

**THE UNIVERSITY OF DANANG
UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING**



CAPSTONE PROJECT
Major: Mechatronics Engineering

**DESIGNING AND FABRICATING
A SODA AND COCA-COLA STREAM**

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Da Nang, June, 2025

ABSTRACT

Topic: Design and manufacture of a fresh Coca-Cola dispensing machine

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Class: 20CDTCLC2

Abstracts: This project focuses on the design and manufacture of a medium- to small-sized COCA-COLA dispensing machine. The study includes both theoretical analysis and experimental investigation of the soda water making process and the mixing process between soda water and syrup. Key components such as actuators are selected and designed to meet the operational requirements and functional demands of the system. In addition, the project incorporates the design of the power and control systems, with the control system implemented using an Arduino-based platform to ensure efficient and reliable operation.

CAPSTONE PROJECT

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1. *Topic: Designing and manufacturing a soda and Coca-Cola stream*
2. *The project is classified as: Subject to an IP agreement on project outcomes*
3. *Contents of explanations and calculations:*
 - a. *General task:*

TT	Student's name	Contents
1	Le Dac Trung	<ul style="list-style-type: none"> - Analysis and selection of design options. - Research. - System design. - Install the system. - Circuit system design. - Programming and interface design.
2	Le Tu Duy	
3	Nguyen Duc Thanh	

- a. *Specific task:*

TT	Student's name	Contents
1	Le Dac Trung	<ul style="list-style-type: none"> - Researching the working principle - Calculating and selecting electronic components for the machine. - Circuit design and PCB fabricate. - Assembly the machine - Flowcharting algorithms and programming for Arduino.
2	Le Tu Duy	<ul style="list-style-type: none"> - Designing and calculating the 3D model from SolidWorks - Circuit design and PCB fabricate. - Assembly the machine

3	Nguyen Duc Thanh	<ul style="list-style-type: none"> - Researching the working principle and selecting the option - Calculating and selecting electronic components for the machine. - Circuit design. - Flowcharting algorithms for Arduino.
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4. *Drawings and graphs:*

a. *General task:*

TT	Student's name	Contents
1	Le Dac Trung	Drawing 3D on SolidWorks 360 and 2D AutoCAD, Draw.io
2	Le Tu Duy	
3	Nguyen Duc Thanh	

b. *Specific task:*

TT	Student's name	Contents
1	Le Dac Trung	<ul style="list-style-type: none"> - 1 Electronic diagram drawing A0. - 1 Wiring diagram drawing A0 - 1 Flowchart diagram A0.
2	Le Tu Duy	<ul style="list-style-type: none"> - 1 Overall layout drawing A0. - 1 Detailed drawing A0. - 1 Disassembly drawing A0.
3	Nguyen Duc Thanh	<ul style="list-style-type: none"> - 1 Kinematic diagram drawing A0. - 1 Flowchart diagram A0.

5. *Supervisor's name: Assoc. Prof. Dr. Dang Phuoc Vinh*

Mr. Nguyen Tan Uy

6. *Project assignment date: February 1th, 2025*

7. *Project completion date: June 2th, 2025*

DaNang, June..... 2025

**Head of Department
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Assoc. Prof. Dang Phuoc Vinh, PhD

PREFACE

Carbonated beverages, commonly known as soda and soft drinks, are widely consumed around the world due to their refreshing taste and variety of flavors. Among them, soda has become especially popular for both commercial and home use. Over the years, technologies such as soda fountains and SodaStream machines have been developed to provide convenient and customizable options for preparing soda beverages.

This report presents our research and development process for designing and constructing a home-based soda machine system. The goal of the project is to create a functional, cost-effective, and easy-to-use soda-making device that meets the daily needs of individuals and households. The project is based on various studies and practical experiments related to carbonation, flavoring, and beverage dispensing systems.

We would like to express our sincere gratitude to Assoc. Prof. Dr. Phuoc Vinh Dang, PhD, who has provided us with continuous support, guidance, and valuable expertise throughout the course of the project. We are also grateful to Mr Nguyen Tan Uy, whose encouragement and resources have been instrumental in the successful completion of this study.

While we have made every effort to ensure the quality and accuracy of our work, we acknowledge that, due to our limited experience, some aspects may still require improvement. We welcome constructive feedback and suggestions from instructors, professionals, and readers to help us enhance the quality of this report and future work.

Once again, we extend our heartfelt thanks to everyone who has supported us during this project.

DaNang, June 2025

Students perform:

Le Dac Trung – Le Tu Duy – Nguyen Duc Thanh

DECLARATION

We hereby declare that this graduation project, is the result of our group's own research, design, and implementation efforts. Throughout the process of developing, assembling, and testing the mechatronic product, we have complied with the standards of academic integrity. All external sources of data, references, and ideas have been properly cited and acknowledged in accordance with academic guidelines.

All calculations and decisions made during the project were based on theoretical knowledge learned throughout our studies, as well as on practical experiments and testing. We understand that real-world conditions may involve inaccuracies or deviations, and we have made every effort to reflect those realistically in the report.

We take full responsibility for the content of this project and affirm our commitment to academic honesty and ethical engineering practices.

Students perform:

Le Dac Trung – Le Tu Duy – Nguyen Duc Than

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CHAPTER 1: INTRODUCTION

1.1. Overview of the company

CHARLES WEMBLEY (S.E.A) CO. PTE LTD and TAN LONG Technical Trading and Services Co., Ltd. were established in 1980 in Singapore and opened their first office in Ho Chi Minh City in 1989. Initially, Charles Wembley and Tân Long were among the pioneering companies in providing high-tech medical equipment and services to Vietnam.



Figure 1.1 HARLES WEMBLEY (S.E.A) CO. PTE LTD and TAN LONG Trading and Technical Services Co., Ltd (Source: Internet).

By 2006, Charles Wembley and Tân Long expanded their business into the fields of kitchen equipment, food, and beverages to meet the growing market demand following Vietnam's accession to the World Trade Organization. This marked the beginning of rapid growth in the hotel market and the fast food chain sector, creating a significant demand for specialized industrial kitchen equipment.



Figure 1.2 Equipment distributed by Charles Wembley and Tan Long (Source: Internet)

Design and manufacture of a fresh Coca-Cola dispensing machine

Over 28 years of development and expansion, with a strong commitment to providing the best quality products and technical services to customers, Charles Wembley and Tân Long have established three offices and showrooms throughout Vietnam, with the headquarters located in Ho Chi Minh City and branches in Hanoi and Da Nang.



Figure 1.3 Staff at Charles Wembley and Tan Long (Source: Internet).

1.2. Overview of topic

The soft drink industry is a large and competitive global market characterized both in Vietnam and around the world, by strong consumer demand, significant technological advancements, and increasing health consciousness. The products are ubiquitous, found in everything from small grocery stores to large supermarkets, restaurants, and cafés. The demand for soft drinks and carbonated beverages remains high, particularly among young people. “Geographically, the Middle East, Africa, and Asia Pacific are projected to contribute a staggering 80% of absolute litre volume growth from 2024 to 2029, highlighting their pivotal role in shaping the industry's future” [5]



Figure 1.4 Soft drinks market share (Source:

<https://www.euromonitor.com/article/soft-drinks-industry-overview>)

Design and manufacture of a fresh Coca-Cola dispensing machine

Industrial soft drinks pose significant health risks to the consumer. The high sugar content is a primary contributor to issues such as obesity, type 2 diabetes, and cardiovascular diseases. Additionally, additives, artificial colors, preservatives, and synthetic flavorings can trigger allergic reactions, affect the digestive system, and are even linked to certain chronic diseases. Even though manufacturers have created many "healthier" versions of soft drinks, they remain fundamentally harmful to the human body.



Figure 1.5 Harmful effects of soft drink [Source: VTV24]

Despite the growing awareness of the harms associated with excessive sugar and additives in soft drinks, many people still find it hard to resist these beverages. This is due to various factors, including habits, appealing flavors, and advertising influences. However, the concerns about health and food safety have formed an option: making soft drinks at home.

Making soft drinks at home, with the ability to control ingredients and choose natural components, is becoming an appealing option for those concerned about their health. This allows individuals to manage the quality of the beverages they consume. Creating delicious, refreshing soft drinks without using preservatives not only ensures peace of mind regarding the source of ingredients but also offers an enjoyable and creative experience.



Figure 1.6 Illustration of DIY Soda (Source: Internet)

1.3. Soda Science

Making soda at home is remarkably simple and accessible, cause it only requires two ingredients: water and carbon dioxide (CO₂), also flavor based on your taste. With the help of a home soda maker, you can easily infuse CO₂ into water to create fresh, fizzy drinks within minutes. The process doesn't involve complex chemistry, hard-to-find ingredients, or industrial equipment, just a bottle of water, a source of CO₂, and a few easy steps.



Figure 1.7 Illustration of how to make soda with water (left) and CO₂ tank (right)

From a scientific perspective, soda is the solution of water (solvent) and CO₂ gas (solute). The process of dissolving CO₂ into water is governed by Henry's Law. This law states that the amount of gas that dissolves in a liquid is directly proportional to the partial pressure of that gas above the liquid. In simpler terms: the higher the pressure of CO₂, the more gas will dissolve into the water, resulting in a stronger carbonation effect. Conversely, when the pressure is released—such as when you open a soda bottle—the CO₂ escapes, creating the characteristic fizzing sound and bubbles.

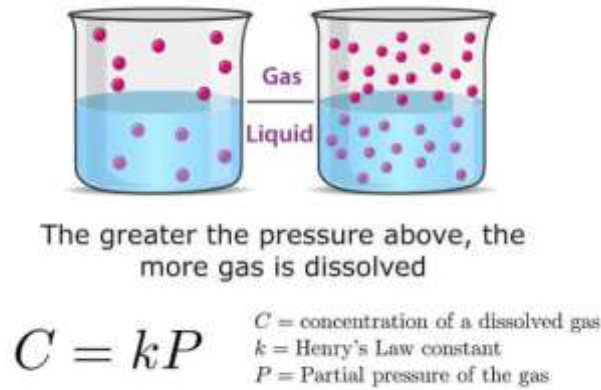


Figure 1.8 Henry's Law illustration (Source: Internet)

Temperature and pressure also affect this process. At lower temperatures, CO₂ molecules move more slowly, making them easier to trap in the water and increasing solubility (Figure 1.9). That's why water is usually chilled before carbonation—it helps retain more gas, resulting in longer-lasting fizziness. When the temperature is higher, the gas escapes more easily, and the soda tends to go flat quicker. For pressure needed for the reaction to create the type of carbonated soda, the higher the pressure, the faster the reaction, as shown in Figure 1.10.

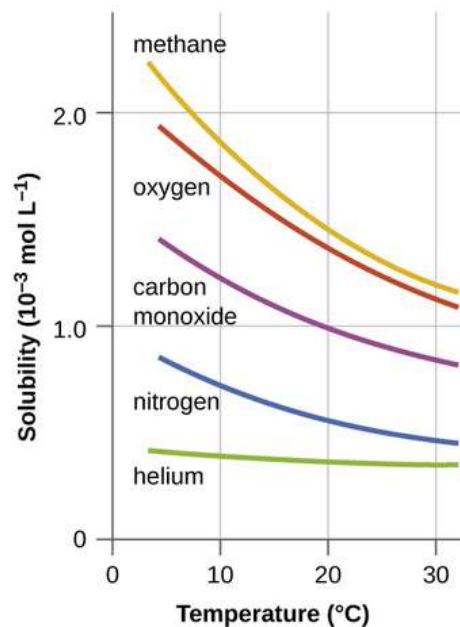


Figure 1.9 The solubility of gas affected by temperature (Source: Internet)

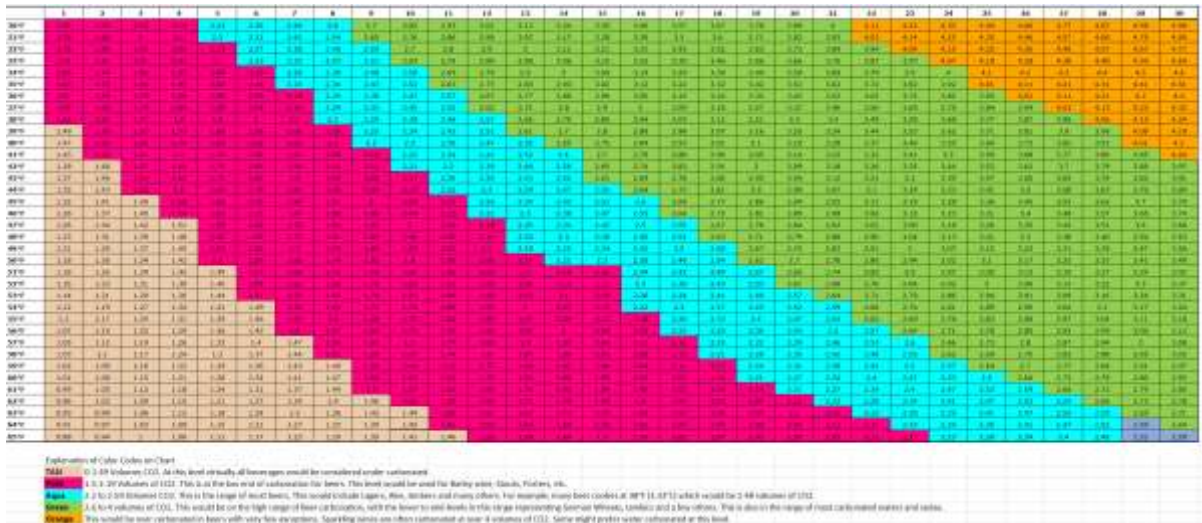


Figure 1.10 Beverage carbonation chart (Source:

<https://www.homebrewhappyhour.com/co2-carbonation-chart-for-beer-soda-water-or-any-beverage/>)

About flavor - which is syrup, each of them has different viscosity, which using differential pump or something similar is the challenge. Cause the ratio of syrup and soda is about 1:5 per volume when serving, so it kinda need the precision volume of syrup, like using peristaltic pump or CO₂-driven syrup pump. This selection will be mentioned in the following chapter.



Figure 1.11 Viscosity chart with values (Source: <https://sciencequery.com/high-viscosity-vs-low-viscosity/>)

1.4. Rationale for topic selection

In the past, Soda Fountain was a familiar sight in beverage shops, especially during the 1980s. It can be called “home-made soda” at that time. However, this option has several drawbacks like very bulky and space-consuming (including backend and panel), difficult to clean and maintain, limited flavor options. Also, the price is kinda high, even the cheapest option. All of the disadvantages and the rise of industrial soda replacing the Soda Fountain.



Figure 1.12 Image of Back-end of Soda Fountain (left) and price (right) of only carbonator (Source: <https://www.sodadisenserdepot.com/>)



Figure 1.13 Image of Panel of Soda Fountain (left) and price (right) (Source: <https://www.sodadisenserdepot.com/>)

Design and manufacture of a fresh Coca-Cola dispensing machine











Tower Soda Fountains				
 <p>REMANUFACTURED Seltzer-only Tower Soda Fountain System with Cold Plate</p> <p>Item #: 100118 \$995.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED Seltzer Tower Soda Fountain System with NEW Compact Remote Chiller</p> <p>Item #: 102090 \$3,300.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 1-Flavor Tower Soda Fountain System with Cold Plate</p> <p>Item #: 100122 \$1,075.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 1-Flavor Tower Soda Fountain System with NEW Remote Chiller</p> <p>Item #: 100201 \$2,535.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 1-Flavor Tower Soda Fountain System with NEW Compact Remote Chiller</p> <p>Item #: 102201 \$3,470.00</p> <p>More info Add to Cart</p>
 <p>REMANUFACTURED 2-Flavor Tower Soda Fountain System with Cold Plate</p> <p>Item #: 100119 \$1,295.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 2-Flavor Tower Soda Fountain System with NEW Under Counter Ice Maker</p> <p>Item #: 100113 \$3,200.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 2-Flavor Tower Soda Fountain System with NEW Remote Chiller</p> <p>Item #: 100202 \$2,660.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 2-Flavor Tower Soda Fountain System with NEW Compact Remote Chiller</p> <p>Item #: 100203 \$3,590.00</p> <p>More info Add to Cart</p>	 <p>REMANUFACTURED 3-Flavor Tower Soda Fountain System with Cold Plate</p> <p>Item #: 100105 \$1,430.00</p> <p>More info Add to Cart</p>

Figure 1.14 Price of cheapest Soda Fountain option (Source: <https://www.sodadispenrdepot.com/>)

With the disappearance of Soda Fountain, the expanded presence of industrial soda, and the core concern remains the health risks associated with drinking industrial soda, SodaStream come out as a perfect solution for those who want to. SodaStream appeared as an home-made soda machine, cause it's compact and elegant to use, as well as efforts to design home soda-making machines to replace soda fountains in eateries and restaurants.



Figure 1.15 Illustration of SodaStream with Coca diet syrup (Source: <https://sodastream.com/products/diet-cola>)

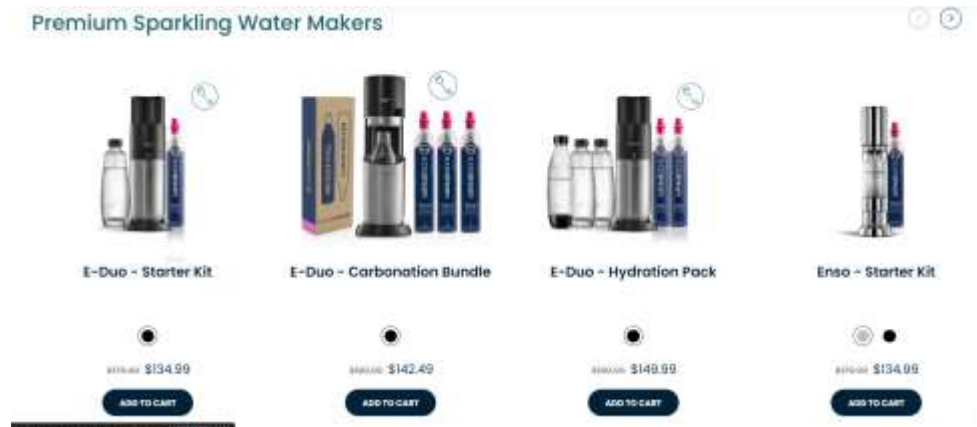


Figure 1.16 Price of SodaStream (Source: <https://sodastream.com/products/>)

Although SodaStream has advantages such as convenience, a variety of flavors, and the ability to customize carbonation levels, it still lacks a continuous water supply system for creating soda and mixing syrup separately. In contrast, Soda Fountain does not have this limitation.

