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Analysis and Construction of a Portable Automatic Handwashing Machine Using a 12 V Lithium Ion Phosphate Battery in the Physics Department, Niger Delta University

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Abstract
Following global health crises, hand hygiene shifted from being a personal practice to becoming a crucial component in maintaining public safety. Cross-contamination from tap handles and poor infrastructure in rural areas sometimes make manual handwashing less efficient. This paper outlines the research and development of a cost-effective, portable automatic handwashing machine designed to provide touchless, off-grid access to hygiene. The device uses a 12 V relay mechanism and an infrared (IR) proximity sensor to automatically supply water from a 10-litre reservoir, so there is no need for human touch. The design includes a 12 V Lithium Iron Phosphate ($LiFePO_4$) battery, which is more thermally stable and has a better energy-to-weight ratio than regular lead-acid batteries. The oscilloscope readings showed that the control module had a 5 V regulated supply with no ripples and that the pump system had a working 2 V TTL trigger. The prototype ensured water conservation and pathogen control by reliably delivering water and quickly shutting off. This technology affords institutions like Niger Delta University a complete solution by combining automation with sustainable power management to address the problem of inconsistent piped water. The successful use of this portable unit shows how decentralised, sensor-driven technologies can make public health more resilient in areas with few resources.

Keywords: *Automatic Handwashing, IR Sensor, $LiFePO_4$ Battery, Portable Hygiene, Public Health, Touchless Technology.*

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I. INTRODUCTION

Hand hygiene has changed from being a personal habit to an important feature of public safety after global health crises like the COVID-19 pandemic and the SARS outbreak in 2003 [1]. Consistent handwashing is the best way to stop the spread of germs, but it doesn't always work because of human mistakes, such as getting germs back on hands from tap handles, and because there aren't enough facilities in distant or busy areas [2, 3]. The traditional way to wash your hands requires you to do it by hand and share soap and water with other people. These manual systems can work well if done correctly, but they have many problems, like inconsistent methods and a higher chance of cross-contamination because people share touchpoints [4]. Effective hand hygiene is essential not only for mitigating respiratory viruses but also for reducing the incidence of enteric and dermatological disorders, including cholera, dysentery, pneumonia, and trachoma [5].

The introduction of automatic handwashing equipment offers a feasible alternative [6, 7, 8]. Still, these kinds of systems don't always work well because of strict plumbing systems. There is a pressing need for portable, off-grid solutions, especially in places like Niger Delta University, where lecture halls sometimes don't have reliable access to running water. This study focusses on creating an affordable, portable automatic handwashing machine that uses infrared sensors and a relay system to stop the spread of germs. A 12V Lithium Iron Phosphate ($LiFePO_4$) battery powers the system to make sure it runs smoothly. $LiFePO_4$ technology has a longer life cycle and a higher energy-to-weight ratio than regular lead-acid batteries, making it the best power source for a mobile hygiene unit [9, 10].

II. METHODOLOGY

The design process for the portable automatic handwashing machine followed a systematic engineering design process (see figure 1). This process involved combining mechanical housing, electronic control systems, and advanced power storage. Figure 1 displays the design model of the portable automatic handwashing machine, highlighting its various components. The physical structure is built on a 10-litre polyethylene tank that serves as both the water storage unit and the base for the chassis. A 2-inch PVC pipe was attached to the reservoir to hold the delivery tap. A 12 V DC surface pump was then put inside the PVC pipe on top of the tank to keep the flow rate steady, which is best for cleanliness and saving water. An active infrared (IR) proximity sensor module carefully designed to detect hand presence within a range of 5 cm to 10 cm controls the system's automation. Figure 2 shows the circuit design, which shows that this sensor is powered by a voltage regulation step that uses an LM7805 IC and a 330 nF capacitor to produce a consistent 5 V DC supply, which is important for preventing false triggers.

