ULK POLYTECHNIC INSTITUTE UPI

P.O.Box .2280 KIGALI
Website ://www.ulkpolytechnic.ac.rw
Email : polytechnic.institute@ulk.ac.rw

DEPARTEMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
OPTION: ELECTRONICS AND TELECOMMUNICATION TECHNOLOGY

PROJECT NAME: DESIGN AND IMPLEMENTATION OF OPTIMIZED BEVERAGE FILLING SYSTEM WITH ARDUINO-BASED PRECISION MEASUREMENT

CASE STUDY: Jus Royale at BUKAVU

Research project submitted in partial fulfillment of the requirement for an award of the Advanced Diploma in Electronics and Telecommunication Technology

Submitted By: MUTATWA DANIEL
ROLL NUMBER: 202150050

Supervisor: **Eng.KARANGWA Augustin**

Kigali, September 2024

DECLARATION A

I, **MUTATWA Daniel** declare that this research study is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Learning". No part of this research should be reproduced without the authors' consent or that of ULK Polytechnic Institute.

Student name: MUTATWA Daniel

Sign: ______________________________ Date: ___________________

DECLARATION B

I, **Eng. AUGUSTIN Karangwa** confirm that the work reported in this research project, was carried out by the candidate under my Supervision and it has been submitted with my approval as the UPI supervisor.

Name Supervisor: Eng .Karangwa Augustin

Sign: ………………………………………….

Date: ………/ ……/2024

DEDICATION

I dedicate this final year of study to the Almighty and Eternal God for His unwavering guidance and blessings.

To my beloved grandmother, **Faida Buhendwa Apoline**, your love and prayers have been my source of inspiration and strength.

To my loving parents, **Mutatwa Ngungu Jules** and **Deborah Muderwa Brigitte**, your endless support and belief in me have made this achievement possible.

To all my brothers and sisters, your camaraderie and encouragement have been invaluable throughout my study.

To my esteemed supervisor, your guidance and patience have been instrumental in my academic development.

To all my lecturers, your dedication to teaching has greatly enriched my educational experience.

To my colleagues and friends, your support and companionship have been essential.

This achievement is a testament to the collective effort, love, and support from all of you during my study. I am profoundly grateful for your presence in my life. Thank you for helping me reach this milestone.

ACKNOWLEDGEMENT

I extend the desire of my heart to thank more than enough those who have mainly contributed to the successful completion of this research project.

Most importantly, I thank and appreciate the Almighty Everlasting God for displaying and teaching me His utmost guidance, blessings, and strength along the way.

I appreciate and thank my very dear grandmother, **Mrs. Faida Buhendwa Apoline**, for the support, unconditional love, and her emotional support.

I would like to express my indebtedness to my parents, **MUTATWA NGUNGU Jules** and **Deborah Muderwa Brigitte**, with honest appreciation for their undivided support, encouragement, and belief in my potential. You made sacrifices and showed me how to learn and be able to carve a successful professional path.

Many thanks go to my supervisor, **Eng. KARANGWA Augustin**, whose expertise, guidance, and patience were instrumental in my academic development. Great thanks also go to you, my mentor in this research.
I would like to thank my instructors for their being dedicated to the teaching profession and always making it more fun and learning.

My colleagues and friends, thank you. You are the people who were core stakeholders in this research process. Your support, cooperation, and comradeship had been extremely important flags of encouragement and motivation for me.

Finally, but by no means last, all my brothers and sisters, your comradeship and support over the course of this academic process have been invaluable.

This research was a great success, due in part to the joint love and support of all of you. I am deeply indebted to you for your presence in my life.

Thank you for your invaluable help and for taking me through this challenging process.

ABSTRACT

Beverages are liquids that play a part in drinking for various purposes: hydration, nutrition, refreshment, and socializing. They can contain water, juices, soft drinks, milk, and alcoholic beverages. They form a part of human consumption, everyday routine and cultural practice.

Beverages are necessary for keeping a person hydrated and for providing many of the necessary nutrients. They have an important social function as part of etiquette in social and cultural contexts, for example, proposals in celebrations or sharing of tea in most cultures. Economically, they play a huge role in the world economy with employment opportunities and gross income.

This would mean huge challenges in the area of consumer demand, product quality assurance, and production wastage if beverages were inefficiently and inaccurately produced. Inefficiency in the filling process may influence product loss—increased costs and reduced profitability, hence affecting availability and quality in the market.

The focus in this project will thus be on developing an Arduino-based, optimized beverage filling system. This system shall be mainly oriented toward the enhancement of efficiency and accuracy in the beverage filling process in industries. The suggested solution will ensure uniformity of quality products and avoid wastage through product loss resulting from leakage and variation in fill levels.

It involves designing a prototype with Arduino, including leak detection sensors and flow meters for accurate readings.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

ULK:	Université Libre de Kigali
UPI:	ULK Polytechnic Institute
LCD:	Liquid Crystal Display
I2C:	Inter-Integrated Circuit
PWM:	Pulse Width Modulation
DC:	Alternating Current
AC:	Alternating Current
PCB:	Printed Circuit Board
IDE:	Integrated Development Environment
ICSP:	In-Circuit Serial Programming
IoT:	Internet of Things

CHAPTER 1: GENERAL INTRODUCTION

1.0 Introduction

In today's industrial landscape, the optimization of beverage filling processes is crucial for ensuring efficiency, reducing wastage, and maintaining product quality. One critical aspect of this optimization is the implementation of advanced technological solutions to enhance accuracy and streamline operations.
Drink bottling is the process of packaging drinks like water, soda, alcohol, or caffeinated beverages into individual containers such as bottles and cans for distribution and sale. The process begins with sourcing the materials used to make the containers for bottling beverages usually plastic, glass, or cans, which are then cleaned and sterilized before filling. (Metabrand, 2023)
However, with the rapid advancement of technology, particularly the emergence of Arduino-based solutions, there is an opportunity to revolutionize these processes.
The objective is to create a cost-effective and reliable solution that addresses these challenges by ensuring accurate fill levels and detecting leaks promptly.
By leveraging Arduino microcontrollers and associated sensors, the system aims to provide real-time monitoring and control capabilities during the beverage filling process. This technology not only enhances accuracy in volume measurement but also facilitates immediate detection and mitigation of leaks, thereby minimizing product loss and ensuring consistent product quality.
This system promises to enhance operational efficiency, reduce downtime, and optimize resource utilization in beverage production facilities.
The design and implementation of this beverage filling system represent a significant advancement in industrial automation. By adopting this technology, beverage manufacturers can achieve higher productivity, reduce operational costs, and maintain stringent quality standards.

1.1 Background of study

The optimization of beverage filling processes within industrial environments is increasingly recognized as essential for enhancing efficiency, minimizing waste, and upholding superior product quality on a global scale. The process of accurately filling containers with liquid products can be complex and requires careful control to ensure that the desired quantity is dispensed every time. One solution to this challenge is implementing advanced filling technologies that offer greater filling accuracy and control. For example, automated filling machines equipped with sensors can precisely measure the amount of liquid being dispensed into each container. (Prostarseo, 2023)These issues underscore the critical need for innovative technological solutions, particularly in the domain of Arduino-based systems, to revolutionize and modernize beverage filling operations.

Arduino microcontrollers present a promising avenue for significantly improving the accuracy and efficiency of beverage filling processes. Through the integration of sophisticated sensors and real-time monitoring capabilities, Arduino-based systems enable precise measurement of fill volumes while swiftly detecting and addressing any leaks that may occur during the production cycle.

The implementation of an optimized beverage filling system marks a substantial leap forward in industrial automation. This system not only promises to elevate production standards but also offers a cost-effective solution that enhances overall efficiency and rigorously maintains quality control measures. Embracing Arduino technology enables beverage manufacturers to boost productivity, reduce operational costs, and effectively meet the evolving demands of the competitive market landscape.

1.2 Statement of the problem

In Bukavu's local beverage industry, the optimization of filling processes is a critical concern due to inefficiencies and product losses caused by inconsistent fill levels and undetected leaks. In the early days, bottle filling was a labor-intensive process. Workers would manually fill bottles using basic tools like funnels and ladles. This method was not only time-consuming but also prone to spillage and contamination. Despite its inefficiencies, manual filling was the norm for small-scale operations and local businesses (Laubhunt, 2024).

