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Design and construction of wireless water level control system with motor protector

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Abstract

This research work presents the design and construction of a micro-controller-based wireless water level control system. The need to bring a solution to the problem of water shortage in various places by eliminating one of the culprit; waste of water during pumping and dispensing into overhead thanks, calls for an automated control system which puts into consideration, means of avoiding mechanical tears and wears that arises with the use of robes as water level sensor, through the incorporation of wireless water level sensor in place of robes in sensing the water level in the modeled tank. To solve this problem, circuit analysis and design, of the five main sub-circuitry units, this includes: power supply unit, logic and switching circuitry unit, relay unit, LCD display unit was carried out using ultrasonic water level sensor, AT89S51 microcontroller, LCD module relay circuitry system and a few discrete components. The design of the controller in this scenario is not just cost effective but helps in avoiding mechanical tears and wears that arises with the use of robes as water level sensor, by providing an improvement on existing water level control system through the incorporation of wireless water level sensor in place of robes in sensing the water level in the modeled tank.

Keywords: Water Level Sensor; Microcontroller; Wireless Module; Ultrasonic Sensor; Motor Protector

1. Introduction

Water scarcity is one of the major problems facing major cities of the world, with sustainability of its (water) availability being a dominant issue and wastage during pumping has been identified as a major culprit. This brings about the need for adequate control system (1).

Control system is very important in our day to day activities; the objective is to free human from erroneous, hazardous or boring repetitive tasks that can be done easily and more economical by automatic control devices. The concept of control system in this project work involves the use of ultrasonic range finder module and 8051 microcontroller in creating a barrier to wastage in order to not only provide more financial gains and energy saving, but also help the environment and water cycle which in turn ensures that we save water for our future.

The project is an electronic system designed to control water pumping machine using microcontroller to automate the process of water pumping in an over-head tank storage system and has the ability to detect the level of water in a tank, switch on/off the pump accordingly and display the status on an LCD screen. This water level controller can monitor and control water tanks up to 2m deep and the accuracy of measuring is as low as 1cm. Since no mechanical float

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switches or electrodes were used, there will not be any mechanical wearing or corrosion and this makes the system highly reliable, and of no corrosive effect on the hygienic level of the water in the modeled tank

Aim and objectives

This project is aimed at designing and implementing a micro-controller-based water level control system with pump protection. The objectives are as follows:

- To design the power supply unit
- To design main circuitry units
- To program the Micro-controller using C language
- To construct the circuitry units.

1.1. Significance of the project

This project work involves the use of microcontroller in creating a barrier to wastage which occur the most during pumping of water to over-head tanks, this does not only provide financial gains by protecting the motor pump from damage due to over-use and poor power supply but also help in saving human energy through automation of the control system. It provides an improvement on existing water level control system by incorporating wireless water level sensor in place of robes in sensing the water level in the modeled tank.

1.2. Problem definition

The need to bring a solution to the problem of water shortage in various places by eliminating one of the culprit; waste of water during pumping and dispensing into overhead thanks, calls for an automated control system which puts into consideration, means of avoiding mechanical tears and wears that arises with the use of robes as water level sensor, through the incorporation of wireless water level sensor in place of robes in sensing the water level in the modeled tank.

2. Methodology

To solve the problem stated above, the following methodology was used:

- The design of the power supply unit
    - Compute maximum power dissipation of the resistor network
    - Compute maximum power dissipation of the transistor BC548
    - Compute the driving power of the relay circuitry unit
- Design of main circuitry units
    - The Logic and Switching Circuitry Unit
    - Water Level Logic Control
    - The Relay Circuitry Unit
- Programming the Micro-controller using assembly language
    - Construction of the circuitry units
        - Water Level Logic Control
        - The Relay Circuitry Unit

3. Literature review

3.1. Introduction

This chapter is on review of literature. It discusses the fundamental concepts of the work which give the theoretical background of the work. The other part of the chapter, reviews the similar works done in the pass.

3.2. Review of fundamental concepts

The wireless water level control system designed in this project work is made of the following components: Microcontroller (AT89C51), Resistor, Transistors, Power Supply, Ultrasonic ranging module HC-RS04.

3.2.1. Microcontroller

Microcontroller (sometimes abbreviated **µC or MCU**) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications (2).

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems (2). The AT89C51 is an 8-bit microcontroller with four ports (32 I/O lines), two 16-bit timers/ counters, on-chip oscillator and clock circuitry. It has on chip ROM in the form of flash memory.

Microcontroller AT89C51 has 40 pins, 32 pins for parallel port. One port includes 8 pins, so 32 pins formed 4 parallel ports, each of them is recognized as port 0, port 1, port 2 and port 3. Number of each pin of parallel port starts from 0 through 7, first pin of port 0 is named P0.0 and the last pin of port 3 is named P3.7 (Ejiofor et.al, 2013). Pins diagram of AT89C51 is as shown in Figure 1

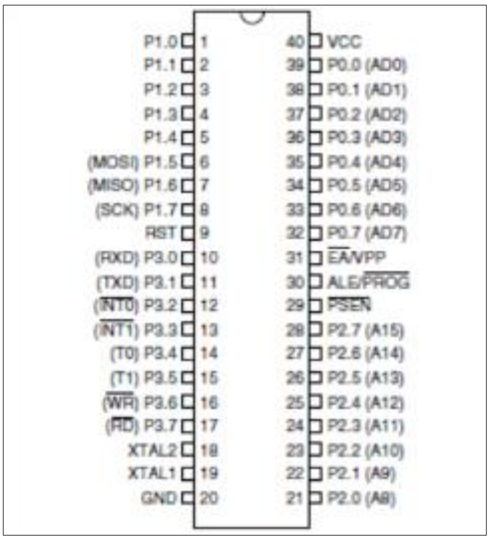

Figure 1 Pin Diagram of AT89C51 Microcontroller (Learn, 2009)

3.2.2. Pin Analysis of the AT89C51

Port 0; is a dual-purpose port on pins 32-39 of the 89C51 1C. In minimum – component designs, it is used as a general purpose I/O Port. For larger designs with external memory, it becomes a multiplexed address and data bus.

