motor Driver

Design ID	Design Specification Requirements
Des 3.3.1 A	This motor driver can deliver up to 1 A current (a heat sink may be required).
Des 3.3.2 A	This motor driver can deliver up to 2 A without a heat sink.
Des 3.3.3 A	This motor driver allows different step resolutions.
Des 3.3.4 A	This motor driver has an 8 V to 35 V operating voltage range.
Des 3.3.5 A	This motor driver has over-temperature thermal shutdown, over-current shutdown, and under-voltage lockout.

Table 3.3.1 - Stepper Motor Drive design requirements

The stepper motor driver A4988 shown in Figure 7 can control a bipolar stepper motor. It is an interface between the Arduino and the motors, which provides simple step and direction control. It can be activated by current flow in one direction or the other to change the polarity of the magnetic field generated inside the motor. A potentiometer is also on the driver that can set the current limit to prevent damage to the stepper driver.

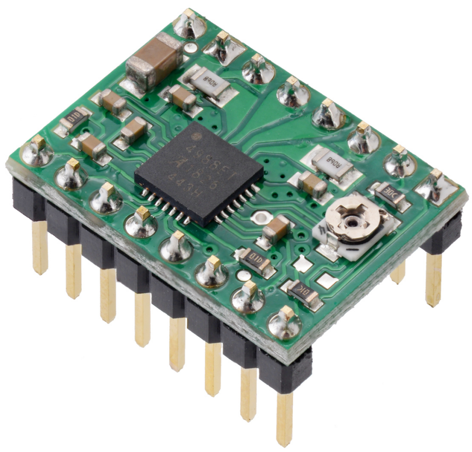

Figure 7: A4988 Stepper Motor Driver [10]

Spec.	Value
Model No.	A4988
Dimension (inch)	0.6 * 0.8
Min. operating voltage (V)	8
Max. operating voltage (V)	35

Continuous current per phase (A)	1
Max. current per phase (A)	2
Min. logic voltage (V)	3
Max. logic voltage (V)	5.5
step resolutions	full, 1/2, 1/4, 1/8, 1/16
Weight (g)	1.3

Table 3.3.2 - Stepper Motor Drive specifications [11]

3.4 Relay

Design ID	**Design Specification Requirements**
Des 3.4.1 A	The input voltage of relay signal ranges from 0 to 5 V.
Des 3.4.2 A	The relay supports a maximum 30 V DC output.

Table 3.4.1 - Relay design requirements

Inside the relay, the primary circuit deals with the control signal, and the secondary circuit deals with the power-consuming device. After the primary circuit has been completed, the current will be transferred to the secondary circuit through the magnetic field produced from an electromagnetic coil to activate the secondary circuit [12].

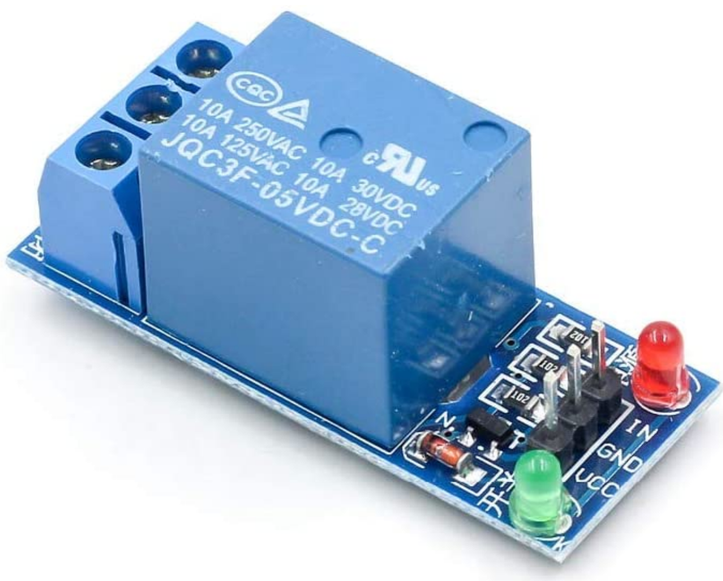

Figure 8: Relay [13]

Spec.	Value
Dimension (cm)	12.9 * 8.41 * 3.3
Rated voltage	DC 5V
Weight (g)	68.04

Table 3.4.2 - Relay specifications [13]

3.5 CNC Shield

Design ID	Design Specification Requirements
Des 3.5.1 A	The CNC shield must be compatible with Arduino UNO.
Des 3.5.2 A	The CNC shield must support 1 axis movement.
Des 3.5.3 B	The CNC shield must support 2 axis movement.

Table 3.5.1 - CNC Shield design requirements

The CNC shield gives the flexibility to build a CNC machine with Arduino. It provides an Arduino board with the power necessary to drive stepper motors and run all the other functions that contribute to a CNC machine operation. It is designed as a shield that can plug on top of a UNO board requiring no external wiring and supports up to 4 axis control (X, Y, Z, A - duplicate of X, Y, or Z), mapping to 4 stepper motor driver slots, one for each motor. 2 end stops for each axis. The pinout of the Arduino CNC shield is shown in Figure 9.

