SMART NOSE FOR RESIDENTIAL HOUSES AND BUILDINGS

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CERTIFICATE OF CORRECTNESS AND APPROVAL

It is certified that work contained in this thesis "Smart Nose for Residential Houses and Buildings", was carried out by Khadija Abid, Qurat-ul-Ain, Anum Sajjad and Aiman Sultan under the supervision of Lec. Intisar Rizwan-i-Haque for partial fulfillment of Degree of Bachelor of Electrical (Telecommunication) Engineering, is correct and approved.

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ABSTRACT

In the last several years, a growing scientific evidence has indicated that the pollutant levels within homes can sometimes be higher than in outdoor air, due to the modern air tight home structure. Most of our time is spend indoors, so poor indoor air quality can put us at risk for health problems from short-term eye and throat allergies-to long-term effect like cancer and even death.

On 22nd January, 2014 it was reported that four person of the family including husband, wife and their two children were found dead due to suffocation caused by gas leakage. In another case, Three real brothers present in the room went unconscious due to suffocation and were rushed to Civil Hospital where doctors confirmed death of the two brothers while third’s condition was also declared serious. A couple and their two children sustained burn injuries in a blast that occurred due to gas leakage. These are only a few incidents while there are a lot more all around the world whereas minor allergies are not reported

The mostly encountered hazardous gases inside buildings are: Carbon-dioxide, Carbon-monoxide, Methane and Hydrogen Sulfide. Most of the dangerous gases are colorless and odorless (for example Carbon-monoxide-the silent killer) and the odorous ones (for example Hydrogen Sulfide) are harmful at low concentrations. So some detecting mechanism is needed to aware us of these dangerous gases at a concentration not dangerous for human health, so that the residents can take timely action to get rid of the gas source.

Gas detectors or sensors available in the market can sense/detect only one gas in one module. Moreover, if user is not present near the detector, it cannot control the safety providing devices. Therefore one compact indoor device for detection of four dangerous gases carbon-dioxide, carbon-monoxide, hydrogen sulfide and methane is designed and implemented. When gas is detected the user is informed via audio visual indications along with a text message. Safety device (e.g. exhaust fan) will be turned on automatically after gas detection to evacuate the gas to keep its concentration as low as possible. The user can take action manually (i.e., turning gas evacuating device on or gas sources off via switch) or via a text message. In case of manual action the user at the mobile end can send a pre-defined text message to know the status of the devices at the residence and can turn any device on or off according to his will. A keypad interface is also provided so that the user can enter, delete and check the numbers to which the messages will be sent. Thus, a Smart Nose is designed and implemented to provide user with all the features mentioned above.

DEDICATION

"If Allah assists you, then there is none that can overcome you, and if He forsakes you, who is there then that can assist you after Him? And on Allah should the believers rely."(3:160)

Dedicated to our beloved families and country Pakistan

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LIST OF SYMBOLS/ABBREVIATIONS

cc	cubic centimetres
LEL	Lower explosive limit
ppm	parts per million
psi	pounds per square inch
TLV-TWA	The time-weighted average concentration for a normal 8 hour work day and a 40 hour work
TLV-STEL	A TWA concentration over 15 minutes that American Conference of Governmental Industrial Hygienists (ACGIH) recommends not to exceed—even if the 8-hour TWA is within the standards.

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INTRODUCTION

1.1 Background

In 1914, Alexander Graham Bell noted:

"Did you ever measure a smell? Can you tell whether one smell is just twice strong as another? Can you measure the difference between one kind of smell and another? It is very obvious that we have very many different kinds of smells, all the way from the odour of violets and roses up to asafetida. But until you can measure their likeness and differences, you can have no science of odour. If you are ambitious to find a new science, measure a smell" [1]. In the decades since Bell made this observation, no such science of odor materialized, and it was not until the 1950s and beyond that any real progress was made.

The expression "electronic sensing" refers to the capability of reproducing human senses using sensor arrays and pattern recognition systems. Since 1982, research has been conducted to develop technologies, commonly referred to as electronic nose, that could detect and recognize odors and flavors [2].

1.2 Problem Statement

Our health is directly related with how clean is the air we breathe. Now, consider that most of our airborne toxins are inhaled while we're inside because indoor air is polluted more and we spend most of our lives indoors whether it's in offices, homes or schools The amount of carbon-dioxide in a building is usually related to how much fresh air is being brought into that building. Exposure to CO2 can produce a variety of health effects. These may include headaches, dizziness, and restlessness to coma, asphyxia, and convulsions. Badly fitted or poorly maintained gas appliances can produce a highly poisonous gas called carbon-monoxide (CO) which can leak into the residence. It can't be seen, tasted or smelled it but it can kill quickly and with no warning. It can also cause serious long term health problems such as brain damage. Un-burnt natural gas (90% methane) and LPG are not poisonous in the same way that carbon-monoxide is but both can lead to fires and explosions. The health effects of hydrogen sulfide which occurs naturally in sewer, well water etc. are seen even at low concentrations. These range from mild, headaches or eye irritation, to very serious, unconsciousness and death.

1.3 Solution

The solution to this problem is to design a Smart Nose a combination of electronic nose interfaced to a GSM along with a device management and monitoring system also interfaced to GSM. This one compact indoor device will detect four dangerous gases carbon-dioxide, carbon-monoxide, hydrogen sulfide and methane and will allow the user to monitor and manage the gas evacuating devices through GSM.

1.4 Inspiration

Many cases are recorded due to negligence of inhabitants and unannounced load shedding of gas which caused an increase in sudden death rates due to gas poisoning. The main drivers behind this project are real cases in different parts of world especially in Pakistan recently. The first case was reported in Quetta, Pakistan [3] where one person was killed and three were injured in an explosion after a gas leak at a house in Pashtunabad area. According to the family, the explosion occurred as they lit a match for the preparation of Fajr prayers. The six room house was completely destroyed by the explosion. The blast was so severe that it also damaged nearby buildings and electricity poles.

In the second case occurred in Qilla Saifullah, Pakistan [4] where two brothers went to sleep in a room after igniting a heater. The deceased were suffocated after coal-run heater absorbed the entire oxygen in the room. They were shifted to a nearby hospital where the doctors pronounced them dead.

In the third case mentioned here, five members of a family including husband, wife and three children died due to suffocation in their home at Baldia town of the city. As reported in newspaper account, the family died apparently due to gas poisoning after the electricity generator was left running throughout the night [5].

One girl was killed and six persons, including a woman, were injured in twin explosion after different incidents of gas leakage in one day at Quetta, Pakistan[6].According to Police, the first explosion occurred after gas filled in the office of Sui Southern Gas Company (SSGC) near the Eastern Bypass. An official was severely injured by the fire that erupted after the explosion. Seven rooms of the officer's mess were completely destroyed by the blast. The second blast took place at a house located at Wali Khan Chowk at the area of Pashtunabad where a heater was left burning. A girl was killed and five persons, including a woman, were injured in the incident.

These all cases mentioned above are just some examples from the daily accidents took place inside Pakistan. However, the dizziness caused by Carbon-dioxide and the silent death caused by Carbon-monoxide is not reported. All these cases could be avoided if there was some detecting mechanism which would detect the gases before they cause dizziness or any other harm. Moreover, we believe that this system should be present in every house as a recent survey indicates that there are no specifications for gas related safety precautions included in building bye laws of most housing societies of Pakistan. Therefore there is a need to design an electronic device that is portable and detects most of the harmful gases that might be present within the household because of leakage or any other unforeseen failure.

1.5 Objectives

The Smart nose should be able to detect the four mostly encountered and dangerous gases in houses and residential buildings that are

i. Carbon-dioxide
ii. Carbon-monoxide
iii. Methane
iv. Hydrogen sulfide

The electronic nose will be having alarm system to alert the user by audiovisual indications when the gas will be detected as it reaches the threshold level. The electronic nose will be interfaced to GSM and as soon the gas is detected a text message will be sent to user which will contain information of the gas detected and requesting the user to take action. The electronic nose will be interfaced to device management and monitoring system also be interfaced to GSM. This device management and monitoring system interfaced to GSM allows the user to turn safety providing devices like exhaust fans etc on using a text message from anywhere. As the gas is detected a safety providing device is turned on automatically to keep the concentration of the gas detected as low as possible. The user will also be able to check the status of the devices at any time. A keypad will also be provided so that the user can enter, delete and check the numbers to which the messages will be sent.

1.4 Document Organization

Chapter 2 gives a review of literature studied for the completion of project including Gas sensors and origin of Electronic Nose concept. Chapter 3 discusses sources of gases and their harmful effects on our health. Chapter 4 provides the comprehensive details on design and schematic of Smart Nose. Chapter 5 discusses the details of the components of Smart Nose. Chapter 6 discusses the functional components of GSM architecture used for sending and receiving of text messages. Chapter 7 details the results and simulations obtained from testing. Chapter 8 discusses the applications of Smart Nose in detail.

Chapter: 2

LITERATURE REVIEW

2.1 Introduction

This chapter starts with the basic review of Gas sensors and their different types are explained. The sensor type used is discussed with its operation and components in detail. The chapter ends with details of the concept of electronic nose.

2.2 Gas Sensors

Gases are the key measures in many industrial or domestic activities. In the last decade reliable detection of hazardous, harmful, or toxic gases has become a major issue due to more stringent environmental and safety regulations worldwide as the awareness of the need to protect the environment has grown. Single gas sensors can, for examples, be used as fire detectors, leakage detectors, controllers of ventilation in cars and planes, alarm devices warning the exceeding of threshold concentration values of hazardous gases in the work places. The detection of volatile organic compounds (VOCs) or smells generated from food or household products has also become increasingly important in food industry and in indoor air quality, and multisensor systems (often referred to as electronic noses) are the modern gas sensing devices designed to analyze such complex environmental mixtures.

Solid state gas sensors, based on a variety of principles and materials, are the best candidates to the development of commercial gas sensors for a wide range of such applications. The great interest of industrial and scientific world on solid state gas sensors comes from their numerous advantages, like small sizes, high sensitivities in detecting very low concentrations (at level of ppm or even ppb) of a wide range of gaseous chemical compounds, possibility of on-line operation and, due to possible bench production, low cost. On the contrary, traditional analytical instruments such as mass spectrometer, nuclear magnetic resonance (NMR), and chromatography are expensive, complex, and large in size. In addition, most analysis requires sample preparation, so that on-line, real-time analysis is difficult.

Several physical effects are used to achieve the detection of gases in solid state gas sensors. In contrast to optical processes, which employ infra-red absorption of gases, chemical processes, which detect the gas by means of a selective chemical reaction with a reagent, mainly utilize solid-state chemical detection principles. A characteristic of solid state gas sensors is the reversible interaction of the gas with the surface of a solid-state material. In addition to the conductivity change of gas-sensing material, the detection of this reaction can be performed by measuring the change of capacitance, work function, mass, optical characteristics or reaction energy released by the gas/solid interaction. Organic (as conducting polymers, porphyrins and phtalocyanines) or inorganic (as semiconducting metal oxides) materials, deposited in the form of thick or thin films, are used as active layers in such gas sensing devices. The read-out of the measured value is performed via electrodes, diode arrangements, transistors, surface wave components, thickness-mode transducers or optical arrangements. Indeed, although the basic principles behind solid state gas sensors are similar for all the devices, a multitude of different technologies have been developed. Hence, nowadays the number of different solid state based gas sensors is really very large. Due to the large variety of sensors, a rich fabric of interdisciplinary science ranging from solid state physics, chemistry, electronics, biology, etc., governs the modern gas-sensing devices [7].

A short list of solid state gas sensors is described below

Table 2-1 Types of solid state gas sensors with the corresponding physical change used as gas detection principle.

Type of Gas sensors	Physical change
Semiconductor gas sensors	Electrical conductivity
Field effect gas sensors	Work function (electrical polarisation)
Piezoelectric sensors	Mass
Optical sensors	Optical parameters: surface plasmon resonance, reflection, interferometry, absorption, fluorescence, refractive index or optical path length
Catalytic gas sensors	Heat or temperature
Electrochemical gas sensors	Electromotive force or electrical current

Note: from **SOLID STATE GAS SENSORS: STATE OF THE ART AND FUTURE ACTIVITIES**

2.2.1 Semiconductor Gas Sensors

Semiconductor gas sensors (SGS), known also as chemoresistive gas sensors, are typically based on metal oxides (e.g. SnO_2, TiO_2, In_2O_3, WO_3, NiO, etc.). Semiconductor gas sensors (metal oxide sensors) are electrical conductivity sensors. The resistance of their active sensing layer changes due to contact with the gas to be detected. In the ideal case, the gas reacts with the sensor surface in a completely reversible reaction [8].

