

**DESIGN AND FABRICATION OF A LABVIEW
AUTOMATED COMPUTER-BASED FIRE FIGHTING
SYSTEM**

KIPNGETICH KETUI DANIEL B.ED. (Sc)

I56/CE/11180/07

A thesis submitted in partial fulfillment of the requirements for the degree of Master of
Science in the School of Pure and Applied Sciences of Kenyatta University

September, 2011

DECLARATION

I declare that the work presented in this thesis is my original work and has never been presented for the award of any degree in any university

Kipngetich Ketui Daniel

Signature.....Date.....

Department of Physics

Kenyatta University

We confirm that the candidate carried out the work reported in this thesis under our supervision

Supervisors:

Dr. P.M. Karimi

Signature.....Date.....

Department of Physics

Kenyatta University

Dr. A.S. Merenga

Signature.....Date.....

Department of Physics

Kenyatta University

DEDICATION

This thesis is dedicated to my wife Priscilla and my son Kipruto

ACKNOWLEDGEMENTS

First, I would like to thank my God for enabling me carry out my research to the end free from health problems. Secondly, Special thanks go to my supervisors, Dr. P.M. Karimi and Dr. A.S. Merenga for their tireless work of assisting me throughout the whole of my research. Whenever I needed them they were ready to assist. Similar thanks goes to the Laboratory chief technician Mr. Njuguna and his colleagues for assisting me with some of the basic electronic components I used in my research. Sincere thanks go to the chairman physics department Dr. C. Migwi and the entire Kenyatta university administration for granting me an opportunity to use all university facilities in my research. Best regards goes to my colleagues Kirwa, A., Masinde, S., Ogaro, E. to mention a few who encouraged me throughout my research. To my late mother Sara Busienei who would have liked to see success in my life, may God rest her soul in peace. To my beloved father Joel Busienei, may God bless him for his constant encouragement. Lastly, other regards goes to my best and only wife Priscilla Ketui and our son Brian Kipruto who gave me humble time and patience for the lengthy period I was away from them during my research.

TABLE OF CONTENTS

DECLARATION.....	ii
DEDICATION.....	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	x
LIST OF FIGURES	xi
ABBREVIATIONS, SYMBOLS AND ACRONYMS	xiii
ABSTRACT.....	xv
CHAPTER 1.....	1
INTRODUCTION.....	1
1.1 Background to study	1
1.2 Statement of the research problem.....	3
1.3 Objectives	3
1.4 Rationale for the research	4
CHAPTER 2.....	5
LITERATURE REVIEW	5
2.1 Introduction.....	5
2.2 Firefighting systems.....	5
2.3 Computer based instrumentation	6

CHAPTER 3	8
THEORY	8
3.1 Introduction.....	8
3.2 Smoke production and distribution	8
3.3 Heat transfer and temperature detection	11
3.4 Temperature sensors	12
3.4.1 Resistor temperature dependent (RTD)	13
3.4.2 Thermistors	14
3.4.3 Thermocouple	14
3.4.4 LM 35 Temperature sensor	16
3.5 Smoke sensors.....	16
3.5.1 Photoelectric smoke sensors	17
3.5.2 Ionization smoke detector	21
3.6 Op amp voltage comparator.....	22
3.7 Parallel port.....	23
3.7.1 Parallel port registers	25
3.7.2 Parallel port addresses.....	26
3.8 USB Port	27
3.9 Serial Port (RS-232).....	29
3.10 GSM (Global system for mobiles) network.....	30
3.10.1 Mobile station	30

3.10.2 Base station subsystem (BSS).....	31
3.10.3 Network and switching subsystems (NSS).....	32
3.11 Short message service (SMS)	33
3.12 Bluetooth.....	34
3.13 LabVIEW	37
3.13.1 Introduction.....	37
3.13.2 Main components of LabVIEW	37
3.13.3 SubVI, icon and connector.....	38
3.13.4 VISA	39
CHAPTER 4	41
EXPERIMENTAL PROCEDURES	41
4.1 Introduction.....	41
4.2 Block diagram of the complete automatic firefighting system	41
4.3 Hardware design	42
4.3.1 Temperature sensor circuit diagram.....	43
4.3.2 Smoke sensor circuit diagram.....	44
4.3.3 Smoke and temperature sensor circuit diagram	45
4.3.4 Interfacing board.....	46
4.3.5 Actuators	47
4.4 Software design.....	48
4.4.1 Parallel port configuration	48

4.4.2 Code for activating the actuators	51
4.4.3 Code for sending SMS to a mobile phone	52
4.4.4 Software selection for text message to be sent.....	55
4.4.5 Flow chart for the system software.....	55
4.4.6 Assembling the hardware.....	57
CHAPTER 5	58
RESULTS AND DISCUSSIONS.....	58
5.1 Introduction.....	58
5.2 System response to smoke.	58
5.3 System response to temperature.....	62
5.4 System response to multiple inputs.....	64
CHAPTER 6	65
CONCLUSIONS AND RECOMMENDATIONS.....	65
6.1 Conclusion	65
6.2 Recommendations.....	66
REFERENCES.....	67
APPENDICES.....	70
1. SMS SELECTION TABLE.....	70
2. CONNECTING BLUETOOTH MOBILE TO A COMPUTER	76
3. INTERFACING BOARD CIRCUIT DESIGNED IN THIS WORK.....	83

4. PHOTOGRAPHS SHOWING HARDWARE COMPONENTS OF THE FIREFIGHTING
SYSTEM DESIGNED IN THIS WORK.....84

LIST OF TABLES

Table 3.1: Seebeck coefficients and temperature ranges for various thermocouple types.	15
Table 3.2: Pin Out for D-Type 25 pin female connector	24
Table 3.3: Parallel port addresses	26
Table 3.4: The USB pinout diagram	28
Table 3.5: Serial port pinout identification for DB-9 and DB-25 connectors.	29
Table 3.6: AT commands for writing and sending of SMS	34
Table 3.7: Power classes	35
Table 3.8: Physical connection of VISA resource string syntax	39
Table 3.9: VISA resource names and their meanings.	40
Table 5.1: Data for system response to smoke using the smoke sensor in room 1.	60
Table 5.2: Data for system response to temperature using temperature sensor in room 1.	63

LIST OF FIGURES

Figure 3.1: The zone model showing the flow of smoke	10
Figure 3.2: RTD Resistance versus temperature.	13
Figure 3.3: Type J Thermocouple sensor	15
Figure 3.4: Symbol for LM 35 temperature sensor	16
Figure 3.5: Cadmium sulphide photoresistor	17
Figure 3.6: Variation of LDR resistance with increase in light intensity	18
Figure 3.7: Circuit diagram for voltage increases with increase in light intensity.	19
Figure 3.8: Circuit diagram for voltage decreases with increase in light intensity.	20
Figure 3.9: Schematic illustration of photoelectric smoke detectors.	21
Figure 3.10: Ion and particles of combustion distribution	22
Figure 3.11: Operational amplifier CA3130	23
Figure 3.12: Register map for status and control port	26
Figure 3.13: Pinouts of standard, mini, and micro USB sockets.....	27
Figure 3.14: 9-pin computer serial port pinout diagram.	30
Figure 3.15: Layout of generic GSM network	31
Figure 3.16: Bluetooth protocol stack.	36
Figure 3.17: LabVIEW front panel and block diagram	38
Figure 3.18: VI icon and connector.....	38
Figure 4.1: Schematic illustration of the designed computer based fire fighting system.....	42
Figure 4.2: Circuit diagram illustrating temperature sensor.....	43

Figure 4.3: Circuit diagram showing the design of a smoke sensor.....	45
Figure 4.4: Combined temperature and smoke sensor circuit.	46
Figure 4.5: Schematic diagram showing the connection of optoisolator and BT 136 triac	47
Figure 4.6: Setting parallel port base address.	49
Figure 4.7: Front panel designed in the work for indicating the default reading of the parallel port registers.....	49
Figure 4.8: Block diagram for setting status and control registers for input.....	50
Figure 4.9: Front panel designed in this work to displaying control and status registers	51
Figure 4.10: Block diagram that writes data input from status and control registers.....	51
Figure 4.11: Block diagram showing the sub VI for a collection of 255 sub VIs.....	52
Figure 4.12: The front panel designed in this work.	53
Figure 4.13: Front panel for the system software designed in this work	54
Figure 4.14: Block diagram for the system software designed in this work	54
Figure 4.15: Flowchart for system software design.	56
Figure 5.1: LabVIEW front panel designed in this work	59
Figure 5.2: LabVIEW front panel indicating room one has been detected to be on fire.....	60
Figure 5.3: Graph in this work for System response to smoke.	61
Figure 5.4: Graph designed in this work for System response to temperature.....	63
Figure 5.5: Front panel designed in this work showing system response to multiple sensor inputs.	64

ABBREVIATIONS AND ACRONYMS

API	Application Programming Interface
AT	Attention Commands
AuC	Authentication Center
BIOS	Basic Input / Output System
BSS	Base Station Subsystem
DC	Direct Current
EIR	Equipment Identity Register
FEMA	Federal Emergency Management Agency
FM	Frequency Modulation
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobiles
HID	Human Input Devices
HLR	Home Location Register
IMEI	International Mobile Equipment Identity
ISM	Industrial Scientific and Medical
L2CAP	Logical Link Control and Adaptation Layer Protocol
LabVIEW	Laboratory Virtual Instruments Engineering Workshop
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LMP	Link Manager Protocol
LPT	Line PrinTer

MS	Mobile Station
MSB	Most Significant Bit
NSS	Network & Switching Subsystem
NTC	Negative Temperature Coefficient
OP	Operational amplifier
PC	Personal Computer
PDA	Personal Digital Assistant
PTC	Positive Temperature Coefficient
RF	Radio Frequency
RTD	Resistor Temperature Dependent
SIM	Subscriber Identity Module
SMS	Short Message Service
USB	Universal Serial Bus
VI	Virtual Instruments
VISA	Virtual Instruments Software Architecture
VLR	Visitor Location Register
VXI	VME eXtensions for Instrumentation

ABSTRACT

Despite many building have firefighting systems installed in them; many people are still losing their lives and property due to fire accidents. The cost of installation of these systems is usually high and most of them are operated manually. They are often located inside the building which may not be accessible during fire accidents. In this research, an automatic cost effective prototype of a fire fighting system for the detection and control of fire has been designed and fabricated. The system has an additional feature of sending a short text message to all the occupants of the building and the fire department for immediate response. It is made up of 8 sensors, computer interfacing board, system software and 8 controlled firefighting equipment (water sprinkler) operated by an electric valve. Smoke and temperature sensors have been integrated to form a single unit to improve the accuracy and efficiency of fire detection. LM 35 IC has been used as temperature sensor while light dependent resistor (LDR) made of cadmium sulphide has been used as smoke sensor. All sensors are interfaced to computer through an 8 input; 8 output interfacing board using parallel port. The controlling software for the whole system is designed in LabVIEW in conjunction with attention (AT) commands. The system is finally tested by introducing fire parameters (smoke and temperature) close to the detector. When the parameters go above the set level in the detectors, audio alarm is initiated. Indicators on the computer are switched on automatically after 5 seconds and the corresponding water sprinkler activated after 10 seconds. Short text messages are sent to all the occupants and the fire fighting department within a period of 70 seconds. With feedback mechanism sprinklers are switched off when fire is fully extinguished.

CHAPTER 1

INTRODUCTION

1.1 Background to study

Many people have lost their lives and property through fire accidents in many building countrywide and in other parts of the world. Between 2004 and 2006 there was an average of 6400 of fire accidents in medical facilities each year that was responsible for approximately 5 civilians fire deaths, 175 injuries and \$34 million of property loss annually in the united states (FEMA, 2009). In Kenya a fire tragedy hit Nakumatt downtown Supermarket in Nairobi on 28th Jan 2009 in which more than 29 people perished and many left with serious injuries (Red Cross, 2009). Manual spraying of fire scene with water supplied by Kenya fire department using their tracks carried out fire extinguishing process despite the fact that building had firefighting systems installed. These installed firefighting systems are normally designed to be operated manually to control fire in case of any detection. Most of them are located within the building and may not be accessible during fire accidents.

On the other hand, a number of fire detectors have also been designed and are installed within such buildings. These include smoke, gas and temperature sensors. Among these types of sensors, the smoke sensor is widely used because of its early fire detection capability and its relatively low cost (Li *et al.*, 2001). However, although this sensor provides rapid response time, it has high false-alarm rates (Jiang *et al.*, 2006 and Chen *et al.*, 2007). In contrast, the temperature sensor provides more reliable responses but with slow response times. Fire detectors that use a single sensor may fail to activate when

required or may cause false alarms. Therefore, a fire detector that uses a combination of the smoke sensor and the temperature sensor will not only provide better smoke sensor compensation but also provide a more intelligent fire alarm system (Cheon *et al.*, 2009). The key subject of interest to many researchers has thus been on fire fighting systems. More interest has been automation of these systems to allow firefighting operation be less dependent of human support. Currently, automated fire fighting systems relies on temperature sensing and ignores smoke. 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. In addition, the installation and maintenance of these firefighting systems are very costly.

With the advancement of computer technologies, there have been possibilities of interfacing different sensors with personal computers (PCs) (Chaudhry, 2004). Boosted by the wide spread of mobile communication and internet access, automated firefighting systems need to be designed. In addition, various programming languages are currently available to enable automation of these systems. National Instruments from USA for instance provides LabVIEW software for instrumentation and control which is a powerful and complex programming environment having graphical icons that can easily be identified by quick visual inspection than text based programming languages such as C, C++, C#, FORTRAN, JAVA, Delphi and others (Franz, 2003; Travis, 2002).

In this research, a computer based firefighting system has been designed and fabricated. Computer running LabVIEW software has been interfaced to sensors, firefighting

equipments and Bluetooth enabled mobile phone. The system has also been tested in the presence of smoke and temperature and its functionality approved.

1.2 Statement of the research problem

A good number of smoke and temperature sensors used in the detection of fire have been designed and introduced in today's market. These sensors are fitted with audio alarm that alerts people to vacate the premises in the event of fire. However, most of these systems are not provided with means of automating the activation of firefighting equipments located inside the building that may be inaccessible during fire accidents. With the rapid growth of technology employing the use of computers and the availability of computer programming languages giving room for instrument control, there is need to automate firefighting systems in order to improve the safety measures of fire. In this work, a firefighting system that employs the use of a computer interfaced to a maximum of eight sensors and the corresponding firefighting equipments (sprinklers) was designed and fabricated. The system has advantage of automatically detecting and controlling fire in the event of fire outbreak as well as automatic sending of notification short message service (SMS) to the firefighting department or building owner and the occupants.

1.3 Objectives

The main objective of this research work was to design and fabricate a computer based firefighting system that detects fire and responds automatically by activating audio alarms and firefighting equipment that puts off fire and sending a notification message to relevant personnel through a short text message.

The specific objectives were:

- i. To design and fabricate the hardware comprising the sensors and computer interfacing board for firefighting system.
- ii. To develop LabVIEW program that control the designed and fabricated hardware.
- iii. To link a Bluetooth enabled computer with Bluetooth enabled mobile phone which sends an SMS to target remote mobile phones.
- iv. To test the designed system in the presence of fire parameters namely smoke and temperature.

1.4 Rationale for the research

Despite the high cost of installation and maintenance of fire detectors and firefighting equipments incurred in virtually all commercial and residential places, most of them end up being hard to use in case of fire outbreak. The main reason being manual operation of these equipments which causes great challenge in their operation during fire accidents especially when they are located inside the building. In addition those automated ignores smoke sensing and uses heat sensitive devices that expand and break at certain temperatures. The breakages of these devices are irreversible hence require immediate replacement after fire has been extinguished. System that detects fire parameters, give audio warning, show exact location of fire, triggers on or off fire fighting equipments before or after fire detection (to reduce wastage of extinguishing agents) and sending notification messages to the concerned personnel's is required. All these are the key subject of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There has been a great development in the design of fire fighting systems to respond to the rise of fire accidents in residential and non-residential places that has led to mass death and property loss. This chapter briefly describes some of the systems designed by earlier scholars and the attempt that has so far been made to automate them.

2.2 Firefighting systems

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 firefighting systems. Angus (2002) designed an intelligent fire alarm system that utilized heat, smoke and infrared sensors. His aim was to reduce the nuisance produced by smoke sensors in areas where smoke is common such as in a kitchen. Jimmy (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 fibers 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 *et al.* (2009) also presented an image processing technique for automatic real time flame and smoke detection in tunnel environment. They used color and motion information to minimize false detections in tunnels which enabled detection of exact position of an event at an

early stage. These researchers mainly geared towards detection of fire rather than automating the extinguishing systems. According to fire report on fire protection in world trade center, 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 firefighting 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 in replacement.

2.3 Computer based instrumentation

With the advancement of computer technologies, instrument control has been made possible. Carlton and Rafic (2004) for instance 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. Obanda (2010) developed a microprocessor-based system for control of temperature, humidity, and light level in a green house. Osman *et al.* (2009) too developed a computer vision based method for wildfire detection at night

where an ordinary range camera was used to detect smoke during the day which switches to fire mode during the night. Apart from this system requiring manual operation, its application was also limited to forest environment. Hassan *et al.* (2006) designed a GSM based security system that made a call to mobile number whenever one blocked infrared rays from reaching the sensor fixed on the entrance. The sensor used by these authors is also used in smoke sensors. Their security system was not automated to fight the intruder hence they gave a recommendation for the design of system that incorporate robots to fight intruders. Borrowing their idea in firefighting and control will be of great importance. Lee (1996) used an already existing smoke alarm circuitry to design a fire detector that sensed the presence of smoke. He interfaced the sensor to a computer and designed the control software using visual basic programming. This enabled the sending of SMS to a target mobile phone for immediate human response. Though the application of this system was also limited to areas where smoke is not common it gave hope to the use of computers in industrial and domestic controls of fire fighting systems. From the foregoing discussions, an automatic system that senses fire, put it off and sends a notification message(s) to relevant personnel will thus address the serious challenges that most people get during fire accidents.

CHAPTER 3

THEORY

3.1 Introduction

Fire detectors employ the use of smoke, temperature and gas sensors among other. This chapter describes theoretical consideration of the production of fire components (smoke and temperature) and the working of smoke and temperature sensors with the aim of combining the two to improve the efficiency of fire detection and control. In addition to this, the chapter also describes computer interfaces with interfacing done in labVIEW programming environment.

3.2 Smoke production and distribution

Burning materials increases the temperature of the surrounding and produces particles of smoke that consists of both solid and liquid particles, as well as gaseous products. The gaseous products depend on the fuel being burned and can include water carbon monoxide, carbon dioxide hydrochloric acid and hydrocyanic acid (James, 2004).

Smoke particles produced are normally described in terms of size (μm or nm), number concentration ($\text{particles}/\text{cm}^3$), mass concentration (g/cm^3) and size distribution. Most naturally occurring aerosols for instance are polydisperse, with Geometric Standard Deviation of 2 and have a lognormal distribution shown by equation 3.1 (James, 2004). This equation describes the size distribution of smoke, including both flaming and non-flaming smoke.

$$f_x(x) = \frac{1}{(2\pi)^{1/2}} x^{-1} \exp\left(-\frac{\ln D_g^2}{2\ln \sigma_g^2}\right) \quad (3.1)$$

In this equation, $f_x(x)$ is the lognormal distribution, D_g is the geometric mean diameter, σ_g is its geometric standard deviation, x is the particle size.

Just as the smoke particles escape above over fire their number concentration is very high but decreases as they move up along with the plume due to decrease in temperature towards the ceilings and the process of collision between the smoke a particle leads to agglomeration. In the initial region of a fire plume, a high number concentration of particles, N , with a fixed volume, V , and soot density, ρ , are expected. The total mass of the soot concentration can be calculated using equation 3.2, (James, 2004).

$$M_s = N\rho \left(\frac{4}{3}\pi\right) \left(\frac{d}{2}\right)^3 \quad (3.2)$$

$$= \frac{1}{6}N\rho\pi d^3 \quad (3.3)$$

Where M_s is the total mass of the soot concentration and d is the diameter of each particle. If the mass concentration, M_s and the density of the particles, ρ remain constant, the number concentration of the smoke particles N can then be written as;

$$N = \frac{6M_s}{\pi\rho d^3} \quad (3.4)$$

This equation shows that when the particle size d for instance doubles due to agglomeration the number concentration decreases by a factor of 8 and so on. As this smoke reaches the ceiling, they form ceiling jets shown by the two-layer model in figure 3.1. These ceiling jets lead to activation of smoke detectors that are normally fixed on the ceilings.

