

Microcontroller-Based Automatic Liquid Soap Refill System Process with Circular Economy Integration

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Submitted: 24/07/2024; Accepted: 09/09/2024; Published: 09/09/2024

Abstract—This research aims to develop a microcontroller-based automatic liquid soap refill system integrated with the concept of a circular economy. The main problem addressed is the high use of single-use soap bottles, which negatively impacts the environment. As a solution, the designed system uses sensors to detect refill needs and perform automatic refills. A microcontroller controls this process, ensuring efficiency and user convenience. Testing was conducted to assess the system's performance under various operational and environmental conditions. The test results showed that the system functions well. Additionally, using this system reduces the use of single-use soap bottles, supports environmental sustainability, and reduces the cost of purchasing new bottles. This research concludes that microcontroller-based automation technology can be integrated with the circular economy concept to produce efficient, environmentally friendly, and economical solutions. This automatic liquid soap refill system not only enhances user convenience but also contributes positively to environmental and economic sustainability. It is hoped that the research results can serve as a reference for developing other automation technologies that support the circular economy concept.

Keywords: Automatic Refilling System, Microcontroller, Circular Economy, Environmental Sustainability, Efficiency

1. INTRODUCTION

In the current technological era, the use of automated devices is increasingly prevalent in various industrial sectors to enhance operational efficiency and effectiveness. One crucial technology in automation is the microcontroller, which allows devices to operate automatically with minimal human intervention. An application of this technology is in the automatic liquid soap refill system. This system not only enhances user convenience but also supports the circular economy concept, focusing on reducing waste and utilizing resources more efficiently. The use of liquid soap in single-use bottles generates significant plastic waste, adding to environmental burdens. Millions of plastic bottles are discarded annually into landfills and oceans, causing pollution and environmental damage [1]. Additionally, manual soap refilling is often inefficient and unhygienic, potentially leading to contamination.

In this stage, problems underlying the research are identified, and literature related to the topic is reviewed. The identified problems include inefficient and time-consuming manual soap refilling, leading to inefficiency in the refill process; manual refilling causing contamination and being unhygienic, creating hygiene issues; and the use of single-use soap bottles generating significant plastic waste, adding to environmental burdens and causing environmental impact. A literature review is conducted to understand the latest technological developments in microcontroller-based automatic soap refill systems and the circular economy. Related studies are analyzed to identify gaps in the research that have not been addressed. Study A developed an automatic soap refill system using ultrasonic sensors to detect soap levels but did not discuss integration with the circular economy concept [2]. Study B used IoT technology to monitor and control the soap refill system remotely, but it did not consider sustainability aspects [3]. Study C implemented a microcontroller-based automatic refill system for industrial use but did not include a business process analysis [4]. Study D developed an automatic soap dispenser for commercial use but did not integrate circular economy elements [5]. Study E focused on reducing plastic waste by using more environmentally friendly refillable bottles, but without automation [6].

From these studies, it is evident that none have comprehensively combined a microcontroller-based automatic soap refill system with circular economy integration and effective business processes. Therefore, this research aims to fill that gap by developing a system that is not only automatic and efficient but also supports the circular economy concept to reduce plastic waste and maximize resource utilization [7]. This research aims to develop a microcontroller-based automatic liquid soap refill system integrated with the circular economy concept. The system is expected to reduce the use of single-use soap bottles, increase the efficiency of the soap refill process, and support environmental sustainability. Specifically, this research will design and develop a prototype of a microcontroller-based automatic liquid soap refill tool, integrate digitalization elements such as sensors and IoT to enhance system performance and efficiency, analyze business processes related to the operation and maintenance of this system in the context of the circular economy, and evaluate the economic and environmental benefits of using this system [8].

This research is expected to produce an efficient, practical, and environmentally friendly automatic liquid soap refill tool. By reducing plastic waste and increasing operational efficiency, this system is anticipated to contribute positively to environmental and economic sustainability [9]. Moreover, the research results are hoped to serve as a reference for developing other automation technologies in supporting the circular economy concept.

2. RESEARCH METHODOLOGY

2.1 Research Stages

This research consists of several main stages that describe the sequence of research processes, method implementation, and method testing to obtain the expected results. The research was conducted through several stages, including problem identification and literature review, system design, prototype development, implementation, testing, and result analysis (see Figure 1).