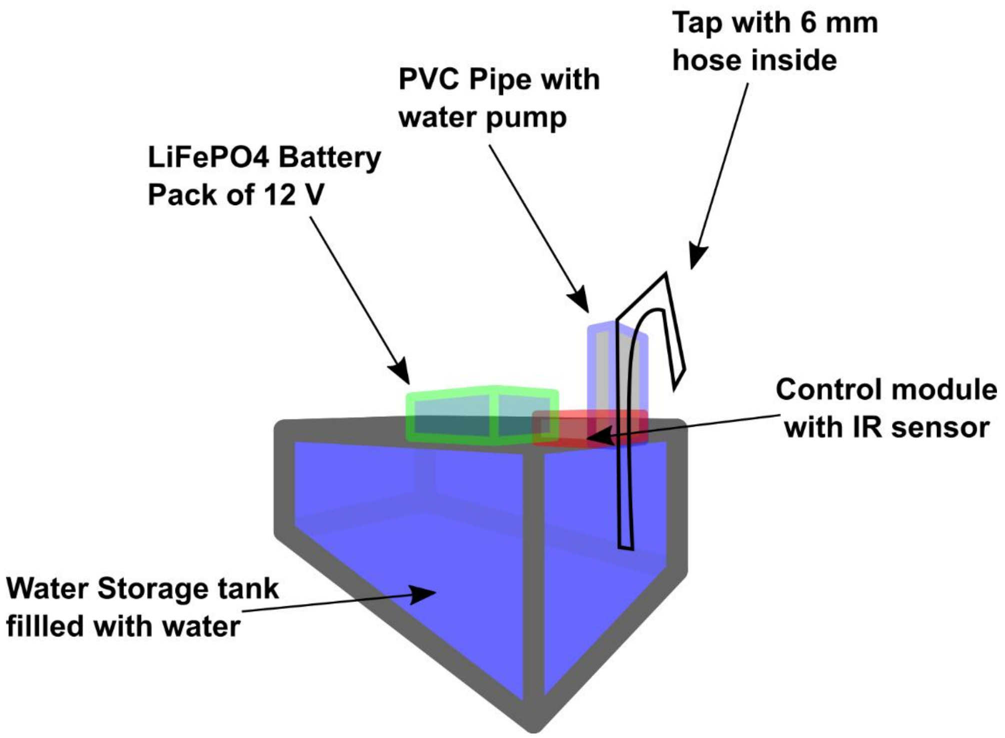

Figure 1: Design of the portable handwashing machine.

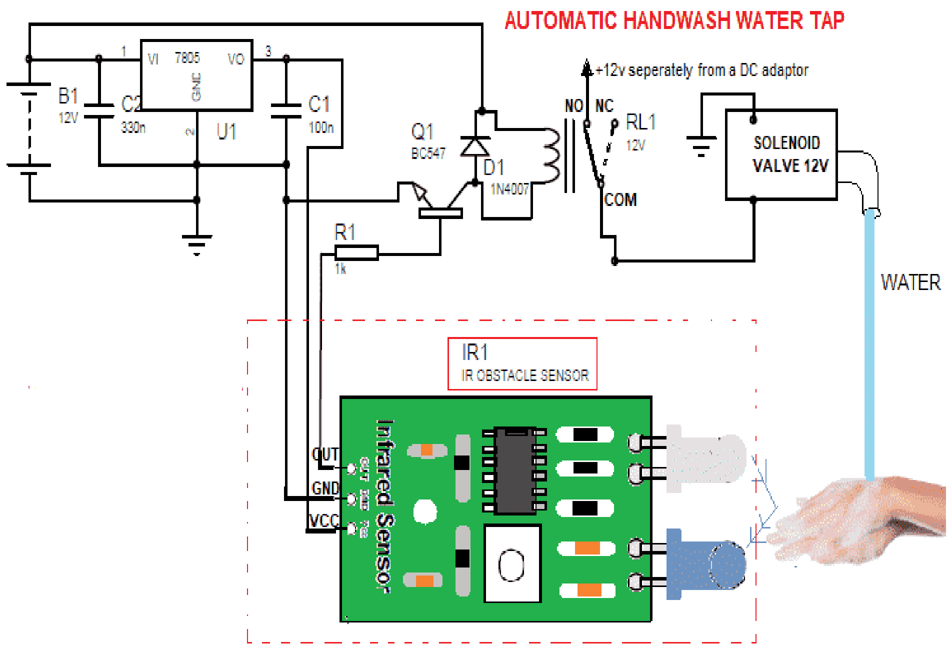

Figure 2: The circuit diagram used for our automatic handwashing machine design (adopted from Aabhishek 2020 [11]).

