USMANU DANFODIYO UNIVERSITY, SOKOTO

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DESIGN AND CONSTRUCTION OF A MICRO-CONTROLLER BASED AUTOMATIC FIRE EXTINGUISHING SYSTEM

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CERTIFICATION

This Dissertation by Rilwanu Bello has met the requirements for the award of the Degree of Master of Science (Physics) of the Usmanu Danfodio University, Sokoto, and is approved for its contribution to knowledge.

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DEDICATION

This dissertation is dedicated to the almighty Allah, who gives me the knowledge and all the necessary requirements to reach this level of education.

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ABSTRACT

Despite many buildings have fire fighting systems installed in them; many people are still losing their lives and properties due to fire accidents. In this research, an automatic cost effective device for the detection and control of fire has been designed and constructed. The system has an additional feature of sending signal to a pump/sprinkler through a relay. It is made up of two sensors, microcontroller, buzzer and a controlled fire fighting equipment (pump/sprinkler). LM 35 IC has been used as temperature sensor while MQ-2 gas sensor has been used as smoke sensor. All sensors are connected to the microcontroller through an input/output port. The controlling software for the whole system was designed in C programming language. The popular high performance, low power 8-bit microcontroller from the AVR family microcontrollers was used. The system was finally tested by introducing fire parameters (smoke and temperature) close to the detectors. When the parameters go above the set level in the detectors, audio alarm, LED indicator and pump/sprinkler were activated. The measured temperature of the system was compared with the reference temperature. The result showed that there was a mean deviation of 1.55^0C between the measured values and reference values which served as the control.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The need for early fire detection is paramount in protecting human life and property as fire disaster is a great threat to lives and properties**.** Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and smoke. It is understood that every fire start with a smoke and heat. A key subject of interest to many researchers has thus been on fire fighting systems. More interest has been given on automation of these systems to allow fire fighting operation be less dependent on human support. Automated fire fighting system, which depends on temperature and smoke sensing devices, is used in many industrial and commercial applications. It is however true that in most cases sensible heat often occurs after great destruction has occurred and thus the use of smoke sensors need not be ignored at any point whatsoever. A number of fire detectors have been designed that can be installed within buildings. Among these types of sensors, the smoke sensor is widely used because of its early fire detection capability and its relatively low cost (Richard et al., 1998). However, although this sensor provides rapid response time, it has high false-alarm rates. In contrast, the temperature sensor provides more reliable responses but with slow response time. Fire detectors that use a single sensor may fail to activate when required or may cause false alarms. Therefore, a fire detecting system that uses a combination of smoke and temperature sensors will not only provide better smoke sensor compensation but also provide a more intelligent fire control system (Cheon *et. al.*, 2009).

The need to safeguard lives and properties from fire disasters has led to the invention of an automatic fire control system using a smoke detector, a heat detector and an automatic sprinkler (Bukowski *et. al.*, 1999). Automatic fire alarm system provides an immediate surveillance, monitoring and automatic alarm. It sends early alarm when the fire occurs and helps to reduce the damage (Zhang and Wang, 2009). A smoke and heat detector is one of the numerous ways of detecting fire outbreak at an early stage, while a water sprinkler is the most common way of extinguishing fire. An automatic fire control system is an electronic circuit designed to control a sprinkler which produces water or any extinguishing element, when it detects the presence of smoke and excessive heat (Bukowski *et. al.,* 1999).

The automatic fire control system brings out efficient automatic fire detection and extinguishing system. The fire detection sensors will sense the occurrence of fire, by monitoring smoke and heat, which automatically generate a signal to interrupt the microcontroller which is connected to a buzzer and a pump. Suddenly after detecting the fire, the buzzer automatically sounds to indicate the presence of fire and starts the relay which runs a pump and pressurizes the extinguishing element to suppress the fire using water sprinkler. The role of the control unit in improving fire detection and control capability has already been recognized, with a system using control unit for decision making being one of two main versions of intelligent fire detection systems (Liu *et. al.,* 2008).

Automatic fire control systems have been made and installed in our buildings, which performed its specific functions accordingly. Both system activation (detection) and notification (alarm) must occur to achieve early warning (Bukowski *et. al.,* 1999).

1.2 Statement of the research problems

The need for people to protect their lives and properties from fire disaster cannot be overemphasized. Today, the incidence of fire outbreak in our homes, offices and industries are increasing. An uncontrolled fire can destroy an entire room contents within few minute and completely burn out a building in a couple of hours. Most of the fire outbreaks occur when the occupant is not at home or sleeping. As these problems need instant human intervention to avoid it, automatic fire detection and control system become necessary in our buildings. The majority of fire fighting systems are manually operated, which cannot be reachable during fire outbreaks. Manual fire fighting systems, though are relatively cheap and do not require any power supply are however associated with the problem of non-controlling fire outbreak without human intervention. Furthermore, the automatic fire control systems available in modern buildings are very expensive and not affordable by most people, hence, the need for designing and constructing a cost effective automatic fire control.

1.3 Objectives of the research

The main aim of this research work is to design and construct a cost effective automatic fire control system.

To achieve this, the following objectives would be accomplished:

- Design and construct a smoke sensing device.
- Design and construct a threshold temperature sensing device.
- Design and construct a control device to switch pump/water sprinkler.
- Develop a computer program (software) to control the constructed system.
- Produce an affordable automatic fire control system.

1.4 Significance of the study

Automatic fire control system finds application in every building that stands the risk of fire outbreak. These includes homes, filling station, large and small scale industries, store houses, school campus, airports, hospitals just to mention a few. Most of the fire fighting systems in Nigeria is manually operated. These systems, is mostly not very effective as fire incidents are often not detected early enough. In some cases the places requiring fire extinguishing are difficult to reach making it impossible for fire fighters. The main reason is manual operation of these systems which causes great challenge in their operation during fire accidents especially when they are located inside the building. System that detects fire parameters, give audio warning, activate water sprinkler will be a reliable system to control the fire accident. All these are the key subject of this research.

1.5 Scope and Limitations

This research work undertakes the design and construction of an automatic fire control system, capable of detecting smoke and heat. It involves design of various units: power supply, sensing and control units.

However, it is hardly that anyone’s research is a complete study of any problem, let alone a postgraduate research work of this nature which is considerably limited by time and resource. This is why the system was constructed with materials that are cheap and readily available thereby making the cost of the system low and easily acquired. This will enable the use of the system throughout every category of person and firm. Coupled with the low cost, the size of the system is also small enough for convenience in installation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Development of Fire Fighting

Fire protection systems are those systems put in place to prevent or mitigate the unwanted effects of fire. According to the National Fire Protection Association (NFPA), United States, about 3,000 people die in the United States from home fires every year. Most of these deaths could be prevented if the proper fire protection systems were put in place. Not only do fire protection systems save lives, they also safeguard property (John and Hall, 2010). Fire control was quite undeveloped until the 17th century, the key advance in fire controlling arrived in the 17th century with the first fire engines. Manual pumps, rediscovered in Europe were only force pumps and had a very short range due to the lack of hoses (Paulison, 2005). German inventor Hans Hautsch improved the manual pump by creating the first suction and force pump and adding some flexible hoses to the pump. In 1672, Dutch artist, and inventor Jan Van der Heyden's workshop developed the fire hose. Constructed of flexible leather and coupled every 50 feet (15 m) with brass fittings. The length remains the standard to this day in mainland Europe whilst in the United Kingdom the standard length is either 23m or 25m (Paulison, 2005). The fire engine was further developed by the Dutch inventor, merchant and manufacturer, John Lofting (1659–1742) who had worked with Jan Van der Heyden in Amsterdam (Paulison, 2005). In the United Kingdom, The first horse-drawn steam engine for fighting fires was invented in 1829, but not accepted in structural fire fighting until 1860, and ignored for another two years afterwards. Internal combustion engine fire engines arrived in 1907, built in the United States, leading to the decline and disappearance of fire steam engines by 1925 (Paulison, 2005).

The first automatic electric fire alarm was invented in 1890 by Francis Robbins Upton (US patent no. 436,961). Upton was an associate of Thomas Edison, although there is no evidence that Edison contributed to this project. In the late 1930s the Swiss physicist Walter Jaeger tried to invent a sensor for poison gas. He expected that gas entering the sensor would bind to ionized air molecules and there by alter an electric current in a circuit in the instrument. His device failed, small concentrations of gas had no effect on the sensor's conductivity. Frustrated, Jaeger lit a cigarette and was soon surprised to notice that a meter on the instrument had registered a drop in current. Smoke particles had apparently done what poison gas could not; Jaeger's experiment was one of the advances that paved the way for the modern smoke detector. The first truly affordable home smoke detectors were invented by Duane D. Pearsall and Stanley Bennett Peterson in 1965, featuring individual battery powered units that could be easily installed and replaced. The first units for mass production came from the manufacturing mind of Stanley B. Peterson in 1975 at Duane Pearsall’s company in Lakewood, Colorado.

2.2 Automatic Fire Control Systems

Automatic fire protecting systems control and extinguish fires without human intervention. Although man has fought fire for centuries, the first fire extinguisher of which there is any record was patented in England in 1723 by Ambrose Godfrey. The world’s first recognizable sprinkler system was installed in the Theatre Royal, Drury Lane in the United Kingdom in 1812 by its architect. The system was designed by Sir William Congreve. From 1852 to 1885, perforated pipe systems were used in textile mills throughout New England as a means of fire protection. However, they were not automatic control systems; they did not turn on by themselves. Inventors first began experimenting with automatic sprinklers around 1860. The first automatic sprinkler system was patented by Philip W. Pratt of Abington, MA, in 1872. Henry S. Parmalee of New Haven, Connecticut is considered the inventor of the first automatic sprinkler head. Parmalee improved upon the Pratt patent and created a better sprinkler system. In 1874, he installed his fire sprinkler system into the piano factory that he owned. His piano company The Mathushek Piano Manufacturing Co, is credited as being the first building in the United States to be equipped with a fire suppression system (automated sprinkler system). Frederick Grinnell improved Parmalee's design and in 1881 patented the automatic sprinkler that bears his name. He continued to improve the device and in 1890 invented the glass disc sprinkler, essentially the same as that in use today. Until the 1940s, sprinklers were installed almost exclusively for the protection of commercial buildings, whose owners were generally able to recoup their expenses with savings in insurance costs. Over the years, fire sprinklers have become mandatory safety equipment in some parts of North America, in certain occupancies, including, but not limited to newly constructed hospitals, schools, hotels and other public buildings, subject to the local building codes and enforcement.

A lot has been done in the design of different types of sensors that can be used to detect fire component but less has been done in the development of automatic fire fighting systems. Angus, (2002) designed an intelligent fire alarm system that utilized heat, smoke and infrared sensors. His aim was to reduce the trouble produced by smoke sensors in areas where smoke is common such as in a kitchen. Jimmy and Yang, (2004) designed a security system that incorporated smoke, heat and motion sensors. Detected heat, smoke or motion triggered the alarm that notified people within the building. Gabriele *et. al.,* (2009) presented the characterization of panels for fire protection made with new composite materials based on basalt fibres and both organic and inorganic impregnating matrix. In their research they found that basalt-composite presented low wall temperature and good residual strength which retards the panel failure. On the other hand Dongil and Lee, (2009) also presented an image processing technique for automatic real time flame and smoke detection in tunnel environment. They used colour and motion information to minimize false detections in tunnels which enabled detection of exact position of an event at an early stage. These researches were mainly geared towards detection of fire rather than automating the extinguishing systems. According to fire report on fire protection in World Trade Centre, United States, fire sprinkler systems that were installed in buildings depended on manually operated pumps (David *et. al.*, 2005). This clearly shows how difficult such systems are to operate whenever fire breakout. Despite these, there are however few automated fire fighting systems in the market employing the use of heat sensitive glass bulb fixed on the nozzle and containing liquid which expands and breaks when ambient temperature is reached thus releasing extinguishing agents such as gas or powder for gas sprinklers and water for water sprinklers (Craighead, 1996). These devices are sensitive to heat and not smoke. The main challenge to this is the fact that more often earlier signs of fire are smoke. In addition when these glass bulbs are broken they are irreversible thus extinguishing agent run continuously even after fire has been fully put off making it very costly.