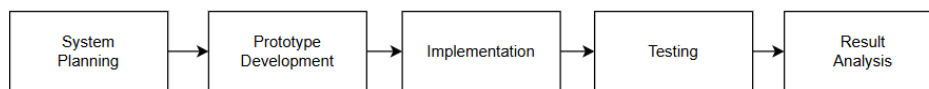


Figure 1. Research Stages

Figure 1 of Research Stages illustrates the research stages for this study. The first stage is Problem Identification and Literature Review, which involves identifying the research problem and reviewing existing literature related to the topic [10]. The second stage is System Design, where the design of the system is planned, including the architecture and components needed [11]. Following this is the Prototype Development stage, where a prototype is developed based on the system design [12]. The fourth stage is Implementation, where the developed prototype is implemented in a simulated testing environment [13]. This is followed by the Testing stage, where the system undergoes rigorous testing to ensure it functions correctly and meets the desired specifications [14]. The final stage is Result Analysis, which involves analyzing the results from the testing phase to evaluate the system's performance and effectiveness. Each stage is sequentially connected, showing the flow of the research process from initial problem identification to final result analysis.

2.2 Problem Identification and Literature Review

In this stage, problems underlying the research are identified, and literature related to the topic is reviewed [15]. The identified problems include: inefficient and time-consuming manual soap refilling, leading to inefficiency in the refill process; manual refilling causing contamination and being unhygienic, creating hygiene issues; and the use of single-use soap bottles generating significant plastic waste, adding to environmental burdens and causing environmental impact. Literature review is conducted to understand the latest technological developments in microcontroller-based automatic soap refill systems and circular economy [16]. Related studies are analyzed to identify gaps in the research that have not been addressed. For example, Study A developed an automatic soap refill system using ultrasonic sensors to detect soap levels [17] but did not discuss integration with the circular economy concept. Study B used IoT technology to monitor and control the soap refill system remotely [18], but did not consider sustainability aspects. Study C implemented a microcontroller-based automatic refill system for industrial use but did not include a business process analysis [19]. Study D developed an automatic soap dispenser for commercial use but did not integrate circular economy elements [20]. Study E focused on reducing plastic waste by using more environmentally friendly refillable bottles, but without automation [21]. By analyzing these studies, this research aims to fill the existing gaps by developing a microcontroller-based automatic liquid soap refill system integrated with the circular economy concept.

2.3 System Planning

After identifying the problems, the next stage is designing the microcontroller-based automatic liquid soap refill system. In this stage, hardware specifications are determined, including the selection of sensors, microcontrollers, and IoT components to be used [22]. The design also includes the system scheme and workflow.

Table 1. Design Scope

Planning	Description	Main Components
Hardware Specifications	Determining the type of sensors, microcontrollers, and other components.	Arduino Uno, Keypad Matrix, Water Pump, Weight Sensor, Obstacle Sensor, Mosfet, Battery Holder, LED Screen.
System Scheme	Creating a system diagram that includes all components.	System Scheme Diagram
System Workflow	Designing the system workflow from object detection to refill completion.	System Workflow Flowchart
Initial Programming	Writing initial code for the microcontroller controlling basic operations.	Arduino Uno, Arduino IDE

Design Scope outlines (Table 1) the different planning stages, descriptions, and main components required for the system design. The design scope provides an overview of the system from hardware specifications, creating system schemes, designing workflows, to initial programming for the microcontroller. It encompasses several critical stages to ensure the successful development of the automatic liquid soap refilling system. The first stage, Hardware

Specifications, involves determining the specific types of sensors, microcontrollers, and other components necessary for the system. This includes selecting main components such as the Arduino Uno, Keypad Matrix, Water Pump, Weight Sensor, Obstacle Sensor, Mosfet, Battery Holder, and LED Screen. Next, in the System Scheme stage, a comprehensive system diagram is created, illustrating how all these components will be interconnected and function together. Following this, the System Workflow stage involves designing a detailed workflow for the system, mapping out the process from object detection to the completion of the refill. This is represented in a system workflow flowchart. Finally, the Initial Programming stage entails writing the initial code for the microcontroller, which will handle basic operations of the system. This programming is done using the Arduino Uno and Arduino IDE.

