**Sudan University of**

**Science &Technology**

**College of Graduate Studies**

**التحكم فى مضخة ماء بواسطة المتحكم الدقيق وحساسات مستوى الماء**

# Water Pump Control Based on Microcontroller and Water Level Sensors

A Thesis Submitted as a Partial Fulfillment of the requirements
for the degree of master in Mechatronic Engineering

**By**

**HOZUIFA ABD ELKARIEM YAGOB BAKHEET**

**Supervisor**

**Dr. ZAKARIA ANWAR ZAKARIA**

**June 2016**

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# الآية

**قال تعالى :**

(آمَنَ الرَّسُولُ بِمَا أُنزِلَ إِلَيْهِ مِن رَّبِّهِ وَالْمُؤْمِنُونَ كُلٌّ آمَنَ بِاللّهِ وَمَلآئِكَتِهِ وَكُتُبِهِ وَرُسُلِهِ لاَ نُفَرِّقُ بَيْنَ أَحَدٍ مِّن رُّسُلِهِ وَقَالُواْ سَمِعْنَا وَأَطَعْنَا غُفْرَانَكَ رَبَّنَا وَإِلَيْكَ الْمَصِيرُ{285} لاَ يُكَلِّفُ اللّهُ نَفْساً إِلاَّ وُسْعَهَا لَهَا مَا كَسَبَتْ وَعَلَيْهَا مَا اكْتَسَبَتْ رَبَّنَا لاَ تُؤَاخِذْنَا إِن نَّسِينَا أَوْ أَخْطَأْنَا رَبَّنَا وَلاَ تَحْمِلْ عَلَيْنَا إِصْراً كَمَا حَمَلْتَهُ عَلَى الَّذِينَ مِن قَبْلِنَا رَبَّنَا وَلاَ تُحَمِّلْنَا مَا لاَ طَاقَةَ لَنَا بِهِ وَاعْفُ عَنَّا وَاغْفِرْ لَنَا وَارْحَمْنَا أَنتَ مَوْلاَنَا فَانصُرْنَا عَلَى الْقَوْمِ الْكَافِرِينَ{286})

صدق الله العظيم البقرة (285، 286)

# Dedication

I dedicate my dissertation work to my family, my friends, and to all who have supported me throughout the implementation of this research.

# Acknowledgement

Praise be to God who helped me to complete this study, then I would like to extend my gratitude to my supervisor Dr. Zakaria Anwar Zakaria, for his constant guidance and the encouragement throughout the endeavor, his support, motivation and innovative ideas that helped me tremendously whenever I met a roadblock.

# Abstract

Pump control system is designed to monitor the level of water in the overhead and underground tank through water level sensors, and run the pump only when the water level in the underground tank is up to the position of the water level sensor as long as the overhead tank is empty and automatically turn off the pump after the fullness of the overhead tank where its has two water level sensors. The circuit is made up of (microcontroller Atmega16), three sensors for water level (Float Switch), display (LCD 16), Driver (ULN2003A), alarm (buzzer), three light emitting diodes (LED) and Relay (5 V).Where the microcontroller keeps track of the exact level of water in the tanks and display it in the LCD display as well as running pump or shutdown it through the driver and relay, And according to the water level it is turned the suitable LED, and when the water level in the underground tank is less than the sensor level the buzzer is turned on.

# المستخلص

تم تصميم نظام التحكم فى المضخة ليقوم بعملية مراقبة مستوى الماء فى الخزانين العلوى والارضى عن طريق حساسات مستوى الماء وتشغيل المضخة فقط عندما يكون مستوى الماء فى الخزان الارضى يصل لموضع حساس الماء طالما الخزان العلوى فارغاً وإيقاف المضخة تلقائياً بعد امتلاء الخزان العلوى حيث يوجد به حساسان لمستوى الماء،وتتكون الدائرة من متحكم دقيق( Microcontroller Atmega16 )، ثلاث حساسات لمستوى الماء (Float Switch) شاشة عرض(LCD16) ،القائد(ULN2003A)، صفارة إنذار(Buzzer)، ثلاث صمامات ثنائية باعثة للضوء(LED) والمرحل (5V).حيث يقوم المتحكم الدقيق بتتبع مستوى الماء فى الخزانين وعرضه فى الشاشة وكذلك عملية تشغيل المضخة وإيقافها عن طريق القائد والمرحل.ووفقاً لمستوى الماء يتم تشغيل الصمام الثنائى الباعث للضوء ذو اللون المناسب وعندما يكون مستوى الماء فى الخزان الارضى أقل من موضع الحساس يتم تشغيل صفارة الانذار.

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# List of Abbreviations

| | |
|---|---|
| LED | Light Emit Diode |
| IC | Integrated Circuit |
| PAL | Programmable Array Logic |
| PLA | Programmable Logic Array |
| FPGA | Field Programmable Gate Array |
| I/O | Input /Output |
| VHSIC | Very High Speed Integrated Circuit |
| VHDL | VHSIC Hardware Description Language |
| ASIC | Application Specific Integrated Circuit |
| PLC | Programmable Logic controller |
| NEMA | National Electrical Manufacturers Association |
| RAM | Random Access Memory |
| ROM | Read Only Memory |
| C | High Level Language |
| PC | Personal Computer |
| R&D | Research and Development |
| DSP | Digital Signal Processing |
| VDU | Visual Display Unit |
| CPU | Central Process Unit |
| EEPROM | Electrically Erasable Programmable Read Only Memory |
| EPROM | Erasable Programmable Read Only Memory |
| PROM | Programmable Read Only Memory |
| UV | Ultra Volatile |
| ADC | Analog-to-Digital Converter |
| ALU | Arithmetic Logic Unit |
| CISC | Complex Instruction Set Computer |
| RISC | Reduced Instruction Set Computer |

| | |
|---|---|
| SISC | Specific Instruction Set Computer |
| IDE | Integrated Development Environment |
| CAN | Controller Area Network |
| USB | Universal Serial Bus |
| RF | Radio Frequency |
| SRAM | Static Read Access Memory |
| USART | Universal Synchronous Asynchronous Receiver Transmitter |
| SPI | Serial Peripheral Interface |
| JTAG | Joint Test Action Group |
| VCR | Video Cassette Recorder |
| $H_2S$ | Ahydrogen Sulfide |
| FMCW | Frequency Modulated Continuous Wave |
| COM | Common |
| NC | Normally Closed |
| NO | Normally Open |
| DC | Direct Current |
| AC | Alternating Current |
| SPST | Single pole, single throw |
| SPDT | Single pole, double throw |
| DPDT | Double Pole, Double Throw |
| LCD | Liquid Crystal Display |
| MDS | Micro-controller Development Systems |
| BASIC | Beginners All-purpose Symbolic Instruction Code |

# List of Symbols

| | |
|---|---|
| $h$ | Fluid level |
| $h_{max}$ | Sensor level |
| $D$ | Tank diameter |
| $d$ | Sensor diameter |
| $C_1$ | Air capacitive |
| $C_2$ | Fluid capacitive |
| tf | Time of travel |
| sensor L | Sensor at the low level of the overhead tank |
| sensor H | Sensor at the high level of the overhead tank |
| sensor U | Sensor at the low level of the underground tank |

# List of Appendices

# CHAPTER ONE

# Introduction

## 1.1 Background

Throughout history mankind has tried to control the world in which he lives. From the earliest days he realized that his puny strength was no match for the creatures around him. He could only survive by using his wits and cunning. His major asset over all other life from flint, stone and bone and discovered that it was possible to train other animals to do his bidding and so the earliest form of control system was conceived. Before long the horse and ox were deployed to undertake a variety of tasks, including transport. It took a long time before man learned to replace animals with machines [1].

Automatic control is one of today's most significant areas of science and technology. This can be attributed to the fact that automation is linked to the development of almost every form of technology. By its very nature, automatic control is a multidisciplinary subject; it constitutes a core course in many engineering departments, such as electrical, electronic, mechanical, chemical, and aeronautical. Automatic control requires both a rather strong mathematical foundation, and implementation skills to work with controllers in practice.

Automatic control has developed rapidly over the last 60 years. An impressive boost to this development was provided by the technologies that grew out of space exploration and the second World War. In the last 20 years, automatic control has undergone a significant and rapid development due mainly to digital computers. Indeed, recent developments in digital computers especially their increasingly low cost facilitate their use in controlling complex systems and processes.

Automatic control is a vast technological area whose central aim is to develop control strategies that improve performance when they are applied to a system or a process. The results reported thus far on control design techniques are significant from both a theoretical and a practical perspective. From the theoretical perspective, these results are presented in great depth, covering a wide variety of modern control problems, such as optimal and stochastic control, adaptive and robust control, and system identification. From the practical point of view, these results have been successfully implemented in numerous practical systems. And processes—for example, in controlling temperature, pressure, and fluid level; in electrical energy plants; in industrial plants producing paper, cement, steel, sugar, plastics, clothes, and food; in nuclear and chemical reactors; in ground, sea, and air, transportation systems; and in robotics, space applications, farming, biotechnology, and medicine.

A close examination of the various machines and apparatus that are manufactured today leads to the conclusion that they are partially or entirely automated; this lead to the conclusion that automatic control is used in all facets of human technical activities and contributes to the advancement of modern technology.

The distinct characteristic of automatic control is that it reduces, as much as possible, the human participation in all the aforementioned technical activities. This usually results in decreasing labor cost, which in turn allows the production of more goods and the construction of more works. Furthermore, automatic control reduces work hazards, while it contributes in reducing working hours, thus offering to working people a better quality of life (more free time to rest, develop hobbies, have fun,etc.).

Control systems have been in existence since ancient times. A well-known ancient automatic control system is the regulator of Heron of Alexandria this control system was designed to open the doors of a temple automatically when a fire was lit at the altar located outside the temple and to close the doors when the fire was put out.

Until about the middle of the $18^{th}$ century, automatic control has no particular progress to show. The use of control started to advance in the second half of the $18^{th}$ century, due to James Watt, who, in 1769, invented the first centrifugal speed regulator. In particular, this regulator was used to control the speed of the steam engine.

The period until about the middle of the $19^{th}$ century is characterized by developments based on intuition, i.e., there was no mathematical background for control design [2].

## 1.2 Importance

Sustainability of available water resource in many reason of the world is now a dominant issue. This problem is quietly related to poor water allocation, inefficient use, and lack of adequate and integrated water management. Water is commonly used for agriculture, industry, and domestic consumption. Therefore, efficient use and water monitoring are potential constraint for home or office water management system. Last few decades several monitoring system integrated with water level detection have become accepted. Measuring water level is an essential task for government and residence perspective. In this way, it would be possible to track the actual implementation of such initiatives with integration of various controlling activities. Therefore, water controlling system implementation makes potential significance in many applications. The existing automated method of level detection is described and that can be used to make a device on/off. Moreover, the common method of level control for underground tank appliance is simply to start the feed pump at a low level and allow it to run until a higher water level is reached in the water tank. This is not properly supported for adequate controlling system. Besides this, liquid level control systems are widely used for monitoring of liquid levels, reservoirs, silos, and dams etc. Usually, this kind of systems provides visual multi level as well as continuous level indication. Audio visual alarms at desired levels and automatic control of pumps based on user’s requirements can be included in this management system. Proper monitoring is needed to ensure water sustainability is actually being reached, with disbursement linked to sensing and automation[3].

## 1.3 Methodology

The programmatic approach entails microcontroller based automated water level sensing and controlling have been used .

## 1.4 Objectives

Main objective is to design device that for control the submersible pump by monitoring the water level in the tanks through water level sensors, which are placed in three places in the tanks using a microcontroller, and the objectives are:

1. To Design an automatic pump control and water monitoring system.
2. To Reduce the user effort and increasing safety.
3. To Prevent over labor of the pumping machine (dry running).

## 1.5 Overview of The Thesis

This chapter has presented an introduction of automatic control and background, importance, methodology, objectives and overview of the thesis, chapter two presents a literature review of the problem, chapter three presents a case study, chapter four presents a result and discussion, chapter five presents a conclusion and recommendations.

# CHAPTER TWO

# Literature Review

## 2.1 Pump Control System

The development of automation and control processes in industrial applications has increased significantly over the past decades. Involvement of human activities in industrial processes has caused so many problems, like safety, health and industrial damages both to humans and the developmental activities within the level of industrial production and service delivery. The effect of automation and control systems in recent production and service delivery development has improved the safety and reliability in technology and most human services in the developing countries.

Some of the industries involved in the development of automation and control systems are the oil/gas industries, power generation companies, water and sewage treatment plants, chemical industries, pharmaceutical, food and beverage industries and some basic systems used by service providers in small companies and homes.

Automation processes is now aiming to progress in the so called complete automation which will remove all human machine interface will not be needed but just to enter parameters of the process to be controlled and the machine performs the rest of the designed activities.

A control system is an interconnection of components connected or related in such a manner as to command, direct, or regulate itself or another system. Automatic control systems enable to operate processes in excellent and accurate manner. Considering some process applications in the industries, the need of control systems to achieve industrial targets and objectives by continually measuring process variables such as temperature, pressure, level, flow and concentration, taking into actions such as opening valves, slowing down pumps and turning up heaters in order to maintain measured process variables at the operator's set point values. With this idea for the future development in technology, software applications like the microcontroller can help to achieve this aim for complete automation processes.