Port 1; is a dedicated I/O port on pins 1-8. The pins, designated as P1.0. P1.1. P1.2 etc. are available for interfacing to external devices as required. No alternate functions are as signed for Port 1 pins; thus they are used solely for interfacing to external devices.

Port 2; (pins 21-28) is a dual – purpose port serving as general purpose I/O, or as the high byte of the address bus for designs with external code memory or more than 256 bytes of external data memory.

Port 3; is a dual – purpose port on pins 10-17. As well as general – purpose I/O, these pins are multifunctional with each having an alternate purpose related to special features of the 89C51)

VCC; Pin 40 provides supply voltage to the chip. The voltage source is +5V.

GND; Pin 20 is the Ground pin.

XTAL1 and XTAL2; the 89C51 has an on-chip oscillator but requires an external clock to run it. Most often a quartz crystal oscillator is connected to inputs XTALI (pin 19) and XTAL2 (pin 18). The quartz crystal oscillator connected to

XTAL1 AND XTAL2 also needs two capacitors of 30 pF value. One side of each capacitor is connected to the ground as shown in the Figure 2 (Learn, 2009).

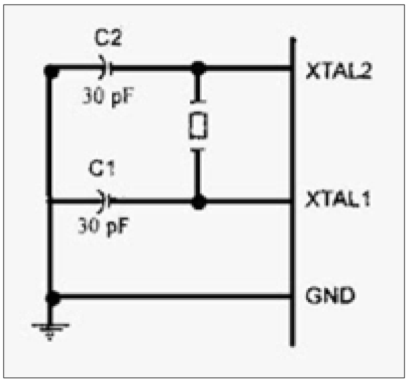

Figure 2 Circuit Connection of External Crystal Oscillator with Capacitors (Learn, 2009)

EA: The 8051 family members, such as the 8751, 89C51, or DS5000. All come with on-chip ROM to store programs. In such cases, the EA pin is connected to VCC for giving power to save and erase program from the memory.

RST (RESET): The RST input on pin 9 is the master rest for the 8051. When this signal is brought high for a least two machine cycles, the 8051 internal registers are loaded with appropriate values for an orderly system start-up. For normal operation, RST is low. Figure 3 shows permanent connections of Reset Pin.

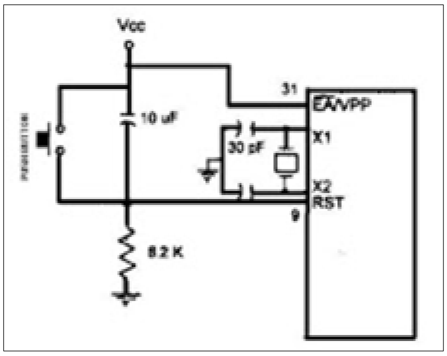

Figure 3 Permanent Connections of Reset Pin

3.2.3. Power Supply Unit

Most of the electronic devices and circuits require a DC source for their operation, but for reasons associated with economics of generation and transmission, the electric power available is usually the A.C supply. Hence the need for conversion from sinusoidally varying A.C mains supply to D.C. this process of converting A.C supply to D.C is known as rectification and accomplished with the help of: Transformer, Rectifier, Filter, Voltage regulator circuit. These elements all together constitute the DC power supply unit as shown in Figure 4

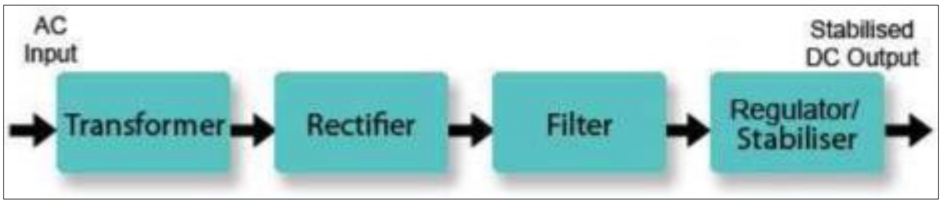

Figure 4 Elements of Direct Current Power Supply Unit (Learn, 2013)

3.2.4. Transformer

In a basic power supply the input power transformer has its primary winding connected to the mains (line) supply. A secondary winding, electro-magnetically coupled but electrically isolated from the primary is used to obtain an AC voltage of suitable amplitude, and after further processing by the Power Supply Unit, to drive the electronics circuit it is to supply (3). The transformer stage must be able to supply the current needed. If too small a transformer is used, it is likely that the power supply's ability to maintain full output voltage at full output current will be impaired. With too small a transformer, the losses will increase dramatically as full load is placed on the transformer. Figure 5 shows a typical transformer unit of a power supply.