2.2.2 Field Effect Gas Sensors

In field effect sensors technology is based on the field effect generated by gases in metal oxide semiconductor field-effect transistor (MOSFET) devices with catalytic metals. The charging of the gate contact by the gas molecules results in a voltage change in the sensor signal. The interaction of gases with the catalytic gate metal induces dipoles or charges, which give an additional voltage to the gate contact. The choice of operation temperature, gate metal, and structure of the gate metal determine the selectivity of the gas response.

This gives response time in the order of milliseconds due to the fast chemical reactions. Furthermore, the catalytic metal remains clean even in highly contaminated environments [9].

2.2.3 Piezoelectric Gas Sensors

A piezoelectric sensor is a device that uses the piezoelectric effect (the electric charge that accumulates in certain solid materials in response to applied mechanical stress [10]), to measure changes in pressure, acceleration, strain or force by converting them to an electrical charge [11].

2.2.3.1 Quartz Crystal Microbalances (QMB)

A quartz crystal microbalance (QMB) measures a mass per unit area by measuring the change in frequency of a quartz crystal resonator. The resonance is disturbed by the addition or removal of a small mass due to oxide growth/decay or film deposition at the surface of the acoustic resonator [12].

2.2.3.2 Surface Acoustic Effect (SAW) Gas Sensors

Piezoelectric acoustic wave sensors apply an oscillating electric field to create a mechanical wave, which propagates through the substrate and is then converted back to an electric field for measurement [13].

2.2.3.3 Microcantilever Gas Sensors

A microcantilever sensor is a device that can act as a physical, chemical or biological sensor by detecting changes in cantilever (A projecting structure, such as a beam, that is supported at one end and carries a load at the other end or along its length) bending or vibrational frequency. This movement changes when a specific mass of analyte (the substance being monitored) is specifically adsorbed on its surface. [14]

2.2.4 Optical Sensors

The optical gas sensors play an important role in sensing field for the measurements of chemical and biological quantities. First optical chemical sensors were based on the measurement of changes in absorption spectrum. At present a large variety of optical methods are used in chemical sensors and biosensors including ellipsometry, spectroscopy (luminescence, phosphorescence, fluorescence, Raman), interferometry (white light interferometry, modal interferometry in optical waveguide structures), spectroscopy of guided modes in optical waveguide structures (grating coupler, resonant mirror), and a surface plasmon resonance (SPR) in which the oscillation of electrons changes of the object at which light falls changes. In these sensors a desired quantity is determined by measuring the refractive index, absorbance and fluorescence properties of the analyte molecules or a chemo-optical transducing element [7].

2.2.5 Catalytic Gas Sensors

Catalytic detectors are based upon the principle that when gas oxidizes it produces heat, and the sensor converts the temperature change via a standard Wheatstone Bridge-type circuit to a sensor signal that is proportional to the gas concentration. The sensor components consist of a pair of heating coils (reference and active). The active element is embedded in a catalyst. The reaction takes place on the surface of the catalyst, with combustible gases reacting exothermically with oxygen in the air to raise its temperature. This results in a change of resistance.

There is also a reference element providing an inert reference signal by remaining non-responsive to gas, thereby acting as a stable baseline signal to compensate for environmental changes which would otherwise affect the sensors temperature [15].

2.2.6 Electrochemical Gas Sensors

The oldest electrochemical sensors date back to the 1950s and were used for oxygen monitoring. More recently, as the Occupational Safety and Health Administration (OSHA) began requiring the monitoring of toxic and combustible gases in confined space applications, new and better electrochemical sensors have been developed.

By the mid-1980s, miniaturized electrochemical sensors became available for detection of many different toxic gases in PEL ranges, with the sensors exhibiting good sensitivity and selectivity. Currently, a variety of electrochemical sensors are being used extensively in many stationary and portable applications for personal safety. Figure 2-1 shows a small collection of such electrochemical sensors.

Figure 2-1: **Electrochemical Sensors**

The physical size, geometry, selection of various components, and the construction of an electrochemical sensor usually depends on its intended use.

The most common misconception about electrochemical sensors is that they are all the same. In fact, the appearance of the electrochemical sensors used to detect various gases may be similar, but their functions are markedly different. Consequently, one can expect varying performance from each of these sensors, in terms of sensitivity, selectivity, response time, and operating life. For example, a low concentration gas sensor with very high sensitivity uses a coarse-porosity hydrophobic membrane and less restricted capillary to allow more gas molecules to pass through to produce enough signal for better sensitivity. However, this design also allows more of the electrolyte's water molecules to escape out to the environment. In other words, an electrochemical sensor with high sensitivity would have a relatively short operating life due to evaporation of moisture through the porous membrane.

Similarly, the electrolyte composition and the sensing electrode material is selected based on the chemical reactivity of the target gas. By careful selection of the electrolyte and/or the sensing electrode, one can achieve the selectivity towards the target gas, but the sensitivity may be reduced.

In summary, different electrochemical sensors may appear very similar, but are constructed with different materials including such critical elements as sensing electrodes, electrolyte composition, and porosity of hydrophobic barriers. Additionally, some electrochemical sensors use external electrical energy to make them reactive to the target gas. All components of the sensors play a crucial role in determining the overall characteristics of the sensors.

2.2.6.1 Principle of Operation

Electrochemical sensors operate by reacting with the gas of interest and producing an electrical signal proportional to the gas concentration. A typical electrochemical sensor consists of a sensing electrode (or working electrode), and a counter electrode separated by a thin layer of electrolyte, Figure 2-2.

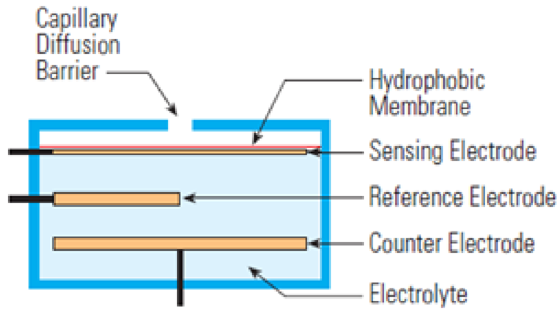


Figure 2-2: **Typical Electrochemical Sensor Setup**

Gas that comes in contact with the sensor first passes through a small capillary-type opening and then diffuses through a *hydrophobic barrier*, and eventually reaches the electrode surface. This approach is adopted to allow the proper amount of gas to react at the sensing electrode to produce a sufficient electrical signal while preventing the electrolyte from leaking out of the sensor, Figure 2-3.

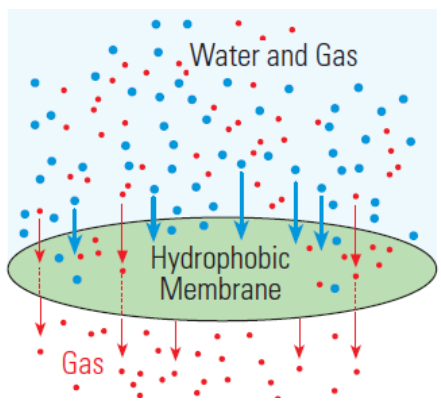


Figure 2-3: **Hydrophobic membrane: prevents liquid electrolyte from leaking out.**

The gas that diffuses through the barrier reacts at the surface of the sensing electrode involving either an oxidation or reduction mechanism. These reactions are catalyzed by the electrode materials specifically developed for the gas of interest. With a resistor connected across the electrodes, a current proportional to the gas concentration flows between the anode and the cathode. The current can be measured to determine the gas concentration.

2.2.6.2 Importance of Reference Electrode

For a sensor requiring an external driving voltage, it is important to have a stable and constant potential at the sensing electrode. In reality, the sensing electrode potential does not remain constant due to the continuous electrochemical reaction taking place on the surface of the electrode. It causes deterioration of the performance of the sensor over extended periods of time. To improve the performance of the sensor, a reference electrode is introduced. This reference electrode is placed within the electrolyte in close proximity to the sensing electrode. A fixed stable constant potential is applied to the sensing electrode. The reference electrode maintains the value of this fixed voltage at the sensing electrode. No current flows to or from the reference electrode. The gas molecules react at the sensing electrode and the current flow between the sensing and the counter electrode is measured and is typically related directly to the gas concentration. The value of the voltage applied to the sensing electrode makes the sensor specific to the target gas.

2.2.6.3 Major Components

An electrochemical sensor consists of the following major components:

2.2.6.3.1 Gas Permeable Membrane (or Hydrophobic membrane)

This is used to cover the sensor's sensing (catalyst) electrode and, in some instances, to control the amount of gas molecules reaching the electrode surface. Such barriers are typically made of thin, low-porosity Teflon membranes. Such sensors are called *membrane clad* sensors. Alternatively, the sensing electrode is covered with a high-porosity Teflon and the amount of gas molecules reaching the electrode surface is controlled by a capillary. Such sensors are referred to as *capillary-type sensors*. Besides offering a mechanical protection to the sensor, the membrane performs the additional function of filtering out unwanted particulates. Selecting the correct pore size of the membrane and capillary is necessary to transfer the proper amount of gas molecules. The pore size should be such as to allow enough gas molecules to reach the sensing electrode. The pore size should also prevent liquid *electrolyte* from leaking out or drying out the sensor too quickly.

2.2.6.3.2 Electrode

The selection of the electrode material is very important. It is a catalyzed material which performs the half-cell reaction over a long period of time. Typically, the electrode is made from a noble metal, such as platinum or gold, and catalyzed for an effective reaction with gas molecules. Depending on the design of the sensor, all three electrodes can be made of different materials to complete the cell reaction.

2.2.6.3.3 Electrolyte

The electrolyte must facilitate the cell reaction and carry the ionic charge across the electrodes efficiently. It must also form a stable reference potential with the reference electrode and be compatible with materials used within the sensor. If the electrolyte evaporates too quickly, the sensor’s signal will deteriorate.

2.2.6.3.4 Filter

Sometimes a *scrubber* filter is installed in front of the sensor to filter out unwanted gases. There is a limited selection of filters, each with different degrees of effectiveness. The most commonly used filter medium is activated charcoal, as shown in Figure. The activated charcoal filters out most chemicals with the exception of carbon-monoxide and hydrogen gases. By properly selecting the filter medium, an electrochemical sensor can be made more selective to its target gases.

Choosing the suitable materials for the above components, and *arranging* the geometry of all these components to determine the optimum operating performance presents a challenge to scientists. Minor variations in the details of the sensor design can have a profound influence on the sensor’s accuracy, response time, sensitivity, selectivity, and life expectancy.

2.2.6.4 Importance of Oxygen

The reactions at the sensing electrode (*anode*) for some gases are as follows:

For carbon-monoxide

$$CO + H_2O \rightarrow CO_2 + 2H+ + 2e-$$

For hydrogen sulfide

$$H_2S + 4H_2O \rightarrow H_2SO_4 + 8H+ + 8e-$$

Simultaneously, the reactions at the counter electrode (*cathode*) need oxygen molecules to complete the process:

$$O_2 + 4H+ + 4e- \rightarrow 2H_2O$$

An inadequate supply of oxygen to complete the reaction will shorten the life of the sensors, hence the sensors will not operate properly. Sensors involving a reduction reaction of the target gas—such as the reduction of nitrogen dioxide, chlorine, and ozone—at the cathode produce water as a byproduct. At the anode, water is simultaneously oxidized [16].

2.3 Electronic Nose

2.3.1 The Role of Aroma in Human Society and Commerce

The sense of smell has long played a fundamental role in human development and biosocial interactions. Consequently, the olfactory sense has become a key element in the development of many commercial industries that manipulate the aroma properties of their manufactured goods in order to improve product appeal, quality, and consistency so that consumers quickly identify with individual brands having unique scents. A wide diversity of examples ranging from the bouquet of wines and cuisine, perfumes and colognes added to personal health-care products, and scents applied to product packaging are obvious paradigms demonstrating the importance of aroma qualities in industrial manufacturing and commercial trade. Similarly, spices have been used throughout human history to enhance the flavor of foods and scent the air with aromatic pot-pourris; other examples of products used and valued for their aromatic characteristics. Indeed, spices were once among the most valued commodities for trade in ancient times and considered sufficiently valuable alone to justify the opening of new commercial trade routes throughout the world. Thus, aroma characteristics have contributed immensely to the value and appeal of many commercial products, and have largely determined what consumers are willing to pay for many manufactured goods. As a result, research and quality control of aroma characteristics during product manufacturing has become of paramount importance in industrial production operations because product consistency is essential for maintaining consumer brand recognition and satisfaction. This importance of product aroma characteristics has been repeatedly demonstrated by devastating losses in corporate sales and market share that typically occur when manufacturing changes are made to product aroma and flavor characteristics.