2.3 Automatic Control Systems

With the advancement of computer technologies, instrument control has been made possible to control system or process without human intervention. For instance, Carlton and Rafic, (2004) designed a feedback control system that regulated temperature of a process at a desired set point. In their design they used LabVIEW as the control software. Their designed system consists of a PC-based data acquisition unit that provides input and output interfaces between the PC, the sensor circuit and hardware. Obanda, (2010) also developed a microprocessor-based system for monitoring and control of temperature, humidity, and light level in a green house. The developed system was based on the microprocessor; the hardware consists of a humidity sensor, an LM 35 temperature sensor and two analogues to digital converters, a clock with reset circuitry, 7-segment displays and LEDs.

Qayum *et al.,* (2012) Designed and created a functional microcontroller based smoke and temperature detectors which after detecting smoke or a high temperature (potential fire), sets an appropriate alarm sound. The detectors also transmit an RF signal to the other smoke detectors in the network so that those detectors, in turn, sound their alarm. Also a similar research was conducted where an automatic fire detection and notification system in trains was developed to help in notifying the passengers and emergency services. The designed system consists of a microcontroller which is interfaced with the GPS module, GSM modem and fire sensors. Once the sensors attached in the compartments of train senses the smoke detection, it assumes a fire accident (Teja, and Angadi, 2013). Borrowing their idea in automatic fire detection and control will be of great importance for this research. In this research, a microcontroller based fire detection system that transmits a signal to turn on a sprinkler is the main target.

2.4 Microcontrollers

A microcontroller is a single integrated circuit, have some important features. Central Processing unit ranges from 4 bit processor to 32 or 64 bit processors. It has Volatile RAM for data storage, ROM, EPROM, EEPROM, Flash memory for programming as well as storage of the processing parameters, Bi-directional I/O pins allowing control and detection of logic state, UART, Serial communication Interfaces, Serial peripheral interface and controller area network for system interconnect, peripherals like timer, counter, PWM generator, watchdog timer, clock generator, ADC, DAC and finally in circuit programming and debugging support (Kumar, *et. al.,* 2013). 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. In general, a microcontroller contains a relatively inexpensive microprocessor core with a complement of on board peripherals that enable a very compact, complete, computing system on a single chip. There is a vast array of single chip microcontrollers on the market that integrate quantities of both RAM and ROM on the same chip along with basic peripherals including serial communication controllers, timers, and general input/output pins.

With the advancement of semiconductor fabrication technology manufacturers are able to integrate memory, input/output interfacing circuits, Timer, Serial Com port and Analogue to Digital Converter and other peripherals into the microcontroller. Thus it is essentially an entire chip fabricated on a single chip. The single chip microcontrollers are used in consumer products like washing machines, copiers, AC machines, printers etc., high speed data processing like video conference, real time compression and security system. Different industrial applications like AC and DC motor Drives, position control, motion control etc. Due to integration of all function blocks on a single chip microcontroller IC, the sizes of control board and power consumption are reduced; system reliability increased and also provides flexibility (Kumar, *et. al.,* 2013). The other advantages of using such microcontroller based systems are easy troubleshooting and maintenance. All of the above mentioned fields of applications depend on the several factors of choosing the right microcontroller unit for specific applications.

Selecting the right microcontroller for a system can be a daunting task. Not only the number of technical features to consider, there are also business case issues such as cost, availability, and flexibility that can cripple this research project. At the start of a project there is a great temptation to jump in and start selecting a microcontroller before the details of the system has been analyzed out. There are several types of microcontrollers used in practice but three types are well-known and easy to work. The following Criteria for choosing a microcontroller need to be considered.

- Meeting the computing needs of the task at hand efficiently and cost effectively.

- Availability of software development tools, such as compilers, assemblers, and debuggers.
- Wide availability and reliable sources of the microcontroller.

2.4.1 Types of microcontroller

There are several vendors manufacturing different architectures of microcontroller. Microcontrollers are classified based on their architecture. The most common types of architecture are; AVR, Freescale's 6811, PIC from Microchip Technology and Intel 8051 are four major 8-bit microcontrollers. Due to their unique instruction set and register set they are not compatible with each other. Program written for one will not run through the other microcontroller from other manufacturers. The features of commonly use microcontrollers are tabulated in table 2.1

Table 2.1: Features of some microcontrollers

Microcontrollers	Features
Intel 8051	It is under 8-bit Microcontroller family. Rom ranges from None to 8KB, RAM Size of 128 or 256 bytes (depending on the specific part number). Clock frequency is up to 12 MHz. Ultra violet light erases data and special electrical programmer writes new data. Architectures consist of four bi-directional I/O ports of 8 bits each.
Microchip PIC16C5X/XX	This 8 bit microcontroller family is manufactured by Microchip Technology. Though lower running clock frequency saves energy but maximum clock speed is limited to 40 MHz. Architecture includes 512 bytes to 2K bytes of ROM, 25 to 73 bytes of RAM, 8 bit real time counter, programmable sleep mode and watchdog timer.
Freescale 68HC11	This is under another 8 bit microcontroller family. Either UV erasable or electrically erasable ROM is used here. RAM is in the order of none

	to 768 bytes of size. They run at clock speeds range up to 3 MHz. Eight 8 bit A to D converters are also embedded for monitoring analog signals.
Atmel AT89CXXXX	ROM used here are of Flash type and size ranges from 1KB to 8 KB. To 256 bytes of RAM. Maximum clock speed is up to 20 MHz. They have 15 to 32 number of bi-directional I/O pins, 1 to 3 number of Timers, 3 to 8 numbers of Interrupts.

2.4.2 Programming microcontroller

Microcontroller programs must fit in the available on-chip program memory, since it would be costly to provide system with external, expandable, memory. Compilers and assemblers are used to run high-level language and assembler language codes into compact machine code for storage in the microcontroller’s memory. Depending on the device, the program memory may be permanent, read-only memory that can only be programmed at the factory, or program memory may be field-alterable flash or erasable read-only memory.

2.4.3 AVR Microcontroller

The AVR is a modified Harvard architecture 8-bit RISC single chip microcontroller which was developed by Atmel. The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to one-time programmable ROM, EPROM, or EEPROM used by other microcontrollers at the time.

The ATmega48P 88P 168P 328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48P/88P/168P/328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed (Chauhan and Semwal, 2013). ATMEGA microcontroller of AVR family was used in the design of smart traffic light control. The designed system controls the traffic light for emergency vehicles and to avoid congestions caused by traffic jams, in this design microcontroller control distance sensor and counts number of vehicles. Based on different vehicles count microcontroller takes decision and updates the traffic light delays (Maqbool et al., 2013). The ATmega microcontroller was also used on the elementary neuron network that used Habbien learning in training a robot to respond to the environment implementing artificial intelligence in robot. The implemented system (robot) tested with an ability to move forward and backward according to intensity of light without human intervention and external computers (Ganotra et al., 2012). The same AVR series of microcontroller was used to control the speed of geared DC motor through RS-232 connector. This was developed using AVR series of microcontroller (ATMEGA16) because of its inbuilt ADC port and its variable frequency.ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed. Further it also minimizes the cost of this research project (Chauhan and Semwal, 2013). The same microcontroller was embedded in the design of a microcontroller based single phase digital prepaid energy meter, they have proposed an ATmega microcontroller from the Atmel AVR family because of its performance, power efficiency and design flexibility (Haque et al, 2011).

2.4.4 Specifications of the Atmel microcontroller

- High Performance, Low Power AVR 8-Bit Microcontroller
- Operating speed: DC - 40 MHz
- 16K Bytes of In-System Self-Programmable Flash program memory
- 512 Bytes EEPROM
- 1K Bytes Internal SRAM

- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85°C/100 years at 25°C
- Two 8-bit Timer/Counters
- One 16-bit Timer/Counter
- Operating voltage range: 2.0V to 7.5V
- Low power consumption: 2 mA typical at 7.5V, 4 MHz and 0.5 mA typical standby current at 2V

2.4.5 Programming AVR microcontroller

There are many means to load program code into an AVR chip. The methods to program AVR chips vary from AVR family to family. The in-system programming (ISP) programming method is functionally performed through SPI plus some twiddling of the Reset line. As long as the SPI pins of the AVR are not connected to anything disruptive, the AVR chip can stay soldered on a PCB while reprogramming. All that is needed is a 6-pin connector and programming adapter. This is the most common way to develop with an AVR. The Atmel AVR ISP device connects to a computer's USB port and performs in-system programming using Atmel's software. AVR Downloader/Up loader runs on Linux, Windows, and Mac OS, and supports a variety of in-system programming hardware. The system software was implemented by C language and the developed code is edited, compiled and debugging by Win-AVR (Haque et al, 2011).

2.5 The power supply unit

The analysed automatic fire control system requires a DC voltage source for its operation. The power supply system requires two outputs: A 5V output each required to supply the microcontroller, smoke sensor, temperature sensor and 12V output required by the relay for the DC pump. The electricity supply from the national grid is an alternating current (AC). An alternating current (AC) power supply usually uses a transformer to convert the voltage from the wall outlet (mains) to a different, nowadays usually lower voltage. If it is used to produce direct current (DC), a rectifier is used to convert alternating voltage to a pulsating direct voltage, followed by a filter, comprising one or more capacitors, resistors, and sometimes inductors, to filter out (smooth) most of the pulsation (Adejumobi et al., 2012).

From the analysis for the whole system, a direct current (DC) voltage is needed to power the complete hardware of the system. A regulated and low ripple DC voltage will be the appropriate voltage to power an automatic control system. The idea of regulating and smoothing DC voltage was gathered from (Mitra and Roy, 2013). Where a high regulated low ripple DC power supply was design and tested. The designed DC power supply comprises of transformer, rectifier, filter and regulator. Also a similar idea was brought up in the development of multi AC/DC power supply system for domestic and laboratory use. The developed system was tested and outputted different values of voltages (Adejumobi et al, 2012).

2.6 Temperature sensors

A temperature sensor is a heat detection device designed to respond when the radiated thermal energy of a fire increases the temperature of the heat sensitive elements. The thermal mass and conductivity of the element regulate the rate of heat flow into the element. Heat detectors are classified into two, based on their operations as rate-of-rise and fixed temperature. Temperature sensors are the core part of any thermal management system, therefore the proper selection of high temperature detecting component has been recognised as a key improvement in detecting fire (Bota *et. al.*, 2005). In this modern world of technology there are many integrated circuits that serve as temperature sensors use for embedded designs. Several temperature sensors based on semiconducting materials has been overviewed by (Yadav *et. al.*, 2006). The different types of temperature sensors overviewed are based on their operations. Selecting the appropriate temperature sensor will be the major challenge; cost, availability, accuracy, flexibility and fast response time are main specifications to be considered in selecting a temperature sensor. A simple and efficient built-in temperature sensor for thermal monitoring of standard cell circuits was presented. The presented smart temperature sensor was made up with a ring oscillator composed of complex gates, which is integrated as single chip (Bota *et. al,* 2005). Fast response time will be of great concern in choosing temperature sensor. (Mohammed *et. al.,* 2010) conducted a research on thermal product of fast response temperature sensors for transient heat transfer applications, where they used sensor that has fast response time. This idea will be applicable in this research work. Several temperature sensing techniques are currently in widespread usage. The most common of these are Resistor Temperature Dependent (RTDs), thermocouples, thermistors, and sensor ICs. The choice of any temperature sensor depends on the required temperature range, linearity, accuracy, cost, features, and ease of designing the necessary support circuitry (National semiconductor, 1997). In the following section, the characteristics of the most common temperature sensing techniques will be discussed.