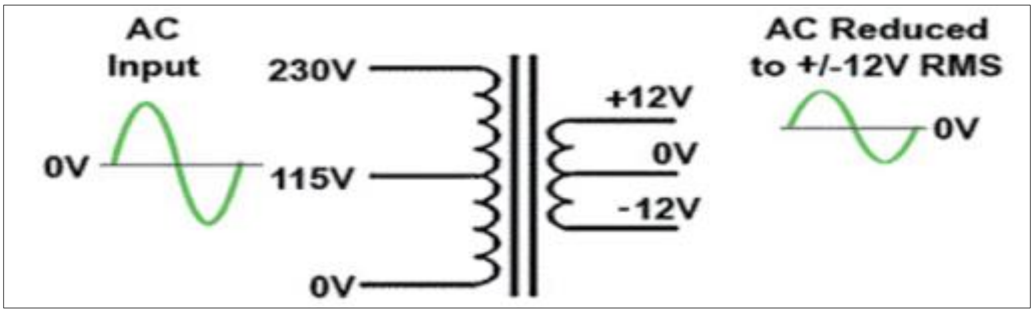

Figure 5 Typical Transformer Unit of the Power Supply Unit (3)

3.2.5. Full Wave Bridge Rectifier

The full wave bridge rectifier uses four diodes arranged in a bridge circuit as shown in Figure 6 to give full wave rectification without the need for a center-tapped transformer. An additional advantage is that, as two diodes (effectively in series) are conducting at any one time, the diodes need only half the reverse breakdown voltage capability of diodes (1) (3) used for half and conventional full wave rectification. The bridge rectifier can be built from separate diodes or a combined bridge rectifier can be used.

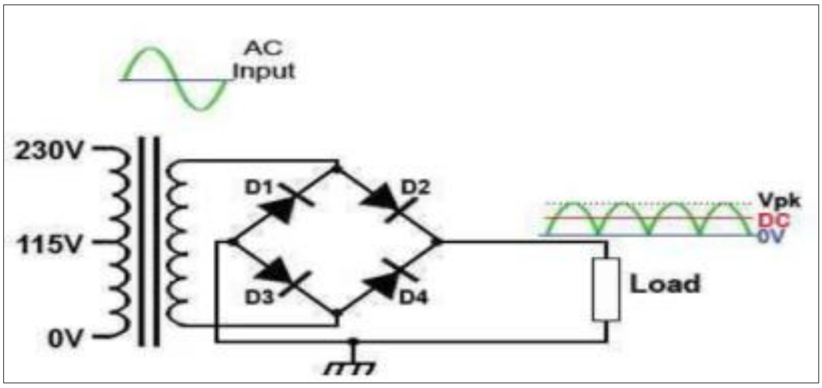

Figure 6 Circuit Diagram of Full Bridge Rectifier (4)

During the positive input cycle supply voltage D1 and D2, connection node is positive. D2 and D4 are forward biased but D1 and D3 reversed biased, thus current flows through D2 and D3 node. During the negative cycle supply voltage, D1 and D2 node is negative while D3 and D4 node is positive. D2 and D4 are reversed biased but D1 and D3, forward biased, thus current still flows through D2 and D3 node (3).

3.2.6. Filter

The output of a rectifier sub unit of the power supply unit is pulsating, it has a DC value and some AC components called ripples. This type of output is not useful for driving some sophisticated circuits and devices. The circuit that converts the pulsating output from a rectifier into a very steady DC level is known as filter. An electrolytic capacitor is usually used as a reservoir capacitor; it's so called (reservoir capacitor) because it acts as a temporary storage for the power supply output current. The rectifier diode supplies current to charge a reservoir capacitor on each cycle of the input wave. The reservoir capacitor is usually of several hundred or even a thousand or more microfarads, especially in mains frequency PSUs. This very large value of capacitance is required because the reservoir capacitor, when charged, must provide enough DC to maintain a steady PSU output in the absence of an input current; i.e. during the gaps between the positive half cycles when the rectifier is not conducting.

3.2.7. Regulator

A regulator is an electronic circuit which is capable of providing relatively close to constant DC output voltage irrespective of the variations in load or input voltage. It is essential for voltage sensitive electronic system.

A measure of the regulation of a power supply is called its voltage regulation and it is the change in voltage from no load condition to full load condition, given by the formula:

$$Regulation = \frac{V_{max} - V_{min} \times 100}{V_{max}} \dots \dots \dots \dots \dots (2)$$

The regulator aims at reducing the value above to the minimum possible (Theraja BL, 1997).

There are different types of regulator in use, but the LM7805 (the last two digits represent the output voltage of the regulator).

Capacitors

This is a physical device which is capable of storing energy by virtues of a voltage existing across it plates. The voltage applied across the capacitor sets up an electric field within it and the energy is stored in the electric field. Capacitance is a measure of a capacitor's ability to store electric charge when its plates are at different potentials and is measured in farads, a farad can therefore be said to be the capacitance of a capacitor between the plates of which there appears a potential difference of 1 volt when it is charged by 1 coulomb of electricity (5).

Therefore, for a given capacitor the following expression holds,

$$\frac{charge\ on\ Capacitor\ (coulombs)}{potential\ difference\ across\ Capacitors\ (volt)} \dots \dots 2.1$$

$$\frac{Q}{V} = C \dots \dots . .2.2$$

Hence,

$$Q = CV \dots . .2.3$$

A capacitor offers low impedance to AC but very high impedance to DC. So capacitors are used to couple alternating voltage from one circuit to another circuit at the same time used in blocking dc voltage from reaching the next circuit, it can also be used as a bypass capacitor where it passes the ac through it without letting the dc go through the circuit across which it is connected. A capacitor forms a tuned circuit in series or in parallel with an inductor.

