A SONAR-Based Water Level Monitoring System: An Experimental Design

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Abstract— Storage of water is common to all human for domestic and industrial utilization. Today, water tanks are the conventional and a major component in water storage systems as they have the capacity to hold large volume of water over a long period of time. They come in different shapes and sizes. However inadequate monitoring of water level in this storage facility may lead to either shortage of water supply when needed or its wastage during lifting process. Hence, there is need for proper monitoring of water level in a storage facility. This need motivates this work, which is the development of water level monitoring system that based on sonar technology. Materials employed in the development include ultrasonic sensor module, ATmega-328P microcontroller, 16MHz crystal oscillator, 12V dc water pump among others. The developed system monitors the water level and activates the pump as appropriate based on the input the ultrasonic sensor gives to the microcontroller which occupies the centre of the system. The developed system has potential of mitigating the attendant problems that usually arise from wastage or shortage of water supply with respect to water storage facility.

Keywords—SONAR, water storage, monitoring system

1 INTRODUCTION

SONAR (Sound Navigation and Ranging) refers to the technique of using sound wave propagation for navigation; detecting and communicating between two entities that are SONAR based devices. SONAR technology relies principally on reflection property of sound, as a form of wave, when it encounters an obstruction in its path of travel. SONAR technology is of two basic types – the passive SONAR and the active SONAR. The former only observes the remotely generated sound without transmitting while the latter has the capability of emitting and receiving pulses of sound signals. The pulse signals involved in SONAR could either be infrasonic (low frequency signals usually below the threshold of human perception, typically 20 Hz) and ultrasonic waves, which consist of high-frequency sound waves that are inaudible to humans (typically above 20 kHz). SONAR based on ultrasonic finds application in range estimation.

The use of tubes as non-mechanical underwater listening devices, for detection and transmission of sound waves in water is ancient. The art of underwater communication via sound wave actually began in 1490, when Leonardo Da Vinci proposed a method of detecting a remote ship at a distance from a stationary onboard ship by placing one head of a long tube inside water and the other outer one to ear (Urick, 1983). Towards the end of 18th century, increased efforts are geared toward exploring physical properties associated with sound transmission in water. Notable achievements in this regard include articulation of the principle of sound transmission, discovery of piezoelectric effect for pulse generation, and invention of the hydrophone, which is designed to utilize acoustic sound waves and echoes in underwater detection system (Smith, 2016). Threat of submarine warfare during WWW I fast-tracked the development of SONAR technology. However not all of the advances were restricted to military applications.

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Among typical civilian applications is a SONAR-based device installed on large ocean-liners for detecting, visualizing and quantifying schools of fish in water in order to enhance fish hunting efficiency (Persons et al., 2014). Also, underwater human-robot interaction where detection and tracking of a diver by an underwater robotic assistant is realized through a high-frequency forward-looking SONAR system has been reported (De-Marco et al, 2013). SONAR equally finds applications in acoustics as well as oceanic engineering for range estimation and terrain modeling (Dombestein and Wegger, 2014; Hjelmervik, 2010; Hodges, 2011). Besides the underwater applications of SONAR, air-borne SONAR has been widely deployed in robots and car navigation (Ullah et al., 2013; Sarabia et al., 2013), driverless cars for people detection and navigation of autonomous Unmanned Aerial Vehicle (UAV) and in medical diagnostics (Terzic et al., 2013).

Ultrasound movement in material media of different densities differs. An ultrasonic wave propagating in a given medium responds to changes in density when it strikes an object of different density along its path. Part of the propagating wave is reflected. Time delay between the transmission and reception of the reflected wave can be used to determine the distance between the transducer and the position of the obstacle. Suppose the transducer generating the ultrasonic waves resides in air and directs its output into a liquid container, the liquid level in the container can be ascertained using SONAR principle. (Terzic et al. 2013) utilized this technique for the determination of the quantity liquid in containers via the use of multiple ultrasonic sensors. Echo pulses are transmitted from the sensors and travel through the fluid and reflect back. The time period from sending to receiving the signal is measured. From the gathered information, the volume of the fluid is determined.

Water is an invaluable gift of nature that sustains human life. Storage of water is common to all human regardless of their source of water. Today, water tanks are the most common and efficient way of storing water because they can hold large quantities of water for days, weeks or even months. They come in different shapes and sizes, however improper monitoring of water level in its storage facility such as a tank often leads to either shortage of water when needed or wastage of water during the lifting process into the tank. Hence, there is a need for proper monitoring of water level in this kind of storage facility. This paper presents a SONAR-based water level monitoring system that could be deployed to address identified problems with use of tanks for water storage.

