An Adaptive Water Level Controller with Smart Monitoring Technologies

A.I.S. Juhaniya, R. Hirshan, M.N.M. Aashiq, W.R.E Fernando and C.R Karunarathna

Abstract Modern technology completely depends on automation and control systems. Automation technology is widely used by many manufacturing industries and people's day-to-day lives to reduce human intervention. The prevention of water wastage also can be controlled by using automation and control system processes. The proposed Advanced Water level Controller in this paper has features such as real-time measurement of water flow and water level, remote control of water supply, calculation of monthly usage along with the bill, and monitoring water tank remotely using the mobile application. The hardware part is mainly based on a microcontroller (STM32). In this microcontrollerbased water level controller, an ultra-sonic sensor (HC-SR04) placed on the top of the water tank is used to measure the water level. The measured water level will be displayed by using LCD and LED. Based on that information, a relay is used to control the water pump. According to process results, the microcontroller collects the data from sensing devices, processes the data, and controls the output devices. The GSM module (SIM800L) and Ethernet module (ESP8266) are used to communicate with mobile devices. The mobile application is developed using the flatter software platform. This system will be more cost-effective, have less power consumption, and adopt more features for water level control. This system improves the existing water level control system and reduces the use of workforce while saving water.

***Index Terms*—water automation, microcontroller, water level sensor, GSM module, mobile application**

I. Introduction

WATER is an asset in numerous parts of the world, and numerous individuals depend on water tanks to supplement their water supply by putting away gathered water or water pumped from a well or bore [1]. Be that as it may, how would you quantify how full a tank is? Most households use water from the main water supply, and the underground water is pumped to the water tank on the rooftop. So, people will switch on the motor and wait till the tank is filled, and then switch off the motor. In a busy life, people might forget to turn off the motor when the tank is full. Therefore, water would overflow from the tank. This scenario is happening in every home in Sri Lanka. There are several research works have been conducted to tackle these issues with conventional water level controlling and monitoring systems. An advanced water level controller is modelled and monitored with android software in smart mobile phone [2]. A basic model of an android-based application is proposed by Paul, Das, Sau, and Patra, (2015) in which water pumps can be turned on and off with the help of wireless radio transmitters and a Wi-Fi router [3]. In addition, users can check the live water level of the tank and turn the pump on the line of the palm remotely using the Android application. A water level monitoring system is developed using an ATmega8 micro controller simulated with Proteus software platform in [4]. A water level controller is proposed using Arduino and ultrasonic sensors to provide alerts to the users when the tank level exceeds in the form of a voice call along with the SMS [5]. An automatic pump control system is designed to control the operation of the water pump when the tank's preset maximum point is reached by the water. This system comprises ultrasonic sensors mounted at the top of the tank [6]. A water level controller with an Arduino UNO micro controller is implemented in the LabVIEW software platform [7]. A solar-powered automated watering system is formulated in [8] to provide the interrupted water for the irrigation system. An energy-efficient water level detection system with dual target monitoring is presented in [9]. It proposes an advanced water level detection system along with the mobile application developed. A review has been done with the existing water level controller-related studies [10].

Although several water level monitoring systems are discussed in the existing studies, they have several shortcomings such as analyzing the schematic diagram with the aid of software instead of hardware implementation, sensor readings were not calibrated, non-linearities arising in the pumps are not taken into account, and computational burden. In addition, the developed Android applications did not adopt user-friendly options such as real-time data saving, remote monitoring, etc. Therefore, this study provides an adaptive mechanism for water level monitoring systems using advanced technologies.

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This system provides a unique method that controls the volume of water in water tanks and water tank overflow problems. In this microcontroller-based water level controller, the water level is measured by placing an ultrasonic sensor (HC-SR04) on the top of the water tank. The measured water level was displayed using the LCD screen and LED lights. Based on that information, a relay is used to control the water pump. The Ethernet module (ESP8266) is used to control and monitor the system from the mobile application remotely. We can get information about the system by text messaging using the GSM module (SIM800L). Furthermore, user can observe the monthly, daily water consumption of the house from the LCD and through the mobile application. In addition, this developed system provides hybrid control comprised of control of the system from the hardware circuit unit and the mobile application remotely. The introduction and related works are discussed in this section and the following section describes about methodology used for this study while section iii deals with the results and discussion. Finally, a conclusion is drawn in the section iv.

