Design and Implementation of Automatic Fluid Dispensing System

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Abstract - *The automatic fluid dispenser introduces a systematic and efficient alternative to manual fluid dispensing and expensive industrial systems like those from Nordson EFD. These high-end solutions, while precise, are often costly and lack flexibility, making them inaccessible for many applications. This project presents a cost-effective, microcontroller-based dispenser that accurately controls the speed and duration of a peristaltic pump to ensure precise, contamination-free fluid delivery. It is especially beneficial in sectors like pharmaceuticals, food and beverage, chemicals, cosmetics, and research, where accurate dosing is critical. By automating the process, it reduces manual effort, prevents health risks, ensures quality, and minimizes resource wastage, offering a reliable solution for precision fluid dispensing.*

Key Words: Liquid dispensing systems, peristaltic pumps, LCD, motors, relays, liquid medication.

1.INTRODUCTION

Fluid dispensing is essential in many industries, including healthcare, manufacturing, and food processing, and cosmetics where precise and consistent liquid handling is critical. The traditional method of fluid dispensing is very time-consuming and prone to human errors as it requires fluids are dispensed manually after measurement. The ability to dispense exact volumes of fluids impacts product quality, safety, and efficiency, making it a key focus in settings that range from administering medications to applying adhesives in production lines. It also results in wastage of resources making the process inexpensive. Despite its importance, fluid dispensing faces several challenges that complicate its effectiveness and reliability. Water is vital for human survival, yet only 0.08% of Earth's freshwater is accessible for use [1]. Rising demand and shrinking resources have intensified global water scarcity. According to the International Water Management Institute, by 2025, most regions in Latin America, Asia, Africa, and the Middle East may face severe shortages [2]. Overexploitation, blocked basins, and poor management practices have further reduced water availability [3]. Modern solutions like agricultural reforms and rainwater harvesting are urgently needed [4], especially as groundwater resources continue to decline [5]. Technological innovations such as coin-operated water dispensers help minimize wastage by enabling controlled and automated distribution [6] , and their integration with cooling, heating, and plumbing systems enhances usability [7]. Available in various models—like wall-mounted or direct-piping—these dispensers promote hygiene and efficiency [8]. In small-scale industries, automation reduces human error, spillage, and delays common in manual bottle-filling processes [9]. With IoT advancements, smart systems now enable app-based fluid dispensing, enhancing hygiene and minimizing contact [10]. For instance, IoT-driven mocktail dispensers can mix drinks via automated pumps based on customer orders [11]. Juice mixer machines also reduce labor costs and improve accuracy by preventing over-pouring [12], while more advanced systems like CAMS offer modular, scalable cocktail automation with precise control [13]. In broader applications—such as labs, households, and industries—automated dispensers ensure consistent measurement and efficient operation [14]. Moreover, automated oil filling systems address issues like leakage and inconsistent volume in small-scale production units [15].

2. RELATED RESEARCH

An automatic fluid dispenser is a device designed to dispense a specific amount of fluid, such as soap, sanitizer, or other liquids, without manual intervention. These systems are often employed in public facilities, healthcare settings, and households to promote hygiene and reduce the spread of germs. With the advent of automation, fluid dispensers have evolved to include sensors, microcontrollers, and advanced mechanisms to enhance precision and reliability.