Despite the importance of the olfactory sense to mankind, the sense of smell in man is often considered the least refined of the human senses, far less sensitive than that of other animals. For example, the human nose possesses only about one million aroma receptors that work in tandem to process olfactory stimuli whereas dogs have about 100 million receptors that distinguish scents at least 100 times more effectively than the average human. Furthermore, the ability to detect chemicals in the environment is critical to the survival of most prokaryotic and eukaryotic organisms. A clear indication of the importance of olfactory systems in higher eukaryotes is the significant proportion (up to 4%) of the genome that is devoted to encoding products used in building olfactory sensory tissues. The relatively low sensitivity and discrimination capabilities of the human nose, coupled with the common occurrence of olfactory fatigue, has led to the need for electronic instruments with sensors capable of performing repeated discriminations with high precision to eliminate human fatigue. The olfactory sense has long been intimately linked with human emotions and aesthetics, yet previously we have lacked a suitable vocabulary to describe aromas with precision and to quantify aromas in more discrete, consistent terms. As a consequence, past researchers have resorted to the use of relative or comparative terms to describe aromatic materials. The need to more precisely quantify and express the aroma characteristics of VOCs, released as mixtures from specific source types, has made necessary the development of methods and instruments capable of recording unique quantitative and qualitative measurements of headspace volatiles derived from known sources. For these reasons, there has been great interest in the development of electrochemical receptors for detecting aromas of complex vapor mixtures.

2.3.2 Origin of Electronic Nose

The sensor technology of artificial olfaction had its beginnings with the invention of the first gas multisensor array in 1982. Advances in aroma-sensor technology, electronics, biochemistry and artificial intelligence made it possible to develop devices capable of measuring and characterizing volatile aromas released from a multitude of sources for numerous applications. These devices, known as electronic noses, were engineered to mimic the mammalian olfactory system within an instrument designed to obtain repeatable measurements, allowing identifications and classifications of aroma mixtures while eliminating operator fatigue. Unlike other analytical instruments, these devices allow the identification of mixtures of organic samples as a whole (identifiable to a source that released the mixture) without having to identify individual chemical species within the sample mixture. Hundreds of different prototypes of artificial-nose devices have been developed to discriminate complex vapor mixtures containing many different types of volatile organic compounds (VOCs). These prototypes collectively represent various electronic aroma detection (EAD) technologies that utilize different sensor types including metal-oxide, semi-conductive polymers, conductive electro-active polymer, optical, surface acoustic wave and electrochemical gas sensors.

An electronic nose system typically consists of a multi-sensor array, an information-processing unit such as an artificial neural network (ANN), software with digital pattern-recognition algorithms, and reference-library databases. The cross-reactive sensor array is composed of incrementally-different sensors chosen to respond to a wide range of chemical classes and discriminate diverse mixtures of possible analytes. The output from individual sensors are collectively assembled and integrated to produce a distinct digital response pattern.

Identification and classification of an analyte mixture is accomplished through recognition of this unique aroma signature (electronic fingerprint) of collective sensor responses. The identity of a simple or complex mixture represented by a unique aroma signature pattern may be determined without having to separate the mixture into its individual components prior to or during analysis. A reference library of digital aroma signature patterns for known samples is constructed prior to analysis of unknowns. The ANN is configured through a learning process (neural net training) using pattern recognition algorithms that look for differences between the patterns of all analyte types included in the reference library. This process continues until a previously selected level of discrimination is met. The results are validated and assembled into the reference library to which unknown samples can be compared. Identification of unknowns is based on the distribution of aroma attributes or elements that the analyte pattern has in common with patterns present in databases of the reference library.

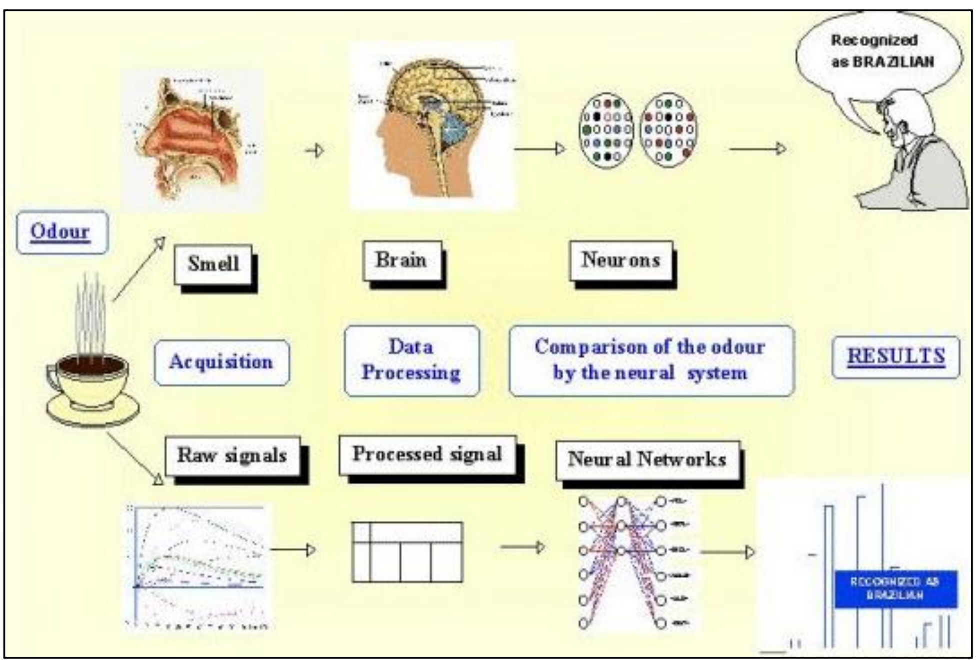


Figure 2-4: **Signal recognition in Brain and in Electronic Nose**

Most applications of EAD technologies hitherto have been in industrial production, processing, and manufacturing. Some of the more common manufacturing applications have been in quality control and grading, product uniformity and consistency, processing controls, gas leak detection and environmental effluents monitoring. Applications are continuously being developed in many new areas of applied research such as for volatile emissions assessments, homeland security, environmental protection, biomedical diagnoses, personnel safety, and in product development research. [18]

Electronic-nose devices have received considerable attention in the field of sensor technology during the past twenty years, largely due to the discovery of numerous applications derived from research in diverse fields of applied sciences. Recent applications of electronic nose technologies have come through advances in sensor design, material improvements, software innovations and progress in micro-circuitry design and systems integration. The invention of many new e-nose sensor types and arrays, based on different detection principles and mechanisms, is closely correlated with the expansion of new applications. Electronic noses have provided a plethora of benefits to a variety of commercial industries, including the agricultural, biomedical, cosmetics, environmental, food, manufacturing, military, pharmaceutical, regulatory, and various scientific research fields. Advances have improved product attributes, uniformity, and consistency as a result of increases in quality control capabilities afforded by electronic-nose monitoring of all phases of industrial manufacturing processes [17].

2.4 Summary

To summarize, in this chapter an introduction to Gas sensors was provided. Six types of gas sensors were discussed and Operation of Electrochemical gas sensors was provided in detail with description of major components. Origin and concept of Electronic Nose were also discussed.

Chapter: 3

SOURCES OF GASES AND THEIR HARMFUL EFFECTS

3.1 Introduction

Indoor air pollution can put risk to our health as we go about our day to day lives. Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are.

Health effects from indoor air pollutants may be experienced soon after exposure or, possibly, years later. In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

3.2 Sources of Gases

3.2.1 Carbon-dioxide (CO_2)

There are natural and human sources of carbon-dioxide emissions. Natural sources include decomposition, ocean release and respiration while Human sources come from activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas.

Due to human activities, the atmospheric concentration of carbon-dioxide has been rising extensively since the Industrial Revolution and has now reached dangerous levels not seen in the last 3 million years. Human sources of carbon-dioxide emissions are much smaller than natural emissions but they have upset the natural balance that existed for many thousands of years before the influence of humans.This is because natural sinks remove around the same quantity of carbon-dioxide from the atmosphere than are produced by natural sources. This had kept carbon-dioxide levels balanced and in a safe range. But human sources of emissions have upset the natural balance by adding extra carbon-dioxide to the atmosphere without removing any.

3.2.1.1 Human Sources

Since the Industrial Revolution, human sources of carbon-dioxide emissions have been growing. Human activities such as the burning of oil, coal and gas, as well as deforestation are the primary cause of the increased carbon-dioxide concentrations in the atmosphere.

87 % of all human-produced carbon-dioxide emissions come from the burning of fossil fuels like coal, natural gas and oil. The remainder results from the clearing of forests and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%).

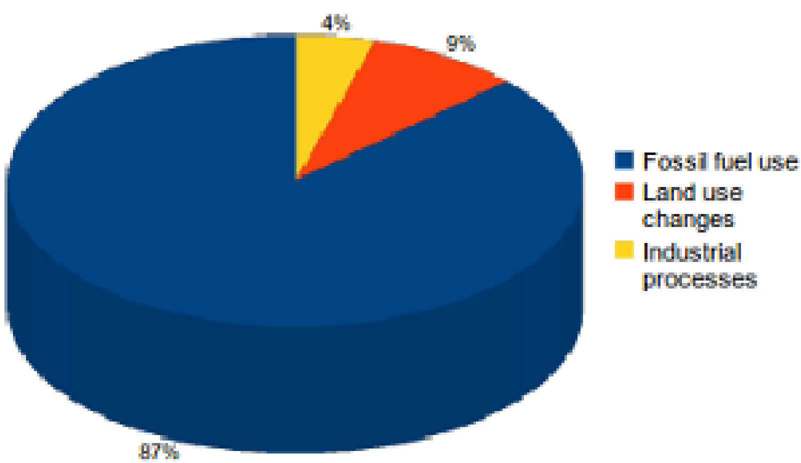


Figure 3-1: **Human sources of carbon-dioxide**

3.2.1.1.1 Fossil Fuel Combustion/Use

The largest human source of carbon-dioxide emissions is from the combustion of fossil fuels. This produces 87% of human carbon-dioxide emissions. Burning these fuels release energy which is most commonly turned into heat, electricity or power for transportation. Some examples of where they are used are in power plants, cars, planes and industrial facilities. In 2011, fossil fuel use created 33.2 billion tonnes of carbon-dioxide emissions worldwide.

The 3 types of fossil fuels that are used the most are coal, natural gas and oil. Coal is responsible for 43% of carbon-dioxide emissions from fuel combustion, 36% is produced by oil and 20% from natural gas.

Coal is the most carbon intensive fossil fuel. For every tonne of coal burned, approximately 2.5 tonnes of carbon-dioxide are produced. Of all the different types of fossil fuels, coal produces the most carbon-dioxide. Because of this and its high rate of use, coal is the largest fossil fuel source of carbon-dioxide emissions. Coal represents one-third of fossil fuels' share of world total primary energy supply but is responsible for 43% of carbon-dioxide emissions from fossil fuel use..

The three main economic sectors that use fossil fuels are: electricity/heat, transportation and industry. The first two sectors, electricity/heat and transportation, produced nearly two-thirds of global carbon-dioxide emissions in 2010.

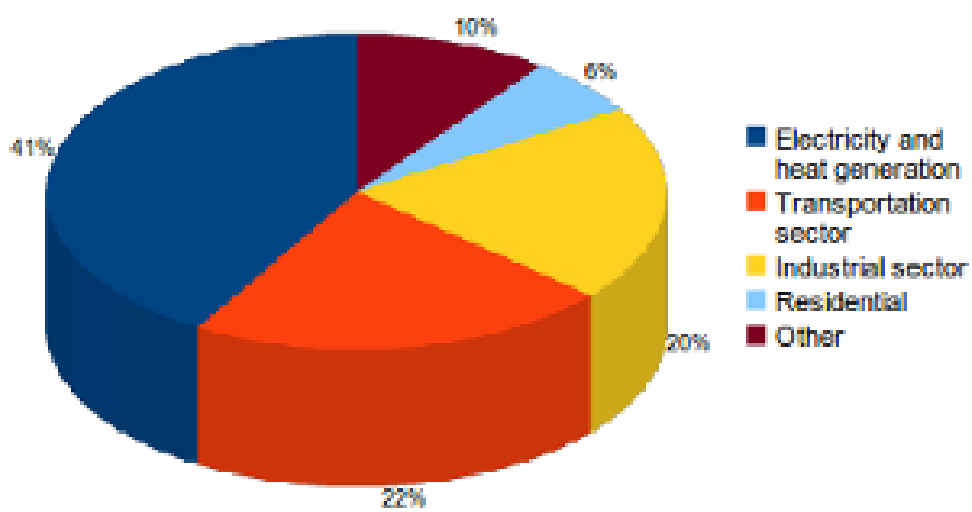


Figure 3-2: **Carbon-dioxide emissions from fossil fuel combination**

3.2.1.1.1.1 Electricity/Heat sector

Electricity and heat generation is the economic sector that produces the largest amount of man-made carbon-dioxide emissions. This sector produced 41% of fossil fuel related carbon-dioxide emissions in 2010. Around the world, this sector relies heavily on coal, the most carbon-intensive of fossil fuels, explaining this sector giant carbon footprint.