Detector activation has been attributed to various smoke characteristics such as velocity, number concentration, neutralization of the charged particles, and temperature changes. A consequence of smoke, most commonly associated with detection, is optical density. Optical density, or obscuration, is a term used to describe the reduction of light transmitted across some path length due to the density of the smoke present in a given volume.

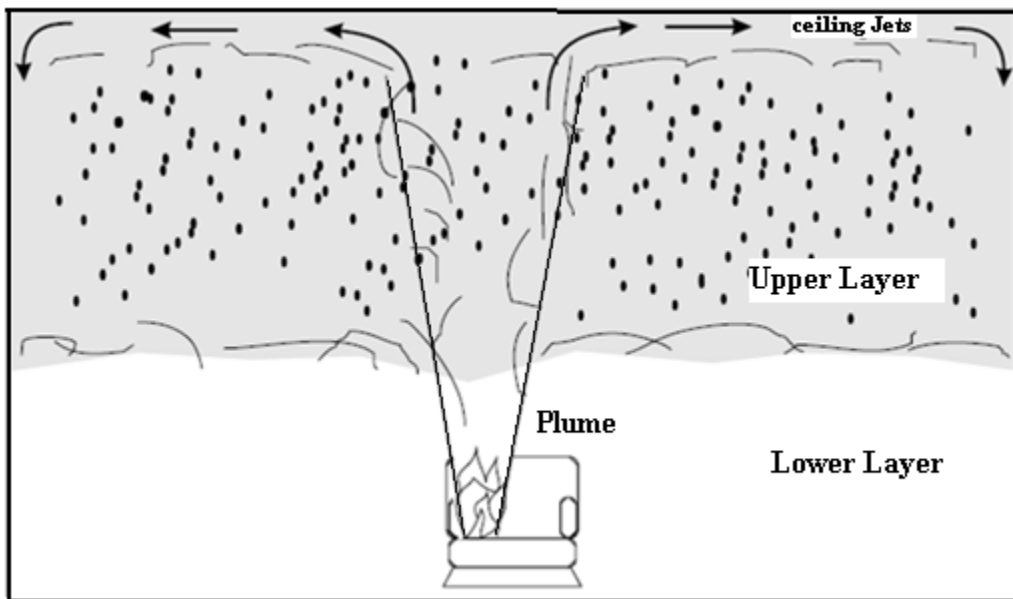


Figure 3.1: The zone model showing the flow of smoke from the fire source to the ceilings thus forming ceiling jets (Walter et al., 2005).

Build up of smoke on the ceiling reduces optical density of light transmitted across some path. This property is utilized in the design of photoelectric smoke detectors. The basis for optical density, or light extinction measurements uses Bouguer's Law. This relates the intensity of the incident monochromatic light I_o , of wavelength λ , and the intensity of the light, I_e transmitted through a path length L of the smoke as depicted in equations 3.5 through 3.7.

$$\tau_\lambda = \ln \frac{I_e}{I_o} \quad (3.5)$$

Equation 3.5 can also be rewritten as;

$$\tau_\lambda = -K_{ext} L \quad (3.6)$$

Combining equation 3.5 and 3.6 leads to equation 3.7

$$\frac{I_e}{I_o} = e^{-K_{ext} L} \quad (3.7)$$

Where K_{ext} is the extinction coefficient, τ_λ is the transmittance. Equation 3.7 shows exponential attenuation in intensity of smoke with distance.

In order to determine the obscuration levels of smoke that leads to smoke detector activation, an aerosol density meter is normally used. The readings of this meter with and without smoke are taken as T_s and T_c respectively. Obscuration Q_u is then calculated from equation 3.8 (James, 2004).

$$Q_u = \left[1 - \left(\frac{T_s}{T_c} \right)^{\frac{1}{d}} \right] \times 100 \quad (3.8)$$

where d is the distance in meters.

3.3 Heat transfer and temperature detection

A part from smoke produced during burning, burning materials cause vertical heat flow through conduction, convection and radiation aided by the fire plume. This heat transfer plays a significant role in raising the temperature surrounding temperature sensors normally fixed on the ceiling or at specific locations raised above the floor of the room to

be protected. The convective portion of the heat release rate by the burning materials is given by equation 3.9 (John, 1997).

$$Q_c = \xi Q \quad (3.9)$$

Where Q is the heat release of fire and ξ is the convective fraction of heat release that depends on the conduction through the fuel and radiative heat transfer through the flame. This fraction is normally taken as 0.7. The average change in temperature of fire plume is given by equation 3.10.

$$\Delta T = \frac{Q_c}{\dot{m} C_p} \quad (3.10)$$

Where ΔT is the average temperature increase above the room temperature in $^{\circ}C$, \dot{m} is the mass flow in plume at height z in Kg/s, Q_c is convective heat release rate of fire in KW, C_p is the Specific heat of plume gases. If the ambient temperature is T_a and the average temperature for detector activation is T_p then equation 3.10 becomes:

$$T_p - T_a = \frac{Q_c}{\dot{m} C_p} \quad (3.11)$$

Equation 3.11 can be rewritten as;

$$T_p = T_a + \frac{Q_c}{\dot{m} C_p} \quad (3.12)$$

This equation shows that the activation temperature T_p depends on the convective heat released from burning materials.

3.4 Temperature sensors

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 are discussed.

3.4.1 Resistor temperature dependent (RTD)

RTD sensors are sensors which are made from materials whose resistance varies with temperature. The resistance versus temperature curve for this sensor is almost linear as depicted in figure 3.2. From this graph, the continuous curve shows the variation of RTD resistance versus temperature while the one represented by the dotted line is for reference. For low and high temperatures the resistance versus temperature of RTD shows non-linearity. This can however be corrected using linearising circuits. Materials used to make RTDs are usually costly and possess self heating hence limiting their application.

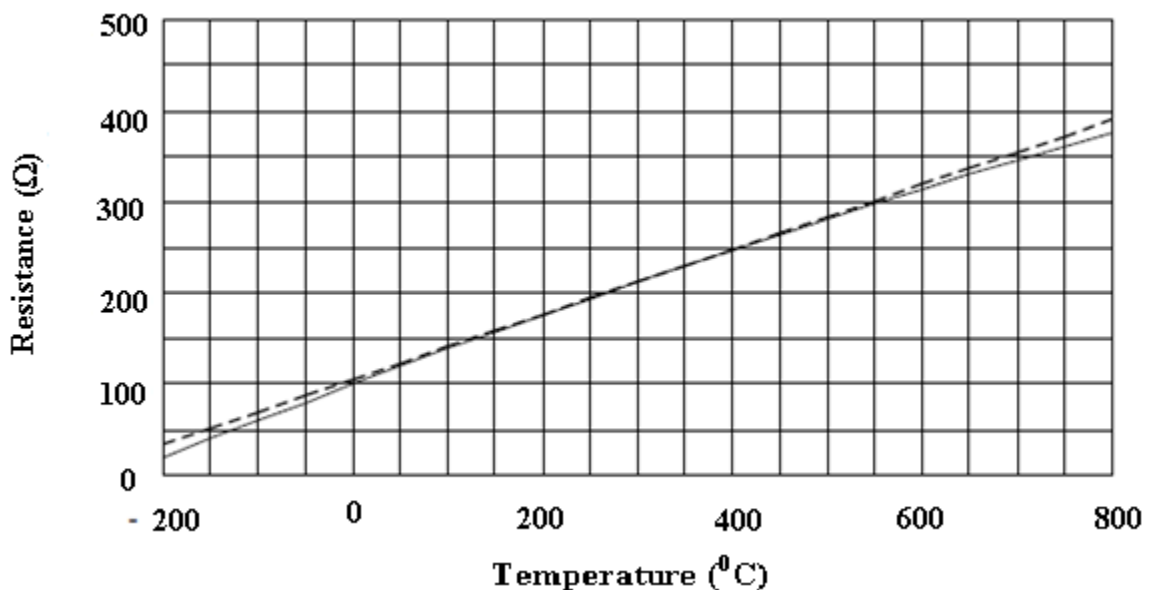


Figure 3.2: RTD Resistance versus temperature (National semiconductor, 1997).

3.4.2 Thermistors

Thermistors are essentially semiconductor devices which behave as thermal resistors having a high negative temperature coefficient (NTC) or positive temperature coefficient (PTC) of resistance. NTC sensors are normally made from mixtures of oxides iron, manganese, nickel, cobalt and copper. The resistance value of these sensors at ambient temperature may range from 100 Ω to 100 k Ω but decreases with increase in temperature in non-linear form. The resistance R_t of a thermistor at temperature T is expressed by equation 3.13 (National semiconductor, 1997).

$$R_t = R_0 \exp\left(\frac{\beta(T_0 - T)}{TT_0}\right) \quad (3.13)$$

Where β is the material constant for the Thermistor and T_0 is the standard reference temperature in kelvin. β is usually about 4000. The change in resistance with temperature for a thermistor is very non-linear hence requires substantial linearization in measuring wider range of temperatures.

3.4.3 Thermocouple

Thermocouple is a sensor made from two metals of different seebeck coefficients. These two metals are tied together to form a junction at one end. Figure 3.3 shows type J thermocouple. Junction 1 is at the temperature to be measured while junctions 2 and 3 are kept at a different known temperature. The output voltage of this sensor is approximately proportional to the difference in temperature between Junction 1 and Junctions 2 and 3. In order to obtain an output voltage proportional to an appropriate scale such as Celsius scale, a second sensor such as LM 35 shown in figure 3.3 is connected to the output of the thermocouple. This output is usually small as depicted by the various thermocouple

3.4.4 LM 35 Temperature sensor

The LM35 is an IC temperature sensor whose output voltage is linearly proportional to the Celsius temperature. It works well with a single power supply whose voltage ranges from 4 – 30 V and draws 60 μA (National semiconductor, 2000). When operating within this range its output voltage is $+10\text{mV}/^{\circ}\text{C}$ (figure 3.4). It does not require any external calibration to provide accuracies of $\pm 1/4^{\circ}\text{C}$ at room temperature and $\pm 3/4^{\circ}\text{C}$ over a full -55 to $+150^{\circ}\text{C}$ temperature range. These features among others make LM 35 most suited for use in many electronic applications.

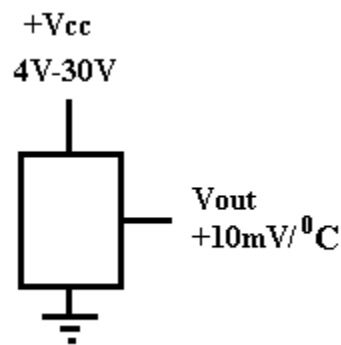


Figure 3.4: Symbol for LM 35 temperature sensor (Microchip, 2004).

3.5 Smoke sensors

There are two categories of smoke sensors namely photoelectric and ionization types. Photoelectric smoke sensors employ the use of light sensitive materials such as cadmium sulphide while ionization sensors use radioactive material such as Americium 241. Next section describes the two types of smoke sensors and their properties.

3.5.1 Photoelectric smoke sensors

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, 2002). Photosensitive materials such as light dependent resistors (LDR) showed in figure 3.5 use this property to sense the presence or absence of light.

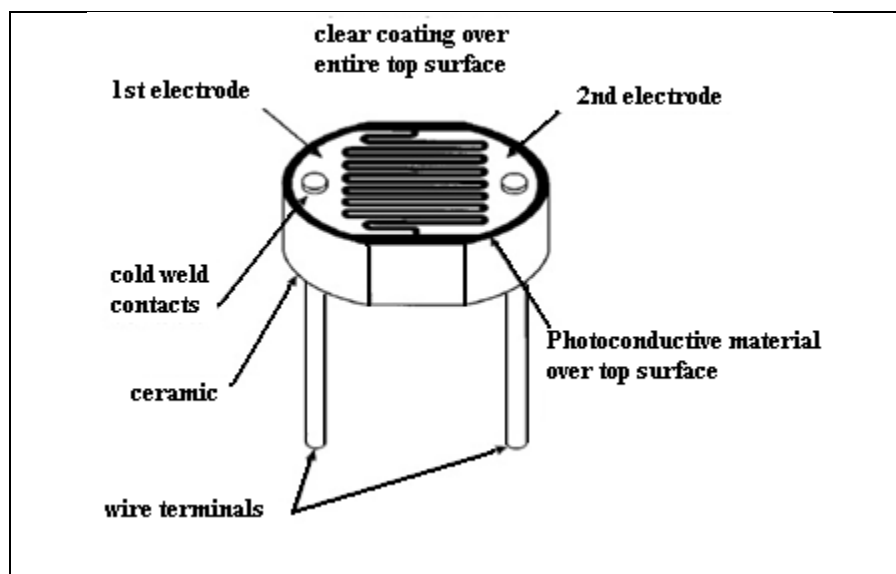


Figure 3.5: Cadmium sulphide photoresistor (Salamanca, 2005).

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 as shown in figure 3.6. These sensors are often made from cadmium sulfide (CdS) which is a direct band gap semiconductor whose band gap energy is 2.42 eV. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance of the material.

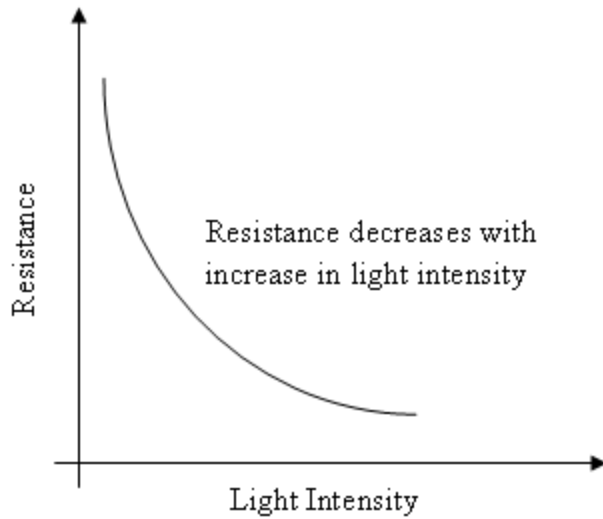


Figure 3.6: Variation of LDR resistance with increase in light intensity (Salamanca, 2005).

The resistance of an LDR is given by equation 3.14 (Salamanca, 2005).

$$R = bE^{-\gamma} \quad (3.14)$$

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 $\gamma = 1$, however many factors contribute to variation of γ , so that in the real case $\gamma < 1$. If theoretical value of γ is taken as 1 then equation (3.14) becomes:

$$R = bE^{-1} \quad (3.15)$$

This shows that as light intensity falling on the material is increased, its resistance decreases.

There are two ways in which we can use this property to design a circuit that produce the desired voltage output. These are shown in figures 3.7 and 3.8. The circuit diagram in the two cases forms a potential divider.

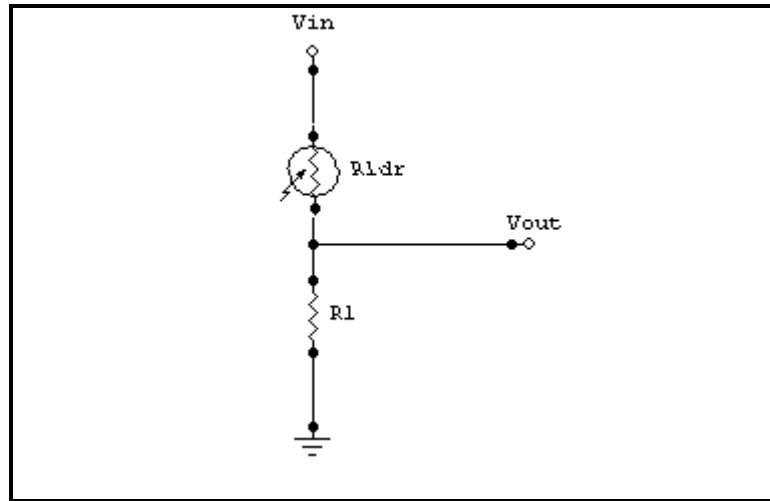


Figure 3.7: Circuit diagram for voltage increase with increase in light intensity.

The output voltage in figure 3.7 is given by equation 3.16

$$V_{out} = \frac{R_1 V_{in}}{R_{ldr} + R_1} \quad (3.16)$$

where R_{ldr} and R_1 are the resistance of LDR and a fixed resistor respectively. This equation shows that as the resistance of the LDR decreases due to increase in light intensity the output voltage V_{out} tends to V_{in} . It tends to zero as LDRs resistance tends to infinity (Due to decrease in light falling on the LDR). In figure 3.8 the output voltage V_{out} is given by equation 3.17.

$$V_{out} = \frac{R_{ldr} V_{in}}{R_1 + R_{ldr}} \quad (3.17)$$

From this equation, it is also clear that as resistance of LDR decreases the output voltage tends to zero. It also tends to V_{in} as light falling on it decreases.

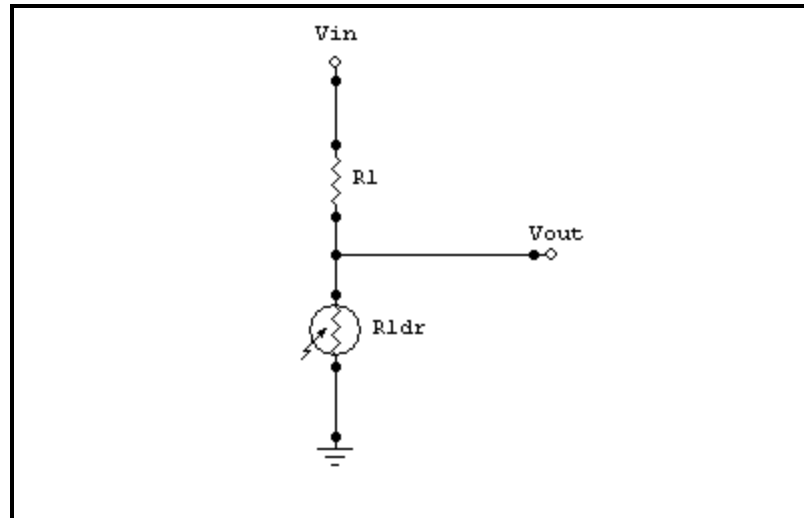


Figure 3.8: Circuit diagram for voltage decrease with increase in light intensity.

Photoelectric smoke detectors employing the properties discussed above are of two types namely: Light scattering smoke detectors and light obscuration smoke detectors. Photoelectric light scattering smoke detector utilizes light from light-emitting diode (LED) beamed into an area not normally “seen” by a photosensitive element, generally an LDR (Figure 3.9b). When smoke particles enters the light path, light strikes the particles and is reflected onto the photosensitive device causing the detector to respond. The obscuration type detectors are usually of the projected beam type. They are made up of light source that spans the area to be protected and photosensitive receiving devices (Figure 3.9c). When smoke particles partially block light beam (Figure (3.9d), the reduction in light reaching the photosensitive device alters its output. The change in output is sensed by the detector’s circuitry, and when the threshold is exceeded, an alarm is initiated

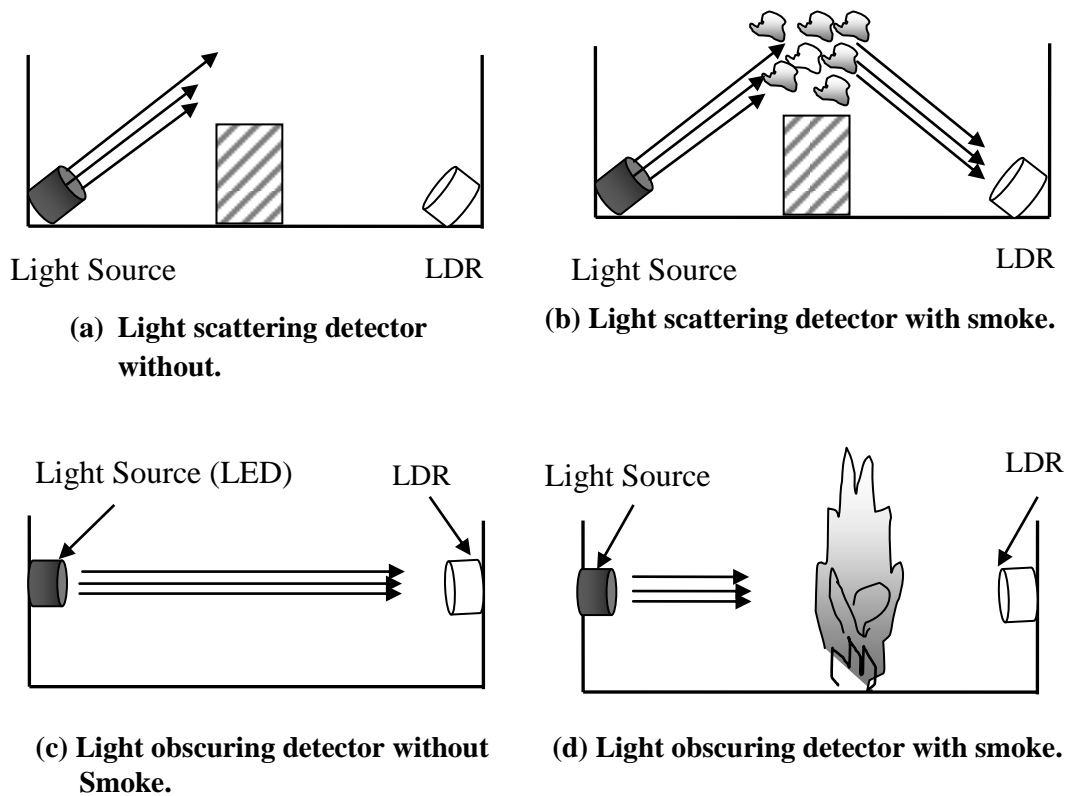


Figure 3.9: Schematic illustrations of photoelectric smoke detectors.