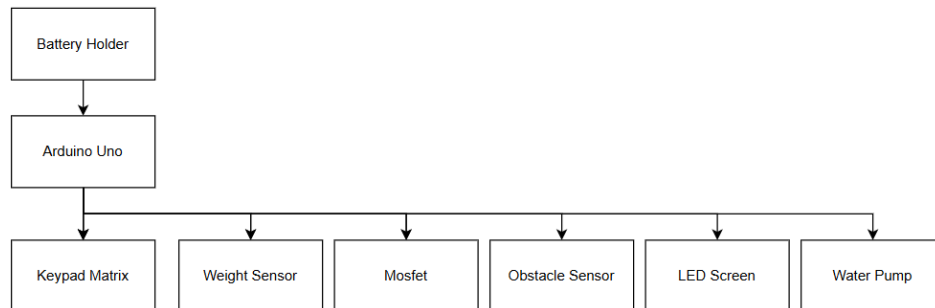


Figure 2. Schematic Diagram of Automatic Liquid Soap Filling System

Schematic Diagram of Automatic Liquid Soap Filling System (Figure 2) shows the schematic diagram of a microcontroller-based automatic liquid soap refilling system with existing components, illustrating the workflow and interactions between various parts of the system. The Battery Holder provides power for the entire system and supplies electricity to the Arduino Uno, which acts as the brain of the system. Arduino Uno controls all other components based on the input it receives. The user enters the desired amount of soap settings via the Keypad Matrix. The Weight Sensor measures the weight of the soap in the container and provides this data to the Arduino Uno. Based on input from the Weight Sensor, Arduino Uno decides whether to activate the Water Pump to refill liquid soap. The Mosfet is used to control the power flow to the Water Pump according to commands from the Arduino Uno. The Obstacle Sensor checks whether there are obstacles in the soap filling line, ensuring the filling process runs smoothly. All system status and information required by the user is displayed via the LED Screen, including charging status and input provided by the user. This block diagram shows how each component interacts to create an efficient and effective automatic liquid soap refilling system in supporting the circular economy concept [23].

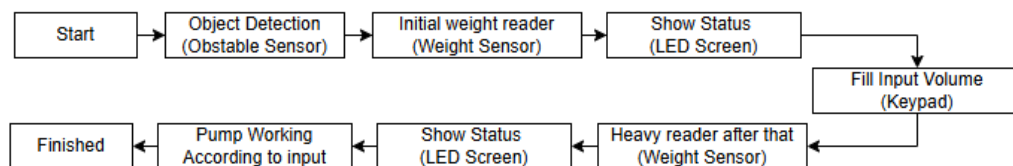


Figure 3. System Workflow

System Workflow (Figure 3) provides a detailed workflow of the system. The system starts by detecting objects using the Obstacle Sensor. Once an object is detected, the weight sensor reads the initial weight of the object. The system status is then displayed on the LED display. The user enters the input volume via the keypad, and the pump works according to the input entered. After that, the system status is again displayed on the LED screen, and the heavy reader checks the weight after the process is complete. This process ends with the system indicating the finish status [24].

2.4 Prototype Development

The prototype of the automatic soap refill tool is developed based on the designed scheme. Development includes component assembly, microcontroller programming, and system integration. Prototype development also involves initial testing to ensure all components work well [25].

Table 2. Development Scope

Scope	Description	Main Components
Component Assembly	Assembling all hardware components into one system	Arduino Uno, Mosfet, Breadboard, Jumper Wires, Battery Holder
Microcontroller Programming	Programming the microcontroller to control all components	Arduino Uno, Arduino IDE Software
System Integration	Connecting the system to the microcontroller platform	Arduino Uno

Initial Testing Testing each component to ensure they function properly All components

The development scope, as outlined in Table 2, details a structured and methodical approach to building and verifying the prototype of the automatic liquid soap refilling system. It begins with the Component Assembly stage, where all hardware components are assembled into one cohesive system. This is followed by the Microcontroller Programming stage, which involves programming the Arduino Uno to control all the connected components using the Arduino IDE software. The System Integration stage ensures that the assembled hardware system is correctly connected to the microcontroller platform, enabling effective communication among all components. Finally, the Initial Testing stage verifies that each component functions correctly, ensuring the overall system operates as intended. This systematic approach ensures that the prototype is well-planned, efficiently developed, and thoroughly tested, laying a solid foundation for the successful implementation and operation of the automatic liquid soap refilling system.

