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Design of a Low-CostArduino-BasedAutomatic Liquid Level Monitoring and Control System in a Cameroon Industrial Plant

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Abstract
In this research, a new Arduino-based system is designed capable ofautomatically monitoringand controlling liquid levels in a tank. The level of liquid in a tank is detected using the ultrasonic sensor HC-SR04 and is interfaced with the Arduino Nano board using the Atmega328 microcontroller, and ESP32 Wi-Fi module. It can measure any type of liquid as we use an ultrasonic sensor. The Arduino receives the level information from the sensors and tracks the liquid level with predefined level indicators. The Bluetooth module receives the command from Arduino and the command will be transferred to various registered mobile phones in the system.Experimental and simulation results demonstrate the flexibility and practical applicability of the solution. Furthermore, this system reduces the high level of human supervision as it enables remote monitoring and control. This system is inexpensive, and easy to build, install, and maintain. The poor internet signal network was observed to affect the real-time monitoring and automation of the system control through delays in system responses to commands. However, the average recorded response time of the system is 40 s, and it could be less in the situation of good internet network services.

Keywords: *Liquid Level, Arduino Nano, ESP32 Wi-Fi module ultrasonic Sensor, Arduino Cloud Platform*

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I. Introduction

Automation, implementation, supervision, and control systems have become fundamental and distinctive in differing sectors of our economy. Every production process requires a monitoring system, so the desired efficiency and productivity can be monitored. These continuousrequirements for supervision, monitoring, and control of the various units of the production processsystems led to the development of the different proprietarysupervisory control and dataacquisition (SCADA) systems existing today. SCADA systems have been the core of industrial automation and control over the years **[1].**However, these differing SCADA systems face some challenges that include high cost ofinstallation, operating and routine maintenance, high technical know-how requirement, low levelof interoperability, and face high scalability issues, opines **[1].** To achieve a comprehensivesolution to these challenges, a system for data acquisition, processing, transfer, anddisplay willhave to be developed for application in the macro, mini and microprocessing systems. To this end,automated liquid level monitoring system addressing the control of liquid wastage, meeting challenges of SCADAsystems are being researched and developed by various researchers. This remains an open research opportunity as every industrial production process requires a monitoring and control system, and the desired efficiency and productivity must be monitored. Some of the production process matrices requiring monitoring and controlling are fluid level, temperature, pressure, humidity, flow rate, etc. These parameters are collected by sensors which are usually distributed over large geographical areas, sometimes in harsh environments [2]. Without reliable monitoring and control systems, the production process may be grounded causing urge financial loss to the enterprise and in some cases, wastes of different nature are recorded. With the increasing number of these industrial and domestic production processes in Cameroon, low-cost monitoring and control systemshave become necessary to ensure proper operation and maintenance.

Aims and Objectives

Liquid-level measurement is often the key to safe and reliable process plant operation and covers both point and continuous level measurement applications [3]. The main aim of this study is to develop and evaluate a low-cost monitoring and control system for the automatic monitoring of liquid levels in industrial applications using the Arduino development platform. This system will enable stock control and offer custody metering benefits, as failure to measure levelreliably has resulted in some of the most serious industrial accidents [3].A lot of physical quantities in industries need to be monitored and controlled and these physical quantities must be adequately measured, monitored, reported, controlled, and even stored.

In this study's design, the premise is that we can monitor the level of the liquid from my smartphone without having to view the level of the liquid or even go near the tank. The study is formulated to design circuit for Smartphone based liquid level monitoring system that will use to remotely monitor liquid level with using the Smartphone based Arduino UNO. The research will also provide a facility that provide access to end-users for monitoring and controlling a visualization platform.