2.6.1 LM 35 Temperature sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy (Yadav *et. al.,* 2006). It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range (National semiconductor, 2010). The same idea, (Obanda, 2010) also used LM35 integrated chip as a temperature sensing device, in his design of a microprocessor-based system for monitoring and control of temperature, humidity, and light level in a green house.

2.6.2 Specifications of LM 35 Temperature sensor

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guarantee (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 20 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±1⁄4°C typical
- Low impedance output, 0.1 W for 1 mA load

2.7 Smoke detectors

A smoke detector is a device that detects smoke, typically as an indicator of fire. Commercial, industrial, and mass residential devices issue a signal to a fire alarm system, while household detectors, known as smoke alarms, generally issue a local audible or visual alarm from the detector itself. Most smoke detectors work either by optical detection (photoelectric) or by physical process (ionization), while others use both detection methods to increase sensitivity to smoke (Ahrens, 2008). The accuracy of smoke detectors is an important consideration in assessing the performance of a fire detection system. The performance of ionization and photoelectric smoke alarms in various fire scenarios has been the great concern in detection part of the automatic fire control system (Cleary, 2009). Studies that have investigated flaming and smouldering fire scenarios have observed that in general, ionization smoke detectors sense flaming fires sooner than photoelectric smoke detectors, while photoelectric smoke detectors sense smouldering fires typically much sooner than ionization smoke detectors Both photoelectric and ionization smoke alarms provided warning early enough to provide the necessary escape time in most scenarios with ionization reacting more quickly to flaming fires and photoelectric operating faster to smouldering fires. These observations suggest that in order to achieve a higher level of performance from ionization or photoelectric sensors, a combination of these two types of smoke detectors will be the solution (Cleary, 2009).

2.7.1 Photoelectric smoke detector

Smoke produced by fire affects the intensity of light beam projected across it. It can block or cause the light to scatter due to reflection of the smoke particles (System sensor, 2001). The photoelectric smoke detector was selected to be a suitable detector for the wireless control system for smoke and fire detection because these detectors react quickly to visible smoke particles from smouldering fires, but are less sensitive to the smaller particles associated with flaming or very hot fires. In a photoelectric smoke detector, a light source and light sensor are arranged so that the rays from the light source do not hit the light sensor (Qayum et al, 2012). Photosensitive materials such as light dependent resistors (LDR) use this property to sense the presence or absence of light. LDR is a simple resistor whose resistance changes depending on the amount of light falling on it. Its resistance varies inversely to the amount of light incident upon it.

The resistance of an LDR is given by equation 2.1 (Salamanca, 2005).

$R=bE-\gamma$-- (2.1)

Where: b is a constant that depends on the composition and geometry of the LDR and γ is a dimensionless parameter that measures the variation of the resistance with the illumination E produced by light source. Theoretically, an ideal LDR would have $\gamma = 1$.

2.7.2 Ionization smoke detector

Ionization smoke detectors mostly use radioactive materials. A typical ionization chamber consists of two electrically charged plates and a radioactive source (typically Americium 241) for ionizing the air between the plates. The radioactive source emits particles that collide with the air molecules and dislodges their electrons. As molecules lose electrons, they become positively charged ions. Molecules that gain electrons become negatively charged ions. Equal numbers of positive and negative ions are then created. The positively charged ions are attracted to the negatively charged electrical plate, while the negatively charged ions are attracted to the positively charged plate. This creates a small ionization current that can be measured by electronic circuitry connected to the plates. Particles of combustion are much larger than the ionized air molecules. As these particles enter an ionization chamber, ionized air molecules collide and combine with them. Some particles become positively charged and some become negatively charged. As these relatively large particles continue to combine with many other ions, they become recombination centres, and the total number of ionized particles in the chamber is reduced. This reduction in the ionized particles results in a decrease in the chamber current that can then be detected by electronic circuits designed.

2.7.3 Pinnacle laser technology smoke detector

The Pinnacle Laser Smoke Detector is a device that senses the earliest particles of combustion. Like an ionization detector, Pinnacle quickly senses a fast flaming fire. Like a photoelectric detector, it quickly senses a slow-smouldering fire. But unlike these detectors, Pinnacle can quickly identify both types of fire. Pinnacle operates on the same principle as a photoelectric detector. When a particle of combustion crosses the light beam, it causes the light to scatter which signals the alarm. But the difference between an LED (light emitting diode) beam and a laser beam is the sharpness of their beam; laser beam is sharper than that of light emitting diode (System sensor, 2001). Laser technology gives you fast response detection in high sensitivity applications such as clean rooms, telecommunications centres or computer rooms

2.7.4 MQ-2 Smoke Detector

Gas Sensor (MQ2) module is useful for gas/smoke detecting. Based on its fast response time, measurements can be taken as soon as possible. Also the sensitivity can be good enough. This detection method, when combined with an efficient housing design, samples air passing through the duct allowing detection of a developing hazardous condition. When sufficient smoke is sensed, an alarm signal is initiated and appropriate action can be taken to shut off fans, blowers, change over air handling systems, etc. These actions can facilitate the management of toxic smoke and fire gases throughout the areas served by the MQ-2 system (System sensor, 2012). These new technologies and concepts will improve the capability of fire detection systems to discriminate between fire and non-fire threats and will increase the time available for property and life protection.

2.7.5 Specifications of the MQ-2 smoke detector

- Operating Temperature: –4° to 158° F (–20° to 70° C)
- Storage Temperature: –22° to 158° F (–30° to 70° C)
- Humidity: 0% to 93% Relative Humidity Non- condensing.
- Weight: 1.8 pounds; 0.82 kg
- Power supply voltage: 3.5-5.5 Volts DC
- Alarm response time: 15 sec.

Peak standby current:	120µA
Average standby current:	60µA
Max. alarm current:	130 Max

2.7.6 Working procedure of the MQ-2 smoke detector

MQ-2 smoke detector it includes a light source (incandescent bulb or infrared LED), a lens to collimate the light into a beam, and a photodiode or other photoelectric sensor at an angle to the beam as a light detector. In the absence of smoke, the light passes in front of the detector in a straight line. When smoke enters the optical chamber across the path of the light beam, some light is scattered by the smoke particles, directing it at the sensor and thus triggering the alarm (System sensor, 2012).

2.8 DC Pump/Sprinkler

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of fire incidence. When sprinklers are present in the fire area, they operate in 93% of all reported structure fires large enough to activate sprinklers (John and Hall, 2010).

The water intercooler pump originally designed for circulating water. This pump designed by Bosch was selected for this project, because of its low cost and availability.

2.8.1 Specifications of the PAC Bosch DC pump

Operating voltage:	12-15V
Operating current:	3.8-5A
Pressure:	up to 8psi
Connection:	19mm push on horse
Power rating:	75W

2.9 Display unit

The display components of the designed system serve as the visual informant to the user for the system condition typically based on temperature. There are various types of display available in this era of electronics advancement. Today there is liquid crystal display (LCD), Cathodoluminescence display, electroluminescence display, photoluminescence display and seven segment display.

For the purpose of this research work seven segment display had been chosen to be analysed, because the interest is in displaying only numbers as the value of temperature in a given time on response of the temperature sensor. (Emhemed, 2012) designed and implement a simple seven segment display. The implemented circuit of the system shows how to connect simple input and output devices to a programmable chip. The switches were used to display 0-9. Digital display use the numbers from 0-9 and are represented by seven segment display, each segment was controlled by a single bit, and combination of segments turned ON/OFF can display all the numbers 0-9 and a few characters such as A,B,C,D,E and F (Emhemed, 2012).

CHAPTER THREE

METHODOLOGY

3.1 System Design

Designing the system is the major part of this project work and this involved the planning and estimation of the entire system before the actual implementation. Here, every component used is accounted for and resolved to obtain the best performance. Computer control based system is made up of two important parts namely the hardware and the software. Hardware provides the required signals to the computer in digital form and software within the computer analyses this signals to provide the desire output. This chapter describes all the procedure involved in the design and implementation of the two parts. It begins by giving an overview of the complete fire fighting system designed, and then describes how the specific hardware and software were designed. The block diagram of figure 3.1 illustrates the major units of the automatic fire control system.

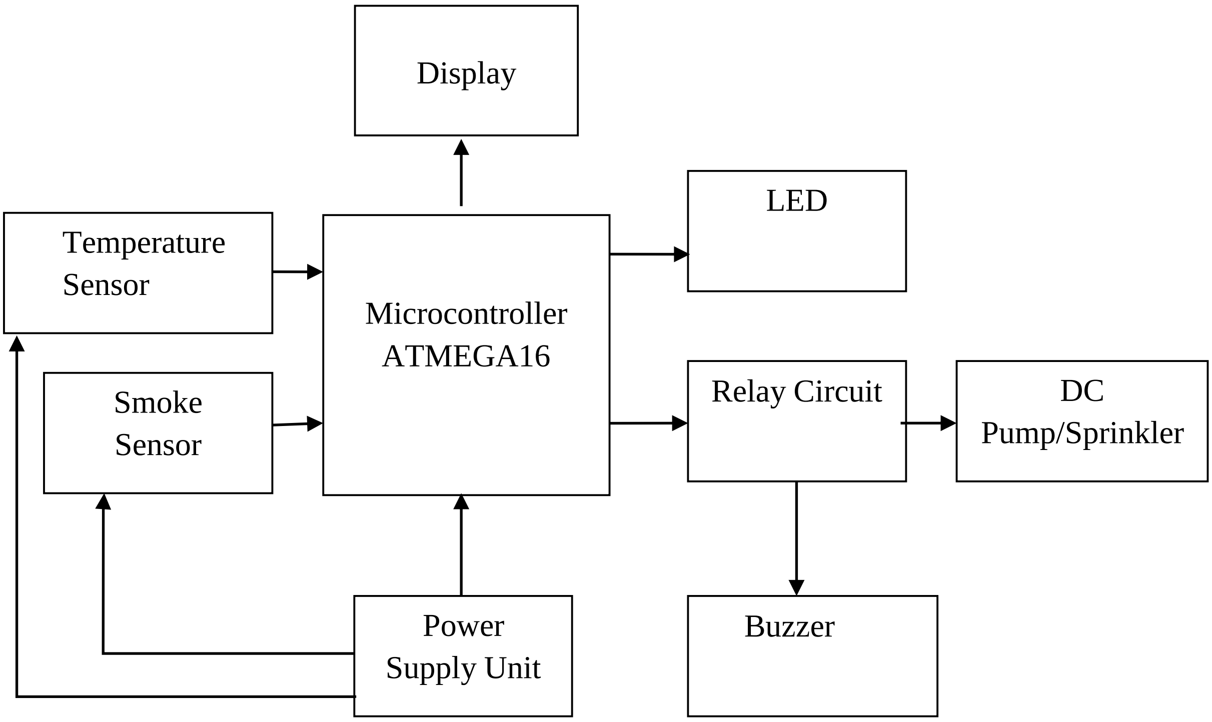

Figure 3.1**:** Block diagram of an automatic fire control system

The block diagram comprises all the subsystems of the designed project, which consist of the power supply unit, smoke sensor, temperature sensor, microcontroller, pump/sprinkler, display/LED, and buzzer. The choice of component selected depends on the project requirements.

A power supply was used to provide DC voltage source by converting AC source to the required voltage values. The microcontroller was then programmed to activate the display/LED, buzzer and a DC pump/sprinkler after detecting smoke and heat through smoke and temperature sensors respectively.