Therefore, we aim to develop a machine that combines the excellent operational capabilities of Soda Fountain while applying modern technology and a compact design suitable for home use like SodaStream.

1.5. Objective and requirements for the topic

Based on the rationale for the topic selection, the main objective is to design and manufacture a small but convenient to make soda and Coca-Cola in auto, the machine size should be moderate and it needs to ensure safety during operation.

Additionally, with this design approach, the company has established operational requirements that are deemed necessary for improvements compared to other soda fountains, specifically:

- Maximum dimensions: 100 × 75 × 170 cm (L × W × H)
- Operating pressure: 2.5-4 bar at the dispensing nozzles.
- Output carbonated water temperature: 2°C – 7°C
- Carbonated water flow rate: 0.5 – 2 LPM
- Carbonated water volume tank: At least 3L
- CO2 Pressure: 30-80 Psi

CHAPTER 2: CALCULATION AND DESIGN OF MECHANICAL SYSTEM

In this chapter, we will discuss the mechanical design (including select option, calculation...), mechatronics system (sensor selection, power supply...) and control paragraph.

2.1. Working principle

The original Soda Fountain can be modeled into 2 blocks as shown in Figure 2.1. The big size of Soda Fountain is affected by the long pipeline and backup operating mechanism. To minimize the big size of Soda Fountain but trying to keep the full function of it, we shorten the displacement from the backroom to the panel and stack it on, as shown in Figure 2.2.



Figure 2.1 The standard layout of Soda Fountain

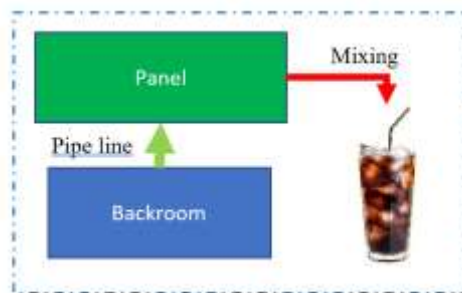


Figure 2.2 The stack-on layout of Soda Fountain

This stack on layout configuration allows for a more compact and efficient use of the overall workspace that we will use for our machine. To build the machine from scratch, Figure 2.3 show the detail functional component of the machine as block. The main components of the machine are: Water filter – Carbonator – Chiller – Dispenser. Detail selection, calculation will be mentioned in the following section.

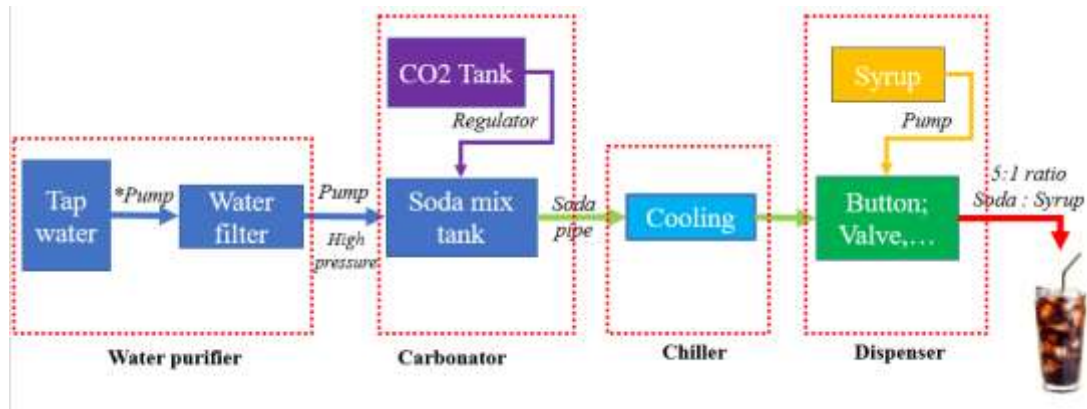


Figure 2.3 Detail layout block of the machine

2.2. Design option

As shown in Figure 2.3, in this section we will select the "optimize" option for our machine, which requires the following working specifications.

2.2.1. Inlet water filter

This part is used for filtering the inlet unfiltered water. For developed countries, tap water is already clean so there will be easier for the installation. But for developing countries, this part is necessary for the consumer. There are 2 options for the water filter.

+ Option 1: Using Reverse Osmosis (RO) filter system.



Figure 2.4 RO water filter system (Source: Internet)

RO water filter works on the principle of reverse osmosis. After being filtered, water is pumped through the RO membrane at high pressure (6-9 bar) so that impurities and

Design and manufacture of a fresh Coca-Cola dispensing machine

bacteria will be retained on the membrane and pure water will pass through the membrane and be collected in the tank. There are some advantages and disadvantages to it.

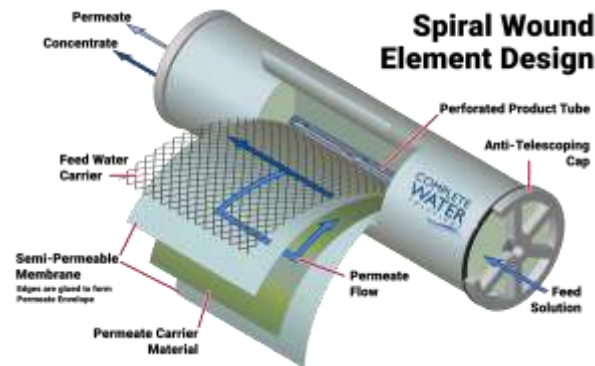


Figure 2.5 RO working principle (Source: Internet)

- Advantages:
 - Affordable price
 - Easy to maintain, replacement part with low cost
 - Simple to operate and control
- Disadvantages:
 - Low flow rate.
 - Still big size.
 - Efficiency is about 20% (4 to 1) between clean water and dirty water.

+ Option 2: Using UV (Ultraviolet light) water filter system.

An UV water filter effectively disinfects water using ultraviolet light without producing wastewater, unlike RO systems that waste 3–4 liters per liter of clean water. It maintains stable water pressure, making it efficient and ideal for daily use.



Figure 2.6 UV water filter system (Source: Internet)

Design and manufacture of a fresh Coca-Cola dispensing machine

- Advantages:
 - Higher efficiency than RO water filter. (about 80%)
 - High flow rate of waters
 - No moving part
- Disadvantages:
 - High cost
 - Not able to clean all the viruses or bacteria inside water

According to the advantages and disadvantages of each option, we choose option 1 to use for the machine because of low price and easy to find.

2.2.2. Carbonator

Sparkling water is the heart of the drink, that is why the carbonator is the heart of the machine. In this part, the key is to mix water with CO₂ in high pressure with the right amount of the water temperature, additional safety of working principle. There are two options for the working principle of carbonator.

+ Option 1: McCann's Carbonator method

This is the “old-school” option when making sparkling water in some restaurants, bar,... Based on *high pressure of water (150-230psi)* into the tank turn into atomizing and high pressure of CO₂ into each water molecule. With high pressure can create a mixing process that doesn't affect much by the temperature of water, which is a selling point.



Figure 2.7 Carbonator (left) and teardown (right) image (Source: Internet)

- Advantages:
 - High performance (water and CO₂ are high pressure)
 - High efficiency

Design and manufacture of a fresh Coca-Cola dispensing machine

- Check valve and safety valve are available
- Disadvantages:
 - High cost
 - Hard to maintain or replace part
 - Can't personalize based on the design because of its size
- + Option 2: SodaStream Carbonator method

SodaStream is a modern, home-friendly device that carbonates water by injecting CO₂ directly into the bottle as a fixed pressure (about 30 psi) that is based on the carbonation chart (Figure 1.7). Unlike traditional Soda Fountain rely on high-pressure water and CO₂ mixing in a tank, SodaStream's system allows users to control the level of carbonation easily without needing complex equipment. This simple and efficient option makes sparkling water more accessible and convenient for everyday use.



Figure 2.8 SodaStream (Source: <https://sodastream.com/>)

- Advantages:
 - Easy to operate for home users
 - Easy to operate
 - Safe to use
- Disadvantages:
 - Higher initial cost compared to some alternatives
 - Requires regular maintenance of CO₂ cylinders and part
 - Limited personalization options based on the fixed design and carbonation levels

According to the advantages and disadvantages of each option, we will combine the design of Option 1 with the simple operating mechanism of Option 2 to create the carbonator. Specifically, CO₂ gas will be finely bubbled, as in Option 2, using a regulator set to a pressure of 0.35 MPa (~51 psi). The inlet water pressure will exceed 51 psi, featuring a tank design as specified in Option 1. In short, we will use the tank to make soda with normal pressure water and diffusion CO₂ gas by ceramic head.

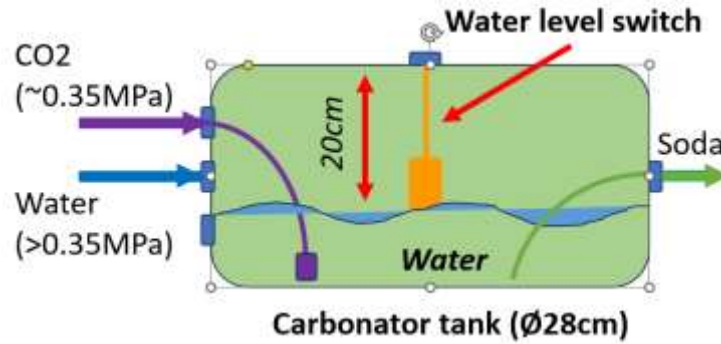


Figure 2.9 Concept of Carbonator for this machine

With this design, the soda water production process will depend on temperature, pressure, and the concentration of the supplied gas, as outlined in Section 1.2.

2.2.3. Chiller

As mentioned in section 1.2, temperature plays an important role in the reaction of CO₂ water. Water before and after reacting with CO₂ will benefit from being at low temperatures: it can absorb more CO₂ (fizzy), maintain the cold of the soda water (when it must travel through a long pipe from the backroom to the panel), and maybe contribute to the formation of CO₂-saturated water. There are two options for the cooler: Condenser and Peltier Module.



Figure 2.10 Unsaturated, saturated and supersaturated solutions (Source: Internet)

+ Option 1: Using vapor-compression refrigeration

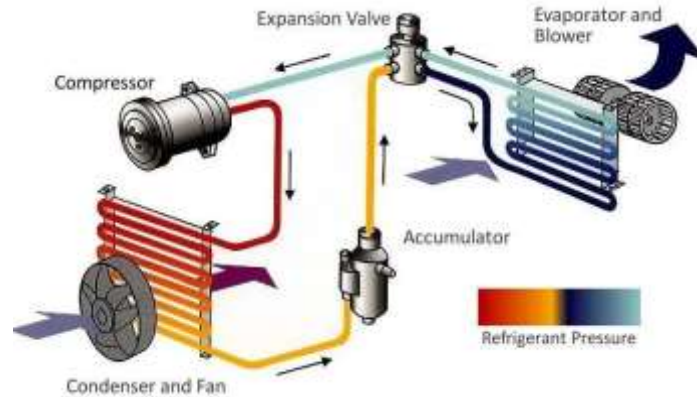


Figure 2.11 Illustration of vapor-compression refrigeration (Source: Internet)

Vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. It is commonly found in household refrigerators, air conditioners, and industrial cooling systems. The main parts are compressor, condenser and evaporator (Figure 2.8).

- Advantages:
 - High energy efficiency (about 40 to 60% of Carnot's theoretical limit)
 - Reliable performance
 - Long-term operational stability
- Disadvantages:
 - Big size
 - Complex working part (pipeline, condenser, liquid,...)
 - High power consumption (100-400W)

+ Option 2: Using Thermoelectric cooler

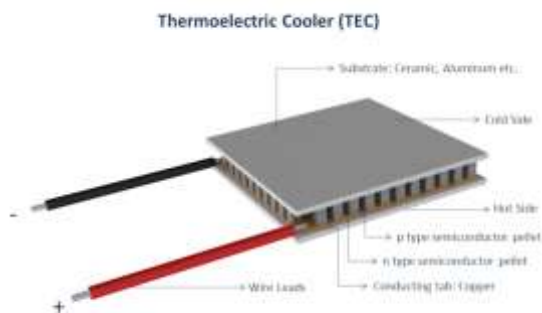


Figure 2.12 Illustration of Peltier module (Source: Internet)

Thermoelectric cooling uses the Peltier effect to create a heat flux at the junction of two different types of materials, which transfer heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. It can be used either for heating or for cooling, although in practice the main application is cooling

- Advantages:
 - No moving parts or circulating liquid
 - Long lifespan
 - Invulnerability to leaks
 - Small size and flexible shape
 - Safe to use
- Disadvantages:
 - High cost for a given cooling capacity
 - Poor power efficiency (often around 5-8% of Carnot's limit)

According to advantages and disadvantages of each option, we choose option 2 to replicate the working principle of making soda, because of the compact size and easy to use. Details of this selection will be shown in section 2.3.

2.2.4. Dispenser

For soda dispenser, it can operate either by utilizing the pressure of CO₂ gas inside a closed tank to push water out (or by employing a pump to extract the soda. When gas pressure from the cylinder is used to propel the liquid, this process induces turbulence and pressure fluctuations, leading to the escape of dissolved CO₂, thereby diminishing the soda's fizziness.

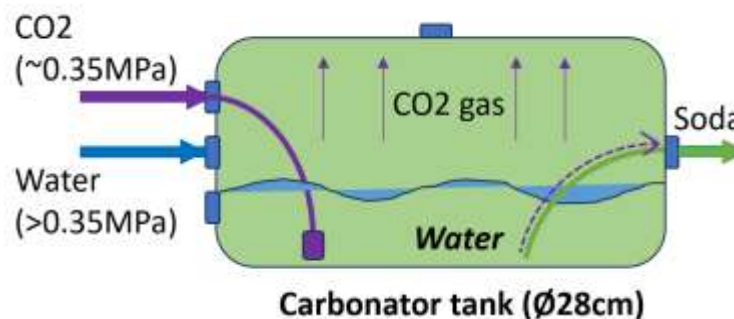


Figure 2.13 Illustration of CO₂ gas pressure and soda outlet

In contrast, the use of a pump mitigates both turbulence and pressure variation, thus better preserving carbonation, which we will use in this system. The pump we use will be feed in like the Piezometer.

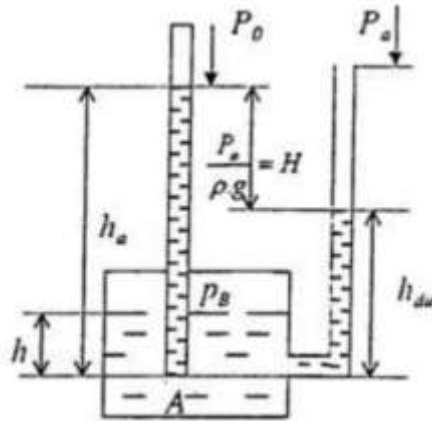


Figure 2.14 Illustration of Piezometer (Source: Internet)

For syrup dispensers, there are two types of syrup dispensers: Bag-in-Box (BIB) systems and peristaltic (dosing) pumps.

+ Option 1: Using BIB system



Figure 2.15 Illustration of Peltier module (Source: Internet)

The Bag-in-Box (BIB) pump used in beverage dispensing systems typically employs a CO₂-driven diaphragm mechanism. Compressed CO₂ gas is supplied to the pump, where it cyclically actuates a flexible diaphragm. This action creates a suction force that draws syrup from the sealed bag and pushes it through the system to the dispenser. Since the syrup is never exposed to air or CO₂ directly, contamination and oxidation are minimized. The system operates pneumatically and requires no electrical power.

- Advantages:
 - No electrical component required
 - Long lifespan
 - Stable and consistent syrup flow rate

Design and manufacture of a fresh Coca-Cola dispensing machine

- Easy integration into soda fountain systems
- Disadvantages:
 - Requires continuous CO₂ supply
 - Performance depends on consistent gas pressure
 - May require periodic maintenance or replacement

+ Option 2: Using Peristaltic pump

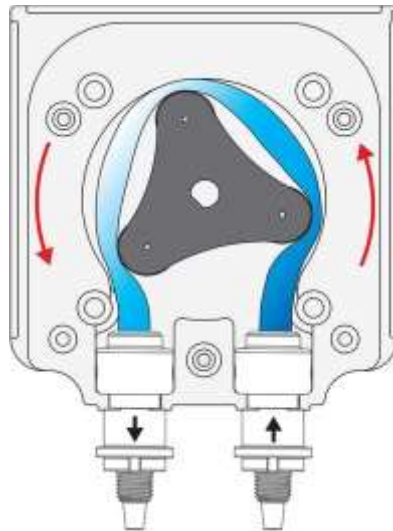


Figure 2.16 Working principle of peristaltic pump (Source: Internet)

The peristaltic pump operates by compressing and releasing a flexible tube in a sequential manner using rotating rollers or shoes mounted on a rotor. As the rotor turns, the rollers squeeze the tube, pushing the fluid forward. Once the roller passes, the tube returns to its original shape, creating a vacuum that draws in more fluid. This design ensures that the fluid only contacts the inner wall of the tubing, making the system ideal for hygienic and metered fluid delivery. Peristaltic pumps are commonly used for syrup dosing in beverage dispensing systems, especially where precise volume control is needed.

- Advantages:
 - Accurate and repeatable dosing
 - Suitable for viscous or shear-sensitive fluids
 - Easy maintenance (no valves or seals in contact with fluid)
 - Self-priming and can run dry without damage
- Disadvantages:
 - Tubing wears out over time and requires replacement
 - Relatively low flow rates
 - Requires electric motor

According to advantages and disadvantages of each option, we choose option 2 cause it's easy to work with and affordable price. Details of this selection will be shown in section 2.3.