Related Work

Research on measuring the fluid level has been studied by earlier researchers. In [5] author described the automatic watering system that depends on the Arduino platform with a moisture sensor, the communication between them is established via ZigBee protocol and the automatic watering process will start according to the value of the moisture sensor. In [6] author has designed and implemented an IoT-based system that monitors water levels and builds a prototype using low-power wide-area network technology. Research in **[7]**describesa developed ultrasonic water level detection (UWLD) system withan energy-efficient design and dual-target monitoring. The authors of **[8]** in their researchprovides a detailed study on how to develop the Arduino UNO based smartphone-based liquid level monitoring system.The work by **[9]** discussed automatic water level indicators using an ultrasonic sensor and GSM module. The objective of this project was to measure the level of water in the tank and notify the user through an SMS alert. In their analysis, the authors observed minor errors from the sensor readings that could be attributed to the tank's temperature and enhancement can be achieved by installing pH sensors which will help to regulate the acidity or alkalinity of the water.The authors of **[10]** developed an Arduino-based water level control system with a design based on an ultrasonic transducer. Liquid level is determined by electronic conversion of echo arrival time. The incident wave from the transmitter (T) is recorded by the receiver (R) of the ultrasonic sensor. The authors of [**11**] design implement a simple and inexpensive feedback controller for use in an application that needs to monitor the water level in real-time. The study reported by **[12]** examines the scheme of managing water level systems in reservoirs using sensors. In their work, the data is sent to the cloud through the IoT module, and the user monitors the water level via an android application.In another study, Taru used Arduino with LabView for a monitoring system. The system was designed to develop, implement, monitor, and control several water parameters such as pH, temperature, and turbidity [**13**]. Faroqi used Arduino Nano-based light-dependent resistors for the Automatic Water Filtration Monitoring and Clarity System. The water clarity monitoring system in the aquarium was designed to detect the level of water clarity/turbidity at a certain level using Arduino Nano Microcontroller as the central controller and LDR (Light Dependent Resistor) as the sensor [**14**].

Working of Automatic Liquid Level Controller

Different researchers have worked on automatic liquid levels monitoring and control systems with each having specified requirements. In this study's design, the key idea is that we can monitor the level of the liquid from visualization platform without having to view the level of the liquid or even go near the liquid tank.In our pilot project, the ultrasonic point or continuous liquid levelmeasurement is based on ECHO principle where ultrasonic sensor module sends the (sound) waves in the liquid tank and detects reflection of waves. A sensor emitsand detects ultrasonic pulses in the adjustable range, which are reflectedfrom the surface of the liquid. We trigger the ultrasonic sensor module to transmit signal using Arduino. The Arduino software reads the time between triggering and received ECHO. The speed of sound is approximately 340m per second, we can calculate distance by using given formula:*Distance= (travel time/2) * speed of sound.*This is the distance from sensor to liquid surface. The liquid level as defined by the Arduino software is given by subtracting resulting distance coming from ultrasonic from total length of liquid tank, which is then convertedinto the percent of liquid. Thetransmission time characteristics of thesensor generally determine a minimum allowabledistance.

The working of the complete liquid level monitor project is shown in below block diagram (Figure 1).To properly accomplishthis pilot project, this study design followedthe construction method as proposed in [**15**], a system development best thought of as a 'proof-by-demonstration [**15**]. The reason for selecting this method is that it allows for iteration.

