Design and Development of a Smart Infrared Touchless Alcohol Dispenser for Enhanced Hand Hygiene

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ABSTRACT

Maintaining proper hand hygiene is essential for preventing the spread of infectious diseases in public and high-traffic environments. However, traditional alcohol dispensers often require physical contact, which may increase the risk of cross-contamination and lack effective monitoring of alcohol levels. This study presents the design and development of an infrared-based touchless alcohol dispenser with SMS notification aimed at promoting safer and more efficient hand hygiene practices.

The proposed system utilizes an infrared (IR) sensor to detect the presence of a user's hand and automatically activates a pump mechanism to dispense a controlled amount of alcohol without physical contact. A microcontroller serves as the central control unit that manages the sensing, dispensing, and monitoring processes. Additionally, a liquid level sensor continuously monitors the remaining alcohol level in the dispenser container. When the alcohol level reaches a predefined threshold, a GSM module automatically sends a Short Message Service (SMS) notification to designated personnel, enabling timely refilling and preventing service interruption.

The prototype was evaluated based on detection responsiveness, dispensing consistency, system reliability, and SMS notification performance. Results show that the system effectively provides touchless operation, controlled dispensing, and real-time refill alerts. The developed prototype demonstrates a low-cost, automated, and scalable hygiene solution suitable for schools, offices, and other public facilities, contributing to improved sanitation management and public health safety.

Keywords— Infrared sensor, touchless alcohol dispenser, GSM notification system, hand hygiene automation, embedded systems, sanitation monitoring.

INTRODUCTION

Maintaining proper hand hygiene is widely recognized as one of the most effective measures in preventing the spread of infectious diseases, particularly in public and high-traffic environments such as schools, offices, and institutions. According to the World Health Organization, proper hand sanitation significantly reduces the transmission of harmful microorganisms and infectious pathogens. Hand hygiene practices, including the use of alcohol dispenser, have been proven to lower infection rates and prevent the spread of communicable diseases in both healthcare and community settings (Boyce & Pittet, 2002).

Despite its importance, the implementation of effective hand hygiene systems remains inconsistent. Traditional alcohol dispensers often require physical contact, which paradoxically increases the risk of cross-contamination and compromises hygiene practices (Kampf & Kramer, 2004). Frequently touched surfaces, such as dispenser pumps, can act as reservoirs for pathogens, thereby negating the intended purpose of sanitation measures. This issue is particularly critical in environments with high user turnover, where multiple individuals interact with the same device within short periods.

Furthermore, many existing alcohol dispensing systems lack monitoring mechanisms to track alcohol levels. As a result, dispensers may become empty without immediate detection, leading to reduced accessibility and decreased user compliance. Studies have shown that accessibility and convenience significantly influence adherence to hand hygiene practices (Judah et al., 2009). When sanitizing agents are unavailable or difficult to access, individuals are less likely to perform proper hand hygiene, increasing the risk of disease transmission.

The limitations of conventional systems became more evident during global health emergencies such as the COVID-19, which emphasized the importance of minimizing physical contact and maintaining continuous sanitation availability. During this period, the demand for touchless and automated hygiene solutions increased significantly as organizations sought safer alternatives to manual systems (Centers for Disease Control and Prevention, 2020). However, many institutions, particularly those with limited resources, continue to rely on traditional dispensers due to cost and accessibility constraints.

Additionally, the lack of real-time monitoring and maintenance systems contributes to operational inefficiencies. Manual inspection of alcohol levels is time-consuming and prone to human error, often resulting in delayed refilling and system downtime. This gap highlights the need for intelligent systems that not only provide contactless operation but also ensure continuous functionality through automated monitoring and notification.

These challenges underscore the necessity for an innovative, cost-effective, and scalable solution that integrates automation, sensing, and communication technologies to improve hygiene practices and system reliability.

In response to these challenges, there is a growing need for innovative and automated solutions that enhance both hygiene and operational efficiency. Advances in embedded systems and sensor technologies have enabled the development of smart devices capable of minimizing human contact while improving system functionality. This study proposes the design and development of an infrared-based touchless alcohol dispenser with SMS notification as a practical solution to these issues.

The system utilizes an infrared (IR) sensor to detect hand presence and automatically dispense a controlled amount of alcohol without physical contact. In addition, a liquid level sensor monitors alcohol availability, while a GSM module sends SMS notifications when the level reaches a critical threshold. This integration of sensing, control, and communication technologies ensures both user safety and system reliability.

The primary objective of this study is to design and develop a functional and efficient touchless alcohol dispenser with SMS notification for safer hand hygiene. Specifically, the study aims to:

1. Develop a contactless dispensing mechanism using an infrared sensor for accurate hand detection.

2. Integrate a microcontroller-based system to manage sensing, dispensing, and monitoring processes.

3. Implement a liquid level monitoring system to track alcohol levels in real time.

4. Incorporate an SMS notification feature for timely refill alerts.

5. Evaluate the system’s performance based on detection accuracy, response time, dispensing consistency, and notification reliability.

The significance of this study lies in its contribution to improving sanitation practices in public and institutional environments. By eliminating the need for physical contact, the system reduces the risk of cross-contamination and enhances user safety. The integration of monitoring and notification features ensures the continuous availability of alcohol, improving compliance with hygiene protocols. Furthermore, the study demonstrates the practical application of embedded systems and automation technologies in addressing real-world public health challenges.

From a sustainability perspective, the proposed system supports environmental, economic, and social dimensions. Environmentally, the controlled dispensing mechanism minimizes excessive alcohol use and reduces waste. Economically, the use of low-cost and widely available components makes the system affordable and scalable. Socially, the system promotes safer hygiene practices by reducing physical contact and limiting the spread of infectious diseases.

Moreover, the SMS notification feature enhances resource management by enabling timely refilling, reducing downtime, and minimizing the need for manual monitoring. Overall, the integration of automation and communication technologies provides a sustainable and efficient approach to modern hygiene management.

METHODOLOGY

This study employed a developmental and experimental research design to design, develop, and evaluate an infrared-based touchless alcohol dispenser with SMS notification. The developmental research approach was used to guide the systematic design and integration of hardware and software components, including sensors, microcontroller, dispensing mechanism, and communication module. This approach focuses on creating a functional prototype that addresses a specific real-world problem—in this case, improving hand hygiene through automation and monitoring.

The experimental research design was applied to test and evaluate the performance of the developed system. Controlled experiments were conducted to assess key performance indicators such as hand detection accuracy, response time, dispensing consistency, level monitoring accuracy, and SMS notification reliability. The system was subjected to multiple trials under varying conditions to ensure its effectiveness, stability, and reliability.

The combination of developmental and experimental approaches allows the study to not only produce a working system but also validate its functionality and performance based on measurable results. This design is appropriate for engineering and technology-based projects where both system creation and performance evaluation are essential.