Table 3. System Component Specifications

Components	Qty	Specification
Mikrokontroler	1	Arduino Uno
Load Cell Module	1	HX711 Dual-Channel 24 Bit
USB Cable	1	USB-A to USB-B 30cm
N-Channel Mosfet	1	Mosfet IRF520PBF TO-220 Vishay Intertech
Resistor	1	1/2W +- 1% 220R Metal Film Resistor (TR)
Water Pump	1	Multi 12Volt DC
Adapter	1	Power Supply 12V 1A 12W 5.5/2.1MM
Weight Sensor	1	Load Cell 1Kg Bar Scale Weight
Obstacle Sensor	1	Infrared Barrier Module
Battery Holder	1	2S 7.4V With Jack DC Male
Breadboard	1	MB-102 Solderless 830P
Keypad	1	Matrix Numeric 4x4 10P

As shown in Table 3, the prototype of the automatic soap refilling device was developed by assembling components such as an Arduino Uno as a microcontroller, an HX711 load cell module to measure the weight of soap, and various other components such as an IRF520PBF Mosfet to control power flow, a 12V DC water pump, and an infrared object detection sensor. These components are integrated with a USB-A to USB-B cable, a weight sensor, an adapter, and a breadboard for assembly. This system is programmed to receive input from the sensors and send commands to the water pump and LED screen, ensuring the automatic refilling of soap when needed [26].

2.5 Implementation and Integration

In this stage, the developed system is integrated into a simulated testing environment. Implementation involves several key steps, including hardware installation, software development, and setting up communication between sensors, microcontrollers, and other IoT components [27].

Table 4. Functionality Testing

Components	Description	Status	Test Results
Mikrokontroler	Controls the entire system	Functional	Sends and receives data correctly
LED Screen	Displays system status	Functional	Information displayed clearly
Mosfet	Controls power flow to the water pump	Functional	Activates & deactivates the pump
Water Pump	Refills the object	Functional	Soap flow according to input
Weight Sensor	Measures the object's weight	Functional	Accurate weight data
Obstacle Sensor	Detects if there is an object	Functional	Detects objects accurately
Battery Holder	Provides power for the system	Functional	System runs stably
Keypad	User Input	Functional	Receives input amount accurately

Functional testing, as shown in Table 4, ensures that each component functions as expected. This includes ensuring that the water pump is activated and deactivated based on input from the keypad matrix. The system is tested under simulated conditions to ensure all components work well in real scenarios [28]. Hardware installation begins by connecting the Arduino Uno to all other components such as sensors, keypad matrix, water pump, MOSFET, and LED screen. The keypad matrix is installed to allow users to input the desired amount of soap. The weight sensor is placed under the soap container to measure the soap weight and provide data to the Arduino Uno. The water pump is integrated into the system using the MOSFET to control the power flow according to commands from the Arduino Uno. The obstacle sensor is installed in the refill path to detect obstacles that may disrupt the refill process. The LED screen is connected to the Arduino Uno to display system status and user input information, while the battery holder provides power for the entire system. Software development involves creating code for the Arduino Uno that regulates the system logic based on input from the keypad matrix and sensors. Serial communication is set up to ensure that the Arduino can communicate with other components through the serial protocol. If necessary, IoT connectivity is

established for remote monitoring and control of the system. The communication setup is completed by connecting the sensors to the Arduino Uno and configuring the communication parameters.

2.6 Testing and Evaluation

System testing was carried out to evaluate the performance and effectiveness of the automatic soap refilling system. Testing includes functionality tests, durability tests, and usage tests in real conditions. Functionality testing involves checking each component and workflow of the system to ensure that each part functions as expected [29]. This includes testing obstacle sensors to detect the presence of objects, weight sensors to measure the weight of soap remaining in the dispenser, water pump to ensure refilling of liquid soap into objects, keypad matrix to receive input from the user, LED screen to display system status information, and MOSFET to control the flow of electricity to the water pump based on signals from the microcontroller.