3.2.8. Resistor

This is a discrete component that is used majorly in regulating the amount of current that flows through a particular branch of a circuit, this depends largely on the value of the resistor and the potential difference concerned. Resistors are generally classified as either fixed or variable. Selection of a resistor for a particular circuit is based not based on the resistance value alone but also on the tolerance and the electric power ratings of the resistor which are very vital. The tolerance value of the resistor denotes how close it is to the actual rated resistance value the symbolic representation of resistor is as shown in figure 7 (6).

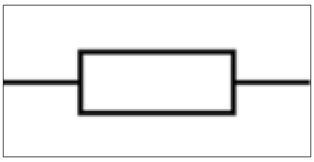

Figure 7 Symbolic Representation of Resistor (3)

3.2.9. Transistor

A transistor is a semiconductor device used in amplifying and switching electronic signals and electric power, voltage stabilization, signal modulation and many other functions. It allows a variable current, from an external source, to flow between two of its terminals depending on the smaller voltage or current applied to a third terminal. Transistors are made either as separate components or as part of an integrated circuit. Millions of individual transistors are known as discrete (7).

The essential usefulness of a transistor comes from its ability to use a small signal applied between one pair of its terminals to control a much larger signal at another pair of terminals. This property is called gain. It can produce a stronger output signal, a voltage or current, which is proportional to a weaker input signal; that is, it can act as an amplifier (8). Alternatively, the transistor can be used to turn current on or off in a circuit as an electrically controlled switch, where the amount of current is determined by other circuit element. Used in this project work is the NPN type of transistor, the symbolic representation of NPN transistor is shown in figure 8.

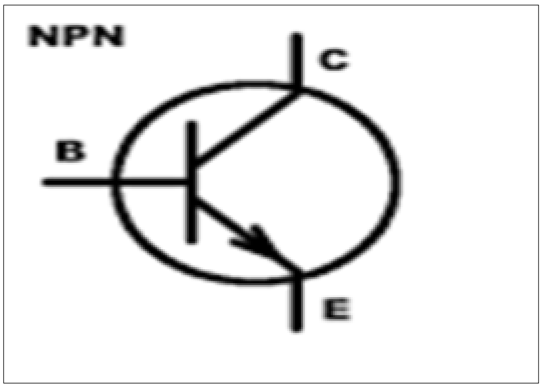

Figure 8 Symbolic Representation of Transistor (3)

3.2.10. Ultrasonic Range Module (HC-SR04)

The HC-SR04 is an ultrasonic sensor which makes use of sonar to determine distance to an object. It offers excellent non-contact range detection with high accuracy and stable readings from 2cm to 400cm or 1feet to13feet, the complete module include transmitter, receiver and control circuitry system. The transmitter emits an 8 bursts of a directional 40 KHz ultrasonic wave when triggered and starts a timer. Ultrasonic pulses travel outward until they encounter an object; the object causes the wave to be reflected back towards the range module unit. The ultrasonic receiver would detect the reflected wave and stop the timer (9). The velocity of the ultrasonic burst is 340m/sec. in air. Based on the number of counts by the timer, the distance can be calculated between the object and transmitter using the following:

$$D = C X T \quad \ldots\ldots\ldots..2.4$$

Which is known as the time/rate/distance measurement formula where

D = measured distance,
C= propagation velocity (Rate) in air (speed of sound)
T= time.

In this application T is divided by 2 as T is double the time value from transmitter to object back to receiver. The measured distance is proportional to the echo pulse width (10). The ultrasonic range module is as shown in figure 2.9

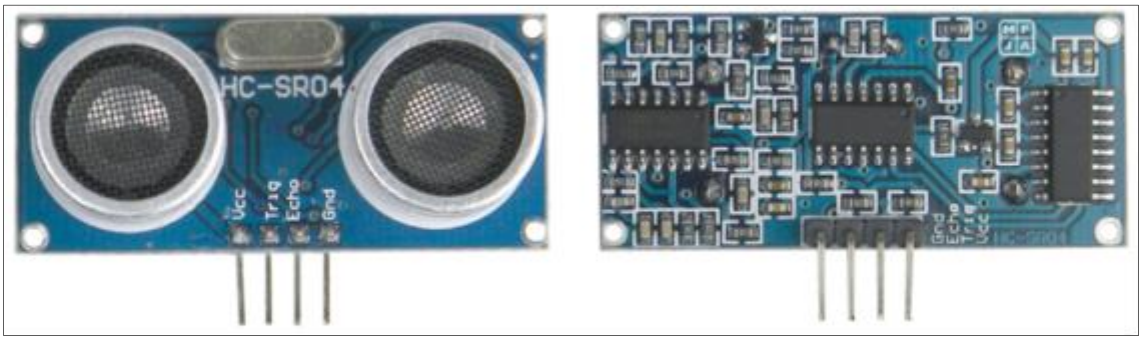

Figure 9 Front and Back View of the Ultrasonic Range Module

3.3. Review of similar work

Presented in this section of the project work, is the review of the various related works and the improvement on these works, which is the major focus of this project work.

Mat L, (2003), designed and implemented measurement system which was used in measuring the level of molten iron liquid inside a tank. The design is based on a torque-controlled drive where the level of the liquid in the tank was measured using a suspended float. The float is lowered from the disc drilled around its perimeter and a lightweight rope, using torque sensitive electric drive and rotary encoder circuit to produce the pulse that is used to calculate the level of the liquid inside a tank. When the float makes contact with the liquid level surface, the torque reduces and the number of revolutions made by the disc is counted and the level is calculated using an appropriate formula and displayed. Despite the achievement of this system, it is only concerned with measuring the level of liquid using torque-controller drive, not how to automate a process which is of utmost concern and benefit.