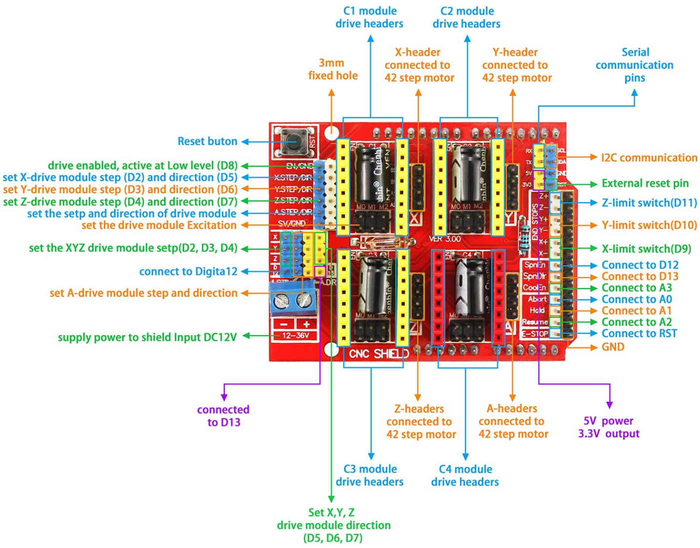

Figure 9: Pinout of CNC Shield [14]

Spec.	Value
Dimension (inch)	2.67 * 2.08 * 0.7
Voltage	DC 12 - 36 V

Table 3.5.2 - CNC Shield specifications [14]

3.6 Power Supply

Design ID	Design Specification Requirements
Des 3.6.1 A	Works at 12 V regularly within components of the circuit.
Des 3.6.2 A	The power supply shall be compatible with a relay.
Des 3.6.3 B	Fits in the *Doggolicious* enclosure easily.

Table 3.6.1 - Power Supply design requirements

Since the maximum operating voltage of components within the circuit is 12 V, the power supply is designed to be transferred from the household 110 V AC to the voltage 12 V DC used and work with a 5V relay.

Figure 10: Power Supply [15]

4 Software Design

In Doggolicious software systems, there are three composite parts: user operating system, condiments adding system and CNC (computer numerical control) machine system. the user shall be able to view and operate the graphical user interface to order the condiments by using a Numpad. The detailed graphical menu will be shown on the LCD interface and process order information to the condiments system and the CNC system.

After the user finishes an order, the order information will be generated by the UNO microcontroller, and be processed to UNO data processing modules. In the primary design, there will be a UNO board for condiments dispensers and CNC machine controlling and a MEGA board to control the LCD user interface and num pad. Therefore, the I2C communication method will be utilized between these two boards. The following figure displays the data flow process of the software systems (Fig 11).

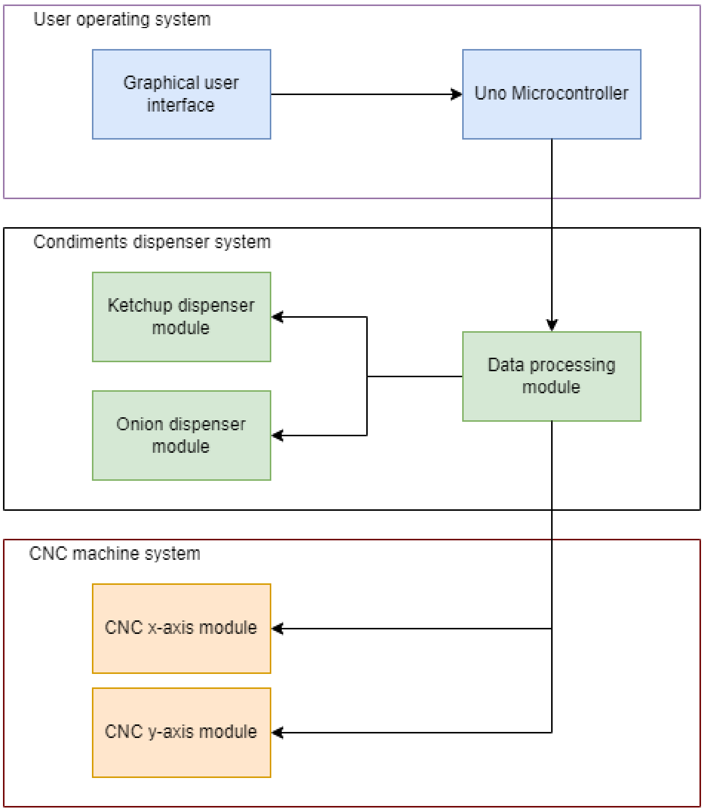

Figure 11: Data Flow Diagram of the Software Systems

4.1 User Operating System

The user operating system is the subsystem that is controlled by an Arduino MEGA board, which has the same functionality but includes more pins compared to the UNO board. Both the user interface and user operating system backend will be developed based on the ATmega328P [4]. Table 4.1.1 describes the requirement specification met by this system.

Design ID	**Design Specification Requirements**
Des 4.1.1 A	The user operating system shall be able to generate order information.
Des 4.1.2 A	The user operating system shall be able to provide the visible options of condiments types and quantity.

Des 4.1.3 B	The user interface shall display the graphical icons and apposite UI design.

Table 4.1.1 - User Operating System design requirements

The order information will be generated in the backend, the following figure 12 displays the brief backend pseudo code in this system and the detailed I2C communication method will be introduced in part 4.4.

```
void function loop()
{
    while User presses any key to start an order {
        if User selects Ketchup with no pattern {
            set Ketchup to 1; }
        else if User selects Ketchup with patter {
            set Ketchup to 2; }
        else if User does not select adding Ketchup {
            set Ketchup to 0; }

        if User selects Onion {
            set Onion to 1; }
        else if User does not select adding ketchup {
            set Onion to 0; }

        while User finishes an order {
            print "Please place your hot-dog";
            if function adding_condiment() {
                print "Thank you for your order, please enjoy your
hot-dog!";
                break; }
            else {
                print "Unkown mistake";
                break; } }
    }
}
```

Figure 12: Pseudocode for user Operating System

4.2 Condiments Adding System

After the UNO board receives the order information from MEGA board, the condiments adding system and CNC machine system will work separately. Where the condiments adding system will only control the liquid condiments pump and solid condiments pipe motor. The following table describes the requirement specification met by this system.