Table 5. System Testing & Evaluation Coverage

Testing	Description	Test Metod	Status
Functionality Test	Inspection of each component and system workflow.	Individual component testing (sensor, pump, keypad, etc.)	All components function as expected.
Endurance Test	System checks under conditions of repeated use.	Operation cycle testing, load testing, component durability testing.	Components survive without damage under repeated use.
Condition Test	Simulation of system use in real conditions.	End user testing, environmental testing.	The system functions well in a variety of conditions.

As outlined in Table 5, functionality testing ensures that each component of the system works correctly and interacts as intended within the overall system. Endurance testing subjects the components to repeated use and stress to verify their durability and long-term performance. Condition testing evaluates the system’s operation in real-life scenarios and varying environmental conditions, confirming that it remains reliable and effective under diverse circumstances. These tests collectively ensure that the automatic soap refilling system meets performance standards and can sustain prolonged use without failure.

2.7 Business Process Analysis and Circular Economy

At this stage, the analysis of the business process and circular economy of the microcontroller-based automatic liquid soap refilling system involves several important stages that are interconnected to ensure efficient and effective operations and become a filler or complement as opposed to the core business function, with the service being technical or non-technical [30]. The business process stages involve data collection using a weight sensor connected to a microcontroller. This sensor detects the weight of the soap in the container and sends the data to the microcontroller for processing, which is used to refill the liquid soap. The microcontroller processes data from the weight sensor to ensure the amount of liquid soap refilled matches the required volume. Additionally, an object sensor detects the presence of objects, and the desired soap volume is input via the matrix keypad. The microcontroller automatically controls the water pump via a MOSFET based on the collected data, monitoring the soap weight in real-time to ensure proper refilling, and stops the pump once the desired volume is reached. System monitoring and maintenance are conducted through an LED screen that displays the status of the refilling system according to the input.

Table 6. Business Processes and Their Impact

Business Processes	Description	Impact	Benefits of a Circular Economy
Holding Data	User input will be accommodated in the microcontroller	Accuracy in refilling	Waste reduction and resource efficiency
Input Volume	The user enters the desired volume via the matrix keypad	Customize user needs	Optimizing the use of liquid soap
Refill	The microcontroller controls the water pump to refill the soap.	Automatic and fast refilling	Minimize the use of single-use bottles
Monitoring	System status is displayed on the LED screen	Ease of monitoring	Improved maintenance and management

As illustrated in Table 6, these business processes with automation and a circular economy approach provide benefits in terms of operational efficiency, waste reduction, and support for environmental sustainability. By accommodating user input within the microcontroller, the system ensures accurate refilling, leading to significant waste reduction and resource efficiency. The customization of soap volume based on user needs optimizes the use of liquid soap, further reducing waste. The automatic and fast refilling process minimizes the reliance on single-use

bottles, directly contributing to environmental sustainability. Additionally, the ease of monitoring the system status on the LED screen improves maintenance and management, enhancing overall operational efficiency and reliability.

3. RESULT AND DISCUSSION

3.1 Development of a Prototype of Automatic Liquid Soap Refilling System

The development of a microcontroller-based automatic liquid soap refilling system prototype involves several main steps, including design, component assembly, and programming. Each component is selected and assembled to ensure seamless integration and optimal functionality.

3.1.1 System Planning

System design includes selecting main components such as Arduino Uno, keypad matrix, water pump, LED screen, weight sensor, mosfet, obstacle sensor, battery holder and breadboard. The system schematic is designed to ensure good connectivity between all components, with Arduino Uno as the central controller.