3.5.2 Ionization Smoke Detector

Ionization smoke detectors 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 (Figure 3.10). The radioactive source emits particles that collide with the air molecules and dislodge 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 (Figure 3.10b). 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 centers, 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.

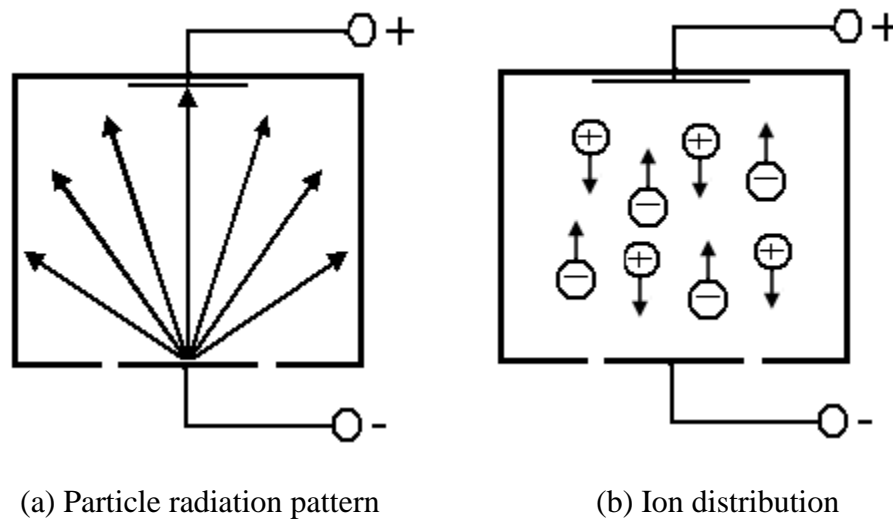


Figure 3.10: Ion and particles of combustion distribution (System sensor, 2002).

3.6 Opamp voltage comparator

A comparator is a device that compares two voltages or currents and switches its output to indicate which is larger. It has two inputs; inverting and non-inverting inputs. When the non-inverting input (+V) is at a higher voltage than the inverting input (-V), the high gain of the op-amp causes the output to saturate at the highest positive voltage it can

output. However when the non-inverting input (+V) drops below the inverting input (-V), the output saturates at the most negative voltage it can output.

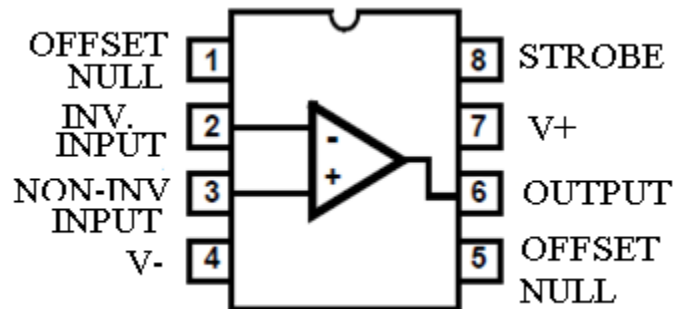


Figure 3.11: Operational amplifier CA3130 (Intersil, 2002).

Figure 3.11 shows an Operational amplifier CA3130 that was used in this research as the comparator. This type of Op amp works with voltage range of (5-16) V. The main advantage of this comparator is the use of positive voltage only as compared to most operational amplifiers that requires both positive and negative voltages.

3.7 Parallel port

Parallel Port is the most commonly used port for interfacing many devices. This port allows the input of up to 9 bits or output of 12 bits at any one given time, thus requiring minimal external circuitry to implement many simpler tasks. The port is composed of 4 control lines, 5 status lines and 8 data lines. The rest of the pins (18-25) are signal grounds. Apart from the D type 25 pin parallel port commonly found at the back of most computers, centonic type with 36 pins also exist. Table 3.2 shows the pinout diagram for both types. The bar on top of the signal name such as $\overline{\text{Error}}$ is used to denote that the

signal is active low. If the printer experiences an error then this line is low but when the printer is working normally this line is high. The "Hardware Inverted" means the signal is inverted by the Parallel card's hardware. Such an example is the Busy line. If +5 V (Logic 1) was applied to this pin and the status register read, it would return back a 0 in Bit 7 of the Status Register.

Table 3.2: Pin Out for D-Type 25 Pin female connector (Peacock, 1998).

Pin No (D-Type 25)	Pin No Centronic	SSP Signal	Direction In/out	Register	Hardware Inverted
1	1	$\overline{\text{Strobe}}$	In/Out	Control	Yes
2	2	Data 0	Out	Data	
3	3	Data 1	Out	Data	
4	4	Data 2	Out	Data	
5	5	Data 3	Out	Data	
6	6	Data 4	Out	Data	
7	7	Data 5	Out	Data	
8	8	Data 6	Out	Data	
9	9	Data 7	Out	Data	
10	10	$\overline{\text{Ack}}$	In	Status	
11	11	Busy	In	Status	Yes
12	12	Paper-Out Paper End	In	Status	
13	13	Select	In	Status	
14	14	$\overline{\text{Outo Linefeed}}$	In/Out	Control	Yes
15	32	$\overline{\text{Error}}$	In	Status	
16	31	$\overline{\text{Initialize}}$	In/Out	Control	
17	36	$\overline{\text{Select-Printer}}$ $\overline{\text{Select- In}}$	In/Out	Control	Yes
18-25	19-30	Ground	Gnd		

3.7.1 Parallel port registers

There are three registers found in the D-Type 25pin connector. These are data register, status register and control register. As shown in table 3.2 data register ($D_0 - D_7$) can be accessed through pins 2-9, Status register ($S_3 - S_7$) through pins 10, 11, 12, 13 and 15 and control register ($C_0 - C_3$) through pins 1, 14, 16 and 17. Data register with the base address 378H is normally used for data output though it can also be made bidirectional. The next register after the data register, base + 1 (379H), is the status register. Five of the bits in the status register map to lines on the 25-pin connector; Busy, $\overline{\text{Ack}}$, PaperEnd, Select and $\overline{\text{Error}}$). These lines are already configured for input. The control register that is normally configured for output is at address base+2 (037A). The four bits in this register maps to lines $\overline{\text{Strobe}}$, $\overline{\text{Outo Linefeed}}$, $\overline{\text{Initialize}}$ and $\overline{\text{Select-Printer}}$).

In order to input 8 bits of data through parallel port without using data lines, status lines (normally set for input) and control lines (normally set for output) can be used. The upper nibble of the status register and the lower nibble of the control register can be combined to form one byte as discussed in chapter 4. However, one has to be careful with all lines that are inverse low and hardware inverted. Control register normally has open collector output (two possible states, high impedance and GND) and thus open collector inverters shown in figure 3.12 have to be used. If inputs is connected directly to the port (For example an ADC0804 with totem pole outputs), a conflict will result if the input is high and the port is trying to pull it down.

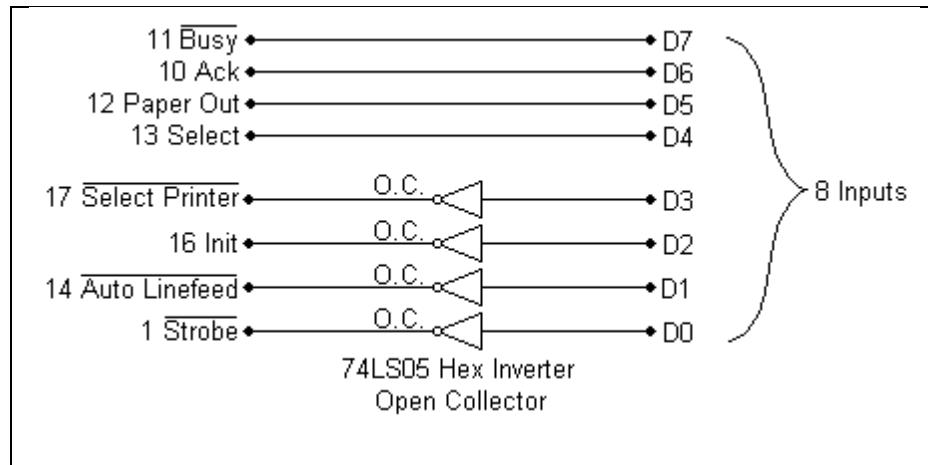


Figure 3.12: Register map for control and status port (National Instruments Corporation, 2004).

3.7.2 Parallel port addresses

Parallel Port has three commonly used base addresses as listed in table 3.3. LPT1 is normally assigned base address 378H, while LPT2 is assigned 278H. However when computer is first turned on, BIOS (Basic Input/output System) searches the devices in the three locations namely address 3BCH, 378H and 278H in that sequence.

Table 3.3: Parallel port addresses (Peacock, 1998).

Address	Notes:
3BCH - 3BFH	Used for parallel port which were incorporated in Video Cards and now, commonly an option for ports controlled by BIOS-Don't support ECP addresses
378H - 37FH	Usual address for LPT 1
278H - 27FH	Usual address for LPT 2

If a device is found in any of these base addresses, BIOS assigns it the label LPT 1, LPT2 & LPT3 depending on which one appeared first. It is therefore possible to have LPT 1 in base address 3BCH, LPT 2 in base address 378H and so on.

3.8 USB Port

USB (Universal Serial Bus) port is an industry standard for short-distance digital data communications. The common versions of USB are USB 1.0, USB 2.0 and USB 3.0. The latest USB 3.0 released the year 2010 has the highest data transfer rate of 5 Gbit/s and allows full duplex signaling when operating in super speed mode. Low USBs are commonly used for Human Input Devices (HID) such as the printers, scanners, Keyboards and mice.

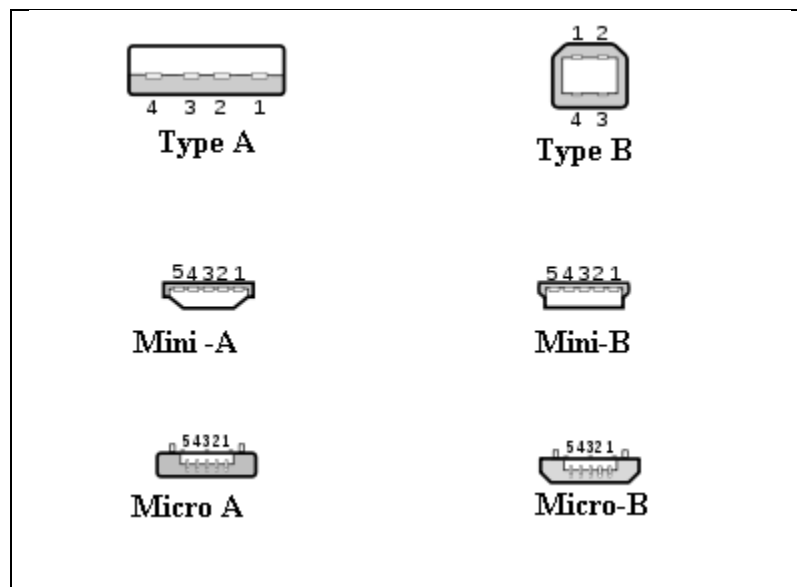


Figure 3.13: Pinouts of standard, mini, and micro USB sockets.
(<http://en.wikipedia.org/wiki/USB>)

There are several types of USB connectors. These include Standard-A, Standard-B, Mini-A, Mini-B, Micro-A, Micro-AB and Micro-B (figure 3.13). Type A connectors are used

in host controllers in computers and hubs designed to provide 5V DC power to the USB port. Type B connector which is square shaped and has slightly beveled corners on the top ends of the connector is designed for use on USB peripheral devices such as printers. On the other hand, the mini and micro USB which are smaller in size compared to type A are designed for use in newer mobile devices such as cellphones, digital cameras, PDAs among others.

The common USB port uses 4 shielded wires. Two of which are for +5V and GND while the rest are for differential data signals labeled D+ and D- as shown in Table 3.4. D+ and D- signals are transmitted on a twisted pair. No termination is needed. Half-duplex differential signaling helps to combat the effects of electromagnetic noise on longer lines.

Table 3.4: The USB pinout diagram (Electus distribution, 2001).

Pin	Name	Cable color	Description
1	VCC	Red	+5 VDC
2	D-	White	Data -
3	D+	Green	Data +
4	GND	Black	Ground

3.9 Serial port (RS-232)

Serial ports being one of the oldest of the interface standards complies with the RS-232 standard. They are nine-pin connectors that relay information, incoming or outgoing, one bit at a time. Each byte is broken up into a series of eight bits, hence the term serial port. Before internal modems became commonplace, external modems were connected to computers via serial ports, also known as communication or ‘COM’ ports. Computer mice and keyboards also use serial ports. Some serial ports use 25-pin connectors, but the nine-pin variety is more common. Serial ports are controlled by a special chip called a UART (Universal Asynchronous Receiver Transmitter). Figure 3.14 shows a 9-pin computer port pinout diagram while table 3.5 provides pinout identification for the 9-pin (DB-9) and 25-pin (DB-25) serial port connectors.

Table 3.5: Serial port pinout identification for DB-9 and DB-25 connectors.

DB-9 Pin number	DB-25 Pin number	Signal
1	8	DCD, data carrier detect
2	3	RXD, receive data
3	2	TXD, transmit data
4	20	DTR, data terminal ready
5	7	GND, signal
6	6	DSR, data set ready
7	4	RTS, request to send
8	5	CTS, clear to send
9	22	R1, ring indicator

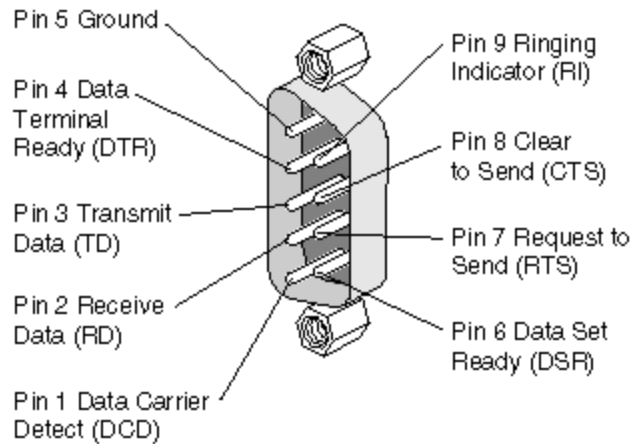


Figure 3.14: 9-pin computer serial port pinout diagram.
http://en.wikipedia.org/wiki/Serial_port

3.10 GSM (Global system for mobiles) network

Global system for mobile communications (GSM) is a cellular network that provides a common set of compatible services and capabilities to the mobile users all over the world. Its structure is shown in the figure 3.15. It consists of three main parts:

- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network & Switching Subsystem (NSS)

3.10.1 Mobile station

Mobile station consists of mobile equipment (ME) and a subscriber identity module (SIM). Mobile equipment can be a mobile phone, portable device or vehicle mounted devices while SIM card is a small memory device mounted on a card that contains all the information of a subscriber. To send messages or dial any number through GSM network, a valid SIM card from any home mobile operator within that area is inserted into the mobile equipment.

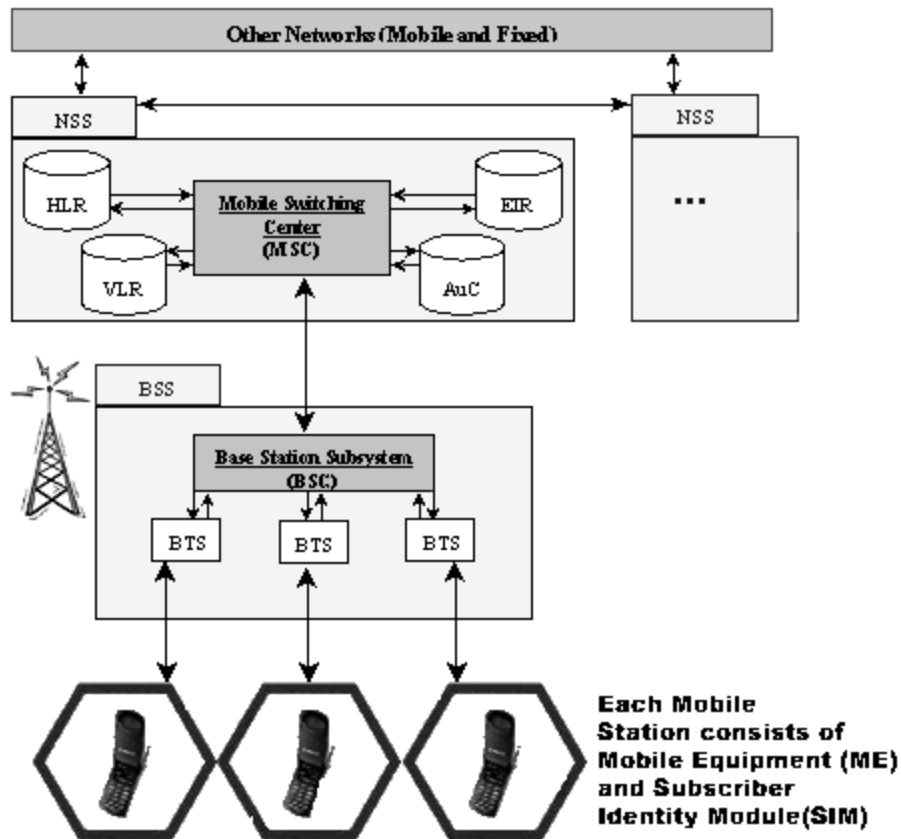


Figure 3.15: Layout of generic GSM network
(http://www.pulsewan.com/data101/gsm_basics.htm).

3.10.2 Base station subsystem (BSS)

BSS provides a link between the ME and the NSS. It consists of the Base Transceiver Station (BTS) and Base Station Controller (BSC). BTS defines a cell and is responsible for radio link protocols with the Mobile Station. BSC connects Mobile Station and Mobile switching center. Its work is to controls multiple BTSs and manages radio channel setup and handovers.

3.10.3 Network and switching subsystems (NSS)

NSS provides mobility management and switching of calls between mobile users, and between mobile and fixed network users. It consists of Mobile Switching Center (MSC), Home Location Register (HLR), Visitor Location Register (VLR), Authentication Center (AuC) and Equipment Identity Register (EIR).

MSC is the central component of the NSS performing all switching functions for the mobiles within its jurisdiction and interface between mobile and other network. HLR is a database for storage and management of subscriptions. This database is important as it stores permanent data about subscribers, including a subscriber's profile, location information and activity status.

(<http://www.cs.ucl.ac.uk/staff/t.pagtzis/wireless/gsm/arch.html>, 2010).

VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers and is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request the database about the mobile station from the HLR. Later if the mobile station makes a call, the VLR will have the information needed for call setup without interrogating the HLR each time.

Authentication Center (AuC) which is part of NSS is a protected database that stores the security information for each subscriber. This protects operators from different types of fraud found in today's cellular world.