The project design follows an embedded systems approach that integrates sensing, processing, actuation, and communication components into a single automated hygiene solution. The system is composed of five major subsystems: input (infrared sensor), processing (microcontroller), output (pump mechanism), monitoring (liquid level sensor), and communication (GSM module).

At the input stage, an infrared (IR) proximity sensor is used to detect the presence of a user's hand within a predefined range of approximately 5–10 cm. Once a valid detection is registered, the signal is transmitted to the microcontroller, which serves as the central control unit of the system. The microcontroller processes the input data and executes programmed instructions to activate the output subsystem.

The output subsystem consists of a relay-controlled mini-DC pump that dispenses a calibrated amount of alcohol. The dispensing duration is controlled through programmed timing, ensuring consistent output per activation cycle. To prevent continuous or unintended dispensing, a cooldown mechanism is implemented within the system logic.

The monitoring subsystem incorporates a liquid level sensor that continuously measures the amount of alcohol remaining in the container. Sensor readings are processed and converted into percentage values to provide a clear indication of the current level. When the alcohol level falls below a predefined threshold, the system triggers the communication subsystem.

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The communication subsystem utilizes a GSM module to send Short Message Service (SMS) notifications to designated personnel. This feature enables real-time alerts for refilling, ensuring that the dispenser remains operational without requiring manual inspection.

The overall system design emphasizes automation, reliability, and user safety. The integration of these components enables a seamless and contactless operation that reduces the risk of cross-contamination while maintaining efficient resource management.

This study focuses on the design and development of a prototype infrared-based touchless alcohol dispenser integrated with SMS notification functionality. The system is intended for use in controlled environments such as schools, offices, and similar facilities where maintaining proper hand hygiene is essential.

The scope includes the integration of key hardware components, namely an infrared (IR) sensor for hand detection, a microcontroller for system control, a relay module for pump activation, a liquid level sensor for monitoring alcohol volume, and a GSM module for SMS-based alerts. The system is programmed to automatically dispense a controlled amount of alcohol upon detecting hand presence and to notify designated personnel when alcohol levels reach predefined thresholds.

This study is limited to prototype development and performance testing. Advanced features such as Internet of Things (IoT) integration, mobile application support, and large-scale deployment are beyond the current scope but are recommended for future enhancement.

Figure 1 Circuit Design

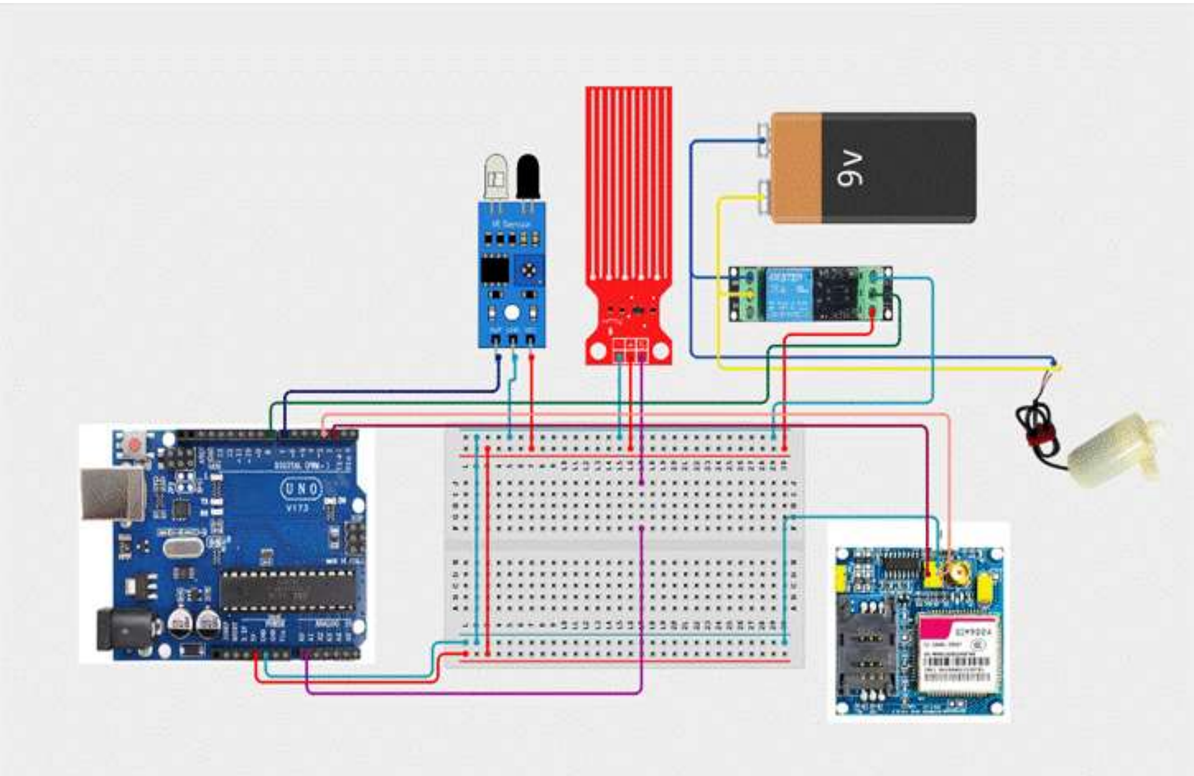


Figure 1 shows the complete circuit diagram of the touchless alcohol dispenser system, as shown in the circuit diagram, where all components are interconnected and powered through an Arduino microcontroller acting as the main control unit.

The infrared (IR) sensor is connected to the Arduino through pin 7, along with VCC and GND. This sensor is responsible for detecting the presence of a user's hand. When a hand is detected, the sensor sends a signal to the Arduino, which then processes the input and triggers the dispensing mechanism.

The water pump, which is responsible for releasing the alcohol, is connected to a relay module. The relay acts as a switch that allows the Arduino to control the higher voltage required by the pump. The relay is connected to Arduino pin 8, as well as VCC and GND, while the pump is powered by a 9V battery. When activated, the relay closes the circuit, allowing the pump to dispense alcohol.

The water level sensor is connected to the Arduino's analog pin A0, along with VCC and GND. This sensor continuously monitors the level of alcohol inside the container. It sends analog signals to the Arduino, which are interpreted to determine whether the alcohol level is sufficient or low.

Additionally, the GSM module is connected to the Arduino using pins 2 and 3, where pin 2 serves as the TX (transmit) and pin 3 as the RX (receive). The GSM module also shares a common ground with the Arduino. This module enables the system to send SMS notifications, particularly when the alcohol level is low, ensuring timely refilling.