2.2.5. System structure

After selecting the appropriate operation mode for each main component, the fresh Coca-Cola dispensing machine operates through a closed-loop process illustrated in the piping and instrumentation diagram (Figure 2.17). The system consists of the following major functional blocks: water treatment unit, carbonator (soda generation), chiller unit, syrup mixing section, and the final dispensing outlet.

The working principle proceeds through the following six steps:

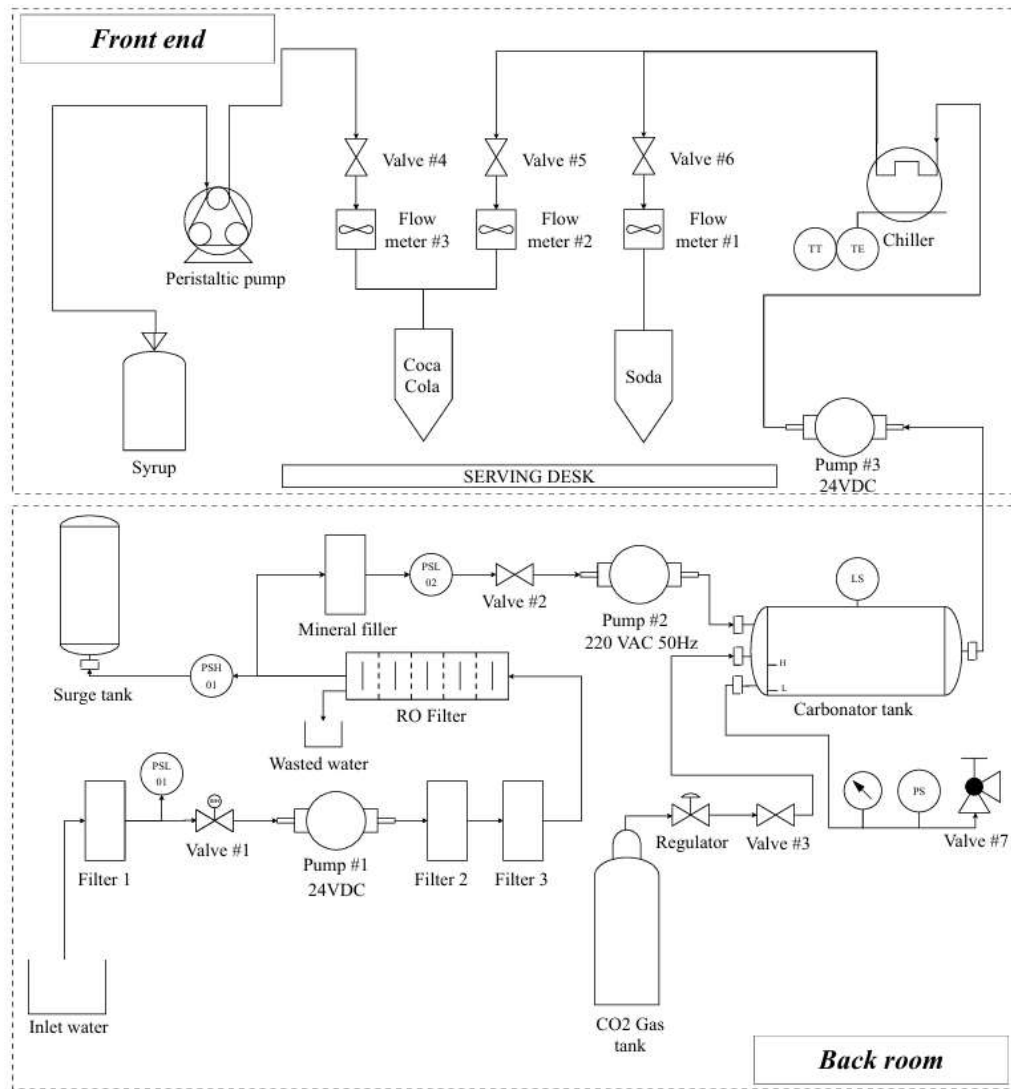


Figure 2.17 Piping and Instrumentation diagram of the system

Design and manufacture of a fresh Coca-Cola dispensing machine

- Step 1: Inlet water treatment

Raw water is supplied to the system via the inlet connection. The water passes sequentially through Filter 1, Filter 2, Filter 3, and finally through a Reverse Osmosis (RO) filter.

The filtration process is activated when Valve #1 opens and Pump #1 (24VDC) runs to generate the required pressure.

A portion of the filtered water is stored in the surge tank, while the rest is directed to the carbonator unit for soda generation.

- Step 2: Water supply to the Carbonator tank

Water from the membrane tank is transferred to the carbonator tank through Valve #2 and Pump #2 (220VAC).

The flow rate is precisely measured and monitored using flow meters to ensure optimal volume and delivery speed.

- Step 3: Soda Generation (Carbonation)

Inside the carbonator tank, water is mixed with pressurized CO₂ gas supplied from a CO₂ gas tank.

The gas pressure is controlled via a regulator, and Valve #3 manages the CO₂ injection.

The carbonation process occurs in a sealed pressurized environment, forming carbonated water (soda) with stable saturation.

The soda is then retained in the carbonator tank, ready for the next stages.

- Step 4: Soda Chilling

Pump #3 (24VDC) is activated to pressurize and transfer the soda from the carbonator.

The soda flows through a chiller unit to lower its temperature, enhancing the refreshing taste and improving syrup mixing quality.

- Step 5: Flow splitting and mixing

After cooling, the soda flow is split into two branches: Through Valve #5 for Coca-Cola mixing and through Valve #6 for plain soda dispensing.

Design and manufacture of a fresh Coca-Cola dispensing machine

In the Coca-Cola mixing path: Coca-Cola syrup, stored in a separate container, is pumped via a peristaltic pump with controlled flow. The syrup and soda meet and mix at the T-junction (Mixing Coupling) to form the final Coca-Cola beverage.

- Step 6: Dispensing to outlet

The final beverage (Coca-Cola or soda) is dispensed to the serving outlet. The entire output volume is continuously monitored using flow meters, ensuring accurate delivery and minimizing waste.

Compared to the classic Soda Fountain system (Figure 2.18), here are some key specification highlights of our machine that offer clear advantages over the classic one:

- Using chilled water in combination with gas introduced via a ceramic diffuser operating at a pressure suitable for the intended gas flow rate (instead of relying on atomizing water with undiffused gas injection).
- Reduce the size of chiller (cold plates)
- Store tank for inlet water
- Replace the syrup pump with electrical system
- Outlet soda by pressure and pump (instead of only by pressure that cause pressure fluctuations)
- Reduce the volume of CO₂ in BIB pump and outlet soda (detail in section 3.3)
- Replace timer with flowmeter on the dispenser
- All control by electronic circuit

These enhancements not only improve the machine's performance and efficiency but also make it more suitable for home use, aligning with the goals of convenience, sustainability, and user-friendly operation.

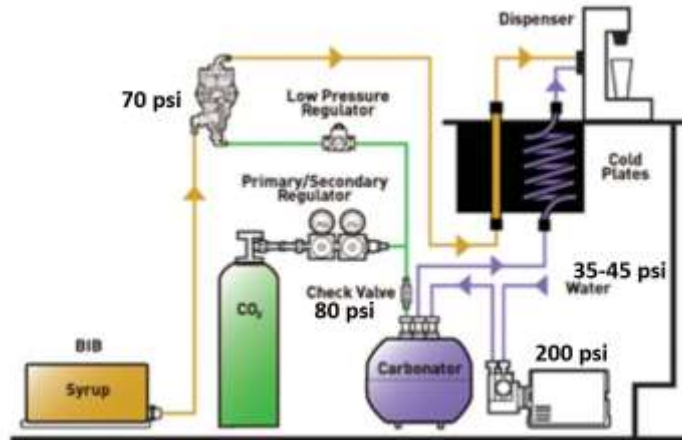


Figure 2.18 Working diagram of the classic Soda Fountain system (Source: Internet)

2.3. Actuator calculation:

In this section, we will select the right actuator for the right specifications, which is necessary for the price/performance and capable of working principle of the system.

2.3.1. Pump for RO membrane

In RO filter, pump applies pressure to overcome osmotic pressure that favors even distributions. RO requires pressure between 2–17 bar (30–250 psi) for fresh and brackish water, and 40–82 bar (600–1200 psi) for seawater [10]. In this section, we will calculate the pump that has enough pressure to overcome the rate of fresh water.

The average flow rate is 0.8L/min (~0.21GPM) for household RO system, but that flow rate is combined from pump and membrane tank. Therefore, we will use a commonly available pump with an assumed specification of 0.21 GPM and calculate the pressure loss across the RO system of the machine. Based on the results, we will determine whether this pump is suitable for filtration through the RO membrane.

The water filter block has a total 1m of 6.5mm diameter plastic pipeline and 0,5m of 3 mm diameter plastic pipeline, sudden small cross section. There are two 90° angle couplings on the 6.5mm pipe and two 90° angle couplings on the 3 mm pipe. The total pressure loss is local resistance (Σh_{cb}) and pipe friction resistance (h_1) combine:

$$h_m = h_1 + \Sigma h_{cb}$$

+ Pipe friction resistance calculation:

Friction resistance (head loss) is the resistance on the pipe, which is 6.35mm and 3mm diameter pipe.

$$h_1 = \Delta p = \lambda \times \frac{l}{d} \times \frac{\rho v^2}{2}$$

Where:

- Δp : pressure loss
 - ξ : friction coefficient (usually the Darcy coefficient)
 - ρ : fluid density (water is 1000 kg/m³)
 - g : acceleration due to gravity (9.81 m/s²)
 - v : average flow velocity [m/s]
 - d_1 : internal diameter of the 6.35mm pipe (0.00635 m)
 - l_1 : length of the d_1 pipe (1 m)
 - d_2 : internal diameter of the 3mm pipe (0,003 m)
 - l_2 : length of the d_2 pipe (0.5 m)
 - Q : flow rate (0.21 GPM = 1.325×10^{-5} m³/s)
 - μ : Dynamic viscosity of the fluid (water is 1.002×10^{-3} Pa·s)
- + For 6.35mm diameter pipe:

- Flow velocity:

$$Q = v_1 \times A_1$$

$$\begin{aligned} v_1 &= \frac{Q}{A_1} = Q \times \frac{4}{\pi d_1^2} = (1.325 \times 10^{-5}) \times \frac{4}{\pi (0.00635)^2} \\ &= (1.325 \times 10^{-5}) \times (0.316 \times 10^5) \approx 0.418 \text{ m/s} \end{aligned}$$

- Reynolds number (Re):

$$Re_1 = \frac{\rho v_1 d_1}{\mu} = \frac{1000 \times 0.418 \times 0.00635}{1.002 \times 10^{-3}} \approx 2649$$

$Re \approx 2649$ is near the transition threshold between laminar and turbulent flow ($Re = 2300-4000$), according to [2/p.92], the coefficient of friction λ is calculated by Blasius formular:

$$\lambda_1 = \frac{0,3146}{Re_1^{0.25}} = 0.044$$

- Friction resistance:

$$\begin{aligned} h_{11} &= \Delta p = \lambda_1 \times \frac{l_1}{d_1} \times \frac{\rho v_1^2}{2} \\ &= 0.044 \times \frac{1}{0.00635} \times \frac{1000 \times 0.418^2}{2} = 605 \text{ Pa} \approx 0.088 \text{ psi} \end{aligned}$$

+ For 3mm diameter pipe:

- Flow velocity:

$$Q = v_2 \times A_2$$

$$v_2 = \frac{Q}{A_2} = Q \times \frac{4}{\pi d_2^2} = (1.325 \times 10^{-5}) \times \frac{4}{\pi(0.003)^2}$$
$$= (1.325 \times 10^{-5}) \times (1.415 \times 10^5) \approx 1.88 \text{ m/s}$$

- Reynolds number (Re):

$$Re_2 = \frac{\rho v_2 d_2}{\mu} = \frac{1000 \times 1.88 \times 0.003}{1.002 \times 10^{-3}} \approx 5629$$

$Re \approx 5629$ is in turbulent flow ($Re > 4000$). According to [2/p.92], Re is still within the limit of $4000 < Re < 10^5$, we still use Blasius formula to calculate the coefficient of friction λ , but the friction resistance will be proportional to 1.75 flow velocity.

$$\lambda_2 = \frac{0,3146}{Re_2^{0.25}} = 0.036$$

- Friction resistance:

$$h_{12} = \Delta p = 1.75 \times \lambda_2 \times \frac{l_2}{d_2} \times \frac{\rho v_2^2}{2}$$
$$= 1.75 \times 0.036 \times \frac{0.5}{0.003} \times \frac{1000 \times 1.88^2}{2} = 18555.6 \text{ Pa} \approx 2.691 \text{ psi}$$

- Total friction resistance:

$$h_1 = h_{11} + h_{12} = 0.088 + 2.691 = 2.779 \text{ psi}$$

+ Local resistance calculation:

Local resistance is the resistance due to sudden changes in shape or flow conditions in the system, which is 90° angle coupling and sudden small cross section of the pipe.

$$\Sigma h_{cb} = h_c + h_s = \xi \times \frac{\rho v^2}{2}$$

+ For 90° angle coupling:

Water flows into 2 couplings, at both 6.35mm and 3mm pipes, so the local resistance of coupling is 4 coupling. According to [3/p.96], coefficient of friction ξ is 0.13.

$$h_c = h_{c1} + h_{c2} = 2 \times \xi \times \frac{\rho v_1^2}{2} + 2 \times \xi \times \frac{\rho v_2^2}{2}$$

$$= 2 \times 0.13 \times \frac{1000 \times 1.88^2}{2} + 2 \times 0.13 \times \frac{1000 \times 0.418^2}{2} = 482 \text{ Pa} \approx 0.07 \text{ psi}$$

+ For sudden small cross section:

Suddenly small cross section is located on the RO filter. According to [2/p.95], the ratio of input line and output line is $\frac{3}{6.35} \approx 0.5$, which have coefficient of friction ξ is 0.3.

$$h_s = \xi \times \frac{\rho v_1^2}{2} = 0.3 \times \frac{1000 \times 0.418^2}{2} = 26 \text{ Pa} \approx 0.004 \text{ psi}$$

- Total local resistance:

$$h_{cb} = h_c + h_s = 0.07 + 0.004 = 0.074 \text{ psi}$$

+ Total resistance of the system:

$$h_m = h_1 + \Sigma h_{cb} = 2.779 + 0.074 = 2.853 \approx 3 \text{ psi}$$

Therefore, using differential pump with flow rate 0.21GPM, pressure 100 psi can filter water through RO membrane. This pump is powered by 24VDC with 0.22A with no load.



Figure 2.19 Image of RO Pump (Source: Internet)

2.3.2. Inlet carbonator pump

After selecting RO pump at 2.3.1, we have 0.21 GPM (~0.8L/min or 800 cc/min) pump with 100 psi at no load operation. As mentioned in section 2.2.1, the efficiency of RO system is about 20%, which mean the flowrate of the clean water will be 0.042 GPM (~0.16L/min or 160 cc/min) at very low psi. That is why we need a surge tank to store clean water to boost pressure and the flow rate of the outlet line, which is about 70 psi at 0.8L/min (or 800 cc/min) after going through mineral filler.



Figure 2.20 Surge tank (Source: Internet)

For the water to get into the carbonator tank, it needs to be pressured that higher than the pre-charge pressure of the tank and the pressure of the inlet CO₂ through regulator, which is about 0.35MPa (~50.763 psi).



Figure 2.21 CO₂ gas regulator 0.35MPa with adjustable LPM (Source: Internet)

The average flow rate of the inlet carbonator is 0.48L/min or 480 cc/min, with the pressure lower than the pressure of the CO₂ inlet line. We use vibration pump because it doesn't affect the inlet pressure but only the flow rate. According to the datasheet of

vibration pump of PHOENIX-50N, this pump can create an average 4 bars (~58 psi) of pressure, which is suitable for using vibration pump over the differential pump.

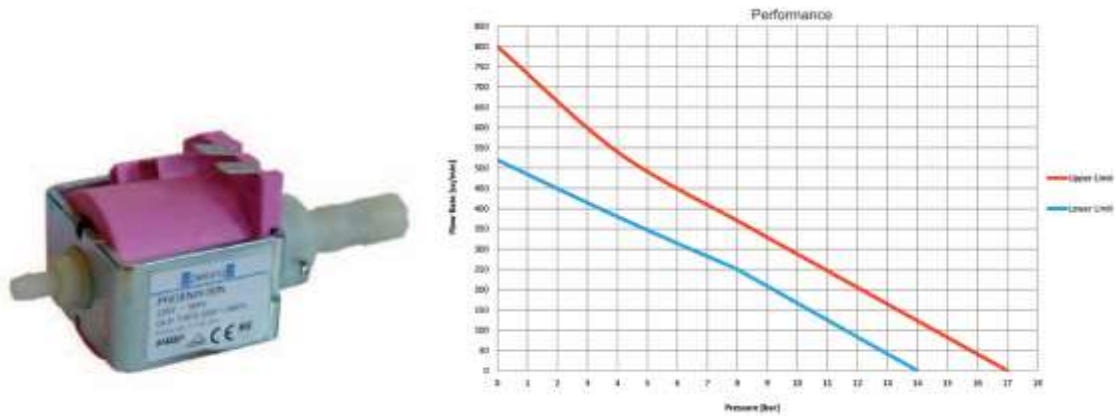


Figure 2.22 Picture (left) and datasheet (right) of PHOENIX-50N vibration pump

2.3.3. Outlet carbonator pump

Outlet carbonator is a soda, which is stored inside a tank. At this stage, the soda water inside the tank needs to be transported by a pump through a 1-meter-long pipeline with an internal diameter of 3 mm, including eight 90-degree bends.