The control logic works by using infrared reflection. When a hand enters the detection zone, the receiver LED picks up the reflected infrared radiation and sends a Transistor-Transistor Logic (TTL) output to the base of a switching transistor (Q1). This transistor turns on a 12 V relay, which moves the connection from the Normally Closed (NC) position to the Normally Open (NO) position. This completes the high-current circuit between the 12 V Lithium Iron Phosphate ($LiFePO_4$) battery and the pump. The $LiFePO_4$ chemistry was chosen because it has a longer life cycle and a higher energy-to-weight ratio than regular lead-acid batteries. This makes the unit lightweight and easy to carry. To prevent this power source from overcharging, deep discharging, and short circuits, a Battery Management System (BMS) was included. After construction (see figure 3), the prototype was tested for sensor reliability, dispensing accuracy, and the overall user experience. The finished portable automatic handwashing machine is shown on the left side of figure 3. On the right-hand side (RHS), there is a picture of the control module that was made to automate the portable handwashing process. This control module uses the circuit design in Figure 2 to work.

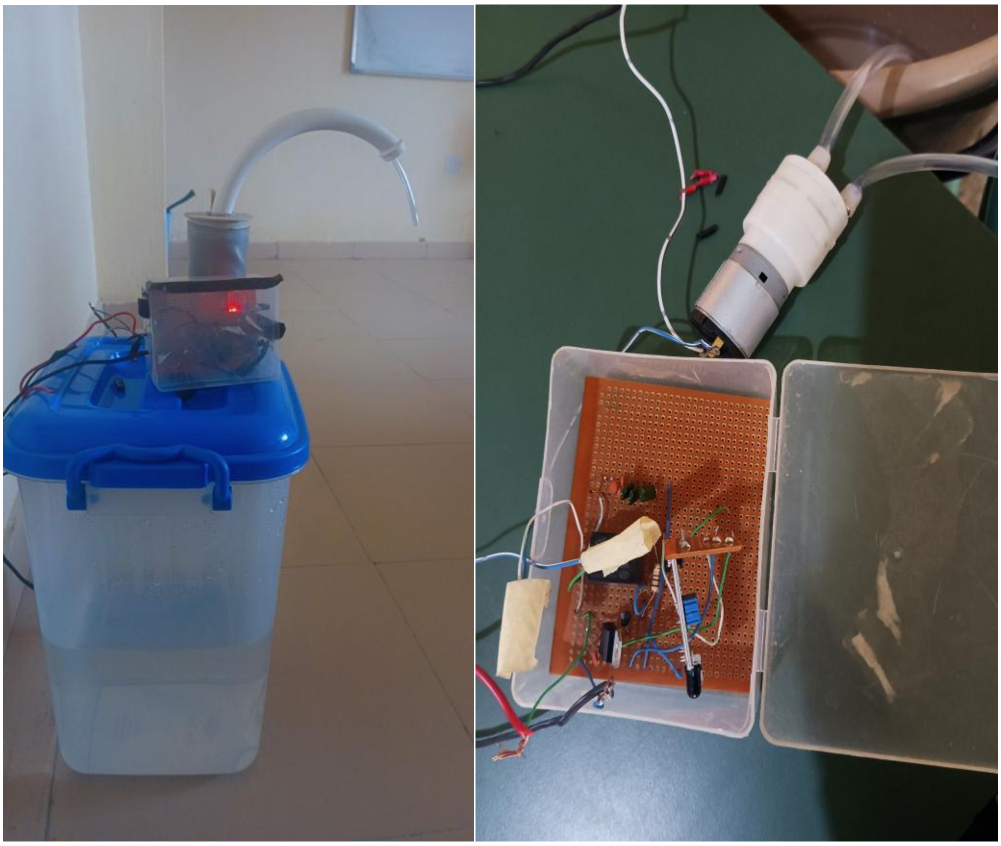

Figure 3: The constructed portable automatic handwashing machine (LHS) and the built sensor control device (RHS).