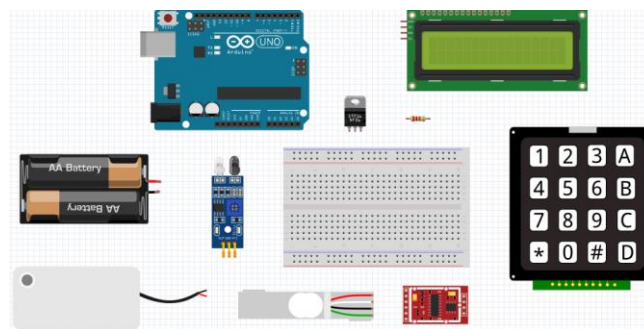


Figure 4. System Planning

The image in Figure 4 presents a comprehensive system planning diagram for an automatic liquid soap refilling system, highlighting the interconnection of essential components. The Arduino Uno, serving as the primary microcontroller, orchestrates the system's operations by receiving input from various sensors and sending commands to other components. The Matrix Keypad allows users to input commands, setting up and managing the system's functions. The Water Pump, controlled by the Arduino Uno, transfers liquid soap from the storage tank to the dispenser. The LED Screen displays important information such as charging status and error messages. The Weight Sensor monitors the amount of liquid soap, ensuring precise measurement. The MOSFET acts as an electronic switch, regulating the power flow to the pump based on the microcontroller's commands. The Obstacle Sensor detects the presence of objects, ensuring that soap is dispensed only when necessary. The Battery Holder secures the batteries, providing a stable power supply for the system. The Breadboard aids in assembling the components without soldering, simplifying the testing and modification process. This image effectively illustrates the connectivity and functionality of each component, ensuring a well-coordinated and efficient automatic liquid soap refilling system.

3.1.2 Component Assembly

The components are assembled based on the designed scheme. A weight sensor is installed under the soap container to detect the amount of soap remaining. A matrix keypad is installed to receive input from the user. An LED screen is installed to display information to users. Obstacle sensors are used to detect the presence of objects in front. The water pump is connected via a mosfet to control the soap flow.

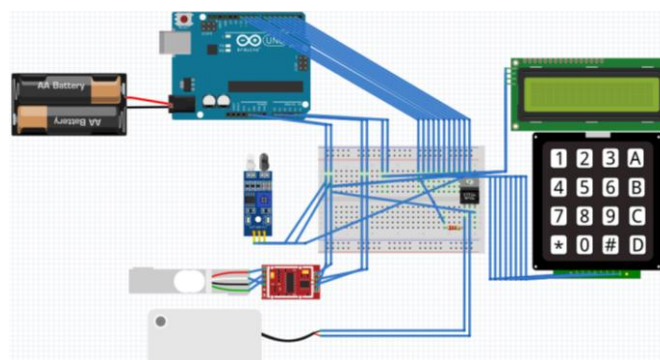


Figure 5. Component Assembly

The image in Figure 5 illustrates the precise wiring required to assemble the automatic liquid soap refilling system. To integrate the 16x2 LCD with I2C to the Arduino, connect the LCD's GND pin to the Arduino's GND pin and the LCD's VCC pin to the Arduino's 5V pin. The LCD's SDA pin is connected to the Arduino's A4 pin and the SCL pin to the Arduino's A5 pin. For the weight sensor using the HX711 module, its VCC pin is linked to the Arduino's 5V pin and its GND pin to the Arduino's GND pin. The HX711's DT pin is connected to pin 3 of the Arduino and the SCK pin to pin 2, ensuring the load cell's E+ (Excitation+), E- (Excitation-), A+ (Amplifier+), and A- (Amplifier-) pins are correctly wired. The MOSFET setup involves connecting its Drain terminal to one terminal of the water pump and its Source terminal to GND, with the Gate terminal connected to pin 9 of the Arduino through a 220-ohm resistor. The other terminal of the water pump is linked to an external +12V power source. The obstacle sensor's VCC pin is connected to the Arduino's 5V pin, its GND pin to the Arduino's GND pin, and its OUT pin to pin 4 of the Arduino. For the 4x4 keypad matrix, pin R1 of the keypad is connected to pin 5 of the Arduino, R2 to pin 6, R3 to pin 7, and R4 to pin 8, while pin C1 is connected to pin A0 of the Arduino, C2 to pin A1, C3 to pin A2, and C4 to pin A3. This detailed wiring ensures each component functions correctly within the system, achieving an efficient and reliable automatic liquid soap refilling system.