3.1.2 Power supply unit

The automatic fire control device or system found to require a DC voltage source for its operation. Therefore for the purpose of this design, an alternating (AC) voltage source of 220V will be used, where the AC voltage must be converted to DC voltage by rectification. Thus the process of converting the AC voltage to the DC voltage was accomplished with the help of a rectifier, filter and voltage regulators to provide the various DC voltages needed by the different electronic components in the system. The steps of driving low ripple, various DC voltage is illustrated in figure 3.2

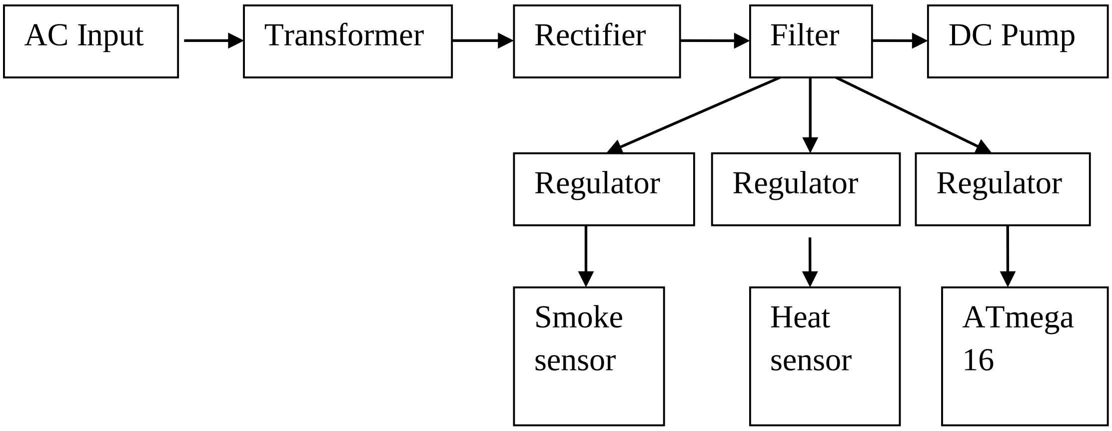

Figure 3.2: Block diagram of power supply

A necessity for all electronic circuits is a power supply. The power supply of the system was properly rated to ensure proper working conditions of the circuit. For this project the sections requiring voltage sources are the microcontroller, smoke sensor, temperature sensor and DC pump. The voltage requirement of these devices is specified in their datasheet to be 5 Volts each except DC pump that requires 12 Volts. Based on the specification 12 volts DC was designed for the whole system, and three 5V voltage regulators were connected to power the microcontroller and two sensors used.

A 12V DC output, require by the relay to power the pump/sprinkler.

A 5V DC output, each required to power the microcontroller, smoke sensor, and temperature sensor.

3.1.3 Transformer

A two unit of 220V/7.5V step-down transformers with 3A rated current was selected for this project. The step-down transformer unit used is 220V/15V with 6A rated current.

3.1.4 Rectifier

The process of deriving DC power from an AC source is called rectification. This stage is just after the transformer, a rectifier circuit employs the use of diodes to convert AC voltage to DC voltage. These circuits are categorized into Half Wave Rectifier and Full Wave Rectifier. For the rectification of this project, the bridge rectifier for full wave rectification will be used, which converts the whole of the AC input waveform to one of constant polarity at its output. The process of rectification was drawn in figure 3.3

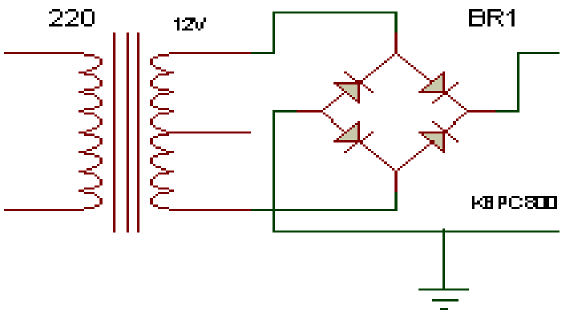

Figure 3.3: Full-wave rectifier circuit diagram

The average and root-mean-square no-load output voltages of an ideal single-phase full-wave rectifier are:

$$V_{\mathrm{dc}} = V_{\mathrm{av}} = \frac{2V_{\mathrm{peak}}}{\pi} \qquad (3.1)$$

$$V_{\mathrm{rms}} = \frac{V_{\mathrm{peak}}}{\sqrt{2}} \qquad (3.2)$$

Where:

V_{dc}, V_{av} is the DC or average output voltage,

V_{peak} is the peak value of the phase input voltages,

V_{rm} is the root-mean-square value of output voltage.

3.1.5 Filter circuit

The main function of the filter circuit is to minimize the ripple content in the rectifier output. The output of the rectifier is pulsating, it has a DC value and some AC component called ripples. This type of output is not use for driving sophisticated electronic devices. The devices require a steady DC output that approaches the smoothness of a battery's output. For the purpose of this project, an inductor capacitor filter will be used. The circuit arrangement for LC filter is illustrated in figure 3.4.

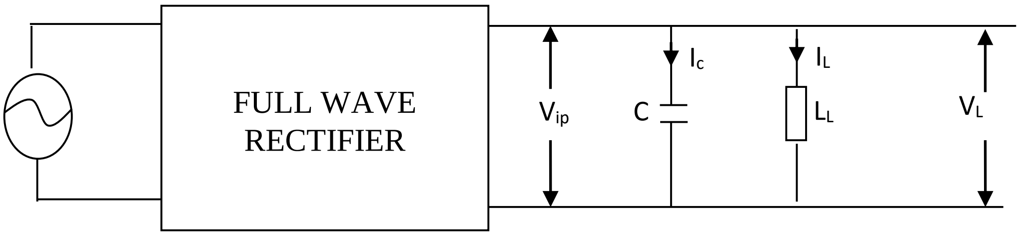

Figure 3.4: LC filter circuit diagram

In the circuit above a suitable single capacitor (C) is connected across the rectifier in parallel with the load R_L as the rectifier circuit diagram in figure 3.4, to achieve the filtering action. This type of filter is known as Capacitor Input Filter and depends on the operation of a capacitor. When connected across a pulsating DC it tends to smooth the voltage pulsation. When positive half cycle of the AC input is applied, D_1 is forward bias and hence is turned on, C quickly charges up to peak value of input voltage V_{ip}. After being fully charged, the capacitor holds the charge till input AC supply to the rectifier starts to decrease.

3.1.6 Voltage regulator

The proposed system will be powered from a voltage of 220V AC mains electricity supply to the suitable low voltages required. Three of LM7805 voltage regulators will be used in this design to regulate the voltages in order to obtain the desirable DC output voltages needed by the electronic components used in the system. The 12V DC voltage output directly from the transformer after being filtered will be used as the operating voltage of the relay to the pump/sprinkler, while each of the LM7805 provides an output of 5V DC. The microcontroller, smoke sensor and temperature sensor was connected to the output terminal of each voltage regulators shown in figure 3.5.

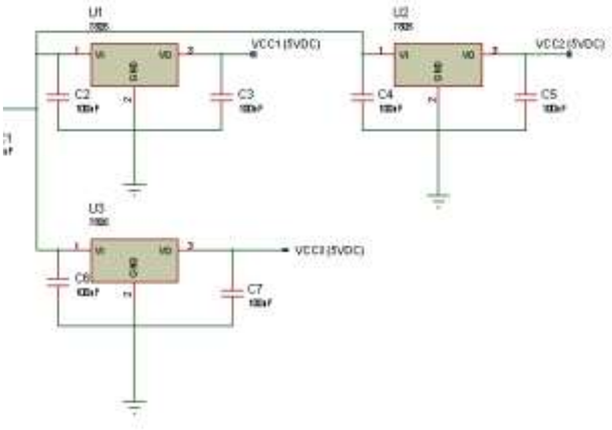

Figure 3.5: Three voltage regulators circuit diagram

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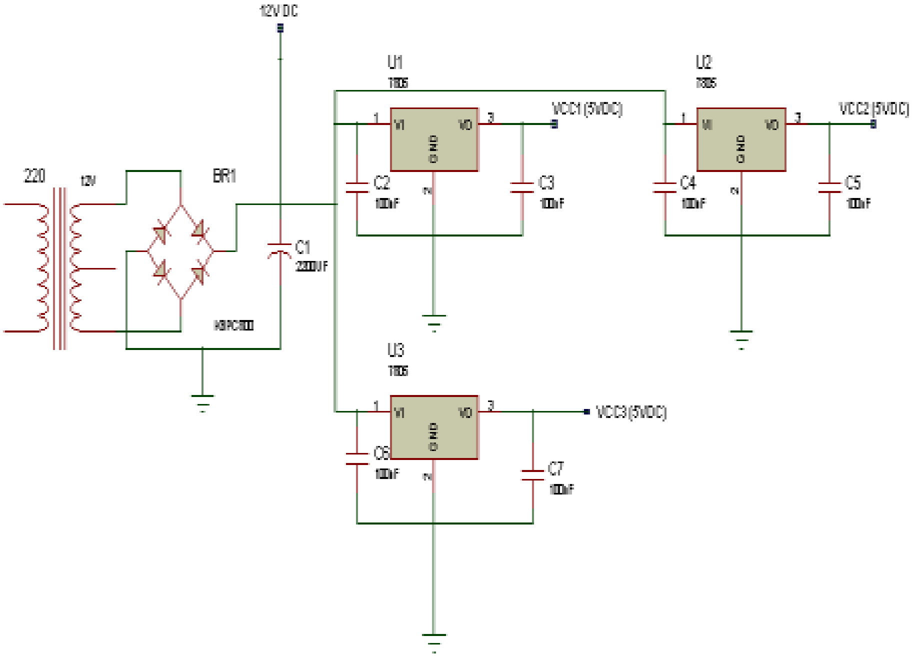

Figure 3.6: Complete power supply circuit diagram.

3.1.7 The sensors

The designed automatic fire control system comprises of two different types of sensors namely; smoke sensor and the temperature sensor. The smoke sensor senses smoke and generates signal which serve as an input to the microcontroller, also the Temperature sensor senses the temperature of the environment of which at a certain temperature rise it will activate the system by the means of microcontroller.

3.1.8 Temperature sensor

The temperature sensor selected for this design is LM35DZ which is a precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. It is used with single power supply, as it draws only 60µA from its supply; it has very low self-heating less than 0.1°C in still air.

The LM35 temperature sensor has three terminals; input, output and ground. Power supply of 5 Volts was connected to the input terminal through voltage regulator. Its output was then connected to the one of input/output pin (34) of ATMEGA16 microcontroller. When the sensor was connected to the power supply and switched on, the output voltage of LM 35 will activate the system through microcontroller. The reason why 5V voltage regulator was connected to the input terminal of LM35DZ used is because the minimum operating voltage is 4V. See figure 3.7 for pin configuration of LM35DZ and voltage specification.

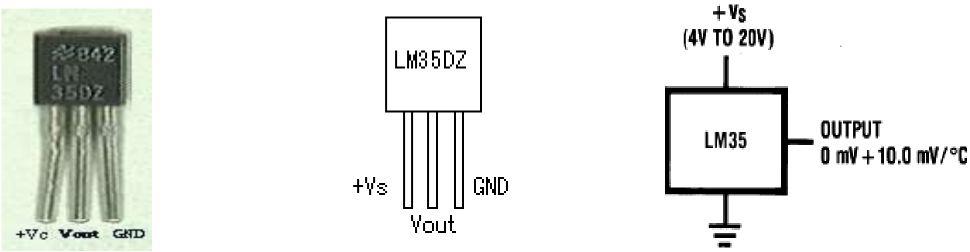

Figure 3.7: Physical view and pin configuration of LM35DZ Temperature sensor.

3.1.9 Smoke sensor

GH-312 module (MQ-2) gas sensor was selected for this design because it is readily available in market, portable in size (suitable for embedded applications) and compatible to the designed system. It is a gas sensing device which senses gases including smoke. The sensitive material of the sensor is Tin Dioxide, which with lower conductivity in clean air.

MQ-2 gas sensing device is a PCB mounted type with two terminals; input and output. This was shown in figure 3.7. The input terminal was connected to the 5 Volts power supply through a voltage regulator. The operating voltage of MQ-2 sensor was found to be 3.5V-5.5V from its datasheet. This was stated in the specifications of this sensing device. The output terminal of the smoke sensor was connected to the one of the I/O pins (pin 37) of the ATMEGA16 microcontroller used. This connection was shown in figure 3.14.