II. METHODOLOGY

This study aims to develop an adaptive water level monitoring system by amalgamating recent microcontroller technology with IoT-based techniques. The block diagram of the proposed water level controller is given in Fig. 1. This study for developing an adaptive water level controller includes steps such as software simulation of the circuit, PCB design, hardware implementation, API development, and formulation of mobile application.

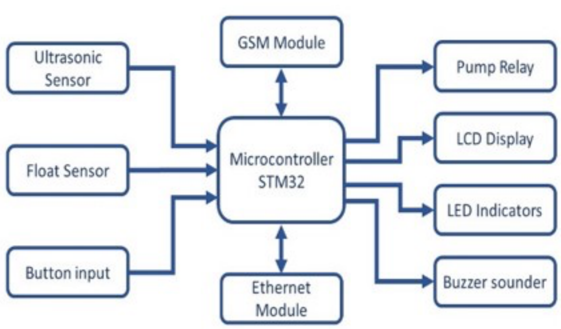

Fig. 1: Block diagram of proposed water level controller

This study for developing an adaptive water level controller includes steps such as software simulation of the circuit, PCB design, hardware implementation, API development, and formulation of mobile application. The entire methodology of the system is simplified in the block diagram in Fig. 2.

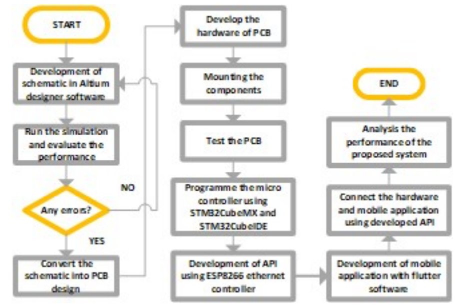

Fig. 2: Flowchart of methodology

A. PCB Development

The circuit schematic is developed using the Altium Designer software platform to analyze the circuit before hardware implementation. The Altium software schematic for all components in the water level controller is depicted in Fig. 3. After developing the schematic diagram, it is converted to a PCB layout to process the hardware design of the PCB. A multilayer PCB is developed and routed as given in Fig. 4 . After obtaining the software-routed PCB design, the hardware of the PCB was prepared using a copper board. Subsequently, all the components in the software schematic are assembled. During the developing phase of the PCB software design in Altium Designer, some components did not appear in the existing library of the Altium Designer. Meanwhile, such components have been added to the library as a new component to complete PCB routing [11]. The ESP8266 and 1602 LCD display are example for the newly added ones to the Altium library.

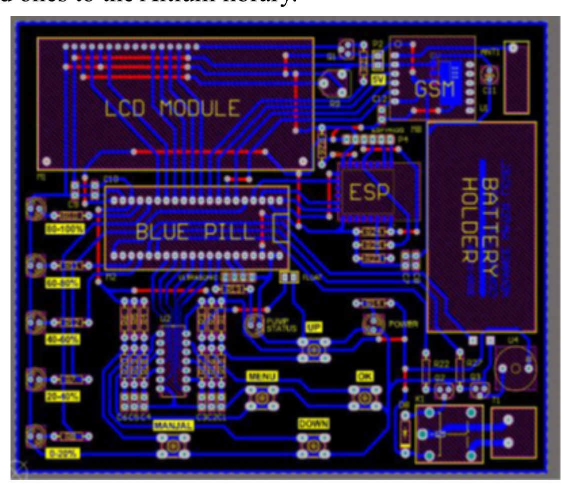

Fig. 3: PCB Layout in Altium software

The top layer of the hardware after mounting all components is presented in Fig. 5. The top layer has the connection for all components while the bottom layer has the ground connections.