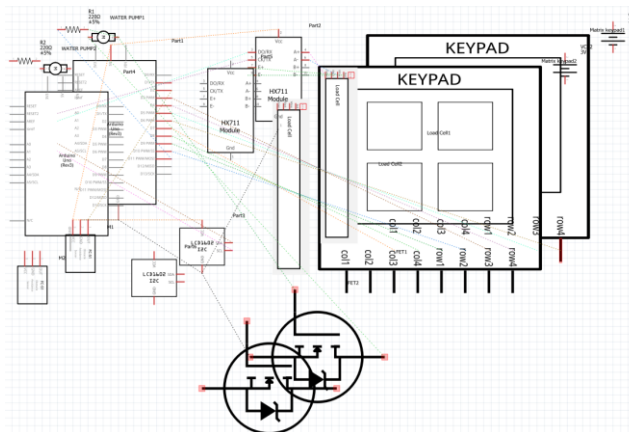


Figure 6. Assembly Scheme

The assembly scheme depicted in Figure 6 demonstrates the integration of various components with an Arduino Uno to form an automatic liquid soap refilling system. This schematic includes connections for sensors, a keypad, MOSFETs, a water pump, and an LCD display. The Arduino Uno is powered through the Vin and GND pins and interfaces with the HX711 module to measure the weight of the soap container. The HX711 module's VCC is connected to 5V, GND to GND, DT to pin 3, and SCK to pin 2 of the Arduino. The LCD display, a 16x2 module with I2C, connects to the Arduino via SDA to A4 and SCL to A5, while the keypad matrix links rows (R1, R2, R3, R4) to digital pins 5, 6, 7, and 8, and columns (C1, C2, C3, C4) to digital pins 10, 11, 12, and 13. The MOSFETs are crucial for controlling the water pump operation: MOSFET1's gate is connected to Arduino pin 9 through a 220-ohm resistor, and MOSFET2's gate connects to pin 8 via a 220-ohm resistor. One terminal of the water pump connects to the drains of both MOSFETs, with the sources connected to GND, and the other terminal to an external 12V power source. The obstacle sensor, vital for detecting objects in the refill path, connects its VCC to 5V, GND to GND, and OUT to digital pin 4 of the Arduino. This comprehensive arrangement automates the refilling process by reading weight data, processing user input from the keypad, and displaying real-time status via the LCD, while the MOSFETs manage the water pump operation efficiently.

3.1.3 Microcontroller Programming

Programs for Arduino Uno were developed to control all components. This program sets a weight sensor to read the weight of liquid soap, an obstacle sensor to detect objects, and a water pump to refill the soap based on input from the keypad matrix. Data from sensors and system status is displayed on the LED screen. The microcontroller program uses several Arduino libraries to control various connected components. The Wire.h library is used for I2C communication, LiquidCrystal_I2C.h to control the I2C LCD, HX711.h to read data from the HX711 module, and Keypad.h to read input from the keypad. In the initialization stage, the I2C addresses and pins for the HX711, water pump, obstacle sensor, and keypad are set. The LiquidCrystal_I2C lcd object is initialized with address 0x27 and size 16x2 for the LCD, while the HX711 scale object is initialized for the HX711 module. The 4x4 keypad is created using the Keypad object.

In the setup function, communication with the LCD is initiated and the backlight is activated. The pins for the HX711 are set and the calibration factors are determined. The pin for the water pump is set as output and it is ensured that the pump is off initially. The pin for the obstacle sensor is set as input. In the loop function, the status of the obstacle sensor is read. The weight of the load cell is read using scale.get_units(10) and the weight status is displayed on the LCD with two decimal places. If an obstacle is detected, the message "Object Detected" is displayed and the input mode for volume is activated using the keypad. If no obstacles are detected, the message "No Object Detected"

is displayed and the pump is confirmed to be off. The water pump is controlled based on the detected input volume and weight. Then initial testing is carried out to ensure all components work properly. Each sensor is tested to ensure accuracy, and the water pump is tested to ensure proper soap flow. The program on the Arduino Uno is also tested to ensure all functions run as planned.