According to the system's operational requirements, the desired flow rate of soda water at the outlet ranges from 0.5 to 2 liters per minute (LPM). For pressure loss estimation in the pipeline, we selected a reference flow rate of 0.8 LPM ($\sim 1.325 \times 10^{-5} \text{ m}^3/\text{s}$), as this is a commonly available pump specification. This flow rate will be used as the basis for calculating the pressure requirements within the pipeline system. The total pressure loss is local resistance (Σh_{cb}) and pipe friction resistance (h_1) combine:

$$h_m = h_1 + \Sigma h_{cb}$$

+ Pipe friction resistance calculation:

Friction resistance (head loss) is the resistance on the pipe, which is 3mm diameter pipe.

$$h_1 = \Delta p = \lambda \times \frac{l}{d} \times \frac{\rho v^2}{2}$$

Where:

- Δp : pressure loss [bar]
- ξ : friction coefficient (usually the Darcy coefficient)
- ρ : fluid density (water is 1000 kg/m^3)

Design and manufacture of a fresh Coca-Cola dispensing machine

- g : acceleration due to gravity (9.81 m/s^2)
 - v : average flow velocity [m/s]
 - d : internal diameter of the 3mm pipe ($\sim 0.003 \text{ m}$)
 - l : length of pipe (1 m)
 - Q : flow rate ($0.21 \text{ GPM} = 1.325 \times 10^{-5} \text{ m}^3/\text{s}$)
 - μ : Dynamic viscosity of the fluid (water is $1.002 \times 10^{-3} \text{ Pa}\cdot\text{s}$)
- Flow velocity:

$$Q = v \times A$$

$$v = \frac{Q}{A} = Q \times \frac{4}{\pi d^2} = (1.325 \times 10^{-5}) \times \frac{4}{\pi(0.003)^2}$$
$$= (1.325 \times 10^{-5}) \times (1.415 \times 10^5) \approx 1.88 \text{ m/s}$$

- Reynolds number (Re):

$$\text{Re}_2 = \frac{\rho v d}{\mu} = \frac{1000 \times 1.88 \times 0.003}{1.002 \times 10^{-3}} \approx 5629$$

$\text{Re} \approx 5629$ is in turbulent flow ($\text{Re} > 4000$). According to [2/p.92], Re is still within the limit of $4000 < \text{Re} < 10^5$, we still use Blasius formula to calculate the coefficient of friction λ , but the friction resistance will be proportional to 1.75 flow velocity.

$$\lambda_2 = \frac{0,3146}{\text{Re}_2^{0.25}} = 0.036$$

- Friction resistance:

$$h_{12} = \Delta p = 1.75 \times \lambda_2 \times \frac{l_2}{d_2} \times \frac{\rho v_2^2}{2}$$
$$= 1.75 \times 0.036 \times \frac{0.5}{0.003} \times \frac{1000 \times 1.88^2}{2} = 18555.6 \text{ Pa} \approx 2.691 \text{ psi}$$

+ Local resistance calculation:

Local resistance is the resistance due to sudden changes in shape or flow conditions in the system, which is 90° angle turn.

$$\Sigma h_{cb} = h_c + h_s = \xi \times \frac{\rho v^2}{2}$$

Water flows into 8 angles, according to [3/p.96], coefficient of friction ξ is 0.13.

$$h_c = 8 \times \xi \times \frac{\rho v_1^2}{2}$$

$$= 8 \times 0.13 \times \frac{1000 \times 1.88^2}{2} = 4241,28 \text{ Pa} \approx 0.62 \text{ psi}$$

+ Total resistance of the system:

$$h_m = h_1 + \Sigma h_{cb} = 2.691 + 0.62 = 3.311 \text{ psi}$$

Therefore, using differential pump with flow rate 0.21GPM, pressure 100 psi able to comply with the requirements/specifications. This pump is powered by 24VDC with 0.22A with no load.



Figure 2.23 Image of RO Pump (Source: Internet)

2.3.4. Peltier module for chiller

For Peltier module, we need to pay attention to power consumption and cooling of the hot side. To increase cooling efficiency, we can stack Peltier on top of each other, but for the chiller purpose only, we aim to use one Peltier module that cools the water at about 5°C

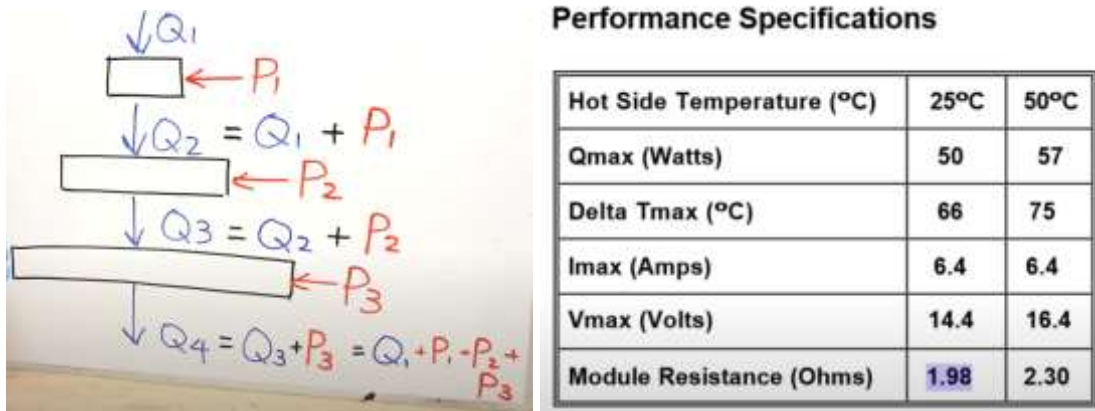


Figure 2.24 Peltier power consumption via stacking (left) and sample performance (right) specifications (Source: <https://www.youtube.com/watch?v=ImiSpAjKjss&t=263s>)

For ideal temperature isolation, no self-increase in temperature when used, we use Peltier TEC1- 12706. Figure 2.14 shows the power consumption with Delta T (differential temperature between the cold and the hot side) of 25°C and 50°C on the hot side

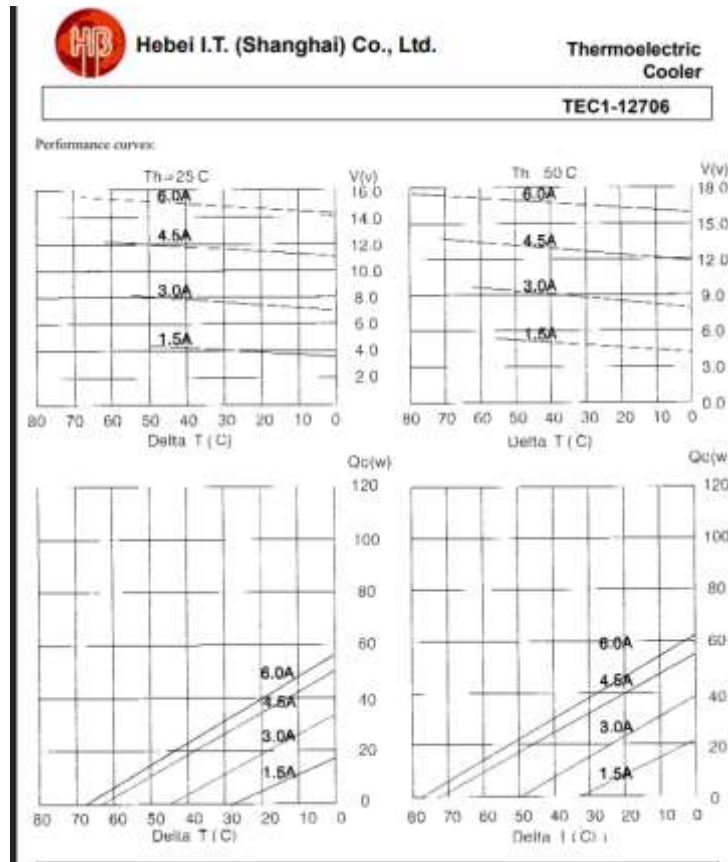


Figure 2.25 Datasheet of Peltier module TEC1- 12706

Assume T_{hot} is 50°C and desired cold temperature is 0°C, the Delta T will be 50. Using 4.5 Ampe line with it, the voltage will be 13V. The overall power consumption will be:

$$Q = Q_{hot} + Q_{cold} = 13 \times 4.5 + 20 = 58.5 + 20 = 78.5W$$

For the cooling of the hot side, we will use the CPU air cooling radiator Jonsboo CR1000 with the TDP is 220W, suitable for 58.5W TDP of the hot side.



Model:	CR-1000 EVO ARGB Black
Dimensions:	120 mm(L)*71mm(W)*154mm(H)
Heatpipe size:	Φ6mm*4PCS
D-TDP:	220W
Fan Dimensions:	120mm* 120mm* 25mm
Fan Speed:	600 -1500RPM(±10%)
Fan Air Flow:	28.12-59.48CFM(MAX)
Fan Air Pressure:	0.26-1.81mmH2O
Fan Noise Level:	22-32dB(A) (MAX)
Fan Bearing Type:	Hydraulic bearing

Figure 2.26 Datasheet of heatsink cooler for the hot side (Source: <https://www.jonsbo.com/en/products/cr1000.html>)

2.3.5. Peristaltic pump for dispenser

The peristaltic pump is utilized to extract syrup from bags or bottles and mix it with soda water to produce the final soft drink. On average, the syrup-to-soda ratio is 1:5 per serving (for example, a 300 ml soft drink consists of 250 ml soda and 50 ml syrup).



Figure 2.27 Ratio of syrup and soda (Source: Internet)

Given that the soda flow rate is 0.8 GPM, which corresponds to approximately 23 seconds to dispense 300 ml, the required syrup volume of 50 ml must be pumped within the same 23-second interval. Therefore, we select the ELT20 peristaltic pump, featuring a

specification of 3.2 ml per pulse at max setting and a pulse frequency adjustable according to the required flow rate.



Figure 2.28 Image of ELT20 peristaltic pump (Source: Internet)

2.4. Mechanical design

According to the requirements in section 1.4, we design a machine which has $75 \times 52 \times 119$ cm (L \times W \times H) in dimensions. Other requirements are not affect the structural design or the arrangement of the machine's components. These requirements mainly relate to functional, electrical, or performance specifications, which are independent of the physical layout. Therefore, the spatial configuration and mechanical design remain consistent and optimized according to the specified dimensions, which Figure 2.29 to Figure 2.34 shows the overall arrangement of each part.

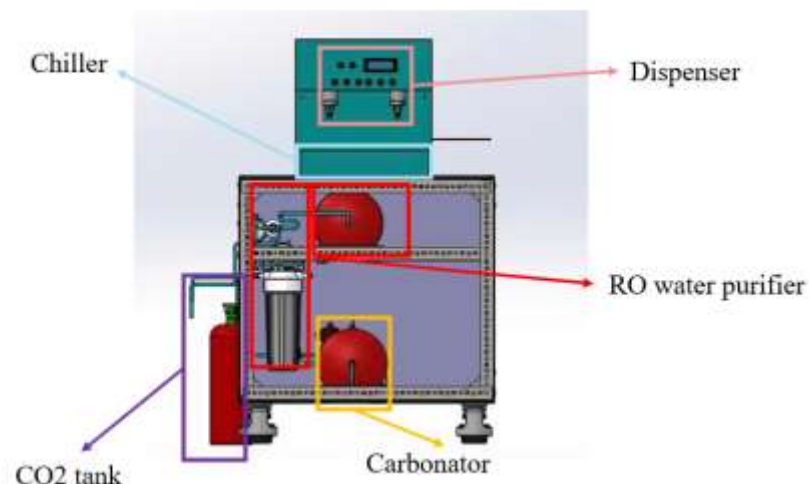


Figure 2.29 Overview of the machine with separate part

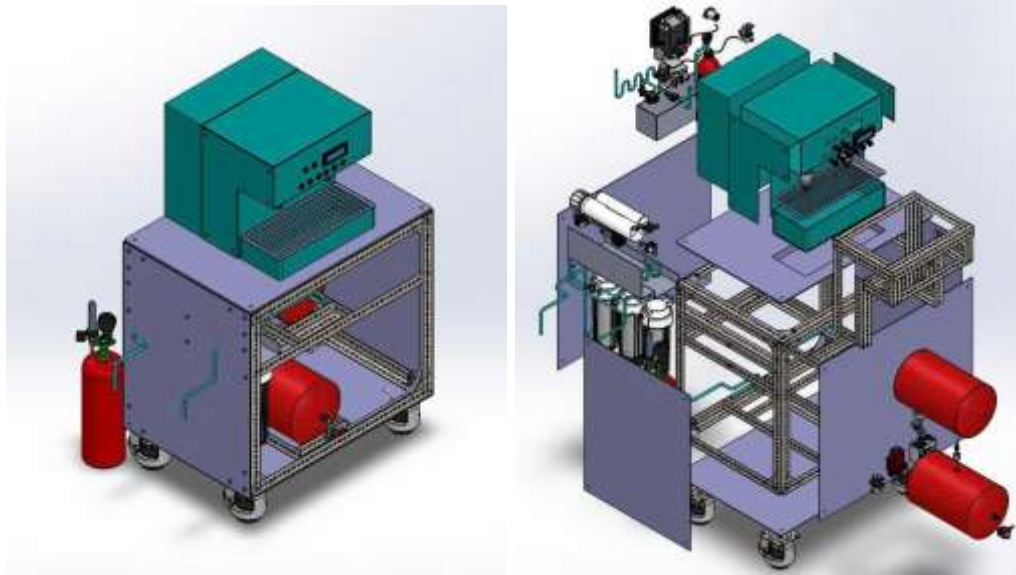


Figure 2.30 Image of overview model (left) and exploded model (right) of the machine

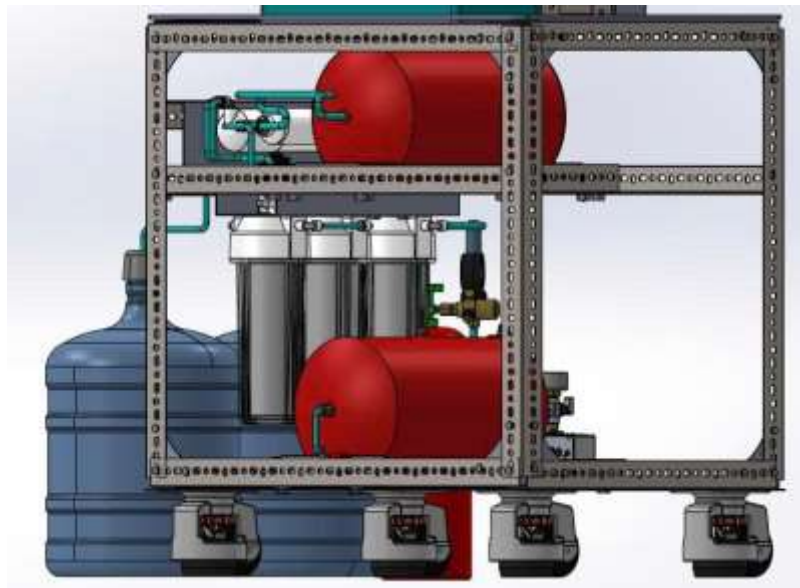


Figure 2.31 Image of water filter model

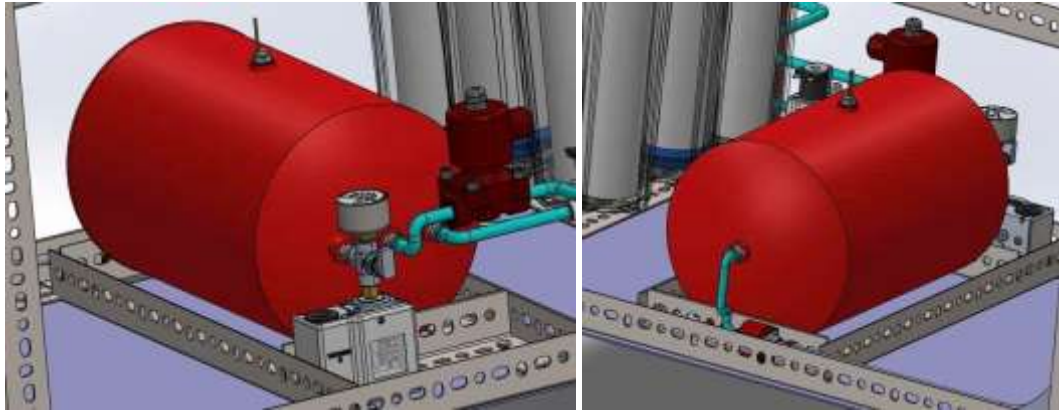


Figure 2.32 Image of carbonator model

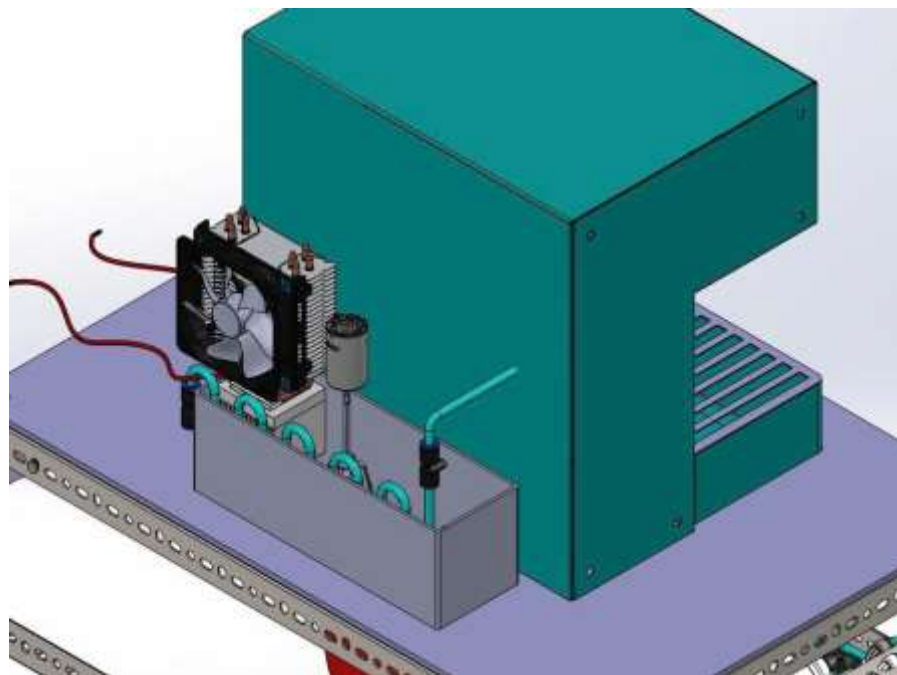


Figure 2.33 Image of chiller model

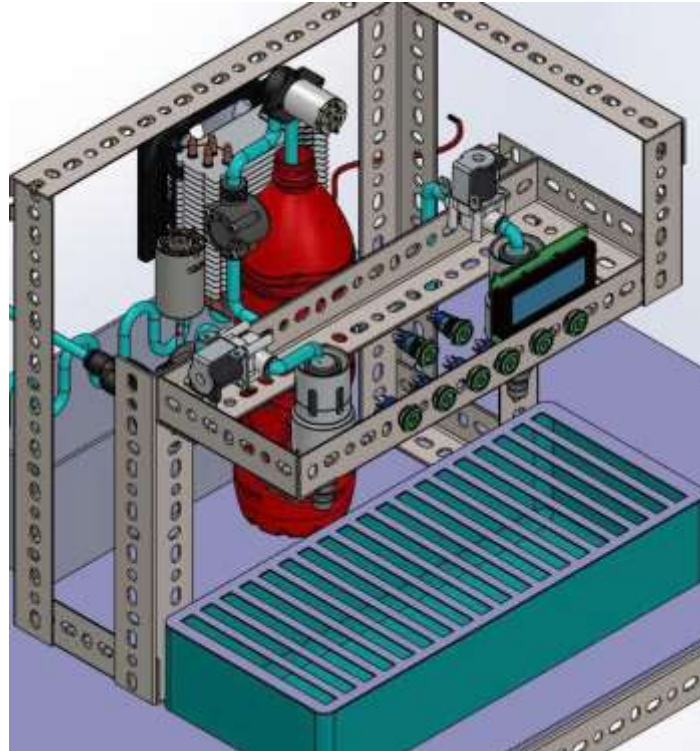


Figure 2.34 Image of dispenser model

2.5. Manufacture and assembly

After designing the structure through SolidWorks, we will assemble the machine with the dimensions in each detail drawing with Figure 2.35 to Figure 2.27