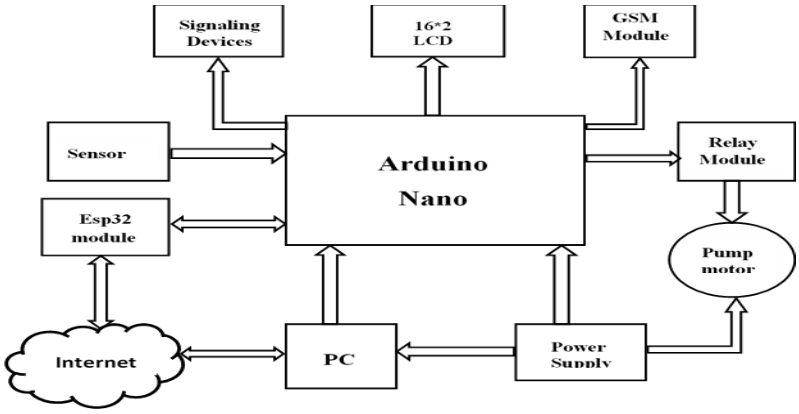

Figure 1. Block diagram of the system

Circuit Diagram and Explanation

The quality, security and flexibility of an application are greatly affected by the system architecture. The low-cost common solution for liquidlevel monitoring and controlconsists of various input and output processes. The system consists of the following different units: apower supply unit, liquid pump unit, Internet module, Ultrasonic sensor, Arduino board, user interface unit, buzzer unit, GSM module unit, Led unit, and a liquid crystal display (LCD) unit. The combination of these components makes the integration of the system easier to debug and provides optimal performance. As shown in the liquid level controller circuit as illustrated in Figure 2, Ultrasonic sensor module's "trigger" and "echo" pins are directly connected to Arduino. A 16x2 LCD, data pin, buzerand Volt relay are all connected at different pinpoints of Arduino for instance for turning on or turning off the liquid pump. A voltage regulator is also used for providing 12volts to relay and to remaining circuit.The LCD unit is a medium through which the microcontroller communicates with the user. The LCD unit is used to display sensed data readings from the sensors.

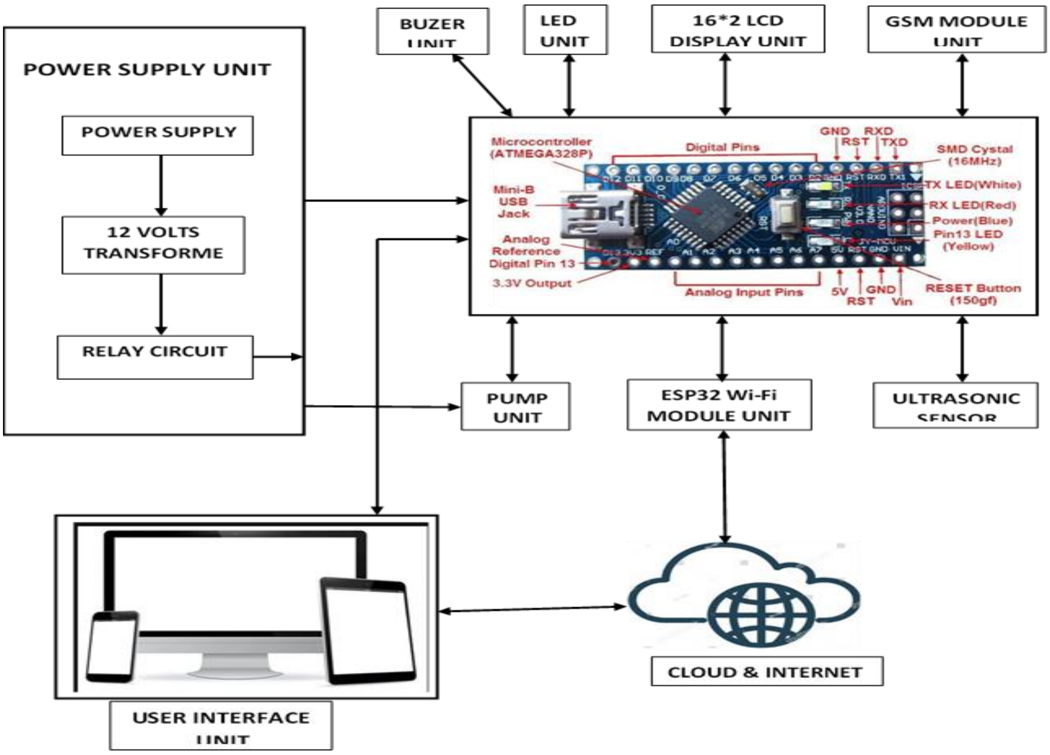

Figure 2. Low-cost sensor interface for monitoring and control system architecture.