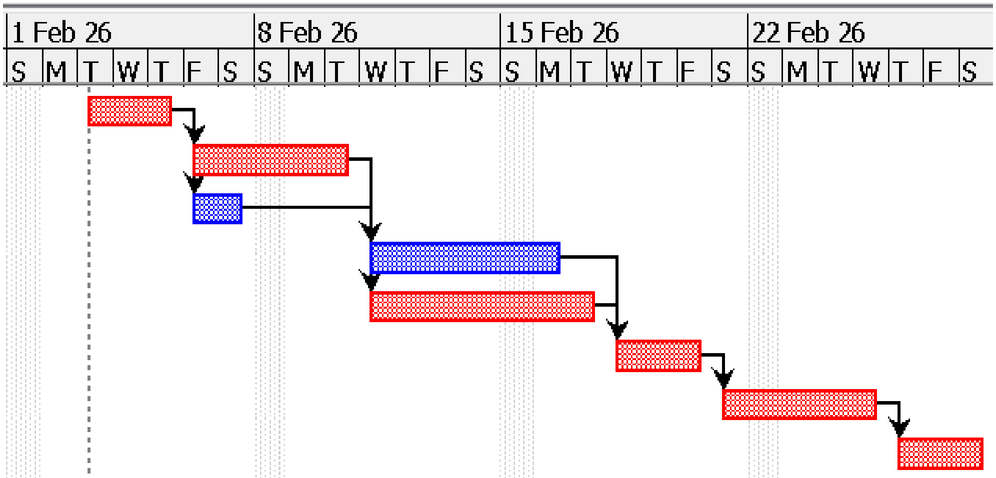
All components are arranged on a breadboard to ensure proper organization, secure connections, and ease of modification. Overall, as shown in the circuit diagram, the system integrates sensing, monitoring, and communication features to provide a fully automated and efficient touchless alcohol dispensing solution.

Table 1 Project Schedule

ID	Name	Duration	Start	Finish	Predecessors
A	Project Planning & Requirements Gathering	3 days	2/3/26, 8:00 AM	2/5/26, 5:00 PM	
B	System Design – Hardware & Block Diagram	4 days	2/6/26, 8:00 AM	2/10/26, 5:00 PM	A
C	Procurement of Components	2 days	2/6/26, 8:00 AM	2/7/26, 5:00 PM	A
D	Hardware Assembly	5 days	2/11/26, 8:00 AM	2/16/26, 5:00 PM	B;C
E	Software Set-Up and Development	6 days	2/11/26, 8:00 AM	2/17/26, 5:00 PM	B;C
F	System Integration	3 days	2/18/26, 8:00 AM	2/20/26, 5:00 PM	D;E
G	Testing and Debugging	4 days	2/21/26, 8:00 AM	2/25/26, 5:00 PM	F
H	Final Documentation and Presentation	3 days	2/26/26, 8:00 AM	2/28/26, 5:00 PM	G

The work breakdown structure divides the project into manageable activities and shows their order and estimated durations. For the touchless alcohol dispenser, the team identified eight key activities: project planning and requirements gathering, system design (hardware and block diagram), procurement of components, hardware assembly, software setup and development, system integration, testing and debugging, and final documentation and presentation. Each activity has an estimated duration, ranging from two to six days, and logical predecessors; for example, hardware assembly cannot start until the design and procurement tasks (B and C) are complete. These tasks form a structured WBS that guides the project from planning through development to testing and documentation. By breaking the project into phases and assigning realistic durations, the team ensures that all essential tasks are covered and that dependencies are clearly understood.

Figure 2 Gantt Chart using ProjectLibre Software



The team used ProjectLibre and critical path analysis (CPA) to build a schedule and identify the critical path for the project. After encoding each activity's duration and predecessors in ProjectLibre, they generated a Gantt chart and performed CPA to calculate slack and determine which activities are critical. The analysis revealed that activities A (planning), B (system design), E (software setup), F (system integration), G (testing and debugging), and H (final documentation and presentation) all have zero slack and thus lie on the critical path. The total project duration is 23 days, and any delay in these critical tasks directly delays project completion. Activities C (procurement) and D (hardware assembly) have some slack, meaning minor delays there will not immediately impact the overall finish date. Understanding the critical path informed the scheduling strategy and allowed the team to focus on managing tasks with no buffer time.

The project adopted a structured and phase-based execution strategy to ensure systematic development and effective implementation. The process was divided into three major phases: Planning and Design, Development and Integration, and Testing and Evaluation.

During the Planning and Design phase, system requirements were identified, project objectives were defined, and the overall system architecture was conceptualized. Necessary components were selected based on functionality, cost, and availability.

The Development and Integration phase involved the assembly of hardware components and the programming of the microcontroller using the Arduino IDE. System functionalities such as infrared-based detection, controlled dispensing duration, cooldown mechanism, level monitoring, and GSM-based notification were implemented and integrated.

In the Testing and Evaluation phase, the system was assessed in terms of detection accuracy, response time, dispensing consistency, and notification reliability. Calibration and debugging were performed to enhance system performance and ensure operational stability.

This structured execution approach facilitated the transformation of project plans into a functional and reliable prototype aligned with the intended objectives.

The successful implementation of the project required the effective utilization of human, technical, material, and financial resources.

Human resources were allocated based on individual competencies, with responsibilities distributed across hardware development, software programming, system testing, and documentation. This role-based approach improved task efficiency and accountability.

Material and technical resources included the use of an Arduino microcontroller, infrared sensor, relay module, GSM module, level sensor, and pump mechanism. The Arduino IDE served as the primary platform for programming and system control.

Financial resources were managed by selecting cost-effective and locally available components, ensuring the project remained economically feasible. Time management was guided by a structured project schedule, enabling the team to complete tasks within the given timeframe.

Overall, efficient resource deployment contributed to the successful execution of the project while maintaining quality and practicality.

The team structure emphasizes clear roles and collaborative decision-making. Engr. Michael Andre Guevarra served as the project manager and developer, responsible for planning, execution, monitoring, and backend coding. Engr. Meshelle Fabro took the role of technical lead and business analyst, handling hardware design decisions and component selection. Engr. Ruth Necio acted as circuit designer and developer, creating schematic diagrams and integrating circuits, while Engr. William Dionisio provided quality assurance and review, ensuring consistency and accuracy. They adopted a consensus-based decision-making approach to balance technical feasibility and business objectives, reduce internal conflicts, and promote shared accountability. The communication framework combined formal channels such as a MS Teams Planner board and weekly meetings—with informal chats for quick clarifications, weekly progress updates, and escalation procedures for conflicts. This structure facilitated coordination among team members and ensured decisions were well-informed and agreed upon.

A systematic risk analysis was conducted to identify potential challenges that could affect project execution. Key risks identified included time constraints, technical skill dependency, hardware malfunction, and communication challenges among team members.

Time-related risks emerged due to the limited availability of team members, who were concurrently engaged in professional responsibilities. Technical dependency was also observed, particularly in hardware development, which relied heavily on a specific team member's expertise.

Hardware-related risks involved the potential failure or inconsistent performance of components such as sensors, the pump, and communication modules. Additionally, communication challenges were identified due to remote collaboration and coordination limitations.