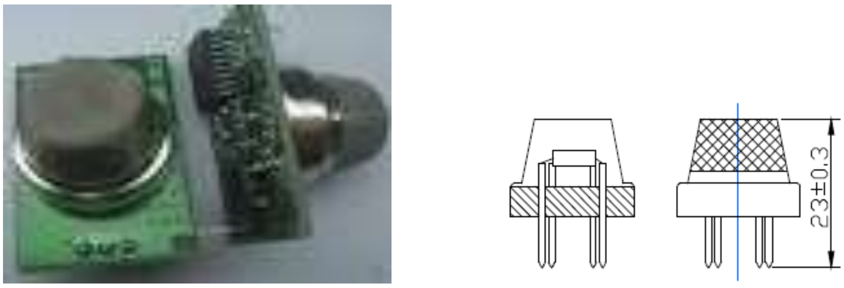

Figure 3.8: Physical view of MQ-2 Smoke Sensor.

3.1.10 Microcontroller (ATMEGA16)

The selected microcontroller for this design is ATMEGA16 because it is a low-power CMOS 8-bit microcontroller with 16KB in-system programmable flash based on the AVR enhanced RISC architecture, by executing powerful instructions in a single clock cycle (Chauhan and Senwal, 2013). The microcontroller serves as the control part of the system. It receives signal from both the smoke sensor and temperature sensor, switches on an LED when smoke is sensed and also checks if the signal from the temperature sensor has surpassed the reference temperature and then switches on both the buzzer alarm and the sprinkler system. It also sends signal to the LED display, displaying the temperature of the environment at any instant of time. The pin configuration of Atmega16 microcontroller was captured in figure 3.9

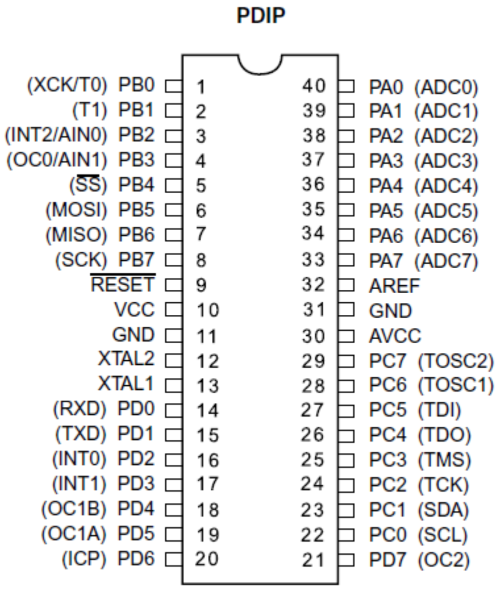

Figure 3.9: Pin configuration of ATMEGA16

3.1.11 Relay

HRS4-S-DC12V relay module was used in this project, which captured in figure 3.10. A relay is an electrically operated switch. It purpose of this project switch ON/OFF power to the premises and then sent to the DC pump. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be ON or OFF.

The relay circuit is connected to DC pump acting as the switching device when it receives signal from the micro-controller after the smoke sensor and the temperature sensor senses smoke and a high temperature respectively.

Figure 3.10: Physical view of 12V DC HRS4-S relay module

3.1.12 Display

Display indicates the current situation of the system. It is connected to the microcontroller through input /output port with data and control lines. The type of display used was a seven segment display. A bipolar junction BC557 PNP transistor for common anode display is use in order to drive the required display, captured in figure 3.11. The microcontroller output interface, outputs the value for a specific display by enabling only its common pin transistor, and the digit driven by that common pin becomes active and also to give the impression that both displays are active at the same time and avoid flickering the digits are cycle through in quick succession and keep each of them lit for 5ms.

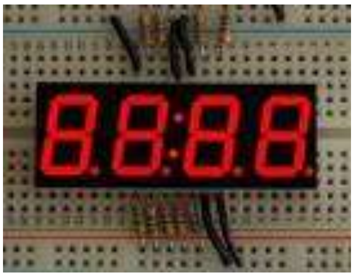

Figure 3.11: Physical view of Seven Segment display

3.1.13 Buzzer

The LED serves as an indicator. Whenever the smoke sensor senses smoke in the environment, it can be indicated on its in-build LED. The buzzer produces sound after the smoke sensor senses smoke and the temperature senses heat. The buzzer used is a PCB mounted type with two pins. The buzzer was captured in figure 3.12.

Figure 3.12: Physical view of SV4/5-S PCB type buzzer

3.1.14 Pump/sprinkler

The DC Pump used for this project is PAC Bosch with 12V DC, 3.8A operating power, which is shown in figure 3.13. The outlet of the pump was attached to the end of a pipe which is also attached to the water sprinkler. The area which the water sprinkles depends on the type of sprinkler and also the pressure of the Pump.

Figure 3.13: Physical view of PAC Bosch DC pump

3.1.15 Assembling the hardware

The relay, which runs the pump, was connected directly from rectified 12V DC supply and output signal that turn ON a relay was connected from PORT B (pin 7) of the microcontroller. The smoke sensor, temperature sensor and microcontroller were powered by 5V DC each through voltage regulators. Smoke sensor inputted signal through PORTA (pin 37), temperature sensor also connected through PORT A (pin 34) of the programmed microcontroller. Buzzer was connected to VCC and through 1 KΩ resistor from microcontroller IC to port B (pin 6). Three seven segment display was connected from PORT C (pin 22-29) and PORT D (14 and 15) of the microcontroller through 100Ω resistors. All these connections are illustrated in figure 3.14.

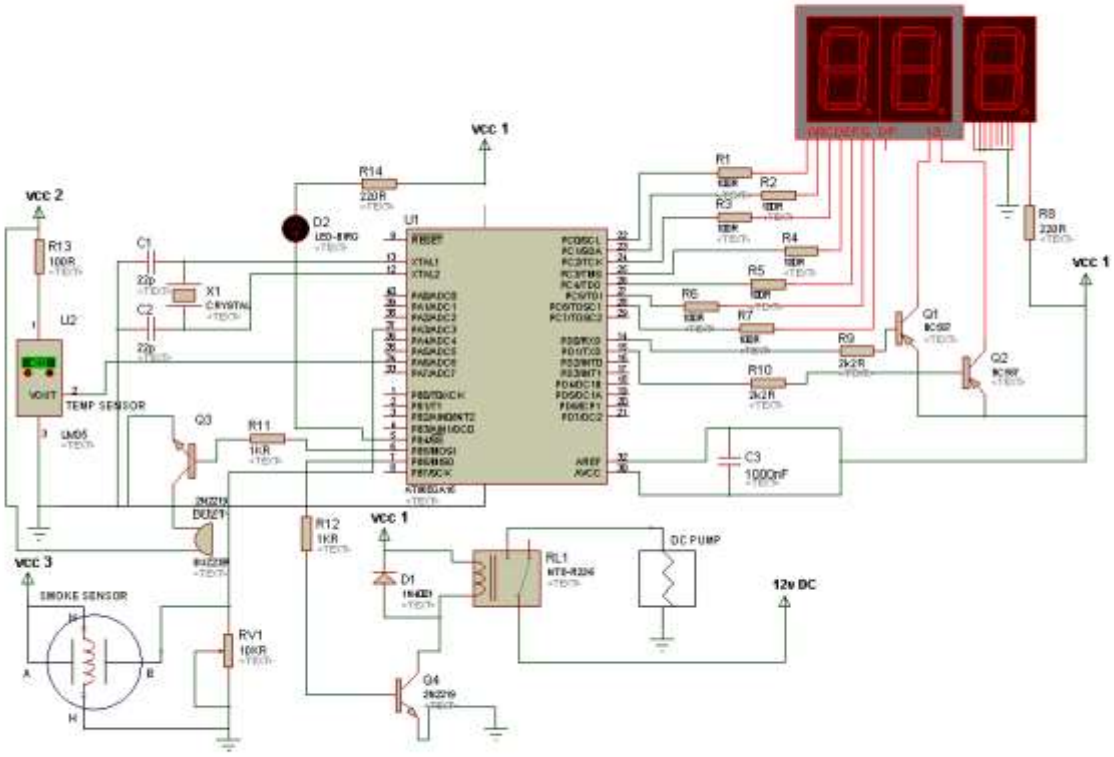

Figure 3.14: Automatic fire control system circuit diagram

3.1.16 Casing

The casing, housing of the entire circuit is a cuboids box made from plastic with several points on the box bored to accommodate and hold the LED, Temperature sensor, smoke sensor, Display and the buzzer. The casing will be measured 30cm × 30cm × 15cm.

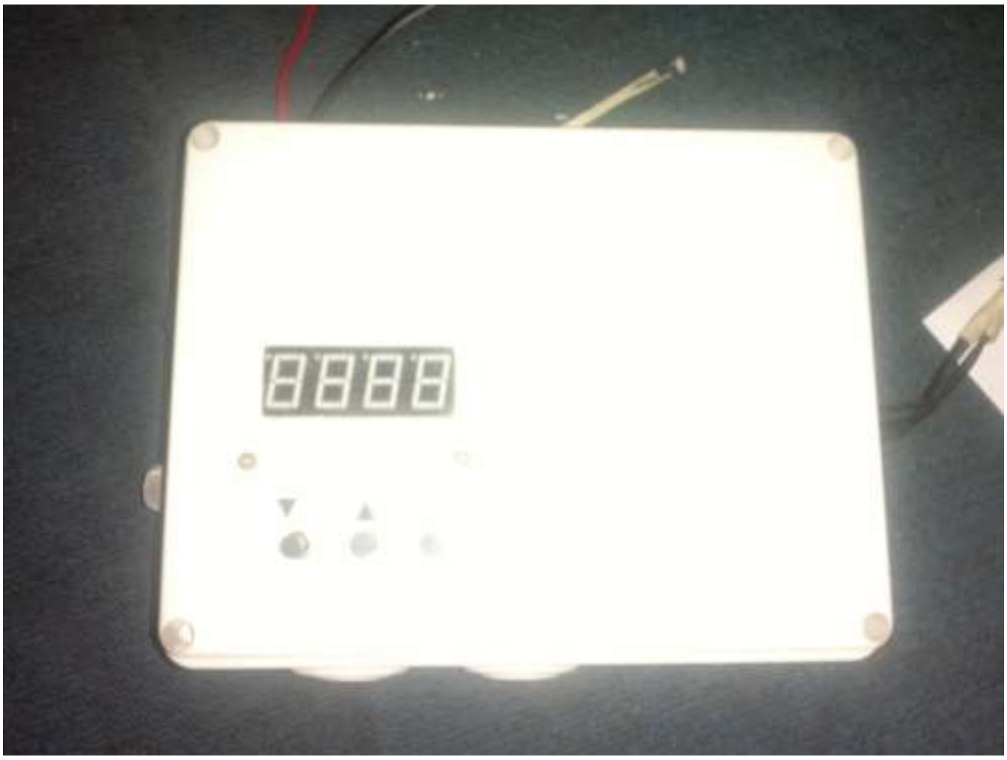

Figure 3.15: Physical view of the casing

3.2.1 System Software design and implementation

In order to link the detected voltages from the sensors to the microcontroller and from microcontroller to the pump/sprinkler through a relay, C programming language was used. Firstly, the input/output port of the microcontroller will be configured such that both the status and the control lines act as inputs from the sensors.

3.2.2 Configuration of microcontroller

To configure Atmega16 Microcontroller for programming, an interfacing board which make the microcontroller active and establish communication between the microcontroller itself and computer where the written codes (program) are provided and tested as shown in figure 3.16. The execution of code in a microcontroller takes place as a hexadecimal code. Also through the use of cross compilers, the microcontroller was programmed using C language. The cross compiler, acts as a bridge between the programming software and microcontroller.