Examples of methods they use upon the time: Filling with a ladle, filling with a funnel, Hand filling, Siphon filling.

Despite advancements in automation technology, many beverage manufacturers in Bukavu have yet to adopt more sophisticated solutions. Current research in industrial automation highlights the potential of Arduino-based systems for enhancing precision and reliability in various applications (Armenta, 2022)However, there remains a gap in the practical implementation of these technologies specifically for beverage filling operations in Bukavu. This research aims to address these challenges by developing and deploying an Arduino-based system for leak detection and precise measurement, thereby improving efficiency and reducing waste in local beverage filling processes.

1.3 Objective of the Study

I conducted this study at Bukavu Industry, aiming to achieve the following objectives.

1.3.1. General Objective

The main objective of this project titled design and Implementation of Optimized Beverage Filling System with Arduino-Based Precision Measurement is to solve the problem of inefficiency and inaccuracy in beverage filling systems.

1.3.2. Specific Objectives

i. To Design and Implement an Optimized Beverage Filling System
ii. To integrate leak detection mechanisms within the Arduino system.
iii. To evaluate the system's effectiveness with reduce waste.

1.4 Research question

i. How can be design and develop an Arduino based system to optimize the beverage filling process?
ii. What is the most viable procedures for integrating leak detection mechanisms into the Arduino based filling system?
iii. To what extent does the Arduino based system improve operational efficiency and reduce waste compared to traditional beverage filling?

1.5 Hypothesis

It greatly improves the efficiency of the filling process and reduce wastage, as opposed to the conventional filling system, due to the optimized beverage filling system implemented with Arduino-based leak detection and precision measurement; and that the developed system can integrate effectively into local beverage manufacturing facilities with established guidelines.

1.6 Scope and Limitation

1.6.1. Scope

The scope of this research encompasses the design, development, and implementation of an Arduino-based system for optimizing beverage filling processes. The theoretical scope includes the integration of sensors, algorithms for precise measurement, real-time monitoring for leak detection, and data analytics for process optimization. Content scope considerations involve factors such as beverage types, production scales, and operational environments within local beverage production facilities.

1.6.1.1. Geographical Scope

This study focuses on local beverage production facilities, specifically those located in Bukavu, South Kivu, Democratic Republic of Congo. The research will be conducted within these facilities to address the identified challenges and explore opportunities for enhancing efficiency and quality in beverage filling operations.

1.6.1.2. Time Scope

The time scope of this project spans from February to September 2023, during which the design, development, implementation, and evaluation phases of the Arduino-based system will be completed. This timeframe ensures a comprehensive exploration of the system's capabilities and effectiveness within the specified geographical and theoretical contexts.

1.6.2. Limitation

Financial Constraints: Limited funding may restrict the extent of system features and implementation scale.

Technological Dependencies: The effectiveness of the Arduino-based system may be influenced by the availability and reliability of supporting technologies and infrastructure.

Personnel Availability: The research outcomes may be affected by the availability and expertise of personnel involved in system deployment and operation within the selected beverage production facilities.

1.7 Significance of Study

The study on "Optimized Beverage Filling system: Based on Arduino Leak Detection & Precise Measurement" holds significant importance for local beverage production in Bukavu by improving operational efficiency and reducing waste. By implementing an advanced Arduino technologies system, it aims to enhance product quality, lower production costs, and increase competitiveness. The research contributes to industrial automation knowledge and sensor technology, fostering innovation in manufacturing processes. It supports economic development by bolstering local industries, promoting sustainability, and enhancing community access to high-quality beverages

1.8 Organization of the Project

The research work is divided into five chapters, as outlined below:

- **i.** **Chapter one**: General introduction: This chapter provides an introduction and background to the research, highlighting the problem statement, research objectives, research questions, scope. and limitations.
- **ii.** **Chapter two**: Literature Review: This chapter defines key terms used in the study, reviews existing related systems, and explores how previous researchers have addressed data exchange challenges.
- **iii.** **Chapter three**: Research methodology: This chapter presents the system analysis and design methodologies used to collect data
- **iv.** **Chapter four**: System design, analysis and implementation: This chapter showcases the implementation of the system and includes screenshots to demonstrate its functionality. The research work concludes with a general conclusion, recommendations, and suggestions for future enhancements.
- **v.** **Chapter five**: Conclusion and recommendation

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The literature review plays a crucial role in any scientific work, serving as the comprehensive overview of key project-related concepts. It summarizes the work of other researchers within the same field, providing context for present study.
Traditionally, beverage-filling processes have faced challenges such as inconsistent fill levels, product loss due to leaks, and manual monitoring systems that are prone to errors. For examples:

-Filling with a ladle

Figure 1: ladle

-Filling with a funnel and Hand filling

Figure 2: Funnel

-Siphon filling

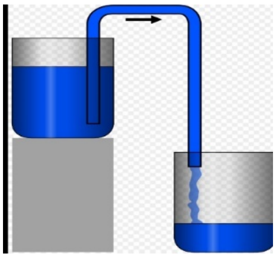


Figure 3: Siphon

2.1 Definition of concepts

This section explores the fundamental concepts derived from the project "**Design and Implementation of Optimized Beverage Filling system: Arduino-Based Leak Detection & Precise Measurement**" with a focus on Bukavu sector

2.1.1. Beverage Filling

Beverage filling is the process by which liquid beverages are filled in defined quantities into a container, such as bottles, cans, or cartons.

Figure 4: Beverage filling processes *(plastics, 2014)*

2.2 System Components and Specifications

2.2.1. Arduino

Arduino is an open source microcontroller which can be easily programmed, erased and reprogrammed at any instant of time. Introduced in 2005 the Arduino platform was designed to provide an inexpensive and easy way for hobbyists, students and professionals to create devices that interact with their environment using sensors and actuators. Based on simple microcontroller boards, it is an open source computing platform that is used for constructing and programming electronic devices. It is also capable of acting as a mini computer just like other microcontrollers by taking inputs and controlling the outputs for a variety of electronics devices.

It is also capable of receiving and sending information over the internet with the help of various Arduino shields, which are discussed in this paper. Arduino uses a hardware known as the Arduino development board and software for developing the code known as the Arduino IDE (Integrated Development Environment). Built up with the 8-bit Atmel AVR microcontroller's that are manufactured by Atmel or a 32-bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE.

Here is a list of the different types of Arduino Boards available along with its microcontroller type, crystal frequency and availabilities of auto reset facility

2.2.2 Type of Arduino Boards and Applications

Arduino boards are available with many different types of built-in modules in it. Boards such as Arduino BT come with a built-in Bluetooth module, for wireless communication. These built-in modules can also be available separately which can then be interfaced (mounted) to it. These modules are known as Shield.

- **Arduino Ethernet shield:** It that allows an Arduino board to connect to the internet using the Ethernet library and to read and write an SD card using the SD library.
- **Arduino Wireless shield:** It allows your Arduino board to communicate wirelessly using ZigBee.
- **Arduino Motor Driver Shield:** It allows your Arduino boards to interface with driver of a motor.

Arduino has endless applications as it has been used extensively for creating projects by hobbyist, amateurs and professional in various fields of engineering. Here are some of those amazing projects that have been developed on an Arduino platform:

2.2.2.1 Arduino Uno (R3)

The Uno is a huge option for your initial Arduino. This Arduino board depends on an ATmega328P based microcontroller. As compared with other types of Arduino boards, it is very simple to use like the Arduino Mega type board. .It consists of 14-digital I/O pins, where 6-pins can be used as PWM(pulse width modulation outputs), 6-analog inputs, a reset button, a power jack, a USB connection, an In-Circuit Serial Programming header (ICSP), etc. It includes everything required to hold up the microcontroller; simply attach it to a PC with the help of a USB cable and give the supply to get started with an AC-to-DC adapter or battery.