3.11 Short message service (SMS)

SMS is a technology that enables the sending and receiving of short messages between mobile phones. It is a technology that has been used extensively in today's wireless world. It was originally designed for person-to-person messaging service where a sender could use his mobile phone to send a brief text message to a recipient (Ueng *et al.*, 2007). Since its invention, its application has been increasing over time. Much information such as alert notification, news, financial information, etc. has been sent through SMS since mobile phones are very popular among many people and are carried by their owners most of the time. Sending and receiving SMS messages through mobile phones can be achieved through AT (Attention) commands. AT commands are set of instructions used for controlling mobile phone or GSM/GPRS modem (Atmel Corporation, 2006). These commands are also used to control dial-up modems for wired telephone system. Dial-up modems, mobile phones and GSM/GPRS modems support a common set of standard AT commands. In addition to this common set of standard AT commands, mobile phones and GSM/GPRS modems support an extended set of AT commands. One use of the extended AT commands is to control the sending and receiving of SMS messages. Table 3.6 lists the AT commands that are related to the writing and sending of SMS messages.

In order to send SMS message to a mobile phone through a computer, a valid SIM card from a wireless carrier is inserted into the mobile phone or GSM/GPRS modem, which is then connected to a computer. There are several ways to connect a mobile phone or GSM/GPRS modem to a computer. These includes: serial cable (RS 232), USB cable, Bluetooth link and infrared link. The actual way to use depends on the capability of the

mobile phone or GSM/GPRS modem. When the connection between the computer and the mobile phone/modem has been established, mobile phone or modem can thus be controlled by sending AT commands to instruct it to send SMS. Since most mobile phones available in today's market come with inbuilt Bluetooth, this link was used in this research and is discussed briefly in the next section.

Table 3.6: AT commands for writing and sending of SMS (Atmel Corporation, 2006).

AT command	Meaning
+CMGS	Send message
+CMSS	Send message from storage
+CMGW	Write message to memory
+CMGD	Delete message
+CMGC	Send command
+CMMS	More messages to send

3.12 Bluetooth

Bluetooth wireless technology is a short-range communications system operating in the unlicensed ISM band at 2.4 GHz. It was intended to replace the cable(s) connecting portable or fixed electronic devices (Jean, 2000). The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack. RF operation uses a shaped, binary FM modulation to minimize transceiver complexity. The symbol rate is 1 Megasymbol per second (Ms/s) supporting the bit rate of 1 Megabit per second (Mb/s). Bluetooth system offers services that enable the connection of devices and the exchange of a variety of

classes of data between these devices. It comes in three classes: Class 1, 2, and 3. The power outputs and range for each of the three classes are shown in table 3.7. Class 2 and 3 are commonly used since they have less power consumption as compared to class 1. However, the greatest advantage of class 1 is their wide range of coverage giving room to wider applications.

Table 3.7: Power classes (Jean, 2000).

Power class	Maximum power output (mW)	Range(m)
1	100	100
2	2.5	10
3	1	1

Figure 3.16 shows a Bluetooth stack. It is made up of the hardware and software portions of the system. Basically Bluetooth stack contains physical layer protocol (baseband), Link Manager Protocol, or LMP), Logical Link Control and Adaptation Layer Protocol (L2CAP) and the application. The radio frequency (RF) that forms part of the physical layer provides digital signal processing component of the system whereas the baseband processes these signals. The link control handles all the baseband functions and supports the link manager. It sends and receives data, identifies the sending device, performs authentication, and determines the type of frame to use for sending transmissions. A part from these, link control also gives direction on how devices listen for transmissions from other devices and can move devices into power-saving modes.

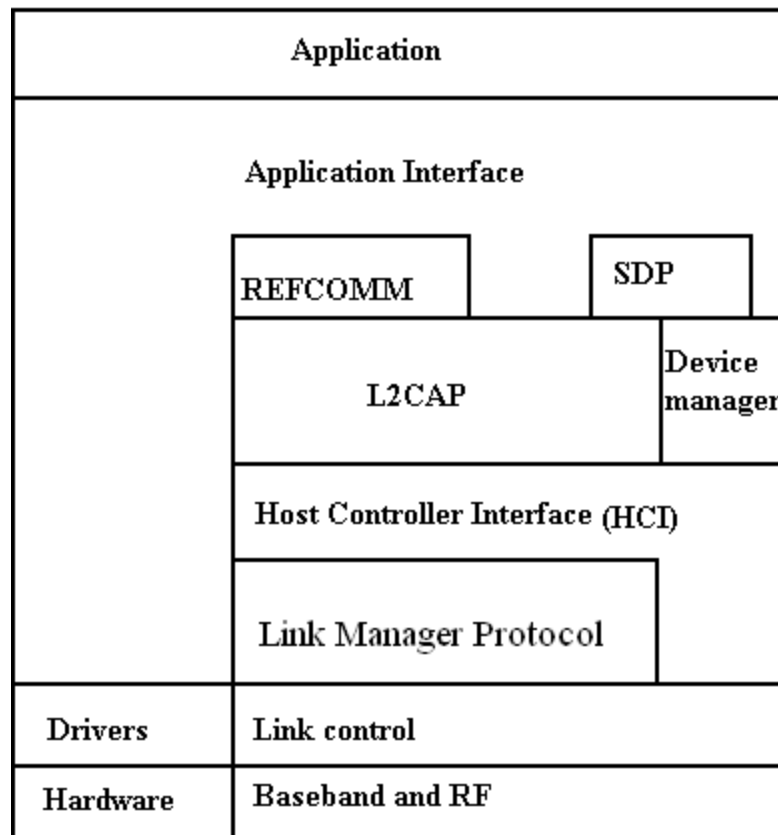


Figure 3.16: Bluetooth protocol stack.
http://media.wiley.com/product_data/excerpt/75/07645488/0764548875.pdf

The host controller interface (HCI) communicates the lower-layer protocols to the host devices such as mobile computer or mobile phone. It contains a processor and the L2CAP. L2CAP supports the upper-layer protocols and communicates between upper and lower layers. The upper-layer protocols consist of service-specific applications that must be integrated into the host application. These include RFCOMM protocol and Service Discovery Protocol (SDP). RFCOMM allows for the emulation of serial ports over the L2CAP while SDP provides the means for Bluetooth applications to discover the services and the characteristics of the available services that are unique to Bluetooth. Bluetooth device manager provides for device inquiry and connection management

services. Bluetooth has a number of profiles that keep on increasing from time to time. Some of these include Generic Access Profile (GAP), Service Discovery Application Profile (SDAP), Serial Port Profile (SPP) and Generic Object Exchange Profile (OBEX).

3.13 LabVIEW

3.13.1 Introduction

In order to link the Bluetooth enabled computer to a Bluetooth enabled mobile phone using Bluetooth link, driving software is required. The software used in this is LabVIEW (Laboratory Virtual Instrument Engineering Workbench). LabVIEW is a graphical programming. Program is created using graphical notations other than text based programming as in C, C++, or Java (Travis and Kring, 2006). Graphical programming eliminates a lot of the syntactical details associated with text-based languages. It allows the programmer to concentrate on the flow of data within the application since its simple syntax does not obscure what the program is doing.

3.13.2 Main components of LabVIEW

LabVIEW program is made up two main parts: a front panel and a block diagram. The front panel is the interactive user interface of a Virtual Instrument (VI). It is named so because it simulates the front panel of a physical instrument (Figure 3.17a). Front panel contains knobs, push buttons, graphs, and many other controls which are user inputs and indicators which are program outputs. Data can be input using a mouse and keyboard, and the results produced viewed on the screen. The block diagram is the VI's source code constructed in LabVIEW's graphical programming language as shown in Figure 3.17b.

This is thus the actual executable program. The components of a block diagram are lower-level VIs, built-in functions, constants, and program execution control structures. Construction of the program is done by drawing wires to connect the appropriate objects together in order to define data flow between them. Front panel objects have corresponding terminals on the block diagram hence data can pass from the user to the program and back to the user.

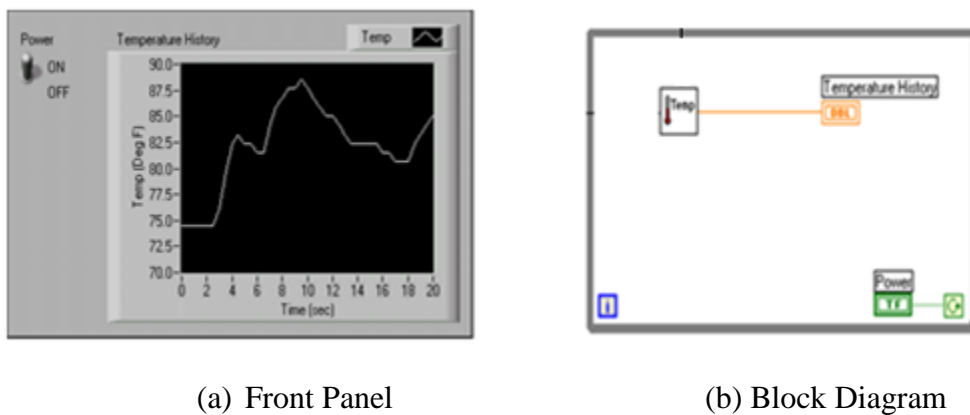


Figure 3.17: LabVIEW front panel and block diagram (Travis and Kring, 2006).

3.13.3 SubVI, icon and connector

A VI that is used within another VI is called a subVI and is analogous to a subroutine in text based programming language. In order to use a VI as a subroutine in the block diagram of another VI, it must have an icon with a connector as shown in Figure 3.18.

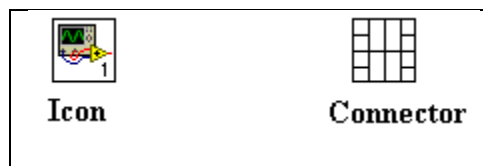


Figure 3.18: VI icon and connector.

The icon is a VI's pictorial representation of a subVI and is used as an object in the block diagram of another VI. A VI's connector is the mechanism used to wire data into the VI

from other block diagrams when the VI is used as a subVI. Much like parameters of a subroutine, the connector defines the inputs and outputs of the VI.

3.13.4 VISA

VISA (Virtual Instrument Software Architecture) is a high-level API (Application Programming Interface) that calls into lower level drivers. It is capable of controlling VXI, GPIB, or Serial instruments and makes the appropriate driver calls depending on the type of instrument being used. In order for Labview to communicate with any instrument, VISA needs to know the physical connection of the instrument and its location. This information is done via VISA resource string. Table 3.8 shows some syntax for constructing VISA resource strings while table 3.9 shows VISA resource names and their meanings.

Table 3:8: Physical connection of VISA resource string syntax (Travis and Kring, 2006).

Physical connection	Visa resource string
VXI	VXI[board]::VXI logical address[::INSTR]
GPIB	GPIB[board]::primary address[::GBIB secondary address][::INSTR]
PXI	PXI[bus]::device[::function][::INSTR]
Serial	ASRL[board][::INTR]
Serial	COM[port number]
TCP-IP	TCPIP[board]::host address[::LAN device name][::INSTR]
TCP-IP (raw)	TCPIP[board]::host address::port::SOCKET
USB	USB[board]::manufacture ID::model cord::serial number[USB interface number][::INSTR]

Table 3.9: VISA resource names and their meanings.

VISA Resource Name	Description
COM 1	Serial Port on COM 1
ASRL3::INSTR	Serial Port on COM 3
GPIB0::12::INSTR	GPIB Board number 0,GPIB primary address 12

CHAPTER 4

EXPERIMENTAL PROCEDURE S

4.1 Introduction

Computer based systems are 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 of the two parts. It begins by giving an overview of the complete firefighting system designed then describes how the specific hardware and the software for the system were designed. Next section thus gives an overview of the designed fire fighting system.

4.2 Block diagram of the complete automatic firefighting system

This research aimed at designing a computer based firefighting system where temperature and smoke were to be under automatic control continuously. To achieve this, sensors that produce analog output were designed. To convert analog signal to digital format, an interfacing board also designed. Also integrated within interfacing board were the actuator switches. Parallel port was then used to feed the acquired input signal from the sensor to the computer. For notification purpose, Bluetooth enabled computer was linked to a Bluetooth enabled mobile phone connected to GSM network to send SMS to target remote mobile phones. A complete block diagram for the system is shown in figure 4.1. Next section discusses how the hardware parts of the system were designed. This includes temperature detector, smoke detector and interfacing board.

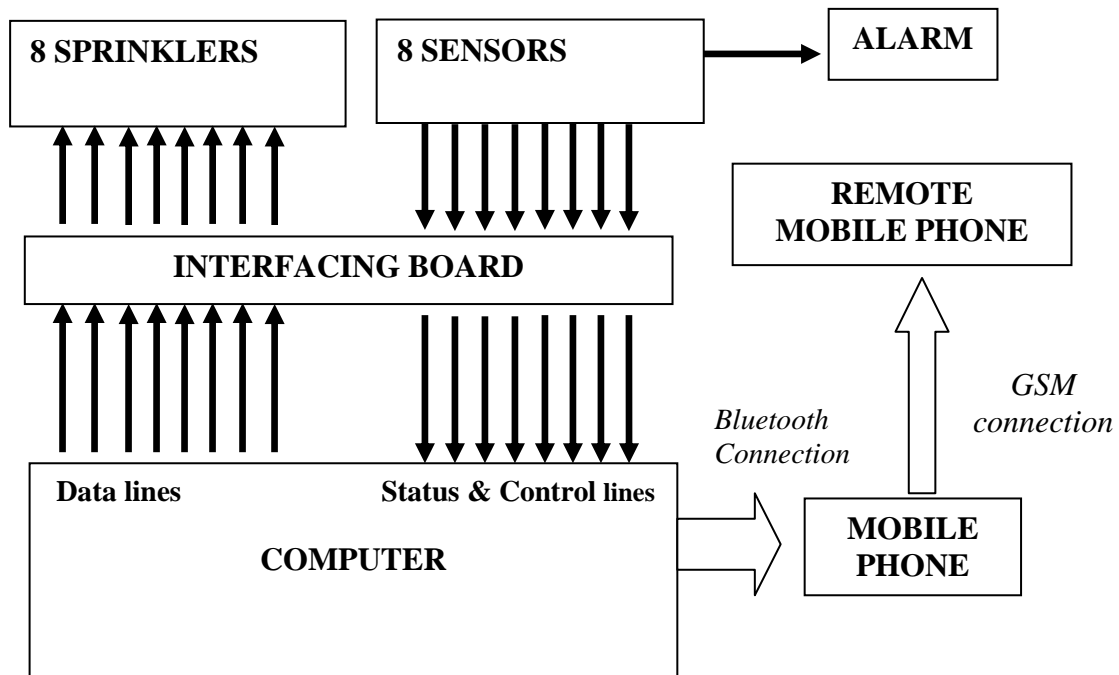


Figure 4.1: Schematic illustration of the designed computer based fire fighting system including the sensors, controlling devices and mobile communication.

4.3 Hardware design

The hardware component of this project is made up of the sensors, interfacing board and the actuators. Sensors were used to detect smoke, temperature or both and its output voltage used to trigger the software in the computer to respond according to the input voltage. The output voltage from the parallel port of the computer is used to activate or deactivate the actuators according to the inputs from the sensor. Due to possibility of inputting 8 data bit to the parallel port of the computer, a maximum of 8 sensors were connected to this system.

4.3.1 Temperature sensor circuit diagram

Temperature sensor used in this project was LM35 that has three terminals; input, output and ground. This sensor produces a linear output of $10 \text{ mV}/^{\circ}\text{C}$. Power supply of 9 V was connected to the input terminal via a $1\text{k}\Omega$ resistor. Its output was then connected to non inverting input (pin 3) of comparator IC3130E through $10 \text{ k}\Omega$ resistor (figure 4.2).

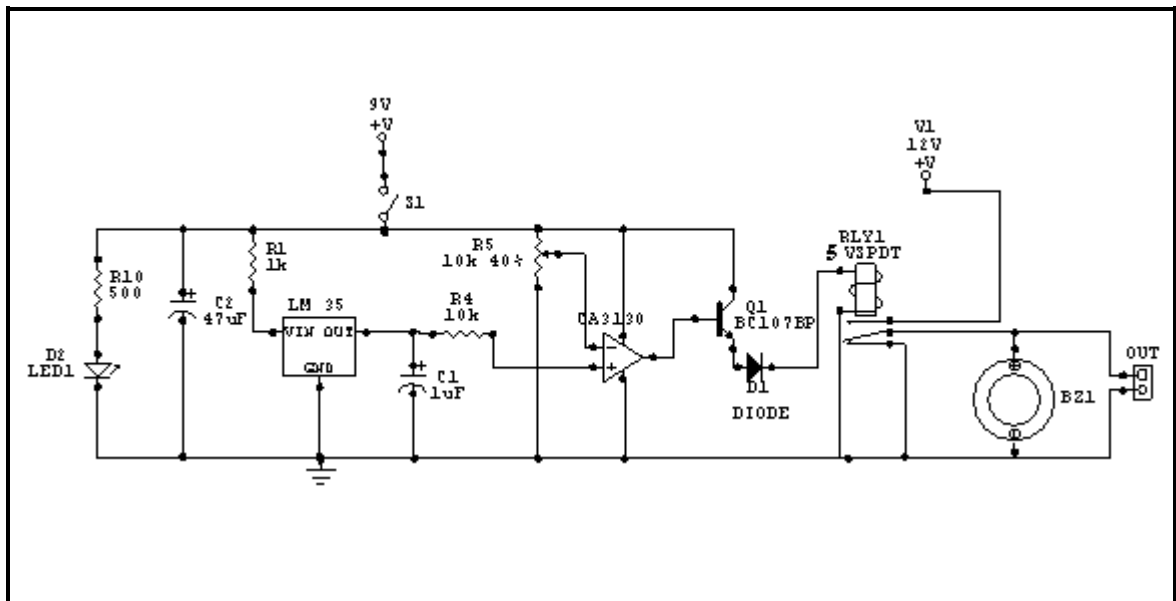


Figure 4.2: Circuit diagram illustrating temperature sensor employing the use of LM 35 IC.

The inverting input (pin 2) of IC CA3130 was connected to positive power supply through a potential divider. If the non-inverting input of this IC receives a voltage lower than the set level, its output goes low (approximately 650 mV). Conversely, if it input receives a voltage higher than the set level, its output goes high (approximately 2200 mV) (Chandra and Kalai, 2005).

The voltage to be compared to the output of the temperature sensor was set in the inverting terminal of the comparator (pin 2) using a 10 k Ω potential divider. Comparator was also powered by 9 V connected to it through pin 7. Output pin (pin 6) of the comparator was then connected to the base of an NPN transistor switch (Q1) (See the figure 4.2).

When the sensor was connected to the power supply and switched on, the output voltage of LM 35 at room temperature was checked using digital multimeter and was found to range from 22mV to 27mV depending on the time of the day in which the test was carried. These voltages corresponded to 22 $^{\circ}$ C to 27 $^{\circ}$ C. Potential divider was then varied such that 57 mV (corresponding to about 57 $^{\circ}$ C) was connected to the inverting input of the comparator. When the temperature of the surrounding was raised by bringing a 100 W electric bulb close to the sensor the output of the sensor rose beyond 57 mV at an average of 20 s which made the output of the comparator to go high biasing the NPN transistor which energized a 5 V relay.

4.3.2 Smoke sensor circuit diagram

Smoke sensor used in this project is an LDR whose source of light is a white LED. This LED was connected to the 9V power supply through 500 Ω resistor as shown in figure 4.3. LED and LDR sensor were separated by 3 cm (not necessarily standard). LDR was connected in series with a 10 k Ω resistor to form a potential divider. The voltage across this 10 k Ω resistor was connected to non-inverting input (pin3) of the second comparator IC3130 as used in the previous sensor. Inverting terminal (pin 2) was also connected to a 10 k Ω potential divider that was also connected to the power supply as shown in the

figure to provide a means of setting the voltage to be compared to that of the non inverting terminal. The output of the IC (at pin 6) was used to switch on transistor Q2 which activates the relay as in the temperature sensor discussed in the preceding section. When the smoke sensor was connected to the power supply and switched on, the output voltage was found to be 0V. When light from the LED falling onto the LDR was blocked the output voltage shoot to V_{cc} . Inverting terminal of the comparator was then set to 1.25 V using R_6 and smoke introduced into the detector and the output of the sensor was found to shoot above 3 V as measured using digital voltmeter. This voltage biased the transistor that energized the relay.