2 Design Considerations

The block diagram of the proposed SONAR-based water level monitoring system is depicted in Fig. 1. The design process of the SONAR-based water monitoring system is divided into two main sections, mainly the hardware and software sections. Hardware components utilized are ultrasonic sensor module, liquid crystal display module, microcontroller, water pump driver, water pump and power supply unit. The hardware design is concerned with the process of selecting required components that meets specification while the software section design has to do with writing and loading of instruction sets for the microcontroller in order to carry out the signal processing functions that are required in the proposed SONAR-based water level monitoring system.

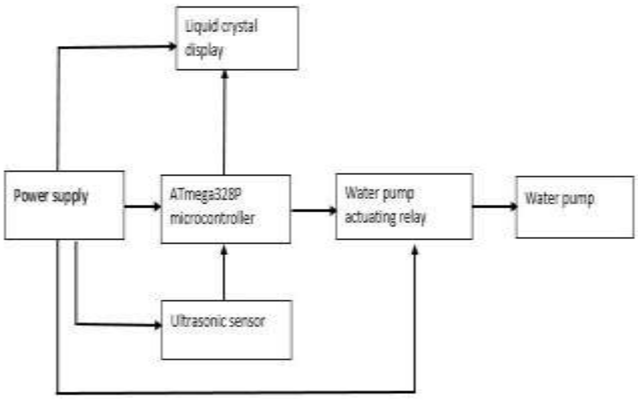

Fig. 1: Block diagram of the developed water level monitoring system

2.1 Hardware Section

Power supply unit: A 12V DC power adapter in conjunction with a 5V voltage regulator serves as the power supply unit.

Ultrasonic Sensor Module: A generic type ultrasonic sensor module HC-SR04 is employed. It has an electronic compatible interface that can be easily plugged in and out of a breadboard. Its minimum detecting range is about 3cm and its maximum detecting range is around 500cm. Other specifications include supply voltage of 5V DC, 15mA supply current, $40kHz$ ultrasonic frequency, trigger pulse width of 10μs, and input triggering signal that is made of 10μs TTL impulse.

ATmega-328P Microcontroller: The ATmega-328P is an eight bit, advanced Reduced Instruction Set Computing (RISC) microcontroller. Its low power consumption, high performance and ease-of-use enhance its suitability for this design. Each of its pins is at 5V dc and 20mA. It requires an external clock which is provided by a 16MHz crystal oscillator. Two equal value capacitors C_1 and C_2 form load the capacitance for the crystal oscillator to smoothen the clock pulses. The values of the capacitors are obtained using the expression given as

$$C_L = \frac{C_1 \times C_2}{C_1 + C_2} + C_s \qquad (1)$$

where C_1 is the load capacitance, C_2 is the stray capacitance.

For this design, the value of C_L is 16pF as specified in the ATmega-328P datasheet while stray capacitance of 5pF is chosen. The values of C_1 and C_2 are determined using (1) to be 22pF.

Display Module: The display module is a 16×2 liquid crystal display unit. Its low power consumption of 5V, 20mA and small size makes it suitable for use in this work. It is required to give a visual display of the instantaneous water level in the tank.

Water Pump and its driver circuit: For the purpose of demonstrating the workability of the design, a prototype is implemented. The water pump utilized in the prototype requires 12V DC and 1.25A for its normal operation. The pin of the microcontroller is at 5V DC and 20mA. Thus, there is a need for a driver circuit to amplify the driving voltage required for the control of the water pump. In this regard, a driver circuit connected to the microcontroller output port is used. The driver circuit comprises of an NPN transistor BC547 in series with a parallel arrangement of IN4007 diode and 12V, 10A relay. Fig. 2 illustrates the driver circuit with respect to the microcontroller output and input of the water pump.