The pump control system based on three main points are the places where the sensors at the tanks, first sensor at top level of the overhead tank and the second at a quarter level of the overhead tank and the third sensor level at the suction level of the submersible pump in the underground tank. The submersible pump cannot draw water from the underground tank only if the water level in the underground tank reaches water level sensor at the underground tank. The microcontroller controls the implementation process according to the level of water in the overhead tank and the underground tank and decides if the pump working or not. The microcontroller stops the pump if the overhead tank is full or the occurrence of any error in the sensor signals or if the underground tank is empty. The microcontroller run the pump if the water level in the underground tank is reaches the water sensor level of the draw submersible pump and the water level in the overhead tank is not touching any of these sensor (tank is empty) or touching the sensor at the quarter of the overhead tank level (not full). Microcontroller signal pass through the driver then to relay for the implementation of the process of turning on or off the submersible pump.

There are three Light Emit Diode (LED) indicators of the water level .red Light Emit Diode (LED) indicates the water level in the underground tank is less than suction level of the submersible pump, yellow Light Emit Diode (LED) indicates the overhead tank is full, and green Light Emit Diode (LED) indicates the water level reaches a quarter level of the overhead tank or slightly more than this. Not only the Light Emit Diode (LED) will switch on but also the buzzer when the fill of the overhead tank. Figure (2.1) show the block diagram of pump control system.

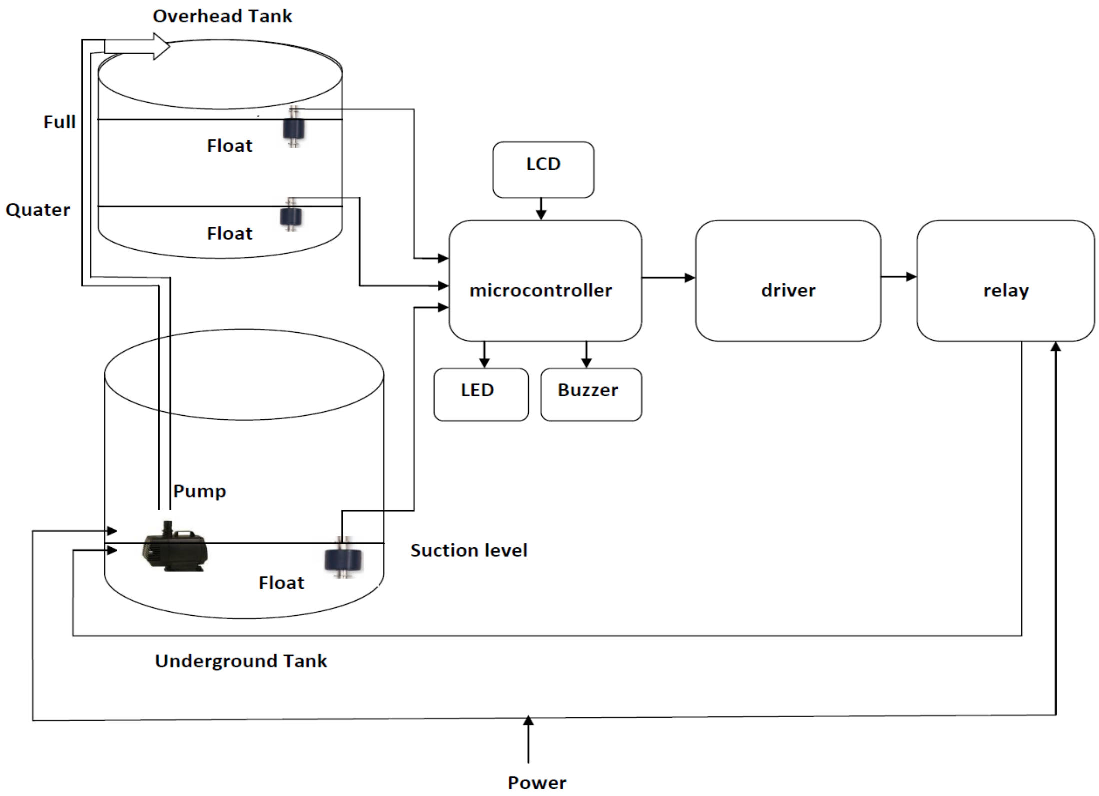


Fig (2.1) The block diagram of the pump control system.

There are some literatures that survey water level control and pump control systems. Also, some papers that overview and compare the current techniques in this area.(Sanjay et al., 2015; Muktha et al., 2013; Khaled et al., 2010) these different methods for water level control or automatic pump. (Sanjay et al., 2015) The paper presents smart water monitor system and by using transistor BC547 as switch (level sensor) send an alert to the system for controlling using wireless Zigbee with microcontroller is responsible for processing network protocol and the modulates signal that has been collected and transmitted the via a Zigbee antenna. The signal receives by Zigbee receiver then accordingly main valve or motor control automatically [4]. The research result was a flexible, low cost easy maintainable wireless system. (Muktha et al.,2013) in this approach water level sensing and controlling with wireless communication and radio frequency transceivers used for send signal to microcontrollers placed at each tank to control the pump. The setback in this approach the large number of circuit components, which makes it high cost [5]. (Khaled et al., 2010) introduced the notion of water level monitoring and management within the context of electrical conductivity of the water. The motivated by the technological affordances of mobile devices, investigated the microcontroller based water level sensing and controlling in a wired and wireless environment. The research result was a flexible, economical and easy configurable system designed on a low cost PIC16F84A microcontroller.

## 2.2 Control Architectures

Control means measuring the value of the controlled variable of the system and applying the control signal to the system to correct or limit deviation of the measured value from a desired value [6]. Many Mechatronics systems have multiple inputs and outputs related by deterministic relationships that result in some form of control of the outputs. A designer can choose from a wide spectrum of control architectures, ranging from simple open loop control to complex feedback control. Implementation of the control can be as simple as using a single operational amplifier or as complicated as programming massively parallel microprocessors.

The following describe a hierarchy of basic control approaches may consider in the design of a Mechatronics system:-

### 2.2.1 Analog Circuits

Many simple Mechatronic designs require a specific actuator output based on an analog input signal. In some cases, analog signal processing circuits consisting of operational amplifier or and transistors can be employed to effect the desired control. Operational amplifier can be used to perform comparisons and mathematical operations such as analog addition, subtraction, integration, and differentiation. They can also be used in amplifiers for linear control of actuators. Analog controllers are often simple to design and easy to implement and can be less expensive than microprocessor-based systems.

### 2.2.2 Digital Circuits

If the input signals are digital or can be converted to a finite set of states, then combinational or sequential logic controllers may be easy to implement in Mechatronics design. The simplest designs use a few digital chips to create a digital controller. To generate complex Boolean functions on a single integrated circuit(IC), specialized digital devices such as programmable array logic (PAL) controllers and programmable logic arrays (PLAs) can be used to reduce design complexity. Programmable array logics (PALs) and programmable logic arrays (PLAs) contain many gates and a grid work of conductors that can be custom connected using a programming Device. Once programmed, the integrated circuits (ICs) implement the designed Boolean function between the inputs and outputs. Programmable array logic (PALs) and programmable logic arrays (PLAs) may offer an alternative to complex sequential and combinational logic circuits that require many integrated circuits (ICs).

Another type of programmable logic-gate-based device is the field programmable gate array (FPGA).Like programmable array logics

(PALs) and programmable logic arrays (PLAs), an field programmable gate array(FPGA) contains a large number of reconfigurable gates that can be programmed to create a wide range of logic functions. Field programmable gate arrays (FPGAs) are different from programmable array logics (PALs) and programmable logic arrays (PLAs) because they also can include memory, input/output (I/O) ports, arithmetic functions, and other functionality found in microcontrollers. Furthermore, field programmable gate arrays (FPGAs) are usually programmed with a high-level software language (e.g., Very High Speed Integrated Circuit (VHSIC) (VHDL Hardware Description Language) field programmable gate array that allows for fairly sophisticated functionality.

Sometimes, it may be economically feasible to design an application specific integrated circuit (ASIC) that provides unique functionality on a single integrated circuit(IC).Logic functions, memory, computation, signal processing, and other digital and analog features can be custom built onto a single application-specific integrated circuit(ASIC). Design and setup for manufacturing can be expensive, but in high volume manufacturing applications, an application specific integrated circuit (ASIC) solution can be cheaper in the long run. Application specific integrated circuits (ASICs) are also attractive because the integrated solution will usually be smaller in size and consume less power.

### 2.2.3 Programmable Logic Controller

Programmable logic controllers (PLCs) are specialized industrial devices for interfacing to and controlling analog and digital devices. They are designed with a small instruction set suitable for industrial control applications. They are usually programmed with ladder logic, which is a graphical method of laying out the connectivity and logic between system inputs and outputs. Programmable logic controllers (PLCs) are designed with industrial control and industrial environments specifically in mind. Therefore, in addition to being flexible and easy to program, they are robust and relatively immune to external interference.

The National Electrical Manufacturers Association (NEMA) has defines a programmable logic controller as: A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes.”

In essence, the programmable logic controller consists of computer hardware, which is programmed to simulate the operation of the individual logic and sequence elements that might be contained in a bank of relays, timers, counters, and other hard-wired components.

Early Programmable logic controllers (PLCs) that were developed during the late 1960s were difficult to program. These early devices were merely relay replacements and could do very little else, in recent years rapidly developed into a sophisticated and highly versatile control system component. Units today are capable of performing complex math functions including numerical integration and differentiation and operate at the fast microprocessor speeds now available. Today's systems can accept and generate analog voltages and currents as well as a wide range of voltage levels and pulsed signals, Programmable logic controllers (PLCs) are also designed to be rugged. Unlike their personal computer cousin, they can typically withstand vibration, shock, elevated temperatures, and electrical noise to which manufacturing equipment is exposed. As more manufacturers become involved in Programmable logic controllers' production and development, and Programmable logic controller capabilities expand, the programming language is also expanding.

### 2.2.4 Single-Board Computer

When an application requires more features or a resource than can be found on a typical microcontroller and size is not a major concern, a single-board computer offers a good alternative. Most single board computers have enough Random Access Memory (RAM) and offer compilers to support programming in a high level language such as C. Single board computers are also easily interfaced to a personal computer. This is useful in the testing and debugging stages of design development and for downloading software into the single-board computer's memory.

The term mini controller refers to another class of device that falls between a microcontroller and a single-board computer. Examples are the Handy board, Basic Stamp, and Arduino. These boards contain microcontrollers and other peripheral components that make it easier to interface to external components.

### 2.2.5 Personal Computer (PC)

In the case of large sophisticated mechatronic systems, a desktop or laptop personal computer may serve as an appropriate control platform. Also, for those not experienced with microcontrollers and single-board computers, the personal computer may be an attractive alternative. The personal computer can be easily interfaced to sensors and actuators using commercially available plug-in data acquisition cards or modules.

These devices typically include software drivers that enable programming with standard high-level language compilers and development environments. Due to the ease and convenience of this approach, personal computer controlled mechatronic systems are especially common in Research and Development (R&D) testing and product development laboratories, where fast prototyping is required but where large-quantity production and miniaturization are not concerns.

### 2.2.6 Digital Signal Processing (DSP)

Digital signal processing is single microcomputer device .A digital signal processor can have functionality similar to that of a microcontroller, but digital signal processors are usually better suited to high-speed floating point calculations. Digital signal processors are useful in communication, audio/video, and control applications where fast calculation of digital filters and weighted sums is important for fast cycle times [7].

### 2.2.7 Microcontrollers

Microcontrollers were first considered at Intel in 1969 when a Japanese company approached Intel to build some integrated circuits for calculators. Marcian Huff used his previous experience on the Programmed Data Processor PDP-8 to propose an alternate solution a programmable integrated circuit(IC). Frederico Faggin transformed this idea to reality and Intel bought the license from the Japanese company (BUSICOM) to create the 4004 4-bit microprocessor capable of 6000 operations per second. This was soon followed by the 8-bit 8008 in 1972. Intel’s efforts were soon followed by Motorola with the 8-bit 6800 series and MOS Technology introduced the 6501 and 6502 for only $25 each. It was all downhill from there.

A single chip microcontroller and 900 MHz radio known as (“Spec”) was designed by Jason Hill at UC Berkeley for a new field in engineering known as “sensor networks.” Because microcontrollers and radios are so cheap and easy to use today, you could fill a building with thousands of them, all talking together over low power radios. By sensing their environment, these small sensors could control lighting, temperature, as well as numerous other environmental controls.

The needs of embedded control are very different from those of the standard personal computers. For the life of the device, usually it will run only one program, apart for the occasional program update. Because there is little support hardware; Visual Display Unit (VDU), keyboard, hard-drive or floppy disk there is little need for mass storage. User-machine, machine-user interaction is also limited. They are often required to operate in hostile environments such as high temperatures, dust/corrosive atmospheres and perhaps both mechanically and electrically noisy.

Microcontroller is a highly integrated chip that contains all the components comprising a controller. Typically this includes a Central Process Unit (CPU), Random Access Memory (RAM), some form of Read Only Memory (ROM), input/output (I/O) ports, and timers. Unlike a general purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task to control a particular system. As a result, the parts can be simplified and reduced, which cuts down on production costs.

Microcontrollers are sometimes called embedded microcontrollers, which just mean that they are part of an embedded system that is, one part of a larger device or system.

#### 2.2.7.1 Microcontroller Advantages

Microcontrollers are widely used in today’s control systems for the following reasons:

1. Design and Simulation

   Because can programmed with software, detailed simulations may be performed in advance to assure correctness of code and system performance.