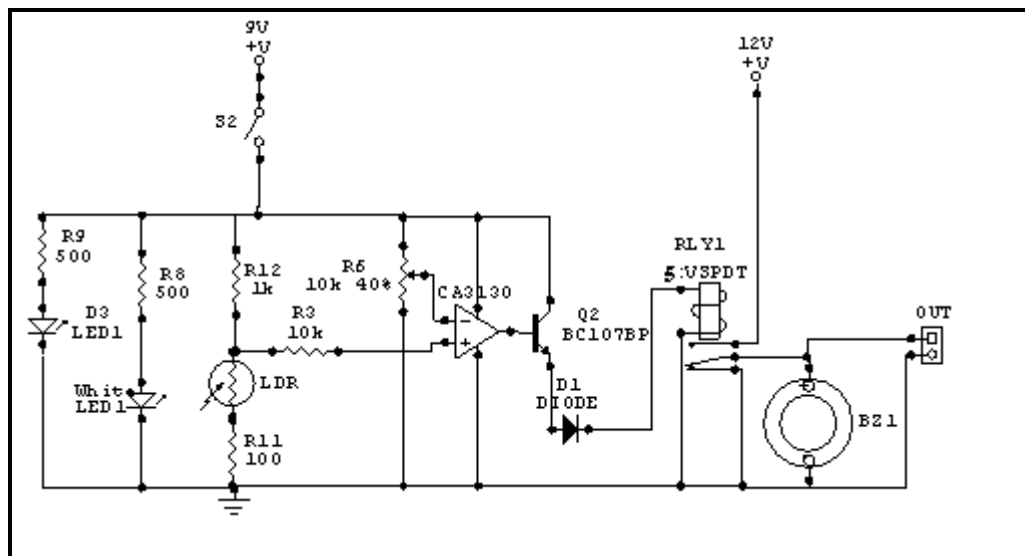


Figure 4.3: Circuit diagram showing the design of a smoke sensor.

4.3.3 Smoke and temperature sensor circuit diagram

The output of the two sensors was finally combined through two diodes as shown in figure 4.4. These diodes prevent the backflow of current to any of the sensor when one is

outputs from the computer through pins 2-9 of data registers was fed to 8 switching circuits of firefighting equipment corresponding to each individual sensor.

4.3.5 Actuators

The designed system has capability of being connected to a maximum of 8 independent sprinklers connected to the computer via an optoisolator to separate the computer from the high voltage power supply. Figure 4.5 shows the circuit diagram for interfacing the actuator to the computer. When the circuit was powered and its input set high, triac was sent into conduction thus enabling the load connected to the system to be switched on. Triac was used in this research since it has low power consumption and can switch on very high voltage as compared to relays.

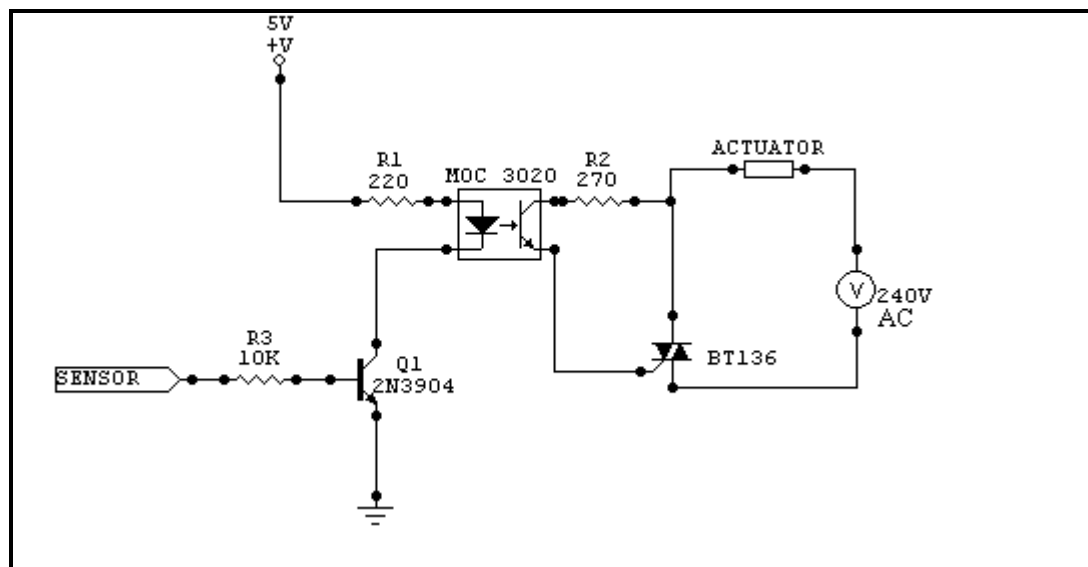


Figure 4.5: Schematic diagram showing the connection of optoisolator and BT 136 triac to the actuator. (Texas Instruments, 1998).

4.4 Software design

In order to link the detected voltages from the sensors to the computer and sending of message from computer to a target mobile phone, LabVIEW together with AT commands were used. First, the parallel port of the computer was configured such that both the status and the control lines act as inputs for sensors. Graphical code that writes down the AT (Attention) commands to a mobile phone connected to computer via Bluetooth was then designed using VISA VIs. The next section discusses how configuration of the parallel port and other codes were done.

4.4.1 Parallel port configuration

In order to use parallel port for basic input/output, base address as discussed in chapter three had to be configured. In this research, base address used was 0378-037F (Hexadecimal) set from Bios as shown in figure 4.6. Data, status and control registers of this port were accessed through address 0378, 0379, and 037A respectively. As discussed in chapter 3, data, control and status registers are normally set for input/output, output and input, respectively. In this research, data registers were used for output while the combination of control and status lines was used for input functions. Figure 4.7 shows the front panel for the default logic status for the three registers as read from LabVIEW. Note that all the bits in the data registers $D_0 - D_7$ are set to logic 1 while bits in the status register S_3, S_4, S_5 and S_6 are set to logic 1 as S_7 set to logic 0. Bits C_0 and C_1 of the control register are set to logic 0 while those of C_2 and C_3 are set to logic 1. The left most indicator as read with labVIEW indicates the LSB while the rightmost indicates the MSB.

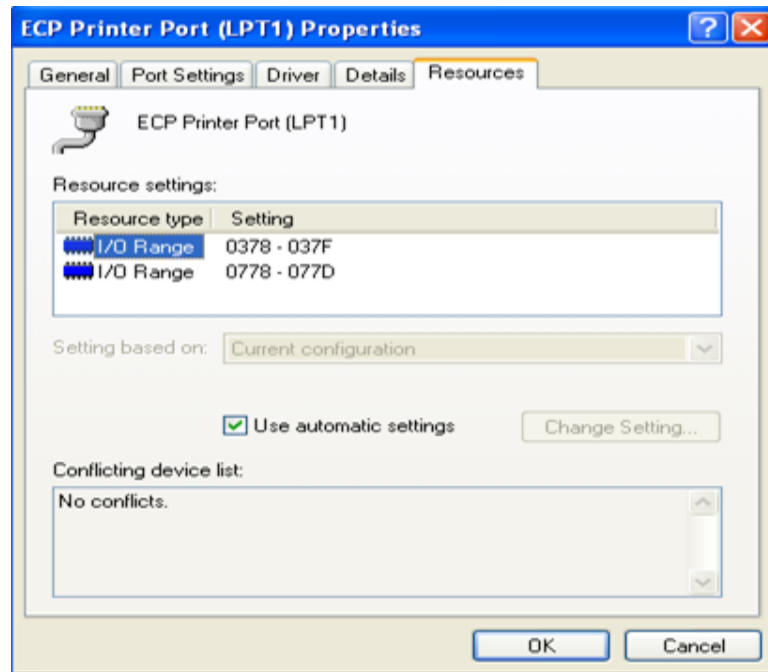


Figure 4.6: Setting parallel port base address.

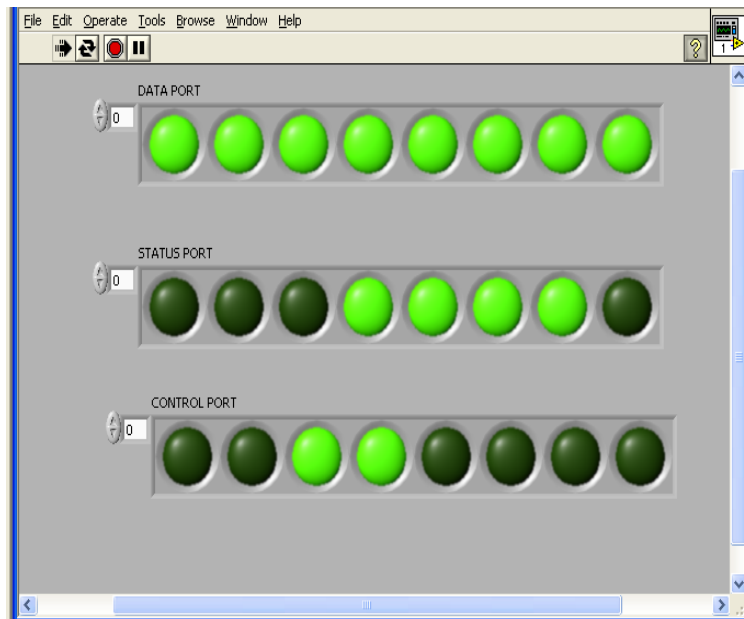


Figure 4.7: Front panel designed in the work for indicating the default reading of the parallel port registers.

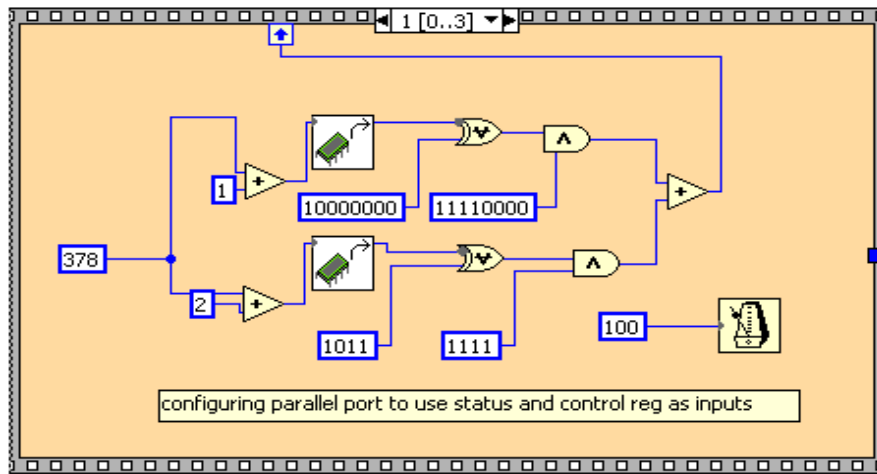


Figure 4.8: Block diagram for setting status and control registers for input.

To configure control registers for input all of its lines were set to logic 1 using software. This was done because for any port to read the input data all of its line must be set to logic 1. If a line is set high and is externally grounded by a signal, the ground wins out and the bit reads low. Lines such as Strobe, nAutoLF, and nSelectIn lines which are inverse logics were also put into consideration during the configuration process. Setting the inverse lines low sets them high at the connector which is exactly what was required. On achieving to configure the control and status lines for data input there was need to combine the two (status lines with the control lines) in order to input a maximum of 8 bits (1 byte) to the computer since the maximum output that could be achieved using the data register was 8 bits. This was made possible by combining the first four bits of the control register (C_0, C_1, C_2 and C_3) using the software to form the lower nibble and the last four bits of the status register (S_4, S_5, S_6 and S_7) to form the upper nibble (See figure 4.8). The results were then designed to be displayed on Boolean indicators on the front panel as shown in figure 4.9.

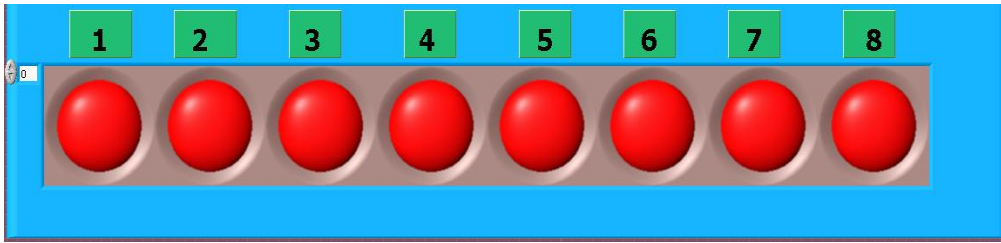


Figure 4.9: Front panel designed in this work to displaying control and status registers all configured for input by setting them to logic 1.

4.4.2 Code for activating the actuators

In order to activate the actuator when voltage from the sensors is detected, code in figure 4.10 was designed. This code sends out a high voltage (3.34 V) to the data lines according to which sensor received the high voltage.

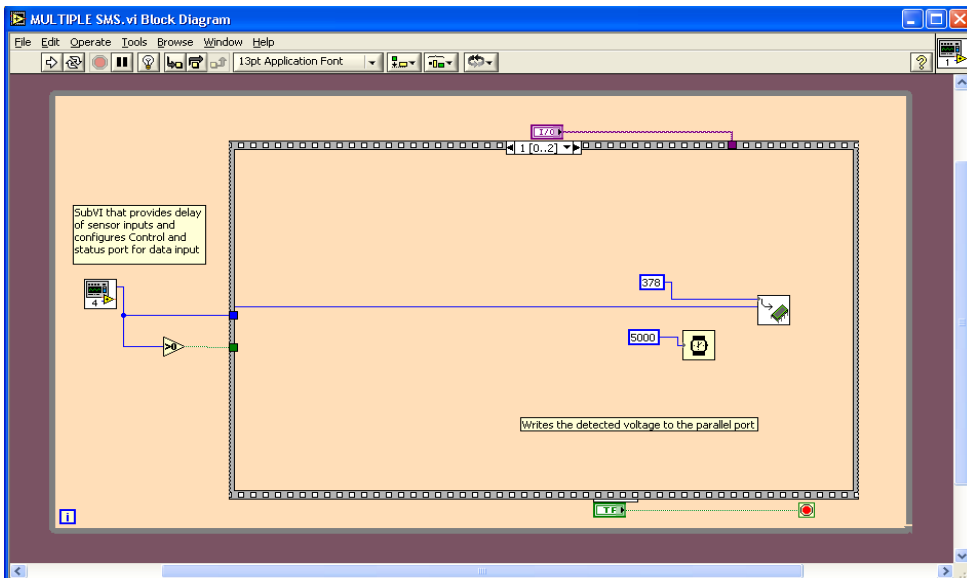


Figure 4.10: Block diagram that writes data input from status and control registers to the data lines with 5000 ms time delay.

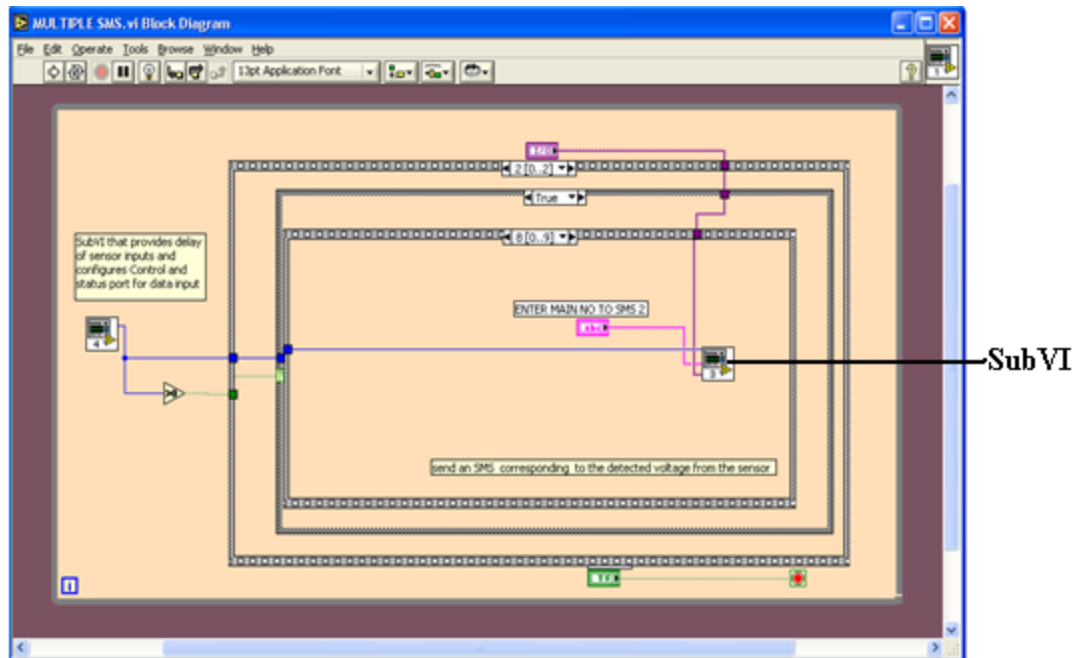


Figure 4.11: Block diagram showing the sub VI for a collection of 255 sub VIs for sending SMS to a target mobile phone.

4.4.3 Code for sending SMS to a mobile phone

Since there were 8 sensors to be connected to the parallel ports, 255 i.e. (2^8-1) codes describing voltage detection by each sensors were designed. They were all combined to form a subVI (figure 4.11) that was to be called by the main program to send the preset short text message to a target mobile phone when fire is detected by any sensor. A sample of the front panel for sub VI is shown in figure 4.12. This VI is used to send an SMS when the pin of the parallel port connected to the sensor that controls the first room receives 5 V from the sensor. At the middle part of the front panel is a space that allows one to write down the mobile number in which the SMS is to be send to. The space at the lower part of the front panel (Visa resource name) is the virtual serial port assigned to the bluetooth enabled mobile phone by the computer.

The front panel and the block diagram for the whole software are shown on figure 4.13 and 4.14 respectively. Front panel shows eight indicators at the lower parts representing all the eight rooms that were to be controlled by the system. When fire in any of the rooms was detected, the corresponding indicator glows red and short text messages were send to the target mobile phones. At the upper part of the front panel are spaces provided for one to enter a maximum of nine mobile numbers to receive an SMS alerts. The leftmost large space is used to send a specific text message such as *“Rooms 1, 2 and 3 on fire”* to either a fire department or the owner of the premise for special attention. The other eight spaces are used to send a notification message such as *“Fire has been detected. Vacate the building !!!!”* to all the eight regions containing the sensors. All the nine numbers are meant for notification purpose and thus cannot stop the program execution if they are not written down. This thus gives the user freedom to fill or not to fill all the mobile numbers and even to change the mobile recipients if need arises.

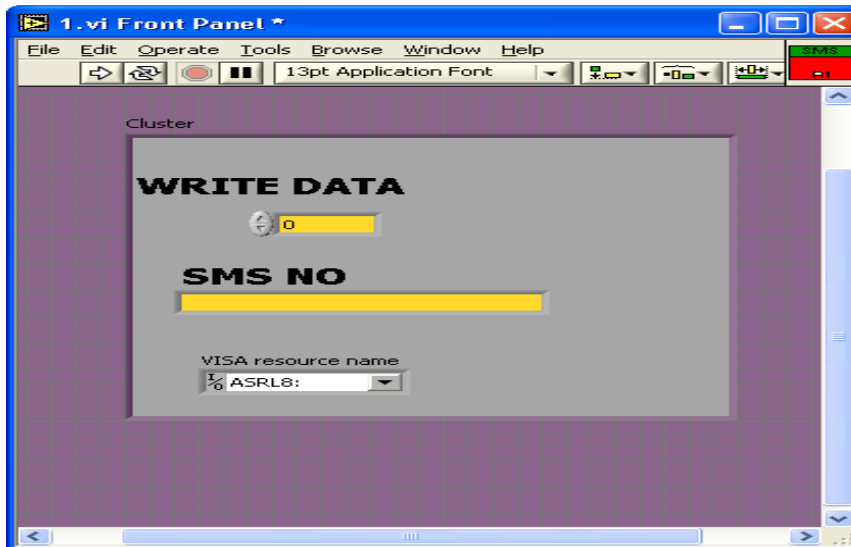


Figure 4.12: The front panel designed in this work to send the SMS to a target mobile phone.