Methodology and System Implementation

The choice of the sensor and transmitter and data transmission methods used are the principal factors affecting the installation costs,accuracy of readings and cansimplify maintenance. The microcontroller is the heart of this project work, as all the control signals pass through and are processed by the microcontroller. The project was simulated using Proteus while the implementation was done on a breadboard.Guided by the logic of the construction method [15]and general definitions extracted from [16], the tasks to be performed were listed while the flowchart for the design was drawn as illustrated in Figure 3. Algorithms that explain the sequence of operations and steps for the design were written thus enabling the diagrammatical representation of the flow of the process through the agency of flowcharting as used in [17].

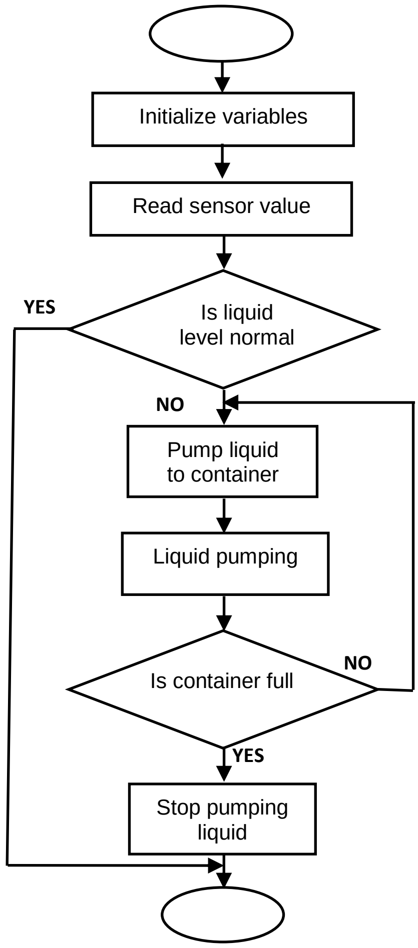

Figure 3. Flow Chart of the Proposed Monitoring and Control System.

When the system is powered ON, the sensor reads the liquid level in the tank or container. If the measured liquid level is below the threshold value, the system puts ON the motor that pumps liquid into the tank. This is followed by the display of appropriate LEDs as described above. The system will continue to monitor and control the level until it will automatically switch the pump OFF when the tank or container gets full. The ON and OFF, of the pump is done automatically, however, the user can also remotely do this manually from any part of the world through the Arduino Cloud Platform using their account.

Simulation using Proteus

The low-cost sensor interface is simulated using the Proteus 8.5 design suite. According to Labcenter Electronics publication [18], Proteus 8.5 Professional is an efficient tool and a high-performance design environment for simulating technical computing [**18**]. It integrates computation and the virtual representation of the systematic operation of the system, displaying how the constructed system components will work. Arduino, as the development board, provides an IDE, by which source codes can be written, verified, and uploaded to the microcontroller.