2. Flexibility

   Ability to reprogram using Flash, Electrically Erasable Programmable Read Only Memory (EEPROM) or Erasable Programmable Read Only Memory (EPROM) allows straightforward changes in the control law used.

3. High Integration

   Most microcontrollers are essentially single chip computers with on-chip processing, memory, and input/output. Some contain peripherals for serial communication and reading analog signals with (an analog to digital converter or analog to digital converter). This differentiates a microcontroller from a microprocessor. Microprocessors require that this functionality be provided by added components.

4. Cost

   Cost savings come from several locations. Development costs are greatly decreased because of the design/flexibility advantages mentioned previously. Because so many components are included on one integrated circuit(IC), board area and component savings are often evident as well.

5. Easy to Use

   Just program and go! While in the past, programming has often involved tedious assembly code, today C compilers are available for most microcontrollers. Microcontrollers often only require a single 5V supply as well which makes them easier to power and use.

**2.2.7.2 Microcontroller architecture**

The Atmel ATmega16 microcontroller for example integrates memory, clock, a central processing unit, input/output, timers, and an analog to digital converter figure (2.2) show ATmega16 microcontroller architecture.

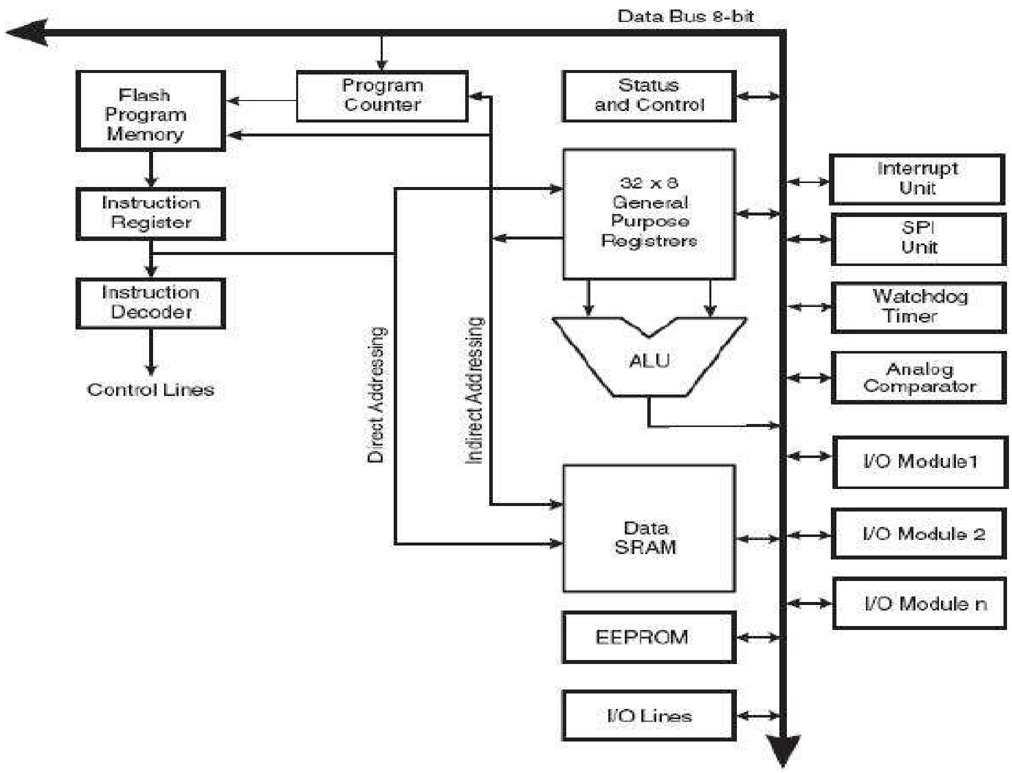


Fig (2.2) ATmega16 microcontroller architecture

1- Memory

Memory on a microcontroller can be used to store data and/or the program to be run. There are often several types of memory on a microcontroller:

- Random Access Memory (RAM).
- Read Only Memory (ROM).
- Programmable Read Only Memory (PROM).
    - Erasable Programmable Read Only Memory (EPROM).
    - Electronically Erasable Programmable Read Only Memory (EEPROM).
    - Flash Memory a type of EEPROM.

Random Access Memory (RAM) can be either read or written, and this usually happens quite fast. Data stored on a microcontroller is often stored in Random Access Memory Random Access Memory (RAM) However, the data stored in Random Access Memory (RAM) is volatile which means that it is lost when power is turned off. Read Only Memory (ROM) is non-volatile and therefore stored between power cycles, but may not be written to.

Programmable Read Only Memory (PROM) is therefore a compromise between these two types of memory. Programmable Read Only Memory (PROM) is nonvolatile and also allows a user to program it Ultra Volatile (UV) light, but more common today is Electronically Erasable Programmable Read Only Memory (EEPROM). Erasable Programmable Read Only Memory allows read and write access and is also non volatile, but the sacrifice here is that data transfers take much longer than with Read Only Memory.

Flash memory is a type of Erasable Programmable Read Only Memory. Program memory (where the program is stored) on the ATmega16 is Flash memory. This is also the same as the memory used in digital cameras and cell phones. Data transfer using flash is much faster than Erasable Programmable Read Only Memory because it works in blocks of bytes instead of single bytes. This makes it perfect for program memory in that case.

2- Clock

The ATmega16 is run off an 8 MHz crystal oscillator. The rate of instruction execution is fixed and synchronized by this clock. However, this does not mean that each instruction takes 125 nsec. Different instructions require a different number of cycles.

3- Central Process Unit (CPU)

This is brains of the microcontroller – the Central Process Unit (CPU) executes instructions such as add, move, jump, multiply, etc. To do so, it must first fetch the instruction and any required data over its data bus.

4- Input/Output (I/O)

The ATmega16 offers 32 programmable input/output (I/O) lines with 4 8-bit ports. By programming specific registers on the ATmega16, these lines may be set to input, output, or some secondary function. If a pin is set as output, setting the corresponding bit in the output register to 1 will output Vdd on that pin and 0 will output ground. If the pin is set to input, it is possible to read either a 1 or 0 on that pin. These pins act just like memory locations so all that is required to output a value is setting a bit in a memory register. To read a pin, all need to do is read a bit in a register.

5- Timers

Timers are internal clocks (2 for 8-bit timers and 1 for 16-bit timer is included in the ATmega16). Each timer can be scaled by some factor from the system clock (8MHz). These timers can then give a sense of time and duration information of great importance in digital control systems. In most cases, just use a timer to count from 0 to 255 for an 8-bit timer, or 0 to 65536 for a 16-bit timer.

In addition, many interrupts can be triggered off of timers. An interrupt is a piece of code triggered by a particular event. That event might be a timer overflowing, or reaching a particular value.

6- Analog-to-Digital Converter (ADC)

In most cases, the real world gives analog signals. Reading light levels from a photoresistor will give an analog voltage relating to the current light falling on the photoresistor. For the microcontroller to deal with this information, it must be converted to a digital format. An analog to digital converter does exactly that.

The ATmega16 provides an 8-channel 10-bit analog-to-digital converter. The number of channels is the number of pins supporting the analog-to-digital converter functionality (this is one of the secondary functions mentioned earlier in input/output). The number of bits tells us the resolution with which can read the analog data.

### 2.2.7.3 Types of Microcontrollers

Microcontrollers can be classified on the basis of internal bus width, architecture, memory and instruction set. Figure (2.3) shows the various types of microcontrollers.

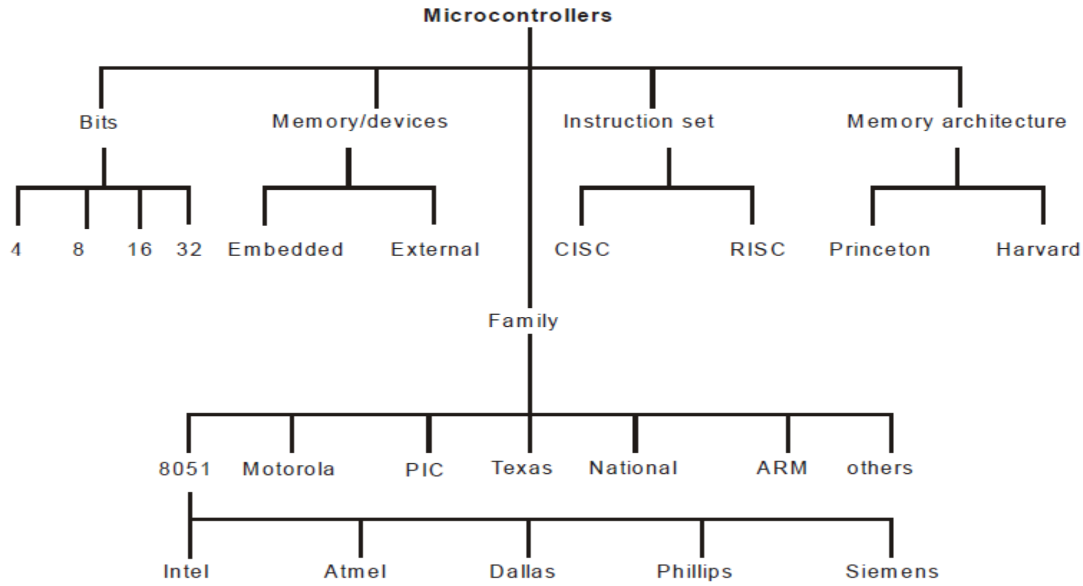


Fig (2.3) Types of microcontrollers

## 1- The 8,16 and 32 bit Microcontrollers

**i-** The 8- bit Microcontrollers

**ii-** The 16- bit Microcontrollers

**iii-** The 32- bit Microcontrollers

## 2- Embedded and external memory microcontrollers

i- Embedded microcontrollers

ii- External memory microcontrollers

## 3- Microcontrollers architecture Features

i- Von-Neuman architecture

ii- Harvard architecture

iii- Complex Instruction Set Computer (CISC) Architecture microcontroller

iv- Reduced Instruction Set Computer (RISC) architecture

v- Specific Instruction Set Computer (SISC)

### 2.2.7.4 Microcontrollers Selection

Choosing a microcontroller from a number of different microcontrollers is a very critical decision for the designers. Three are the vital major criteria for selecting them. These are wide availability and reliable sources, meeting the requirements efficiently and cost effectively, availability of the software development tools like compilers, Assemblers and debuggers etc. The main criteria in selecting a microcontroller are given below in the order of importance.

**1- System Requirement**

Design should start with a blank sheet of paper specifying the application needs, if the system requires a single chip microcontroller or additional peripherals are to be used with it. Selection process starts with a decision of choosing either the 4-bit, 8-bit, 16-bit or 32-bit microcontroller required by the application. To develop code for 4-bit architectures is harder and handling 4-bit instructions and data widths can limit arithmetic capabilities. Most of the embedded applications are implemented using 8-bit microcontroller as the technology has been around a long time and huge number of controllers is available in the market. They are used from low cost, low speed 4-bit micro replacement to device which deliver tens of MIPS, such as Atmel's AVR series which achieves a 50 ns instruction cycle time when clocked from a 20 MHz crystal. If the application needs more processing power the choice is most likely to be 16-bit or 32-bit microcontroller. Vendors offer 32-bit performance cost effectively. 32-bit devices come at virtually no cost to the user. The on chip peripherals available exhibit heavy influence on component selection. Check the availability of Timers, Serial interfaces, Read Only Memory, Random Access Memory, analog to digital converter, digital to analog converter sufficient number of input/output (I/O) ports. Too many input/output (I/O) ports lead to bear excessive cost but few cannot do the job.

### 2- Memory Architecture

This is very important factor while designing any microcontroller based system. Three different types of memory play an important role in the selection process are program memory i.e. (Flash, OTP, Read Only Memory (ROM) and Read Only Memory (ROM) less components), Data memory i.e.( on-chip SRAM or external SDRAM) and Non volatile Memory i.e. Electronically Erasable Programmable Read Only Memory (EEPROM) or Flash. Whether the memory is on-chip or off-chip and how much the size is required may be a key factor defines cost of building the system and speed of operation. For an example Atmel AVR family include Flash memory of 1KB to 128KB, on chip SRAM for data storage and for the storage of configuration information and serial numbers a few bytes of Electronically Erasable Programmable Read Only Memory (EEPROM) are reserved. These golden features make the AVR family more popular in different applications. Flash gives the flexibility to make code changes and provides facility to use In System

Programmed. Atmel 89C51 and Mega AVR families have the segmented Flash blocks which allows reprogram one segment under control of another segment, without removing the power. Lastly it is best to choose a device from a family which provides sufficient or more memory space than the expectation of need.

**3- Availability**

Before going to implement the system, the availability of the device should be checked. The criteria in choosing microcontroller is its ready availability in needed quantities both now and future. If sufficient quantities are available with bright future then no need to be worried about the failure of the project.

**4- Size**

If integrated circuit(IC) of 15 input/output (I/O) pins is required to develop the system there is no need to use 40 pin integrated circuit (IC) with 32 input/output (I/O) pins. In this way the size of the integrated circuit(IC) can be reduced and thus physical space required to implement the system is also reduced. So, physical size of integrated circuit(IC) may well be critical factor for specific applications.

**5- Compatibility**

The function of a system can be changed or upgraded by changing the software or replacing one integrated circuit(IC) with another one without incurring heavy additional cost. The new one will be pin compatible as well as function compatible.

**6- Functionality Testing**

To check the function of the implemented system correctly the function of the microcontroller unit should be checked within the test circuit designed earlier before going to develop the overall system.