Almost all industrialized nations get the majority of their electricity from the combustion of fossil fuels (around 60-90%). Only Canada and France are the exception.

The industrial, residential and commercial sectors are the main users of electricity covering 92% of usage. Industry is the largest consumer of the three because certain manufacturing processes are very energy intensive. The production of chemicals, iron, steel, cement, aluminum, pulp and paper account for the majority of industrial electricity use. The residential and commercial sectors are also heavily reliant on electricity for meeting their energy needs, particularly for lighting, heating, air conditioning and appliances.

3.2.1.1.1.2 Transportation sector

The transportation sector is the second largest source of anthropogenic carbon-dioxide emissions. Transporting goods and people around the world produced 22% of fossil fuel related carbon-dioxide emissions in 2010. This sector is very energy intensive and it uses petroleum based fuels (gasoline, diesel, kerosene, etc.) almost exclusively to meet those needs. Since the 1990s, transport related emissions have grown rapidly, increasing by 45% in less than 2 decades.

Road transport accounts for 74% of this sector's carbon-dioxide emissions. Automobiles, freight and light-duty trucks are the main sources of emissions for the whole transport sector and emissions from these three have steadily grown since 1990. Apart from road vehicles, the other important sources of emissions for this sector are marine shipping and global aviation.

Marine shipping produces 14% of all transport carbon-dioxide emissions. While there are a lot less ships than road vehicles used in the transportation sector, ships burn the dirtiest fuel on the market, a fuel that is so unrefined that it can be solid enough to be walked across at room temperature. Because of this, marine shipping is responsible for over 1 billion tonnes of carbon-dioxide emissions. This is more than the annual emissions of several industrialized countries (Germany, South Korea, Canada, UK, etc.) and this sector continues to grow rapidly.

Global aviation accounts for 11% of all transport carbon-dioxide emissions. International flights create about 62% of these emissions with domestic flights representing the remaining 38%. Over the last 10 years, aviation has been one of the fastest growing sources of carbon-dioxide emissions. Aviation is also the most carbon-intensive form of transportation, so its growth comes with a heavy impact on climate change.

The emissions caused by the transportation of goods are examples of indirect emissions since the consumer has no direct control of the distance between the factory and the store. The emissions caused by people traveling (by car, plane, train, etc...) are examples of direct emissions since people can chose where they are going and by what method.

Since the distance traveled by goods during production is continuing to grow, this is putting more pressure on the transportation industry to bridge the gap and ends up creating more indirect emissions. What's worse is that 99% of the carbon-dioxide emissions caused by transportation of people and goods all over the world comes from the combustion of fossil fuels.

3.2.1.1.1.3 Industrial sector

The industrial sector is the third largest source of man-made carbon-dioxide emissions. This sector produced 20% of fossil fuel related carbon-dioxide emissions in 2010. The industrial sector consists of manufacturing, construction, mining, and agriculture. Manufacturing is the largest of the 4 and can be broken down into 5 main categories: paper, food, petroleum refineries, chemicals, and metal/mineral products. These categories account for the vast majority of the fossil fuel use and CO_2 emissions by this sector.

Manufacturing and industrial processes all combine to produce large amounts of each type of greenhouse gas but specifically large amounts of CO_2. This is because many manufacturing facilities directly use fossil fuels to create heat and steam needed at various stages of production. For example factories in the cement industry, have to heat up limestone to 1450°C to turn it into cement, which is done by burning fossil fuels to create the required heat.

3.2.1.1.2 Land Use Changes

Land use changes are a substantial source of carbon-dioxide emissions globally, accounting for 9% of human carbon-dioxide emissions and contributed 3.3 billion tonnes of carbon-dioxide emissions in 2011. Land use changes are when the natural environment is converted into areas for human use like agricultural land or settlements. From 1850 to 2000, land use and land use change released an estimated 396-690 billion tonnes of carbon-dioxide to the atmosphere, or about 28-40% of total anthropogenic carbon-dioxide emissions.

Deforestation has been responsible for the great majority of these emissions. Deforestation is the permanent removal of standing forests and is the most important type of land use change because its impact on greenhouse gas emissions. Forests in many areas have been cleared for timber or burned for conversion to farms and pastures. When forested land is cleared, large quantities of greenhouse gases are released and this ends up increasing carbon-dioxide levels in three different ways.

Trees act as a carbon sink. They remove carbon-dioxide from the atmosphere via photosynthesis. When forests are cleared to create farms or pastures, trees are cut down and either burnt or left to rot, which adds carbon-dioxide to the atmosphere.

Since deforestation reduces the amount of trees, this also reduces how much carbon-dioxide can be removed by the Earth's forests. When deforestation is done to create new agricultural land, the crops that replace the trees also act as a carbon sink, but they are not as effective as forests.

When trees are cut for lumber the wood is kept which locks the carbon in it but the carbon sink provided by forests is reduced because of the loss of trees.

Deforestation also causes serious changes in how carbon is stored in the soil. When forested land is cleared, soil disturbance and increased rates of decomposition in converted soils both create carbon-dioxide emissions. This also increases soil erosion and nutrient leaching which further reduces the area's ability to act as a carbon sink.

3.2.1.1.3 Industrial Processes

Many industrial processes emit carbon-dioxide directly through fossil fuel combustion as well indirectly through the use of electricity that is generated using fossil fuels. But there are four main types of industrial process that are a significant source of carbon-dioxide emissions: the production and consumption of mineral products such as cement, the production of metals such as iron and steel, as well as the production of chemicals and petrochemical products.

Cement production produces the most amount of carbon-dioxide amongst all industrial processes. To create the main ingredient in cement, calcium oxide, limestone is chemically transformed by heating it to very high temperatures. This process produces large quantities of carbon-dioxide as a byproduct of the chemical reaction. So much so that making 1000 kg of cement produces nearly 900 kg of carbon-dioxide.

Steel production is another industrial process that is an important source of carbon-dioxide emissions. To create steel, iron is melted and refined to lower its carbon content. This process uses oxygen to combine with the carbon in iron which creates carbon-dioxide. On average, 1.9 tonnes of CO_2 are emitted for every tonne of steel produced.

Fossil fuels are used to create chemicals and petrochemical products which lead to carbon-dioxide emissions. The industrial production of ammonia and hydrogen most often uses natural gas or other fossil fuels as a starting base, creating carbon-dioxide in the process. Petrochemical products like plastics, solvents, and lubricants are created using petroleum. These products evaporate, dissolve, or wear out over time releasing carbon-dioxide.

3.2.1.2 Natural Sources

Apart from being created by human activities, carbon-dioxide is also released into the atmosphere by natural processes. The Earth's oceans, soil, plants, animals and volcanoes are all natural sources of carbon-dioxide emissions.

Human sources of carbon-dioxide are much smaller than natural emissions but they upset the balance in the carbon cycle that existed before the Industrial Revolution. The amount of carbon-dioxide produced by natural sources is completely offset by natural carbon sinks and has been for thousands of years. Before the influence of humans, carbon-dioxide levels were quite steady because of this natural balance.42.84 percent of all naturally produced carbon-dioxide emissions come from ocean-atmosphere exchange. Other important natural sources include plant and animal respiration (28.56%) as well as soil respiration and decomposition (28.56%). A minor amount is also created by volcanic eruptions (0.03%).

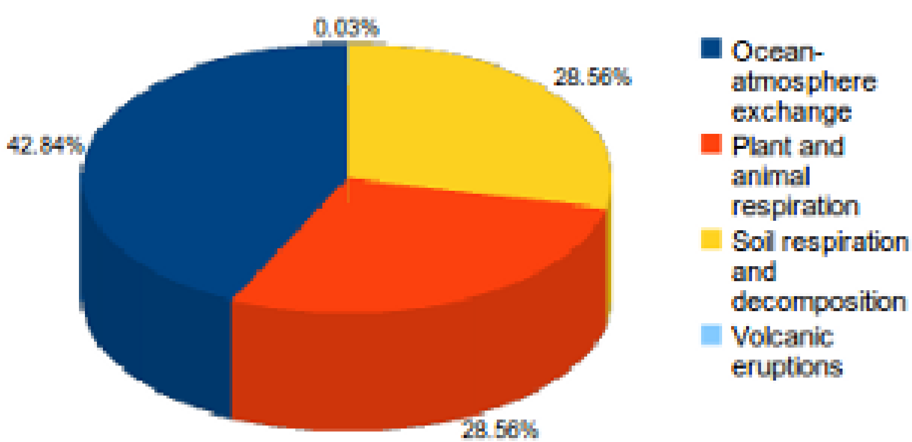


Figure 3-3: **Natural sources of Carbon-dioxide**

3.2.1.2.1 Ocean-atmosphere exchange

The largest natural source of carbon-dioxide emissions is from ocean-atmosphere exchange. This produces 42.84% of natural carbon-dioxide emissions. The oceans contain dissolved carbon-dioxide, which is released into the air at the sea surface. Annually this process creates about 330 billion tonnes of carbon-dioxide emissions.

Many molecules move between the ocean and the atmosphere through the process of diffusion, carbon-dioxide is one of them. This movement is in both directions, so the oceans release carbon-dioxide but they also absorb it. The effects of this movement can be seen quite easily, when water is left to sit in a glass for long enough, gases will be released and create air bubbles. Carbon-dioxide is amongst the gases that are in the air bubbles.

3.2.1.2.2 Plant and Animal Respiration

An important natural source of carbon-dioxide is plant and animal respiration, which accounts for 28.56% of natural emissions. Carbon-dioxide is a byproduct of the chemical reaction that plants and animals use to produce the energy they need. Annually this process creates about 220 billion tonnes of carbon-dioxide emissions.

Plants and animals use respiration to produce energy, which is used to fuel basic activities like movement and growth. The process uses oxygen to break down nutrients like sugars, proteins and fats. This releases energy that can be used by the organism but also creates water and carbon-dioxide as byproducts.

3.2.1.2.3 Soil Respiration and Decomposition

Another important natural source of carbon-dioxide is soil respiration and decomposition, which accounts for 28.56% of natural emissions. Many organisms that live in the Earth's soil use respiration to produce energy. Amongst them are decomposers who break down dead organic material. Both of these processes release carbon-dioxide as a byproduct. Annually these soil organisms create about 220 billion tonnes of carbon-dioxide emissions.

Any respiration that occurs below-ground is considered soil respiration. Plant roots, bacteria, fungi and soil animals use respiration to create the energy they need to survive but this also produces carbon-dioxide. Decomposers that work underground breaking down organic matter (like dead trees, leaves and animals) are also included in this. Carbon-dioxide is regularly released during decomposition.

3.2.1.2.4 Volcanic Eruptions

A minor amount carbon-dioxide is created by volcanic eruptions, which accounts for 0.03% of natural emissions. Volcanic eruptions release magma, ash, dust and gases from deep below the Earth's surface. One of the gases released is carbon-dioxide. Annually this process creates about 0.15 to 0.26 billion tonnes of carbon-dioxide emissions.

The most common volcanic gases are water vapor, carbon-dioxide, and sulfur dioxide. Volcanic activity will cause magma to absorb these gases, while passing through the Earth's mantle and crust. During eruptions, the gases are then released into the atmosphere [18].

3.2.2 Carbon-monoxide (CO)

Unvented kerosene and gas space heaters, leaking chimneys and furnaces, back-drafting from furnaces, gas water heaters, wood stoves, fireplaces, gas stoves; generators , gas stoves, gas dryers, charcoal grills, lawnmowers, snow blowers, other yard equipment and other gasoline powered equipment, automobile exhaust from attached garages, tobacco smoke are few sources of carbon-monoxide. Incomplete oxidation during combustion in gas ranges and unvented gas or kerosene heaters may cause high concentrations of CO in indoor air [19-20]. Worn or poorly adjusted and maintained combustion devices (e.g., boilers, furnaces) can be significant sources, or if the flue is improperly sized, blocked, disconnected, or is leaking along with auto, truck, or bus exhaust from attached garages, nearby roads, or parking areas can also be a source [21]. Other sources of carbon-monoxide include transportation, road vehicles, industrial processes and smelters [22].

3.2.3 Methane (CH_4)

There are both natural and human sources of methane emissions. The main natural sources include wetlands, termites and the oceans. Natural sources create 36% of methane emissions. Important human sources come from landfills, livestock farming, as well as the production, transportation and use of fossil fuels. Human-related sources create the majority of methane emissions, accounting for 64% of the total.Since the Industrial Revolution, human sources of methane emissions have been growing.