Design ID	Design Specification Requirements
Des 4.2.1 A	The condiments adding system shall control the liquid pump and pipe motor Open/Close.
Des 4.2.2 B	The condiments adding system shall be capable of controlling the pump and motor drivers to limit the condiment quantities.

Table 4.2.1 - Condiments Adding System design requirements

The following figure provides the brief pseudo code in this system, ketchup and onions will be the examples for liquid and solid condiments.

```
bool function adding_condiments()
{
    if User selects ketchup {
        if User selects pattern {
            Condiment dispenser pump (Ketchup port) open;
            function cnc_movement(with pattern); }
        else if User select no pattern {
            Condiment dispenser pump (Ketchup port) open;
            function cnc_movement(no pattern); } }

    if User selects onion {
        Condiment dispenser motor (Onion port) open;
        function cnc_movement(no pattern); }
    if All condiments orders finish
        return true;
    else
        return false;
}
```

Figure 13: Pseudocode for Adding Condiments System

4.3 CNC Machine System

The CNC machine system will be the carrier of the condiments. After the condiments pump and motors are opened, the CNC machine system will call the corresponding script (no pattern or with pattern), then move on the x and y rails to help the condiments dispenser add condiments to the hot dog. The following table illustrates the requirement specification in this system. The detailed information for the CNC machine will be described in the mechanical design section.

Design ID	Design Specification Requirements
Des 4.3.1 A	The CNC machine system shall be able to be well controlled by UNO ATmega328P and CNC shield.
Des 4.3.2 A	The CNC machine system shall be able to move the condiments exits on the x-axis and y-axis.
Des 4.3.3 B	The CNC machine system shall be able to move appropriately by calling scripts.
Des 4.3.4 B	The CNC machine system will be able to solve over two different pattern scripts.

Table 4.3.1 - CNC Machine System design requirements

The brief pseudo code of the CNC machine system is shown below.

```
void function cnc_movement(condition)
{
    if condition is 'pattern'{
        CNC machine follows script moving to draw pattern;  }
    else
        CNC machine follows script moving to draw straight line;
}
```

Figure 14: Pseudocode for CNC Machine System

4.4 I2C Communication

Communication between microcontrollers will be handled via I2C protocol. The basic setup is the controller sender/peripheral receiver with the MEGA board as the controller and the UNO as the peripheral. [16] After the user-selected order is processed by the MEGA board, it will send the encoded order details over the I2C bus. The UNO will then handle the calculations for CNC routing based on the received data. After all of the data is sent, the MEGA will then swap to controller reader mode and request data for when the CNC operation is complete.

An alternative for inter-microcontroller communication was considered in the form of interrupts, but given the fact we need to transmit a string of bits of data for the order details and CNC status, I2C was a more rational choice.

Design ID	Design Specification Requirements
Des 4.4.1 A	The microcontroller of the MEGA board is able to relay order details to the UNO microcontroller board via I2C.

Des 4.4.2 A	The microcontroller of the MEGA board is able to request the result of CNC operation via I2C.

Table 4.4.1 - I2C Communication design requirements

5 Mechanical Design

This section will include the details of mechanical design. *Doggolicious* has 2 main mechanical parts, a condiment dispenser system and a CNC machine system.

The condiment dispenser system is primarily responsible for delivering the various condiments from the storage to the hotdogs. It can also be subdivided into a sauce dispenser and a dry food dispenser. The sauce dispenser will use peristaltic pumps to pump sauce, such as ketchup or mustard, from sauce bottles. The dry food dispenser is based on gravity feeding (Figure 15). Pre-chopped onion dice will be put in the hopper, and a servo motor will be used to control the position of the actuator. To avoid jamming at the bottom of the hopper, a vibrator may be applied.

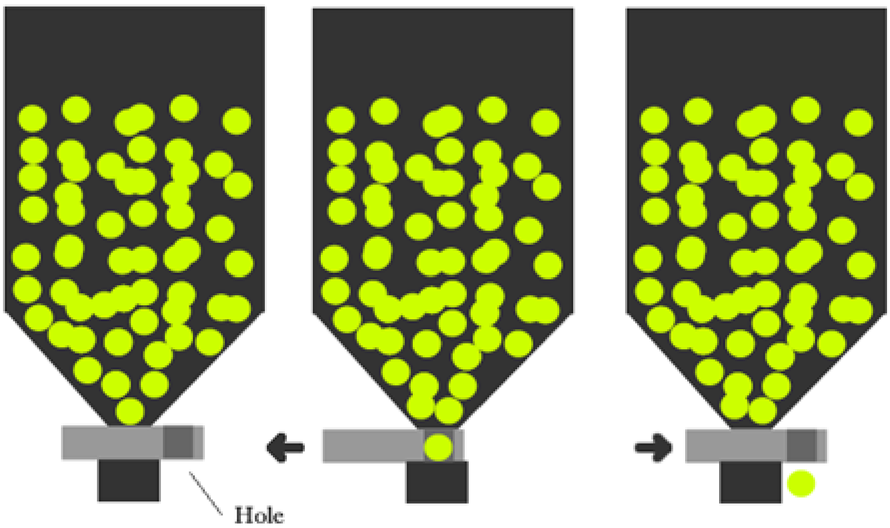

Figure 15: Onion dispenser overview [17]

The CNC machine is used to position the condiment nozzle over the hotdog, and spread the sauce evenly on the hotdog in different styles, wavy or linear stripes. This machine, refer to Figure 16, is basically composed of 2 stepper motors for moving along the x, y-axis, 2 limit switches for homing the CNC machine (one for the x-axis, one for the y-axis). 2 stepper motor drivers and 1 CNC shield for controlling the stepper motor and the whole CNC machine, which are being discussed in Electrical Design part (Section 3).