III. RESULTS AND DISCUSSION

Signal analysis and functional testing of the built-in electrical parts showed that the portable automatic handwashing machine worked as it should. The experimental findings, obtained by oscilloscope readings, illustrate the effectiveness of power control and the responsiveness of the sensing logic. The first measurements focused on how reliable the power module was. Figure 4 shows that the system successfully changed the raw battery output into the stable levels that automation needs. The IR sensor module needs a precise power supply to avoid false triggering. Figure 5 shows that the oscilloscope readings show a ripple-free 5 V regulated input voltage. The LM7805 regulator's stability is important for keeping sensors accurate in a wide range of situations. As shown in figure 6, the IR sensor module sends out a TTL output of about 2 V DC when it detects an obstacle. This signal is the main trigger. It goes to the base of the switching transistor (Q1), which then powers the relay coil.

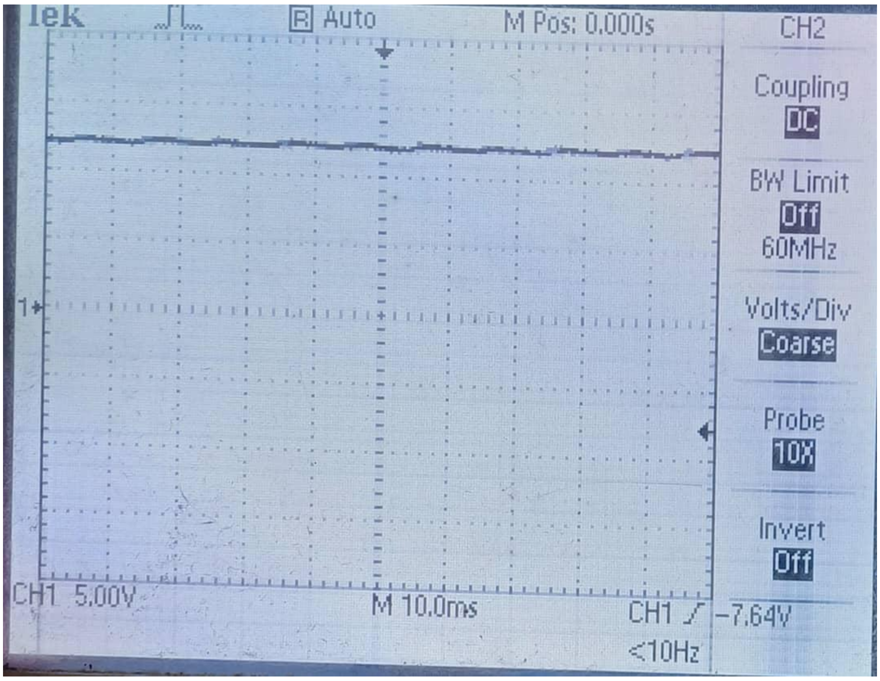

Figure 4: The 12 V input signal to the IR sensor module power supply.

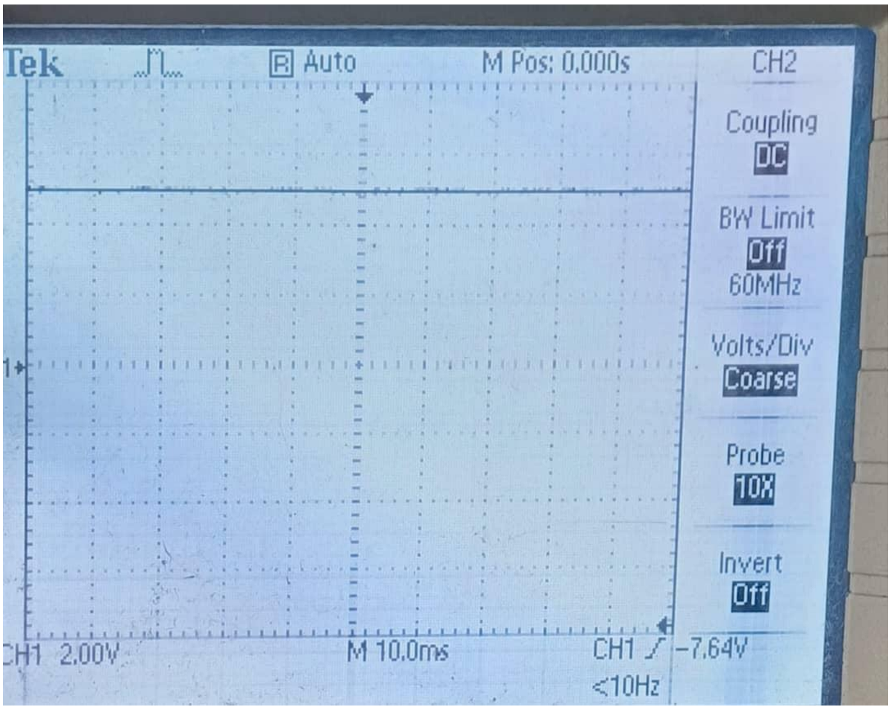

Figure 5: 5 V regulated input voltage to the IR sensor module.

