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Design Construction of an Automatic Liquid Soap Dispenser Based on an Infrared (IR) Sensor

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ABSTRACT

This study aims to design and implement an automatic liquid soap dispenser based on an infrared (IR) sensor to Hand hygiene is an important factor in preventing the spread of disease, especially those caused by bacteria and viruses. The use of conventional liquid soap dispensers still requires physical contact, thus potentially causing cross-contamination. Therefore, this study aims to design and build an automatic liquid soap dispenser based on infrared (IR) sensors that can work without contact. The research method used is Research and Development (R&D), which includes the stages of needs analysis, system design, prototyping, and tool testing. This tool uses an infrared sensor to detect the presence of hands, Arduino Uno as the main controller, and a TDR Delay module to set the active duration of the liquid soap pump. When a hand is detected by the infrared sensor, the signal will be processed by the Arduino Uno to activate the delay module, then the DC pump will turn on for a predetermined duration so that liquid soap is dispensed automatically. After the set time is reached, the pump will automatically turn off and the system will return to standby mode. The test results show that the automatic liquid soap dispenser can work well and responsively in detecting hands and dispensing liquid soap consistently according to the set duration. This system is able to reduce direct physical contact, improve hygiene, and has a simple design, is energy efficient, and is easy to implement.

INTRODUCTION

The development of technology in the digital era has significantly influenced various aspects of human life, especially in improving efficiency and automation systems. One of the rapidly growing technologies is the Internet of Things (IoT), which enables devices to communicate and operate automatically through interconnected systems (Kopetz & Steiner, 2022). The implementation of automation technology can also be applied in daily hygiene equipment, including liquid soap dispensers.

Hand hygiene is an important effort to prevent the spread of diseases caused by bacteria and viruses. However, conventional liquid soap dispensers still require direct physical contact through buttons or levers, which may become a medium for cross-contamination (Angellia et al., 2024). This issue became increasingly important after the global pandemic, where hygiene and touchless technology gained greater attention in public facilities such as schools, hospitals, and shopping centers (Mohanty & Munir, 2024).

Several previous studies have developed automatic handwashing or soap dispenser systems using infrared sensors and microcontrollers. Sonam Sherpa et al. developed an automatic dispenser integrated with GSM and multiple sensors, but the system required complex components and higher power consumption (Michael et al., 2022). Another study by Irine Kartika Pebrianti et al. designed an automatic handwashing system using Arduino Uno; however, the system focused on a complete sink installation and was less portable (Pebrianti & Azis, 2025). Risa Annisa et al. also proposed an automatic handwashing tool based on Arduino Nano and infrared sensors, but the system used a more complex distance-based control mechanism (Annisa et al., 2024).

Based on these studies, this research proposes a simpler and more efficient automatic liquid soap dispenser system using an infrared (IR) sensor and TDR Delay module. The system focuses only on liquid soap dispensing with a touchless mechanism, making it more practical, portable, and suitable for educational purposes and public facilities. The infrared sensor functions as a hand detector, while the TDR Delay module controls the pump activation duration to ensure stable and efficient soap output.

Therefore, the purpose of this study is to design and implement an automatic liquid soap dispenser based on an infrared sensor and evaluate its performance in detecting 2hands and dispensing soap automatically. The proposed system is expected to improve hygiene, reduce physical contact, and provide an affordable automatic hygiene solution for daily use.

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LITERATURE REVIEW

Liquid Soap Dispenser

A dispenser is a device used to distribute liquid materials automatically or manually according to user needs. In the context of hygiene systems, a liquid soap dispenser is designed to release liquid soap in measured amounts for handwashing activities. Conventional soap dispensers generally require physical contact through buttons or levers, which can potentially become a medium for cross-contamination. Therefore, automatic soap dispensers using sensor technology are developed to improve hygiene and user convenience (Majid et al., 2024).

Internet of Things (IoT)

Internet of Things (IoT) is a concept in which physical devices are connected through networks and can exchange data automatically. IoT technology allows devices equipped with sensors and controllers to perform monitoring and automation functions efficiently. The development of IoT has encouraged the use of automation systems in various fields, including smart home technology and hygiene equipment (Rustiyana et al., 2025).

Infrared Sensor (IR)

An infrared (IR) sensor is an electronic sensor used to detect objects using infrared light reflection. The sensor consists of an infrared transmitter and receiver. When an object such as a hand is placed in front of the sensor, the reflected infrared light is received by the receiver and generates an output signal. Infrared sensors are widely used in automation systems because they provide fast response, simple operation, and low cost (Suryana, 2021).

Microcontroller

A microcontroller is a compact integrated circuit designed to control electronic systems automatically. It contains a processor, memory, and input/output pins in a single chip. In automation systems, microcontrollers are commonly used to process sensor data and control output devices. Arduino Uno is one of the most popular microcontrollers because it is easy to program and suitable for educational and prototype development purposes (Lukman et al., 2024).