Arduino Uno is the most frequently used board and it is the standard form apart from all the existing Arduino Boards. This board is very useful for beginners

Figure 5: Arduino Uno *(electronics-lab.com, 2014)*

2.2.2.2 Arduino Nano

The Arduino Nano is a small, precise, and dependable microcontroller board that hosts

ATmega328P or ATmega628, having almost the same functions as the Arduino Uno but making it much smaller. It boasts of 8 analog pins and 14 digital pins. It uses mini USB, which requires the Arduino IDE software as a programming environment.

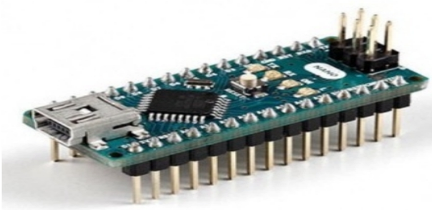


Figure 6: Arduino nano *(electronics-lab.com, 2014)*

2.2.2.3 Arduino Micro

The Arduino Micro is a small board based on the ATmega32U4 microcontroller featuring 20 pins, with 7 PWM pins and 12 analog input pins. It has in-built USB connection and is like a compact version of the Leonardo board.

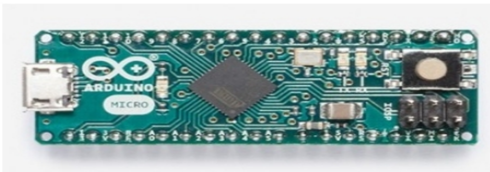


Figure 7: Arduino Micro *(electronics-lab.com, 2014)*

2.2.2.4 RedBoard Arduino

The RedBoard Arduino is programmable via a Mini-B USB cable and the Arduino IDE. It's got reliability, Windows 8 compatibility out of the box without security setting tweaks, and a flat back so it's easy to use in projects.

Figure 8:Redboard Arduino (electronics-lab.com, 2014)

2.2.2.5 Arduino Esplora

The Arduino Esplora is a game controller loaded with a lot of sensors and actuators; a joystick, slider, temperature sensor, etc. It is easy to program with Arduino IDE and perfect for interactive projects.

connections—perfect for compact and feature-rich projects.

Figure 9: Arduino Explora *(electronics-lab.com, 2014)*

2.2.2.6 Arduino Zero:

The Arduino Zero is a smart 32-bit board based on the SAMD21 microcontroller that packs even more punch for IoT, wearable, and automation projects. It has an embedded debugger, and project development can be advanced with it.

Figure 10: Arduino Zero *(electronics-lab.com, 2014)*

2.2.2.7 Elements of Arduino Bords

Elements of an Arduino Board can be done into two categories:

- Hardware
- Software

2.2.2.8 Hardware

The Arduino Development Board consists of many components that together makes it work. Here are some of those main component blocks that help in its functioning:

- **Microcontroller:** This is the heart of the development board, which works as a mini computer and can receive as well as send information or command to the peripheral devices connected to it. The microcontroller used differs from board to board; it also has its own various specifications.
- **External Power Supply:** This power supply is used to power the Arduino development board with a regulated voltage ranging from 9 – 12 volts.
- **USB plug:** This plug is a very important port in this board. It is used to upload (burn) a program to the microcontroller using a USB cable. It also has a regulated power of 5V which also powers the Arduino board in cases when the External Power Supply is absent.

- **Internal Programmer:** The developed software code can be uploaded to the microcontroller via USB port, without an external programmer.
- **Reset button:** This button is present on the board and can be used to resets the Arduino microcontroller.
- **Analog Pins:** There are some analog input pins ranging from A0 – A7 (typical). These pins are used for the analog input / output. The no. of analog pins also varies from board to board.
- **Digital I/O Pins:** There are some digital input pins also ranging from 2 to 16 (typical). These pins are used for the digital input / output. The no. of these digital pins also varies from board to board.
- **Power and GND Pins:** There are pins on the development board that provide 3.3, 5 volts and ground through them

2.2.2.9 Software overview

The program code written for Arduino is known as a sketch. The software used for developing such sketches for an Arduino is commonly known as the Arduino IDE. This IDE contains the following parts in it:

Text editor: This is where the simplified code can be written using a simplified version of C++ programming language.

Message area: It displays error and also gives a feedback on saving and exporting the code.

Text: The console displays text output by the Arduino environment including complete error messages and other information

Console Toolbar: This toolbar contains various buttons like Verify, Upload, New, Open, Save and Serial Monitor. On the bottom right hand corner of the window there displays the Development Board and the Serial Port in use.

Features of Arduino ID

- The project file or the sketches for a project are saved with the file extension uno.
- Features such as cut / copy / paste are supported in this IDE.
- There also is a facility for finding a particular word and replacing it with another by pressing the Ctrl + F buttons on the keyboard
- The most basic part or the skeleton of all Arduino code will have two functions

2.2.2.10 PROGRAMMING BASICS

Now we'll discuss about the programming techniques of Arduino sketch in the Arduino IDE. There are two main parts every sketch will always have; they are:

- void setup ()
- void loop ()

1. void setup ():

This is the first routine that begins when the Arduino starts functioning. This function is executed only once throughout the entire program functioning.

The setup function contains the initialization of every pin we intend use in our project for input or output. Here is an example of how it should be written:

```
void setup()
  {
    pinMode(pin, INPUT);
    pinMode(pin, OUTPUT);
  }
```

Here the pin is the no. of the pin that is to be defined. INPUT / OUPUT correspond to the mode in which the pin is to be used.

```
void setup()
  {
     Serial.begin(9600);
  }
```

It also contains the initialization of the Serial Monitor. A serial monitor is used to know the data that are being sent serially to any peripheral device.

Before using any variables for programming it is necessary to define them above the function "void setup ()"

2. void loop ():

This function is the next important function in the Sketch. It consists of that part of the code that needs to be continuously executed unlike the part of the code written in the setup function. An example of a void loop is as follows:

```
void loop()
  {
    digitalWrite(pin, HIGH);
  }
```

Here digital Write is a function that writes a high or a low value to a digital pin. If the pin has been configured as an OUTPUT with pin Mode (), its voltage will be set to the corresponding value: 5V (or 3.3V on 3.3V boards) for HIGH, 0V (ground) for LOW.

Similarly, if there is a need for delay in the sketch then there is another function that creates a delay in the execution of the code

```
delay(1000);  //delay for a second
```

This creates a delay in the execution of the program for the time period specified (in milliseconds). Using the above two function lets create a sketch for blinking a led.

```
// this loop function executes only once
void setup()
  {
    pinMode(13, OUTPUT);  // initialize digital pin 13 as an output.
  }

// this loop function executes forever
void loop()
  {
    digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage level)
    delay(1000);              // wait for a second
    digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
    delay(1000);              // wait for a second
  }
```

Arduino shields are prefabricated circuit boards designed to extend the functionality capabilities of the original Arduino boards by giving them more power, including wireless communication, internet connectivity, motor control, and more. These are usually designed in such a way that they fit more easily into the top of Arduino boards for increased functionalities.

There are different types of Arduino boards existing in the market today such as the FreeDuino & NetDuino. The best way to select the Arduino board is by checking and differentiating the trade names on the original boards. So getting low-cost Arduino boards is easy through online sites as well as electronic stores. These boards are available with different versions as well as specifications.

The programming of all the boards can be done with the Arduino IDE software that permits anyone to write as well as upload the code, but each board varies based on the inputs, outputs, speed, form factor, voltage, etc. The voltage required to operate these boards range from 3.7V to 5V.

2.2.3 Sensor

A Sensor is an electronic device that is used to measure some sort of physical parameters (e.g. temperature, pressure, light intensity, etc). The output of an electronic sensor is an electrical signal that is either analog or digital. Processing the sensor's output can be done in hardware (using discrete electronic elements) or in software (using some sort of microcontrollers or MPUs).

Each sensor has a different working principle depending on the physical construction and the physical parameter it's actually measuring. The common thing between all sensors is they all convert a physical parameter (such as temperature) to an electric signal

2.2.3.1 Sensors Classification

There are, in fact, many classifications for sensors. We can classify sensors depending on the type of output signal or the physical parameters they measure and other considerations could be taken resulting in a variety of ways to classify sensors.