3.2.3.1 Human Sources

Human activities such as fossil fuel production and intensive livestock farming are the primary cause of the increased methane concentrations in the atmosphere. Together these two sources are responsible for 60% of all human methane emissions. Other sources include landfills and waste (16%), biomass burning (11%), rice agriculture (9%) as well as biofuels (4%).

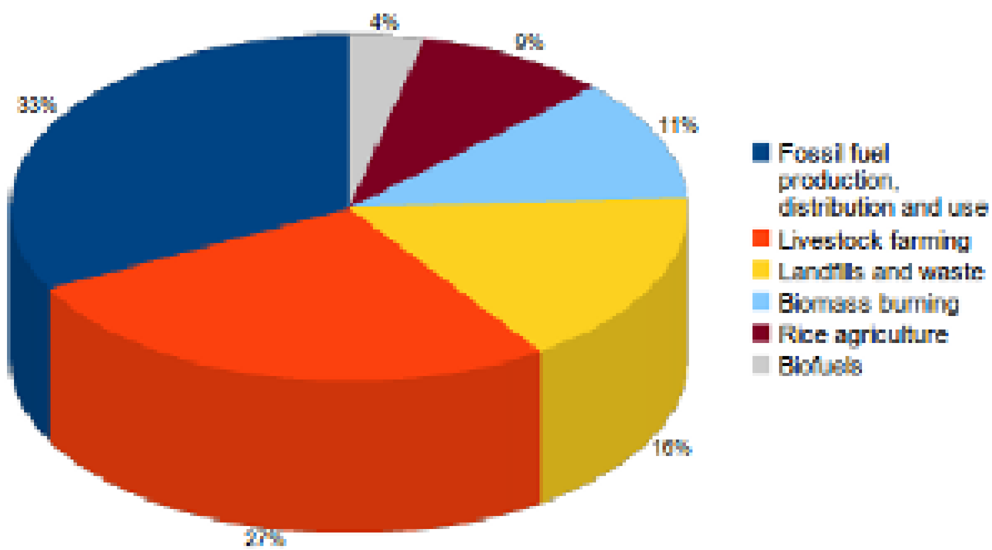


Figure 3-4: **Human sources of methane.**

3.2.3.1.1 Fossil Fuel Combustion/Use

The largest human source of methane emissions is from the production, distribution and combustion of fossil fuels. This is responsible for 33% of human methane emissions.

Methane emissions are produced wherever there are fossil fuels. It is released whenever fossil fuels are extracted from the earth whether it is natural gas (which is mostly methane), coal or petroleum. There are additional methane emissions that are created during any type of handling, transportation (pipeline, truck delivery, etc.) or refinement of fossil fuels. Finally some methane is also produced during fossil fuel combustion.

3.2.3.1.2 Livestock Farming

An important source of methane emissions is from enteric fermentation in farm animals. This is responsible for 27% of human methane emissions. Animals like cows, sheep and goats are examples of ruminant animals and during their normal digestion process they create large amounts of methane. Enteric fermentation occurs because of microorganisms in the stomach of these animals, which creates methane as a by-product that is either exhaled by the animal or released via flatus. Because humans raise these animals for food, their emissions are considered human-related. The meat that we eat everyday contributes significantly to total methane emissions because of this. Livestock farming creates 90 million tonnes of methane annually.

3.2.3.1.3 Landfills and Waste

Another important human source of methane emissions is from landfills and waste. Methane is generated by the decomposition of biodegradable solid waste in landfills as well as animal and human waste streams. This accounts for 16% of human methane emissions. Landfills and waste produces 55 million tonnes of methane annually.

Landfills and open garbage dumps are full of organic matter from our garbage (things like food scraps, newspapers, cut grass and leaves). Every time new garbage comes in it is pilled over the old garbage that was already there. The organic matter in our garbage gets trapped in anaerobic conditions where there is no oxygen. This provides excellent conditions for methane producing microbes to break down the waste, which produces large amounts of methane emissions. Even after a landfill is closed, the bacteria will continue to decompose the buried waste and emit methane for years.

Wastewater from domestic, municipal and industrial sources can also produce methane emissions. Wastewater can be released, stored or sent for treatment to remove contaminants. As with landfills, if at any of these steps the decay of organic material in wastewater happens in an anaerobic environment then this will create methane.

3.2.3.1.4 Biomass Burning

Biomass burning causes a substantial amount of methane emissions. Biomass is material from living or dead organic matter. Incomplete burning of biomass creates methane emissions and huge amounts can be produced during large scale burning. This is responsible for 11% of human methane emissions.

Large open fires are mainly used by humans to destroy crop waste and clear land for agricultural or other uses. While natural wildfires can contribute to this, the great majority of biomass burning is caused by human beings. Biomass burning creates 38 million tonnes of methane annually.

3.2.3.1.5 Rice Agriculture

Another substantial human source of methane emissions is from rice agriculture. Paddy fields for rice production are essentially man-made wetlands. They are characterized by high moisture content, oxygen depletion and ample organic material. This creates a great environment for methane producing microbes that decompose the organic matter.

Though some of the methane produced is absorbed by methane-consuming microorganisms, the vast majority is released into the atmosphere. Due to the swamp-like environment of rice fields, this crop is responsible for 9% of human methane emissions. Rice agriculture creates 31 million tonnes of methane annually.

3.2.3.1.6 Bio Fuels

Annually 12 million tonnes of methane are produced by biofuels making it a significant source. Biomass that is used to produce energy for domestic, industrial or transportation purposes are called biofuels. Incomplete biofuel combustion leads to the production of methane. This is responsible for 4% of human methane emissions.

An estimated 80% of biofuels are used for domestic cooking, heating, and lighting mostly in open cooking fires burning wood, agricultural waste, or animal dung. This is the single largest contributor to global biofuel emissions. Almost half of the world's population, about 2.7 billion people, uses solid biofuels to cook and heat their homes on a daily basis. Most are poor, and live in developing countries.18% of biofuels are used by low-technology, largely unregulated, micro-enterprises such as brick or tile making kilns, restaurants, etc. The balance of the biofuels is consumed for transportation uses.

3.2.3.2 Natural Sources

Apart from being created by human activities, methane is also released into the atmosphere by natural processes. Wetlands, termites and the oceans are all natural sources of methane emissions. The amount of methane produced by natural sources is completely offset by natural methane sinks and has been for thousands of years. Before the influence of humans, methane levels were quite steady because of this natural balance. Today, human-related sources create the majority of total methane emissions which has upset the natural balance that existed before the Industrial Revolution. Wetlands are an important source of methane, accounting for 78% of all naturally produced emissions. Other natural methane sources include termites (12%) and the oceans (10%).

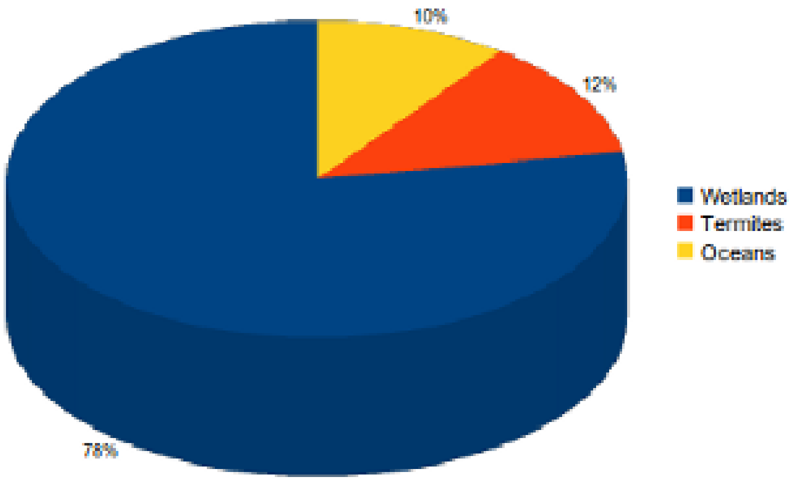


Figure 3-5: **Natural sources of methane.**

3.2.3.2.1 Wetlands

Wetlands are the largest natural source of methane. This produces 78% of natural methane emissions. The water-logged conditions of wetlands are perfect for microbes who require environments with no oxygen and abundant organic matter.

While part of wetland related emissions is absorbed by methane-consuming microbes, a large percentage escapes into the atmosphere. Wetlands create 147 million tonnes of methane each year.

3.2.3.2.2 Termites

Termites are a significant natural source of methane. During the normal digestion process of a termite, methane is produced. Termites eat cellulose but rely on micro-organisms in their gut to digest it which produces methane during the process. This is responsible for 12% of natural methane emissions.

Each termite produces very small amounts of methane on a daily basis. However, when this is multiplied by the world population of termites, their emissions add up to 23 million tonnes of methane annually.

3.2.3.2.3 Oceans

Another significant natural source of methane comes from the oceans. Methane producing microbes living in the ocean create these emissions. This creates 10% of natural methane emissions. Globally, oceans create 19 million tonnes of methane annually.

The majority of oceanic methane emissions gets produced in deeper sediment layers of productive coastal areas. This accounts for 75% of the oceans methane emissions. The methane created by these microbes mixes with the surrounding water and is emitted to the atmosphere from the ocean surface [23].

3.2.4 Hydrogen Sulfide (H_2S)

Hydrogen sulfide occurs both naturally and from industrial processes. Natural sources include crude oil, natural gas, salt marshes, sulfur springs, and swamps. For instance, some natural gas deposits contain up to 42% hydrogen sulfide. Industrial sources include manure handling operations, oil refineries, pulp and paper mills, tanneries, wastewater treatment plants, and solid waste landfills [24]. Also in industry, hydrogen sulfide can be formed whenever elemental sulfur or sulfur-containing compounds come into contact with organic materials at high temperatures. Hydrogen sulfide is formed, for instance, during coke production, in viscose rayon production, in waste-water treatment plants, in wood pulp production using the sulfate method, in sulfur extraction processes, in oil refining and in the tanning industry [25]. In the home, exposure may occur because of faulty plumbing. Sewer drains that have dry traps can allow hydrogen sulfide gas to enter the home. Workers involved in occupations such as livestock farming, sewage treatment and oil refining may be exposed to hydrogen sulfide gas at work. People living in the neighborhood of these types of industry can also be exposed to these gases via breathing [26].

3.3 Effects of Gases

3.3.1 Carbon-dioxide

The health effects of carbon-dioxide gas at different ppm is given below: [27-29]

Table 3-1: Effects and Symptoms of carbon-dioxide at different concentrations

CO_2 Concentration	Effects and Symptoms
400 ppm	Normal outdoor fresh air
400-1000 ppm (0.04-0.1%)	Typical level found in occupied spaces with good air exchange.
1000-2000 ppm (0.1-0.2%)	Over ventilation
2000-5000 ppm (0.2-0.5%)	Shortness of breath and increased heartbeat frequency
5000 ppm (0.5%)	Hygienic limit value
15,000-50,000 ppm (1.5-5%)	Headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present
75,000 ppm (7.5%)	Headaches, dizziness, restlessness, breathlessness, increased heart rate and blood pressure, visual distortion
100,000 ppm (10%)	Impaired hearing, nausea, vomiting, loss of Consciousness
300,000 ppm (30%)	Coma, convulsions, death

3.3.2 Carbon-monoxide

Health effects of carbon-monoxide at different concentrations for 1 hour exposure are given below: [30]

Table 3-2: Harmful effects of carbon-monoxide at different ppm

CO Concentration	Harmful effects
0-9 ppm	No health risk; normal CO levels in air.
10-29 ppm	Problems over long-term exposure; chronic CO problems such as headaches, nausea- not the most dangerous level
30-35 ppm	Flu-like symptoms begin to develop, especially among the young and the elderly
36-99 ppm	Flu-like symptoms among all; nausea, headaches, fatigue or drowsiness, vomiting.
100 ppm+	Severe symptoms; confusion, intense headaches; ultimately brain damage, coma, and/or death, especially at 300 to 400 ppm+

Carbon-monoxide is also dangerous because it inhibits the blood's ability to carry oxygen to vital organs such as the heart and brain. Inhaled *CO* combines with the oxygen carrying hemoglobin of the blood and forms carboxyhemoglobin (*COHb*) which is unusable for transporting oxygen [31]. Below is the Percentage of carboxyhemoglobin along with carbon-monoxide concentration.