Khaled et al, (2010), introduced the notion of water level monitoring and management within the context of electrical conductivity of the water. The authors motivated by the technological affordances of mobile devices and the believe that water level management approach would help in reducing the home power consumption and as well as water overflow; proposed a web and cellular based monitoring service protocol to determine and senses water level globally. The research result was a flexible, economical and easy configurable system designed on a low cost PIC16F84A microcontroller, though the researcher was able to achieve a degree of automation by using microcontrollers, but the restriction to mobile communication system as a means of alerting is a great limitation, because the researcher does not consider area where there are no GSM services (12).

Uzoigwe et al, (2011), proposed a system that automatically detects the level of water in a reservoir (storage tank) at a preset level and initializes information to the users in case of low water level. The functionality of this sensor depends basically on the electrical conductivity of water (probes) which varies, depending on the level of its impurity (13). It is of this note that the electrical conductivity of saline (35g/kg at 25oC) is 4.8S.m-1, while the electrical conductivity of high quality drinking water ranges between 0.0005 – 0.05 S.m-1, and that of deionized water is 5.5 x 10-6 S.m-1. In this sensor system, an actuator that operates on the basic principle of an astable multivibrator, operating with a duty cycle of 50.25% with an output frequency of 3.256Hz is required to operate on the water level detection. Hence, a continuous train of rectangular pulses whose band width is 0.154s at a period of 0.306s was designed and developed for the system. The device is powered by a dual power source for redundancy sake, reliability and maximum efficiency. Despite the analysis details considered by the researcher, the proposed design does not address how the issue of automation of the pumping control system will be achieved, it (proposed design) only detect water level by using the electrical conductivity of water.

Muhammed *et al.*, (2015). Designed and implemented water level control system using arduino in order to automate the process of water pumping in a tank by detecting the water level, switching on or off the pump accordingly and display the status on an LCD screen. The system monitors the level of water in the sump tank (source tank). If the level inside the sump tank is low, the pump will not be switched ON and this protects the motor from dry running. A beep sound is generated when the level in the sump tank is low or if there is any fault with the sensors. Though the designed system provide some level of automation, but the use of metallic robes in the modeled tank as sensor, will bring about mechanical wearing or corrosion and this makes the system highly unreliable with time.

Having reviewed various related work, it was found that most water level detector designed do not put into consideration the issue of mechanical wearing or corrosion which arise as a result of using mechanical float switches or electrodes as water level sensor. This research has successfully provided an improvement on existing water level controllers by incorporating wireless sensor in monitoring water level by using ultrasonic ranging module, this makes the system highly reliable, and of no corrosive effect on the hygienic level of the water in the modeled tank.

4. Design and analysis

4.1. Introduction

This chapter gives the detail procedure in the design and analysis of the wireless water level control system. It describes the design of the various circuitry units that make up the automatic wireless sensor based water level control system.

4.2. General circuit diagram and operation

Figure 10 shows the circuit of the wireless water level controller using ultra-sonic water level sensor. It comprises of ultrasonic water level sensor, AT89S51 microcontroller, LCD module relay circuitry system and a few discrete components