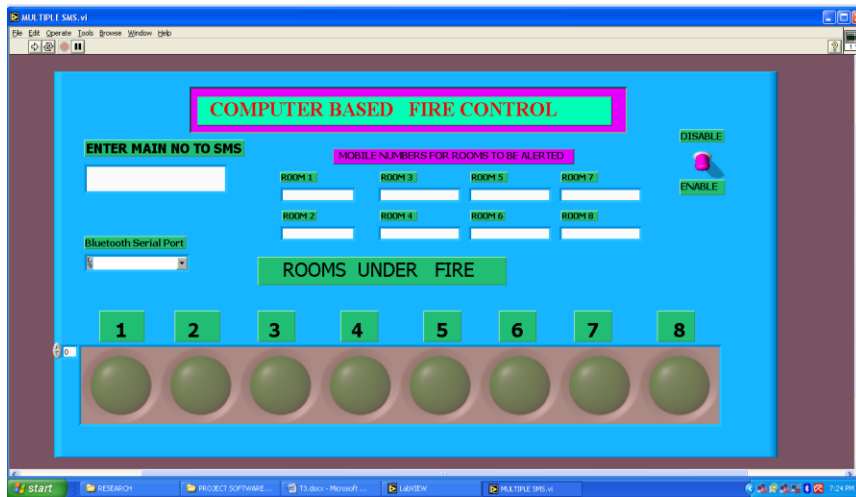


Figure 4.13: Front panel for the system software designed in this work .

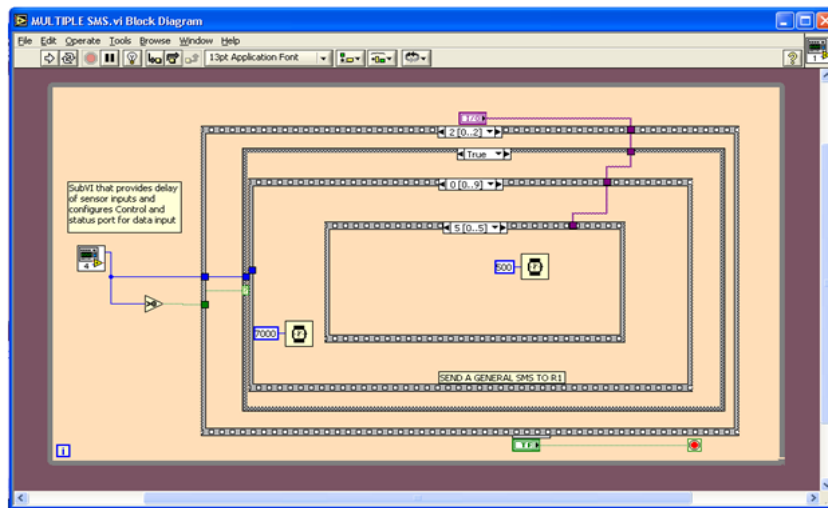


Figure 4.14:Block diagram for the system software designed in this work .

At the right upper corner is a button that allows one to disable the execution of the program manually when it is required. If a high voltage is detected in any of the pin as the program is running and this button is disabled (clicked to turn black), sending of SMS is aborted and the outputs of the parallel port are left in their immediate previous state before abortion of execution is done. This can be used especially when a certain fault

occurs in the system. However one has to be very careful not to abort program execution without switching off water supply to the sprinkler. Below the number for the specific SMS at the left most side is a space provided for selecting the virtual serial port assigned to the Bluetooth mobile phone near the computer by Bluetooth software installed in the computer or from the Bluetooth dongle connected to the computer through USB port. Selection of this port can be done by clicking the downward arrow and selecting the assigned serial port.

4.4.4 Software selection for text message to be sent.

The preset messages to be sent to a target mobile phones were determine by the input to the computer via parallel port. If the input to the port has binary value 00110111 equivalent to 55 in decimal and read in Labview in reverse pattern as 11101100 message indicating that room numbers 1, 2, 3, 5 and 6 on fire will be selected. A complete table showing all the 255 message selections are shown in appendix 1.

4.4.5 Flow chart for the system software.

Figure 4.15 shows the flowchart for the system software. When the program is run 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 are activated and the corresponding SMS is send to the target mobile phones. When fire has been put off the software reads low at the input lines thus stopping the sending of SMS and any activated sprinkler.

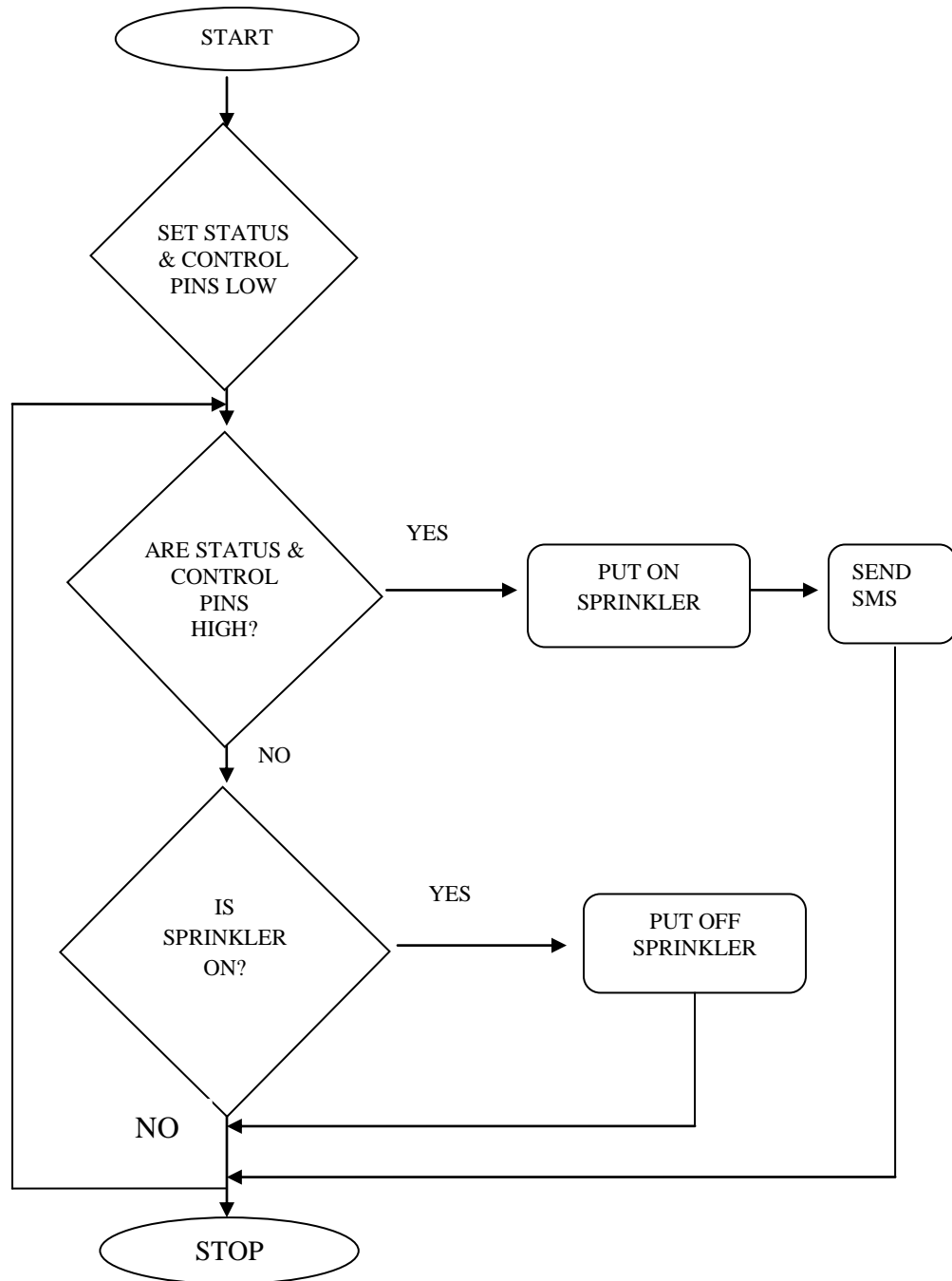


Figure 4.15: Flowchart for system software design.

4.4.6 Assembling the hardware.

Photograph on appendix 4 shows how the hardware parts of the designed fire fighting system were assembled. When all the various parts of the system had been designed, tested and verified the complete system were integrated for final testing. The input terminal of the sensor designed was connected to 9 V DC power supply. The 12 V input terminal was also connected to 12 V power supply. 12 V output terminal was also connected to any input terminal of interfacing board which also powered by 5 V power supply. Computer and interfacing board was connected together using 1.5 m parallel port cable. 240 V ac power was then connected to interfacing board. The output ac voltage from interfacing board that controls the opening and closing of the actuator was tapped from 8 sockets to which the sprinklers were connected to. With the confirmation of water at high pressure along the line of the actuator, computer was turned on and a Bluetooth enabled mobile phone activated and connected with the computer as described in Appendix 2. Systems software in Labview was opened and run continuously to provide continuous monitoring of the inputs from the sensors to the computer through parallel port.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter discusses the results obtained when the system was tested in the two fire parameters. It starts with the results obtained from the smoke sensor and finally with temperature sensor.

5.2 System response to smoke.

When the output of the sensor was connected to input terminal number 1(one) on the interfacing board, power supplies to the sensor and interfacing board was then switched on and the smoke sensor turned on. On the front panel of the system software, the mobile number(s) to receive SMS were entered and the assigned Bluetooth serial port selected (i.e. ASRL8::INSTR). Without introducing smoke or raising the temperature of the sensor, the software was then run continuously with the Bluetooth mobile phone connected to the computer. All the indicators on the front panel turned green after five seconds and no messages were send as well as sprinklers activated implying that no fire was detected. This is shown in figure 5.1. Smoke was then introduced below the sensor.

The response time for the sensor, alarm, computer screen display, sprinkler and the sending of short text messages was recorded for a period of 75 s. Table 5.1 shows the results obtained. From the onset, alarm was triggered by the presence of the smoke and on the fifth second computer LED display turned red for room number 1 as shown in figure 5.2. On the 10th second, sprinkler was triggered which sprinkled water to the source of smoke. The first short text message (SMS 1) was send at 15th second to

recipient in room 1. This being a warning to the occupants indicated, “*Fire has been detected. Vacate the building !!!!*”.

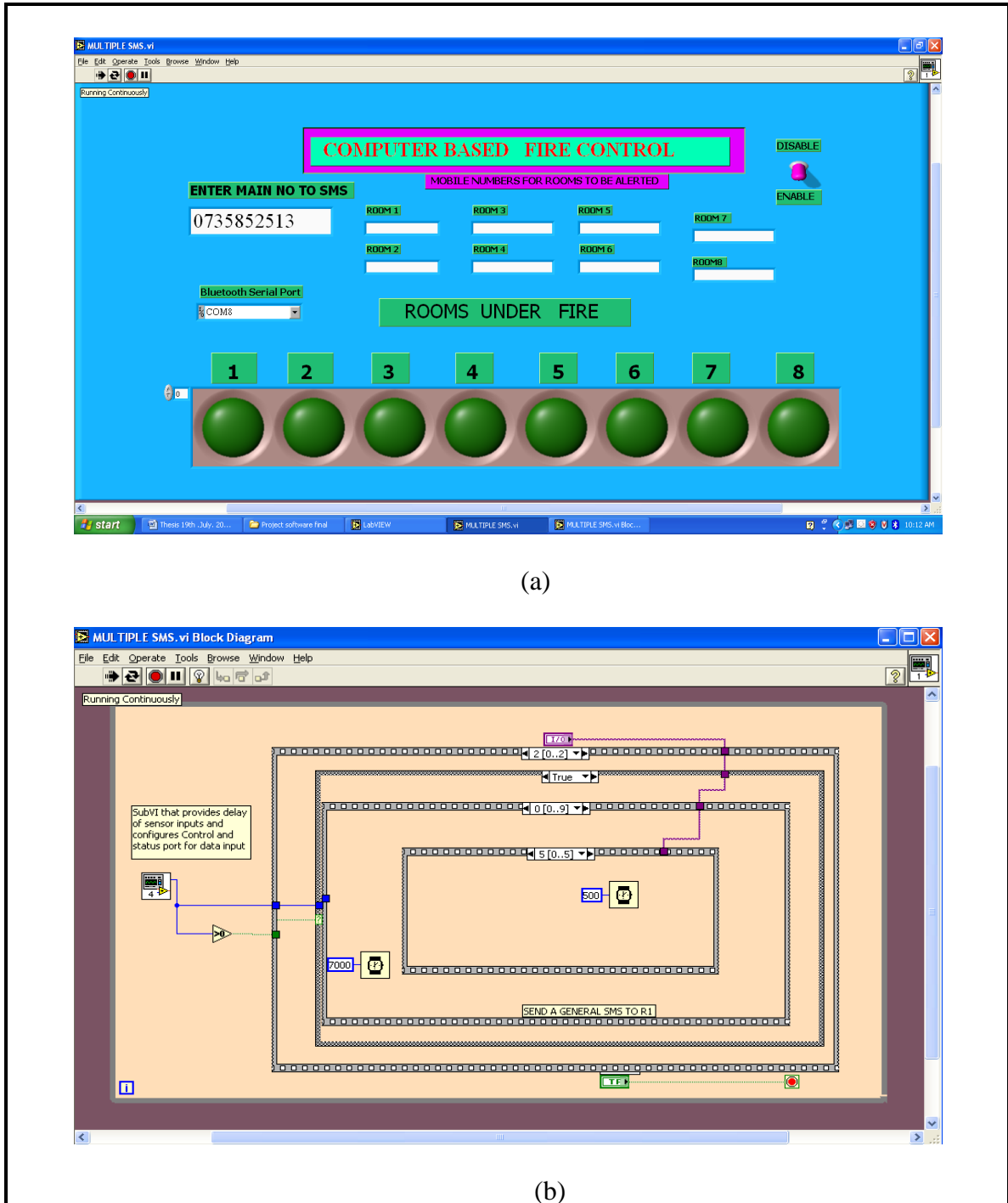


Figure 5.1: LabVIEW front panel (5.1 a) designed in this work in run mode displaying all indicators in off state before smoke detection. Its block diagram is shown in figure (5.1 b).

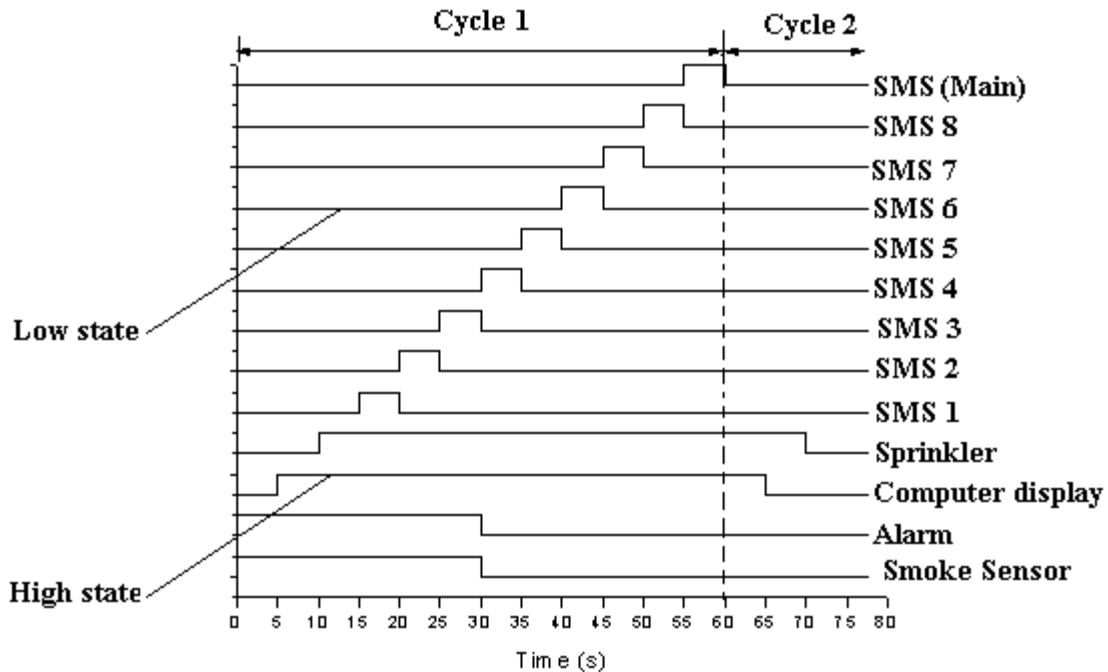


Figure 5.3: Graph in this work for System response to smoke.

A series of such similar messages to the occupants in the rest of the seven rooms were sent within the 20th and the 55th second. The specific message giving the exact location of fire detected (i.e. “ROOM 1 ON FIRE”) is sent to recipient mobile number 0736852513 as indicated in the left most white box of figure 5.2 at the 55th second. This message was purposely meant to notify either the firefighting department or the owner of the premise thus calling for further assistance. The 60th second happens to be the end of the first cycle of program execution. As shown in table 5.1 and figure 5.3, at 30th second alarm stopped because of the low voltage output from the sensor. This occurs as a result of the extinction of smoke in the sensor chamber brought about by the showering water. However, computer continued indicating the presence of smoke in room 1 until the second cycle at 55th second. Indicators on the computer as well as the sprinkler went off (low state) at 65th and 70th second respectively. This thus restores the condition of the room.

During this research, it was found that smoke sensor had a faster response to smoke. If the intensity of smoke is high its response time will be faster and slower for low smoke intensity. It was also noted that smoke sensor took a longer time to switch off than to switch on. This was attributed to the fact that smoke accumulates within the sensor due to its buoyancy thus reducing intensity of incident light to the sensor for a longer period.

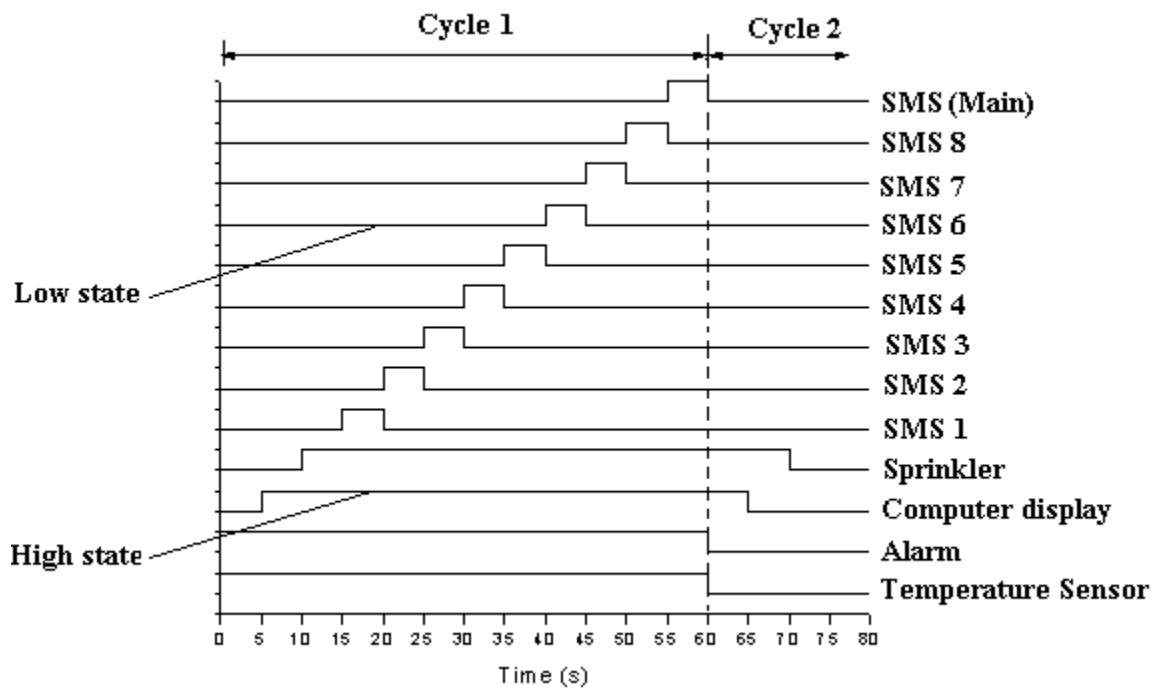
5.3 System response to temperature

Smoke sensor was then turned off and temperature sensor turned on. Its output was connected to input terminal number 1 of the interfacing board as in the previous set up. The temperature was then raised by directing 100 W electric bulb to the sensor until alarm was heard. The response time of temperature sensor, alarm, computer displays, sprinkler and the sending of short text messages to the relevant recipients as in the smoke sensor was the noted. The time duration was also fixed to 75 seconds from the time the alarm was heard.

Table 5.2 shows the results obtained while figure 5.4 show the states of each part of the system with time. Temperature sensor was found to respond to change in temperature at a slower rate compared to that of the smoke sensor. From the time the sprinkler is triggered on at 10th second it took 50 seconds to completely suppress temperature below the set 57 °C in order to completely switch of the alarm. This time is 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 prone to much false detection than temperature sensors.