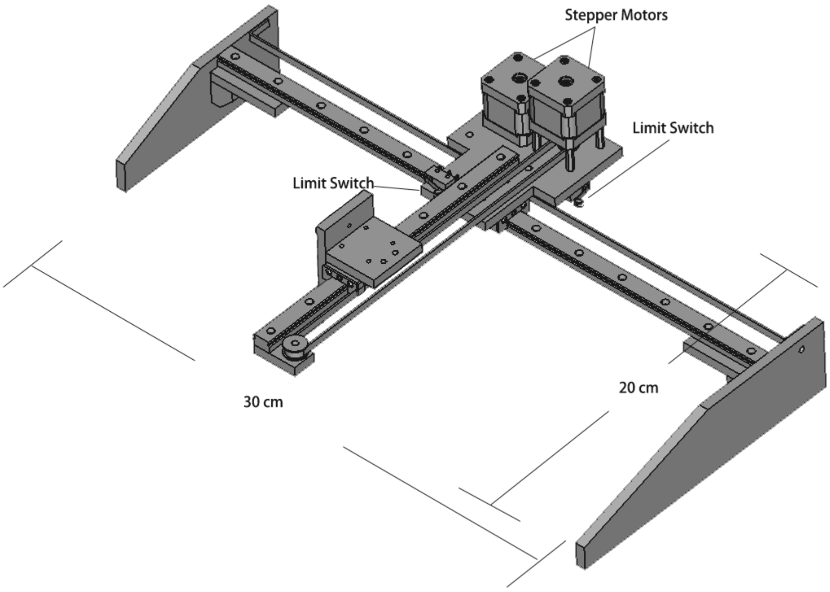

Figure 16: CNC machine [18]

5.1 Peristaltic Pump

Design ID	Design Specification Requirements
Des 5.1.1 A	Peristaltic pumps are ideal for pumping viscous fluids such as ketchup and mustard.
Des 5.1.1 A	Peristaltic pumps can offer constant and accurate flow rates.
Des 5.1.1 A	The pumping process is sanitary since the fluid only contacts pipes.

Table 5.1.1 - Peristaltic Pump design requirements

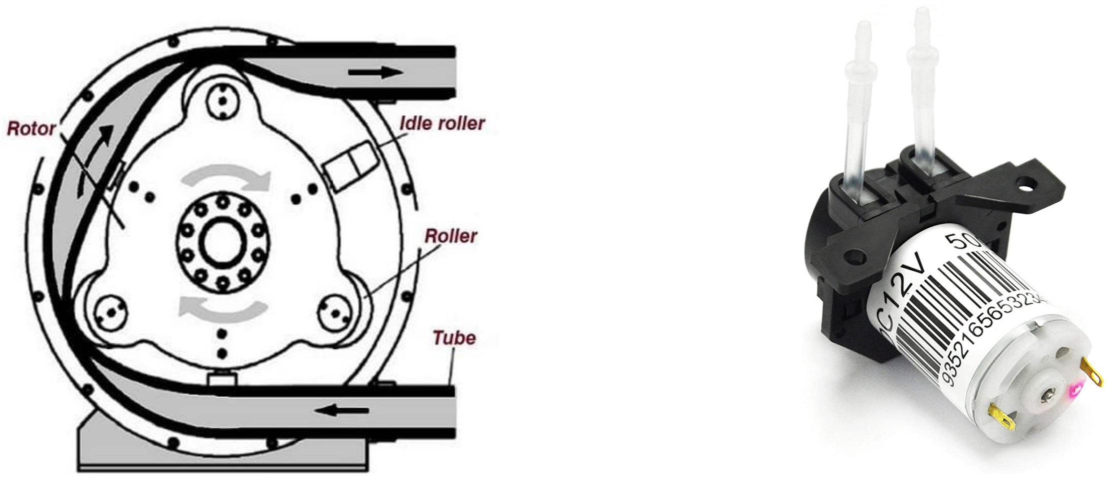

Figure 17: Peristaltic Pump [19]

In the peristaltic pump dispenser, the ketchup is being stored in a tube, which is associated with the circular pump. When the tube is closed, the ketchup will start flowing due to the rotor of the pump. While the pump is working, the tube will receive the ketchup, and then the rollers will operate to prevent the pump parts from being contaminated by the ketchup. When the tube is opened, the amount of rotation can be controlled, then a certain amount of ketchup can be squeezed out [20]. Apart from the working principles of the peristaltic pump dispenser, its basic functions are listed as the requirements in Table 5.1.1. Some advantages can be found for using this peristaltic pump dispenser. First, no contamination will be made with the pump parts in the pumping progress. Second, at least one roller acts as the switch inside the tube, meaning no extra valves are needed [20].

Spec.	Value
Motor speed (rpm)	5000
Rotate speed (rpm)	0.1-100
Rated voltage (V)	12
Rated current (mA)	80
Flow rate (ml/min)	0-100
Pump head (m)	25

Table 5.1.2 - Peristaltic Pump specifications [20]

5.2 Servo Motor

Design ID	Design Specification Requirements
Des 5.2.1 A	The servo motor can run on 5V.
Des 5.2.2 A	The servo motor can move for 0 to 180°.