Table 3-3: Percentage of carboxyhemoglobin along with carbonmonoxide concentration

CO in atmosphere (ppm)	COHb in Blood (%)
10	2
70	10
120	20
220	30
350-520	40-50
800-1220	60-70
1950	80

Note:**From Carbon-monoxide (CO)** Michigan Department of Licensing and Regulatory AffairsMichigan Occupational Safety & Health Administration Consultation Education & Training Division

Symptoms associated with a Given Concentration of COHb are given below: [32]

- **10% COHb** - No symptoms. Heavy smokers can have as much as 9% COHb.
- **15% COHb** - Mild headache.
- **25% COHb** - Nausea and serious headache. Fairly quick recovery after treatment with oxygen and/or fresh air.
- **30% COHb** - Symptoms intensify. Potential for long term effects especially in the case of infants, children, the elderly, victims of heart disease and pregnant women.
- **45% COHb** - Unconsciousness
- **50+% COHb** – Death

3.3.3 Methane

The adverse effects of methane are as follows:

- Toxic by inhalation and skin exposure
- Chemicals classification: extremely flammable

- Inhalation causes agitation, slurred speech, nausea, vomiting, facial flushing and headache. In severe cases breathing and heart complications, coma and death may occur
- Methane in its gas form is an asphyxiant, which in high concentrations may displace the oxygen supply you need for breathing, especially in confined spaces such as lungs. Decreased oxygen can cause suffocation and loss of consciousness [33].

3.3.4 Hydrogen Sulfide

The first sign of exposure to hydrogen sulfide is usually a rotten egg smell. However, the rotten egg smell usually occurs when the chemical is at a low level. At higher, more harmful levels, there is no odor. Breathing very high levels of hydrogen sulfide can be fatal. The symptoms depend upon the concentration of the gas. At the lowest concentrations, the effects are chiefly on the eyes; that is, conjunctivitis, swollen eyelids, itchiness, smarting, pain, photophobia, and blurring of vision. At higher concentrations, respiratory tract symptoms are more pronounced. Rhinitis, pharyngitis, laryngitis, and bronchitis may occur. Pulmonary edema may result. At very high concentrations, unconsciousness, convulsions, and cessation of respiration rapidly develop [34].

Table 3-4: Effects of hydrogen sulfide at different concentrations

Concentration (ppm)	Symptoms/Effects
0.00011-0.00033	Typical background concentrations
0.01-1.5	Odor threshold (when rotten egg smell is first noticeable to some). Odor becomes more offensive at 3-5 ppm. Above 30 ppm, odor described as sweet or sickeningly sweet.
2-5	Prolonged exposure may cause nausea, tearing of the eyes, headaches or loss of sleep. Airway problems (bronchial constriction) in some asthma patients.
20	Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness.
50-100	Slight conjunctivitis ("gas eye") and respiratory tract irritation after 1 hour. May cause digestive upset and loss of appetite.
100	Coughing, eye irritation, loss of smell after 2-15 minutes (olfactory fatigue). Altered breathing, drowsiness after 15-30 minutes. Throat irritation after 1 hour. Gradual increase in severity of symptoms over several hours. Death may occur after 48 hours.
100-150	Loss of smell (olfactory fatigue or paralysis).
200-300	Marked conjunctivitis and respiratory tract irritation after 1 hour. Pulmonary edema may occur from prolonged exposure.
500-700	Staggering, collapse in 5 minutes. Serious damage to the eyes in 30 minutes. Death after 30-60 minutes.
700-1000	Rapid unconsciousness, "knockdown" or immediate collapse within 1 to 2 breaths, breathing stops, death within minutes.

*Note:*From Health hazards https://www.osha.gov/SLTC/hydrogensulfide/hazards.html

3.4 Summary

To summarize this chapter, it has enumerated all the natural and human sources of the four highly dangerous gases inside a building and their effects on human beings.

Chapter: 4

WORK DONE

4.1 Introduction

This chapter comprises of the methodology followed in development of the Smart Nose. It starts with design and development of electronic nose and GSM management and monitoring and then interfacing the two systems and calibrating the sensors to specific thresholds.

4.2 Methodology

Project is divided into following segments

- Design of electronic nose to detect gases at threshold level along with alarm system. Following table shows the range of detection of sensors selected for detection of the four gases taken from respective sensor datasheets.

Table 4-1: Detection range of gas sensors

Gas	Sensor	Detection range
Carbon-dioxide	MG-811	350—10000ppm
Carbon-monoxide	Mq-7	20-2000ppm
Methane	Mq-4	300-10000ppm
Hydrogen sulfide	Mq 136	1-100ppm

The gases should be detected before their level becomes dangerous. Following table shows threshold limit of each gas.

Table 4-2: Threshold limit of gases

Gas	TLV-TWA	TLV-STEL
Carbon-dioxide	5000ppm	15,000ppm
Carbon-monoxide	25ppm	100ppm
Methane	1000ppm	5000ppm
Hydrogen Sulfide	-	10ppm

We will calibrate the gases at TLV-TWA limit of the gases and for hydrogen sulfide as there is no TLV-TWA limit so we will calibrate the Mq-136 sensor at 6ppm.The Smart Nose will detect the gases at following concentration.

Table 4-3: Detection concentration of gases

Gas	Detection Concentration (ppm)
Carbon-dioxide	5000
Carbon-monoxide	25
Methane	1000
Hydrogen sulfide	6

Thus, these gases are detected before their level becomes dangerous. The electronic nose will generate alarm to alert the user when the gas will be detected as it reaches the threshold level. The alarm system will have a buzzer and LED's of Green and Red color to show output of system along with character LCD for displaying the name of gas detected.

i. When no gas is detected.
   1. Green LED lights on.
   2. Buzzer is at off state.
   3. Red LED lights off.

ii. When gas is detected.
   1. Green LED lights off.
   2. Buzzer operates.
   3. Red LED lights on.

- Interfacing of electronic nose to GSM. A text message containing the notification about the gas detected will be sent to the user and user will be asked to take safety measures and actions.
- Designing of device management and monitoring system.

- Interfacing of device management and monitoring system to GSM. This allows the user to turn safety providing devices like exhaust fans etc on using a text message from anywhere in the world. If the user takes action manually then in this case the user at the mobile end can send a pre-defined text message to know the status of the devices at the residence and can turn any device on or off according to his will. If the user is unable to take action either via cell phone or manually then the safety providing devices will be automatically turned on
- Interfacing of the above two systems (i.e. electronic nose interfaced to GSM and device management and monitoring system interfaced to GSM) to each other.

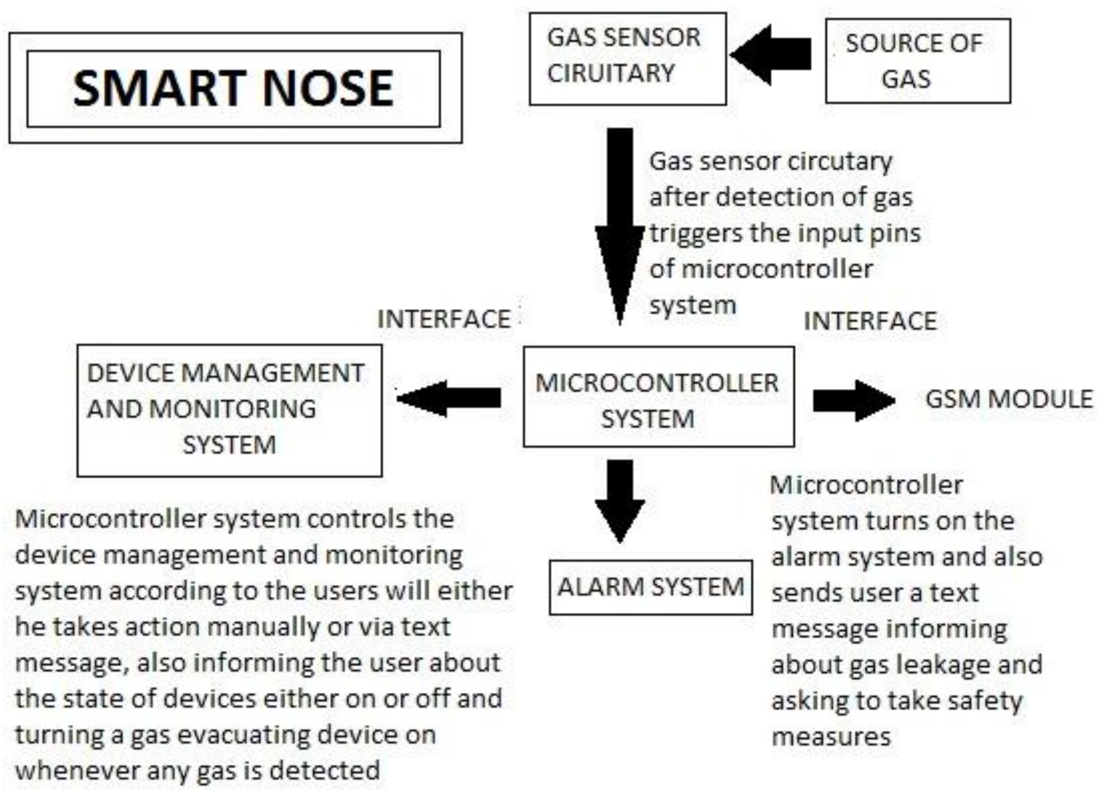


Figure 4-1: **Model schematic of Smart Nose**

4.3 Circuit Design

4.3.1 Power supply circuit for Electronic Nose

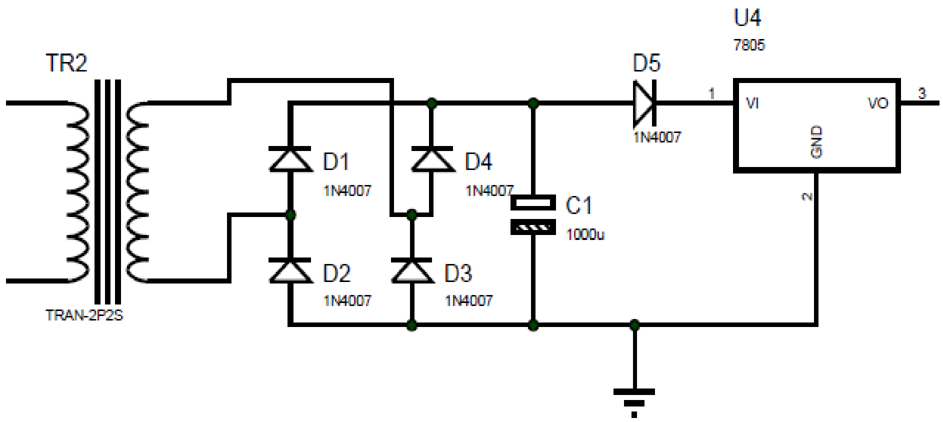


Figure 4-2: **Power supply circuit for electronic nose**

Power supply circuit converts 220V AC TO 5V DC. It contains a step down transformer which converts 220V AC to 12V AC. Ahead of it is the bridge rectifier circuit which converts 12V AC to 12 V DC. The capacitor removes the ripples from the DC output voltage. This is then supplied to LM 7805 which gives 5V fixed output voltage. The diode before the LM7805 IC is to stop back voltage in the circuit.