### 7- Power Management

Power consumed by the system determines the lifetime of the battery. Due to reduction in size of the devices the size of the components are reduced and their placement within the design is very compact. This phenomenon makes the devices to be sensitive to the heat dissipated from the microcontroller unit and the other peripherals connected with it. It is the duty of an engineer to look first at the power required at the clock speed necessary to run the application. Read Only Memory (ROM) based devices tolerate very low operating voltages (around 0.9v). In case of Atmel AVR devices Flash based microcontroller can be operated at the voltages down to 1.8V. Most microcontrollers have the features of power down, idle & sleep modes and consideration needs to be given to maximize the use of intelligent power management systems to reduce power consumption.

### 8- Manufacturer's Track Record

Manufacturers should ensure the stability, good performance, better throughput, Reliability; better Serviceability, software support, correctness, wide and timely availability of their products. For an example product of Intel, Freescale, Zilog, and Microchip Technology are stable, mature and single sourced. The points like design challenges, on time delivery, performance, years in business and year of transaction, financial report should be followed as the track record of the manufacturers. They must provide the datasheet or user guide which consists of characteristics, functionality, sample test circuit, electrical characteristics and dimension etc. The documentation of maintenance of the development system, the range of services and its associated software must be available for the common user.

### 9- Manufacturer's Support

During the step by step implementation of the system if the design engineer faces any kind of problem he/she may communicate with the marketing/sales, field application engineers. The manufacturers should have some facilities like a help line, toll free number, fax number, after-sales support, sufficient knowledgeable and helpful expertise support personnel who will give a prompt reply or they will follow through in a regular manner when they promise to do something.

### 10- Availability of Development Support

Here the key consideration includes Assembler, Debugger, a code efficient C compiler, emulator, technical support. Trend towards programming in high level language like C is increasing day by day. This language allows using of some portability of code and libraries. This provides more practical consideration using different microcontroller family. Choosing the appropriate Hardware and software development tools is also important while selecting microcontroller unit. An Integrated Development Environment (IDE) facilitates the development efforts by providing the project management tools. IDE enables to create source files and their organization in to a project, creation of database for many devices. An example of IDE is Keil uVision 2 which compiles to point out and correct the errors, assembles and links the device datasheet, user guides and development tool manuals. Another good example is MPLAB for PIC and dsPIC microcontrollers from Microchip Technology. This is mainly used for development of embedded systems.

### 11- Cost

This is the most important factor. If the system is to be implemented within the limit of the budget calculated earlier the cost of each and every component (selected microcontroller unit along with supporting integrated circuits) used to build the system should be minimized tactfully to fulfill the requirements. On chip features will trade with inventory and assembly cost of using extra supporting external components. They can also cut development time and effort by providing a ready integrated solution. Design of special hardware requires non recurring engineering cost and cost for manufacturing the unit. Integration of some peripherals like 10/100 base T Ethernet MACs, Controller Area Network (CAN bus) interfaces, Universal Serial Bus (USB), Radio Frequency (RF) transmitter and graphics driver cuts the system cost in some great extent. For high volume applications most users prefer Read Only Memory (ROM) based devices due to their lower cost and code security [8].

According to these criteria the microcontroller has been selected is ATmega16 has the following features:-

The device is manufactured using Atmel's Mega AVR family with low power consumption an 8-bit high performance microcontroller four 8-bit ports designated as PORTA, PORTB, PORTC and PORTD. Atmega16 is based on enhanced Reduced Instruction Set Computing (RISC). Most of the instructions execute in one machine cycle. Atmega16 can work on a maximum frequency of 16MHz and has 16 KB programmable flash memory, Static Read Access Memory (SRAM) of 1 KB and Electronically Erasable Programmable Read Only Memory (EEPROM) of 512 Bytes. ATmega16 is a 40 pin microcontroller. There are 32 input/output (I/O) lines which are divided into in-built peripherals like Universal Synchronous Asynchronous Receiver Transmitter (USART) analog to digital converter, Analog Comparator, Serial Peripheral Interface (SPI), Joint Test Action Group (JTAG) etc. Each input/output pin has an alternative task related to in-built peripherals. Figure (2.4) shows the pin configuration of ATmega16.

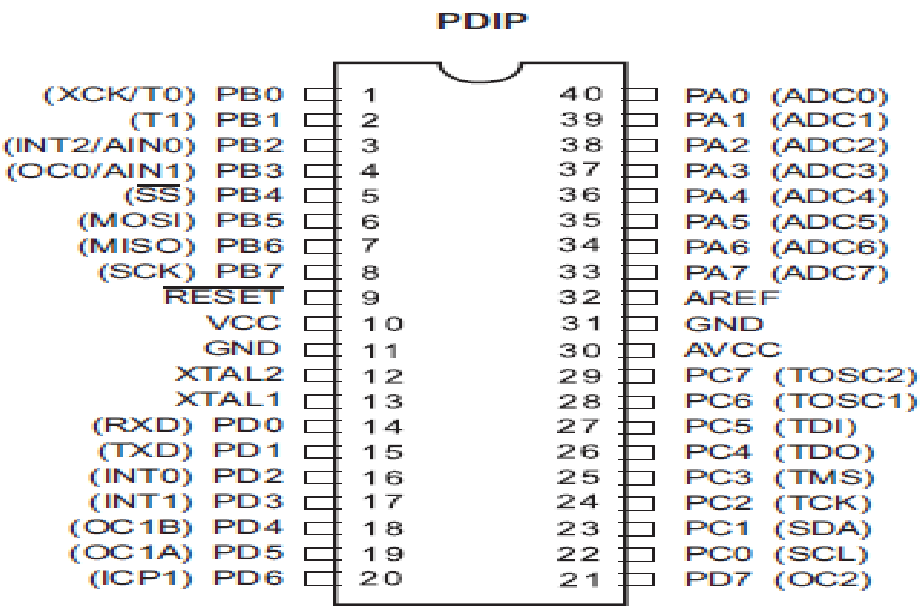


Fig (2.4) The pin configuration of ATmega16

**2.2.7 .5 ATmega16 Microcontroller Pin Out Description**

VCC : Digital supply voltage.

GND : Ground.

Port A :

serves as the analog inputs to the analog to digital converter. also serves as an 8-bit bi- directional input/output (I/O) port, if the analog to digital converter is not used. Port pins can provide internal pull-up resistors (selected for each bit).

Port B :

is an 8-bit bi-directional input/output (I/O) port with internal pull-up resistors (selected for each bit).

Port C :

is an 8-bit bi-directional input/output (I/O) port with internal pull-up resistors (for each bit).If the interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs selected, also serves the functions of the interface and other special features of the ATmega16,serves the functions of various special features of the ATmega16.

Port D :

is an 8-bit bi-directional input/output (I/O) port with internal pull-up resistors (selected for each bit). also serves the functions of various special features of the ATmega16.

RESET:

Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running.

XTAL1 :

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2 :

Output from the inverting oscillator amplifier.

AVCC :

is the supply voltage pin for Port A and the analog to digital converter. It should be externally connected to VCC, even if the analog to digital converter is not used. If the analog to digital converter is used, it should be connected to VCC through a low-pass filter.

AREF :

is the analog reference pin for the analog to digital converter [9].

**2.2.7.6 Microcontroller Applications**

In addition to control applications such as the home monitoring system, microcontrollers are frequently found in embedded applications. Among the many uses that can find one or more microcontrollers: automotive applications, appliances (microwave oven, refrigerators, television and Video Cassette Recorders VCRs, stereos), automobiles (engine control, diagnostics, climate control), environmental control (greenhouse, factory, home), instrumentation, aerospace, and thousands of other uses. Microcontrollers are used extensively in robotics. In this application, many specific tasks might be distributed among a large number of microcontrollers in one system. Communications between each microcontroller and a central, more powerful microcontroller (or microcomputer, or even large computer) would enable information to be processed by the central computer, or to be passed around to other microcontrollers in the system.

A special application that microcontrollers are well suited for is data logging. By stick one of these chips out in the middle of a corn field or up in a balloon, one can monitor and record environmental parameters (temperature, humidity, rain, etc). Small size, low power consumption, and flexibility make these devices ideal for unattended data monitoring and recording [10].

## 2.3 Pumps

The purpose of a hydraulic pump is to supply a flow of fluid to a hydraulic system. The pump does not create system pressure, since pressure can be created only by a resistance to the flow. As the pump provides flow, it transmits a force to the fluid. As the flow encounters resistance, this force is changed into a pressure. Resistance to the flow is the result of a restriction or obstruction in the pass of the flow. This restriction is the normally work accomplished by the hydraulic system, but can also be restriction of lines, fittings, and valves within the system. Thus, the pressure is controlled by the load imposed on the system or the action of a pressure regulating device. Pumps are in general classified as centrifugal pumps or positive displacement pumps.

### 2.3.1Positive Displacement Pumps

The positive displacement pump operates by alternating of filling a cavity and then displacing a given volume of fluid. The positive displacement pump delivers constants volume of liquid against varying discharge pressure or head. The positive displacement pumps can be classified as:

2.3.1.1 Reciprocating pumps

2.3.1.2 Power pumps

2.3.1.3 Rotary pump

2.3.1.4 Steam pumps

### 2.3.2 Centrifugal Pumps

The centrifugal pump produces ahead and a flow by increasing the velocity of the liquid through the machine with the help of a rotating vane impeller. The centrifugal pumps can be classified as:

2.3.2.1 End suction pump

2.3.2.2 In line pump

2.3.2.3 Multistage pump

2.3.2.4 Self-priming pump

2.3.2.5 Axial flow pumps

2.3.2.6 Regenerative (turbine) pumps

2.3.2.7 Submersible pumps

The centrifugal pump is commonly found inside a submersible fountain pump and some air conditioning units. As the impeller inside it turns, water is drawn in one side of the pump. It is then expelled out the other end. The power and size of the impeller decide the amount of water flow. More water can be pumped if we have a larger impeller. As the impeller rotates, it moves water from the inlet (which is located near the center of rotation of the impeller) along the surfaces of the impeller to the outer portions of the volute by means of centrifugal force (thus, its name centrifugal pump). As this water collects in the outer regions of the volute, it is directed to the outlet. The water leaving the outlet causes the water pressure to drop at the inlet. To match the rate with which water is leaving the outlet, the pump sucks in new water at the inlet. These pumps must be primed before starting, which in this case is already done because of its underwater application. Figure (2.5) show the Submersible pump.

Fig (2.5) The Submersible pump

## 2.4 Level Sensor

Sensor is the prime element or device that used to detect/measure the magnitude of something. Sensors principle always based on a certain phenomenon type. In principle there are two types of level measurements:

### 2.4.1 Continuous level Measurement

Continuous level measurement provides information on the actual level. The threshold detection provides information whether given critical level(s) have been reached. A continuous level measurement sensor provides a signal proportional to the level of the material.

#### 2.4.1.1 Capacitive Sensors

Filling the space between electrodes with a material having a relative permittivity more than one increases capacitance of the sensor proportionally to the relative permittivity and the level figure (2.6) show the capacitive sensor with planar electrodes for level measurement.

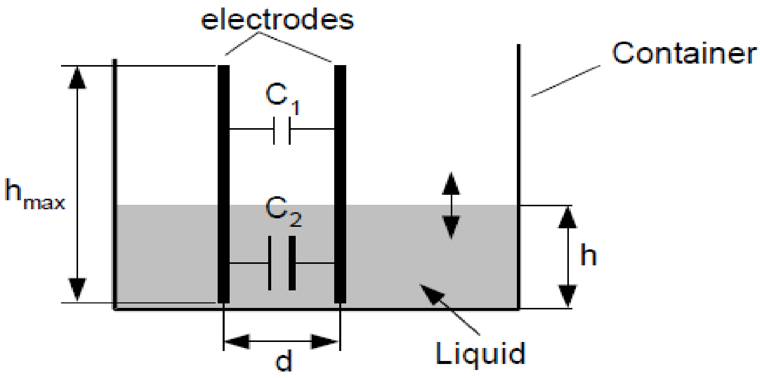


Fig (2.6) Capacitive sensor with planar electrodes for level measurement

The first expression corresponds to the capacity of the empty container. Variation of the permittivity value causes systematic errors which could be compensated for by using an additional capacitive sensor which measures the permittivity. Capacitance of level sensor also depends on density, concentration, temperature and humidity. There are other type is capacitive level sensor with cylindrical coaxial electrodes where the capacitance of the cylindrical coaxial capacitor is dependent on the fluid level (h) ,tank diameter (D),and the sensor diameter (d) figure (2.7) show the capacitive sensor with cylindrical coaxial electrodes.