Table 5.2.1 - Servo Motor design requirements

For the dry food dispenser, a big container will be used, then the separating boards will be inserted inside the container to separate the dry foods and other ingredients. The drawer will be controlled by a servo motor [21].

Figure 18: Servo Motor [21]

Spec.	Value
Voltage (V)	5
Torque (kg*cm)	1.8
Weight (g)	9
Angle (°)	180
PWM period (ms)	20

Table 5.2.2 - Servo Motor specifications [21]

5.3 Stepper Motor

Design ID	Design Specification Requirements
Des 5.3.1 A	The stepper motor is capable of delivering required torque while also being fast enough.
Des 5.3.2 A	The stepper motor is bipolar.

Table 5.3.1 - Stepper Motor design requirements

NEMA 17 stepper motor follows National Electrical Manufacturers Association (NEMA) defined standard with 1.7 by 1.7 inches faceplate. They typically have more torque than smaller variants, and they are most commonly used in robotics, CNC machines, and 3D printers.

Figure 19: NEMA 17 Stepper Motor [22]

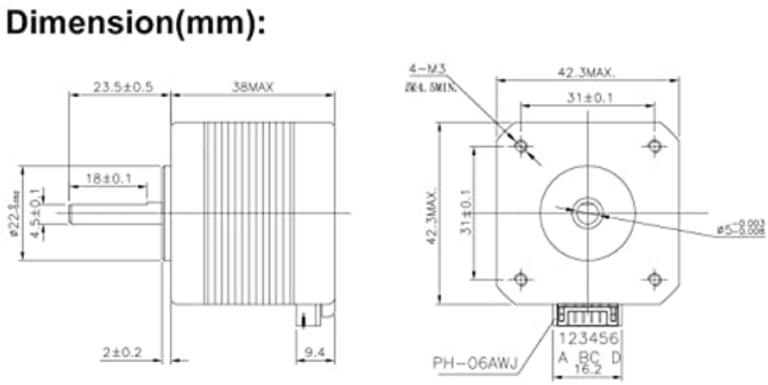

Figure 20: Dimension view of Stepper Motor [22]

However, NEMA 17 tells you nothing about the performance of the motor, but usually a larger motor means it is more powerful. Usually, stepper motors with around 50 N*cm can drive a desktop CNC router with a work area under 45 by 45 cm [23]. Since our CNC machine has a smaller dimension (around 30 by 20 cm), and there are only some light pipes for sauce dispensing on the gantry, The motor with torque around 40 N*cm should be good enough for our project, and the further calculation will be shown below.

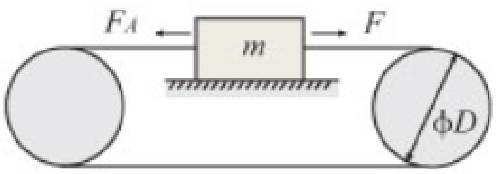

Figure 21: Load torque model [24]

A model in Figure 21 is used to calculate the required torque of the stepper motor, where

Parameters	Definition	Value
F_A	**External force**	0N
F_f	**Friction force**	0.49N (calculated)
F	**Force produced by motor**	50.49N (calculated)
D	**Pully diameter**	12mm
m	**Total mass of the bearing carriage and load**	5kg
µ	**Friction coefficient of sliding surface**	0.01
a	**Max acceleration of the load**	10 m/s^2

Table 5.3.2 - Parameters of the load torque model

$$\tau = F \times D/2 \qquad \text{Equation 5.3.1}$$

$$F - F_A - F_f = ma \qquad \text{Equation 5.3.2}$$

$$F_f = \mu N = \mu mg \qquad \text{Equation 5.3.3}$$

Substituting equation 5.3.3 and equation 5.3.2 into equation 5.3.1 gives

$$\tau = (F_A + F_f + ma) \times D/2 = (F_A + \mu mg + ma) \times D/2 \qquad \text{Equation 5.3.4}$$

Since there is no external force, $F_A = 0N$. The friction coefficient between the bearing carriage and linear rail is around 0.01. The expected acceleration is around 10 m/s^2. The diameter of the pulley is 12mm. The total loaded mass will be within 5kg.

Plugging the numbers into equation 5.3.4 gives

$$\tau = (0 + 0.01 \times 5kg \times 9.81m/s^2 + 5kg \times 10m/s^2) \times 12mm/2$$

$$\tau = 302.9Nmm = 30.29Ncm$$

The calculation shows that the stepper motor with torque around 40 N*cm should be fairly enough for this project.

In addition, stepper motors can be categorized as unipolar or bipolar based on its wiring configuration (Figure 22). Bipolar motors will be selected for this project since they have higher torque than unipolar motors at the same speed (Figure 23). As a trade-off, bipolar motors require more complex circuitry to reverse the polarity of the voltage applied to the coils. However, this issue can be easily solved by using appropriate stepper motor drivers.

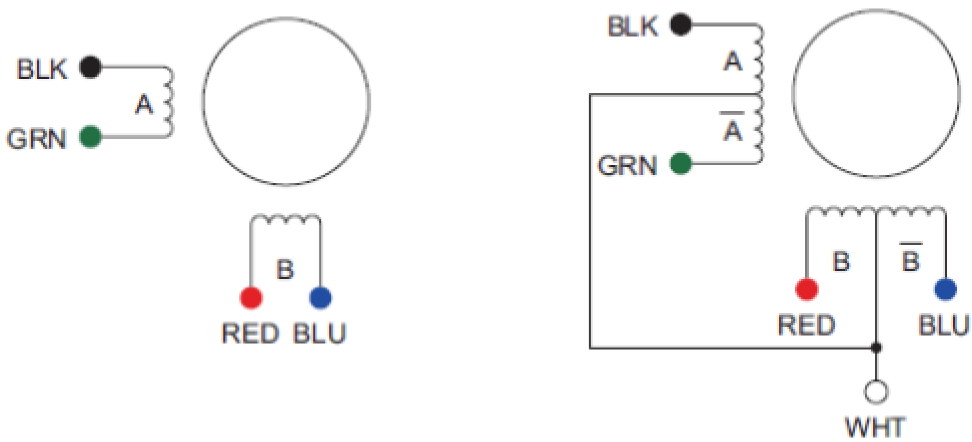

Figure 22: Bipolar Stepper Motor(left) and Unipolar Stepper Motor (right) [25]