3.2 Development of a Prototype of Automatic Liquid Soap Refilling System

Discussion of the results of this research includes analysis of data obtained during testing as well as comparisons with previous research. The data obtained shows that this automatic liquid soap refilling system is successful in overcoming several problems that have been previously identified. This system has proven to be more efficient than manual refilling methods. Users only need to enter the desired volume of soap into the system, and refilling will occur automatically. This significantly reduces the time required for refilling and improves overall operational efficiency. In addition, the use of sensors and automatic water pumps in this system reduces the risk of contamination that may occur with manual refilling. This system ensures that soap is refilled without direct contact, which maintains cleanliness and hygiene. Thus, this system not only increases efficiency but also ensures higher standards of cleanliness.

The use of this automatic liquid soap refilling system also contributes to reducing the use of single-use soap bottles. By reducing reliance on single-use plastic bottles, this system helps reduce plastic waste, which has a positive impact on the environment. Implementation of this system supports the circular economy concept by optimizing resource use and reducing pollution. Overall, this research shows that the microcontroller-based automation technology implemented in this automatic liquid soap refilling system is not only efficient and environmentally friendly but also provides a practical solution to the problems encountered in manual refilling. It is hoped that this system can become a reference for the development of other automation technologies that support the circular economy concept.

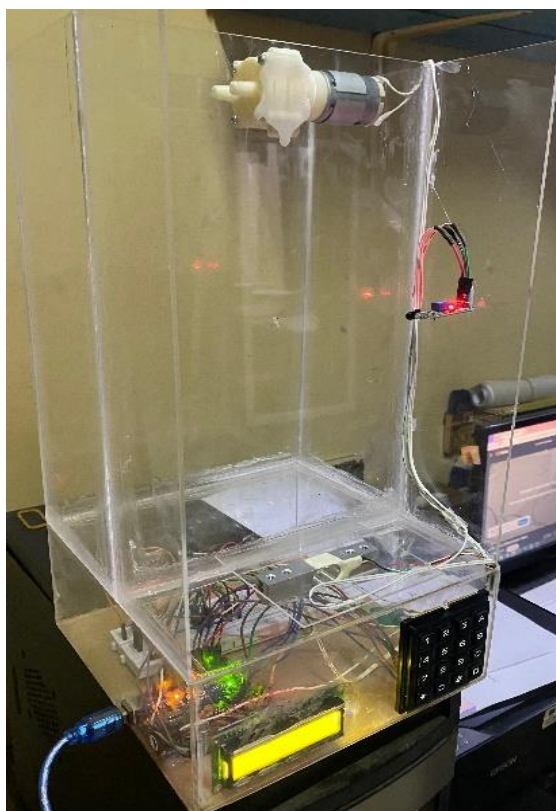


Figure 7. Design Results Tool

Figure 7 displays the design results of the automatic liquid soap refilling system, which highlights its practical implementation and functionality. The tool comprises two main sections: the storage area for the Arduino and other components, measuring 20x10 cm, and the object section, measuring 20x30 cm in diameter. The back part of this section stores the liquid soap, while the front part is designated for the object to be filled with soap from the water pump. An LCD screen on the system displays the status of the object. If no object is detected, the screen shows a message indicating the absence of an object. Once an object is detected, the user can input the desired amount of soap using the keypad. The water pump operates according to this input, ensuring that the soap is refilled as needed. This system not only efficiently manages the refilling process but also reduces the reliance on single-use plastic bottles,

supporting the circular economy by minimizing plastic waste and optimizing resource use. This microcontroller-based automation technology offers a practical and environmentally friendly solution to the challenges of manual refilling.

4 CONCLUSION

This research succeeded in developing a microcontroller-based automatic liquid soap refilling system that is integrated with the circular economy concept. The system is designed to refill soap automatically without the need for manual intervention, increasing efficiency and convenience for users. The use of single-use soap bottles can be reduced, supporting environmental sustainability through recycling or reusing soap bottles. Testing shows that the device functions well in a wide range of environmental and operational conditions, able to detect the need for recharging and doing so automatically. By reducing the use of single-use soap bottles and supporting the concept of recycling, this system makes a positive contribution to environmental sustainability as well as offering economic benefits through reducing the cost of purchasing new soap bottles. It is hoped that the results of this research will become a reference for the development of other automation technologies that support the circular economy concept, providing insight and inspiration for other applications that support environmental and economic sustainability. Overall, this research shows that microcontroller-based automation technology can be integrated with circular economy concepts to produce efficient, environmentally friendly and economical solutions.

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