Table 5.2: Data for system response to temperature using temperature sensor in room 1.

Time	Temp Sensor	Alarm	Display	Sprinkler	Sms 1	Sms 2	Sms 3	Sms 4	Sms 5	Sms 6	Sms 7	Sms 8	sms (main)
0	1	1	0	0	0	0	0	0	0	0	0	0	0
5	1	1	1	0	0	0	0	0	0	0	0	0	0
10	1	1	1	1	0	0	0	0	0	0	0	0	0
15	1	1	1	1	1	0	0	0	0	0	0	0	0
20	1	1	1	1	0	1	0	0	0	0	0	0	0
25	1	1	1	1	0	0	1	0	0	0	0	0	0
30	1	1	1	1	0	0	0	1	0	0	0	0	0
35	1	1	1	1	0	0	0	0	1	0	0	0	0
40	1	1	1	1	0	0	0	0	0	1	0	0	0
45	1	1	1	1	0	0	0	0	0	0	1	0	0
50	1	1	1	1	0	0	0	0	0	0	0	1	0
55	1	1	1	1	0	0	0	0	0	0	0	0	1
60	0	0	1	1	0	0	0	0	0	0	0	0	0
65	0	0	0	1	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0

**Figure 5.4:** Graph designed in this work for System response to temperature.

5.4 System response to multiple inputs

To observe the system response to multiple inputs from the sensors, three sensor inputs were simulated by connecting 12 V to inputs 1, 2, and 4 of the interfacing board. This time mobile numbers for rooms 1 to 8 on the front panel were not written down. The program was then run continuously and the resulting front panel is shown in figure 5.5. Short text message “R1,R2 and R4 on Fire” was finally sent to mobile subscriber indicated on the left top corner of the front panel.

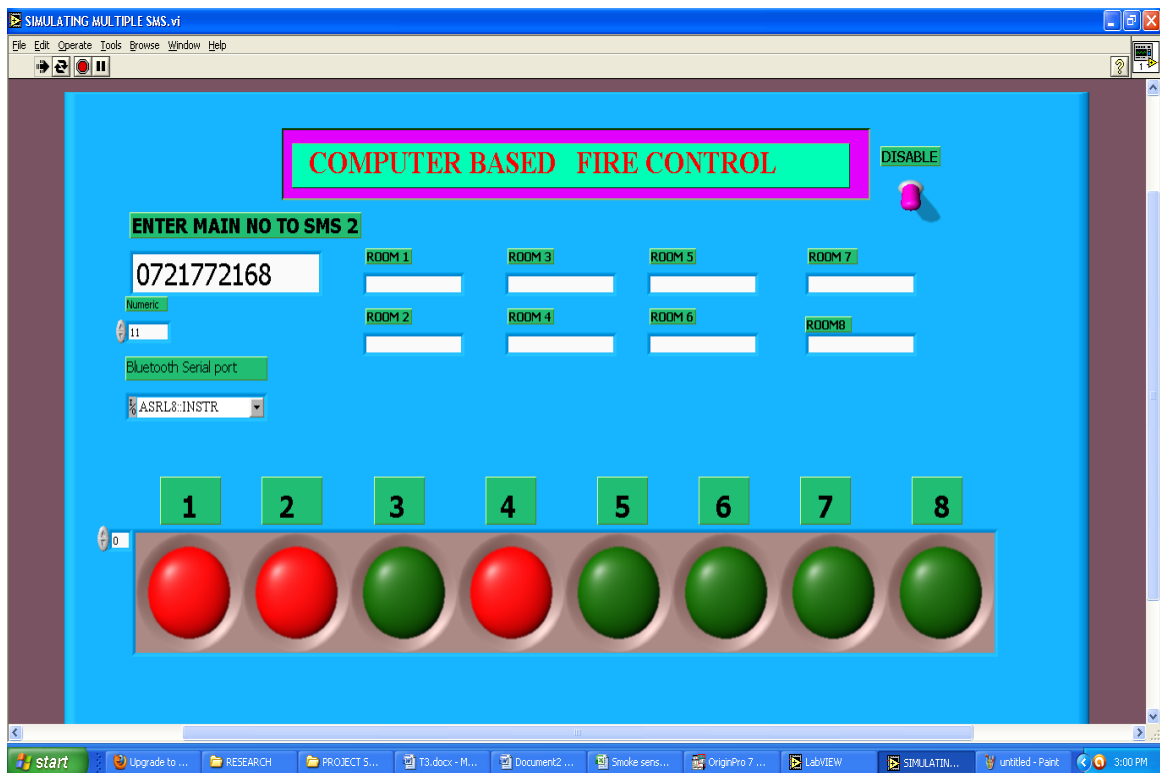


Figure 5.5: Front panel designed in this work showing system response to multiple sensor inputs.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

An automatic computer based fire fighting has been designed and fabricated. Labview software to control the system has also been designed and tested. The system integrates smoke and temperature sensors, interfacing board, actuators, Bluetooth enabled mobile phone connected to any GSM mobile operators and a Bluetooth enabled computer running labVIEW software. The system managed to acquire 8 inputs from the sensors and controls 8 actuators (water sprinklers employing the use of solenoid valves) in line with the sensors. Interfacing the computer through parallel port was also achieved. The prototype system managed to put off the smoke within the first 30 second of detection provided there is an even sprinkling of water on the smoke source. It also managed to lower the temperature below 57 °C within the first 60 seconds of detection provided sprinklers are properly directed to the source of fire. Eight mobile phone subscribers received a short text message warning them to vacate the premise due to fire detection. An extra mobile phone subscriber which can be a firefighting department or the owner of the premise was also notified of the exact location of fire detected in the premise. With the achievement of all the objectives of this research, we can conclude that the designed system is reliable and cost effective which should be employed in firefighting operations to help limit the number of death and property loss in our buildings.

6.2 Recommendations

The designed system managed to have maximum protection of a premise that requires a maximum of 8 sensors. If the place to be monitored requires more than 8 independent sensors, the designed system will not cater for them. It is therefore recommended that a system which accepts as many inputs from sensors as may be required by the user be designed. This may be possible by use of multiplexers. When this is achieved, measurement of temperature, smoke intensity as well as detection of the two parameters will be achieved.

Due to various environmental factors such as change in pressure outside the premise and air inflow, normal vertical flow of smoke may be diverted and the smoke drifted to undesired sensor that may be triggered accidentally. Sensor that uses the coordinate system to check the direction of the flow before triggering the sprinklers is thus required. In addition, sensors that are immune to strong heat, high humidity and dust repellent are also required to enhance the degree of accuracy. The system could further be enhanced by interfacing it to other firefighting equipments such as gas and powder extinguishers that can be used to fight different classes of fire. This will broaden the application of the designed system to data centers, chemical industries among others. The designed software has no limited application. It may also be used in areas outside fire detection and firefighting. These include object counters, burglar alarms, road traffic monitoring (over speeding and overloading) and other businesses. Some of these may require the use of microcontrollers, microprocessors and other programming languages.

REFERENCES

- Angus, M. (2002). *The intelligent Fire Alarm*. School of Information Technology and Electrical Engineering. University of Queensland.
- Atmel Corporation. (2006). *Interfacing GSM modems*. www.atmel.com/literature. San Jose, CA 95131, USA.
- Carlton, P. and Rafic, B. (2004). *Implementing PID Temperature Control Using LabVIEW*. Proceedings of ASEE Gulf-Southwest Annual Conference. Texas Tech University.
- Chandra, M.K. M. and Kalai, P. (2005). *Heat sensitive switch*. www.EFYMAG.com.
- Chaudhry, K.K. and Nakra, B.C. (2004). *Instrumentation, Measurement and Analysis*. Tata McGraw-Hill, New Delhi, pp. 113-455.
- Chen, S.J., Hovde, D. C., Peterson, K. A. and Marshall, A. W. (Nov. 2007). *Fire detection using smoke and gas sensors*. Fire Safety Journal. **42**(8):507–515.
- Cheon, J., Jeonghwan, L., Inhee, L., Youngcheol, C., Youngsin. Y., and Gunhee, H. (2009). *A Single-Chip CMOS Smoke and Temperature Sensor for an Intelligent Fire Detector*. IEEE Sensors Journal. **9**(8).
- Craighead, G. (1996). *High rise security and Fire Life Safety*. Butter worth. Heinemann. USA, pp89-95.
- David, D.E., Peacock, R.D., Kuligowski, D.E., Staurt, D.W. and Grosshandler, L.W. (2005). *Active Fire Protection System*. World Trade Center (WTC).
- Dongil, H. and Lee, B. (2009). *Flame and Smoke Detection Method for Early Real –Time Detection of Tunnel Fire*. Fire safety Journal. **44**:951-961.
- Electus Distribution, (2001). *The USB or Universal Serial Bus Electus Distribution Reference Manuals*
- FEMA. (2009). *Medical Facility Fire*. Topical Fire Report Series. **9** (4). www.usfa.dhs.gov/statistics/report/index.shtm.
- Franz, H. (2003). *Use of LabviewTM for Virtual Instrumentation Technology*. Proceedings of 2003 American Society for Engineering Education (ASEE) Annual Conference and Exposition.
- Gabriele, L., Francesco, R., Cristiano, N. and Severino, Z. (2009). *Design and Testing of Innovative Material for Passive Fire Protection*. Fire safety Journal. **44**:1103-1109.

Hassan, B., Muhammad, O., Muhammad, S.A., Kamran, S. and Hamza, A. (2006). *GSM based Security System using Labview*. University of Engineering and Technology. Pakistan.

http://en.wikipedia.org/wiki/Serial_port, (2010). Serial Port.

<http://en.wikipedia.org/wiki/USB>

http://media.wiley.com/product_data/excerpt/75/07645488/0764548875.pdf

<http://www.cablestogo.com/resources/usb.asp>. (2010). About USB.

<http://www.cs.ucl.ac.uk/staff/t.pagtzis/wireless/gsm/arch.html>, 2010

http://www.pulsewan.com/data101/gsm_basics.htm

Intersil. (2002). *Operational Amplifier CA3130/CA3130A*. Intersil corporation. www.intersil.com.

James, A.L. (2004). *A study of smoke aging examining changes in smoke particulate size*. M.S.C. (Fire protection Engineering) Thesis, Worcester polytechnic institute.

Jean, P. (2000). *Investigation into Bluetooth Technology*. B Eng final year project in Computer and Communications Engineering. Liverpool John Moores University.

Jiang, G., Shang, F., Wang, F., Liu, X., and Qiu, T. (Jun. 2006). *A combined intelligent fire detector with BP networks*. In Proc. World Congr. Intell. Control Autom. Dalian, China. **2**: 5417–5419.

Jimmy, H. and Yang, C. (2004). *Home Security System*, Cornell University.

John, H.K. (1997). *Smoke movement in Buildings*. Fire protection hand book. 18th edition. NFPA.

Lee, W.Y. (1996). *Mobile cellular Telecommunication Systems*. McGraw-Hill. New York.

Li, J., Wang, S., Dou, Z. and Yang, Z. (Jan. 2001). *Discrimination of smoke particles using infrared photoelectrical detection*. Int. J. Infrared and Millimeter Waves. **22**(1): 141–151.

Microchip. (2004). *Precision temperature measurement with silicon IC temperature sensors, thermocouples, RTDs circuits and Thermistor*. Temperature sensor design guides.USA. www.microchip.com.

National instruments. (2004). *Using the parallel port in Labview*. Tuition Developer Zone. National Instruments Corporation.

National Semiconductor. (1997). *Temperature sensor handbook*. National semiconductor corporation .USA. <http://www.national.com>.

National semiconductor. (2000). *LM 35 Precision Centigrade Temperature Sensors*. National semiconductor corporation .USA. <http://www.national.com>.

Obanda ,W.N. (2010). *Design and fabrication of an electronic system for monitoring Temperature,Light illuminance and Humidity in a green house*. M.S.C.(Physics) Thesis, Kenyatta University

Osman,G., Kasim, T. and Ugur, B. (2009). *Video Based Wild Fire Detection at Night*. Fire Safety Journal. **44**: 860-868.

Peacock ,C. (1998). *Interfacing Parallel The Port*. <http://www.senet.com.au/~cpeacock>

Red Cross. (2009). *Kenya: Fires. DREF Operation Final Report*. International Federation of Redcross and Red Crescent Society. Nairobi.

Salamanca. (2005). *Planck's constant in the light of incandescent lamp*. 36th International physic Olympiad.

Shin, J., Hovde, D.C., Kristen. A.P. and Marshall, A.W. (2007). *Fire detection using smoke and gas sensors*. Fire safety Journal. **42**:507-517. www.elsevier.com/locate/firesafe.

System sensor. (2002). *System smoke detector. Application guide*. www.systemsensor.com.

Texas Instruments, (1998). MOC 3020 datasheet. Dallas Texas 75265.

Travis, J. (2002). *Labview for everyone, 2nd edition*. Prentice Hall. Upper Saddle River, New Jersey,USA.

Travis, J. and Kring, J. (2006). *LabVIEW for Everyone: Graphical Programming Made Easy and Fun, Third Edition*. Prentice Hall,USA.

Ueng, T.S, Tsai, Z.D. and Chang J.C. (2007). *SMS Alert System at NSRRC*. Proceedings of PAC07. Albuquerque. New Mexico, USA.

Ueng, T.S., Tsai, Z.D. and Chang, J.C. (2007). *SMS Alert System at NSRRC*. Proceedings of PAC07. Albuquerque. New Mexico, USA.

Walter, W. J., Richard, D. P., Glenn,P. F. and Reneke, P.A. (2005). *CFAST – Consolidated Model of Fire Growth and Smoke Transport*. National Institute of Standard and Technology (NIST) 1030 Publication.

APPENDICES

1. SMS SELECTION TABLE

DEC	BINARY INPUT								ROOMS ON FIRE
	S ₇	S ₆	S ₅	S ₄	C ₃	C ₂	C ₁	C ₀	
0	0	0	0	0	0	0	0	0	NONE
1	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	1	0	2
3	0	0	0	0	0	0	1	1	1,2
4	0	0	0	0	0	1	0	0	3
5	0	0	0	0	0	1	0	1	1,3
6	0	0	0	0	0	1	1	0	2,3
7	0	0	0	0	0	1	1	1	1,2,3
8	0	0	0	0	1	0	0	0	4
9	0	0	0	0	1	0	0	1	1,4
10	0	0	0	0	1	0	1	0	2,4
11	0	0	0	0	1	0	0	1	1,2,4
12	0	0	0	0	1	1	1	0	2,3,4
13	0	0	0	0	1	1	0	1	1,2,3,4
14	0	0	0	0	1	1	1	0	2,3,4
15	0	0	0	0	1	1	1	1	1,2,3,4
16	0	0	0	1	0	0	0	0	5
17	0	0	0	1	0	0	0	1	1,5
18	0	0	0	1	0	0	1	0	2,5
19	0	0	0	1	0	0	1	1	1,2,5
20	0	0	0	1	0	1	0	0	3,5
21	0	0	0	1	0	1	0	1	1,3,5
22	0	0	0	1	0	1	1	0	2,3,5
23	0	0	0	1	1	1	1	1	1,2,3,5
24	0	0	0	1	1	0	0	0	4,5
25	0	0	0	1	1	0	0	1	1,4,5
26	0	0	0	1	1	0	1	0	2,4,5
27	0	0	0	1	1	0	1	1	1,2,4,5
28	0	0	0	1	1	1	0	0	3,4,5
29	0	0	0	1	1	1	0	1	1,3,4,5
30	0	0	0	1	1	1	1	0	2,3,4,5
31	0	0	0	1	1	1	1	1	1,2,3,4,5
32	0	0	1	0	0	0	0	0	6
33	0	0	1	0	0	0	0	1	1,6
34	0	0	1	0	0	0	1	0	2,6
35	0	0	1	0	0	0	1	1	1,2,6
36	0	0	1	0	0	1	0	0	3,6
37	0	0	1	0	0	1	0	1	1,3,6

38	0	0	1	0	0	1	1	0	2,3,6
39	0	0	1	0	0	1	1	1	1,2,3,6
40	0	0	1	0	1	0	0	0	4,6
41	0	0	1	0	1	0	0	1	1,4,6
42	0	0	1	0	1	0	1	0	2,4,6
43	0	0	1	0	1	0	1	1	1,2,4,6
44	0	0	1	0	1	1	0	0	3,4,6
45	0	0	1	0	1	1	0	1	1,3,4,6
46	0	0	1	0	1	1	1	0	2,3,4,6
47	0	0	1	0	1	1	1	1	1,2,3,4,6
48	0	0	1	1	0	0	0	0	5,6
49	0	0	1	1	0	0	0	1	1,5,6
50	0	0	1	1	0	0	1	0	2,5,6
51	0	0	1	1	0	0	1	1	1,2,5,6
52	0	0	1	1	0	1	0	0	3,5,6
53	0	0	1	1	0	1	0	1	1,3,5,6
54	0	0	1	1	0	1	1	0	2,3,5,6
55	0	0	1	1	0	1	1	1	1,2,3,5,6
56	0	0	1	1	1	0	0	0	4,5,6
57	0	0	1	1	1	0	0	1	1,4,5,6
58	0	0	1	1	1	0	1	0	2,4,5,6
59	0	0	1	1	1	0	1	1	1,2,4,5,6
60	0	0	1	1	1	1	0	0	3,4,5,6
61	0	0	1	1	1	1	0	1	1,3,4,5,6
62	0	0	1	1	1	1	1	0	2,4,5,6
63	0	0	1	1	1	1	1	1	1,2,4,5,6
64	0	1	0	0	0	0	0	0	7
65	0	1	0	0	0	0	0	1	1,7
66	0	1	0	0	0	0	1	0	2,7
67	0	1	0	0	0	0	1	1	1,2,7
68	0	1	0	0	0	1	0	0	3,7
69	0	1	0	0	0	1	0	1	1,3,7
70	0	1	0	0	0	1	1	0	2,3,7
71	0	1	0	0	0	1	1	1	1,2,3,7
72	0	1	0	0	1	0	0	0	4,7
73	0	1	0	0	1	0	0	1	1,4,7
74	0	1	0	0	1	0	1	0	2,4,7
75	0	1	0	0	1	0	1	1	1,2,4,7
76	0	1	0	0	1	1	0	0	3,4,7
77	0	1	0	0	1	1	0	1	1,3,4,7
78	0	1	0	0	1	1	1	0	2,3,4,7
79	0	1	0	0	1	1	1	1	1,2,3,4,7
80	0	1	0	1	0	0	0	0	5,7
81	0	1	0	1	0	0	0	1	1,5,7
82	0	1	0	1	0	0	1	0	2,5,7

128	1	0	0	0	0	0	0	0	8
129	1	0	0	0	0	0	0	1	1,8
130	1	0	0	0	0	0	1	0	2,8
131	1	0	0	0	0	0	1	1	1,2,8
132	1	0	0	0	0	1	0	0	3,8,
133	1	0	0	0	0	1	0	1	1,3,8
134	1	0	0	0	0	1	1	0	2,3,8
135	1	0	0	0	0	1	1	1	1,2,3,8
136	1	0	0	0	1	0	0	0	4,8
137	1	0	0	0	1	0	0	1	1,4,8
138	1	0	0	0	1	0	1	0	2,4,8,
139	1	0	0	0	1	0	1	1	1,2,4,8
140	1	0	0	0	1	1	0	0	3,4,8
141	1	0	0	0	1	1	0	1	1,3,4,8
142	1	0	0	0	1	1	1	0	2,3,4,8
143	1	0	0	0	1	1	1	1	1,2,3,4,8
144	1	0	0	1	0	0	0	0	5,8
145	1	0	0	1	0	0	0	1	1,5,8
146	1	0	0	1	0	0	1	0	2,5,8,
147	1	0	0	1	0	0	1	1	1,2,5,8
148	1	0	0	1	0	1	0	0	3,5,8
149	1	0	0	1	0	1	0	1	1,3,5,8
150	1	0	0	1	0	1	1	0	2,3,5,8
151	1	0	0	1	0	1	1	1	1,2,3,5,8
152	1	0	0	1	1	0	0	0	4,5,8
153	1	0	0	1	1	0	0	1	1,4,5,8
154	1	0	0	1	1	0	1	0	2,4,5,8
155	1	0	0	1	1	0	1	1	1,2,4,5,8
156	1	0	0	1	1	1	0	0	3,4,5,8
157	1	0	0	1	1	1	0	1	1,3,4,5,8
158	1	0	0	1	1	1	1	0	2,3,4,5,8
159	1	0	0	1	1	1	1	1	1,2,3,4,5
160	1	0	1	0	0	0	0	0	6,8
161	1	0	1	0	0	0	0	1	1,6,8,
162	1	0	1	0	0	0	1	0	2,6,8
163	1	0	1	0	0	0	1	1	1,2,6,8,
164	1	0	1	0	0	1	0	0	3,6,8
165	1	0	1	0	0	1	0	1	1,3,6,8
166	1	0	1	0	0	1	1	0	2,3,6,8
167	1	0	1	0	0	1	1	1	1,2,3,6,8
168	1	0	1	0	1	0	0	0	4,6,8
169	1	0	1	0	1	0	0	1	1,4,6,8
170	1	0	1	0	1	0	1	0	2,4,6,8
171	1	0	1	0	1	0	1	1	1,2,4,6,8
172	1	0	1	0	1	1	0	0	3,4,6,8