Arduino IDE

Arduino IDE (Integrated Development Environment) is software used to create, edit, compile, and upload programs into Arduino boards. The programming language used in Arduino IDE is based on C/C++. This software simplifies the development of microcontroller-based systems and is widely used in automation and prototype projects (Rosad et al., 2025).

DC Mini Pump

DC mini pump is an actuator component used to transfer liquid from one place to another using low-voltage electrical power. In this study, the pump functions to transfer liquid soap from the container to the nozzle after receiving a trigger signal from the sensor system. The pump operates by rotating an internal impeller that creates suction and pressure to move the liquid soap through the hose (JAYA, 2021).

TDR Delay Module

The TDR Delay module is a timer relay module used to regulate the activation duration of electronic devices automatically. In the proposed system, the module controls the ON duration of the DC pump after receiving a trigger signal from the infrared sensor. The use of the TDR Delay module helps maintain stable and efficient soap output during operation (Fabrianto et al., n.d.).

METHOD

This study used the Research and Development (R&D) method to design, develop, and test an automatic liquid soap dispenser based on an infrared (IR) sensor. The R&D method was chosen because this research focused on developing a prototype system integrating hardware and software components into an automatic hygiene device (Rahayu, 2025).

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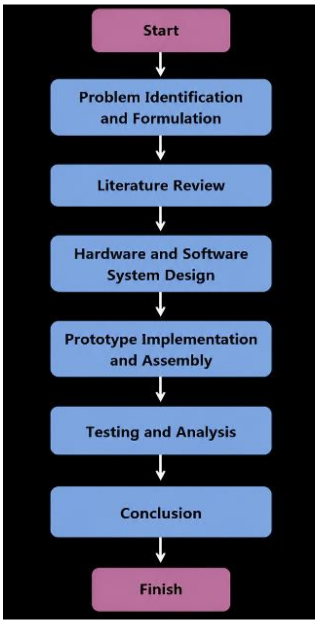

Figure 1. Research Stages

The research stages began with problem identification and needs analysis related to the risk of cross-contamination in conventional soap dispensers. After identifying the problem, a literature study was conducted to obtain references regarding infrared sensors, Arduino Uno, DC mini pumps, and TDR Delay modules used in the system design.

The next stage was system design, including hardware and software planning. The hardware design consisted of an infrared sensor, TDR Delay module, relay, DC mini pump, power supply, and liquid soap container. The software design focused on configuring the system workflow so that the sensor could detect the user's hand and activate the pump automatically for a predetermined duration.

After the design process, the prototype was assembled by integrating all electronic and mechanical components into a complete system. The infrared sensor functioned as the hand detector, while the TDR Delay module regulated the pump activation duration. When a hand was detected within a distance of approximately 2–8 cm, the sensor sent a trigger signal to activate the pump and dispense liquid soap automatically.

System testing was conducted to evaluate the performance and reliability of the developed prototype (Mushlihudin & Ramadhan, 2026). The testing process included infrared sensor testing, DC mini pump testing, TDR Delay module testing, and integrated system testing. The evaluation focused on sensor responsiveness, pump stability, soap dispensing duration, and overall system consistency during repeated operations.

RESULT

System Implementation

The automatic liquid soap dispenser based on an infrared (IR) sensor was successfully designed and implemented. The system consists of several main components, namely an infrared sensor, TDR Delay module, relay, DC mini pump, power supply, and liquid soap container. All components were integrated into a single automatic system capable of dispensing liquid soap without physical contact.

The system works when the infrared sensor detects the presence of a hand within a distance of approximately 2–8 cm. The sensor then sends a trigger signal to the TDR Delay module, which activates the relay and DC mini pump for a predetermined duration. As a result, liquid soap is dispensed automatically through the hose and nozzle system. After the activation time ends, the pump stops automatically and the system returns to standby mode.

Hardware Implementation

The hardware implementation includes the installation and integration of all electronic and mechanical components. The infrared sensor was placed at the front side of the dispenser to optimize object detection. The DC mini pump was connected to the liquid soap container through a hose to ensure stable soap flow during operation. The TDR Delay module was configured to activate the pump for approximately 1 second for each detection cycle.

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Figure 2. Automatic Liquid Soap Dispenser Prototype

Infrared Sensor Testing

Infrared sensor testing was conducted to determine the sensor's ability to detect objects at different distances. The testing process was performed by placing a hand in front of the sensor with distance variations from 2 cm to more than 8 cm.

Figure 3. Infrared Sensor Testing

Table 1. Infrared Sensor Testing

No	Room Condition	Hand distance	Sensor response	Response time	Information
1	Dark	2-8 cm	Detected	Fast (<1 second)	The sensor is very stable
2	Dark	>8 cm	Not detected		Out of reach
3	Bright	2-8 cm	Detected	A little slow	Still working
4	Bright	>8 cm	Not detected		Weak IR reflection

The test results showed that the sensor was able to detect objects properly within a distance range of 2–8 cm. At distances greater than 8 cm, the sensor response became unstable due to weaker infrared light reflection. In addition, very bright environmental lighting slightly affected the sensor sensitivity, although this issue could be reduced by adjusting the potentiometer on the sensor module.