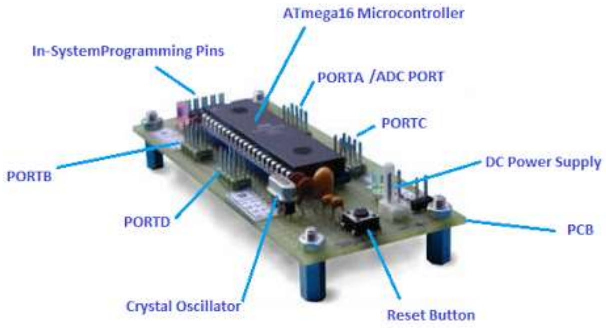

Figure 3.16: ATmega16 interfacing board

3.2.3 Programming of microcontroller

In order to program ATmega16 microcontroller a special technique to load the program into the microcontroller was followed. One of the methods was to use a microcontroller flash memory. Flash memory is similar to erasable programmable read only memory. So the program was written and debugged using cross compiler. The compiled program was loaded to the flash memory of the microcontroller. Once program was flashed the microcontroller was loaded with the hex code and it will be ready for execution. For the instructions (program) see Appendix 1

3.2.4 Communication protocols

The following steps were followed in other to load the written instructions (program) into the Atmega16 microcontroller.

- Downloading the device driver:

- Connecting USB programmer to the USB port of computer
- SPI/ISP communication with microcontroller (Appendix 2 to 6)
- The program was in the system in form of C or hex format and the microcontroller was on the interfacing board
- The program written in the system was loaded into the AVR microcontroller through intermediate (AVR burner software and programmer circuit).

3.2.5 USB Port

USB (Universal Serial Bus) port is an industry standard for short-distance digital data communications. The common version of USB, USB 2.0 was used. The USB 2.0 has the data transfer rate of 5 Gbit/s and allows full duplex signalling when operating in supper speed mode. USB connectors are used in host controllers in computers and hubs designed to provide 5V DC power to the other USB port. The common USB port uses 4 shielded wires. Two of which are for +5V and GND while the rest are for differential data signals labelled D+ and D- as shown in Table 3.2.0. D+ and D- signals are transmitted on a twisted pair. The pin out diagram was shown in table 3.

Table 3.1: The USB pin out diagram

Pin	**Name**	**Cable color**	**Descriptions**
1	VCC	Red	+5V DC
2	D-	White	Data-
3	D+	Green	Data+
4	GND	Black	Ground

3.2.6 Flow chart for the system software.

Figure 3.17 shows the flowchart for the system software. When the program is running continuously the software set the status and control registers low and keep on monitoring for the presence of a high voltage in any of its pin. If a high voltage is detected in any of these lines, Sprinklers will be activated. When fire has been put off the software reads low at the input lines thus stopping the activated sprinkler.

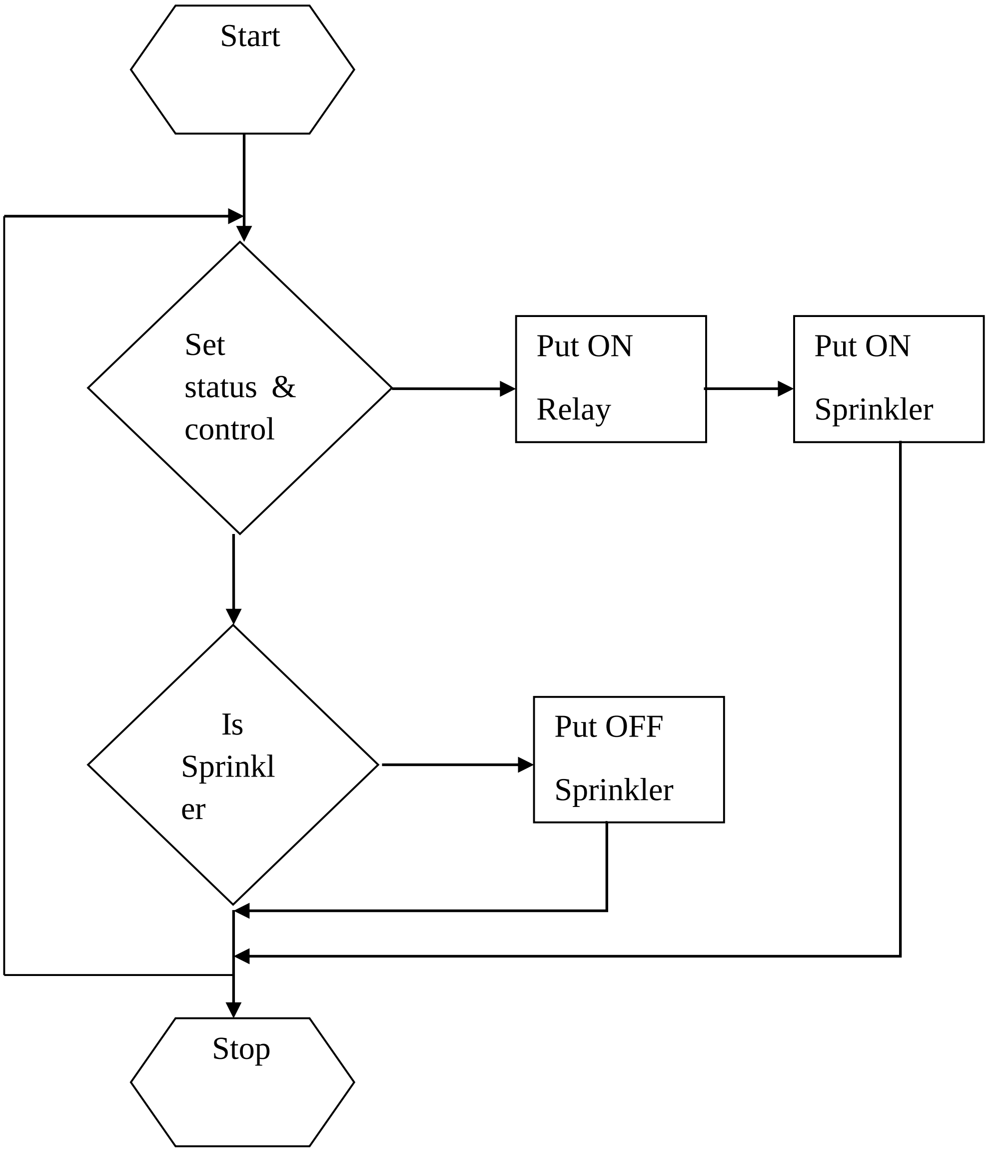

Figure 3.17: Flowchart for system software design

3.3 Principles of Operation

The main purpose of this project is to first detect fire by using temperature and smoke sensors and then to be control using embedded microcontroller to eliminate the fire through water pump. Fire produces heat and smoke which is detected by the temperature and smoke sensors respectively mounted in the system. These sensors produce a voltage difference across its leads when it is subjected to heat and smoke. This voltage/signal is received by ATmega16 series microcontroller through the input/output port of the microcontroller .The processed signal is simultaneously sent to the buzzer, display, relay, which run the DC pump, by the means of loaded program in the microcontroller. 12V DC HRS4-S module on the other hand is a relay circuit chip with higher voltage/current loads. This allows the microcontroller to send signal to the DC pump/sprinkler. The power to the pump is connected to the normally closed contact of the relay. At the presence of fire, the contact to the pump/sprinkler that of timer delay relay closes. This starts the water pump/sprinkler. The current situation on the display reads the falling temperature value from the set point to environment temperature.

CHAPTER FOUR

TESTING, RESULT AND DISCUSSION

4.1.1 System testing

After completion of the project construction, it was subjected to test to see if the design claim is met. A performance test of the system was carried based on each block as indicated in the block diagram of figure 3.1.

4.1.2 Power supply test

The constructed system required two outputs voltage for its operation:

A 5V DC output, each required by microcontroller, smoke sensor and temperature sensor.

A 12V DC output, required by relay to activate DC pump.

A multi meter was used to monitor the performance of the power supply unit of figure 4.1.

Firstly, a multi meter was connected across the 12V to monitor the supply voltage from 12V-0V. The observed value of output voltage was recorded in table 4.1.

Secondly, a multi meter was connected to the output of each 5V voltage regulators (U_1,U_2 and U_3) to monitor the output voltage of each regulator. The observed value of voltages is tabulated in table 4.1.

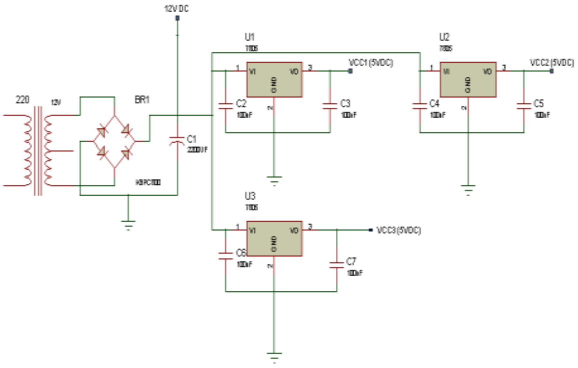

Figure 4.1: Power supply circuit diagram

4.1.3 Temperature sensor test

Temperature sensor used was used to measure the environment temperature. Two tests were conducted directly using the selected sensor.

Firstly, the temperature of the constructed system was monitored without introducing heat source to the sensor for seven days. Test was done by monitoring the room temperature and compared with a thermometer measured values during the peak hours of the day and observed for seven days. The observed temperature from the system and thermometer measured temperature was tabulated in table 4.2.

Secondly, various tests were carried out by introducing heat source (soldering iron) to the temperature sensor. Both system temperature and thermometer measured temperature were tabulated in table 4.3.

4.1.4 Smoke sensor test

The smoke sensor was connected to the designed system. The smoke sensor used is a PCB mounted type, which can be test after mounting it in the designed system. Two tests were carried out with different smoke sources.

Firstly, mosquito coil was used as a source of smoke. The smoke was introduced at the top view of the MQ-2 smoke sensor, when ever system responded the build-in LED in the sensor will start blinking. To determine the response time of the sensor, the time at which LED start blinking was recorded.

Secondly, burning paper was used as a source of smoke. The same procedure with that of mosquito coil was followed, for us to get the response time of the sensor.

4.2.1 Result of the construction

The design electrical circuit board, internal view of the constructed system are captured in figure 4.2.