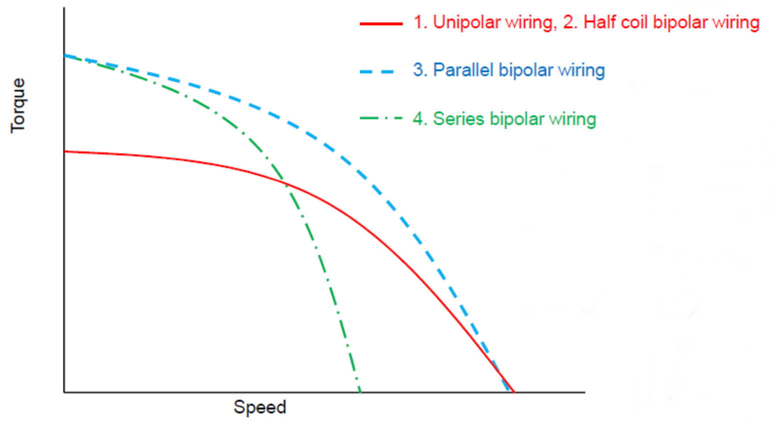

Figure 23: Speed-torque curve for Unipolar & Bipolar Stepper Motors [25]

Spec.	**Value**
Dimension (mm)	42*42*38
Bipolar/Unipolar	Bipolar
Rated Current (A)	1.5
Step angle (°)	1.8
Steps/rev	200
Holding torque (N*cm)	42
No. of lead	4
Weight (g)	290

Table 5.3.3 - Stepper Motor specifications

5.4 Micro Limit Switch

Design ID	**Design Specification Requirements**
Des 5.4.1 A	The limit switch has three terminals NO, NC, C.
Des5.4.2 A	The limit switch has a hinge roller.

Table 5.4.1 - Limit Switch design requirements

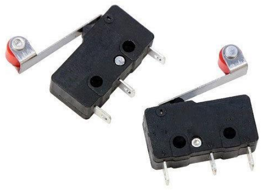

Figure 24: Limit Switch [26]

The purpose of the limit switch is to send a signal that will prevent the axis from moving past the end of the travel range and also to home the CNC machine.

The limit switches are usually wired either normally open (NO) or normally closed (NC). For safety reasons, normally open wiring will be applied to this project. The circuit should be closed when the switch is actuated, but the controller will not function as it is expecting the switch actuated if there are any broken wires or defective switches. This will be good for debugging the system.

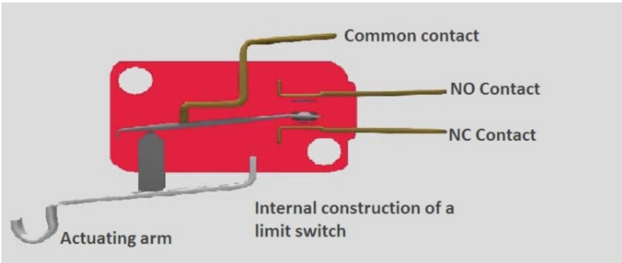

Figure 25: Dimension view of Limit Switch [27]

5.5 Mandatory Safety design

In the part of risk analysis and corresponding safety requirements, there are two sections that can be considered: mechanical safety and food safety.

5.5.1 Mechanical Safety

The mechanical safety focuses more on the user experience. When the user is operating *Doggolicious*, different types of potential physical risks should be considered as the following requirements table shows.

Design ID	**Design Specification Requirements**
Des 5.5.1.1 A	All the selected components must be engineered for safety and follow engineering standards.
Des 5.5.1.2 B	The shell of *Doggolicious* must not have sharp edges.

Table 5.5.1 - Mechanical Safety design requirements

5.5.2 Food Safety

The food safety section is the most significant part of risk analysis. UpDawg's members must ensure the product is food-grade and avoid any factors that may cause food contamination.

Design ID	Design Specification Requirements
Des 5.5.2.1 A	The hot dog plate must be made of food-grade metals (stainless steel and aluminum) [28].
Des 5.5.2.2 A	The condiments containers must be made of FDA(Food and Drug Administration) Edible Plastic [29].
Des 5.5.2.3 B	All the condiments must pass the FSA (Food Safety Act) [30].

Table 5.5.2 - Food Safety design requirements

6 Conclusion

This document specifies the necessary design specifications that need to be met in order to implement and build UpDawg's *Doggolicious* PoC prototype. As the project idea is re-designed, the design specification requirements will be largely different from the requirement specification. The separate subsystems include UNO and MEGA board development, LCD and Numpad user interface, liquid and solid condiments dispenser design, the implementation and selections of motors and the CNC machine system. The summary of design is shown below:

User Operating System Design Specification

- The user interface shall provide easy-to-understand condiment selection prompts.
- All the possible options shall be selectable with num pad mappings.
- The data of order information shall be able to be processed and transferred between microcontrollers.