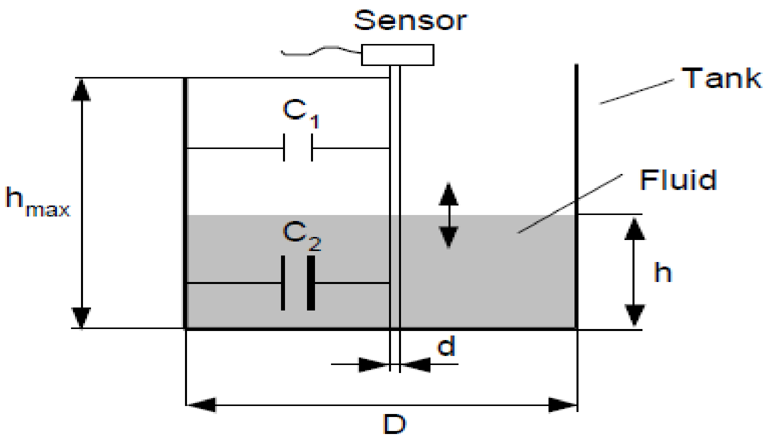


Fig (2.7) Capacitive sensor with cylindrical coaxial electrodes

### 2.4.1.2 Ultrasonic Sensors

The transducer emits pulses of ultrasonic waves which are then reflected from interfaces between materials with different mechanical properties (discontinuities of acoustical impedance). The piezoelectric transducer can operate alternatively either as transmitter or a receiver. The distance (d) between the transducer and the level is found from the sound velocity and the travel time of the ultrasonic pulses. Compensation of temperature effect on sound velocity is carried out using data from an outside temperature sensor. The sensor axis must be perpendicular to the reflecting surface and reflections from tubes and bracing have to be avoided in order to produce an echo without disturbances (false echoes). Installation of the sensor in the focus of a parabolic tank cap increases the level of disturbing signals. The optimal position would generally be at half of the container radius in the center. The principle of operation of ultrasonic sensors is shown in Figure (2.8).

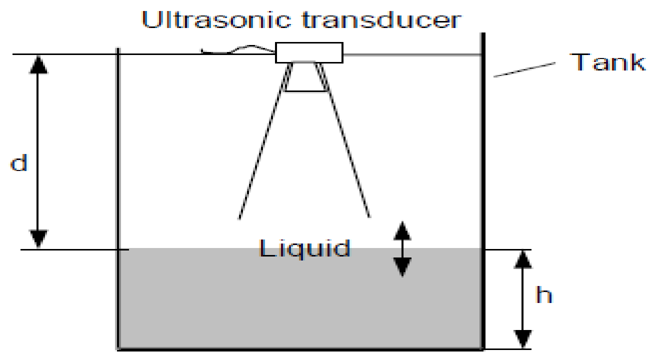


Fig (2.8) The principle of ultrasonic sensors for level measurement

#### 2.4.1.3 Microwave Sensors (radar)

Regarding pulse-radar, the travel time of microwave signals is measured. Due to the high value of light velocity c0, the duration of the pulses is only 1 ns, otherwise the transmitted and received pulse would overlap. Short pulses pose high requirements on time interval Δt measurement. Therefore, most of the level sensors use Frequency Modulated Continuous Wave (FMCW) principle .Microwave sensors are used in cases of high temperature, mist or dust, for rapidly moving objects or for long distance measurement. Their disadvantage is the relative high cost of sensors compared to other types of level measurement principles. The microwaves can penetrate non conducting materials such as glass or nylon with low reflection, thus measurement can be made through the nylon container side without contact with the inner side of the container system. It is possible to choose the thickness of the penetrated material, so that the reflection of waves entering and leaving the material will cancel each other out. The resulting reflecting disturbance will then be zero. This is called wave cancellation and is based on the same principle as antireflection coating used for optical components.

#### 2.4.1.4 Pressure Difference (hydrostatic) Sensors

The pressure of a liquid is the difference between the hydrostatic pressure in the liquid on the bottom of the container and in the space above the liquid level is proportional to the specific weight and the level(h).

## 2.4.2 Detection of Threshold Values (limits)

The sensors for level detection limits act as switches outputting a logical signal when a certain level has been reached there are many type:

### 2.4.2.1 Capacitive level Switch

Whenever the bulk material has reached the position where the sensor had been installed the value of the sensor capacitance is higher than a preset value and switch is activated. The resolution of 0.01 mm can be reached and therefore they can be used for leakage control in oil tanks.

### 2.4.2.2 Ultrasonic Switch

In ultrasonic sensors the time of travel (tf) is evaluated and when the value of (tf) reaches the set limit the output logical signal is generated. The sensor can also identify the presence of an object within the switch area.

### 2.4.2.3 Vibrational Switch

The vibrational sensor uses a vibrator (rod, tuning fork) driven by a piezostrictive (or magnetostrictive) force and oscillates at its mechanical resonant frequency. If the material is in contact with the oscillating rod, its presence will dampen the oscillation amplitude which is sensed mostly by a piezoelectric sensor. When the vibration amplitude drops below a certain level, the switch is activated. The sediments of the bulk material on the vibrating rod are removed by forced pulses of vibrations.

### 2.4.2.4 Conductive Sensors

Conductive sensors consist of electrodes inserted into the container which measures the resistance of the bulk material. A conductive container can serve as a common electrode and in this case the sensor consists of only one electrode.

#### 2.4.2.5 Fiber Optics Level Switches

The function of these switches is based on the change of the optical fiber properties when the level of a liquid with appropriate refraction index reaches the end of the fiber immersed in the fluid

#### 2.4.2.6 Floating Switch

Due to the higher fluid density, the float (buoy) floats on the surface of the liquid. The float may carry a permanent magnet, which produces a magnetic field strong enough to activate a reed switch located at the position of the level being detected. Using two floats with different buoyancy, it is possible to measure the respective level of immiscible liquids such as water and oil in a storage tank [11]. Figure (2.9) show the float switch.

Fig (2.9) The float switch

## 2.5 ULN2003A driver

Is high voltage, high current Darlington arrays each containing seven open collector Darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak current of 600 mA . Suppression diode are included for inductive load driving and the input are pinned opposite the outputs to simplify board layout and the interface use with is commons (COMS) or 5V Transistor Transistor Logic (TTL)[12] . Figure (2.10) show ULN2003A driver.


Fig (2.10) ULN2003A driver

## 2.6 The Relay

Relay is an electromagnetic device which is used to isolate two circuits electrically and connect them magnetically. They are very useful devices and allow one circuit to switch another one while they are completely separate. They are often used to interface an electronic circuit (working at a low voltage) to an electrical circuit which works at very high voltage. For example, a relay can make a 5V Direct Current (DC) battery circuit to switch a 230V Alternating Current (AC) mains circuit. Thus a small sensor circuit can drive say, a fan or an electric bulb.

A relay switch can be divided into two parts: input and output. The input section has a coil which generates magnetic field when a small voltage from an electronic circuit is applied to it. This voltage is called the operating voltage. Commonly used relays are available in different configuration of operating voltages like (5 V, 6V, 9V, 12V, 24V etc). The output section consists of contactors which connect or disconnect mechanically. In a basic relay there are three contactors: Normally Open (NO), Normally Closed (NC) and common (COM). At no input state, the COM is connected to NC. When the operating voltage is applied the relay coil gets energized and the COM changes contact to NO. Different relay configurations are available like Single pole, single throw(SPST), Single pole, double throw (SPDT), Double pole, double throw(DPDT) etc, which have different number of changeover contacts. By using proper combination of contactors, the electrical circuit can be switched on and off [13] . Figure (2.11) show 5V relay.

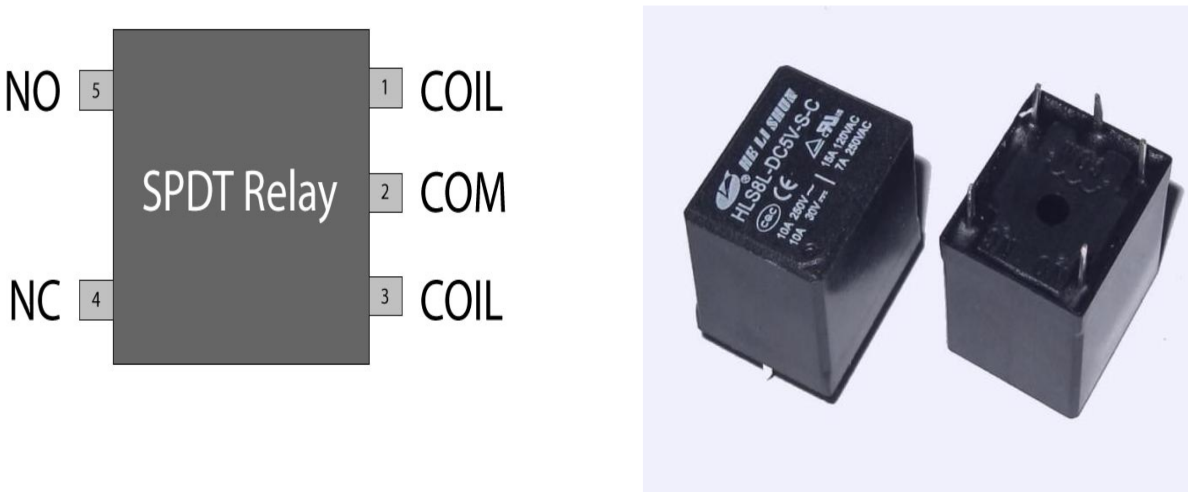


Fig (2.11)  5V relay

# CHAPTER THREE

## Case Study

### 3.1 Introduction:

There are many methods of designing an automatic water level control system with switching device but all these methodologies require human assistance. Pump control system is designed using electronic control to refill the water without human intervention. The system design was carefully arranged to refill the water overhead tank, when the water arrive to certain level in the overhead tank if and only if the water level in the underground tank is over than the submersible pump sensor level, finally the system will automatically stop the submersible pump when the overhead tank is full.

### 3.2 Components Used

The pump control system has the following main components:-

- Solder breadboard
- Float switch
- Atmega16 microcontroller
- Uln2003 driver
- 5v relay
- Buzzer
- LCD16 display
- Various resistances (3K ,330) Ω
- Variable resistance 1K
- Various LED (red,yallow,green)
- Wires

### 3.2.1 Solder Board

All the components of the circuit is connected by it to form welding joint rugged and durable.

### 3.2.2 Float Switch

It is used to detect water level at the two tanks and send electrical signal to the microcontroller.

### 3.2.3 Atmega16 Microcontroller

It is a highly integrated chip that contains all the components comprising a controller. Play the main role in the control system through receiving the sensors signal and take the appropriate decision not only to turn pump on or stop it, but also control the status of the buzzer, a various LED color and the LCD display.

### 3.2.4 ULN 2003 Driver

The driver amplifies the current to suit the relay or the buzzer.

### 3.2.5 5v Relay

The relay will act as a switch to control the pump.

### 3.2.6 Buzzer

Device that converts electrical energy into sound and is used in the audio notification when the underground tank is empty. Buzzer model works on 6-12 volts effort and carries a constant stream of approximately 25 mA.

### 3.2.7 LCD16 Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. LCDs are economical, easily programmable, have no limitation of displaying special characters and animations.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc.

The LCD displays status of the pump and sensors as well as the water level in the tanks according to the microcontroller signal. Figure (3.1) shows the LCD16 display pins.

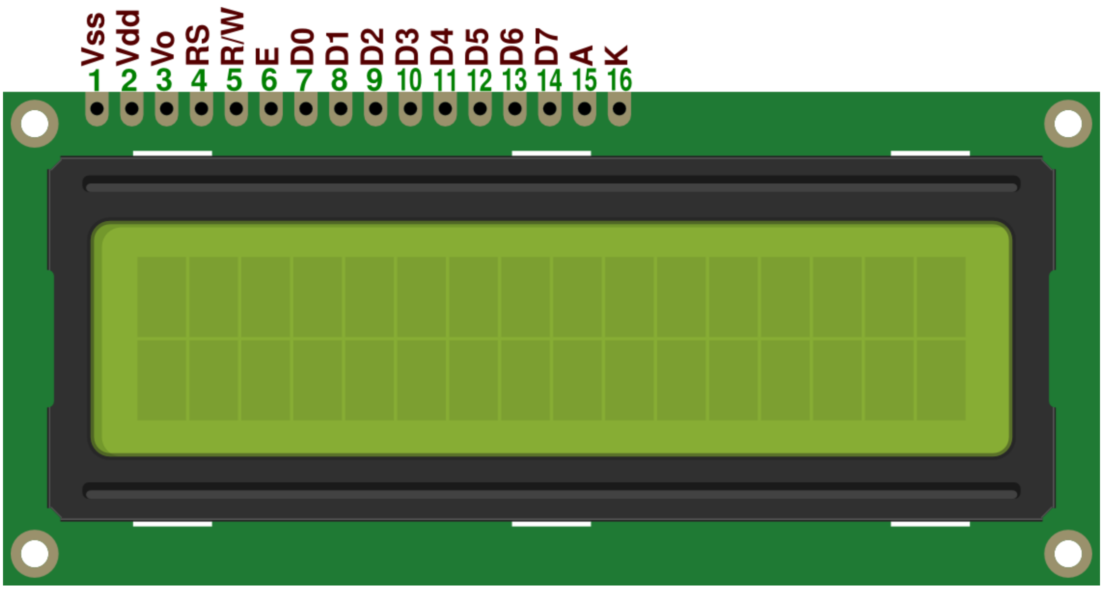


Fig (3.1) The LCD16 display pins

**3.2.7.1 LCD16 Display Pins Description**

D0 ~ D3: input/output 4 lines of low order data bus. Bi-directional transfer of data between microcontroller unit and module is done through these lines. In 4 bit operation, these are not used and should be grounded.

DB4 ~ DB7: input/output 4 lines of low order data bus. Bi-directional transfer of data between microcontroller unit and module is done through these lines. In 4 bit operation, these are not used and should be grounded

Vss: Power Supply 0V (GND)

Vcc: Power Supply +5V

Vee: Power Supply terminal for LCD drive power source.

RS : Input microcontroller unit Register Select.

R/W : Input microcontroller unit Signal to select Read or Write.