173	1	0	1	0	1	1	0	1	1,3,4,6,8
174	1	0	1	0	1	1	1	0	2,3,4,6,8
175	1	0	1	0	1	1	1	1	1,2,3,4,6,8
176	1	0	1	1	0	0	0	0	5,6,8
177	1	0	1	1	0	0	0	1	1,5,6,8
178	1	0	1	1	0	0	1	0	2,5,6,8
179	1	0	1	1	0	0	1	1	1,2,5,6,8
180	1	0	1	1	0	1	0	0	3,5,6,8
181	1	0	1	1	0	1	0	1	1,3,5,6,8
182	1	0	1	1	0	1	1	0	2,3,5,6,8
183	1	0	1	1	0	1	1	1	1,2,3,5,6,8
184	1	0	1	1	1	0	0	0	4,5,6,8
185	1	0	1	1	1	0	0	1	1,4,5,6,8
186	1	0	1	1	1	0	1	0	2,4,5,6,8
187	1	0	1	1	1	0	1	1	1,2,4,5,6,8
188	1	0	1	1	1	1	0	0	3,4,5,6,8
189	1	0	1	1	1	1	0	1	1,3,4,5,6,8
190	1	0	1	1	1	1	1	0	2,3,4,5,6,8
191	1	0	1	1	1	1	1	1	1,2,3,4,5,6,8
192	1	1	0	0	0	0	0	0	7,8
193	1	1	0	0	0	0	0	1	1,7,8
194	1	1	0	0	0	0	1	0	2,7,8
195	1	1	0	0	0	0	1	1	1,2,7,8
196	1	1	0	0	0	1	0	0	3,7,8
197	1	1	0	0	0	1	0	1	1,3,7,8
198	1	1	0	0	0	1	1	0	2,3,7,8
199	1	1	0	0	0	1	1	1	1,2,3,7,8
200	1	1	0	0	1	0	0	0	3,7,8
201	1	1	0	0	1	0	0	1	1,4,7,8
202	1	1	0	0	1	0	1	0	2,4,7,8
203	1	1	0	0	1	0	1	1	1,2,4,7,8
204	1	1	0	0	1	1	0	0	3,4,7,8
205	1	1	0	0	1	1	0	1	1,3,4,7,8
206	1	1	0	0	1	1	1	0	2,3,4,7,8
207	1	1	0	0	1	1	1	1	1,2,3,4,7,8
208	1	1	0	1	0	0	0	0	4,7,8
209	1	1	0	1	0	0	0	1	1,5,7,8
210	1	1	0	1	0	0	1	0	2,5,7,8
211	1	1	0	1	0	0	1	1	1,2,5,7,8
212	1	1	0	1	0	1	0	0	3,5,7,8
213	1	1	0	1	0	1	0	1	1,3,5,7,8
214	1	1	0	1	0	1	1	0	2,3,5,7,8
215	1	1	0	1	0	1	1	1	1,2,3,5,7,8
216	1	1	0	1	1	0	0	0	4,5,7,8
217	1	1	0	1	1	0	0	1	1,4,5,7,8

2. CONNECTING BLUETOOTH MOBILE TO A COMPUTER

In order for computers to communicate with the Bluetooth enabled mobile phone, both must be paired. Some computers are Bluetooth enabled while other requires the installation of Bluetooth software using Bluetooth dongles. The procedures involved in connecting the Bluetooth mobile phone to the computer in the two cases are discussed below.

A. Connecting Bluetooth mobile to computer with inbuilt Bluetooth

The following steps were followed to connect computer to Bluetooth enabled mobile phone:

- I. Turn on Bluetooth's in the Bluetooth enabled mobile phone and the computer.
- II. Double click the Bluetooth icon from *my computer* and click "Add a Bluetooth device" to obtain window in figure A.
- III. Click *next* in the Bluetooth wizard to search the device. Figure B shows the discovered devices.
- IV. Highlight your detected device by clicking it.
- V. Click *next* to obtain the window that requires pairing password.
- VI. Click *next* to generate the password for pairing.
- VII. Enter the generated password in the mobile phone and press OK. This enables the pairing process.
- VIII. From the Bluetooth service selection window in figure C select Bluetooth virtual serial port 0 and click *finish*. This displays the serial port assigned to the

Bluetooth device (Figure D). Computer is now set to communicate to the Bluetooth enabled mobile phone through serial port COM 8 in this exercise.

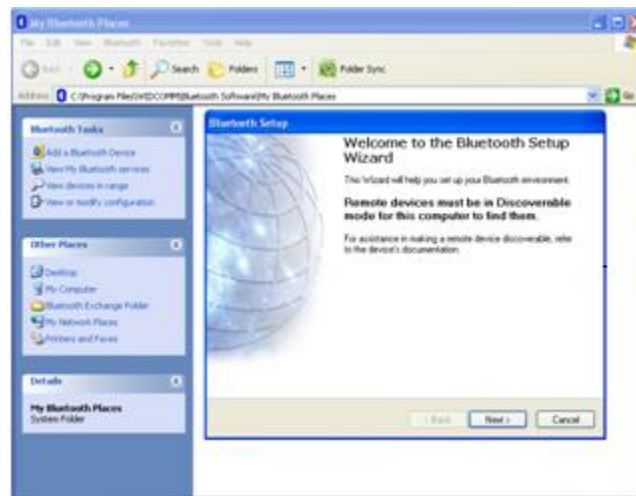


Figure A: Window showing the Bluetooth set up wizard.



Figure B: Window showing Bluetooth mobile phone TECNO T570.

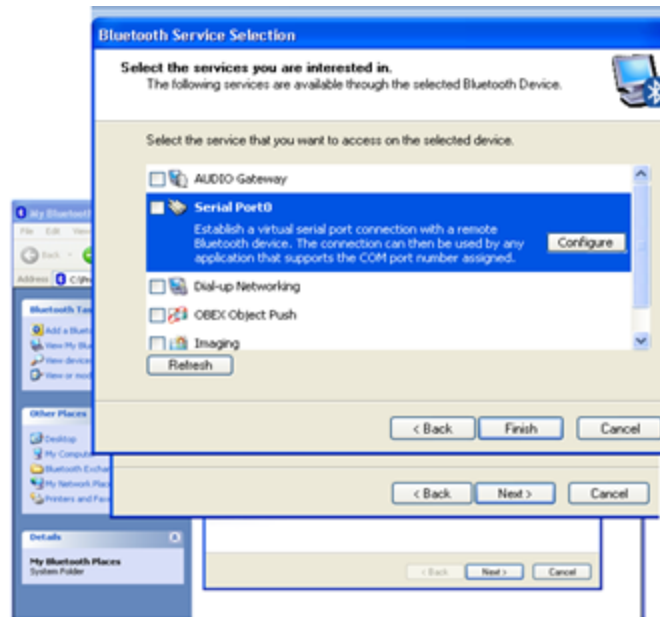


Figure C: Window showing Bluetooth profile selection.

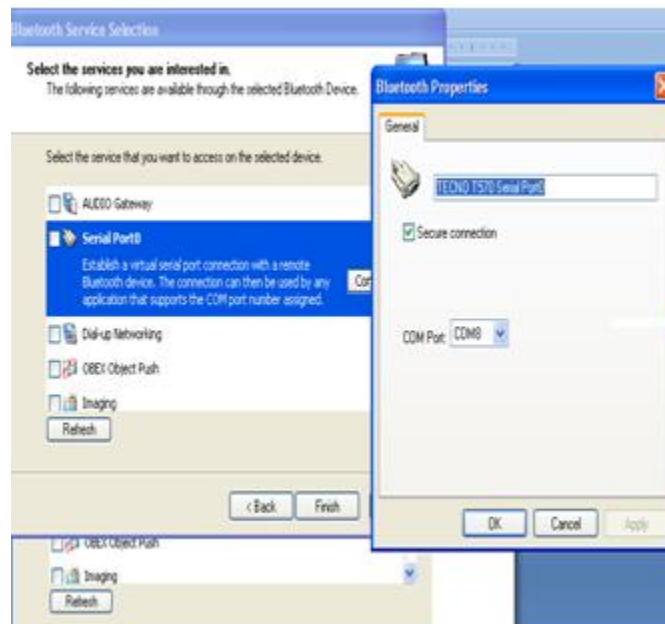


Figure D: Window showing the selected Bluetooth profile and its assigned COM port.

B. Connecting Bluetooth mobile to computer using Bluetooth dongle.

To connect a Bluetooth mobile device to a computer without inbuilt Bluetooth, a Bluetooth dongle is required. When this device is connected to the computer through USB port, it is installed by the computer. To begin the pairing process the following procedures are followed:

- I. Turn on the Bluetooth mobile phone.
- II. Right click the Bluetooth icon on the task bar to obtain window shown in figure E.
- III. Click the *add* button on this window to obtain the Bluetooth wizard shown in figure F.
- IV. Put a check mark on the small box on *my device is set and ready to be found* and then click *next* button for computer to search for devices.
- V. Select the detected device as shown in figure G then click next to display figure H. This window gives option for password to enable pairing of the two devices.
- VI. Enter the password as shown in figure H and click the next button.
- VII. Enter the same password in the mobile phone when prompted to pair the devices.
- VIII. Click finish to complete the process of pairing.
- IX. To confirm the serial port number assigned to the Bluetooth device, highlight the device and click properties. In this description, COM 29 is shown to have been assigned to the Bluetooth mobile phone TECKNO T 570 for dial up networking.
- X. Select the COM port assigned and click *ok* to confirm the port for DUP networking.

NB: For appendix 2A and 2B, procedures were based on a computer working with Windows XP. For other operating systems procedures may vary.

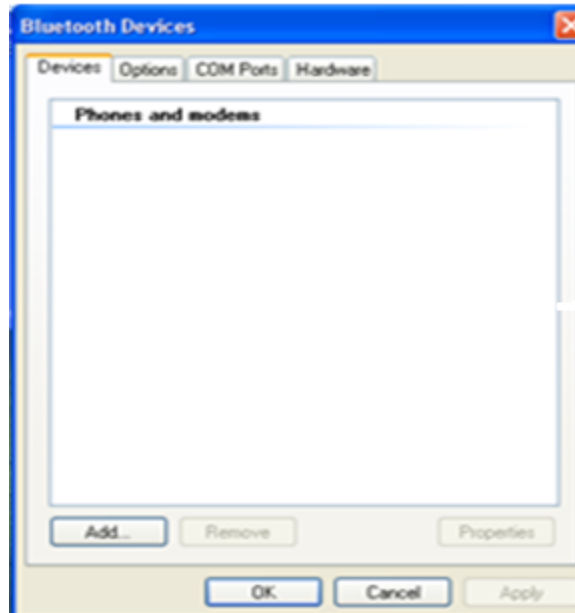


Figure E: Window for adding Bluetooth devices.



Figure F: Bluetooth device wizard that install the Bluetooth devices.



Figure G: Selecting the Bluetooth device (TECNO T570).



Figure H: Entering passkey to pair the bluetooth device.

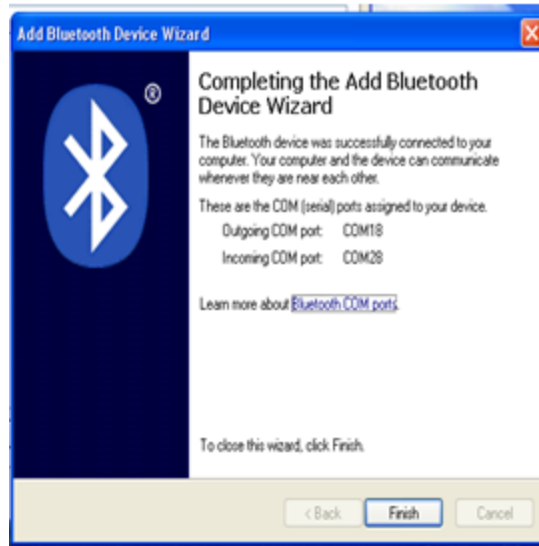


Figure H: Window showing outgoing and incoming com ports.

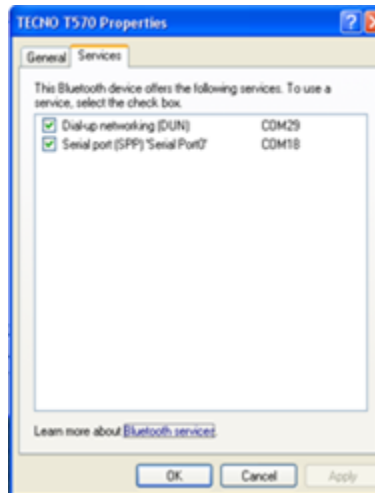
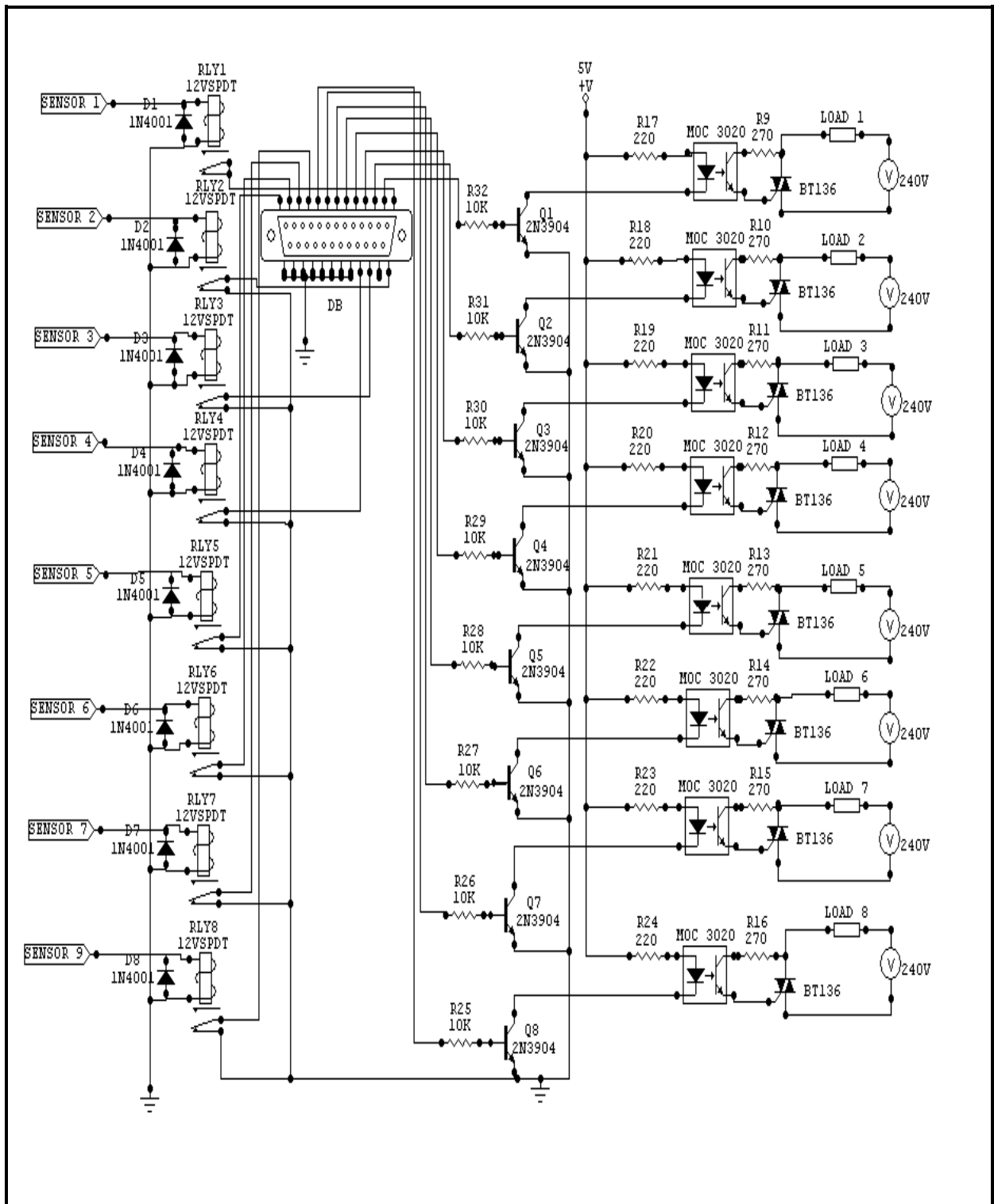


Figure I: Window showing COM29 assigned to TECNO T570 for dial up networking.

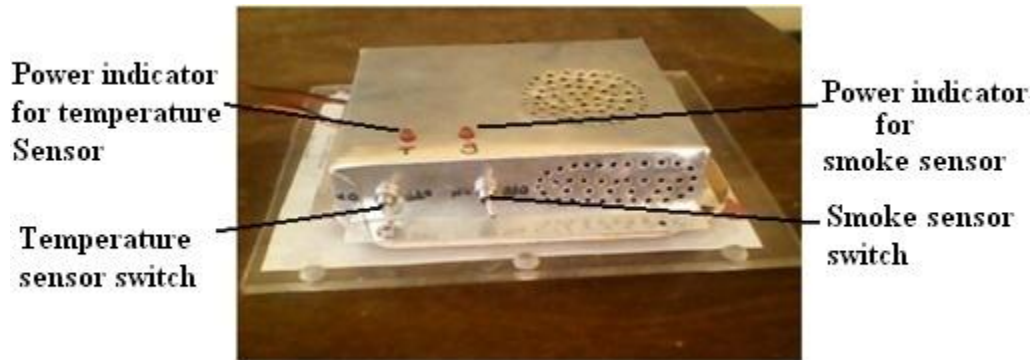
3. INTERFACING BOARD CIRCUIT DESIGNED IN THIS WORK.



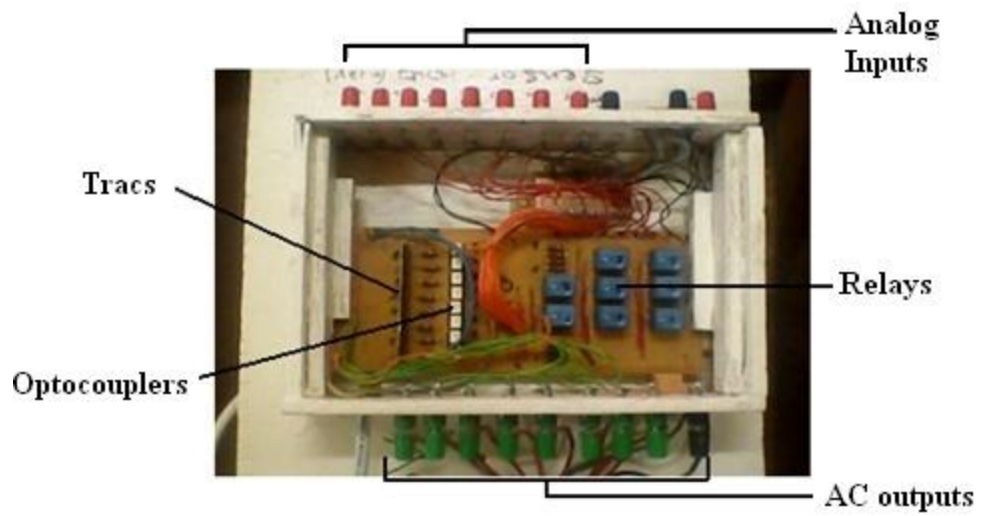
4. PHOTOGRAPHS SHOWING HARDWARE COMPONENTS OF THE FIREFIGHTING SYSTEM DESIGNED IN THIS WORK.



A. Solenoid valve.



B. Smoke and temperature sensing unit.



C. Computer interfacing board.



D. Complete firefighting system.