To mitigate these risks, the team implemented structured communication practices, clearly defined roles and responsibilities, conducted regular progress monitoring, and performed iterative testing of system components. These measures reduced uncertainties and improved overall project execution.

RESULTS

The development of the Infrared-Based Touchless Alcohol Dispenser with SMS Notification resulted in a functional prototype designed to improve hand hygiene practices through automation and monitoring capabilities. The project successfully integrated multiple hardware and software components to achieve touchless alcohol dispensing and real-time level monitoring.

The primary output of the project is a working prototype capable of detecting hand presence using an infrared (IR) sensor and automatically activating a pump to dispense a controlled amount of alcohol. The system operates without physical contact, thereby reducing the risk of cross-contamination commonly associated with traditional manual dispensers.

Another significant output is the alcohol level monitoring feature. The system continuously monitors the alcohol level using a liquid level sensor and converts the sensor readings into percentage values for monitoring purposes. When the alcohol level drops below the predefined threshold, the system automatically sends a Short Message Service (SMS) notification through the GSM module to designated personnel, prompting timely refilling.

Additional deliverables include the embedded system program, circuit design, and documentation detailing the system architecture, hardware integration, and operational workflow. Testing results indicate that the system provides reliable hand detection, consistent dispensing performance, and effective notification functionality.

Overall, the project outputs demonstrate the feasibility of implementing a low-cost, automated hygiene solution that can support sanitation management in schools, offices, and other public environments.

Evaluating schedule performance involved comparing the planned timeline with actual progress. According to the CPA analysis, the project was scheduled to finish in 23 days. Critical tasks had zero slack, meaning any delays would push the finish date, while two non-critical tasks had small slack allowances. The team managed to adhere closely to the planned schedule by focusing on the critical path, holding weekly progress reviews, and allocating resources appropriately. Monitoring and control strategies—such as weekly coordination meetings and tracking activities against the project timeline—helped identify potential delays early. Consequently, the project was able to stay on track, and milestones were met according to the ProjectLibre schedule.

The developed Infrared-Based Touchless Alcohol Dispenser with SMS Notification contributes to sustainability in several aspects related to health, resource management, and operational efficiency. The system promotes health sustainability by enabling touchless alcohol dispensing, which reduces physical contact with shared surfaces and helps minimize the spread of germs and communicable diseases in public environments such as schools, offices, and institutions.

From a resource sustainability perspective, the system dispenses a controlled and calibrated amount of alcohol for each use. This controlled dispensing mechanism helps prevent excessive alcohol usage and reduces unnecessary waste. In addition, the integrated alcohol level monitoring feature ensures efficient resource management by continuously tracking the alcohol level inside the container.

The SMS notification capability further enhances sustainability by enabling timely refilling of the dispenser. When the alcohol level reaches a predefined threshold, the system automatically sends a notification to the designated personnel. This proactive monitoring reduces downtime and ensures that the dispenser remains operational without requiring constant manual inspection.

Furthermore, the use of low-cost and widely available electronic components supports economic sustainability by making the system affordable and scalable for wider deployment. Overall, the project demonstrates how embedded systems and automation technologies can support sustainable hygiene management and contribute to improved public health practices.

Table 2 Observed Issues During System Testing

Observed Issue	Description	Possible Cause	Impact on System	Suggested Improvement
IR Sensor Sensitivity	Sensor detection sometimes varies depending on hand position and environmental lighting conditions.	Sensor calibration and ambient light interference.	May slightly affect detection accuracy in certain conditions.	Improve sensor calibration and add shielding or adjust detection threshold.
Fluctuation in Level Sensor Readings	Raw sensor readings sometimes fluctuate during real-time monitoring.	Liquid movement and electrical noise in the sensor readings.	Minor variations in percentage level calculation.	Implement signal filtering or averaging techniques in the code.
SMS Notification Delay	SMS alerts occasionally experience slight delays before being received.	GSM network signal strength and	Delay in receiving refill notification.	Improve GSM signal reception or use alternative wireless

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		service provider latency.		communication such as Wi-Fi.
Breadboard Prototype Limitations	Breadboard wiring may become loose during extended operation.	Breadboards are intended only for prototyping.	Possible instability during long-term deployment.	Replace breadboard connections with a soldered PCB for permanent installation.
Pump Flow Variation	Slight variation in alcohol volume dispensed per activation.	Pump mechanical characteristics and liquid pressure.	Small differences in alcohol output volume.	Use flow control valves or calibrated pump timing.

Table 3 System Testing and Evaluation Results

Test Category	Test Description	Method	Result
Infrared Sensor Detection – Presence Test	Evaluates if the IR sensor can detect the presence of a hand within the calibrated range.	A hand was placed within the sensor's detection range (approximately 5–10 cm).	The sensor successfully detected the hand and activated the dispensing mechanism.
Infrared Sensor Detection – Absence Test	Ensures the system does not activate when no object is present.	No object was placed in front of the sensor during testing.	The pump did not activate, confirming proper detection logic.
Infrared Sensor Detection – False Trigger Test	Tests whether nearby movement without direct presence causes false activation.	Movement was made near but outside the calibrated detection range.	The system did not trigger dispensing, indicating minimal false detection.
Infrared Sensor Detection – Response Time Test	Measures how quickly the system reacts after hand detection.	A hand was placed within the detection range and response time was observed.	The system responded immediately and activated the pump within milliseconds.
Dispensing Performance Test	Verifies consistency of alcohol released per activation.	Pump was activated repeatedly with a programmed duration of **0.3 seconds**.	Each activation released approximately **1–2 mL** of alcohol consistently.
Level Monitoring Test	Evaluates the accuracy of the liquid level sensor.	Alcohol level was gradually reduced while monitoring sensor readings.	The system correctly converted sensor readings into percentage values.
GSM Notification Test	Tests the reliability of SMS alerts when alcohol level is low.	Alcohol level was reduced to the predefined threshold.	SMS notification was successfully sent to the registered phone number within a few seconds.
System Stability Test	Evaluates system performance during continuous operation.	The system was operated repeatedly for multiple dispensing cycles.	The prototype maintained stable operation without malfunction.

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Table 4 System Performance Metrics

Performance Metric	Measurement Method	Result	Interpretation
Hand Detection Accuracy	Multiple trials were conducted by placing a hand within the detection range of the IR sensor.	**≈ 98–100% detection accuracy**	The IR sensor reliably detected hand presence within the calibrated range.
Sensor Response Time	Time measured between hand detection and pump activation.	**< 1 second**	The system responded almost instantly, ensuring smooth user interaction.
Dispensing Consistency	Alcohol output measured across several dispensing cycles.	**1–2 mL per dispense**	Controlled dispensing ensures proper hand sanitation while minimizing waste.
Cooldown Control Efficiency	Multiple detection attempts performed during cooldown period.	**100% prevention of repeated activation**	The cooldown logic successfully prevented continuous dispensing.
Level Monitoring Accuracy	Sensor readings compared with actual alcohol levels in the container.	**High accuracy within calibrated range**	The system effectively tracks alcohol levels in real time.
SMS Notification Delay	Time measured from threshold detection to SMS arrival on mobile phone.	**5–10 seconds**	The GSM module successfully sends alerts within an acceptable time frame.
System Stability	Continuous operation and repeated dispensing cycles tested.	**Stable operation without system failure**	The prototype demonstrated reliable performance during testing.