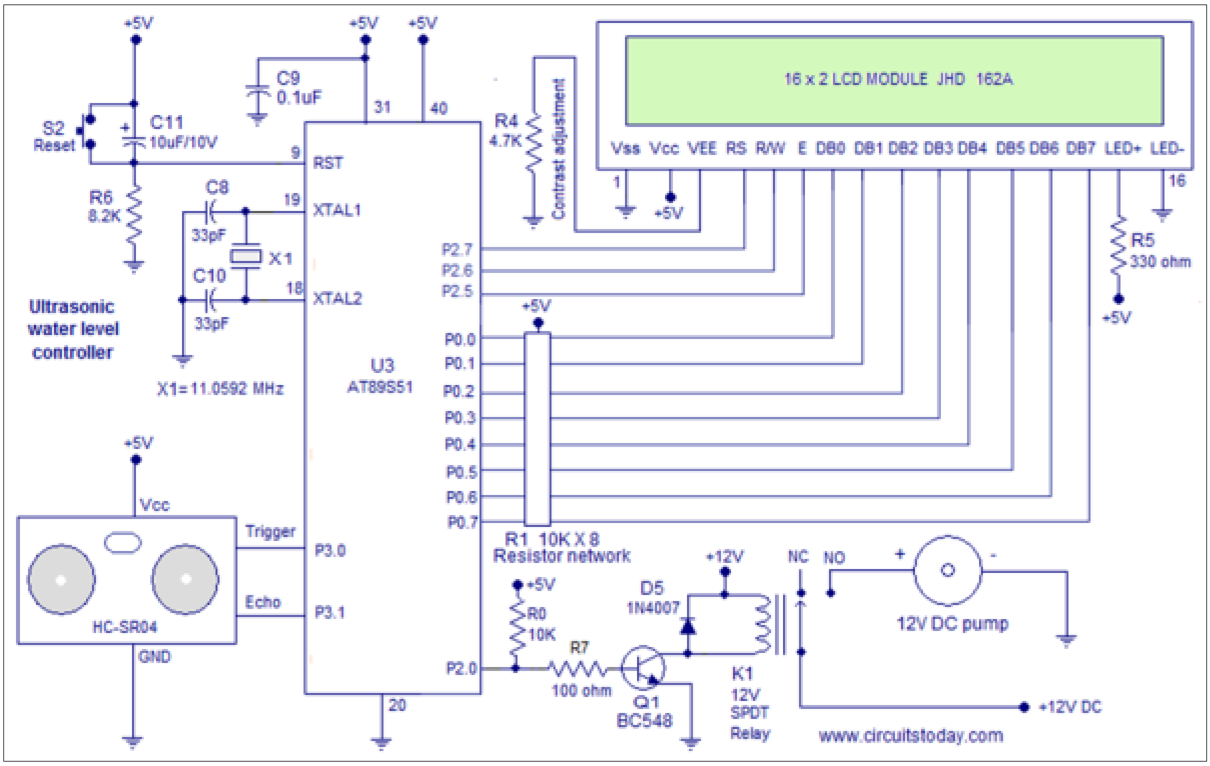

Figure 10 Circuit diagram of Wireless Water Level Control System

The AT89S51 is an 8 bit microcontroller with four ports designated as P1, P2, P3, P0. All these ports are 8 bit bidirectional ports i.e. they can both be used as input and output ports. Eight pins of port-0 and three pins of port-2 are interfaced with data and control lines of the LCD module, pin-9 connected to the reset switch.

The Micro-controller has an on-board oscillator but requires an external clock to run it. a quartz crystal oscillator is connected to inputs XTAL 1 (pin 19) and XTAL2 (pin 18). The quartz crystal oscillator connected to XTAL1 AND XTAL2 also needs two capacitors of 33 pF value. One side of each capacitor is connected to the ground

The Ultrasonic water level sensor was used in monitoring the water level through the use of two different signals: which are echo and trigger signals. The combination of echo signal and received (reflected wave) signal will be used in measuring the water level based on the distance of the echo signal and received signal reflected back by the water body, the controller takes decision as to when to switch on and off the pump respectively.

The relay circuitry unit was used in controlling the load (Pump) by a low power signal, with transistor Q1 (BC548) used as switching unit. The relay circuitry unit will provide complete electrical isolation between the controlling circuitry unit and the controlled circuitry unit (Pump).

4.3. Design of the main circuitry units

For easy circuit analysis and design, the circuit is divided into five main circuitry units, which includes:

- Power supply unit
- Logic and switching circuitry unit
- Relay unit
- LCD display unit

Below is the block diagram of the whole circuitry units

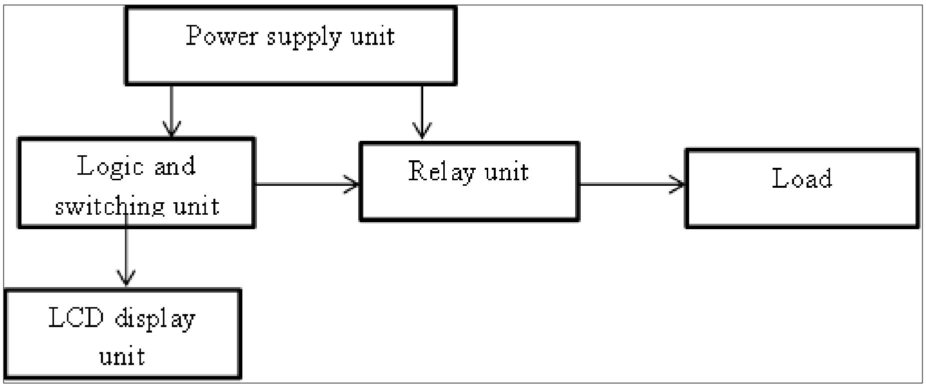

Figure 11 Block Diagram of the Water Level Control System with Motor Protector

4.3.1. The design of the power supply unit

The following were considered in designing the power supply unit of the project:

Maximum power dissipation of the resistor network

$$10k\Omega \text{ x } 8 = 80\text{k} \quad \ldots\ldots\ldots\ldots\ldots\ 3.1$$

Estimated voltage across resistors Vc = 5v,

$$Current\ through\ resistors\ =\ 5/80000\ =\ 0.0000625Amps \quad \ldots\ldots\ldots\ 3.2$$

Therefore the power consumed by this resistor network = Vc x I

$$5\ x\ 0.0000625\ =\ 0.3125mW \quad \ldots\ldots\ldots\ 3.3$$

$$Power\ dissipation\ of\ R4\ =\ 0.001064\ x\ 5\ =\ 5.319mW \quad \ldots\ldots\ldots 3.4$$

$$Power\ dissipation\ of\ R2 =\ 0.0005\ x\ 5 = 2.5mW \quad \ldots\ldots\ldots\ 3.5$$

$$Power\ dissipation\ of\ R5 = 0.0152\ x\ 5 = 75.7mW \quad \ldots\ldots\ldots\ldots\ 3.6$$

$$Power\ dissipation\ of\ R6 = 0.000609\ x\ 5 = 3.048mW \quad \ldots\ldots\ldots\ldots\ 3.7$$

$$Power\ dissipation\ of\ R7 = 0.05x\ 5 = 250mW \quad \ldots\ldots\ldots\ 3.8$$

The maximum power dissipation of the transistor BC548= 500mW

The driving power of the relay: since the relay impedance (Z) = 400ohms, a maximum estimated voltage of 12V (12 volts supply) applied across it.