Condiments Dispenser System

- The liquid and solid condiments shall be added to the hot dog with selected quantities.
- The condiments dispenser shall supply over two different types of condiments dispenser methods (liquid, solid, powdered, etc.).

CNC Machine System

- The CNC machine shall be able to move the condiments nozzles on the x-axis and y-axis.
- The CNC machine shall accurately move by calling pre-designed pattern scripts.

At the proof-of-concept stage, UpDawg's members shall let customers interact with the designed UI through the keypad and LCD to demonstrate the service of adding sauce, which includes one solid (Onion dice) sauce through a dry food dispenser and one fluid (ketchup) sauce through a peristaltic pump. UpDawg's members plan to achieve all of the key features that include a CNC machine and better performance, such as: improving the resolution of the UI screen by using OLED at the stage of the final prototype so that customers can enjoy all kinds of sauce adding service of *Doggolicious*. For the appearance of the prototype at the proof-of-concept stage, UpDawg's members do not plan to build the enclosure for the machine until the final prototype stage.

Some uncertainties could be resolved in later stage:

- Building an enclosure for the machine
    - Since it is usually necessary to check the test results, such as compatibility with other components inside the machine of key features applied and consider the effect of using improper material to build the enclosure, UpDawg's members will build the enclosure at the later stage to decrease the uncertainty of designing the CAD size of the enclosure and related issues.
- Using a CNC machine with an x-axis and y-axis to draw some patterns on the foods provided by customers
    - Until the end of the proof-of-concept stage, a CNC machine with one dimension (either x or y) movement will be achieved for dispensing condiments along with a hot dog. Assuming UpDawg's members need to achieve the x-axis and y-axis of a CNC machine, the progress of making the machine will be delayed. However, it is necessary to finish all designs of the CNC machine to enhance user experience, thus UpDawg's members will complete the design of the CNC machine.
- Adopting a better screen as the user interface
    - Since the current status is to make all specified and key features work, an LCD 1602 can be used for those tests within the early stage. However, a better screen needs to be used at the later stage to represent some pictures so that it can improve the user experience because of a better resolution. Besides, the screen with some pictures can get more attention from users.
- Adding algorithm to control the quantity of sauce dispensing
    - Because designing a more complete system to control the quantity of sauce for users needs more time and tests, thus UpDawg's members put this task at a later stage and wish to design this system to provide different quantity sauce for various needs from users.
- More condiments combination
    - At the PoC stage, UpDawg's members will only focus on dispensing ketchup and onions. More condiments will be considered in the later stage.
- Internal lock
    - An internal lock will be introduced in the later stage, so that the users cannot interact with the machine until a hot dog is placed in the designed position.

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Appendix A: Design Alternatives

Each part in this project has different choices which we have considered before, and this project is combined by different parts, namely the software performance, materials used, shape and trigger of sauce dispenser, food production steps and data collection.

A.1 Display screen

For the display components, LCD and OLED were considered before, LCD was chosen since the color decay is not affected by the current, lower cost, and longer lifespan [31][32].

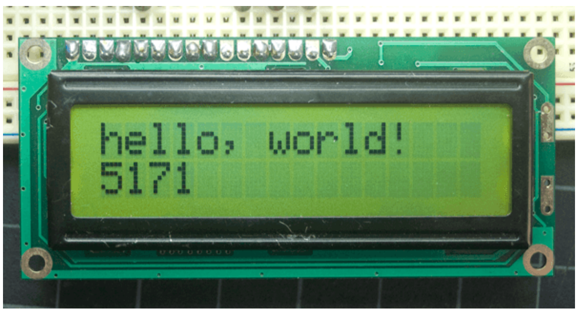
Options	**Specification**
LCD [33] 	To combine with Arduino, different pins of LCD have different functions, such as power supply, read/write, etc [33]. A 10 kΩ potentiometer is connected with a +5V signal and ground (GND) for current limit. [33] Current = $5V/10k\Omega$ = 0.5 mA
OLED [34] 	OLED can have higher contrast and operate well without backlight in dark places, but the brightness depends on the current [34]. Size: 1.3 inches Resolution: 128 * 64 pixels Weight: 10 g

Table A.1 - Display Screen options

A.2 Materials

Safety for users is an important issue, hence the materials of the machine need to be chosen carefully. We have considered using cast iron, aluminum, copper, or stainless steel as the machine material. The selected materials are aluminum and stainless steel because they are safe to use, environmentally-friendly, high-temperature-resistant, and corrosion-resistant [35].

A.3 Shape of sauce dispenser

Two types of the shape of sauce dispenser are being considered, funnel and cylindrical. While the cylindrical shape of the sauce dispenser has a larger volume and can save more sauces, the funnel shape is selected because it is easier to squeeze the sauces out on the sausages and buns.

A.4 Ketchup Dispenser Pump

This pump is used for dispensing sauce, so the food safety requirement must be met. We chose a peristaltic pump since the fluid only contacts pipes and it is easy to control by an electric circuit.