4.3.2 Microcontroller circuitry

4.3.2.1 Electronic Nose

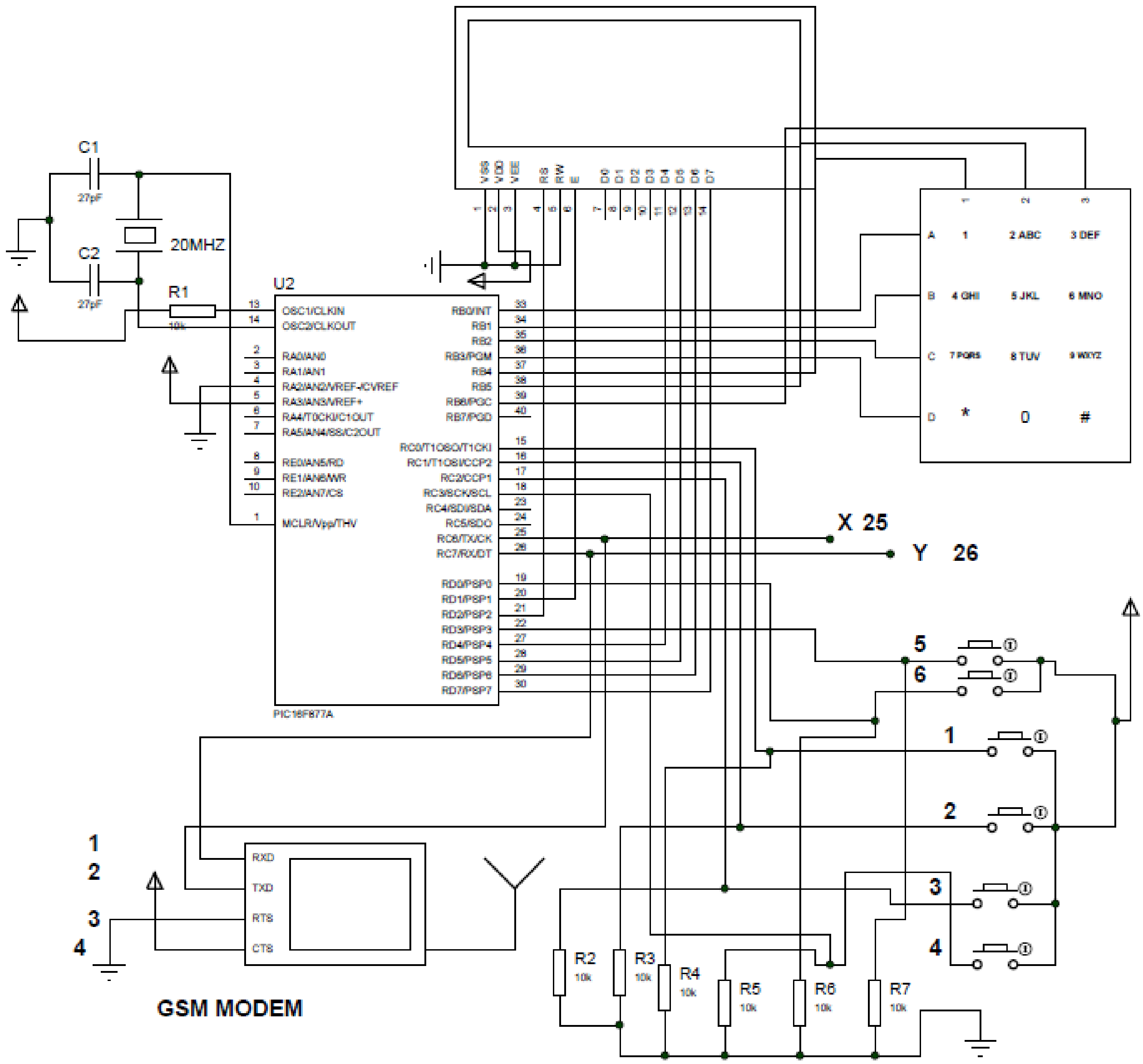


***Figure 4-3*: Microcontroller Circuit for Electronic Nose**

The microcontroller is getting 4 inputs from the sensors connected at pin 15-18. The microcontroller is pre-programmed to display the message for each gas according to the pin which is triggered by the sensor and also to generate the text message according to it. The pins are internally programmed to get trigered when it receives low voltage (negative voltage), which occurs only when gas is detected. Pullup resistors are used to provide these pins continuous high voltage.

At pin 19 the battery backup system is connected and this pin is pre-programmed to send the user a text meassage if the battery goes low. Pin 22 is pre-programmed to send the user a text measssage asking him or her to check the balance of Smart Nose when ever trigered.

Pins 25 and 26 are the serial ports of the microcontroller attached to the GSM modem. Pin 25 is connected to the transmission pin of GSM modem while pin 26 is connected to the receiving pin of GSM modem. A keypad is connected from pin 33 to 39 this allows the user to enter the number to which the messages will be sent. The LCD screen is connected to pins 20,21,27-30 for displaying which gas is detected for user at residence.

4.3.2.2 Device management and monitoring system

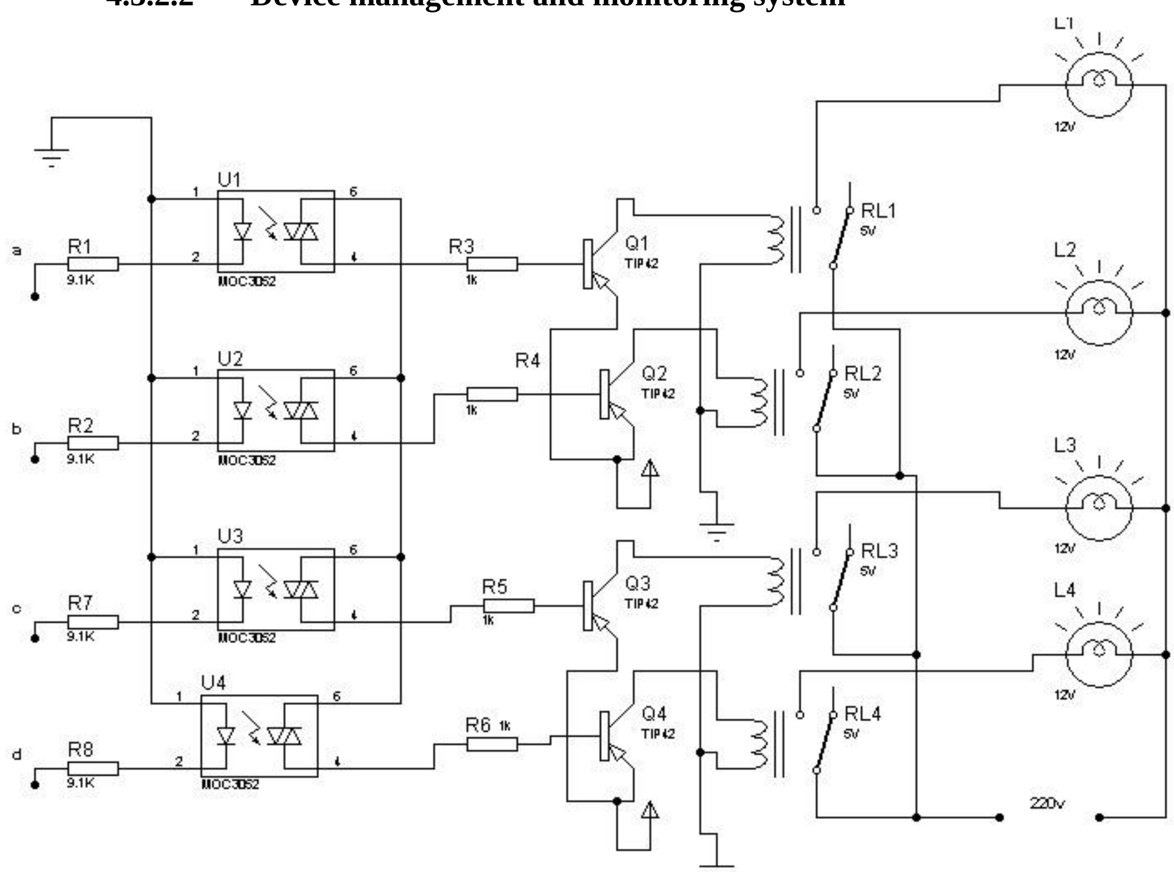


Figure 4-4: **Circuit for device management and monitoring system**

The device mangement circuit is connected to the pins of microcontroller which provides 5V to the optocoupler PC 817 when turned on via pre defined text message. This provides 0.7 V to thePNP transistor 2SA1015. This transistor provides 12V to the relay to switch the relay to provide 220V to the device. When any device is turned on or off manually its state is saved by the microcontroller and text message is sent to the user informing about state of devices after receiving the pre determined message.

4.3.3 Calibration Circuit for MQ-4, MQ-7, MG-811 and MQ-136 Gas sensors

The calibration circuit for MQ-4, MQ-7, MG-811and MQ-136 is given below

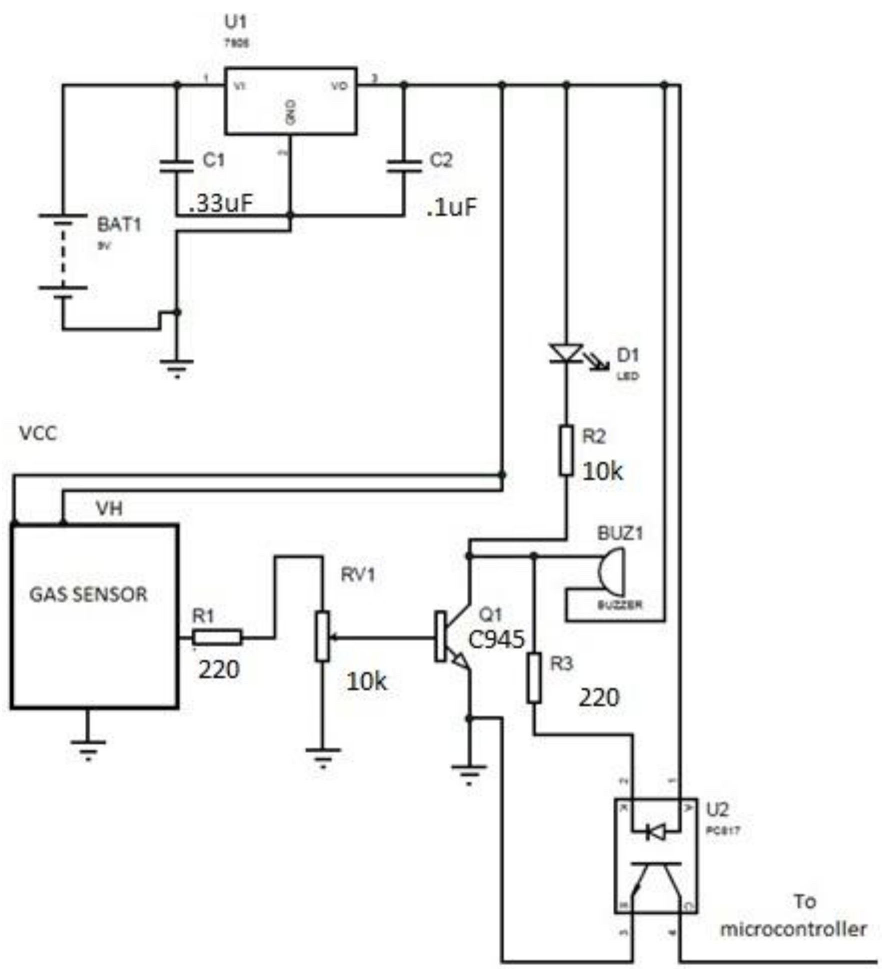


Figure 4-5: **Calibration circuit for MQ-4, MQ-7, MG-811 and MQ-136 Gas sensor**

The circuit is being supplied 5V from the power supply circuit of Electronic Nose described above. The 5V is given to the sensors at 2 pins at one it provides VCC to drive the circuit whereas V_H is the heating voltage which is used to supply certified working temperature to the sensor. The variable resistor in combination with the fixed resistor in the circuit is for tuning the circuit to detect the gases at required ppm concentration. The output at end of the variable resistor is then fed to a NPN transistor C945. When the base of transistor receives enough current then the current flows through the LED, buzzer and the optocoupler as the transistor is forward biased. The LED and the buzzer are kept as an indication at the current moment to know when the gas is detected. The optocoupler then transfers negative potential to input pins of the microcontroller to drive the circuit.

4.4 GSM monitoring through use of AT Commands

AT commands are used to control MODEMs. AT is the abbreviation for Attention. These commands come from Hayes commands that were used by the Hayes smart modems. The Hayes commands started with AT to indicate the attention from the MODEM. The dial up and wireless MODEMs (devices that involve machine to machine communication) need AT commands to interact with a computer. These include the Hayes command set as a subset, along with other extended AT commands.AT commands with a GSM/GPRS MODEM or mobile phone can be used to access following information and services:

- Information and configuration pertaining to mobile device or MODEM and SIM card.
- SMS services.
- MMS services.
- Fax services.
- Data and Voice link over mobile network.

The Hayes subset commands are called the basic commands and the commands specific to a GSM network are called extended AT commands.

4.4.1 AT-Command set overview

Command	Description
AT	Check if serial interface and GSM modem is working.
ATE0	Turn echo off, less traffic on serial line.
AT+CNMI	Display of new incoming SMS.
AT+CPMS	Selection of SMS memory.
AT+CMGF	SMS string format, how they are compressed.
AT+CMGR	Read new message from a given memory location.
AT+CMGS	Send message to a given recipient.
AT+CMGD	Delete message.

4.4.2 Sending SMS through AT Commands:

One way to send AT commands to a mobile phone or GSM/GPRS modem is to use a terminal program. A terminal program's function is like this: It sends the characters you typed to the mobile phone or GSM/GPRS modem. It then displays the response it receives from the mobile phone or GSM/GPRS modem on the screen. The terminal program on Microsoft Windows is called HyperTerminal. Below shows a simple example that demonstrates how to use AT commands and the HyperTerminal program of Microsoft Windows to send an SMS text message. Below are mentioned the commands for sending a text message using HyperTerminal.

```
AT
OK

AT+CMGF=1
OK

AT+CMGW="+923335485578"
> A simple demo of SMS text messaging.

+CMGW: 1
OK

AT+CMSS=1
+CMSS: 20

OK
```

A brief description of each command is given in figure 4-6.