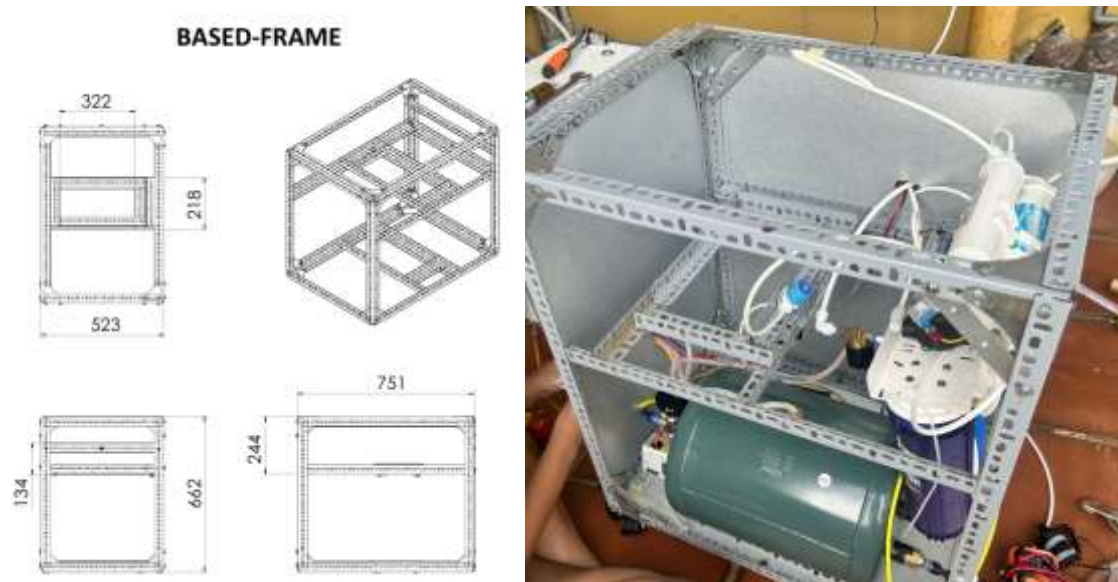


Figure 2.35 Detail drawing (left) and actual assembly (right) of the based frame

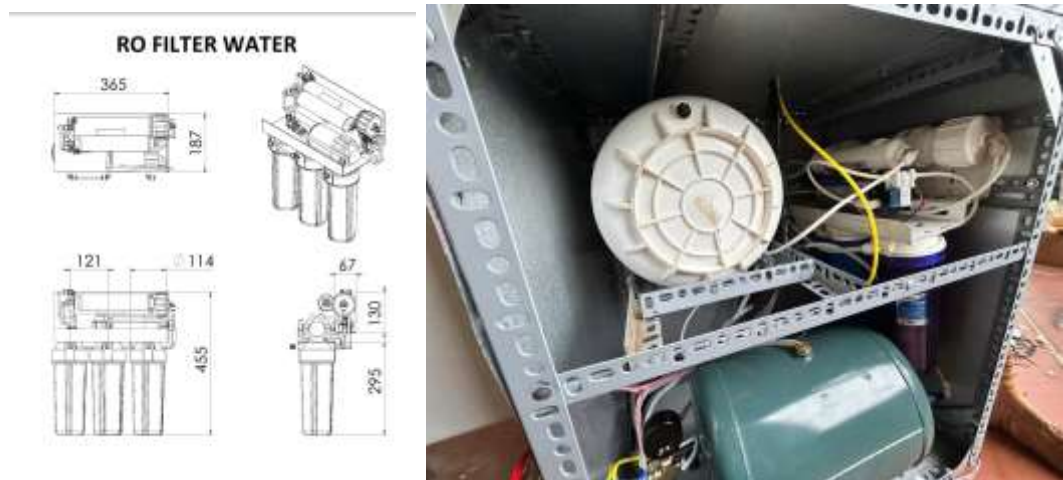


Figure 2.36 Detail drawing (left) and actual assembly (right) of the RO water filter

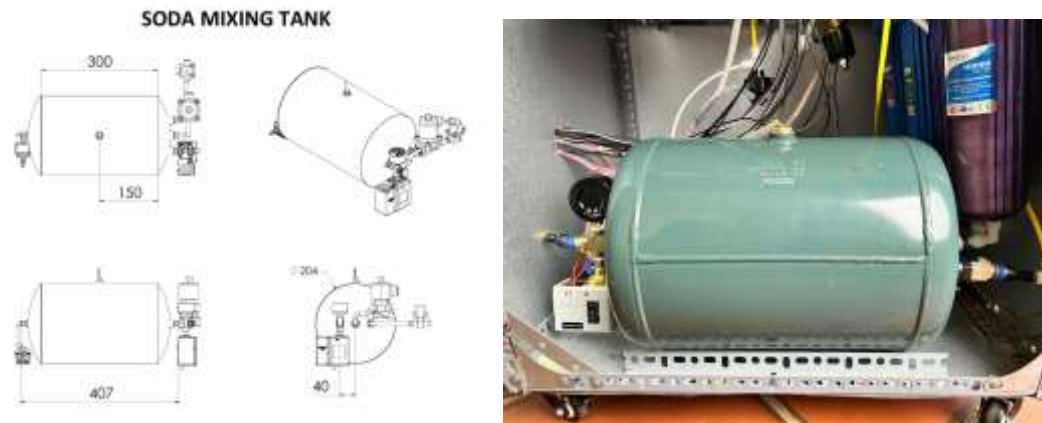


Figure 2.37 Detail drawing (left) and actual assembly (right) of the carbonator

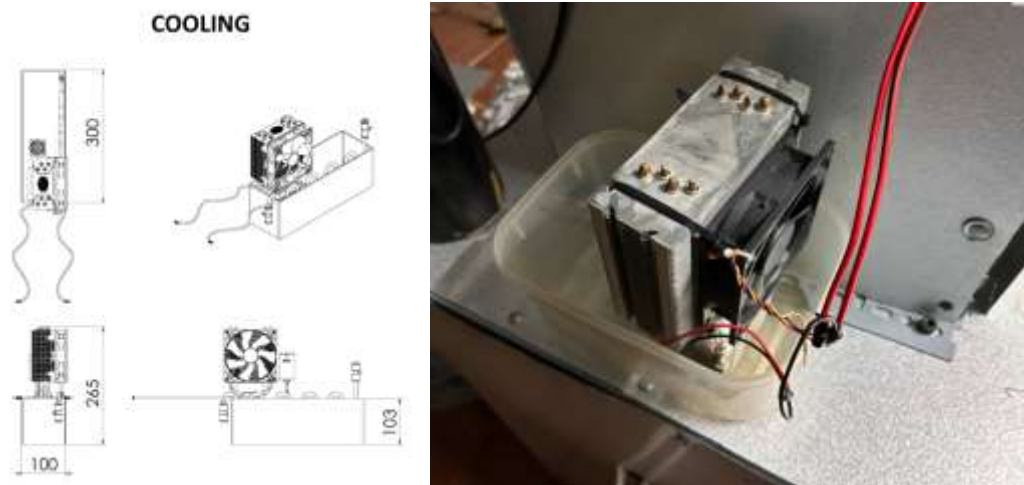


Figure 2.38 Detail drawing (left) actual assembly (right) of the chiller

Design and manufacture of a fresh Coca-Cola dispensing machine

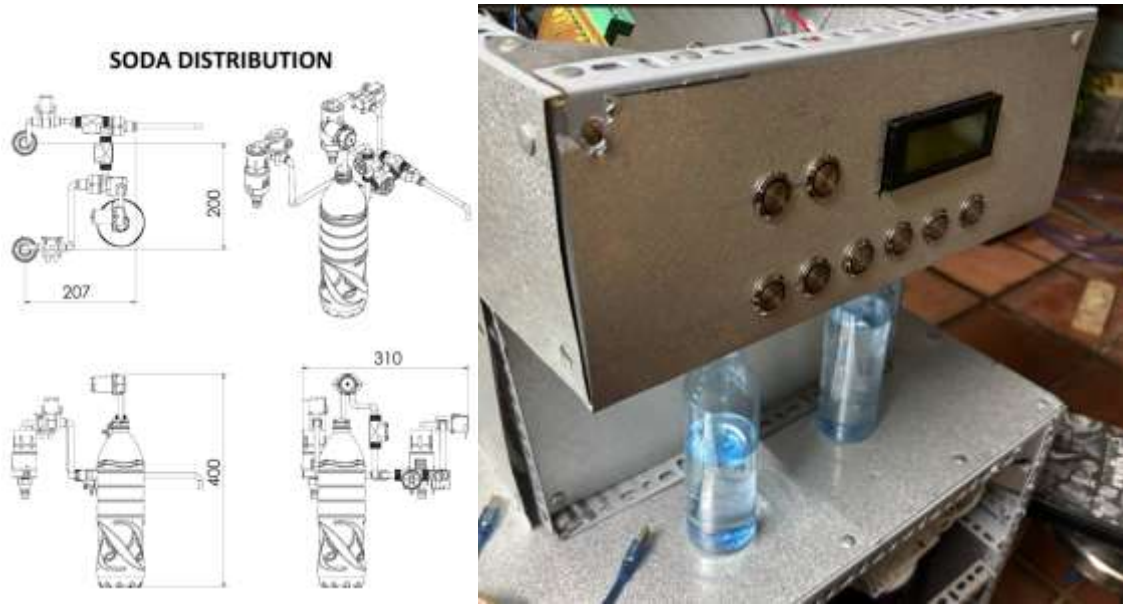


Figure 2.39 Detail drawing (left) and actual assembly (right) of the dispenser

CHAPTER 3: CALCULATION AND DESIGN OF CONTROL SYSTEM

3.1. System modeling

The typical model of a mechatronics system usually have these module, as shown in Figure 3.1.

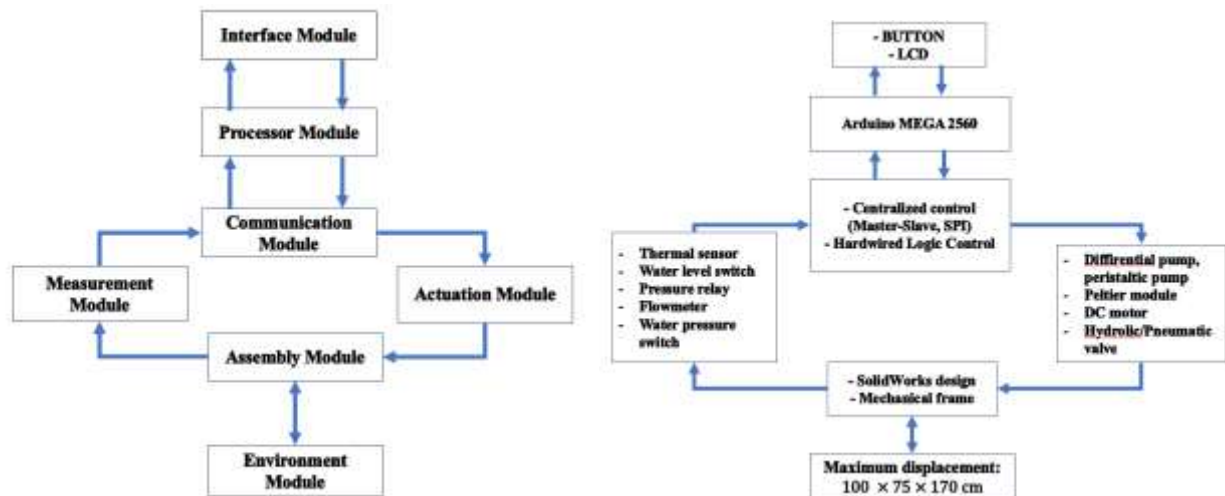


Figure 3.1 Schematic diagram in a basic (left) and our machine (right) mechatronics system

3.1.1. Environment Module:

The working environment requires coffee shops, bakeries, and small-scale stores often demand machines with compact sizes and simple operations. This is a fundamental factor in determining the appropriate size and meeting the working environment or operational standards of each machine, which is mentioned in section 1.4.

3.1.2. Assembly Module:

The basic requirements for creating a machine involve the combination of mechanical parts (including kinematic diagram analysis, selection of suitable mechanisms, and design and structural strength calculations). Determining the basic working principle diagram of a machine and selecting appropriate movements, which is mentioned in section 2.2

3.1.3. Measurement Module:

The measurement module consists of sensors used in a machine to enable automatic operation or object detection. In this machine, the sensors focus on detecting the water level, the air pressure inside the tank and the temperature of the cooling. Figure 3.1 shows the basic of all the sensor that we use and will be mentioned in section 3.2.

3.1.4. Actuation Module:

The execution mechanisms receive signals from the Measurement module that have been processed and controlled through the Processing module. As mentioned in section 2.3, these actuator mechanisms include:

- Mechanical motion: none.
- Electrical motion: Differential pump, dosing pump.
- Pneumatic/ hydraulic motion: 3/2 valve for water and CO₂, regulator for CO₂ gas
- Energy conversion: Peltier module

3.1.5. Communication Module:

To connect the Measurement module with the Actuation module and control by Processor module, the Communication module is determined by the direction of simple or complex control. In this system, we tend to use a simple control system that is only focused on the Panel (front end), so it will be relatively simple and centralized control. Communication through bus plug standards, Half-Duplex control communication is the easiest way to do that.

3.1.6. Processor Module:

This is an important processing unit of a machine system that receives signals from sensors, connects with the processing unit through the Communication module, and operates the execution mechanisms from the Execution module. The choice of processing unit depends on the workspace requirements (Environment module), necessary I/O ports for control, processing speed... In this system, we intended to use microcontroller, which is Arduino for the centralized control purposed.

3.1.7. Interface Module:

To interact with the machine, an Interface module is important to operate and test, check if there is something wrong. Operation control through buttons and LCD on the control box. Control interface through a computer UI will be available later if we have time to upgrade.

3.2. Electronic design and selection

3.2.1. Sensor selection

3.2.1.1. Thermal sensor

Thermal sensor is used to read the temperature inside the chiller tank, if there is a differential temperature between setting and reality temperature. We use thermal couple RTD K Type PT1000 with Max6675 module.



Figure 3.2 RTD K Type thermal couple with Max6675 module (Source: Internet)

- Temperature sensor:
 - Thermocouple RTD K Type:
 - Measuring range: 0~800 degrees C.
- MAX6675 signal converter circuit:
 - Works with Thermocouple type K.
 - Operating voltage 3.0 ~ 5.5VDC.
 - ADC resolution 12bit, 0.25 degrees per unit.
 - SPI communication.
 - Working temperature: -20 to 85 degrees C.

3.2.1.2. Flowmeter

To control the volume of soda and syrup for each serving portion, we use flowmeter to control the 3/2 valve that allow liquid to go through or not. We use Sea YF-S401 flowmeter sensor for both soda and syrup line.



Figure 3.3 Flow sensor Sea YF-S401 (Source: Internet)

Design and manufacture of a fresh Coca-Cola dispensing machine

- Operating voltage: 3.5 – 12VDC
- Consumption current: 15mA
- Output signal: using hall effect, pulse output signal.
- Operating temperature: <80 degrees C
- Maximum pressure: 1.75Mpa
- Flow rate: 0.3 – 6 L/1 minute

3.2.1.3. Pressure relay

For safety and control of the working principle of the carbonator, we use pressure relay, which is similar to some electrical relay but using pressure instead. Wiring diagram will be mentioned in section 3.3. We use pressure relay HS-210 for the machine.