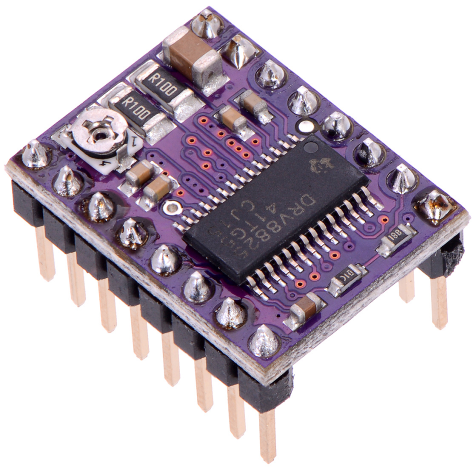
Options	**Specification**
Peristaltic Pump [36] 	Easy for changing and cleaning, the position of the tubes are fixed well during operation, and suitable for most types of liquids [36]. Motor speed: 5000 rpm Rotate speed: 0.1-100 rpm Rated voltage: DC 12V Rated current: 80 mA Flow rate: 0-100 ml/min Pump head: 25 m
Pail Pump [37] 	Convenient to refill the sauces, and stores the sauces effectively [37], but needs to operate manually.
Water Pump [38]	Pump the sauces using water for the operation principle, but can only be operated for a short period of time [38]. Rated voltage: DC 2.5 - 6 V Rated current: 180 mA Flow rate: 100 L/h

	Pump head: 0.55 m

Table A.2 - Ketchup Dispenser Pump options

A.5 Stepper Motor Drivers

DRV8825 is an upgraded version of A4988. It can handle higher voltage and current than A4988, and it also has a higher step resolution. Otherwise, they are very similar. To meet our target budget, we chose A4988 because we don't need that precise control and we can get similar performance at a much lower price.

Options	**Specification**
DRV8825 [39] 	Dimension: 0.6 * 0.8 inches Min. operating voltage: 8.2 V Max. operating voltage: 45 V Continuous current per phase: 1.5 A Max. current per phase: 2.2 A Min. logic voltage: 2.5 V Max. logic voltage: 5.25 V Step resolutions: full, 1/2, 1/4, 1/8, 1/16, 1/32 Weight: 1.6 g Price: $7.20/item
A4988 [40]	Dimension: 0.6 * 0.8 inches Min. operating voltage: 8 V Max. operating voltage: 35 V Continuous current per phase: 1 A Max. current per phase: 2 A

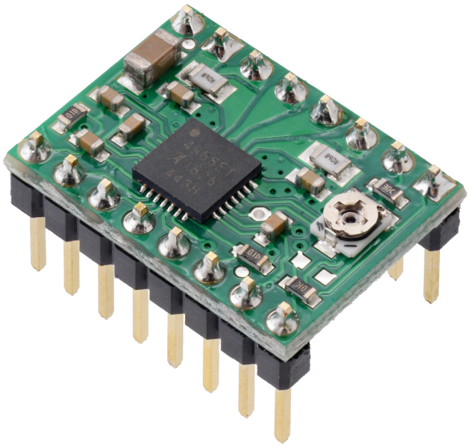
	Min. logic voltage: 3 V Max. logic voltage: 5.5 V Step resolutions: full, 1/2, 1/4, 1/8, 1/16 Weight: 1.3 g Price: $2.94/item

Table A.3 - Stepper Motor Drivers options

Appendix B: Test Plan

B.1 Introduction

This appendix contains the test plans for verifying the Proof-of-Concept prototype of *Doggolicious*, all the test plans shall meet the design specification requirements.

B.2 System Testing

This section will outline the test plans for the whole *Doggolicious* product in PoC phase.

Date:	
Test Description: Press any key on the num pad.	
Expected Outcome: The user should be able to start an order and the LCD should display the condiment selection page.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Use num pad to select the wanted condiments (ketchup and onions).	
Expected Outcome: The order information of the corresponding shall be updated.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Press the pre-designed order finishing key on num pad (might be ‘*’).	
Expected Outcome: The order process will be ended and order information will be sent to the peripheral board for CNC processing.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Place the prepared hot dog on the plate.	
Expected Outcome: There shall be a food-grade metal plate for the user to place a hot dog. The hot dog will not move while the machine is dispensing condiments.	
Actual Outcome:	
Tester:	Score: Pass/Fail

B.3 User Operating System Testing

Date:	
Test Description: Look at the LCD screen and recognize the menu.	
Expected Outcome: The text on LCD should be easy-understanding and clear.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Press the pre-designed order cancelling key on num pad (might be ‘#’).	
Expected Outcome: The order information will be cleared and the LCD displays the primary condiments selection page.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Press any key on the num pad as the tester wants.	
Expected Outcome: All the operable keys should have the corresponding responses (Confirmation/Error operation and numbers in Numpad).	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Finish an order and wait for the response of the device.	
Expected Outcome: The CNC machine system and condiments dispenser system shall work automatedly based on the order information.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: Wait to finish adding condiments and look at the LCD screen.	
Expected Outcome: LCD screen shall display the reminder to the tester ("Your order is processed, please take the hot dog!").	
Actual Outcome:	
Tester:	Score: Pass/Fail

B.4 Condiments Dispenser System Testing

Date:	
Test Description: Select the ketchup in an order.	
Expected Outcome: After confirming the order, the ketchup pump should be opened, then ketchup should be added to the hot dog.	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:
Test Description: Select the onions in an order.
Expected Outcome: After confirming the order, the motor for the onion dispenser should be opened, then the onion dice should be added to the hot dog.

Actual Outcome:	
Tester:	Score: Pass/Fail

B.5 CNC Machine System Testing

Date:	
Test Description: Finish an order and order at least one condiment.	
Expected Outcome: CNC machine shall be able to move across the x-axis.	
Actual Outcome:	
Tester:	Score: Pass/Fail

B.6 User Experiences Testing

Date:	
Test Description: Touch the edge of the machine shell.	
Expected Outcome: Tester shall not feel the edge is sharp	
Actual Outcome:	
Tester:	Score: Pass/Fail

Date:	
Test Description: View the external information of the machine.	
Expected Outcome: Tester shall be able to know the rough function of each component from text reminder (“Please place your hot dog here”, “Press any key to start an order”, “Please don’t put hands into food port”, etc.).	
Actual Outcome:	
Tester:	Score: Pass/Fail