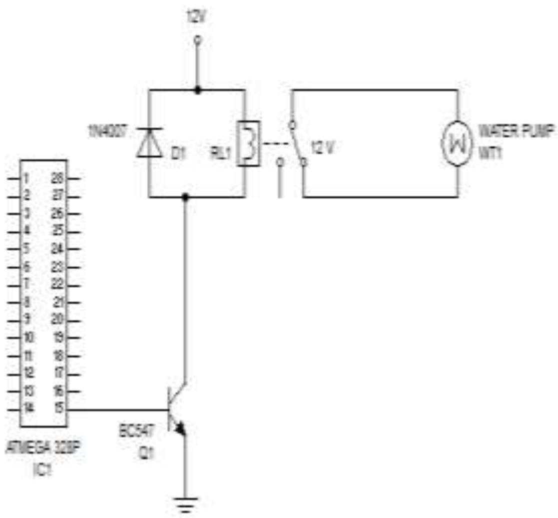

Fig. 2: Control circuit diagram with the water pump

2.2 Software Section

The software section involves programming of the microcontroller and its interfacing with ultrasonic sensor and liquid crystal display. For the proposed SONAR-based monitoring system, Arduino uno was used to bootload the ATmega-328P. The software design flow is illustrated in Fig. 3.

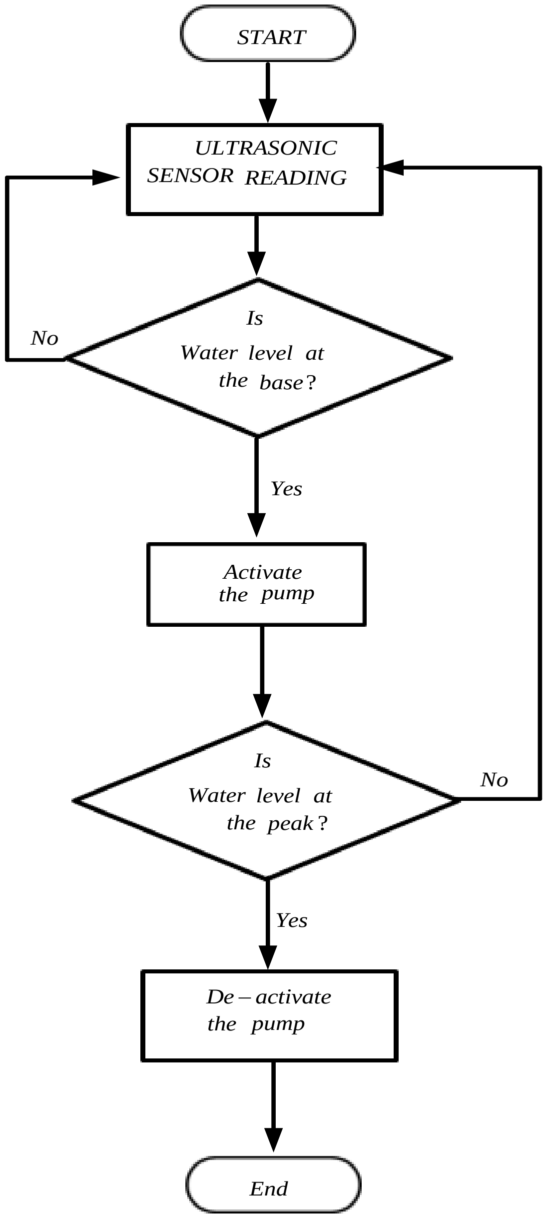

Fig. 3: Flowchart of the software design for the developed water level monitoring system

3 IMPLEMENTATION

The circuit diagram showing all units and components of the developed SONAR-based water level monitoring system is depicted in the Fig. 4. The developed SONAR-based water level monitoring system is implemented by assembling the components in line with the circuit diagram presented in Fig. 4. The microcontroller ATmega-328P has the written operational code loaded on it. The entire construction is powered by a 12V DC source.

4 TEST AND RESULT

After the assembling of electronic components and modules, the developed device is put to test to establish its extent of conformity with the specifications. Shown in Fig. 5 are plates showing part of the experimental setup during testing of the constructed device. The storage tank used for the exercise is a plastic bucket that is 25 cm high. The bucket is calibrated such that the base level and the peak water level is at 9cm and 21cm, respectively. When the water has depleted to the base level, it is expected that the water pump is activated to begin water lifting into the water tank. When the water level in the storage tank reaches 21cm, the water pumping action is expected to cease.

Obtained results are presented in Table 1. The water level test showed that at the preset base level of 9cm, the water pump switched on and continuously pump water into the bucket until the peak level of 21cm is reached at which the water pump automatically switched off.

Table 1: Performance test results

Preset value	Expected action	Test observation
Base level (9cm)	Switching on of water pump	Water pump switched on
Peak level (21cm)	Switching off of water pump	Water pump switched off

With this demonstration, SONAR-based technology was successfully utilized in the monitoring of the water level in the bucket in order to accurately effect the desired control of the water supply. By extension, the design can be deployed to effectively monitor and regulate water lifting into storage tank in a large scale water supply scheme.