Table 1: Sensor Classification

Analog Output	**Digital Output**
The output of these sensors is an analog voltage that you can measure then determine the desired physical parameter using the sensor's transfer function. It may also be capacitive or resistive or anything analog.	The output of these sensors is digital data that you can read via serial or parallel communication buses (as UART, SPI, I2C, etc). The typical format for the data is demonstrated exactly in the sensor's datasheet.
Example: The temperature sensor (specifically LM35) is an analog sensor whose output	**Example**: The accelerometer sensor (ADXL345) is a digital sensor that sends out its output data via the I2C two-wire bus.

2.2.3.2 Types of Sensors

2.2.3.3 Flow sensor

Water flow sensors are installed at the water source or pipes to measure the rate of flow of water and calculate the amount of water flowed through the pipe. Rate of flow of water is measured as liters per hour or cubic meters.

Figure 11: Flow Sensor *(electronics-lab.com, 2014)*

2.2.3.4 Temperature sensor

One of the most common and most popular sensors is the Temperature Sensor. A Temperature Sensor, as the name suggests, senses the temperature i.e., it measures the changes in the temperature.

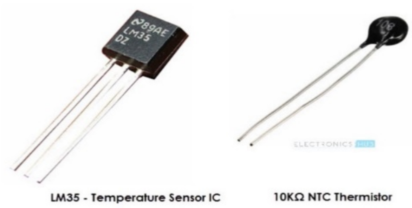


Figure 12: Temperature Sensor *(electronics-lab.com, 2014)*

2.2.3.5 Infrared Sensor

IR Sensors or Infrared Sensor are light based sensor that are used in various applications like Proximity and Object Detection. IR Sensors are used as proximity sensors in almost all mobile phones.

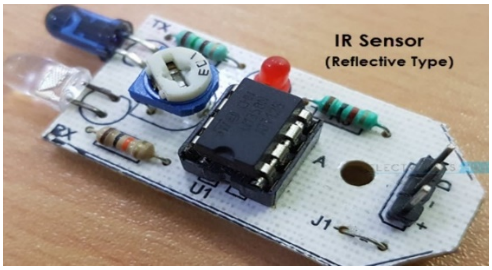


Figure 13: Infrared Sensor *(electronics-lab.com, 2014)*

2.2.3.6 Ultrasonic Sensors

An Ultrasonic Sensor is a non-contact type device that can be used to measure distance as well as velocity of an object. An Ultrasonic Sensor works based on the properties of the sound waves with frequency greater than that of the human audible range.

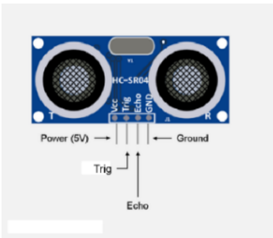


Figure 14: Ultrasonic Sensor *(electronics-lab.com, 2014)*

2.2.3.7 Smoke and Gas Sensors

One of the very useful sensors in safety related applications are Smoke and Gas Sensors. Almost all offices and industries are equipped with several smoke detectors, which detect any smoke (due to fire) and sound an alarm.

Gas Sensors are more common in laboratories, large scale kitchens and industries. They can detect different gases like LPG, Propane, Butane, Methane (CH4), etc.

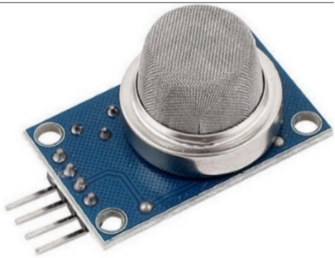


Figure 15: Smoke and Gas sensor *(electronics-lab.com, 2014)*

2.2.3.8 Humidity Sensor

If you see Weather Monitoring Systems, they often provide temperature as well as humidity data. So, measuring humidity is an important task in many applications and Humidity Sensors help us in achieving this.

Often all humidity sensors measure relative humidity (a ratio of water content in air to maximum potential of air to hold water). Since relative humidity is dependent on temperature of air, almost all Humidity Sensors can also measure Temperature

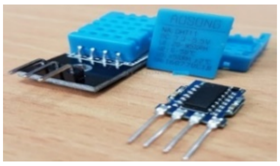


Figure 16:Humidity sensor *(electronics-lab.com, 2014)*

2.2.4 Pump

A Pump is Mechanical Device, that uses to move fluids by mechanical action, typically converted from electrical energy into hydraulic energy. It is a hydraulic device that lifts fluids from low to high levels, moves fluids from low to high-pressure areas.

2.2.4.1 Types of Dynamic Pumps & Positive Displacement Pumps

Dynamic pumps are classified into different types but some of them are discussed below:

2.2.4.2 Centrifugal Pumps

These types of pumps are most commonly used worldwide. The work is very simple, described well, and carefully tested. This pump is strong, efficient, and fairly cheap to make. Whenever the pump is in action, then the fluid pressure will increase from the inlet of the pump to its outlet. The change of pressure will drive the liquid throughout the system.

2.2.4.3 Vertical Centrifugal Pumps

Vertical centrifugal pumps are also called cantilever pumps. These pumps use an exclusive shaft & maintain a design that permits the volume to fall within the pit as the bearings are external to the pit. This mode of pump utilizes no filling container to cover the shaft however in its place uses a throttle bushing. A parts washer is the common application of this kind of pump.

2.2.4.4 Submersible Pumps

These pumps are also named as storm water, sewage, and septic pumps. The applications of these pumps mainly include building services, domestic, industrial, commercial, rural, municipal, & rainwater recycle applications.

These pumps are apt for shifting storm water, subsoil water, sewage, black water, greywater, rainwater, trade waste, chemicals, bore water, and foodstuffs.

2.2.4.5 Water pump

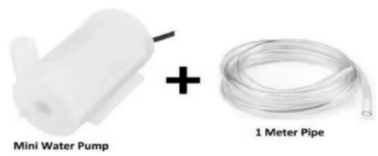


Figure 17: Water pump and pipe *(yaang Pipe industry co., 2015)*

2.2.4.6 Application of Pump

Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.

Also, mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering, and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers and other components of heating, ventilation and air conditioning systems.

In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.

2.2.5 Solenoid valve

The solenoid valve is a basic automatic component used for controlling the flow direction of fluid and is considered part of the actuator. It is widely utilized in mechanical control systems and industrial valves to regulate the direction of the fluid, thereby controlling the valve's switch.

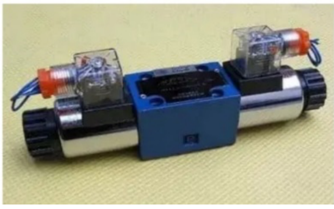


Figure 18: Solenoid valve *(yaang Pipe industry co., 2015)*

2.2.5.1 Direct acting solenoid valve

The direct acting solenoid valve is usually used in small caliber and low pressure environment. For this kind of structure, when the valve is open, it will be able to start in zero pressure, without need of the minimum pressure of the medium. Therefore, it is faster in terms of the start-up speed compared with the pilot-operated solenoid valve. Thus, it is particularly suitable for the occasion in need of fast connection and disconnection.

The power consumption of direct acting solenoid valve is higher than that of the pilot-operated solenoid valve, usually ranging from 5W to 20W. Under the high-frequency power supplying, it is easy to make the coil burnt out. But, it is simple to control and has a wide application scope. It can work normally in the conditions of vacuum, negative pressure and zero pressure. Nevertheless, its diameter doesn't exceed 25mm.

Figure 19: Direct acting solenoid valve *(yaang Pipe industry co., 2015)*

Working Principle: The solenoid coil generates electromagnetic force when energized, which lifts the closure piece from the valve seat and opens the valve. When the power is cut off, the electromagnetic force disappears, causing the spring to press the closure piece back onto the valve seat, thereby closing the valve.

2.2.5.2 Pilot-operated solenoid valve

The pilot-operated solenoid valve is usually used in big diameter and high pressure occasions. As the valve is open, the minimum pressure of the solenoid valve is not allowed to be lower than 0.05MPa. So, the pilot pressure is required, otherwise it cannot be opened. In addition, the flow capability of the pilot-operated solenoid valve is bigger than that of the direct acting solenoid valve. It has a relatively higher requirement to the purity of the compressed air. Instead, the directly operated solenoid valve has no such high requirement.