Figure 3.4 Pressure sensor HS-210 (Source: Internet)

- Working pressure: 0 to 10 bar
- Diff: 1 to 4 bars
- Reset type: Auto (Single pressure switch)
- Switch type: ON/OFF, SPDT
- Working temperature: -10 to 120 degrees C

3.2.1.4. Water level switch

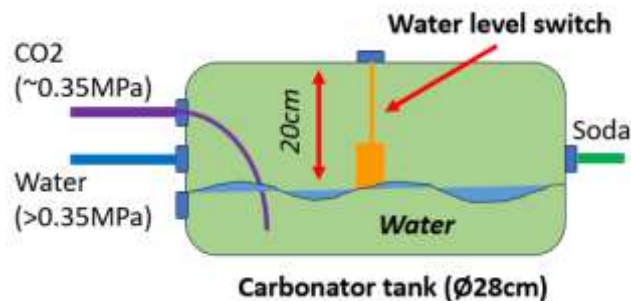


Figure 3.5 Carbonator tank simplifies

Figure 3.5 shows the simple structure of the machine's carbonator. The mixing tank diameter is 280mm, the water volume is 1/3 of the tank and the remaining 1/3 to 2/3 of the capacity is for CO₂ gas (head pressure). Based on the design requirements, the float length is determined to be 20 cm with an ON/OFF water level. The selected component is the CTP15010 float switch, featuring a 15 cm height.

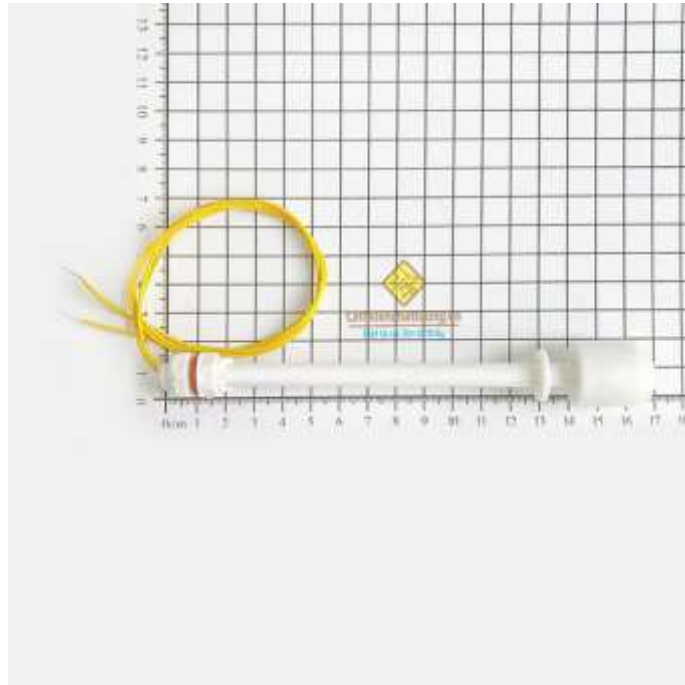


Figure 3.6 CTP15010 water level sensor float switch (Source: Internet)

3.2.1.5. High pressure and low pressure water switch

In a reverse osmosis (RO) water filtration system, both low-pressure (LP) and high-pressure (HP) valves play critical roles in ensuring safe operation for the RO pump and efficient for the system. The low-pressure valve is typically installed before the booster pump and serves as a protective mechanism to shut off the system in case of insufficient inlet water pressure, thereby preventing pump damage due to dry run. Conversely, the high-pressure valve is located after the RO membrane and is responsible for maintaining optimal pressure within the membrane housing, as well as activating system shutdown when the storage tank reaches full pressure.



Figure 3.7 High-pressure water switch (left) and low-pressure water switch (right)

(Source: Internet)

3.2.1.6. Relay

For back room, relays are main electrical devices used to switch on and off in control logic schematic. Relays are often used to carry intermediate loads with different load line (220V) for the actuator, which 24V relay input is suitable for the back room working principle.



Figure 3.8 24VDC Relay (Source: Internet)

Identical for front end, relays are main electrical devices used to control actuator. We use button 5V connect to control 24V actuator, so we using 5V Relay.



Figure 3.9 5VDC Relay (Source: Internet)

3.2.1.7. Solenoid valve

The solenoid valve is used to control the flow of both water and CO₂ gas within the machine. Its working principle is based on an electromagnetic coil: when electrical power (24VDC) is supplied, the valve opens to allow the fluid (liquid or gas) to pass through. The valve operates unidirectionally, which simplifies the control mechanism and enables seamless integration into both the back room and front-end systems.



Figure 3.10 Solenoid valve for water and pneumatic (Source: Internet)

3.2.2. Microcontroller selection

Since the working environment is not affected by interference from other machines and does not require heavy operating mechanisms, using a PLC is unnecessary. Therefore, a microcontroller is used as the main processing unit, handling all signals centrally.

The Arduino Mega 2560 is chosen to fulfill the requirements, with its I/O pins connecting to the sensor pins, travel switch pins, and motor control pins (25 input pins, including 9 pins for 3 motors, 7 pins for pneumatic valves, and 9 pins for proximity sensors). The advantages of selecting Arduino over STM32 and PIC16F877A include



Figure 3.11 Arduino MEGA 2560 (Source: Internet)

- Large number of I/O pins, allowing connection and control of multiple devices.
- Ample memory for storing program code and data.
- Support for open-source code and large community, facilitating easy development and application expansion.
- Affordable cost.

3.2.3. Interface

The interface control of the machine through the front panel via 8 buttons and an LCD to show the . These buttons are: “Soda” – “Coca” (Type of drink); “Small” – “Medium” – “Large” (Size of serving); “Set” – “Up” – “Down”.

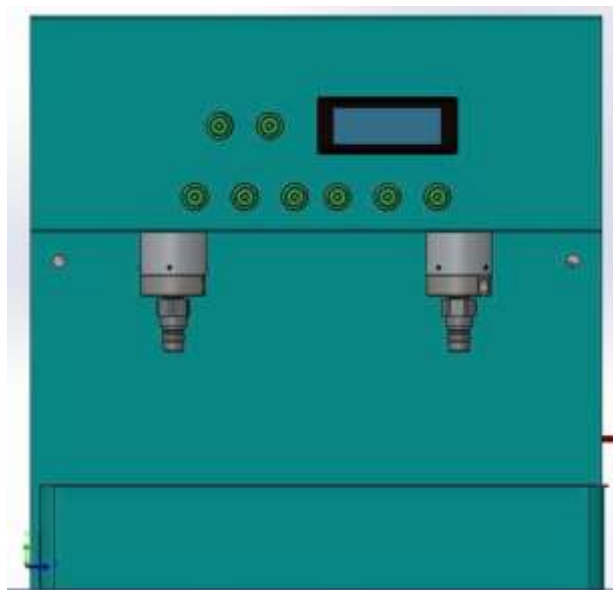


Figure 3.12 Front panel with button

For this we use push button and a 20x4 LCD screen for this interface

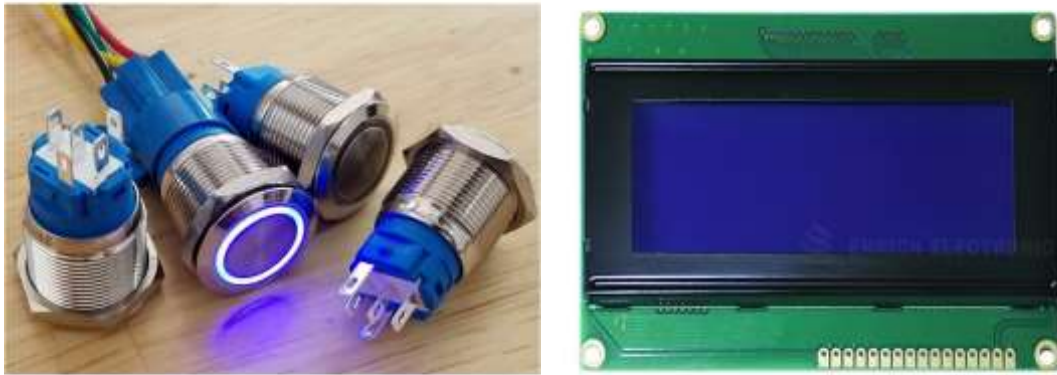


Figure 3.13 Push button (left) and 20x4 LCD screen (right) (Source: Internet)

3.2.4. Power supply selection

Figure 3.14 shows the voltage range of all the actuator and sensor, including:

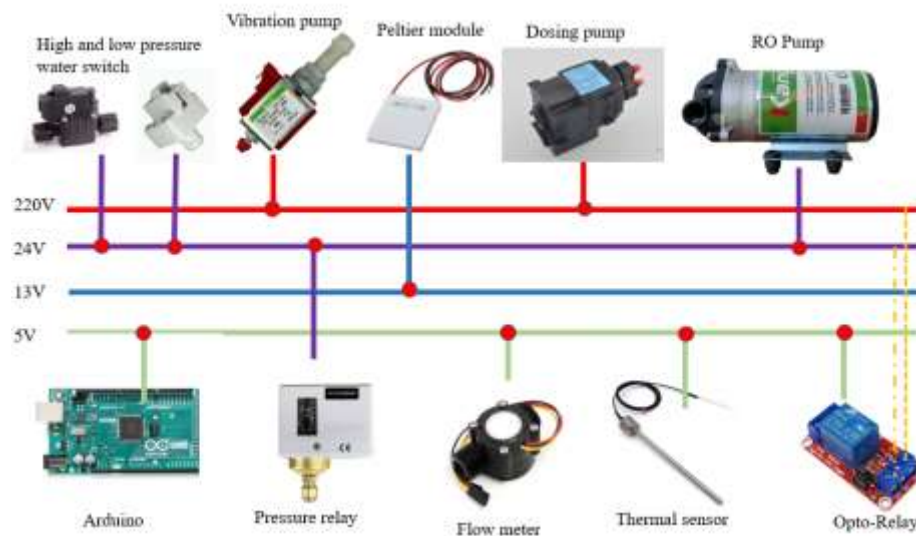


Figure 3.14 Power line for the actuator and sensor

- All water valve, RO pump, water level sensor and pressure relay are using 24VDC line. There are 2 pumps 24x0.22A.
- Vibration pump and dosing pump are using 220V AC 50Hz line
- The Arduino microcontroller is powered by a 5-12 VDC (voltage reduction circuit from 24V)

- Peltier module is powered by a 2-18 VDC line. Take 13Vx4.5A for reference.
- Flowmeter and thermal sensor are powered by 5 VDC
- Control from Arduino to the 220V and 24V line is 5V through an opto-relay module.

Based on the provided specifications, a 24V-10A power supply is used for the DC line. AC line is connect with the main grid that take into the adapter. Voltage reduction circuit is adjusted for the Arduino (7 VDC) and Peltier module (13 VDC). The 5V output is provided by Arduino.

3.3. Circuit design

3.3.1. Back room wiring diagram

3.3.1.1. Power circuit diagram

For Back-room part, there are RO pump (Pump#1) and inlet CO₂ gas, both control via solenoid 24VDC to control. Pump#2 is vibration pump, which using 220 VAC so it need a relay to control via 24V relay, as mentioned in section 3.2.

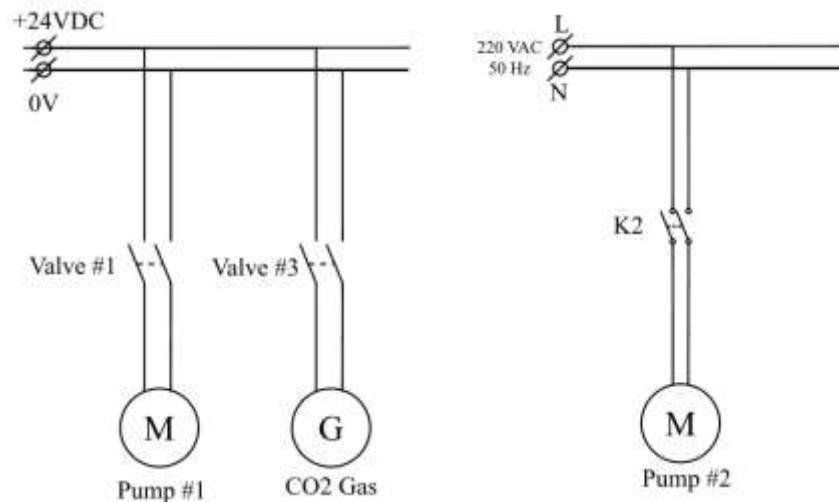


Figure 3.15 Power circuit of back room

3.3.1.2. Wiring diagram

This system consists of two independently operating sections that do not affect each other. The RO water filtration system (Figure 3.16) functions separately from the carbonator unit (Figure 3.17). Both systems operate on a 24V DC power supply. Figure 3.18 shows the actual wiring inside the electrical box.

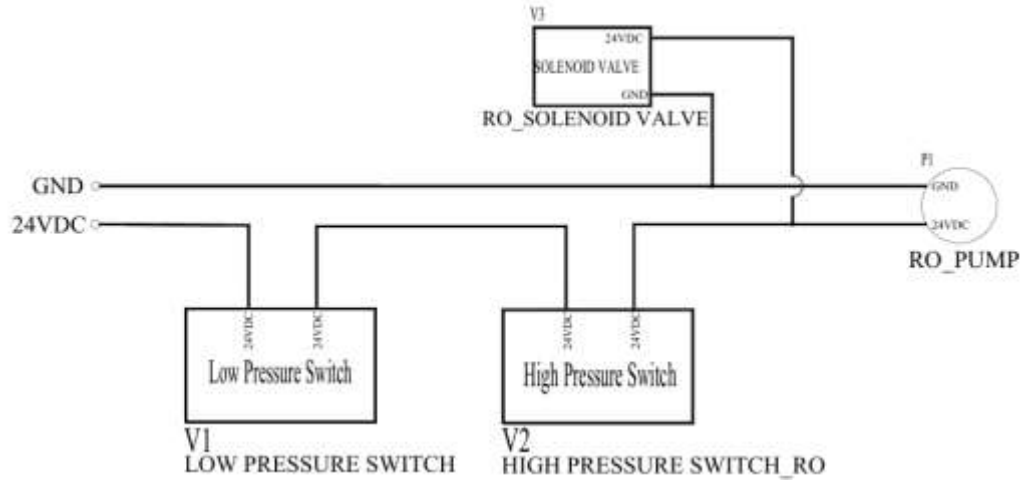


Figure 3.16 Wiring diagram of RO water filter

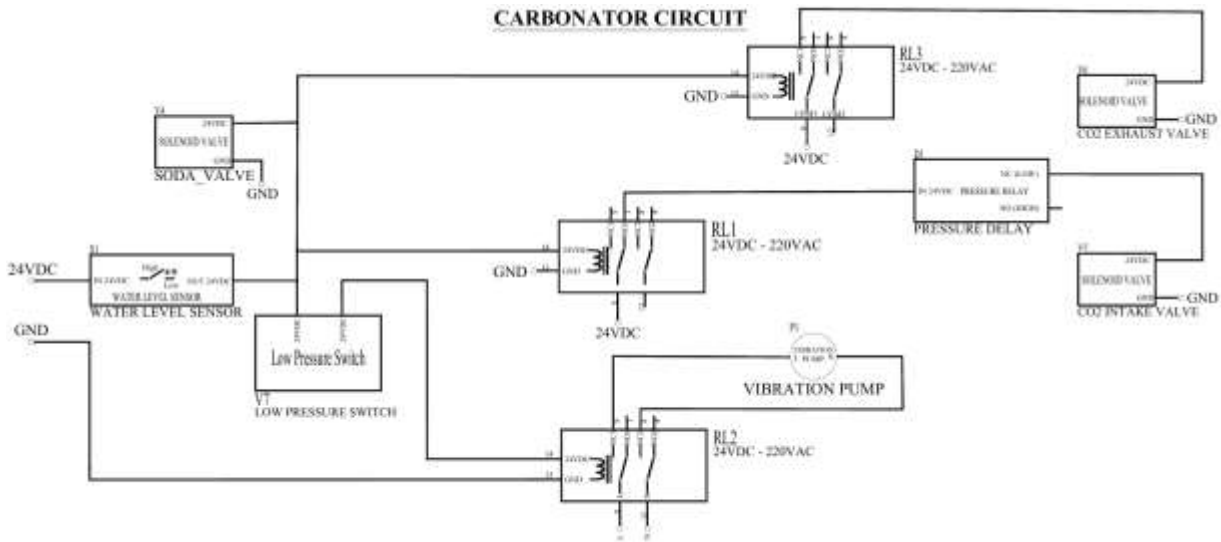


Figure 3.17 Wiring diagram of carbonator



Figure 3.18 Electrical box of the machine

3.3.2. Front end wiring diagram

3.3.2.1. Electrical principle diagram

After selecting all the sensor, actuator, microcontroller and the material for the interface control, we use Proteus to make an circuit diagram for the Front end, focusing on button (input) to control the relay.