Anita Joshi et al. [1] developed an Arduino-based automated liquid dispenser aimed at delivering precise liquid measurements using sensors, pumps, and valves. Kiran Patil et al. [2] implemented a similar system with an IR sensor, solenoid valve, and pump to dispense accurate amounts of liquid efficiently. Ayush Vats et al. [3] proposed a smart dispenser equipped with an LCD and Arduino, targeting safe and accurate fluid handling in medical applications. Chaitanya Salunkhe et al. [4] presented a customizable multi-liquid dispenser using microcontrollers and solenoid valves. Kalpana M. and Snehal B. [5] designed a smart beverage dispenser with Arduino and a GSM module to reduce manual intervention. Isha Sharma et al. [6] developed a voice-controlled dispenser using a voice recognition module, making it accessible for differently-abled users. Pooja Pawar et al. [7] introduced an automated system with a user interface to select liquids and volume, operated by sensors and microcontrollers. Sushant Kadam et al. [8] built a juice dispenser with Arduino and solenoid valves to ease beverage service. Sarvesh Chaudhary et al. [9] created a drink mixer using Raspberry Pi and peristaltic pumps for precise ingredient blending. Tehreem Naeem [10] implemented a GUI-based flow control system using Arduino and a peristaltic pump for monitoring and controlling fluid dispensing. Sahil Bendale et al. [11] designed an IoT-based automatic mocktail maker with Bluetooth and flow mixer technology to ensure precision and avoid leakage. Naing Kyaw Soe [12] proposed a five-channel juice mixer machine using gear pumps, allowing percentage-based or manual mixing options. Cameron Glass [13]introduced the Cocktail Automation Management System (CAMS), a scalable and modular solution that automates cocktail preparation using a central controller and ingredient modules. Another paper by Anita Joshi et al. [14] highlighted the use of Arduino in liquid dispensing with a user-friendly interface and safety features. Lastly, S. Menaga et al. [15] developed an IoT-based automaticoil dispenser that uses sensors to monitor quantity and shares stock information remotely, aiming for cost-effective and precise dispensing in small industries.

3. PROBLEM STATEMENT

Manual fluid dispensing often results in inaccurate measurements, leading to either wastage or insufficient application. Physical contact with manual dispensers increases the risk of cross-contamination and spread of infectious diseases. Inconsistent output from manual systems reduces operational efficiency and increases long-term costs. There is a growing need for a hygienic, touchless dispensing mechanism, especially in healthcare and public settings post-COVID-19.

Existing manual methods are unsuitable for applications requiring precision, such as laboratories and agriculture.

1. A reliable, low-cost automated system is required to provide consistent, safe, and user-friendly fluid dispensing.

2. The goal is to develop a scalable solution that minimizes waste, enhances hygiene, and improves user convenience across multiple industries.

4. PROPOSED SYSTEM

4.1 Components

- LCD 20x04 Display

The 20x4 LCD display is a versatile and cost-effective solution for visual output in embedded systems. It can show 20 characters per line across 4 lines, making it suitable for displaying more data compared to smaller displays. Its ease of programming and ability to display custom characters and animations make it ideal for projects requiring a clear and customizable user interface

- I2C Module

Hitachi HD44780-based LCDs use I2C piggy-back boards with the PCF8574 I/O expander for easy communication with microcontrollers. These boards simplify wiring by using only two I2C lines. The default I2C address is 0x27 for PCF8574T and 0x3F for PCF8574AT, assuming address pins A0–A2 are left unconnected.

- Rotary Encoder

A rotary encoder is an electro-mechanical device that converts the angular position or movement of a shaft into digital or analog signals. It is commonly used for adjusting settings, navigating menus, or detecting rotation in applications like robotics, industrial controls, and user interfaces. There are two main types: absolute, which gives exact position, and incremental, which detects movement or speed.

- Peristaltic Pumps

A peristaltic pump, also commonly known as a roller pump, is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained in a flexible tube fitted inside a circular pump casing. Most peristaltic pumps work through rotary motion, though linear peristaltic pumps have also been made. The rotor has a number of "wipers" or "rollers" attached to its external circumference, which compress the flexible tube as they rotate by.

Peristaltic pumps move fluid by compressing a flexible tube with rollers, creating a peristalsis motion similar to biological systems like the gastrointestinal tract. This design ensures no direct contact between the pump and fluid. Kamoer's latest peristaltic pumps use a 24V DC supply, offer up to 360 ml/min flow rate, and support speed control via a PWM signal, making them ideal for clean and precise liquid handling.

Calculation of Flow rate:

Theoretical flow rate (ml/min)

F = V*L*N RPM

Where,

V= volume of occulated tubing (mm /mm).

L=tubing length that will be occluded by pump roll(mm).

N=number of rollers on the rotor.

- Channel Relay Board

A relay is an electrically operated switch that controls high-voltage devices using low-voltage signals. The 4-Channel Isolated 5V 10A Relay Module supports up to AC 250V/10A or DC 30V/10A per channel, with opto-isolation for safety and LED indicators. It works with 1.0V–5V inputs, making it compatible with Arduino, AVR, PIC, and ARM. Common uses include industrial automation, PLCs, and smart home systems.