Table 5 Hardware Specifications

Component	Model / Type	Function	Power Requirement
Microcontroller	Arduino Uno	Main system controller that processes sensor inputs and controls system operations	5V
Infrared Sensor	IR Proximity Sensor	Detects hand presence for touchless dispensing	3.3–5V
Level Sensor	HW-038 Liquid Level Sensor	Measures remaining alcohol level in the container	3.3–5V
Pump	Mini DC Water Pump	Dispenses alcohol	12V
Relay Module	1-Channel Relay	Controls ON/OFF switching of the pump	5V

GSM Module	SIM900A	Sends SMS notification when alcohol level is low	3.7–4.2V
Buck Converter	LM2596 Step-Down Converter	Regulates voltage for GSM module stability	12V input
Breadboard	Standard Breadboard	Used for circuit prototyping and component connections	—
Power Supply	12V 5A Adapter	Provides power to pump and electronic components	12V

Table 6 Experimental Test Cases

Test Case	**Description**	**Number of Trials**	**Successful Trials**	**Success Rate**
Hand Detection Test	Detecting hand presence within the calibrated IR sensor range	20	20	100%
No-Object Detection Test	Verifying that the system does not activate when no hand is present	20	20	100%
False Trigger Prevention Test	Checking if movement outside the calibrated range causes activation	15	14	93.3%
Dispensing Activation Test	Verifying proper pump activation after valid hand detection	20	20	100%
Cooldown Prevention Test	Testing repeated hand detection during the cooldown period	15	15	100%
Level Monitoring Test	Evaluating whether the sensor correctly tracks alcohol level	15	14	93.3%
Low-Level SMS Alert Test	Sending SMS when the alcohol level reaches the threshold	10	10	100%
Continuous Operation Test	Running the system for repeated dispensing cycles	20	19	95%

The experimental results show that the system achieved a high success rate across all functional tests. The highest reliability was observed in hand detection, dispensing activation, cooldown prevention, and SMS notification. Minor inconsistencies were observed in false-trigger prevention and level monitoring due to sensor sensitivity and environmental conditions, but overall performance remained highly acceptable for prototype implementation.

DISCUSSION

To accurately determine the remaining alcohol level inside the container, the system converts raw analog sensor readings into percentage values through a calibration-based mapping process. This method ensures that the sensor output corresponds to meaningful and interpretable measurements.

Table 7 Sensor Calibration and Percentage Conversion

Parameter	Value	Description
RAW_EMPTY	120	Sensor reading when container is empty
RAW_FULL	650	Sensor reading when container is full
Sample Raw Value	178	Actual sensor reading during test
Adjusted Value	58	(178 − 120)
Full Range	530	(650 − 120)

The calibration process defines two reference values: the raw sensor reading when the container is empty (RAW_EMPTY = 120) and when it is full (RAW_FULL = 650). Using these parameters, the percentage of the remaining alcohol is computed using the following formula:

$$\text{Percentage} = \frac{(\text{raw} - \text{RAW}_{\text{EMPTY}})}{(\text{RAW}_{\text{FULL}} - \text{RAW}_{\text{EMPTY}})} X\ 100$$

To illustrate, when the sensor produces a raw value of 178, the computation is performed as follows:

- 178−120=58
- 650−120=530
- 58/530=0.10958
- 0.109×100=10.9%

This result indicates that the remaining alcohol level is approximately 11%.

The implementation of this calibration approach enables the system to monitor liquid levels in real time and trigger threshold-based alerts. For instance, SMS notifications are automatically sent when the alcohol level falls below predefined levels such as 50% and 10%, ensuring timely refilling and continuous operation of the dispenser.

The performance of the developed Infrared-Based Touchless Alcohol Dispenser with SMS Notification was quantitatively evaluated using basic statistical methods to ensure accuracy, consistency, and reliability of the system outputs.

To analyze the system performance, multiple trials were conducted for each functional component, including hand detection, dispensing mechanism, and SMS notification. The collected data were subjected to statistical treatment, specifically using mean (average), percentage, and success rate analysis.

The mean was used to determine the average response time and dispensing volume. For instance, the pump activation duration across multiple trials resulted in a consistent average of approximately 0.3 seconds, producing an estimated 1–2 mL per dispense. This indicates uniformity in alcohol distribution.

The percentage method was applied in converting raw sensor readings into alcohol level values. Through calibration, raw values were mapped into percentage levels, allowing real-time monitoring of the liquid inside the container.

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The success rate (%) was used to evaluate system reliability. Detection tests showed a high success rate, with the infrared sensor accurately detecting hand presence in most trials after calibration. Similarly, SMS notification tests confirmed that alerts were successfully transmitted once the predefined thresholds were reached.

Additionally, range and variation analysis were considered to assess consistency. Minimal variation in repeated trials indicates stable system performance, while any deviations were attributed to environmental factors and hardware limitations.

Overall, the statistical results demonstrate that the system operates with high reliability, consistent performance, and accurate monitoring capabilities, making it suitable for real-world implementation in hygiene-sensitive environments.

Statistical Formulas Used

1. Mean (Average) $\bar{x} = \frac{\sum x}{n}$

Where:

x = mean

$\bar{x}$ = values

n = number of trials

2. Success Rate (%)

$$\text{Success Rate} = \left(\frac{\text{Number of successful trials}}{\text{Total trials}}\right) \times 100$$

3. Percentage Conversion (Sensor Calibration)

$$\text{Percentage} = \frac{(\text{raw} - \text{RAW}_{\text{EMPTY}})}{(\text{RAW}_{\text{FULL}} - \text{RAW}_{\text{EMPTY}})} \text{X } 100$$

Table 8 Statistical Table (Computed Values)

Trial	**Response Time (s)**	**Dispensed Volume(mL)**
1	0.28	1.5
2	0.3	1.6
3	0.29	1.5
4	0.31	1.7
5	0.3	1.6
6	0.29	1.5
7	0.3	1.6
8	0.28	1.5
9	0.31	1.7
10	0.3	1.6