For the pilot operated solenoid valve, the electromagnetic head is small and the power consumption is low, usually 0.1-0.2W. It can be energized frequently or for a long time, without getting burnt. It is also energy saving. As for the fluid pressure scope, it has a high upper bound. It can be installed randomly (need to be customized), but the requirement for differential pressure condition of the fluid should be satisfied. For the impurities in the liquid is easy to block the pilot valve holes. Therefore, it is unsuitable for the liquid.

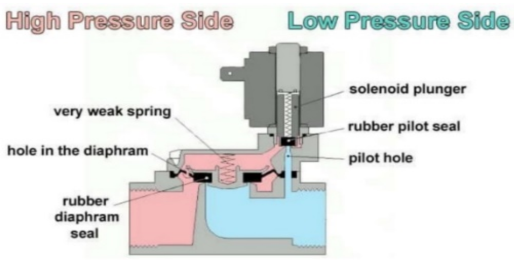


Figure 20: Pilot operated solenoid valve *(yaang Pipe industry co., 2015)*

2.2.6 Leak Detection

Leak detection is the process of identifying and locating unintended fluid or gas leaks in a system. It involves using various methods and technologies, such as sensors and monitoring systems, to detect the presence of leaks, ensuring the integrity and safety of the system.

2.3 Theoretical Perspectives

In this section, we will investigate the theoretical underpinning that supports the study of optimized beverage filling using Arduino-based systems for leak detection and precise measurement. The theoretical perspectives will help provide a framework with which to understand the variables involved in this research.

2.3.1 Systems Theory

This framework considers a system to be a set of interrelated parts that work together for some common purpose. The emphasis is on understanding the relationships and interactions between the constituent parts.

In my project, Systems Theory helps in understanding how different components of the beverage filling system (sensors, valves, pumps) interact and contribute to the overall performance.

2.3.2 Control Theory

Control theory oriented toward the manner in which systems can be controlled and regulated to achieve a given end. It is, therefore, based on feedback mechanisms that rectify the system's operation in view of obtained performance data.
Control Theory is relevant for designing feedback loops in my beverage filling system to regulate the filling process and ensure precision and efficiency.

2.3.3 Lean Manufacturing Theory

A methodology aimed at reducing waste and improving efficiency by optimizing processes and eliminating non-value-added activities.
Lean Manufacturing Theory can guide me in streamlining the beverage filling process to minimize waste and maximize efficiency.

2.3.4 Automation Theory

Automation theory it is the research into the use of technology in automating tasks and processes for improved efficiency, consistency, and less human intervention.
The implementation of the Arduino-based system in the integration of automated filling and leakage detection also affiliates to the automation theory. It makes the accuracy and operation of the system efficient.

2.3.5 Combined Theory

It is an integrated approach that draws on elements from multiple theories to consider in a holistic way complex systems and processes.

2.4 Related research

This section presents the empirical studies conducted in the past, specifically those that focused on the optimization of beverage filling processes using Arduino-based systems for leak detection and accurate measurement. A Targeted review of studies enables the understanding of the current state of research, identification of gaps, and positioning of the present study within the broader literature on similar discourse.

2.4.1 Automated Beverage Filling Systems

Study by : (Foram Gandi, 2015)
The field of automation has a notable impact in a wide range of industries beyond manufacturing. Automation is nothing but the utilization of control systems and information

technologies to minimize the need for human work in the production of goods and services Important issues related to the automation of such lines are overviewed and the real time example of one such successful implementation is discussed. The system components are clearly defined and important considerations are discussed with reference to actual implementation of the system. Qualitative comparison of controller is presented to facilitate the selection process for cost effective optimization. Control valve operating mechanism, electric drives and significance of PLCs are also discussed.

2.4.2 Leak Detection Technologies in Industrial Processes

Research by: (Hamilton, 2013)

Ageing infrastructure and declining water resources are major concerns with a growing global population. Controlling water loss has therefore become a priority for water utilities around the world. In order to improve efficiencies, water utilities need to apply good practices in leak detection. Leak Detection: Technology and Implementation assists water utilities with the development and implementation of leak detection programs. Leak detection and repair is one of the components of controlling water loss. In addition, techniques are discussed within this book and relevant case studies are presented. This book provides useful and practical information on leakage issues.

2.4.3 Precise Measurements in Liquid Dosage

Research by : (T. Matsumoto, 2002)

An improved oscillating drop method was developed to measure the surface tension and viscosity of a liquid without any external forces under microgravity conditions. The combination of a drop levitation system, a laser backlight system, and a line sensor enables the properties to be measured precisely.

2.4.4 Sensor integration into industrial automated systems

Study by : (Jersson X. Leon-Medina, 2023)

The use of sensors in different applications to improve the monitoring of a process and its variables is required as it enables information to be obtained directly from the process by ensuring its quality. This is now possible because of the advances in the fabrication of sensors and the development of equipment with a high processing capability.

CHAPTER 3: RESEARCH METHODOLOGY AND MATERIALS

3.0 Introduction

This chapter focuses on the methodologies adopted for research in "Optimized Beverage Filling: Arduino-Based Leak Detection & Precise Measurement." It explains the design, population, research instruments, data-gathering procedures, analysis, and interpretation. In this section, details regarding ethical considerations and limitations are provided.

3.1 Case study location

The case study for the "Design and Implementation of Optimized Beverage Filling System with Arduino-Based Leak Detection and Precision Measurement" was conducted in an industry located in Bukavu. This setting provided a realistic environment to test and refine the system, ensuring it met the operational demands of a beverage production facility.

Figure 21: Location of Bukavu industry *(wikipedia, 1997)*

3.2 Data collection

3.2.1 Primary Data Collection:

Primary data collection is the process of collecting data from a live source, such as a human being. The goal of primary data collection is to collect data that is as accurate and complete as possible. This data can be used to improve the quality of life for people and the environment.

3.2.1.1 Observations

During the research, I made several detailed observations mainly during the testing phases of the old system. I observed the beverage filling process to verify that the Arduino-based system was measuring and dispensing the right volume. I further observed the leak detection mechanism to verify that it was sensitive enough and reacted within a suitable timeframe. These observations were pivotal in helping to identify and iron out issues, such as inconsistent filling volumes or undetected leaks, which really allowed me to fine-tune the new system to be both more accurate and more reliable.

3.2.1.2 Questionnaires

To gather feedback on the usability and effectiveness of the system, I distributed questionnaires

1. How accurate are the volumes filled using manual methods like siphons, funnels, and ladles?

a. Inconsistency:

b. Limited Precision:

c. Difficult for Complex or Large Batches: **For large**

d. Best Practices: **To**

2. Is there a mechanism for detecting leaks in the current manual filling system?

a. Visual Inspections:

b. Lack of Automation:

c. Human Error:

d. Improving Detection: **Simple measures**

3. How does the manual system handle adjustments for different filling conditions and calibration needs?

a. Manual Calibration: In

b. Time-consuming Adjustments:

c. Lack of Precision in Calibration**: Calibration**

d. Standard Operating Procedures: **A set of instructions or procedures can help maintain consistency. Operators can be trained to adjust techniques based on environmental factors or product changes.**

4. How user-friendly is the interface for monitoring and controlling the manual filling system?

a. No Digital Interface:

b. Human-Dependent Monitoring:

c. Fatigue and Attention :

d. Recommandations :

to a select group of potential end-users, including factory workers and quality control experts. The questionnaires focused on their experiences with the system, asking them to evaluate aspects such as ease of operation, reliability of the leak detection feature, and overall satisfaction with the precision measurement capabilities. The insights gained from these questionnaires provided valuable input for further improving the system's design, ensuring that it not only met technical requirements but also aligned with user expectations.

3.2.2 Secondary Data Collection

3.2.2.1 Published Sources

For the "Design and Implementation of Optimized Beverage Filling System with Arduino-Based Leak Detection and Precision Measurement" project, I consulted published sources such as academic journals, books, and conference papers. These sources provided foundational knowledge on fluid dynamics, sensor integration, and microcontroller programming, all of which were critical in designing an efficient and accurate filling system. The information gathered from these published works helped in understanding best practices and identifying potential pitfalls in similar systems, allowing me to apply proven techniques to my project.