Therefore maximum current through the relay = 12/400 = 0.003Amps, then

The driving power of the relay = I x Voltage supply = 12 x 0.003 = 0.36mW

Therefore total estimated power consumption of the circuit

= 336.88mW + 500mW + 0.36mW + 10.25mW = 847.40mW ……………. 3.9

By choosing the transformer (240/12) secondary Voltage of 12V, the estimated current rating can be obtained as follows:

If P = IV, then I = P / V = 847.49/12 = 70.61.mAmps ……………. 3.10

By assuming a maximum current allowance of 10%, overall current will be

70.49 + (0.1 x 377.55) = 77.67mAmps ……………… 3.11

Therefore having considered the percentage of current allowance, the overall power rating will be = 77.67 x 12 = 922.14mW …………….. 3.12

Therefore the transformer current rating = 922.14/12 = 77.67mAmps

Hence the estimated minimum rating of the transformer is as follows:

I. Rated voltages (i.e. primary and secondary) 240V / 12V
II. Rated minimum current = 415.30mAmps

Therefore a transformer with the maximum rating of 500mAmps was chosen.

4.3.2. The voltage regulator

The voltage regulator is used in supplying a regulated voltage of the value 5v in powering the sensitive control components of the circuit; to achieve this, regulator 7805 of the family 78xx series was chosen.

4.3.3. The Logic and Switching Circuitry Unit

The logic unit of the circuit provides the necessary control system of the project. To achieve the logic sub-circuitry unit of the water level control system, microcontroller AT89S51 was used

4.3.4. Water Level Logic Control

In designing this logic control circuitry system which helps in achieving automatic water level control, two logic states were employed with each representing the two different levels of water sensor in the modeled over-head tank. This water levels as defined, is as follows:

- Full or maximum level
- Low level

Let

- A = full or maximum level
- B = Low level

With zero (0) indicating empty and one (1) representing the presence of water at that level, the result (i.e. the output) is such that, the pumping machine will be made to turn on only when all the state is empty (0) and turned off when all the state not empty (1).

Using two (2) bit in representing the three states will give $2^2 = 4$ therefore the truth table is as follows:

Table 1 Truth Table of the Water Level Control System

Output			
B	**A**	**MOTOR ON**	**MOTOR OFF**
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

The results obtained from the truth table indicates that for the on state to be achieved, the microcontroller needs to be configured as a NAND gate and as AND gate to obtain the off state of the pumping machine respectively at the design state.

4.3.5. The Relay Circuitry Unit

The relay circuitry unit is used in controlling the load circuitry unit by a low power signal, with complete electrical isolation between the controlling circuitry unit and the controlled circuitry unit.

In designing the relay circuitry units the following considerations were made

- From the datasheet, the voltage across the coil is 12V and the coil resistance in ohms is 400ohms
- Using transistor SL100 as a switch, the current that will be transferred to the relay circuitry by the transistor can be obtained as follows:

As obtained from the datasheet maximum collector current $I_c = 0.5A$

The sourcing current from the output of the $I_c = 56.5mA$

Current gain $\beta = 50$

Hence using the transistor current relationship:

$$I_c = \beta \times I_B$$

$$I_B = I_c / \beta$$

$$= \frac{56.6 \times 10^{-3}}{50} = 1.13mA$$

However the maximum current the relay may be able to withstand is given by

$$I = \frac{V}{R}$$

Where V (voltage across the relay) =12V,

R (relay coil resistance) = 400Ω

$$\text{Therefore } I = \frac{12}{400} = 30\text{mA}$$

Hence the calculated maximum current the relay coil can withstand I_{max} = 30mA, thus having a design current of 1.13mA is within the coil limit.

4.4. Programing the Microcontroller using C Language

P3.0 of the microcontroller is used for triggering the HC-SR04 ultrasonic module and P3.1 of the microcontroller is used for receiving the echo signal. Both timers of the 8051 microcontroller are used in this project. The ultrasonic module provides 40 kHz of directional ultrasonic wave when the microcontroller provides trigger signal through P3.0, until it encounters water in the modeled tank. The microcontroller waits for the echo signal at the echo pin of the module. Echo pin of the module and P3.1 of the microcontroller are connected.

Whenever a valid echo signal is received at this pin Timer1 is started. The timer counts from 200D to 255D (55 counts) and then it starts over. But after every roll over (count of 55) the echo pin is checked again and the timer is restarted if there is any echo signal present. For each roll over, the accumulator is incremented and this cycle is repeated until the echo vanishes.

The program is set to switch ON the load (pump, modeled using electric-bulb) when the level goes below --- (low level) from top and to switch OFF pump when the level rises to ---- (high level) from top. The switch ON condition is identified by subtracting (highest level) D from the accumulator value. If the carry flag is not set, it means that the water level is below (highest level in cm) from top and the motor is switched ON.

If carry flag is not set, OFF subroutine is called. In this subroutine, (LOWEST ALLOWABLE LEVEL WITOUTH cm) D is subtracted from the value stored in accumulator and the status of carry flag is checked using JNC instruction. If carry flag is not set, it means that the level is below (LOWEST ALLOWABLE LEVEL) cm from top and the pump remains ON. If the carry flag is set it means the level is above 5cm from top and the pump is switched OFF.

The pump is controlled through P2.0 of the microcontroller. If this pin is high, that means the pump is ON and status message" Motor ON" is displayed on the LCD. If the P2.0 pin is low that means the pump is OFF and the status message "Motor OFF" is displayed on the LCD screen. The source is provided in appendix A

5. Construction and results

5.1. Introduction

This chapter provides the procedure followed in constructing the circuit of the wireless sensor based water level control system and the results obtained from the testing carried out.

5.2. Temporary construction

The electronic components for the wireless sensor based water level control system was first of all mounted on the bread board, after powering it, the circuit works according to expectation before it was transferred to the vero board for permanent construction (soldering). The diagram in Figure 12 shows the temporary construction of the automatic water level control system.