Design and manufacture of a fresh Coca-Cola dispensing machine

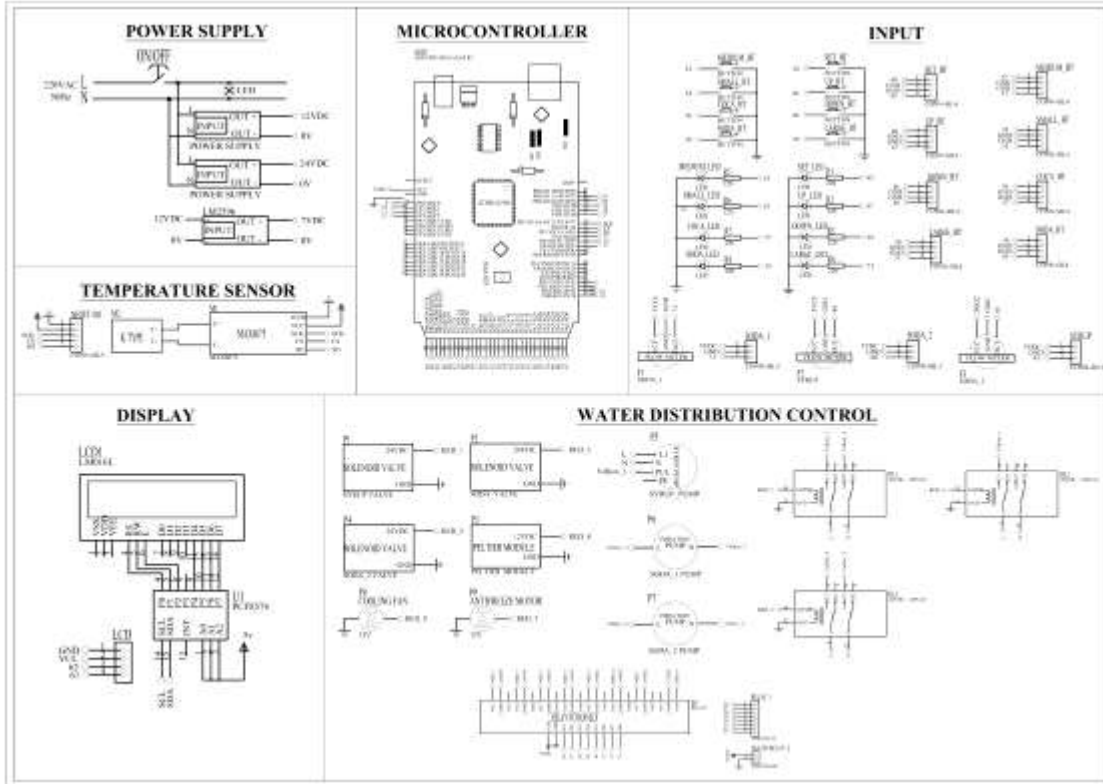


Figure 3.19 Proteus circuit diagram

3.3.2.2. PCB Layout

Completed the Proteus circuit diagram, we make an PCB layout for it and manufacture. All the input, sensor have the power line connect into group which is optimized for the cable plugin

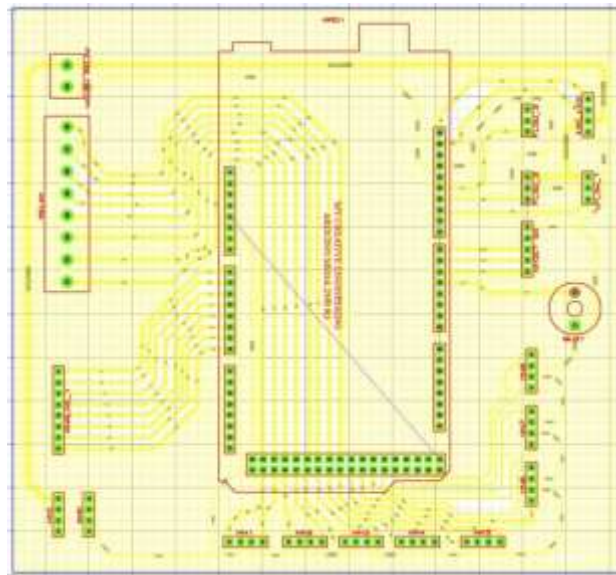


Figure 3.20 PCB layout in Proteus

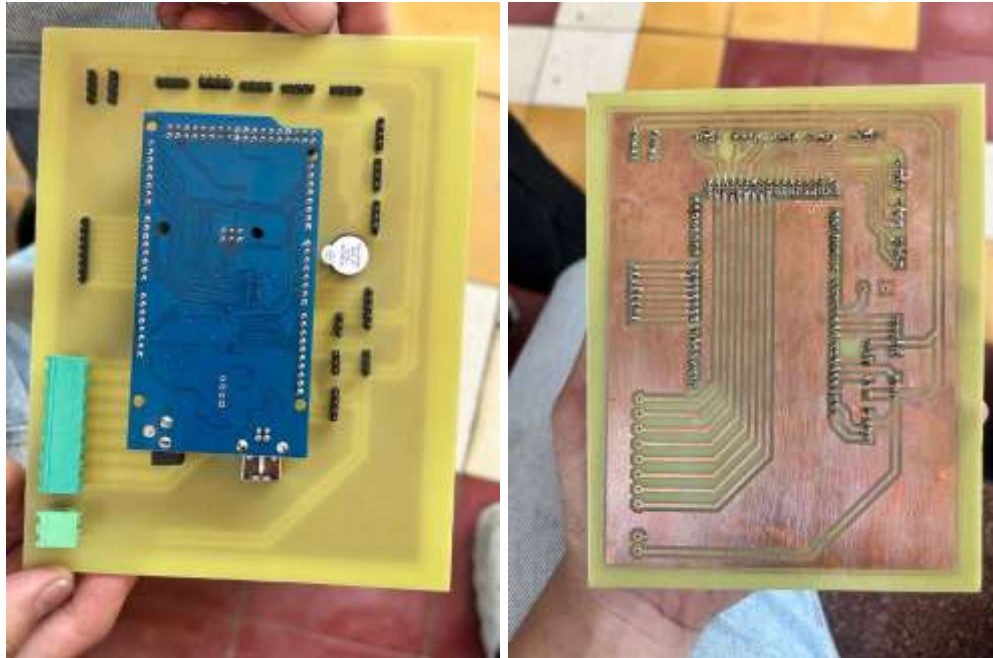


Figure 3.21 PCB in production

3.4. Control system

The machine has 2 parts: Backroom, controlled by a logical setup, and Front ends, controlled in a centralized processing manner, where the microcontroller controls all tasks without relying on external control communications for sequential control. The algorithm flowchart is also built on 2 parts. For Front end, the basis of centralized control, divided into subprograms, with external interrupts used at functional checkpoints as well as travel switches.

3.4.1. Control schematic of Back room

Figure 3.22 shows the working schematic of back room, rely on the water level switch, water pressure switch, pressure relay and some other valve, relay. K1, K2 and K3 are relays, PS is pressure switch, LS is water level switch.

PSL01 and PSH01 with Valve #1 is schematic of RO water filter, doesn't affected by the carbonator. When there is no inlet water filter and the water inside the membrane tank is full, the Vavle#1 shut the Pump#1 down and block the inlet water

Carbonator is mainly controlled by LS. When the water inside carbonator isn't full, it check if there is outlet water for water filter and active the K1 and K2 relay. K1 turn on the relief valve for air come out of the tank and K2 turn on vibration pump and pump water inside the carbonator.

When level inside the carbonator is full, it shut off all the inlet water inside the carbonator, ready to carbonating by block the relief valve and open the CO2 gas by Valve#3

inside the tank. When the pressure inside the tank is at target, the Valve#3 shut off and block the CO2 get into the carbonator tank.

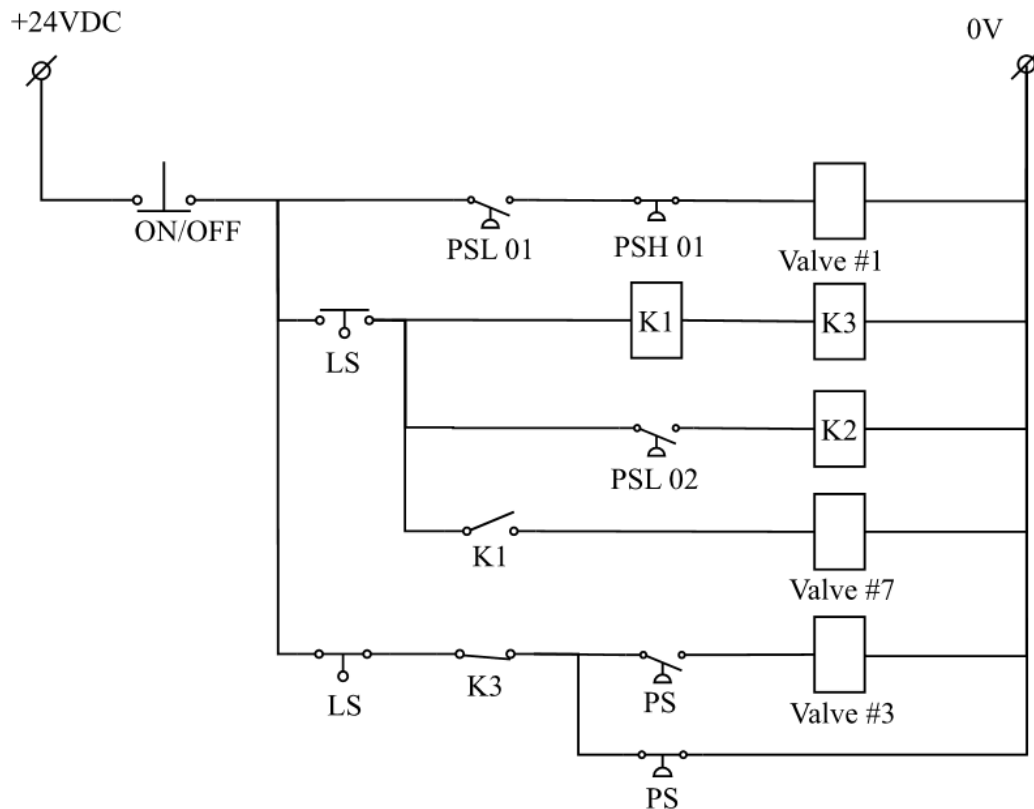


Figure 3.22 Control schematic of Backroom

3.4.2. Flowchart of Front end

3.4.2.1. Main program

The primary function revolves around receiving the external push-button input and controlling the dispensing process. Specifically, after updating the information on the LCD screen, the program sequentially continues from the push-button subroutine, the valve control subroutine, and finally the completion subroutine. During this process, the flowmeter is monitored directly within the main loop. Additionally, the loop checks the "SET" button to cancel the ongoing operation.

MAIN PROGRAM

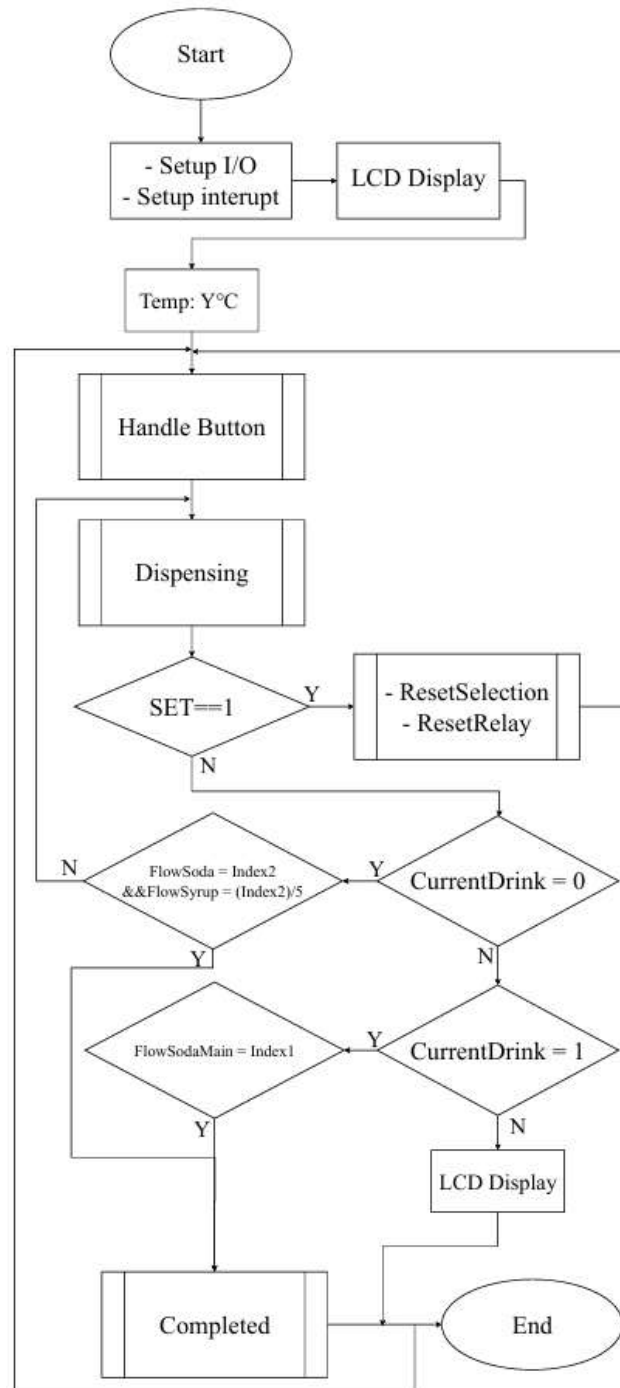


Figure 3.23 Main program flowchart

3.4.2.2. Handle button sub-program

This sub-program checks the push buttons on the front end. Specifically, Index1 selects the type of beverage: (0 for Coca-Cola, 1 for Soda). Index2 determines the volume

of the drink, referred to as the cup size, with options (2 for Small, 3 for Medium, 4 for Large). The "SET" button remains active during the beverage selection process; if an incorrect choice is made, pressing "SET" allows the user to reselect the desired beverage.

HANDLE BUTTON SUB-PROGRAM

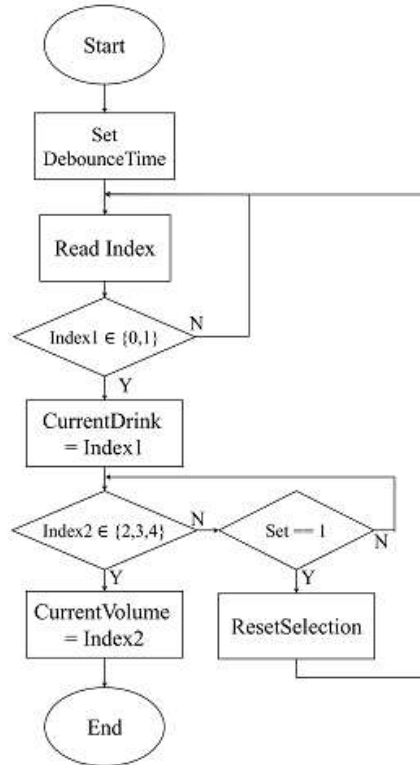


Figure 3.24 Handle button sub-program flowchart

3.4.2.3. Dispensing sub-program

This sub-program is the actuator control of the Front end. It reads the Index values from the push buttons, subsequently updating the LCD and activating the flowmeter, syrup pump, and the water valves through relay. Specifically, the SodaMainValve controls the soda line outlet, while the SodaValve manages the water mixed with syrup from the SyrupValve.

DISPENSING SUB-PROGRAM

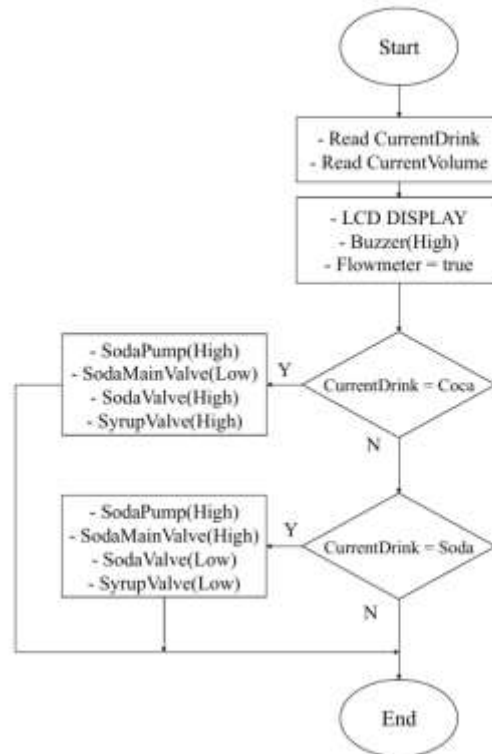


Figure 3.25 Dispensing sub-program flowchart

3.4.2.3. Reset sub-program

Reset sub-program is used to reset all the variable, parameter and valve. This is mainly use for “SET” button (if there is something wrong) and Completed sub-program (if the dispensing process is completed).

OTHER SUB-DIAGRAM

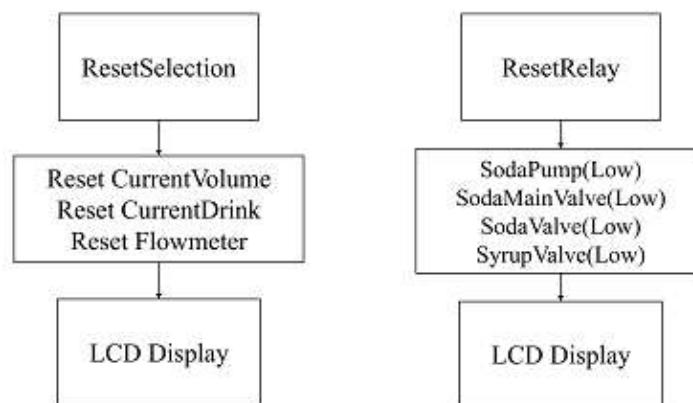


Figure 3.26 Dispensing sub-program flowchart

3.4.2.4. Completed sub-program

Completed sub-program is used to notify the user that the process is complete. It turn on the buzzer, update the LCD display and reset all the variable, parameters of the machine and ready for a new serving.

COMPLETED SUB-DIAGRAM

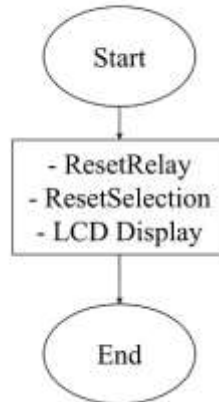


Figure 3.27 Dispensing sub-program flowchart

CHAPTER 4: CONCLUSION

4.1. Result

After completing the mechanical design and fabrication process, we finalized the machine to tests to evaluate the system's performance and reliability. Figure 4.1 shows the final assembly of the machine. Figure 4.2 shows the results of dispensing soda and Coca-Cola. Figure 4.3 shows the close-up of CO2 inside the soda.



Figure 4.1 Final assembly of the machine



Figure 4.2 Result of the machine is Coca-Coca (left) and Soda (right)



Figure 4.3 CO2 inside the soda bubbling

After several tests and compared to the requirements in Section 1.5, we made a Table 4.1 to show the results. Overall, the machine is kind of fulfilling the criteria of the working requirements, but there are also some disadvantages of the system that we will mention in section 4.2.