E : Input microcontroller unit Enable - Operation start signal for data read/write

### 3.2.8 Various Resistors (3K ,330) Ω

Used to protect whether for microcontrollers or any other element of the current and voltage changes.

### 3.2.9 Various LED (red , yellow , green)

LEDs work as indicator to water level for example red LED explained that underground tank is empty. Yellow or green LED indicates that overhead tank is empty or full respectively. There is special case, occur when LEDs turned together as flash, this means an error in the sensors signal.

### 3.2.10 Variable Resistance 1K

Used to control the intensity of LCD Lighting.

### 3.2.11 Wires

Used to connect the circuit components.

## 3.3 Welding Process

The welding process include two stage, first stage welding elements on the board, this process will applied to the microcontroller ,driver, LCD display, constant or variable resistances, LEDs and the relay. Taking into account the direction of the parties that will be connected with other elements.

The second stage includes welding elements to each other by connecting wires through the pins designed for that purpose.

### 3.3.1 Microcontroller Welding

The microcontroller is connected to the source (+5V) and the ground through pins VCC and GND respectively. considering port A as input port then PA.1,PA.2,PA.3 connected to the float switch through the resistances 10KΩ,considering port B as output port then PB.2, PB.3 connected to the ULN2003driver,also port C then PC.0, PC.1, PC.2 connected to the LEDs through 330Ω resistances, even port D connected to the LCD display except PD.0 and PD.7.

### 3.3.2 LCD Display Welding

The LCD display is connected with microcontrollers through port D, so that pins D7, D6, D5, D4 connected to PD.6, PD.5, PD.4, PD.3 as data line, while (E) and (R/S) are connected to PD.2, PD.1 respectively, also VDD and Anode connected to the source (+5V), but VSS, R/W, and the Cathode are connected to the ground and (VE) connected to the variable resistance.

### 3.3.3 ULN 2003 Welding

The ULN 2003 driver is connected to the source (+5V) and the ground through pins COM and GND respectively. The input from the microcontroller connected to IN4, IN5 so that the output pin OUT12 connected to the normal open of the rely pin and the output pin OUT13 connected to the buzzer.

### 3.3.4 Relay Welding

The input section has a coil which content two pins, one connected to the source (+5V) and the other pin connected to the microcontroller, the output section consists of contactors which connect the COM to the power supply (220V) and NO connected to the pump.

### 3.3.5 Pump Welding

The pump is connected to the power supply (220V) and the NO pin of the relay.

### 3.3.6 Variable Resistance

The variable resistance has three terminals connected to the source and the ground, while the third terminal connected to the screen.

### 3.3.7 Buzzer Welding

The buzzer is connected to the source (+5V) and the OUT13 pin of the driver.

## 3.4 Welding Test

After completion of the welding process, the welding must be test to ensure that the welding process has the required image was done by direct examination and ensure the safety of the circuit connections by using test equipment such as a voltmeter to check the voltage difference through the circuit elements. Figure (3.2) show the pump control system circuit.

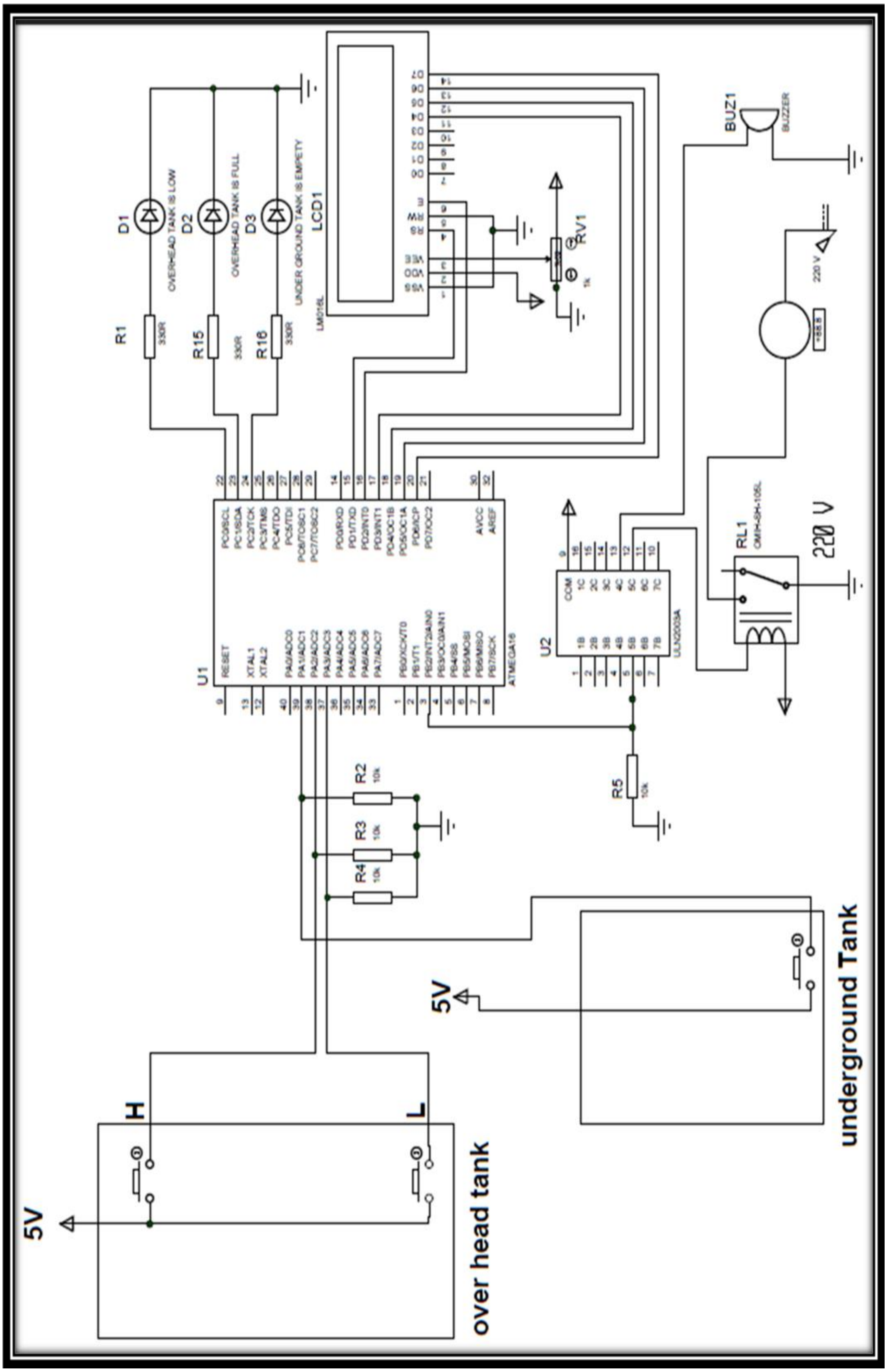


Fig (3.2) Pump control system circuit

## 3.5 Programming Process

Programming is the process of developing and implementing various sets of instruction to enable a programmer device to do a certain task. A sensitive automatic detector of water level through microcontroller as programmer device cans the design process characterized by the following steps:

1. Definition of task.
2. Requirement.
3. Factor that influence choice.

In defining a task, every design comes from an idea or a problem that require a solution. Questions may be generated on what exactly that is required to be achieved and the feasibility of the ideas as regards to the implementation. If these questions are analyzed critically with tangible solutions to the problem, a development of this idea into a reality is the next step. Requirement for design process have to be considered once an idea has been establish. The need to determine whether or not the idea require a computer or not depends on complexity of the circuitry, or whether the circuit to be designed needs to make a complex data. The compare of these factors with topic. Three float switch as the input point to detect the water level at tanks, proportion to the cheap price and its availability, a micro-controller will be the option base on the circuit to be design with less hardware connection and flexibility. The adapter fed the circle through (5V) voltage of which requires a broker to raise the current in order to become enough to run the buzzer and relay for this purpose ULN2003 driver been used. Also it is known that the relay and driver voltages must be equal to the source voltage (5V). This requires 5V relay and ULN2003 driver also. Then the pump consume about 220V this require not only other electric source but also a broker to connect the circuits so that a relay must be used.

## 3.6 Software Design

A set of instructions written for the microcontroller to perform a task is called a program, and a group of programs is called software. Software as whole can be divided into a number of categories base on the type of work done. The two primary software are operating software (system software), which controls the working of the computer, application software, which addresses the multitude of task for which people use computer. Application software, perform word processing, data base management, and the like. Two additional categories that are either system software nor Application software, but contain elements of both, are network software, which enables groups of computers to communicate, and language software, which provide programmers with tools they need to write programs. In addition to these task-based categories, several types of software are described based on their application.

Software development involves series of steps or is a set of activities that are necessary to be taken for the development of reliable and maintenance software; it is of great importance because hardware design cannot be used with micro-controller base system without depending on software. A typical Micro-controller Development Systems (MDS) include, Visual display unit (VDU) registers, read access memory (RAM) which serve as a stone for the Programmable Read Only Memory (PROM) programmer. Software system is the term use to describe a program. That is providing by the manufacturer to aid the development of users (applications) programs. These include programs that convert assembly language into machine code (assembler), or high level language into machine code (interpreter or compiler). It also include programs that facilitate modifications (edition), the computer aided development methodology, which is essential for software development is summarized below.

### 3.6.1 Text Editor

This is kind of word processing that is used. After keying in the used in programs code using the input device and the programs is display on the VDU, the text edition can be used to check and correct errors in the programs. In a nutshell, the text edition is used to edit the programs after it has been written.

### 3.6.2 Translator

There are two types of translators, assembler, interpreter and compiler. An assembler translate assembly language in the form of ammonic (memory aids) into machine code. A good feature of assembler is creating a list that shows the machine code and the assembly language of the programs side by side. A compiler on the other hand translates a high-level language into machine code. An interpreter reads the source code of the programs one line at a time and performs the specified instructions contained in that line.

### 3.6.3 Linker/Locator

This is used to join the different modules that make up the programs together in the correct sequence and this is to be bound to addresses. The linker/locator pair works together to co-ordinate between the separate modules for smooth programs execution.

### 3.6.4 Loader

The loader aids in loading an object code into RAM.

### 3.6.5 Testing

After the programs is written, it was tested, this involve executing the programs with selected input called test cases, the result shows whether or not the program is functioning as desired.

### 3.6.6 Debugging

This involves detecting out and removing errors in the program.

## 3.7 Development Process

In writing the software for this project, a modular approach was employed. This made it easier to check for errors and debug the program. Three major tools were used in the development process; the Basic Compiler BASCOM-AVR compiler was used to translate from the source code into the object code. Universal IC programmer has been used to the microcontroller programming.

## 3.8 Choice of Programming Language

In programming implementation for a microcontroller is BASIC (Beginners All-purpose Symbolic Instruction Code) programming language reasons being the fact that BASIC have several purposes, high-level programming language, also professional language used to write complex and high-level business programs, it  is one of the most popular languages and prevalent in addition the easy to use and learn.

## 3.9 Pump Control System Program Steps

Microcontroller monitor the water level at tanks through three water level sensors, the first at the low level of the underground tank (sensor U), the second at the low level of the overhead tank (sensor L) and the third at the high level of the overhead tank (sensor H) then the microcontroller decide to run the pump or stop it and display the status of water at the two tanks, sensors, and the pump at the display unit, also according to the water level the microcontroller switching the appropriate LED and the buzzer alarm. The operation of pump control system based on the micro-controller and water level sensors is summarized as follows;

- When sensor U is 0 the LCD display (underground tank empty), and the pump is off. With neglecting the status of sensor L and sensor H this is the main condition. The buzzer and red LED will turned on.
- When sensor H and sensor U are both 0 the LCD display (overhead tank is empty), and the pump running.
- When sensor H is 0 and sensor U is 1 the LCD display (overhead tank Quarter level), the pump is off, and yellow LED will turned on.
- When sensor H is 1 and sensor U is 1 the LCD display (overhead tank full), the pump is off, and green and yellow LED will turned on.
- When sensor H is 1 and sensor U is 0 the LCD display (sensors error), the pump is shut down, and all LED will turned on and off for small time.
- Otherwise the pump is shut down. Figure (3.3) show the flow chart that explains the Pump Control System Program Steps.