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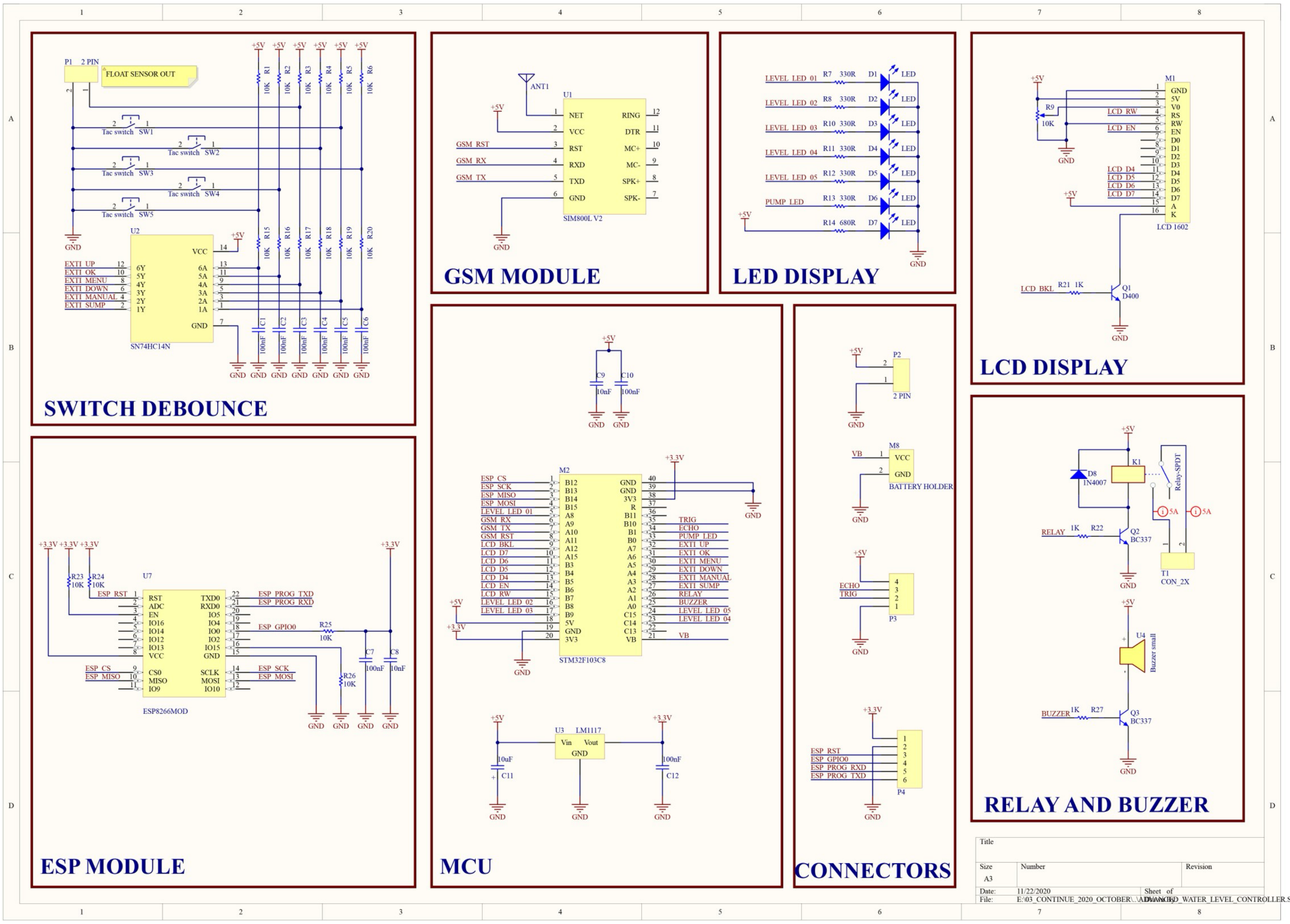