3.2.2.2 Online Databases

I also used online databases to access a wide range of scholarly articles and research papers relevant to my project. Databases like IEEE Xplore, Science Direct, and Google Scholar were particularly useful in providing access to the latest research on Arduino-based systems, precision measurement technologies, and industrial automation. These databases allowed me to stay updated on recent advancements and incorporate state-of-the-art methodologies into my project, ensuring that my system was both innovative and grounded in current scientific knowledge.

3.3 Research Design

The type of research design that shall be adapted in this research is a quasi-experimental design. This will be appropriate since it allows the manipulation of the independent variable that is, the implementation of the system based on Arduino for leak detection and precise measurement while observing the effects on the dependent variable, which includes efficiency and accuracy of beverage filling processes. In this regard, both quantitative and qualitative methods will be used to give a comprehensive analysis of the data.

3.4 Data Gathering Procedures

Data will be gathered in three phases:

Field Type Page

1. Pre-Implementation Phase: This involves the collection of baseline information on the current beverage filling process using the questionnaire and observation checklist.
2. Implementation Phase: An Arduino-based leak detection and measurement system setup and observed.
3. Post-Implementation Phase: Data on the performance of the new system is collected with the same instruments to ascertain improvements.

3.5 Data Analysis and Interpretation

The quantitative data shall be analyzed using descriptive statistics, chi-square tests, and ANOVA comparative analysis for performance before and after the implementation. For qualitative data through observation, operational improvement patterns and insights are extracted by way of thematic analysis. This mixed-method approach hence assures rigors in analyzing the data.

3.6 Ethical Considerations

This will be addressed with an ethics approval request presented to the appropriate committee. The study has acting consent from participating facilities. Permission will be sought from all the facilities and institutions involved, thus gaining permission. The anonymity and confidentiality of the respondents will be guaranteed in this research. While conduction the research he well-being of people and the intact operations of participating institutions and facilities will be highly esteemed.

CHAPTER 4: SYSTEM DESIGN, ANALYSIS AND IMPLEMENTATION

4.0 Introduction

The present chapter is devoted to the comprehensive design, analysis, and implementation of the optimized beverage filling system. It contains information about the step-by-step procedure for developing an Arduino-based system with precision measurement, leak detection mechanisms, and automated controls. This chapter shall begin with necessary calculations that helped in ascertaining the parameters for the system, proceed to analyze in detail the design choices, and end with the practical implementation of the system.

4.1 System Design

4.1.1. Flow Rate Calculation

Flow Rate is the volume of water passing through the sensor per unit of time. It can be calculated using the following formula: Q=V/T

Where:

- Q is the flow rate (in liters per minute, L/min, or milliliters per second, mL/s).
- V is the volume of water measured (in liters or milliliters).
- T is the time over which the volume was measured (in minutes or seconds).

Example Calculation: If your flow sensor measures 200 milliliters in 30 seconds:

1. Convert volume to liters (200 mL = 0.2 L).
2. Convert time to minutes (30 s = 0.5 minutes).

Q=0.2 L/0.5 minutes=0.4 L/min

So, the flow rate is 0.4 liters per minute.

4.2 Drawings

4.2.1. Block Diagram

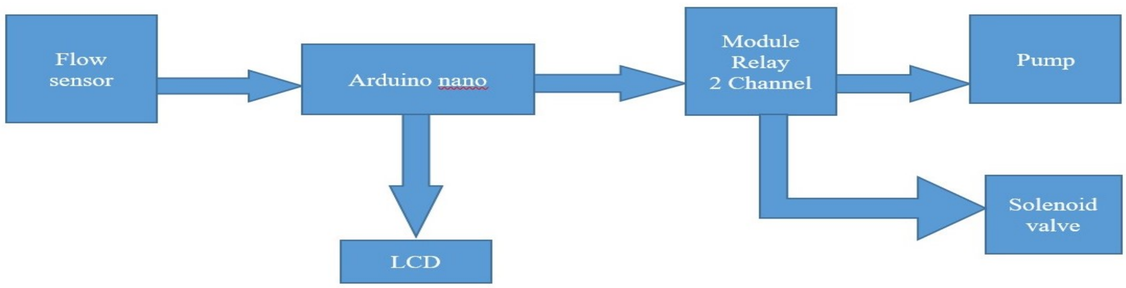
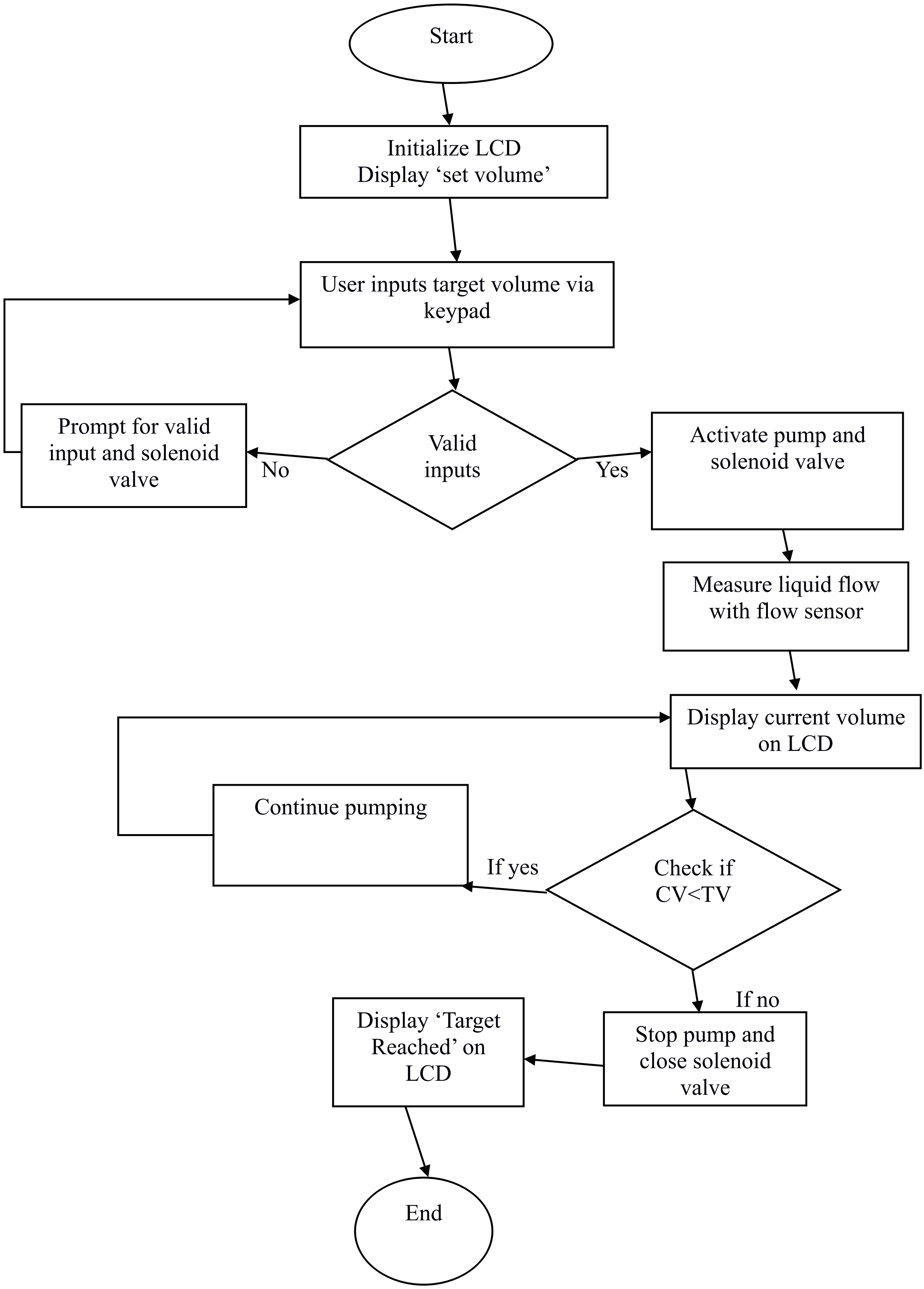