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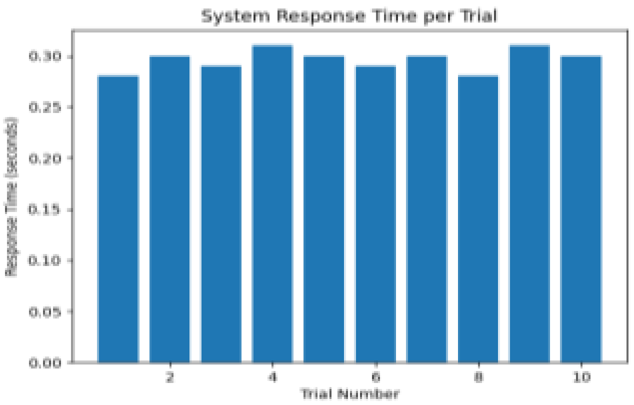
Table 9 Summary of Results

Metric	Value
Mean Response Time	0.30 seconds
Mean Dispensed Volume	1.58 mL
Detection Success Rate	100%

Figure 3 System Response Time per Trial Graph



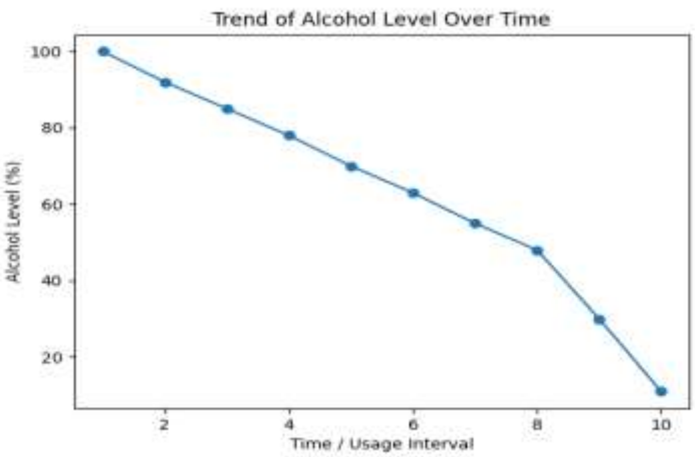
The graph illustrates the system response time measured across ten experimental trials. The x-axis represents the trial number, while the y-axis indicates the response time in seconds.

As observed, the response time remains highly consistent throughout all trials, ranging from approximately 0.28 to 0.31 seconds. This consistency indicates that the system is able to detect hand presence and activate the dispensing mechanism with minimal variation in delay.

The slight differences in response time across trials are negligible and can be attributed to minor factors such as sensor sensitivity, processing latency, and environmental conditions. Despite these small variations, the system maintains a stable average response time of approximately 0.30 seconds.

These results demonstrate that the system is both fast and reliable, ensuring consistent performance in real-time operation. The uniformity of response times further validates the effectiveness of the system's design and its suitability for practical deployment in touchless hygiene applications.

Figure 4 Trend of Alcohol Level Over Time Graph



The graph illustrates the relationship between usage interval and the corresponding alcohol level percentage within the dispenser. The x-axis represents the time or usage interval, while the y-axis indicates the remaining alcohol level expressed as a percentage.

As observed, the alcohol level demonstrates a gradual and continuous decline from 100% to approximately 10% as usage increases. This decreasing trend reflects the actual consumption of alcohol during system operation and confirms that the dispensing mechanism is functioning as intended.

During the initial intervals, the decline appears relatively steady, indicating consistent and controlled dispensing behavior. However, as the alcohol level approaches lower values, the rate of decrease becomes more pronounced, suggesting either increased usage frequency or the system nearing depletion.

The results validate the system's capability for real-time monitoring and accurate tracking of liquid levels. Furthermore, the observed trend supports the effectiveness of the threshold-based SMS notification feature, wherein alerts are triggered when the alcohol level approaches predefined critical points, such as 50% and 10%.

Overall, the graph demonstrates that the system provides reliable, continuous, and responsive monitoring of alcohol levels, making it suitable for practical implementation in hygiene-sensitive environments.

The results obtained from the system testing and evaluation indicate that the developed Infrared-Based Touchless Alcohol Dispenser with SMS Notification performs reliably and effectively in achieving its intended objectives. The infrared sensor demonstrated a high level of detection accuracy during multiple test trials, confirming its capability to detect hand presence within the calibrated range while minimizing false triggers. This result indicates that the touchless detection mechanism is suitable for real-world hygiene applications where fast and reliable user interaction is required.

The dispensing performance tests further confirmed that the pump releases a consistent amount of alcohol per activation. With a calibrated activation time of approximately 0.3 seconds, the system was able to dispense an estimated 1–2 mL of alcohol per use, which is sufficient for proper hand sanitation while preventing excessive alcohol consumption. This controlled dispensing mechanism contributes to efficient resource utilization.

The level monitoring functionality also demonstrated accurate tracking of the remaining alcohol inside the container. Sensor readings were successfully converted into percentage values, allowing the system to continuously monitor alcohol levels. When the alcohol level reached the predefined threshold, the GSM module successfully transmitted SMS notifications within a few seconds, ensuring timely refilling and preventing system downtime.

Overall, the interpretation of results confirms that the integration of sensing, control, and communication technologies provides a reliable, automated, and cost-effective solution for improving hygiene management in public environments such as schools, offices, and institutions.

Through the project, the team gained several insights into effective project management. First, execution discipline and communication are more important than technical complexity; having a clear plan and regular communication reduces confusion and ensures that everyone stays aligned. Second, defining roles and responsibilities early improves accountability and helps team members focus on their tasks. Third, proactively identifying risks allows the team to implement mitigation strategies before problems grow. The team also learned that sustainable solutions require balancing technical feasibility, usability, and resource efficiency. Finally, the project reinforced that good project management integrates technical skills, teamwork, and structured decision-making to transform ideas into practical solutions.

The project employed a collaborative decision-making approach, primarily based on consensus among team members. This approach facilitated the integration of diverse perspectives, ensuring that decisions were both technically sound and practically feasible.

A key example of this process was the transition from ultrasonic sensing to infrared-based detection. This decision was made after evaluating system requirements, response time, and implementation complexity. The shift reflects the team's ability to adapt to project constraints and prioritize efficiency and reliability.

Furthermore, the decision-making process emphasized open communication, shared responsibility, and continuous evaluation of alternatives. This contributed to improved coordination and minimized conflicts within the team.

The experience demonstrates that effective project decision-making extends beyond technical considerations and requires collaboration, flexibility, and strategic thinking.

Communication dynamics played a crucial role in the project's success. The team used a combination of formal communication channels (MS Teams Planner, weekly meetings, and structured updates) and informal chat messages to share progress and clarify issues. Weekly updates included completed tasks, current progress, issues, and next steps, ensuring transparency and early identification of problems. Escalation procedures were in place—if consensus could not be reached, the project manager would make decisions or consult the instructor—to maintain momentum. They also planned for asynchronous updates to accommodate members with limited availability and aligned tasks based on individual strengths. This structured yet flexible communication framework kept the team coordinated and allowed them to respond quickly to emerging risks.

Despite the successful development of the prototype, several limitations were identified.