5 CONCLUSION

A SONAR-based water level monitoring system was designed and prototype implemented. Performance test on the prototype revealed that the developed system has the potential to effectively monitor water level and aid the control of water lifting process in a large scale water supply scheme when deployed. The preset base and peak levels of the water tank in the designed SONAR-based water level monitoring system can be easily changed by re-programming of the microcontroller.

However, a more versatile approach needs to be explored for a water level monitoring system that is targeted at commercialization. This is very important in order to facilitate more intermediate switching positions in addition to the base and peak thresholds that are demonstrated in this work. As such, it is therefore recommended that an electronic prototyping platform which has a Graphical User Interface (GUI) could be incorporated into the design through which the desired water levels can be easily altered by the user rather than going through the laborious process of re-loading of the firmware of the microcontroller.

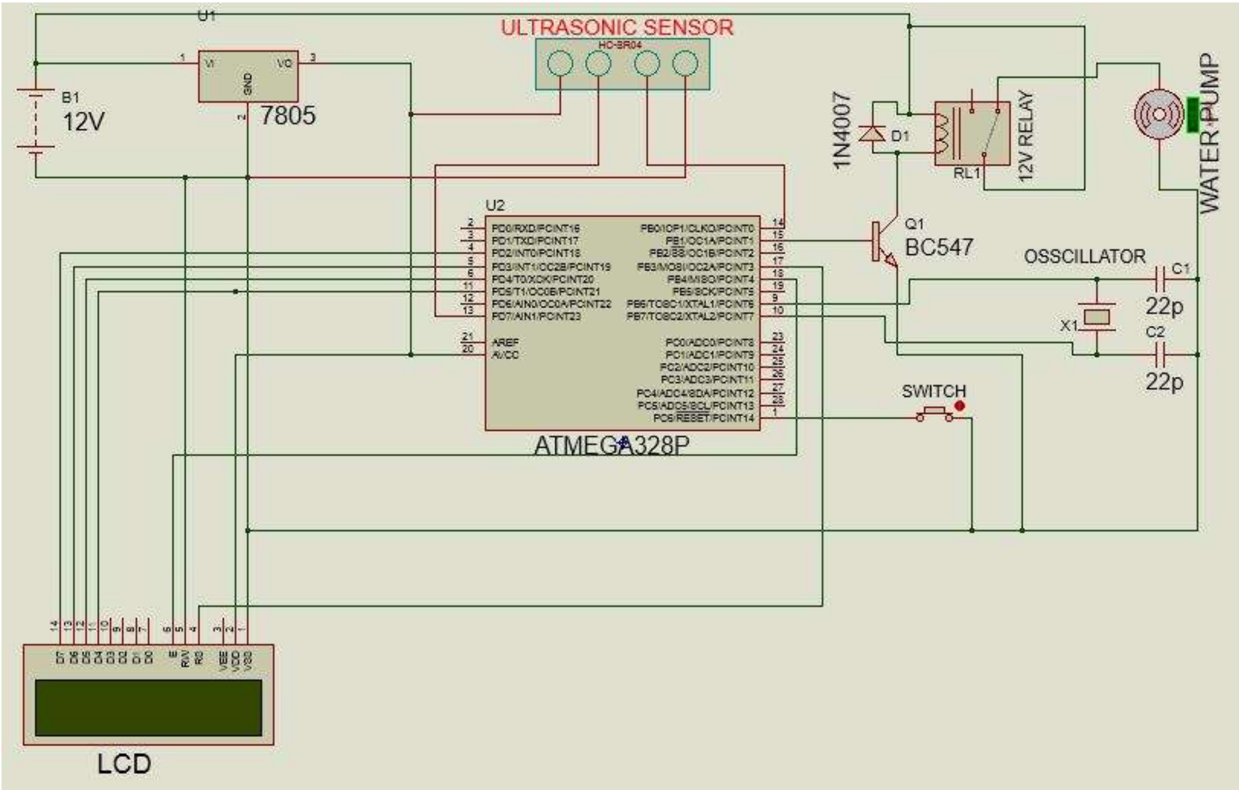

Fig. 4: Circuit diagram of the developed SONAR-based water level monitoring system

(*a*) (*b*) (*c*) (*d*)

Fig. 5: Plates showing construction and experimental setup of the developed SONAR-based water level monitoring system (a) control unit with 12V DC adapter (b) water pump head (c) assembly of water pump inside the reservoir (d) lifting of water from the reservoir to the tank

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