Figure 22: Block Diagram

4.2.2 Flow Chart



4.2.3 Circuit Diagram

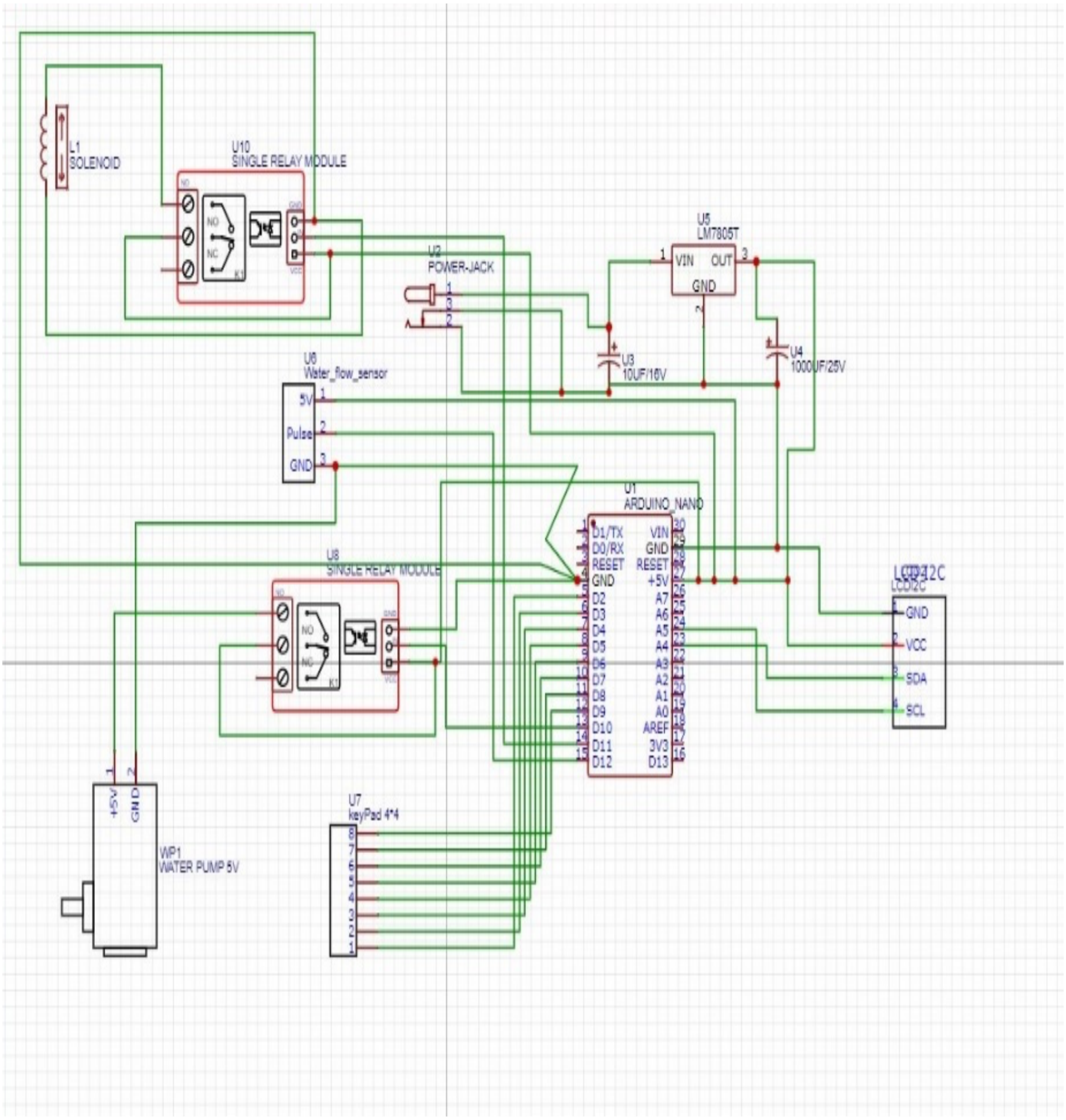


Figure 23: Circuit Diagram

4.3 Specifications

Table 2: Specifications of components

Component	Specifications	Quantity
Arduino nano	-Operating Voltage: 5V -Input Voltage (recommended): 7-12V -Digital I/O Pins: 14 (of which 6 provide PWM output) -Analog Input Pins: 8 Clock Speed: 16 MHz	1
16x2 LCD i2c display	-Display: 16 characters wide, 2 rows -Interface: I2C (uses only 2 data lines - SDA and SCL) -Operating Voltage: 5V	1
4x4 Keyboard module	-Number of Keys: 16 (arranged in 4 rows and 4 columns) -Operating Voltage: 5V	1
2 channel relay	-Channels: 2 (for controlling two devices) -Operating Voltage: 5V -Max Switching Voltage: 250V AC / 30V DC -Max Current: 10A	1
Female pin helper	-Standard pitch: 2.54mm -Number of Pins: Varies based on application	10
Male pin helper	-Standard pitch: 2.54mm -Number of Pins: Varies based on application	10
Dc power jack	-Input Voltage: Typically, 5V to 12V (based on the adapter used) -Connector: 2.1mm or 2.5mm center-positive	1
2 Capacitor	-10uf/16v,100uf/24v	2
7805 tage regulator IC 400	-Output Voltage: 5V -Input Voltage: 7V to 35V -Maximum Output Current: 1.5A	1
9v and 12v dc adapter	-Output Voltage: 9V and 12V -Power: Typically ranges from 0.5A to 1A or more	1
Water pump	-Voltage: Typically, 12V DC	1

	-Flow Rate: Varies, commonly 2-3 liters per minute -Max Lift: Depends on the pump, often around 23m	
Water flow sensor	-Output: Pulses proportional to flow rate -Operating Voltage: 5V to 18V -Flow Rate Range: Typically 1-30 litters per minute	1
Solenoid valve	-Voltage: Typically, 12V DC -Type: Normally closed or normally open, depending on the application -Pressure Rating: Varies, often suitable for low to moderate pressures	1
PCB	-Material: Fiberglass substrate (e.g., FR4). -Layers: Single-layer or multi-layer. - Thin copper layers for electrical connections. - Insulates copper traces to prevent short circuits. - Labels components for assembly and troubleshooting.	1

4.4 Implementation

Figure 24 implementation

4.4.1 Working Principle

The working principle of the liquid filling system begins with the initialization phase. When the system is powered on, the LCD display is activated, and it prompts the user to input a target volume in milliliters using the keypad. This ensures that the user knows the system is ready for operation and can input the desired volume to be dispensed.

Next, the user inputs the desired volume using the keypad. The system validates the input to make sure it is a correct and reasonable number. Once the input is confirmed, the system displays the target volume on the LCD, providing feedback to the user that the input has been successfully received.

After a valid volume is set, the system activates the pump and opens the solenoid valve, allowing the liquid to flow. The flow sensor continuously measures the liquid passing through, and the LCD provides real-time updates of the current dispensed volume, giving the user a live view of the filling process.

Throughout the process, the system checks whether the current dispensed volume has reached the target volume. If the dispensed volume is still below the target, the pump and valve remain active to continue the liquid flow. This ensures that the system delivers the precise amount of liquid the user requested.

Finally, once the target volume is reached, the pump and solenoid valve are automatically turned off, stopping the liquid flow. The system then displays a message on the LCD indicating that the target volume has been reached, signifying the completion of the process.