Fig. 4: Schematic diagram of water level controller in Altium designer

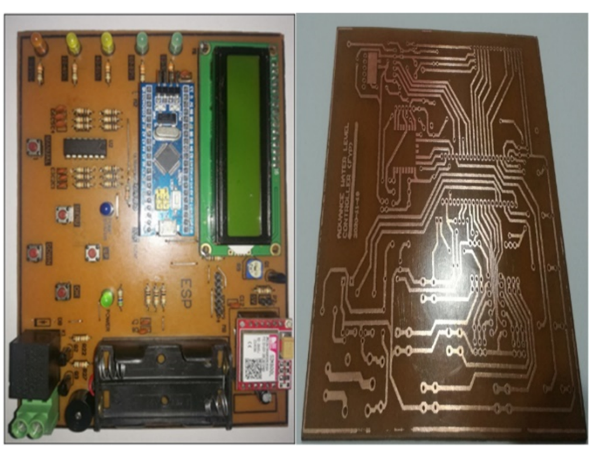

Fig. 5: Developed PCB

B. Configuration of Microcontroller

STM32CubeMX is a graphical tool that allows a very easy configuration of STM32 microcontrollers and microprocessors, as well as the generation of the corresponding initialization C code for the Arm Cortex-M core devices through a step-by-step process [12]. All peripherals related to the microcontroller are initialized by using the STM32CubeMX software platform. In addition, Keil μVision software is used for microcontroller programming.

C. API Development

REST API is an application program interface (API) that uses HTTP requests to GET, PUT, POST, and DELETE data. However, our design for this application only accepts GET, PUT and PATCH requests. These requests allow users to retrieve data from the controller and change data present in the controller. The designed API supports the client in retrieving all information of the controller and change all control details of the controller [13]. This API server runs on the ESP8266 microcontroller and it can connect with the internet.

This API implementation has more advantages than using an external server to exchange data between the controller

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and client application. In addition, it can work without any external server interaction due to the lack of a middle server. API implementation allows us to develop desktop software applications, mobile applications and web applications very easily. Another advantage is cost spent for an external message exchange server is not present with this system. The ESP8266 wireless Ethernet controller connects with the STM32 main controller through the SPI bus. They make several handshakes to give correct information to the user. The connection diagram between the ESP8266 and STM32 is given in Fig. 6.

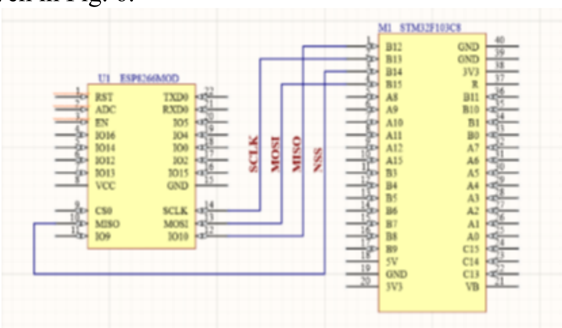

Fig. 6: connection diagram between the ESP8266 and STM32

D. Development of mobile application

The mobile application shows all the details about the water level controller. Hence the user can easily monitor the water tank from a mobile phone. The mobile application was developed in the Flutter platform. We got the system data from the mobile application. ESP module sent the data to the API and mobile application got the data from the API. Users can control the pump from the application and all the features such as water level monitor, alarm setting, water consumption, and water bill calculation can be done using the mobile application. Fig. 7 shows the proposed architecture of the mobile application.

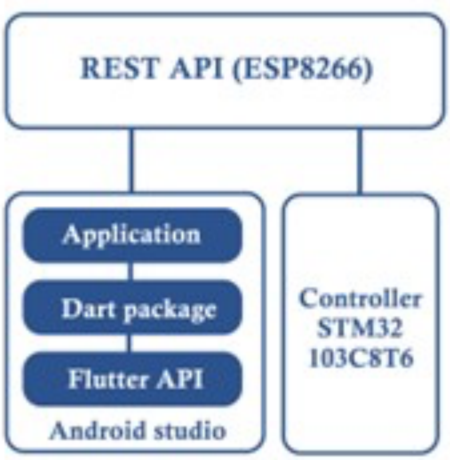

Fig. 7: Proposed architechture of mobile application

Flutter is a cross-platform UI toolkit that is designed to allow code reuse across operating systems such as iOS and Android. The Android Studio is used as an IDE. In the Flutter framework, it is important to build a set widget that will be reused and customized. The programming language used was the Dart language. After finishing our mobile application, the application is connected through the REST API interface to get the data from the water level controller. The results obtained using this methodology are discussed in the following section.