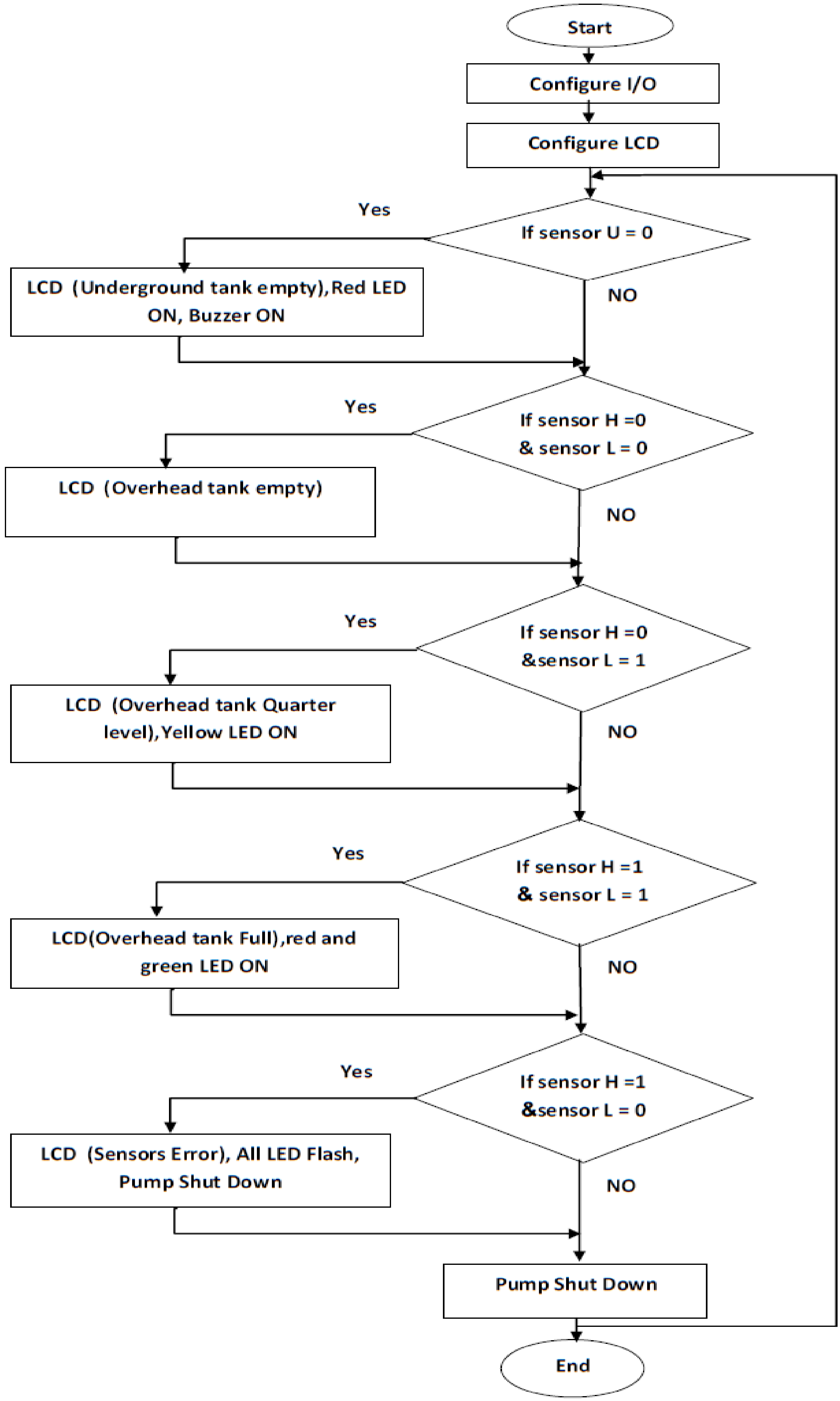


Fig (3.3) The flow chart of the Pump Control System Programming Steps.

# CHAPTER FOUR

# The Results

## 4.1 Results

After the completion of the programming process and testing of the program, comes stage of the overall test to the system to ensure that there is no deviation in the results and then compatibility with the expected design results. Table (4.1) shows the experimental results.

Table (4.1) the experimental results of the system

| NO | Sensors Status U | H | L | Tanks Status Head | Ground | Yellow LED | Green LED | Red LED | Buzzer Status | Pump Status | LCD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | - | Empty | 0 | 0 | 1 | 1 | 0 | Underground tank empty |
| 2 | 0 | 0 | 1 | - | Empty | 0 | 0 | 1 | 1 | 0 | Underground tank empty |
| 3 | 0 | 1 | 0 | - | Empty | 0 | 0 | 1 | 1 | 0 | Underground tank empty |
| 4 | 0 | 1 | 1 | - | Empty | 0 | 0 | 1 | 1 | 0 | Underground tank empty |
| 5 | 1 | 0 | 0 | Empty | Full | 0 | 0 | 0 | 0 | 1 | Over Head Tank Empty |
| 6 | 1 | 0 | 1 | Low | Full | 1 | 0 | 0 | 0 | 1 | Over Head Tank Quarter level |
| 7 | 1 | 1 | 0 | - | Full | 1 | 1 | 1 | 0 | 0 | Sensors Error |
| 8 | 1 | 1 | 1 | Full | Full | 1 | 1 | 0 | 0 | 0 | Over Head Tank Full |

- According to the results table (4.1) in the first four columns when the underground tank is empty (sensor U) is 0, ignored the case of the over head tank as well as (sensor H, sensor L), the red LED and the buzzer are switched on and stop the pump and the LCD display (underground tank empty).figure (4.1) show the status of the LCD display and the red LED.

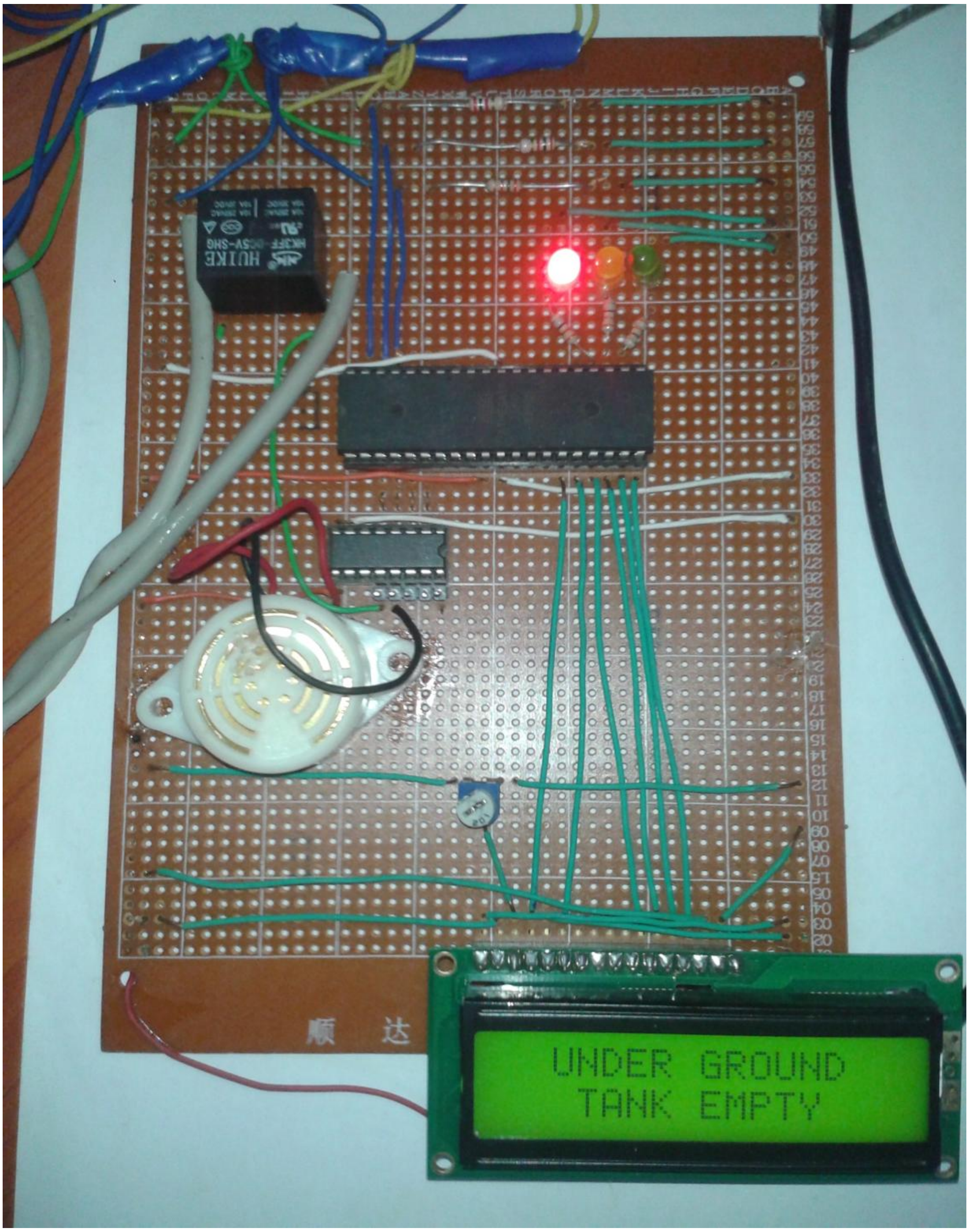


Fig (4.1) show the status of the LCD display and the red LED

* In the fifth columns when the over head tank is empty the pump will start running and the LCD display (over head tank empty), and figure (4.2) show the status of the LCD display and the LED.

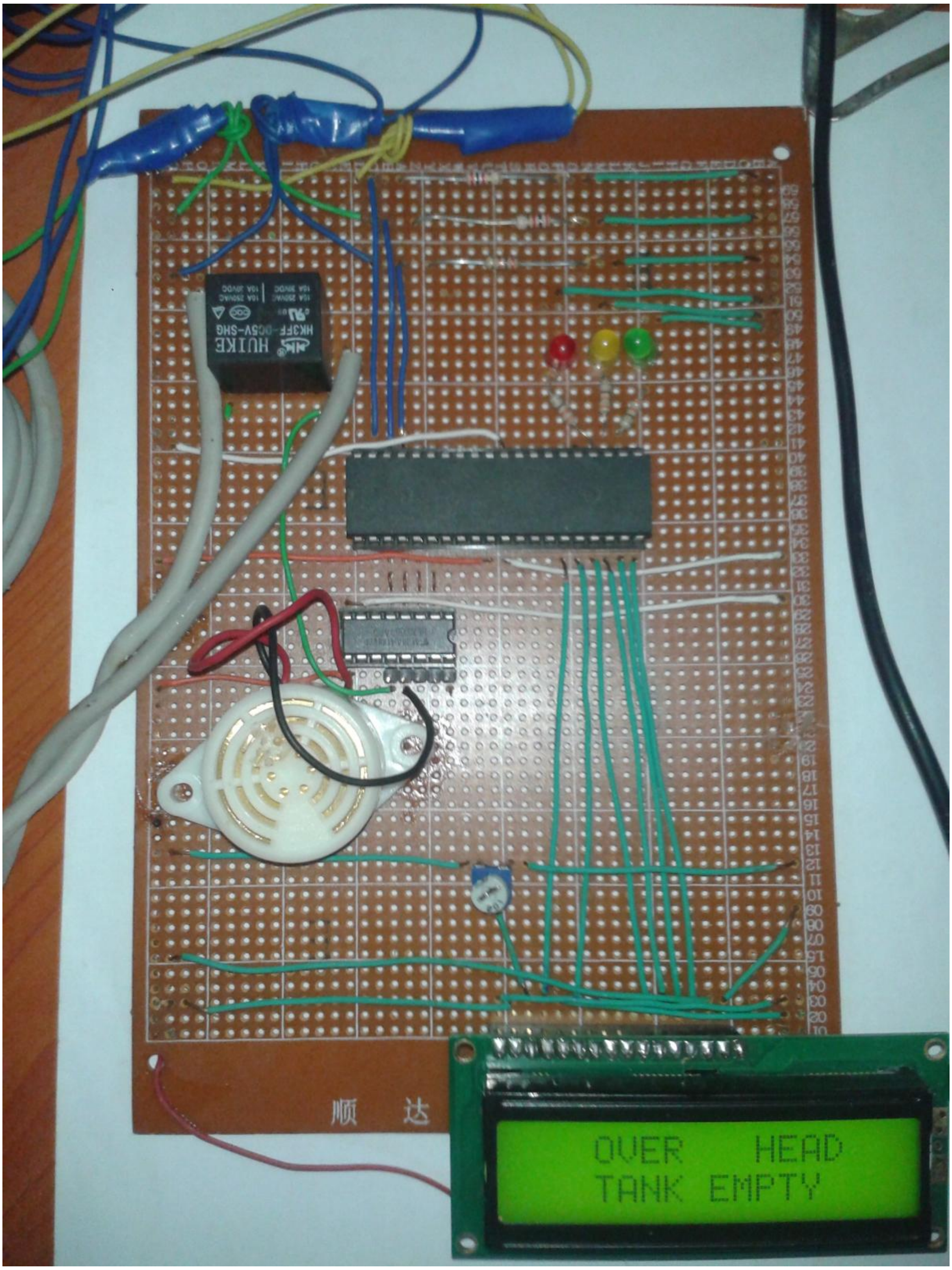


Fig (4.2) show the status of the LCD display and the LED

* In the sixth columns when the water reaches the low level of the over head tank the pump will continue running and the yellow LED is switched on the LCD display (over head tank quarter level).figure (4.3) show the status of the LCD display and the yellow LED.