Figure 4.2: Constructed automatic fire control system

4.2.2 Power supply test results

Table 4.1: Power supply test results

S/No.	Reference Voltage	Measured Voltage	Device acquired
1	12V	11.96V	Relay (DC pump/sprinkler)
2	5V	4.92V	Microcontroller
3	5V	4.87V	Temperature sensor
4	5V	4.97V	Smoke sensor

4.2.3 Temperature sensor test results

Table 4.2: Temperature sensor test results (without heat source)

Days	**System temperature (T_S)**	**Thermometer temperature (T_T)**
1st day	43 ^{0}C	41 ^{0}C
2nd day	42 ^{0}C	41 ^{0}C
3rd day	43 ^{0}C	40 ^{0}C
4th day	40 ^{0}C	39 ^{0}C
5th day	40 ^{0}C	38 ^{0}C
6th day	42 ^{0}C	40 ^{0}C
7th day	40 ^{0}C	38 ^{0}C

Table 4.3: Temperature sensor test results (with heat source)

Tests	**Reference temperature (T_R)**	**Operating temperature (T_O)**	**Response Time**
1	50 ^{0}C	54 ^{0}C	21 s
2	55 ^{0}C	58 ^{0}C	19 s
3	60 ^{0}C	63 ^{0}C	15 s
4	65 ^{0}C	66 ^{0}C	11 s
5	70 ^{0}C	71 ^{0}C	11 s
6	75 ^{0}C	76 ^{0}C	9 s
7	80 ^{0}C	81 ^{0}C	7 s
8	85 ^{0}C	85 ^{0}C	6 s
9	90 ^{0}C	90 ^{0}C	6 s

4.2.4 Accuracy of temperature sensor

Table 4.4: Temperature sensor accuracy

Tests	**System temperature (T_R)**	**Operating temperature (T_O)**	**Difference (^{0}C) (T_O – T_R)**
1	50 ^{0}C	54 ^{0}C	4
2	55 ^{0}C	58 ^{0}C	3
3	60 ^{0}C	63 ^{0}C	3
4	65 ^{0}C	66 ^{0}C	1
5	70 ^{0}C	71 ^{0}C	1
6	75 ^{0}C	76 ^{0}C	1
7	80 ^{0}C	81 ^{0}C	1
8	85 ^{0}C	85 ^{0}C	
9	90 ^{0}C	90 ^{0}C	

T_M = 1.55 ^{0}C

The mean difference (T_M) can be calculated from:

$$T_M = \frac{\sum(TO - TR)}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4.1$$

4.2.5 System performance test results

Table 4.5: System response test results

Test	**Reference Temperature**	**Operating Temperature**	**Response Time**	**LED**	**Buzzer**	**Pump**
1	50^{0}C	54^{0}C	21s	ON	ON	OFF
2	55^{0}C	58^{0}C	19s	ON	ON	ON
3	60^{0}C	63^{0}C	15s	ON	ON	ON
4	65^{0}C	66^{0}C	11s	ON	ON	ON
5	70^{0}C	71^{0}C	11s	ON	ON	ON
6	75^{0}C	76^{0}C	9s	ON	ON	OFF
7	80^{0}C	81^{0}C	7s	ON	ON	ON
8	85^{0}C	85^{0}C	6s	ON	ON	ON
9	90^{0}C	90^{0}C	6s	ON	ON	ON

4.3.1 Discussion of results

The proper/expected function of the constructed system was observed during the testing and recorded as results.

4.3.2 Power supply

The results of power supply tests indicate that, four output voltages were observed. The output from all three voltage regulators remain approximately, 5V each, which are the specified voltages for operation of microcontroller, smoke sensor and temperature sensor. The DC output directly from rectifier remains approximately 12V, which was used for DC pump/sprinkler. There are slight differences in voltages when compared with the reference voltages of 0.04V, 0.08V, 0.13V and 0.03V, which are not large enough to affect the performance of the system.

The voltage differences may be due to the resistivity of wires used or variation in temperature or any other environmental factor, which sometimes affect the performance of the system.

4.3.3 Temperature sensor response

The tests were conducted to observe the temperature of the environment for seven days using temperature sensor (LM35DZ). The observed temperature was compared with thermometer temperature, which tabulated in table 4.1.

Secondly, another series of tests were also conducted to observe the temperature at which the system activates. The operating temperature values were compared with the reference temperature values, which tabulated in table 4.2.

The results of the experiment in table 4.3 indicate that the fire sensors detect the presence of fire within the average time of 11.7s. This implies that, temperature sensor responds to the fire in the 12th seconds of detection. The response time of this sensor is perfectly good, since 12th seconds is not enough time for fire to destroy huge amount of properties.

4.3.4 Temperature sensor accuracy

In the test result in table 4.3, shows the accuracy of the temperature sensor, it was seen that all the differences are positive. This means that in all the cases the value of the operating temperature (T_O) is always greater than or equal to the reference temperature (T_R). The highest temperature difference is 4^0C and the lowest is 1^0C. The mean of the differences was found to be 1.55^0C and this implies that if 1.55^0C is added to each measurement of the reference temperature a more accurate result would be obtained.

$T_O = T_R + 1.55$ 4.2

4.3.5 System performance

The temperature was then raised by introducing 100 W soldering irons to the sensor until alarm was heard and LED turn ON and the DC pump. The response time was also found to be about 21s for the selected temperature of 54^0C. Temperature sensor was found to respond to change in temperature at a slower rate compared to that of the smoke sensor. From the time that the pump was triggered on 21th second it took 50 seconds to completely suppress temperature below the set 54^0C in order to completely switch OFF the blinking LED, buzzer and DC pump. This time is about 30 seconds higher than that of the smoke sensor. The main cause of this is the slow cooling of LM 35 temperature sensor. It is thus evident that smoke sensors are more adequate for early fire detection though may be smooth to much false detection than temperature sensors. To observe the proper function of the constructed system response to multiple inputs from the sensors (temperature and smoke), must be observed. Two sensor inputs were simulated by connecting 5V to inputs of these sensors. These two generated signals must be together to interrupt the microcontroller. When only one signal was generated, there is no response from the constructed system.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

In this research an automatic fire control device was designed and constructed. The system, which is microcontroller based is suitable for detecting fire (smoke and heat) within a given range, and activating display/ LED, DC pump and buzzer. The AC source from mains was converted in to DC voltage by the means of rectifier. The rectified voltage is a form of unfiltered electrical signal, which was filtered to lower the ripples of the rectified DC voltage using an LC filter. An ATmega16 series of microcontroller was configured and programmed using C programming language, to activate the activation part of the system (Display, buzzer and DC pump). The system was activated after detecting smoke and heat through smoke and temperature sensing devices. After the construction, the system was subjected for tests to find out its performance. The power supply performance was found to meet the design specification. The response time of sensors was found to 11.7s, which is enough to control the fire without much destruction. The system/reference temperature was compared with the observed temperature, showed the mean error of 1.55^0C and consequently it was recommended that 1.55^0C should be added to any measurement of the system temperature values.

5.2 Conclusion

In this research an automatic fire control devise has been designed and constructed, that could be of use in the building and construction sector. The fire control device was found to be working satisfactorily with low mean error and high accuracy. The constructed system is compact and easy to install. The constructed fire control device is quite cheap and affordable to every category of person. With the achievement of all the objectives of this research, we can conclude that the constructed device operates as expected, which is reliable and cost effective. The device should be employed in fire fighting operations to help limit the number of death and property loss in our buildings.

5.3 Recommendations

Based on the findings in this research these recommendations are suggested:

- The sensitivity of fire control device may be improved upon especially at large place to be monitored. It is therefore, recommended that a system that accepts many input from sensors may be designed. This may be possible by use of multiplexers.
- A rechargeable power supply unit may be incorporated in the constructed device to avoid power failure problems.
- The constructed device could further be enhanced by interfacing it to other fire fighting equipments such as gas and powder extinguishers that can be used to different classes of fire.
- The designed software may also be used in areas outside fire control. These include object counters, burglar alarm, road traffic monitoring and other areas.
- Further work needs to be done to find other alternative sensors such as RTDs, thermistors, ionisation smoke detectors.

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APPENDICES

Appendix 1: AVR Programming codes

```
/*

Project:      Automatic Fire Control system

Device:       ATMEGA16A

Language:     C

Designed By:  Rilwanu Bello

Company:      Department of Physics, Faculty of science, Usmanu Danfodiyo University,
              Sokoto.

*/

#include <built_in.h>

/*port definitions

7-seg data port       = PORTC

7-seg_hun Enable      = PORTA0

7-seg_tens Enable     = PORTA1

7-seg_unit Enable     = PORTA2

Flash LED pin         = PORTB4

Buzzer signal pin     = PORTB5

Pump control pin      = PORTB6
```

```
*/
//Bit Variables
sbit LED        at      PORTB.B4;
sbit Buzz       at      PORTB.B5;
sbit Pump       at      PORTB.B6;
sbit unit_EN    at      PORTA.B0;
sbit ten_EN     at      PORTA.B1;
sbit hun_EN     at      PORTA.B2;
char disp  = 1;
char Units = 0;
char Tens  = 0;
char Hundreds  = 0;
unsigned short int adc_Data = 0;
unsigned short int temp = 0;
unsigned short int smoke = 0;

unsigned short int Seven_Seg_Data[10] =
{0xC0,0xF9,0xA4,0xB0,0x99,0x92,0x82,0xF8,0x80,0x90};
char smoke_state_LED = 0;
```

```
char status;

char pump_time         = 0;

char Buzz_rate         = 0;

char LED_time          = 0;

char fire_check_time  = 0;

char fire_check_state  = 0;




void ADC_Rd(void);

void display(void);



void TIMER1_COMPA() iv IVT_ADDR_TIMER1_COMPA                //Timer1A Compare

                                                              Match

{

if(smoke_state_LED == 1){

LED = ~LED;                                     //ON LED

  }

else{LED = 1;}

if(fire_check_state == 1){
```

```
if(fire_check_time < 40){

fire_check_time ++;

if(fire_check_time >= 40){fire_check_time = 0;}

if(temp >= 40){

Buzz = ~Buzz;

if(Pump != 1){Pump = 1;}

 }

else{

if(Buzz == 1){Buzz = 0;}                              //disable buzzer

   }

     }

        }

if((Pump == 1)&&(pump_time < 20)){

pump_time++;

  }

else{

if(Pump == 1){

Pump = 0; Pump_time = 0;

   }
```

```
      }

         }




//INTERRUPT SERVICE ROUTINE FOR TIMER_2 COMPARE MATCH

void Timer2_Compare() iv IVT_ADDR_TIMER2_COMP     //Timer2 Compare Match

                                                   (6.667 (20/3)msec)

{

display();

}




void ADC_Rd(void){

 //Get ADC data

adc_Data = ADC_Read(6);

temp = adc_Data/2;

Hundreds = temp/100;

Tens = (temp/10)%10;

Units = temp % 10;
```

```
adc_Data = ADC_Read(3);                         //detect smoke

smoke = adc_Data;

if(smoke >= 400){

smoke_state_LED = 1;  fire_check_state =1;

   }

else{

smoke_state_LED = 0;

if(fire_check_time > 0)

{        }

else {fire_check_state = 0;}

     }

         }



//Dispaly on 7 seg

void display(void)

{

switch(disp){

case 1 :{

PORTC = 255;                              //Port Cleared
```

```
unit_EN = 1; ten_EN = 1; hun_EN = 1;          //All 7-seg disabled
PORTC = Seven_Seg_Data[Units];
unit_EN = 0;                             //Enable unit Display at PortB.0
disp = 2;
break;                             //Exit from loop
 }
case 2 : {
PORTC = 255;                            //Port Cleared
unit_EN = 1; ten_EN = 1; hun_EN = 1;         //All 7-seg disabled
PORTC = Seven_Seg_Data[Tens];
ten_EN = 0;                            //Enable Tens Display at PortB.1
disp = 3;
break;
   }
case 3 : {
PORTC = 255;                            //Port Cleared
unit_EN = 1; ten_EN = 1; hun_EN = 1;
if(Hundreds>0){                            //All 7-seg disabled
PORTC = Seven_Seg_Data[Hundreds];
```

```
hun_EN = 0;                          //Enable Hundreds Display at PortB.2

}

else{

PORTC = 255;

unit_EN = 1; ten_EN = 1; hun_EN = 1;

  }

disp = 1;



break;

  }

      }

           }

void main()                                   //Main Program starts here

{

DDRB.B2 = 0; DDRB.B3 = 0;                          //Analog inputs

DDRB.B4 = 1; DDRB.B5 = 1; DDRB.B6 = 1;                    //PORTA  set as Input

DDRA.B6 =  0; DDRA.B4 =  0;

DDRA.B0 = 1; DDRA.B1 = 1; DDRA.B2 = 1;                    //PORTB  set as Output

DDRC    =  0xFF;                                //7_seg data PORT  set as Output
```

```
PORTC   =  0xFF;                                    //PORTC  Initialized
PORTB.B4 = 1; PORTB.B5 = 0; PORTB.B6 = 0;
unit_EN = 1; ten_EN = 1; hun_EN = 1;
OCR2     =  72;                                           //Enable Timer2 Compare Match (6.667
(20/3)msec with 1024 prescale
OCR1AH = 0x54;
OCR1AL = 0x60;
TCCR2  =  (((1<<WGM21)|(0<<WGM20))|((1<<CS22)|(1<<CS21)|(1<<CS20)));        //Start
Timer2 with 1024 Prescalar
TCCR1A = 0;
TCCR1B = ((1<<WGM12)|(1<<CS12)|(0<<CS11)|(0<<CS10));                  //Enable Timer1
compare matchA (0.5 sec)   at 256 prescaler
TIMSK  = ((1<<OCIE2)|(1<<OCIE1A));
asm  {sei}                                          // set Global Interrupt Enable


 while (1){
ADC_Rd();
delay_ms(500);
```

```
}

 }
```