The system is currently implemented using a breadboard-based setup, which may limit long-term durability and reliability. Additionally, the performance of the infrared sensor may be affected by environmental conditions such as lighting variations and reflective surfaces, potentially influencing detection accuracy.

The GSM-based notification system may also experience delays depending on network signal strength and service availability. Similarly, the level sensor readings may exhibit minor inconsistencies due to liquid movement and electrical noise.

Moreover, the system does not incorporate advanced functionalities such as remote monitoring, data analytics, or IoT integration, which could enhance scalability and user accessibility.

These limitations highlight areas for future improvement, including hardware optimization, enhanced sensor calibration, and the integration of more advanced monitoring technologies.

The development of the Infrared-Based Touchless Alcohol Dispenser with SMS Notification presents several strategic and sustainability implications for improving hygiene management in public environments. From a strategic perspective, the system demonstrates how embedded systems and automation technologies can be applied to address health and sanitation challenges efficiently. The integration of touchless detection, automated dispensing, and remote monitoring allows organizations such as schools, offices, and public facilities to improve hygiene practices while reducing the need for constant manual supervision.

The system also provides strategic value by enabling proactive maintenance and monitoring. The GSM-based SMS notification feature ensures that responsible personnel are immediately informed when the alcohol level reaches a critical threshold, allowing timely refilling and minimizing service interruptions. This capability improves operational efficiency and supports better resource management.

From a sustainability standpoint, the system promotes health sustainability by minimizing physical contact with shared surfaces, thereby reducing the risk of cross-contamination. It also contributes to resource sustainability by dispensing a controlled amount of alcohol per use, which helps prevent excessive alcohol consumption and unnecessary waste. Additionally, the use of low-cost and widely available electronic components supports economic sustainability, making the system scalable and accessible for broader deployment.

Overall, the proposed system demonstrates that combining automation, monitoring, and communication technologies can provide a sustainable and strategic solution for improving sanitation practices and public health safety.

CONCLUSIONS

This study successfully designed and developed an Infrared-Based Touchless Alcohol Dispenser with SMS Notification for Safer Hand Hygiene as an innovative solution to improve sanitation practices and reduce the risk of cross-contamination in public environments. The system integrates an infrared sensor for touchless hand detection, a microcontroller for system control, a pump mechanism for automated dispensing, a liquid level sensor for monitoring alcohol levels, and a GSM module for SMS-based refill notifications. The integration of these components enabled the development of a functional prototype capable of providing automated dispensing and remote monitoring features.

The testing and evaluation results demonstrated that the system performed reliably in terms of hand detection accuracy, dispensing consistency, sensor responsiveness, and SMS notification functionality. The infrared sensor effectively detected hand presence within the calibrated range, enabling the system to dispense alcohol without requiring physical contact. The dispensing mechanism released a controlled amount of alcohol during each activation cycle, which helped ensure efficient alcohol usage while minimizing waste. Additionally, the level monitoring system accurately tracked the remaining alcohol in the container and successfully triggered SMS alerts when the alcohol level reached the predefined threshold, allowing timely refilling.

The results of this study highlight the potential of embedded systems and automation technologies in addressing real-world health and sanitation challenges. By combining touchless operation, automated dispensing, and remote notification capabilities, the developed system contributes to safer hygiene management and improved operational efficiency in public settings such as schools, offices, and institutions.

Furthermore, the prototype demonstrates that a cost-effective and scalable hygiene solution can be developed using readily available electronic components. The proposed design not only enhances hand hygiene practices but also supports sustainable resource management by controlling alcohol consumption and reducing manual monitoring requirements.

In conclusion, the developed infrared-based touchless alcohol dispenser provides a practical approach to promoting safer hand hygiene practices. The system serves as a promising platform for further development and potential deployment in public environments. Future improvements may focus on enhancing sensor accuracy, integrating wireless monitoring platforms, improving system durability, and expanding the system's capabilities to support large-scale hygiene management applications.

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APPENDIX A

Source Code

```
#include <SoftwareSerial.h>

// ====================================================
// SMART DISPENSER + SIM900A (Instant LOW-level SMS)
// Components: Arduino Uno, SIM900A, HW-038 level sensor, IR sensor, Relay+Pump
// ====================================================

// ----------------- PINS -----------------
const int PIN_LEVEL = A0;   // HW-038 AO
const int PIN_IR    = 7;    // IR sensor DO
const int PIN_RELAY = 8;    // Relay IN

// ----------------- MODULE LOGIC (flip if needed) -----------------
const bool IR_ACTIVE_LOW    = true;  // true: IR DO = LOW means cup detected
const bool RELAY_ACTIVE_LOW = true;  // true: relay IN = LOW turns ON

// ----------------- LEVEL CALIBRATION (CHANGE THESE!) -----------------
// Measure analogRead(A0) when tank is empty/min-usable and when full
const int RAW_EMPTY = 120;  // <-- replace with your empty reading
const int RAW_FULL  = 650;  // <-- replace with your full reading

// ----------------- BEHAVIOR -----------------
const int LOW_LEVEL_PERCENT   = 15;    // <= this => LOW lockout + SMS
const int RESET_LEVEL_PERCENT = 25;    // >= this => clear lockout + allow SMS again
const unsigned long DISPENSE_MS = 300;
const unsigned long COOLDOWN_MS = 3000;

// ----------------- SIM900A (GSM) -----------------
const int GSM_RX_PIN = 2; // Arduino RX  <- SIM900A TX
const int GSM_TX_PIN = 3; // Arduino TX  -> SIM900A RX
SoftwareSerial gsm(GSM_RX_PIN, GSM_TX_PIN);

const long GSM_BAUD = 9600; // try 9600; if unstable/no AT response try 19200
const char PHONE_NUMBER[] = "+639752407273"; // <-- your number

// Retry sending SMS if first attempt fails (e.g., not registered yet)
const unsigned long SMS_RETRY_MS = 30000; // 30 seconds (adjust as you like)

// ----------------- STATE -----------------
bool lowLockout = false;
bool prevLowLockout = false;
bool lowAlertSent = false;

unsigned long lastDispenseTime = 0;
unsigned long lastSmsAttempt = 0;

// ====================================================
// Helper functions
// ====================================================
int clampInt(int v, int lo, int hi) {
```

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```
  if (v < lo) return lo;
  if (v > hi) return hi;
  return v;
}

int levelPercentFromRaw(int raw) {
  long den = (long)(RAW_FULL - RAW_EMPTY);
  if (den == 0) return 0;
  long num = (long)(raw - RAW_EMPTY) * 100L;
  int pct = (int)(num / den);
  return clampInt(pct, 0, 100);
}

int readLevelPercentSmoothed(int &rawOut) {
  const int N = 10;
  long sum = 0;
  for (int i = 0; i < N; i++) {
    sum += analogRead(PIN_LEVEL);
    delay(5);
  }
  rawOut = (int)(sum / N);
  return levelPercentFromRaw(rawOut);
}

bool isCupDetected() {
  int s = digitalRead(PIN_IR);
  return IR_ACTIVE_LOW ? (s == LOW) : (s == HIGH);
}

void relayOn()  { digitalWrite(PIN_RELAY, RELAY_ACTIVE_LOW ? LOW : HIGH); }
void relayOff() { digitalWrite(PIN_RELAY, RELAY_ACTIVE_LOW ? HIGH : LOW); }