III. Results and Discussion

The designed PCB is tested to do further analysis. The working PCB is depicted in Figure . The user can observe water consumption in three different bases with the help of a navigational menu structure using this water level controller system. Those are daily usage, weekly usage and monthly usage. Furthermore, the system is capable of calculating monthly water bills and users can configure tariff criteria at any time according to the current Sri Lankan tariff plan.

A. PCB Testing

LCD display menu consists of the options such as, the current working mode, the current water level of the tank, the sump sensor status, the presence of interrupt timers, and the beep sound on/off status. The working mode has six options namely, automatic mode, manual mode, automatic manual mode, pre-set mode, power saving mode and leakage test mode. Automatic mode and automatic manual mode allow users to control this system with the ultrasonic sensor. Users can change the working mode using the menu structure. Using the manual pump control button, users can switch on and off the water pump when the system is working in both manual and automatic manual mode. In addition, there is a timer manipulation algorithm, which will work with the RTC hardware module of the MCU. There are two types of timers which can be used to switch on the water pump automatically in real-time. Interrupt timers can switch on the water pump according to the given time and date and interrupts are onetime events. Pre-set timers can be used to switch on the water pump at a given time daily. This water level controller is designed with a timer manipulation function to manipulate all alarm timers. Fig. 8 shows the images taken for different modes of operation.

B. Power consumption

Power consumption calculation was done using a multimeter. With the power saving mode active, When the power saving mode is active, the microcontroller works up for regular periods with a power consumption of 28 mW which is lower than the power consumed by water level controller by Kang, David, Yang, Yu, and Ham, (2021). In normal mode, the microcontroller always runs at its maximum speed and consumes much current than in the power-saving mode resulting in 85% additional power consumption. However, when the pump status is on, the power relay is also on and consumes 530 mA current with a power consumption of 2.65 W.

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(a)

(b)

Fig. 8: (a) Timer configuration menu and (b) mode selection menu

C. Mobile application

In the mobile application, initially there is a login page. After logging in to the application, there is a main menu screen. Users can get any information such as water level, water consumption, water bill and pump state from the application. Also, the user can turn on and off the pump and make changes to the system. The mobile application interface is given in Fig. 9.

Fig. 9: Mobile application interface

D. Ultrasonic sensor reading and water usage calculation

The final model of the proposed water level controller implemented in the project box is shown in Fig. 10. When the system needs distance measurements, the microcontroller pulls higher trigger pin of the ultrasonic sensor. Then, the microcontroller waits until the eco pin state changes. Subsequently, the microcontroller reads pulse time of the eco pin. The system calculates the distance to the water surface using this pulse time value. There are two methods used to get accurate readings from the ultrasonic sensor. One is based on using a correction factor and the other one is based on highly accurate timer implementation. The proposed water controller uses the highest accurate timer for ultrasonic sensor readings. Finally, with the help of the correction factor equation, the measurement deviation due to air temperature changes is avoided and the sensor can measure distance with 1 mm accuracy.

Fig. 10: Mobile application interface

IV. Conclusion

This research proposes an adaptive system to control the water level of the tank and water pump. A SMT32 microcontroller is used for this purpose. A mobile application is developed for the real-time monitoring using Flutter crossplatform UI toolkit. Rest API is implemented to establish the communication between the developed hardware system and the mobile application. The designed mobile application is capable of retrieving data from the controller and controlling its operation remotely. Therefore, proposed water level monitoring system may be the replacement for the existing systems. Furthermore, this system can be extended by considering the remote monitoring of entire plumbing system not only in domestic level but also industrial needs along with the tank control.

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