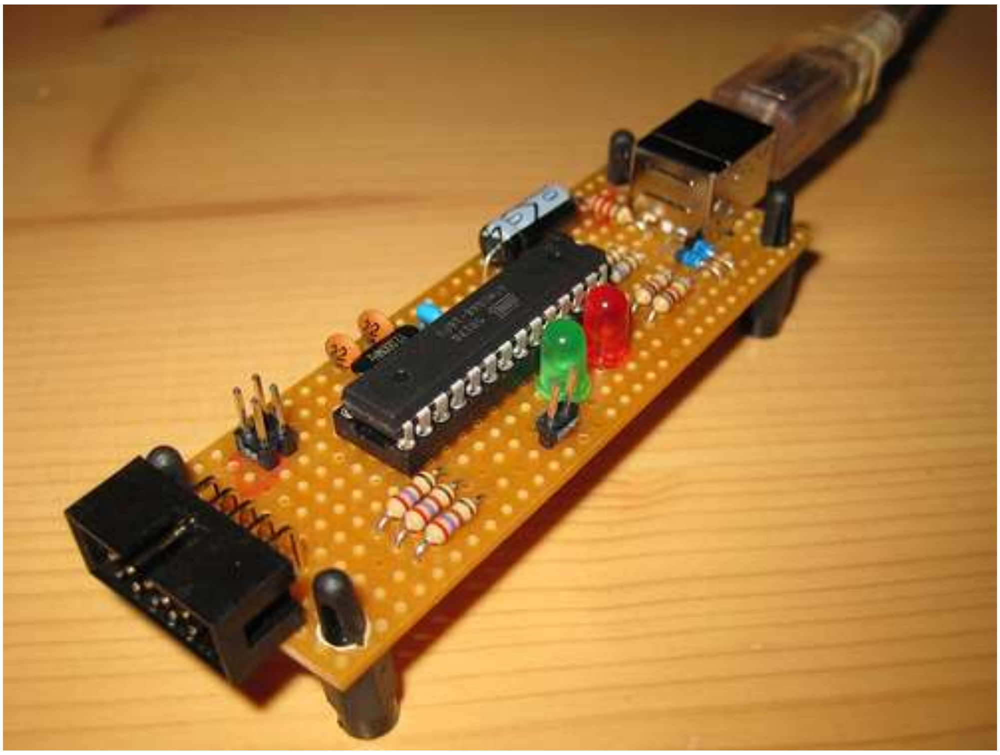
Appendix 2: Cost evaluation

S/N	**COMPONENT NAME AND RATINGS**	**UNIT USED**	**COST PER UNIT (₦)**	**TOTAL COST (₦)**
1	MQ-2 Gas sensor	1	4000	4000
2	Temperature sensor	1	550	550
3	DC Pump	1	8000	8000

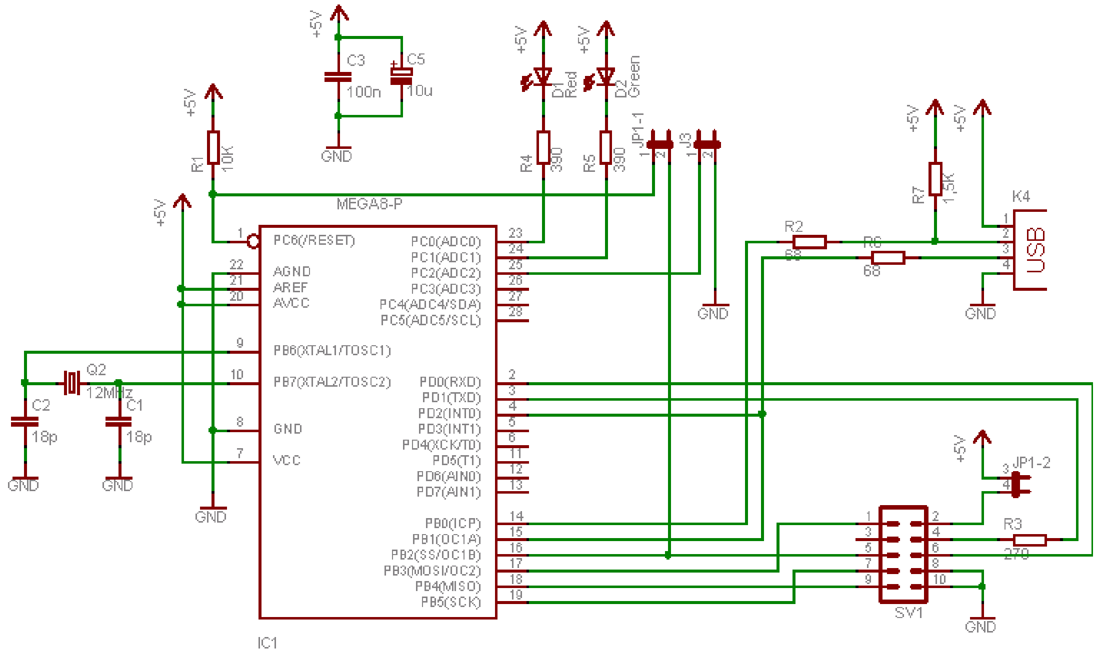
4	0.1 µF ceramic capacitor	4	20	80
5	LED (red)	1	20	20
6	Dual 7 Segment display	1	2000	2000
7	Single 7 Segment display	1	1000	1000
8	BC557 PNP transistor	3	100	300
9	2K2Ω Resistor	2	30	60
10	220Ω resistor	2	30	60
11	10kΩ variable resistor	1	100	100
12	2N2222 NPN transistors	2	300	600
13	Buzzer	1	200	200
14	Dc relay	1	150	150
15	1KΩ resistor	2	30	60
16	22pF capacitor	2	100	200
17	100Ω resistor	8	30	240
18	Crystal oscillator	1	150	300
19	1N4001 Diode	1	20	20
20	1N5401Diode	4	20	80
21	12v step down transformer	1	1200	1200
22	5V LM7805 regulator	3	80	220
23	2200µF polarised capacitor	1	100	100
24	Vero board	1	300	300
25	ATMEGA16 microcontroller	1	1800	1200
26	Casing	1	3000	3000
27	0.1µF tantalum capacitor	2	50	100

28	Transformer	1	2000	2000
	Total cost			26,140

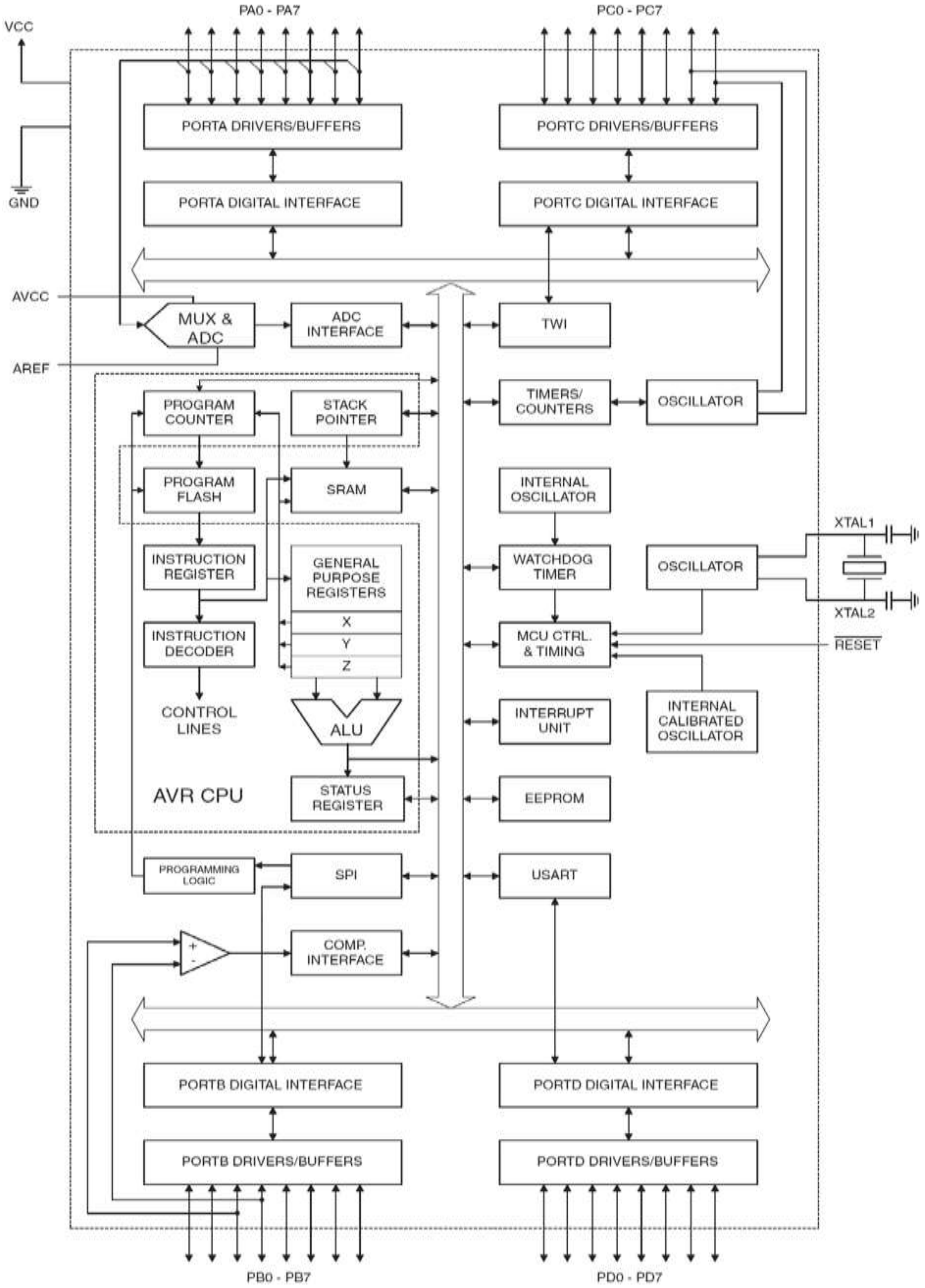
Appendix 3: SPI (Serial peripheral interface) communication with microcontroller



Appendix 4: Schematic of AVR serial peripheral interface



Appendix 5: Block diagram of ATMEGA16


PA0 - PA7
PC0 - PC7
VCC
GND
PORTA DRIVERS/BUFFERS
PORTC DRIVERS/BUFFERS
PORTA DIGITAL INTERFACE
PORTC DIGITAL INTERFACE
AVCC
MUX & ADC
ADC INTERFACE
TWI
AREF
PROGRAM COUNTER
STACK POINTER
TIMERS/ COUNTERS
OSCILLATOR
PROGRAM FLASH
SRAM
INTERNAL OSCILLATOR
XTAL1
INSTRUCTION REGISTER
GENERAL PURPOSE REGISTERS
WATCHDOG TIMER
OSCILLATOR
X
Y
Z
XTAL2
INSTRUCTION DECODER
MCU CTRL. & TIMING
RESET
CONTROL LINES
ALU
INTERRUPT UNIT
INTERNAL CALIBRATED OSCILLATOR
AVR CPU
STATUS REGISTER
EEPROM
PROGRAMMING LOGIC
SPI
USART
+
-
COMP. INTERFACE
PORTB DIGITAL INTERFACE
PORTD DIGITAL INTERFACE
PORTB DRIVERS/BUFFERS
PORTD DRIVERS/BUFFERS
PB0 - PB7
PD0 - PD7