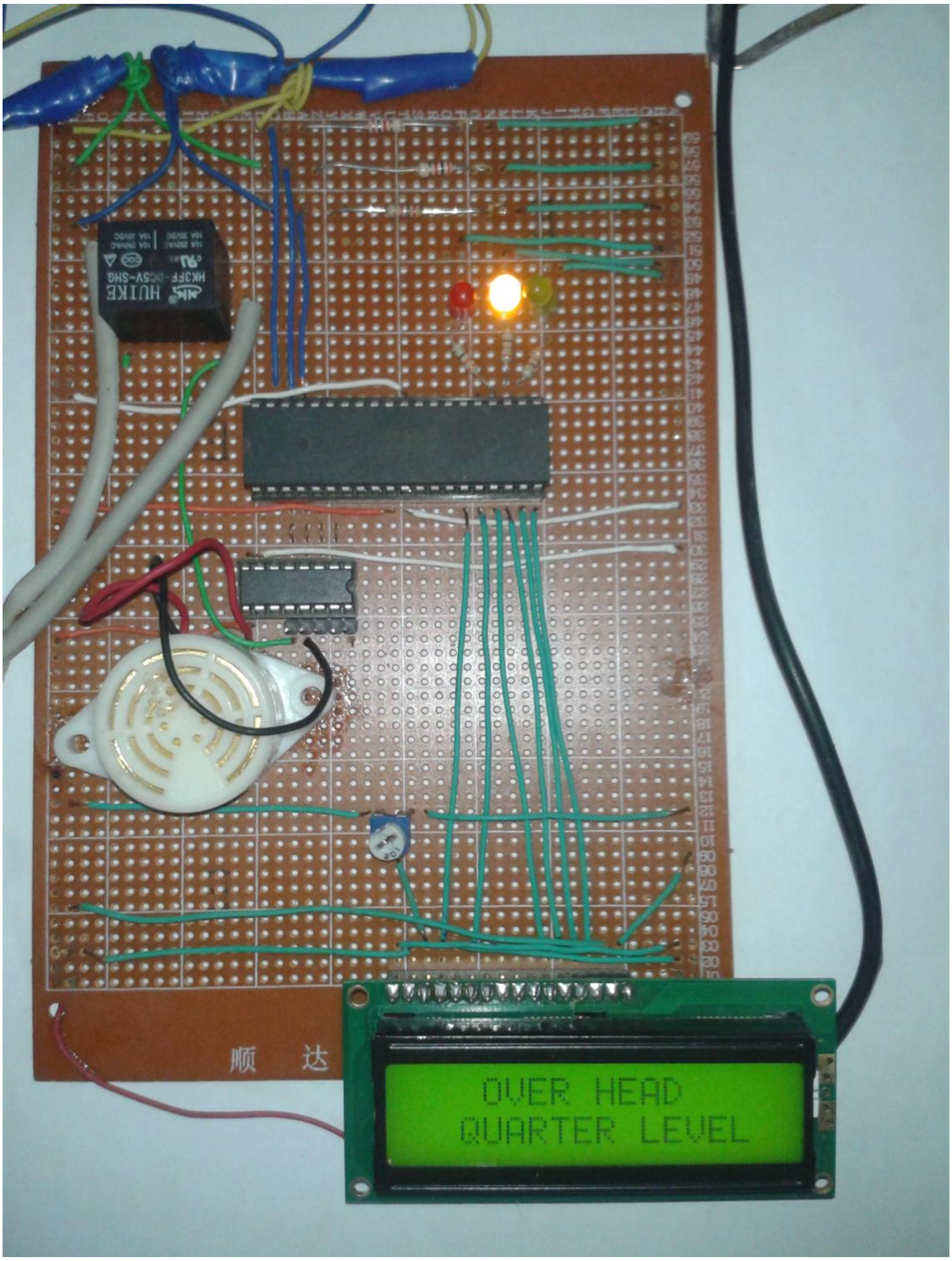


Fig (4.3) show the status of the LCD display and the yellow LED

- In the seventh columns when the water reaches the high level of the over head tank and the water don't reaches the low level of the over head tank the pump will stop running for un expected signal and the all LED is switched on and off looks like flash the LCD display (sensor error!! pump shut down) and the pump will shut down. Figure (4.4) show the status of the LCD display and the LED.

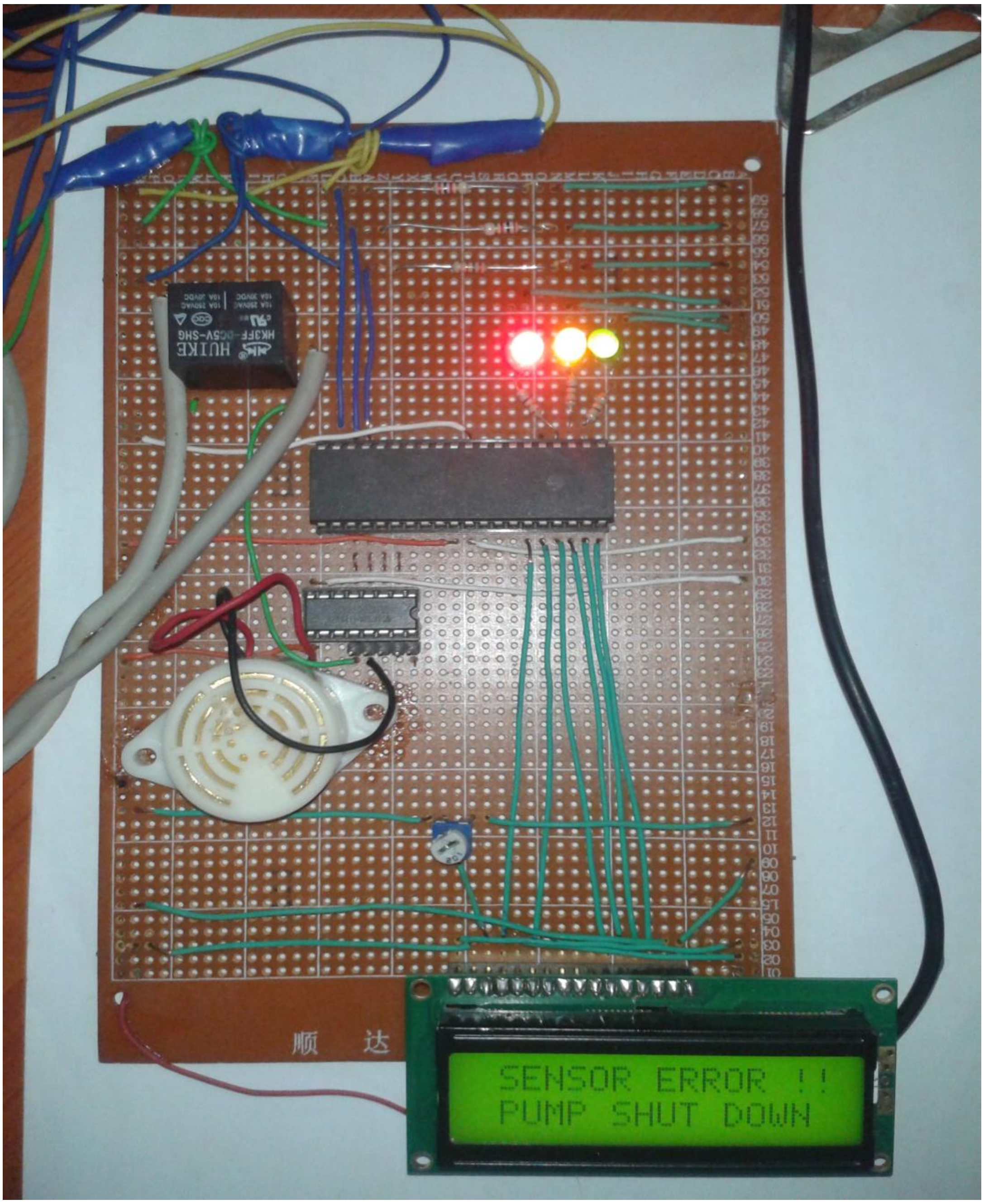


Fig (4.4) show the status of the LCD display and the LED

- In the eighth columns when the water reaches the high level of the over head tank (full) the pump will shut down. And the yellow LED is still on and the green LED is switched on the LCD display (over head tank full) and the pump will shut down. Figure (4.5) show the status of the LCD display and the green LED.

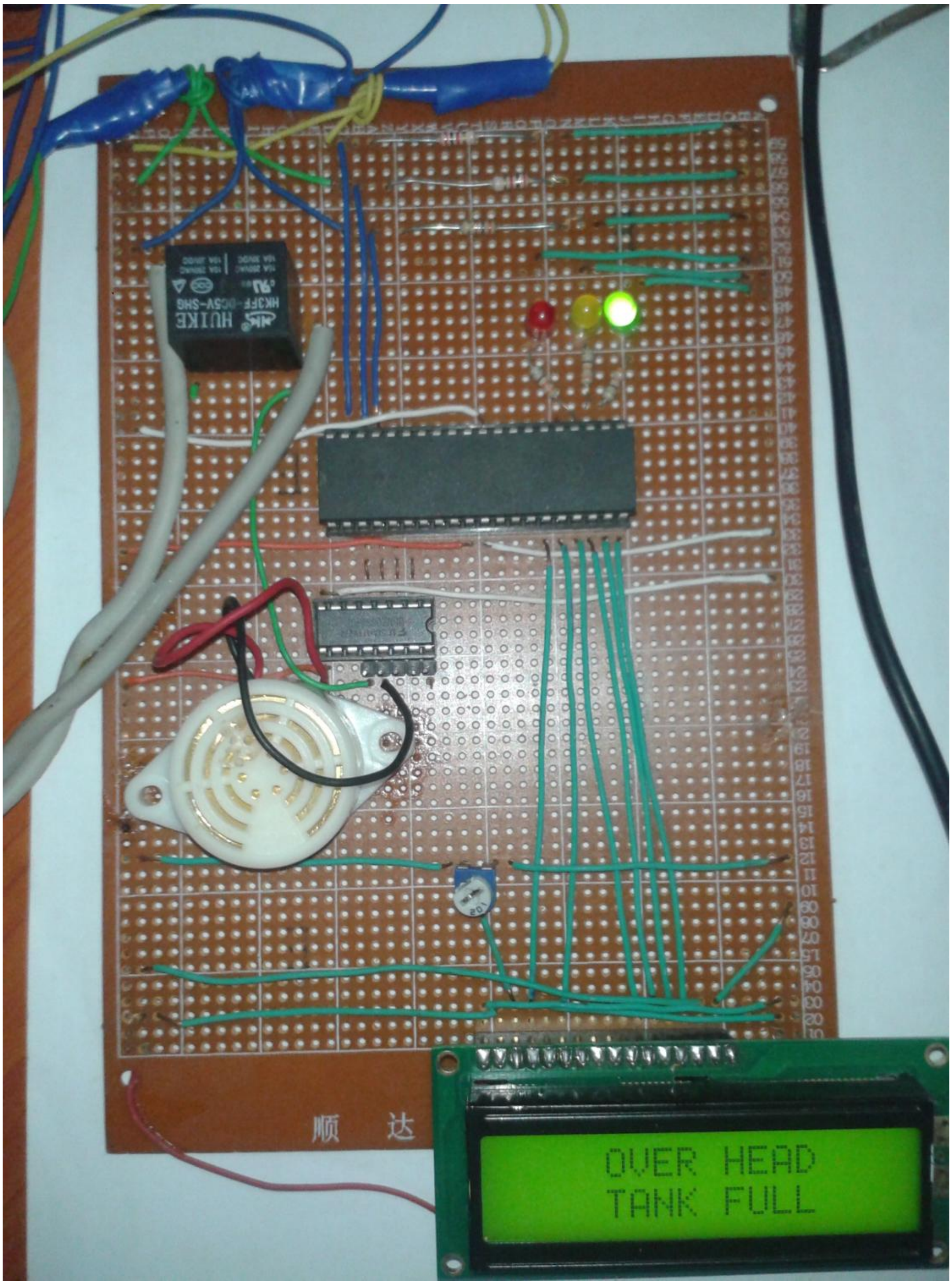


Fig (4.5) The status of the LCD display and the green LED

# CHAPTER FIVE

## Conclusion and Recommendation

### 5.1 Conclusion

Extensive growth of population development and technology has leads to the need of proper utilization of the natural resources especially water. Thus the proposed system and the review of all the possible implementation of technology is the first step toward prevention and proper utilization of water. Automatic water pump control system employs the use of different technologies in its design, development, and implementation. The system used microcontroller to automate the process of water pumping, it is observed that domestic and offices are one of the major areas of water polling. So implementing the low cost easy maintainable system is one among the solutions.

The experimental model was made according to the circuit diagram and the results were as expected. The submersible pump doesn't start until water reaches a certain level in the underground tank, the pump switched ON when the overhead tank was about to go quarter level and switched OFF when the overhead tank is full. Since the pump is not running when the underground tank is empty or the water level is low and operated only in the case of the water reaching the sensor level in the underground tank that leads to a lack of the dry running for the pump thus avoiding the pump self heating, increasing its operating life. And also the pump turned off when the overhead tank is filled or the arrival of the water level in the overhead tank to the upper sensor, this limiting the amount of water flowing from the reservoir after it is full and provides amount of the power that had previously been wasted because of the operation of the pump after the fullness of the overhead tank, As long as the microcontroller operation is to process of the run and stop the pump without the human intervention that reduces safety risks, as well as the effort to process operation and monitoring.

## 5.2 Recommendations

1. The use of wireless sensors or sensor is suitable for operation of centrifugal pumps.
2. The use of PLC

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12. ULN2003A driver data sheet.
13. Relay 5V data sheet.

# Appendix (1)

## The pump control system programme steps

```
$regfile = "m16def.dat"
$crystal = 8000000
Config Pina.1 = Input                          'DANGER LEVEL
Config Pina.2 = Input
Config Pina.3 = Input
Config Portc.0 = Output                         'green
Config Portc.1 = Output                         'yellow
Config Portc.2 = Output                         'red
Config Lcd = 16 * 2
Config Lcdpin = Pin , Db4 = Portd.3 , Db5 = Portd.4 , Db6 = Portd.5 ,
Db7 = Portd.6 , E = Portd.2 , Rs = Portd.1
Config Portb.2 = Output                         'relay
Config Portb.3 = Output                         'buzzer
Cls
Cursor Off
Locate 1 , 1
Lcd "PUMP CONTROL ..."
Wait 2
Cls
Portc.0 = 1
Portc.1 = 1
Portc.2 = 1
Wait 1
Portc.0 = 0
Portc.1 = 0
Portc.2 = 0
Do
```