DC Mini Pump Testing

The DC mini pump testing was performed to evaluate the pump's capability in dispensing liquid soap during operation. The pump was supplied with 6V power and controlled through the TDR Delay module.

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Figure 4. Mini Pump Testing

The results indicated that the pump operated properly and consistently dispensed liquid soap during the activation period. Within approximately 1 second of operation, the pump produced a sufficient amount of soap for one handwashing activity. However, thicker soap liquid and excessively long hoses slightly reduced the soap flow rate.

TDR Delay Module Testing

The TDR Delay module testing aimed to evaluate the stability of the ON-time configuration used to control the DC mini pump. The module was configured with an ON duration of approximately 1 second.

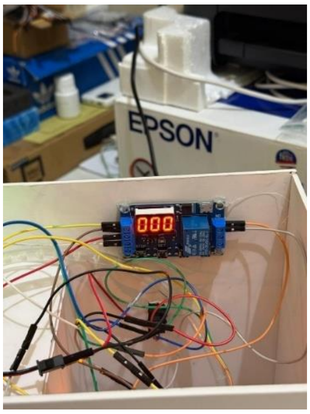

Figure 5. TDR Delay Testing

The testing results showed that the module successfully activated the pump according to the configured duration. After the ON duration ended, the pump stopped automatically and could not be reactivated until the user's hand was removed and detected again by the sensor. The module also produced stable timing performance during repeated testing.

Integrated System Testing

Integrated system testing was conducted by connecting all components according to the system workflow: infrared sensor - TDR Delay module - DC mini pump - soap output. The testing process was repeated several times to evaluate system consistency and reliability.

Table 2. Integrated System Testing

Testing Parameter	Result
Hand Detection	Succesfull
Pump Activation	Succesfull
Soap Dispensing	Stable
Automatic Soap	Succesfull
System Consistency	Stable

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The results demonstrated that the system operated automatically and consistently. Every time a hand was detected, the sensor immediately triggered the TDR Delay module and activated the pump. Liquid soap was dispensed smoothly and stopped automatically after the configured duration. The system returned to standby mode and was ready for the next operation cycle.

DISCUSSION

The results of this study indicate that the automatic liquid soap dispenser based on an infrared (IR) sensor was able to operate properly and perform automatic soap dispensing without physical contact. The infrared sensor showed a stable response in detecting hands within a distance range of 2–8 cm. This performance demonstrates that the sensor is suitable for touchless hygiene systems because it provides a fast response and stable detection capability during operation. The use of the TDR Delay module also contributed significantly to the stability of the system. The module successfully controlled the activation duration of the DC mini pump for approximately 1 second, resulting in consistent soap output for each operation cycle. This mechanism helped prevent excessive soap dispensing and improved the efficiency of soap usage. In addition, the system required the user's hand to be removed before a new trigger could occur, reducing the possibility of repeated soap output caused by continuous object detection.

The integrated system testing showed that all components worked together properly. The infrared sensor functioned as the input device, the TDR Delay module acted as the timing controller, and the DC mini pump served as the actuator for dispensing liquid soap. The overall system demonstrated stable and consistent operation during repeated testing, indicating that the developed prototype is reliable for daily use. Compared with previous studies, the proposed system offers a simpler and more practical design. Previous research generally used more complex systems involving additional sensors, GSM modules, or complete handwashing installations. In contrast, this study focused specifically on a stand-alone liquid soap dispenser using fewer components and lower power consumption. Therefore, the developed system is more portable, economical, and easier to implement in public facilities and educational environments.

However, several limitations were identified during the testing process. The infrared sensor performance was slightly affected by excessive environmental lighting, which reduced detection sensitivity. In addition, thicker liquid soap and longer hoses reduced the pump flow performance. The developed system also does not include additional features such as liquid level monitoring, IoT integration, or automatic notifications when the soap container is empty. These limitations indicate that further improvements are still needed to enhance system performance and functionality in future research.

CONCLUSION

This study successfully designed and implemented an automatic liquid soap dispenser based on an infrared (IR) sensor. The developed system was able to detect the presence of a user's hand automatically and dispense liquid soap without physical contact. The integration of the infrared sensor, TDR Delay module, relay, and DC mini pump worked properly and produced stable system performance during testing.

The testing results showed that the infrared sensor could detect objects effectively within a distance range of 2–8 cm, while the TDR Delay module successfully controlled the pump activation duration consistently. The developed system improved hygiene by reducing direct contact with the dispenser and provided efficient soap usage through controlled dispensing duration.

Overall, the proposed automatic liquid soap dispenser can be considered a simple, low-cost, and practical hygiene solution suitable for public facilities and educational environments. Future research may improve the system by integrating IoT technology, liquid level monitoring, and additional safety features to enhance functionality and system performance.

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