4.5 Cost estimation

Table 3: Cost Estimations

No	Items (material/equipment)	unity	quantity	Unity price	Total price
1	PCB	**1**	**1**	**1000**	**1000**
2	Arduino nano	**1**	**1**	**10,000**	**10,000**
3	16x2 LCD i2c display	**1**	**1**	**7000**	**7000**
4	4x4 Keyboard module 8k	**1**	**1**	**8000**	**8000**
5	2 channel relay	**1**	**1**	**2500**	**2500**
6	Female pin helper	**10**	**10**	**2500**	**2500**
7	Male pin helper	**10**	**10**	**2500**	**2500**
8	Dc power jack	**1**	**1**	**400**	**400**
9	2 Capacitor 10uf/16v,100uf/24v	**2**	**2**	**1000**	**1000**
10	7805 voltage regulator IC	**1**	**1**	**400**	**400**

11	9v and 12v dc adapter	**2**	**2**	**8000**	**8000**
12	Water pump	**1**	**1**	**2500**	**2500**
13	Water flow sensor	**1**	**1**	**7500**	**7500**
14	Solenoid valve	**1**	**1**	**8000**	**8000**
15	Jumper	**50**	**50**	**2500**	**2500**
17	Transport			**10000**	**10000**
18	Col	**6**	**6**	**6000**	**6000**
19	Box	**1**	**1**	**12000**	**12000**
	Tot				**96,500**

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter summarizes the findings from the study on the "Design and Implementation of

Optimized Beverage Filling System with Arduino-Based Leak Detection and Precision Measurement." It answers the research questions, provides recommendations based on the conclusions drawn, and suggests areas for further research.

5.1 Conclusions

The project has well reflected that an optimized beverage filling system will be very much capable of enhancing the effectiveness and efficiency of the filling process in beverage manufacturing by using Arduino. Leak detection mechanisms, as well as precision measurement capabilities, ensure less wastage along with consistent product quality. Implementation of such a system has shown that it can be effectively conducted in similar facilities with the increase in operational efficiency and a reduction of production costs.

5.2 Recommendations

Industrial Collaborations and Internships: UPI should collaborate with local industries to establish internship and co-op programs. These partnerships would provide students with real-world experience, helping them apply theoretical knowledge to current projects while improving their technical skills.

Funding and Support for Projects: To improve practical learning at ULK, the government and university should consider extending the duration of internships during Year 2 and Year 3. Longer internships will allow students to gain deeper, hands-on experience with real-world projects. This would enhance their ability to apply theoretical knowledge, develop technical skills, and become more adept at problem-solving, making them more prepared for the industry. These extended internships should be in collaboration with local industries, giving students the opportunity to tackle real-time challenges and work on current innovations.

5.3 Suggestions for further study

For further study, researchers can explore implementing a **scheduled automation feature** for the beverage filling system. This feature would allow the system to automatically start and stop at specific times during the workweek.

References

Armenta, A. (2022, September 15). control automation . Retrieved july 22, 2024, from google: https://control.com/technical-articles/arduino-applications-in-industrial-automation/

Foram Gandi, H. P. (2015, feb 1). ADVANCED INSTRUMENTATION AND AUTOMATION FOR FILLING AND. Retrieved august 10, 2024, from google schoolar: https://d1wqtxts1xzle7.cloudfront.net/37207233/1._Electrical_-_IJEEER_-_Advanced_Instrumentation_and-Foram_Gandhi-libre.pdf?1428149912=&response-content-disposition=inline%3B+filename%3DADVANCED_INSTRUMENTATION_AND_AUTOMATION.pdf&Expires=1722103122&Signat

Hamilton, S. (2013, mars 2). google schoolar. Retrieved august 5, 2024, from open access: http://library.oapen.org/handle/20.500.12657/33035

Jersson X. Leon-Medina, M. A. (2023, july 5). google schoolar. Retrieved august 10, 2024, from mdpi: https://www.mdpi.com/1424-8220/23/13/6178

Laubhunt. (2024, june 9). laubhunt.com. Retrieved august 2, 2024, from laubhunt.com: https://www.laubhunt.com/the-evolution-of-bottle-filling-technology-a-historical-perspective

Metabrand. (2023, november 1). metabrandcorp.com. Retrieved august 2, 2024, from metabrandcorp.com: https://metabrandcorp.com/bottling-beverages-techniques/

Prostarseo. (2023, august 9). geninox.com. (prostarseo, Editor, prostarseo, Producer, & geninox) Retrieved august 2, 2024, from geninox.com: https://geninox.com/what-are-the-common-challenges-faced-in-the-liquid-bottling-process/

T. Matsumoto, T. N. (2002, february 11). google schoolar. Retrieved august 10, 2024, from aps: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.65.031201

APPENDICES

APPENDIX A

```
#include "WaterFlow.h"
```

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Keypad.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);

const byte ROWS = 4; // 4 rows
const byte COLS = 4; // 4 columns
char keys[ROWS][COLS] = {
  {'1', '2', '3', 'A'},
  {'4', '5', '6', 'B'},
  {'7', '8', '9', 'C'},
  {'*', '0', '#', 'D'}
};
byte rowPins[ROWS] = {11, 3, 4, 5};
byte colPins[COLS] = {6, 7, 8, 9};
Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);

const int pumpPin = 10;      // Pump relay pin
const int valvePin = 12;     // Electrovalve control pin

WaterFlow waterFlow(2, 510.99);  // PIN2 for the flow sensor

unsigned long beforeTime;
int targetVolume = 0;
static String input = "";
int currentVolume = waterFlow.getVolume();

void count() {
  waterFlow.pulseCount();
}

void setup() {
  waterFlow.begin(count);
```

```
  pinMode(pumpPin, OUTPUT);
  pinMode(valvePin, OUTPUT);
  digitalWrite(pumpPin, LOW);  // Ensure pump is off initially
  digitalWrite(valvePin, LOW); // Ensure electrovalve is closed initially

  Serial.begin(9600);

  lcd.init(); // Initialize LCD
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Set Volume:");
}

void loop() {
  char key = keypad.getKey();
  if (key) {
    if (key == 'D') { // Si la touche 'D' est pressée, envoyer la valeur
      targetVolume = input.toInt(); // Convertir l'entrée en entier
      input = ""; // Réinitialiser l'entrée
      lcd.clear();
      lcd.print("Volume: ");
      lcd.print(targetVolume);
      lcd.print(" ml");
      delay(1000);
      lcd.clear();
      digitalWrite(pumpPin, HIGH); // Activer la pompe
      lcd.setCursor(0, 0);
      lcd.print("Flowing...");
      lcd.print(targetVolume);
      lcd.print(" ml");


    lcd.setCursor(0, 1);
```

```
  lcd.print("Dispense:");
 lcd.print(currentVolume);
 lcd.print(" mL");


   digitalWrite(valvePin, HIGH); // Ouvrir la solenoidValve
  } else if (key == '#') {
   input = ""; // Clear input
   lcd.clear();
   lcd.print("Annulee");
   delay(1000);
   lcd.clear();
   digitalWrite(pumpPin, LOW);
   digitalWrite(valvePin, LOW);
   lcd.print("set volume:");
  } else {
   input += key; // Ajouter la touche appuyée à l'entrée
   lcd.clear();
   lcd.print("Enter: ");
   lcd.print(input);
   lcd.print(" mL");
  }
 }

waterFlow.read();

if ((millis() - beforeTime) >= 1000){
  beforeTime = millis();

 if(!waterFlow.isFlowing()){
   waterFlow.clearVolume();
   return;
  }
```

```
    int currentVolume = waterFlow.getVolume();

    Serial.print(waterFlow.getFlowRateOfMinute());
    Serial.print(" L/m   ");
    Serial.print(waterFlow.getFlowRateOfSecond());
    Serial.print(" mL/s   ");
    Serial.print(currentVolume);
    Serial.println(" mL");

    lcd.setCursor(0, 1);
    lcd.print("Dispense:");
    lcd.print(currentVolume);
    lcd.print(" mL");

    // Check if target volume is reached
    if (currentVolume = waterFlow.getVolume() >= targetVolume && targetVolume > 0) {
      digitalWrite(pumpPin, LOW);  // Turn off pump
      digitalWrite(valvePin, LOW); // Close electrovalve
      lcd.setCursor(0, 0);
      lcd.print("Target Reached");
       delay(1000);
    lcd.clear();
    lcd.print("Set Volume:");
    } //else {
     // digitalWrite(pumpPin, HIGH); // Turn on pump
      //digitalWrite(valvePin, HIGH); // Open electrovalve
    //}
  }
}
```