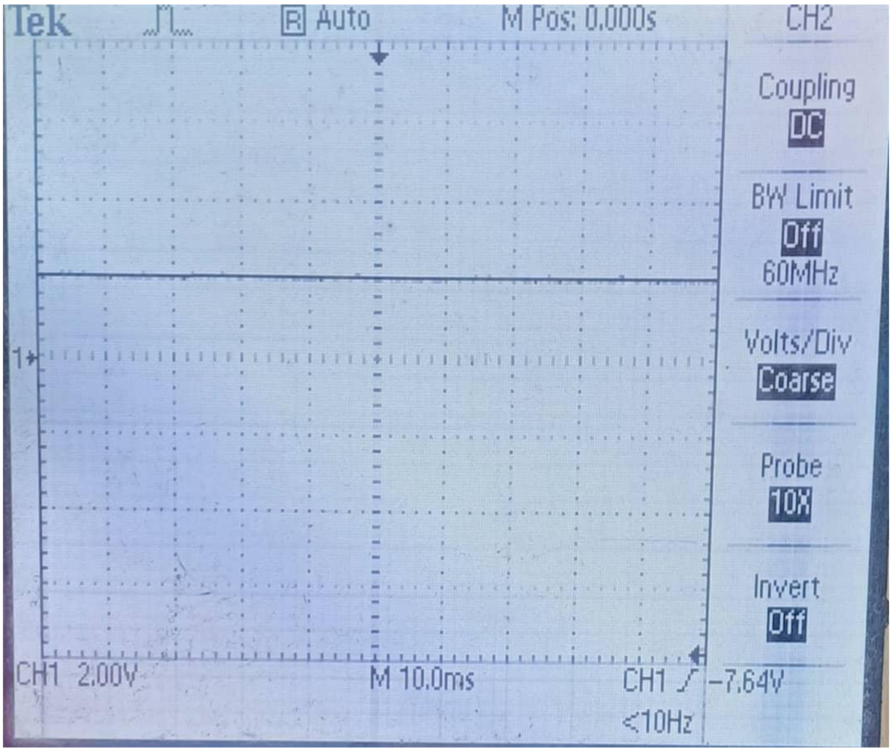

Figure 6: Output voltage from the IR sensor module.

The infrared sensor and the mechanical relay work together to control the flow of water. When the relay switches to the Normally Open (NO) state, it completes the high-current circuit that the 12 V LiFePO4 battery powers. The oscilloscope data shows that when the relay is turned on, it sends a full 12 V to the solenoid valve and pump, which starts the flow of water right away. On the other hand, when the hand is taken away, the TTL signal goes down, the relay goes back to the Normally Closed (NC) state, and the voltage across the load goes to 0 V. The quick response time is important for saving water and lowering the risk of cross-contamination by making sure that the experience is fully touchless. The LiFePO4 battery worked well because it kept a steady voltage discharge profile during the testing cycles. This meant that the solenoid valve worked reliably without the voltage drop that is sometimes seen with regular lead-acid batteries. This automatic handwashing machine prototype cost about $50 to make. This charge is a lot less than gadgets that are sold in stores, like the Meritech Clean Tech 500EZ Automatic Handwashing System, which costs $2,500.

IV. CONCLUSION

This research shows very well that using infrared sensors with $LiFePO_4$ battery technology can help fix the lack of clean infrastructure in places with few resources. The prototype that was made has a high power-to-weight ratio and is thermally stable, which means it is portable, cost-effective, and safe. The test results indicated that the IR-activated relay system works as intended, giving an accurate, contactless response. This means that it successfully reduces the risk of cross-contamination.

It would be a good idea for future generations of this device to include a flexible solar photovoltaic panel that can recharge itself. Additionally, incorporating an ultrasonic sensor to monitor fluid levels would streamline the process of sending real-time maintenance alerts. These improvements would make the machine even more of a long-term solution for public health problems in schools and other places throughout the world.

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