Table 4.1. Evaluation table

Criteria	Results	Fulfill	Note
Maximum dimension (L × W × H): 100 × 75 × 170 cm	69 × 51 × 125 cm	Fulfill the requirement	
Dispensing nozzles pressure: 2.5 - 4 bar	1.5 - 2bar	80%	When the air inside the carbonator tank is reduce, the pressure is getting lower than 2 bar but still pump out
Soda temperature: 2°C – 7°C	10°C	70%	Affected by the small copper line into the chiller tank
Dispensing flow rate: 0.5 – 2 LPM	0.5 - 0.8 LPM	Fulfill the requirement	When the air inside the carbonator tank is reduce, the flowrate is reduce but not so much thanks to the Pump#3
Soda volume in the tank: At least 3L	1L	35%	There are at least 3L inside the carbonator tank, but due to the level sensor working principle, after 1L of soda the machine has to fill up 1L again.

4.2. Problem

Overall, the system operates stably; however, several issues have been identified:

- System vibration occurs due to the operation of the pulsation pump, which causes resonance.
- Relay, valve causing noise affects the controller and the sensor
- Water levels have only ON/OFF function, causing inlet carbonator has to be pumped into equal to outlet carbonator
- The pressure relay occasionally responds sluggishly, likely due to the slow return action of its internal spring mechanism.
- Cooling efficiency is affected by the pipe layout.

The corresponding solutions to the issues mentioned are as follows:

Design and manufacture of a fresh Coca-Cola dispensing machine

- Vibration pump need to be installed rubber vibration isolators or flexible mounting brackets at the pump base to minimize the transmission of oscillations to the frame.
- Isolate the cause of noise out of the devices
- Using water level stick/sensor that have multiple working stage
- Replace the existing pressure relay with a model equipped with a faster-return spring mechanism to improve response time.
- Using stack-Peltier-module for higher efficiency

4.3. Future developments

Currently, the machine operates as two independent subsystems with no interconnection between them. Additionally, there is no external control or monitoring mechanism integrated into the system. As such, the future development of this machine will largely depend on improvements in these aspect:

- Connect the backroom to the frontend with sensor (water lever sensor, pressure sensor, water flow sensor... feedback to the controller).
- Control the machine using GUI, HMI or apply IoT into the machine to interact with
- Expand the syrup nozzle into 4 or 5 more drinks without expanding to much the size of the machine

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APPENDIX

Arduino code:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include "max6675.h"
LiquidCrystal_I2C lcd(0x27, 20, 4);
// Cấu trúc nút nhấn
struct Button {
    int pin;
    int ledPin;
    bool lastState;
    bool pressed;
    unsigned long lastDebounceTime;
};
// Khai báo chân
const int sodaLed = 23;
const int sodaPin = 25;
const int cocaLed = 27;
const int cocaPin = 29;
const int smallLed = 31;
const int smallPin = 33;
const int mediumLed = 35;
const int mediumPin = 37;
const int largeLed = 39;
const int largePin = 41;
const int setLed = 51;
const int setPin = 53;
```

```
const int buzzerPin = 4;
const int sodaPump = 52;
const int syrupPump = 50;
const int soda1Valve = 48; // flow1 (Soda)
const int syrupValve = 44; // flow2 (Syrup)
const int soda2Valve = 46; // flow3 (Soda)
// Cấu hình cảm biến lưu lượng
const float calibrationFactor = 4.5; // 4.5 pulses per second per litre/minute
// Biến flow meter với volatile
volatile unsigned long pulseCount1 = 0; // Flow1 (Soda)
volatile unsigned long pulseCount2 = 0; // Flow2 (Syrup)
volatile unsigned long pulseCount3 = 0; // Flow3 (Soda)
// Biến lưu lượng
float flowRate1 = 0.0;
float flowRate2 = 0.0;
float flowRate3 = 0.0;
unsigned int flowMilliLitres1 = 0;
unsigned int flowMilliLitres2 = 0;
unsigned int flowMilliLitres3 = 0;
unsigned long totalMilliLitres1 = 0;
unsigned long totalMilliLitres2 = 0;
unsigned long totalMilliLitres3 = 0;
unsigned long currentTime;
unsigned long lastFlowCalcTime = 0;
bool measuring = false;
unsigned int targetVolume = 0;
unsigned long startMeasuringTime = 0;
// Khai báo kích thước nước
const unsigned int targetVolumeSmall = 360;
const unsigned int targetVolumeMedium = 450;
```

```

const unsigned int targetVolumeLarge = 700;

Button buttons[] = {
    {sodaPin, sodaLed, HIGH, false, 0},
    {cocaPin, cocaLed, HIGH, false, 0},
    {smallPin, smallLed, HIGH, false, 0},
    {mediumPin, mediumLed, HIGH, false, 0},
    {largePin, largeLed, HIGH, false, 0},
    {setPin, setLed, HIGH, false, 0}
};

const unsigned long debounceDelay = 50;
const int buttonCount = sizeof(buttons) / sizeof(buttons[0]);
String currentDrink = "None";
String currentSize = "None";
// Khai báo chân cho cảm biến nhiệt độ
const int thermoSO = 5; // Serial Out
const int thermoCS = 6; // Chip Select
const int thermoCLK = 7; // Serial Clock
// Khởi tạo đối tượng nhiệt kế
MAX6675 thermocouple(thermoCLK, thermoCS, thermoSO);
// ===== HÀM NGẮT CHO FLOW METER =====
void pulseCounter1() {
    static unsigned long lastIntTime = 0;
    unsigned long now = millis();
    if (now - lastIntTime > 10) { // Debounce 10ms
        pulseCount1++;
        lastIntTime = now;
    }
}

void pulseCounter2() {

```

```

static unsigned long lastIntTime = 0;
unsigned long now = millis();
if (now - lastIntTime > 10) {
    pulseCount2++;
    lastIntTime = now;
}
}

void pulseCounter3() {
    static unsigned long lastIntTime = 0;
    unsigned long now = millis();
    if (now - lastIntTime > 10) {
        pulseCount3++;
        lastIntTime = now;
    }
}

void setup() {
    pinMode(buzzerPin, OUTPUT);
    digitalWrite(buzzerPin, LOW);
    Serial.begin(9600);
    lcd.begin();
    lcd.backlight();
    // Khởi tạo cảm biến nhiệt độ
    delay(500); // Đợi cảm biến ổn định
    Serial.println("MAX6675 init");
    // Khởi tạo relay
    pinMode(sodaPump, OUTPUT);
    pinMode(syrupPump, OUTPUT);
    pinMode(soda1Valve, OUTPUT);
    pinMode(soda2Valve, OUTPUT);
    pinMode(syrupValve, OUTPUT);
}

```

```

resetRelays();

// Khởi tạo nút nhấn
for (int i = 0; i < buttonCount; i++) {
    pinMode(buttons[i].pin, INPUT_PULLUP);
    pinMode(buttons[i].ledPin, OUTPUT);
    digitalWrite(buttons[i].ledPin, LOW);
}

// Thiết lập ngắt cho flow meter
pinMode(2, INPUT_PULLUP); // Soda1 (chân 2)
pinMode(18, INPUT_PULLUP); // Syrup (chân 18)
pinMode(19, INPUT_PULLUP); // Soda2 (chân 19)
attachInterrupt(digitalPinToInterrupt(2), pulseCounter1, FALLING);
attachInterrupt(digitalPinToInterrupt(18), pulseCounter2, FALLING);
attachInterrupt(digitalPinToInterrupt(19), pulseCounter3, FALLING);
updateLCD();
Serial.println("Hệ thống sẵn sàng");
}

void loop() {
    currentTime = millis();
    // Đọc và hiển thị nhiệt độ mỗi giây
    static unsigned long lastTempUpdate = 0;
    if (currentTime - lastTempUpdate >= 1000) {
        updateLCD(); // Cập nhật LCD với nhiệt độ mới
        lastTempUpdate = currentTime;
        // Debug nhiệt độ qua Serial
        float temperature = thermocouple.readCelsius();
        if (isnan(temperature)) {
            Serial.println("Thermocouple error!");
        } else {

```

```

Serial.print("Temperature: ");
Serial.print(temperature);
Serial.println(" °C");
}
}
// Kiểm tra trạng thái nút nhấn
for (int i = 0; i < buttonCount; i++) {
  bool reading = digitalRead(buttons[i].pin);
  if (reading != buttons[i].lastState) {
    buttons[i].lastDebounceTime = millis();
  }
  if ((millis() - buttons[i].lastDebounceTime) > debounceDelay) {
    if (reading == LOW && !buttons[i].pressed) {
      buttons[i].pressed = true;
      if (measuring && i == 5) { // Nếu đang pha và nhấn nút Set
        resetSelection();
      }
      else if (!measuring) {
        handleButtonPress(i);
      }
    }
    if (reading == HIGH && buttons[i].pressed) {
      buttons[i].pressed = false;
    }
  }
  buttons[i].lastState = reading;
}
// Xử lý đo lưu lượng
if (measuring) {
  // Tính toán lưu lượng mỗi giây

```

```

if (currentTime - lastFlowCalcTime >= 1000) {
    // Tạm ngưng ngắt để đọc giá trị
    noInterrupts();
    // Tính toán lưu lượng cho từng cảm biến
    flowRate1 = ((1000.0 / (currentTime - lastFlowCalcTime)) * pulseCount1) /
calibrationFactor;
    flowRate2 = ((1000.0 / (currentTime - lastFlowCalcTime)) * pulseCount2) /
calibrationFactor;
    flowRate3 = ((1000.0 / (currentTime - lastFlowCalcTime)) * pulseCount3) /
calibrationFactor;
    // Tính lượng nước chảy qua (mL)
    flowMilliLitres1 = (flowRate1 / 60) * 1000;
    flowMilliLitres2 = (flowRate2 / 60) * 1000;
    flowMilliLitres3 = (flowRate3 / 60) * 1000;
    // Cộng dồn vào tổng
    totalMilliLitres1 += flowMilliLitres1;
    totalMilliLitres2 += flowMilliLitres2;
    totalMilliLitres3 += flowMilliLitres3;
    // Reset bộ đếm xung
    pulseCount1 = 0;
    pulseCount2 = 0;
    pulseCount3 = 0;
    // Cho phép ngắt lại
    interrupts();
    // Cập nhật thời gian
    lastFlowCalcTime = currentTime;
    // Hiển thị thông tin lên Serial
    Serial.print("Flow1: ");
    Serial.print(flowRate1, 2);
    Serial.print(" L/min (");
    Serial.print(totalMilliLitres1);

```

```

Serial.print(" mL) | Flow2: ");
Serial.print(flowRate2, 2);
Serial.print(" L/min (");
Serial.print(totalMilliLitres2);
Serial.print(" mL) | Flow3: ");
Serial.print(flowRate3, 2);
Serial.print(" L/min (");
Serial.print(totalMilliLitres3);
Serial.println(" mL");
// In trạng thái relay mỗi giây khi đang pha
printRelayStatus();
}
// Kiểm tra hoàn thành pha chế
if (currentDrink == "Coca") {
    // Chỉ kiểm tra soda2 (thay vì soda1) và syrup
    if (totalMilliLitres3 >= targetVolume && totalMilliLitres2 >= targetVolume/5) {
        completeDispensing();
    }
}
else if (currentDrink == "Soda") {
    if (totalMilliLitres1 >= targetVolume) {
        completeDispensing();
    }
}
// Kiểm tra cảnh báo sau 8s
// if (currentTime - startMeasuringTime > 20000) {
//   if (currentDrink == "Coca") {
//     if (mL1 < 10) alertLowWater("HET SODA!");
//     else if (mL2 < 2) alertLowWater("HET SYRUP!");
//   }
}

```

```

// else if (currentDrink == "Soda") {
//   if (mL1 < 10) alertLowWater("HET SODA!");
// }
// }
}
}

void handleButtonPress(int index) {
  Serial.print("Button pressed: ");
  Serial.println(index);
  // Nếu chọn nước
  if (index == 0 || index == 1) {
    digitalWrite(buttons[0].ledPin, LOW);
    digitalWrite(buttons[1].ledPin, LOW);
    digitalWrite(buttons[index].ledPin, HIGH);
    currentDrink = (index == 0) ? "Soda" : "Coca";
    // Reset kích thước khi chọn nước mới
    currentSize = "None";
    for (int i = 2; i <= 4; i++) {
      digitalWrite(buttons[i].ledPin, LOW);
    }
  }
  // Nếu chọn kích thước
  if (index >= 2 && index <= 4) {
    if (currentDrink != "None") {
      for (int i = 2; i <= 4; i++) {
        digitalWrite(buttons[i].ledPin, LOW);
      }
      digitalWrite(buttons[index].ledPin, HIGH);
      currentSize = (index == 2) ? "Small" : (index == 3) ? "Medium" : "Large";
    }
    // Đặt thẻ tích mục tiêu

```

```

    if (currentSize == "Small") targetVolume = targetVolumeSmall;
    else if (currentSize == "Medium") targetVolume = targetVolumeMedium;
    else if (currentSize == "Large") targetVolume = targetVolumeLarge;
    confirmAndDispense();
  }
}
// Reset tất cả lựa chọn khi nhấn nút Set
if (index == 5) {
  resetSelection();
  resetRelays();
}
updateLCD();
}
void confirmAndDispense() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Dang pha ");
  lcd.print(currentDrink);
  lcd.setCursor(0, 1);
  lcd.print("Size: ");
  lcd.print(currentSize);
  Serial.println("Dang tien hanh pha nuoc...");
  // Buzzer kêu trong 500ms để xác nhận pha
  digitalWrite(buzzerPin, HIGH);
  delay(500);
  digitalWrite(buzzerPin, LOW);
  // Bắt đầu bơm
  startPumping();
  // Bắt đầu đo lưu lượng
  measuring = true;

```

```

startMeasuringTime = millis();
// Hiển thị trạng thái
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Dang pha nuoc...");
lcd.setCursor(0, 1);
lcd.print(currentDrink);
lcd.setCursor(0, 2);
lcd.print(currentSize);
}
void startPumping() {
  resetVolume();
  lastFlowCalcTime = millis();
  if (currentDrink == "Coca") {
    digitalWrite(sodaPump, HIGH);
    digitalWrite(syrupPump, HIGH);
    digitalWrite(soda1Valve, LOW); // Tắt valve soda1
    digitalWrite(soda2Valve, HIGH); // Bật valve soda2
    digitalWrite(syrupValve, HIGH); // Bật valve syrup
    Serial.println("Bật relay: Coca mode (dùng soda2Valve)");
  }
  else if (currentDrink == "Soda") {
    digitalWrite(sodaPump, HIGH);
    digitalWrite(soda1Valve, HIGH); // Bật valve soda1
    digitalWrite(soda2Valve, LOW); // Tắt valve soda2
    digitalWrite(syrupValve, LOW); // Tắt valve syrup
    digitalWrite(syrupPump, LOW); // Tắt pump syrup
    Serial.println("Bật relay: Soda mode (dùng soda1Valve)");
  }
  printRelayStatus();
}

```

```

}
void completeDispensing() {
  resetRelays();
  resetVolume();
  measuring = false;
  Serial.println("Hoàn thành pha chế");

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Hoan thanh!");
  // Buzzer thông báo hoàn thành
  for (int i = 0; i < 2; i++) {
    digitalWrite(buzzerPin, HIGH);
    delay(300);
    digitalWrite(buzzerPin, LOW);
    delay(300);
  }
  delay(1500);
  resetSelection();
}

void resetVolume() {
  totalMilliLitres1 = 0;
  totalMilliLitres2 = 0;
  totalMilliLitres3 = 0;
  flowMilliLitres1 = 0;
  flowMilliLitres2 = 0;
  flowMilliLitres3 = 0;
  pulseCount1 = 0;
  pulseCount2 = 0;
  pulseCount3 = 0;
}

```

```

}
void resetRelays() {
    digitalWrite(sodaPump, LOW);
    digitalWrite(syrupPump, LOW);
    digitalWrite(soda1Valve, LOW);
    digitalWrite(soda2Valve, LOW);
    digitalWrite(syrupValve, LOW);
    Serial.println("Tất tất cả relay");
    printRelayStatus();
}
void printRelayStatus() {
    Serial.print("Relay Status: ");
    Serial.print("SodaPump=");
    Serial.print(digitalRead(sodaPump));
    Serial.print(", Soda1Valve=");
    Serial.print(digitalRead(soda1Valve));
    Serial.print(", Soda2Valve=");
    Serial.print(digitalRead(soda2Valve));
    Serial.print(", SyrupPump=");
    Serial.println(digitalRead(syrupPump));
}
void resetSelection() {
    for (int i = 0; i < buttonCount; i++) {
        digitalWrite(buttons[i].ledPin, LOW);
    }
    currentDrink = "None";
    currentSize = "None";
    resetVolume();
    measuring = false;
    updateLCD();
}

```

```

}
void alertLowWater(String message) {
  resetRelays();
  measuring = false;
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("CANH BAO!");
  lcd.setCursor(0, 1);
  lcd.print(message);
  // Buzzer cảnh báo
  for (int i = 0; i < 5; i++) {
    digitalWrite(buzzerPin, HIGH);
    delay(200);
    digitalWrite(buzzerPin, LOW);
    delay(200);
  }
  // Chờ nhấn nút Set
  while (digitalRead(setPin) == HIGH) {
    delay(100);
  }
  resetSelection();
}

void updateLCD() {
  float temperature = thermocouple.readCelsius(); // Đọc nhiệt độ
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Nuoc: ");
  lcd.print(currentDrink);
  lcd.setCursor(0, 1);
  lcd.print("Size: ");
}

```

```
lcd.print(currentSize);
lcd.setCursor(0, 2);
lcd.print("Nhiệt độ: ");
if (isnan(temperature)) {
  lcd.print("Error"); // Hiện thị lỗi nếu không đọc được
} else {
  lcd.print(temperature, 1); // Hiện thị 1 số thập phân
  lcd.print((char)223);
  lcd.print("C");
}
}
```