// =====================================================
// GSM functions (based on your logic, improved for instant send)
// =====================================================
String readAll(unsigned long timeoutMs) {
  String out = "";
  unsigned long t0 = millis();
  while (millis() - t0 < timeoutMs) {
    while (gsm.available()) out += (char)gsm.read();
  }
  return out;
}

void gsmFlushInput() {
  while (gsm.available()) gsm.read();
}

bool sendCmdWait(const char* cmd, const char* expect, unsigned long timeoutMs) {
  gsm.println(cmd);
  String resp = readAll(timeoutMs);

  Serial.print(">> "); Serial.println(cmd);
  Serial.print("<< "); Serial.println(resp);
```

```
  if (expect == nullptr) return true;
  return (resp.indexOf(expect) >= 0);
}

bool isRegistered() {
  gsm.println("AT+CREG?");
  String r = readAll(2000);
  Serial.print("<< "); Serial.println(r);
  return (r.indexOf(",1") >= 0) || (r.indexOf(",5") >= 0);
}

// Wait for the '>' prompt after AT+CMGS, faster/more reliable than fixed delay
bool waitForPromptOrError(unsigned long timeoutMs) {
  unsigned long t0 = millis();
  String buf = "";

  while (millis() - t0 < timeoutMs) {
    while (gsm.available()) {
      char c = gsm.read();
      Serial.write(c);   // show GSM output live
      buf += c;

      if (c == '>') return true;
      if (buf.indexOf("ERROR") >= 0) return false;
      if (buf.indexOf("+CMS ERROR") >= 0) return false;
    }
  }
  return false;
}

// Init GSM once (so SMS send is more "instant")
bool gsmInitOnce() {
  if (!sendCmdWait("AT", "OK", 2000)) return false;
  sendCmdWait("ATE0", "OK", 1000);                // echo off
  if (!sendCmdWait("AT+CMGF=1", "OK", 2000)) return false; // text mode
  return true;
}

// Fast SMS send: assumes CMGF=1 already set in setup
bool sendSMSFast(const char* number, const char* message) {
  gsmFlushInput();

  gsm.print("AT+CMGS=\"");
  gsm.print(number);
  gsm.println("\"");

  if (!waitForPromptOrError(5000)) {
    Serial.println("\n[GSM] No '>' prompt (not ready/not registered).");
    return false;
  }

  gsm.print(message);
  gsm.write(26); // CTRL+Z
```

```
  String resp = readAll(8000);
  Serial.print("\n<< "); Serial.println(resp);

  return (resp.indexOf("+CMGS") >= 0) || (resp.indexOf("OK") >= 0);
}

// Attempt to send the low-level SMS (instant on LOW transition, retry later if fail)
bool attemptLowLevelSMS(int levelPct, int rawLevel) {
  // Optional: show signal once in a while (comment out if you want faster)
  // sendCmdWait("AT+CSQ", "OK", 2000);

  Serial.println("Checking network registration...");
  bool reg = isRegistered();
  Serial.println(reg ? "Registered (or roaming)." : "Not registered yet.");

  if (!reg) return false;

  char msg[160];
  snprintf(msg, sizeof(msg),
          "ALERT: Alcohol level LOW (%d%%). Please refill. (raw=%d)",
          levelPct, rawLevel);

  Serial.println("LOW detected -> sending SMS NOW...");
  return sendSMSFast(PHONE_NUMBER, msg);
}

// =====================================================
// SETUP / LOOP
// =====================================================
void setup() {
  Serial.begin(9600);

  pinMode(PIN_IR, INPUT);
  pinMode(PIN_RELAY, OUTPUT);
  relayOff();

  gsm.begin(GSM_BAUD);
  delay(1500);

  Serial.println("Dispenser + SIM900A (Instant LOW SMS) starting...");

  // Initialize GSM once to reduce delay later
  bool ok = gsmInitOnce();
  Serial.println(ok ? "[GSM] Init OK." : "[GSM] Init FAILED (check power/baud/wiring).");
}

void loop() {
  int rawLevel = 0;
  int levelPct = readLevelPercentSmoothed(rawLevel);

  // --- LOW lockout with hysteresis ---
  if (levelPct <= LOW_LEVEL_PERCENT) lowLockout = true;

  if (levelPct >= RESET_LEVEL_PERCENT) {
    lowLockout = false;
```

```
    lowAlertSent = false;   // allow SMS again after refill
    lastSmsAttempt = 0;     // reset retry timer
  }

  // --- Instant SMS trigger: LOW transition ---
  if (lowLockout && !prevLowLockout && !lowAlertSent) {
    lastSmsAttempt = millis(); // mark attempt time
    bool sent = attemptLowLevelSMS(levelPct, rawLevel);
    if (sent) {
      Serial.println("SMS sent/queued successfully.");
      lowAlertSent = true;
    } else {
      Serial.println("SMS failed (not registered / error). Will retry.");
    }
  }

  // --- Retry while still LOW if not sent yet ---
  if (lowLockout && !lowAlertSent) {
    if (lastSmsAttempt != 0 && (millis() - lastSmsAttempt >= SMS_RETRY_MS)) {
      lastSmsAttempt = millis();
      bool sent = attemptLowLevelSMS(levelPct, rawLevel);
      if (sent) {
        Serial.println("SMS sent/queued successfully (retry success).");
        lowAlertSent = true;
      } else {
        Serial.println("Retry failed. Will retry again later.");
      }
    }
  }

  // --- Dispense logic (only if NOT low) ---
  bool detected = isCupDetected();
  bool cooldownPassed = (millis() - lastDispenseTime >= COOLDOWN_MS);

  if (detected && cooldownPassed && !lowLockout) {
    Serial.println("Dispensing...");
    relayOn();
    delay(DISPENSE_MS);
    relayOff();
    lastDispenseTime = millis();
  }

  // --- Debug ---
  Serial.print("Raw="); Serial.print(rawLevel);
  Serial.print(" | Level="); Serial.print(levelPct); Serial.print("%");
  Serial.print(" | Cup="); Serial.print(detected ? "YES" : "NO");
  Serial.print(" | Lockout="); Serial.print(lowLockout ? "YES" : "NO");
  Serial.print(" | SMSsent="); Serial.println(lowAlertSent ? "YES" : "NO");

  // Update previous state for transition detection
  prevLowLockout = lowLockout;

  delay(300);
}
```