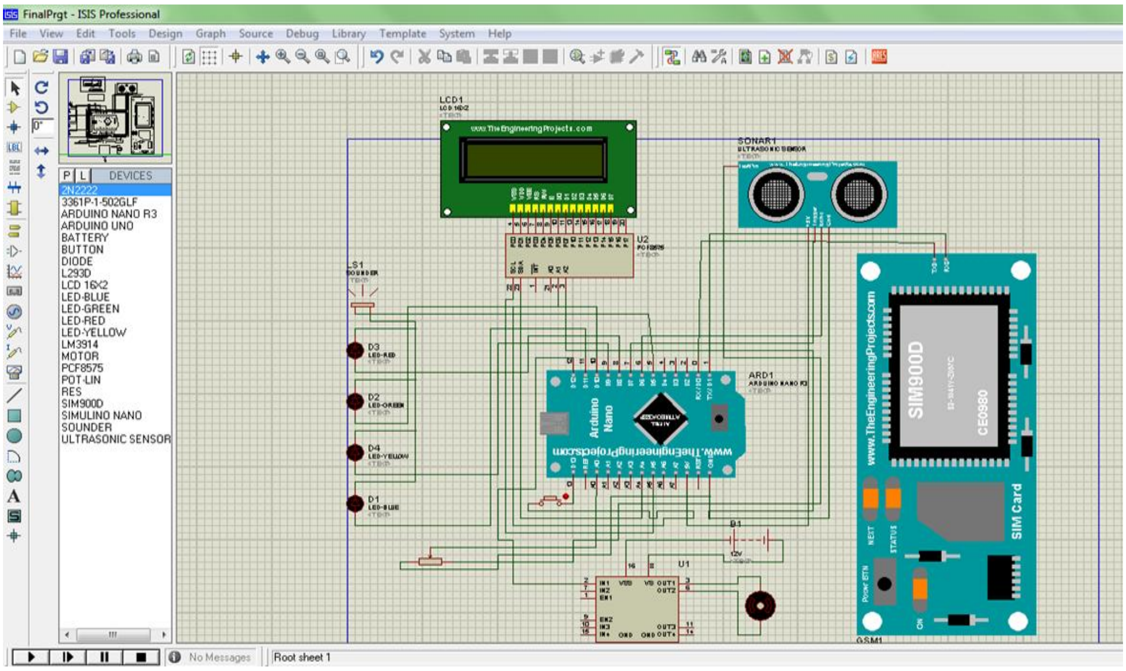

Figure 4.The System simulation test and result on Proteus

Figure **4** shows the Proteus software simulation diagram obtained from this study. In the circuit, the ultrasonic sensor will get the distance. Then it will show the level on the LCD screen with the message "Depth: xx cm". We are here measuring empty spaces of distance for the liquid instead of the liquid level. Because of this functionality, we can use this system in any liquid tank or container. We subtract the distance from the tank depth to get the liquid level. Three distinct states were established: low, normal, and high. When the fuel level is equal to 25% the Arduino turns ON the pump by driving the relay. And now LCD will show "level xx%" and "pump ON", relay/motor status LED will start glowing. Now if the liquid level reaches 90%, the Arduino turns OFF the relay and the LCD will show "level 90%" "pump OFF" and the relay status LED will turn OFF. Using the GUI, the system could be controlled by either the turning ON or OFF the motor and viewing the liquid level. As a result, the prototype could be operated remotely, automatically, or manually.

Study Complete Circuit

Figures 5, 6 and 7 illustrate the implementation setup of the system. The system was prototyped using a pair of 5 litres of graduated plastic containers serving as the overhead and underground tank as seen in Figure 5. In the lab, the volume of the liquid in the containers can be varied and the corresponding depth and sensor reading were recorded. The potentiometer was used to set the minimum value of the overhead container and the system was programmed to set the maximumvalue to 80 % of the container (i.e., 100% of the container = 80% in the program, however, it is considered and displayed as 100%).

Figure **5.**Implementation on breadboard.

This is to avoid the overflow of the liquid if it reaches the actual 100 % of the container. The corresponding volume of the reservoir was displayed on the LCD.Figure 6 shows the front panel of the laboratory modification of the liquid minimum set point.