- DFPlayer Mini Audio Module

The DFPlayer Mini is a low-cost, compact MP3 module that supports direct speaker output and works standalone or with microcontrollers like Arduino via UART. It supports 8KHz–48KHz sampling, 24-bit DAC, FAT16/FAT32 file systems, and up to 32GB TF cards. Key features include a built-in 3W amplifier, multiple control modes, support for 100 folders (1000 files each), 30 volume levels, 10 EQ settings, and background audio pause for prompt playback.

- Step Down Transformer

A step-down transformer reduces AC voltage using mutual induction, where the primary winding induces a lower voltage in the secondary winding. The 2-0-12 2Amp Center Tapped Transformer steps down 230V AC to 12V-0-12V AC. It features a center-tapped secondary, a high-permeability silicon steel core for efficiency, and is ideal for general-purpose applications

- Bridge Rectifier

A bridge rectifier converts alternating current (AC) to direct current (DC) by using four diodes in a bridge configuration, ensuring current flows in one direction during both positive and negative half-cycles of the AC input.

- Voltage regulator IC's

The LM78XX series of three-terminal positive regulators is available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut-down, and safe operating area protection. If adequate heat sinking is provided, they can deliver over 1 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components for adjustable voltages and currents.

4.2 Methodology

Circuit Design :

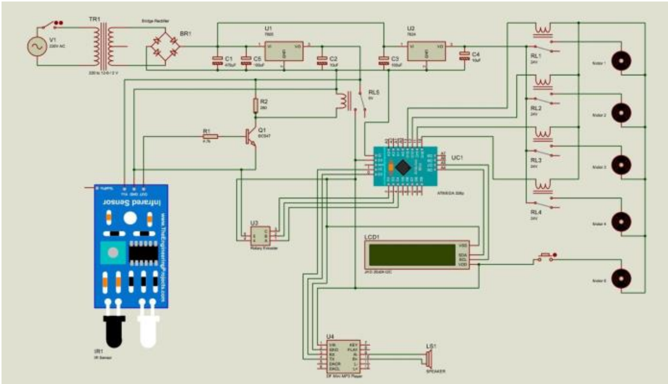

Fig -1: Circuit Diagram

Automatic fluid dispenser is a system designed to dispense precise amounts of fluid across four channels using a peristaltic pump. It utilizes a rotary encoder to get input from the user, which helps to control the amount of fluid dispensed. ATMega328p acts as the central controller to manage the dispensing process, while an LCD display provides real-time feedback and control options for the user, along with audio feedback given by the machine to the user. The entire system has inbuilt AC to DC converting circuitry so, external it can be directly connected to 220v AC mains supply.

Working :

The device is powered by an AC 220V supply, which is stepped down using a center-tapped transformer to 12-0-12V AC. This AC output is then rectified using a Full Bridge Rectifier and filtered by electrolytic capacitors to obtain a smooth DC voltage. Voltage regulator ICs 7805 and 7824 provide regulated 5V and 24V outputs for the circuit.

In idle condition, the system remains in sleep mode. When a glass is placed on the holder, an IR sensor detects its presence and activates the relay, powering the entire circuit. An LCD greets the user and a DF Mini player plays a welcome audio clip. The LCD then prompts fluid selection starting from FLUID1. The user can rotate a rotary encoder to select the desired quantity (e.g., 60 ml) and press the encoder to confirm and move to the next fluid. This process continues up to FLUID4.

After finalizing the input, a "THANK YOU!" message is displayed, and an exit audio is played. The microcontroller processes the selected quantities and sequentially activates the corresponding relays to control four peristaltic pumps, dispensing each fluid in the specified amount. The DF Mini player is also controlled via UART to play appropriate audio prompts.

Once dispensing is complete, if the glass remains on the holder, the system returns to the selection screen. If the glass is removed, the system goes back to sleep mode to conserve power. A stirring mechanism is also provided, which can be manually activated using a switch to mix the dispensed fluids. Fluid input tubes are connected at the back, and all outputs are channeled through a single dispensing nozzle equipped with an IR sensor above the glass holder.