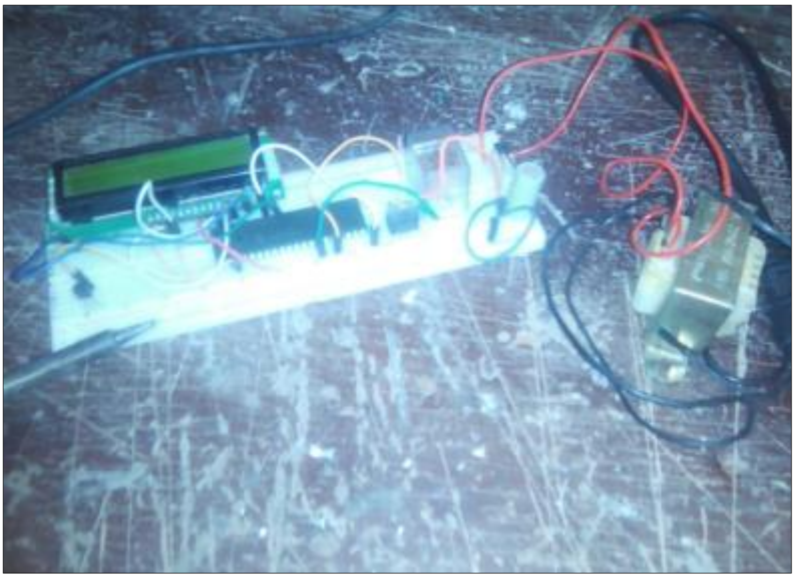

Figure 12 Temporary Construction of Water Level Control System Using Breadboard

The Trigger pin of the ultrasonic module was connected to P3.0 of the microcontroller and the echo pin of the module connected to P3.1 of the microcontroller. Data lines of the LCD module were interfaced through Port0 of the microcontroller. The control lines RS, RW and E of the LCD module were connected to P2.7, P2.6 and P2.5 pins of the microcontroller respectively. The load was controlled using Port 2.0 of the microcontroller. The load was modelled with the use of electric bulb.

Here the ultrasonic ranging module is placed on top of the tank facing the water surface. The water reflects the ultrasonic pulses emitted by the module. The module picks the reflected waves and also measures the time lag. The distance between the water surface and the sensor is calculated from the collected data and the module outputs a pulse whose width is proportional to the distance. The microcontroller reads the width of this output pulse and does necessary calculation on it to get the distance, with the water level being measured from top to bottom unlike most sensors which measure the level from bottom to top. This is done to make this device suitable for a wide range of depths. Since the sensor was placed on top of the tank we need to subtract the distance from the sensor to the water surface from the total depth of the tank in order get the level of water from bottom to top.

5.3. Permanent construction

After certifying the functionality of the circuit using the breadboard, the circuit was transferred onto a Vero board where the components were soldered together. Mounting of components on Vero board for permanent construction was done in stages putting into consideration the various unit of the entire circuitry system.

The power supply unit was connected and tested to ensure that the output conforms to the desired value. It (power supply) was constructed using 240V step down transformer and three different bridge rectifiers, with each having its own filtering circuit, which was mounted on one edge of the Vero board, with its positive terminals soldered to different rails of the board. Figure 13 shows the permanent construction using Vero board.

Figure 13 Permanent Construction of the Wireless Water Level Control System

5.4. Results presentation and discussion

After construction, tests were carried out on the various stages of the entire circuitry with the help of oscilloscope, multi-meter and its probes. This section provides the description of the testing carried out and the result obtained in the following sub-circuitry units of the designed control system:

- Power circuitry unit
- Logic level and switching unit.

5.4.1. Power Circuitry Unit

The power sub-circuitry unit was tested with the aid Volt-meter, with an output of DC main supply of 5V and 9V voltage value to the logic and switching units and relay units respectively.

5.4.2. Testing of the Logic and Switching Unit

Testing of the logic and switching unit involves testing of the water level control system units that performs the necessary logic control system of the project. In accordance with the design specification, the water level control system was designed, employing two different logic states, with each representing two different water levels of water sensor in the modeled tank.

The various water level defined, was tested for, separately in order to ascertain the functionality of the different logic states.

As shown figure 14, the LCD was able to display the response of the control system, when water level in the modeled tank goes below --- (the indicated high level) switches ON the load which is modeled using electric bulb. This represents the low state of the water level control system. At this state of the control system, the microcontroller automatically turns ON the pumping machine without human intervention.

Figure 14 Testing of High Logic State of the Water Level Control System

As shown in figure 15, the LCD was able to display the response of the control system, when water level in the modeled tank goes above **---** (the indicated high level) switches ON the load which is modeled using electric bulb. This represents the High state of the water level control system. At this state of the control system, the microcontroller automatically turns OFF the pumping machine without human intervention.

Figure 15 Testing of the Low State of the Water Level Control System

6. Conclusion

The result obtained after the construction of the automatic water level control system with motor protector shows that the design objective of the project work was achieved. The design of the controller in this scenario is not just cost effective but helps in avoiding mechanical tears and wears that arises with the use of robes as water level sensor, by providing an improvement on existing water level control system through the incorporation of wireless water level sensor in place of robes in sensing the water level in the modeled tank.

Recommendation

Though this work has improved on the related works reviewed, but much can still be done to improve on the achievement of this project work. The aspect of web-based control system is an aspect that can be looked into in subsequent construction work

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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