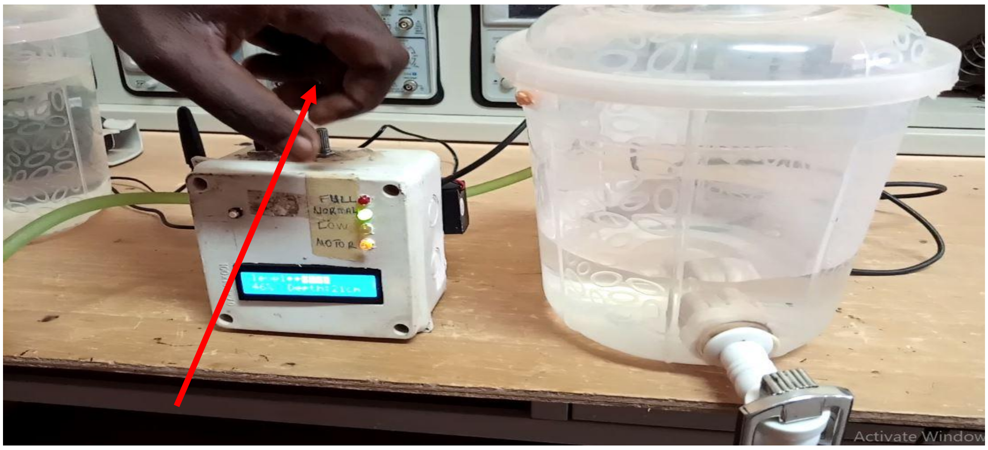

Figure**6.**Modification of the liquid minimum set point

The system uses four LEDs for its visual signaling. The green LED is always ON, indicating that the system is functioning correctly, as seen in Figure 6. The red LED indicates that the liquid level is attained (container full), as shown in Figure 7. Also, the potentiometer seen in Figure 6 is used to set the minimum level of a container. Let's assume two containers of A and B with an equal depth of 4m. These containers' depths can be set to 20cm for container A and 40cm for container B by varying the potentiometer. This functionality gives the user the latitude to decide what they want their low and high level to be. Whenever the system senses a low liquid level, it puts ON the white LED. This means the white LED is ON only when the low level is attained. Finally, the yellow LED is ON only when the motor switches ON. Supervisory control actions were demonstrated with an alarm triggered and SMS notifications sent when the pump motor did not start or stop when the minimum or maximum set points of the container were met.

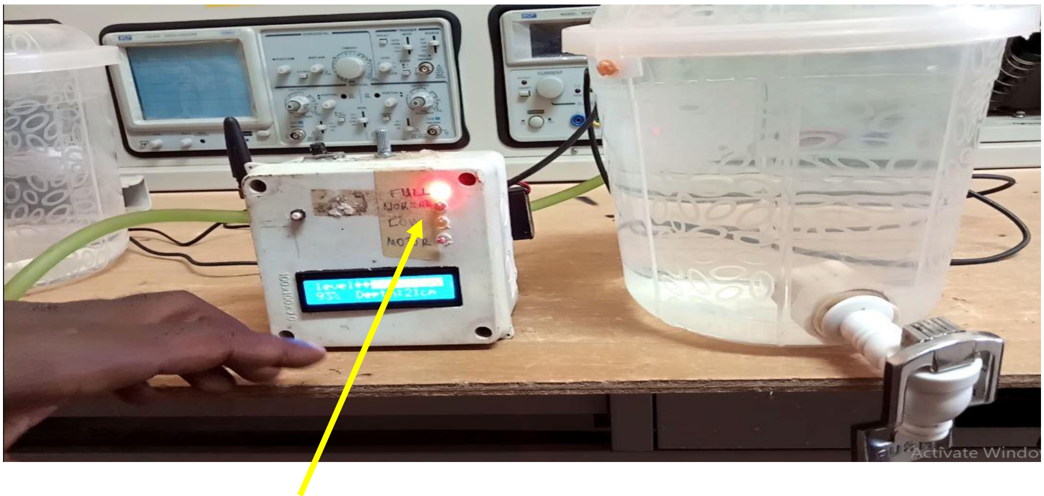

Figure **7.**System indicating maximum level attained (Red LED 'ON')

II. Conclusion

The demands of today's automated processing systems, the need for tight process control, and regulatory environment drive process engineers to seek more precise and reliable level measurement systems.This paper describes a low-cost "Arduino Based Liquid Level Monitoring System". For Cameroon with a growing economy, commercialization of such application will be a welcome development. It is concluded that the proposed system can potentially benefit industrial-level control applications, both for stand-alone operations and those integrated within a wider supervisory control scheme.By using this system, any type of liquid level value can be controlled. Study of unit maintenance and system protection under different environments will be considered in future research, including different water flow conditions and differentprotection strategies of the sensors from the environmental conditions.

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