4.3 Actual Enclosure

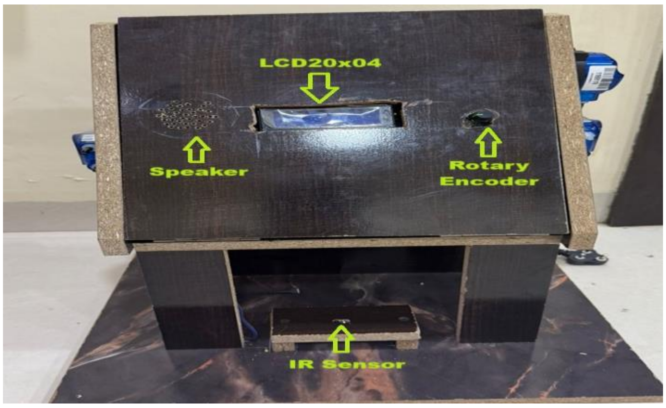

Fig -2: Front View

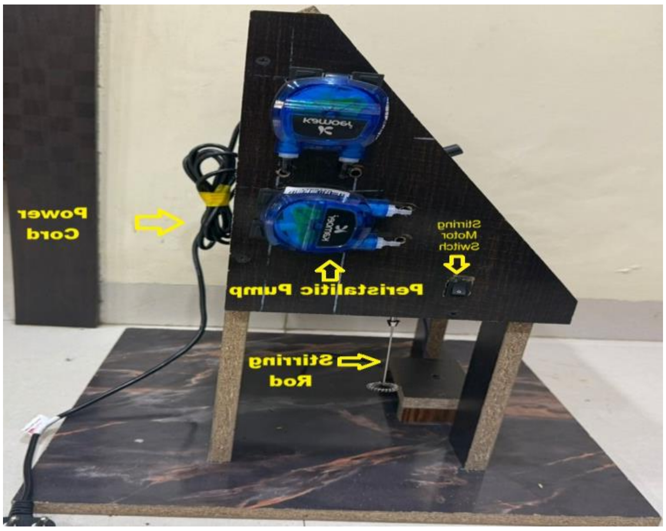

FIg -3: Side View

5. ADVANTAGES AND USE CASES

The automatic fluid dispenser ensures accurate and consistent fluid delivery with adjustable flow rates. It offers real-time feedback, manual control options, and audio alerts to improve user interaction and operational reliability. The system is low-power, easily programmable, and supports additional features like timed dispensing and batch modes, making it suitable for compact and cost-effective applications.

Typical use cases include medical dosing, reagent mixing, food and beverage dispensing, personal care product filling, and industrial fluid handling. It also supports automated soap and cleaning dispensers for hygiene and maintenance applications.

6. EXPECTED OUTCOMES

Based on the specifications of the peristaltic pump, which has a flow rate of 560 ml/min , the system is expected to dispense fluids accurately and efficiently within a range of small to moderate volumes.

For ex :-

The estimation time to dispense 100 ml is ~ 10.7 seconds.

The estimated time to dispense 250 ml should be ~ 26.8 seconds.

The system is anticipated to achieve a high degree of accuracy, with a margin of error ± 5%, ensuring that even small quantities like 50 ml, are dispensed reliably within a range of 47.5 ml -52.5 ml. Once implemented, the systems is projected to be capable of efficiently dispensing volumes ranging from 10 ml to 500 ml, making it suitable for diverse applications. These theoretical results provide a strong foundation for further testing and optimization once the prototype is fully developed.

7. CONCLUSION

The project successfully demonstrates the design and implementation of an automatic fluid dispenser system leveraging the ATmega328P microcontroller. The system combines precision hardware components—such as peristaltic pumps, IR sensors, and rotary encoders—with a user-friendly interface provided by the LCD display and DFPlayer Mini for audio feedback.

The dispenser operates efficiently in various fluid dispensing scenarios, making it suitable for applications in industries such as pharmaceuticals, food and beverage, and chemical processing.

8. FUTURE SCOPE

Advanced fluid dispensing systems are evolving with the integration of modern technologies. IoT enables remote control and real-time monitoring via Wi-Fi or Bluetooth modules. AI and machine learning allow predictive maintenance and smart dosage adjustments. Multi-fluid dispensers handle several liquids simultaneously, useful in medical and chemical applications. Energy-efficient designs include battery-operated and solar-powered models for portability and off-grid use. Advanced sensors improve accuracy and safety by monitoring flow, pressure, and fluid type. These systems are also essential in automated labs for high-throughput screening and in industrial automation for precise, large-scale liquid handling.

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