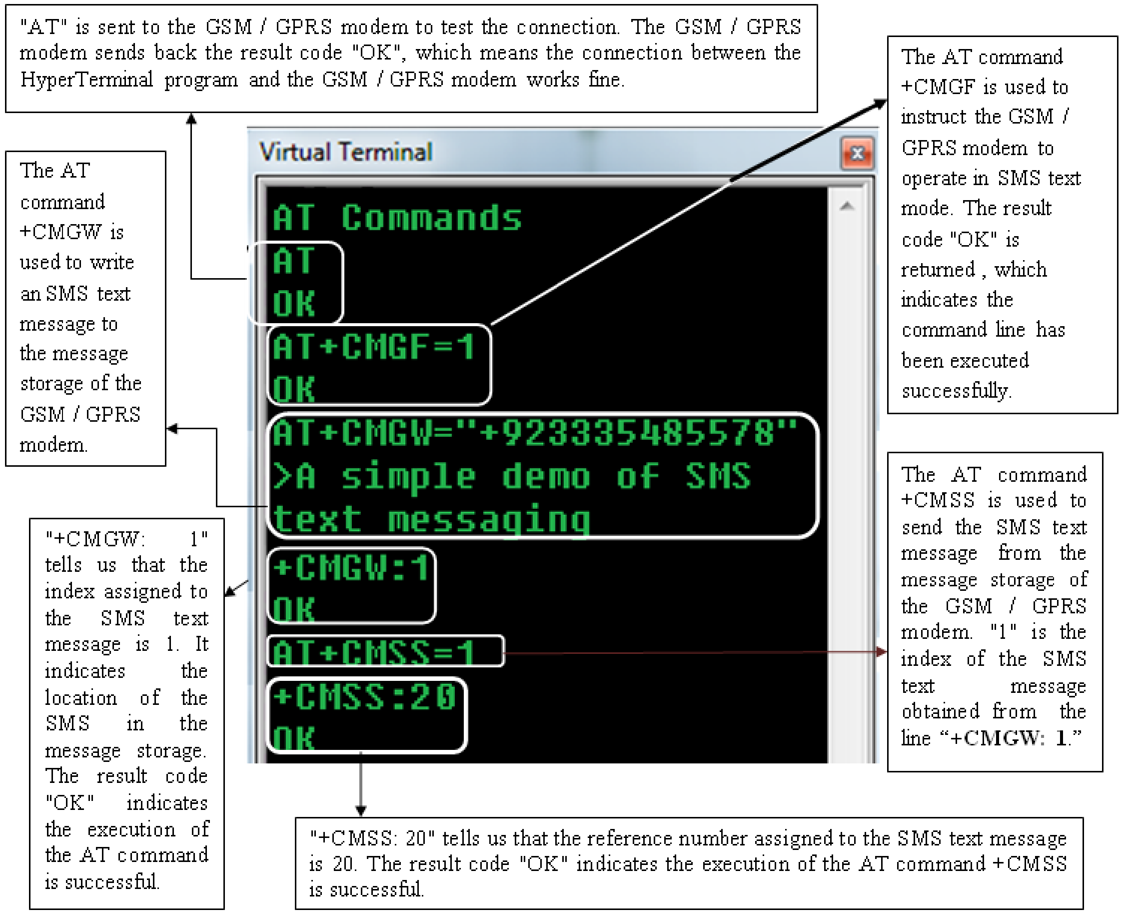


Figure 4-6. **A simple example of sending SMS via hyper terminal**

4.5 Calibration for the gas sensors

Gas sensors need to be calibrated to ensure sensor accuracy and system integrity. Calibration here is simply a safety check, unlike laboratory analyzers that require a high degree of accuracy. For area air quality and safety gas monitors, the requirements need to be simple, repeatable, and economical. Calibration of the gas sensor involves two steps. First the "zero" must be set and then the "span" must be calibrated.

4.5.1 Setting the "zero" reading

A good reference point can be in the area where air is always considered clean. This will give a more realistic representation of the zero point because it will be representative of the local ambient air condition. The lack of water vapor can cause the zero point setting to read lower than in ambient air making the sensor zero appear to drift. This is most noticeable in solid-state sensors and PIDs.

4.5.1.1 Calibration Methods

Taking all factors such as the type of sensor and the conditions of the application into consideration, the following are some proposed methods of calibration:

- In applications where the ambient air is normally clean, and, based on the operator's judgment that no abnormal condition exists and the instrument is indicating a close to zero reading, the procedure to zero the sensor can be skipped. When in doubt, use a plastic bag to get a sample of what is considered to be "clean air" in the facility and expose it to the sensor for a few minutes. This is a very quick and easy procedure. It is also a very effective way to differentiate a real alarm from a false alarm.
- Compressed air has the advantage that it is easy to regulate and can be carried around in a bottle. Also, in many facilities, shop air is available throughout the plant, making it very accessible and convenient. However, most shop air contains small concentrations of hydrocarbons, carbon-monoxide, carbon-dioxide, and possibly other interference gases. Also, the air is typically very low in humidity. A solution to this is that the air can be filtered through activated charcoal to remove most of the unwanted gases and water vapor can be added into the air using a humidifier in the sampling system. After this conditioning, the air can be used to calibrate most types of sensors. However, it is important to note that carbon-monoxide is *not* removed by charcoal filters. It is therefore imperative to make sure that the CO concentration in the shop air is the same as in the ambient air. Furthermore, a soda ash filter should be used to remove carbon-dioxide. This is also a very good way to zero carbon-dioxide sensors since placing a soda ash filter in-line with the sampling system will remove all carbon-dioxide, thus providing an easily obtainable zero baseline.

4.5.1.2 Span Calibration

The span calibration can be quite easy or it can be very complicated and expensive, depending on the gas type and concentration range. In principle, to achieve the best accuracy, *a mixture of the target gas balanced in the background environmental air is the best calibration gas.* In practice, most calibration gases are purchased from commercial suppliers. The following section describes a few methods of span calibration.

4.5.1.2.1 Premixed Calibration Gas

This is the preferred and most popular way to calibrate gas sensors. Premixed gas mixtures are compressed and stored under pressure in a gas bottle. The bottles are available in many sizes but most field calibrators employ smaller, lightweight bottles. These small portable bottles come in two different categories: a low-pressure and a high-pressure version. The low-pressure bottles are thin-walled, lightweight bottles that are usually nonreturnable and disposable. High-pressure bottles are designed to bottle pure hazardous chemicals. For calibration gases, these bottles are normally made of thick-walled aluminum which has a service pressure of 2000 psi. To get this highly pressurized gas out of the bottle in order to calibrate the sensor, a regulator assembly is needed. This assembly consists of a pressure regulator, a pressure gauge, and an orifice flow restrictor. The orifice flow restrictor is a fitting with a hairline hole that allows a constant air flow at a given pressure difference. In operation, the high pressure from the bottle is reduced to a lower pressure of only a few psi, which provides a constant air flow through the orifice. Flow rates between 600-1000 cc/min are most common. Models can be fitted with an adjustable pressure regulator so that the flow rate can be adjusted accordingly. Figure 4-7 illustrates typical models of high- and low-pressure bottle assembly.

Low-Pressure Assembly

High-Pressure Assembly

***Figure 4-7*: Calibration Gas Bottles**

Many gases can be premixed with air and stored under pressure, but some gases can only be mixed in inert gas backgrounds, such as nitrogen. Some mixtures can only be stored in bottles that are specially treated or conditioned.Each type of mixture will have a different amount of time before it expires or before it can no longer be used. Generally, high vapor pressure gases with low reactivity, such as methane, carbon-monoxide and carbon-dioxide, can be mixed with air and stored under high pressure. Low vapor pressure gases, such as liquid hydrocarbon solvents, can only be mixed with air and stored under low pressure. Most highly reactive chemicals are mixed with a nitrogen background. With certain sensors, such as solid-state sensors, whether the mixture of the gas is in the air or in the nitrogen background will dramatically affect the sensor reading.

To estimate the volume of a pressurized gas in a cylinder, take the total pressure (P) divided by the atmospheric pressure (Pa) and multiply this ratio by the volume of the cylinder:

$$V_{mix} = V \cdot (P/P_a)$$

where

V_{mix} = the volume of the gas mixture

V = the volume of the cylinder

P = the pressure in the cylinder

P_a = the atmospheric pressure

4.5.1.2.2 Permeation Devices

A *permeation device* is a sealed container that contains chemicals in liquid and vapor phase equilibrium. The gas molecules are either permeated through the permeable container wall or through the end cap. The rate in which the gas molecules permeate depends on the permeability of the material and temperature. The rate of permeation is constant over long periods of time. At a known rate of permeation at a given temperature, a constant flow rate of air mixed with the permeated chemicals forms a constant stream of calibration gas. A calibrator with constant temperature and flow regulation is needed. However, the permeation tube continuously emits chemicals at a constant rate thus creating a storage and safety problem. Also, the rate of permeation for a given gas of interest can be too high or too low for a given application. For example, high vapor pressure gases permeate too quickly while very low vapor pressure chemicals have a permeation rate that is too low to be of any use.

Permeation devices have been found to be of limited use.

4.5.1.2.3 Cross Calibration

Cross calibration takes advantage of the fact that every sensor is subject to interference by other gases. For example, for a sensor calibrated to 100% LEL hexane, it is usually much easier to use 50% LEL *methane* gas to calibrate the sensor instead of using an actual hexane mixture. This is because hexane is a liquid at room temperature and it has a low vapor pressure. Therefore, it is more difficult to make an accurate mixture and to keep it under high pressure.

On the other hand, methane has a very high vapor pressure and is very stable. Furthermore, it can be mixed with air and still be kept under high pressure. It can be used for many more calibrations than a hexane mixture in the same size bottle and it has a long shelf life. A 50% LEL methane mixture is also readily available. Therefore, it is common practice for manufacturers of combustible gas instruments to recommend the use of methane as a substitute to calibrate for other gases.

Many low-range toxic gas sensors can be calibrated using cross gas calibration. Also, with infrared instruments, any gas within the same wavelength of absorption can be used for cross calibration. The advantage of cross calibration is that it allows the sensor to be calibrated with a gas and range that is easier to obtain and handle.

4.5.1.2.4 Gas Mixing

Not all calibration gases are available. Even if they are available, it is very possible that they would not be available in the right concentration or in the proper background mixture. However, many mixtures are available for some process uses which can be diluted to use in calibration of gas monitors in lower concentration ranges. For example, 50% LEL methane has a concentration of 2.5% or 25,000 ppm. To make a 20% LEL mixture having a volume of 2000 cc, the following formula can be used:

$$V_b = \frac{C}{C_b} . V, \qquad V_a = \frac{C - C_b}{C} . V$$

and

$$V_a = V - V_b$$

where

Cb = concentration in the bottle, 50% in this case

C = new concentration, 20% in this case

V = total final volume, 2000 cc in this case

Vb = volume of mixture

Va = volume of air or other dilutant [35]

4.6 Working of Smart Nose

Smart nose system working can be divided into two parts,

1) Detection of gases, production of alarm and informing the user
2) Device monitoring and management

4.6.1 Detection of gases, production of alarm and informing the user

Smart nose will detect the gas and after its detection it will produce alarm to inform the user about the detection of gas. Along with alarm the green colour LED will be turned off and red colour LED will turn on. If the user is not at the residence when gas is detected then to cater for this issue smart nose will send the text message to the user. Where each sensor is separately in contact with different pins of microcontroller and upon interrupt the pulse generated will activate the function of microcontroller. The microcontroller will send AT commands with some predefined message for interrupted pin to GSM device. The GSM device upon accepting those AT commands will deliver the message to users' cell phone i.e. the number defined inside the microcontroller.

4.6.2 Device monitoring and management

4.6.2.1 Monitoring

The message is delivered to the user cell phone if any device is turned on/off manually. A GSM device attached to the microcontroller will deliver a message predefined for each pin of microcontroller to the user's cell phone far away from the device. The devices/appliances which need to be monitored are brought in contact with system first. Where each appliance is separately in contact with different pins of microcontroller and upon interrupt the pulse generated will activate the function of microcontroller. The microcontroller will send AT commands with some predefined message for interrupted pin to GSM device. The GSM device upon accepting those AT commands will deliver the message to users' cell phone i.e. the number defined inside the microcontroller.

4.6.2.2 Management

Management is the control part of FMM system. As said earlier the user can turn on/off devices from cell phone. The user will send a message i.e. predefined message to the GSM modem embedded inside FMM system, upon receiving the message it will be transferred to the microcontroller and microcontroller is programmed in such a way that it will take the action accordingly. Different appliances are connected to different pins of microcontroller via small transformers and relays. Along with this as the gas is detected a gas evacuating device (e.g. exhaust fan) will be turned on automatically.

A user interface in the form of keypad is also provided to enable the user to add delete and check the numbers to which all the text messages will be sent.

4.7 Summary

To summarize, this chapter has the detailed design and development carried out for the **completion of Smart Nose.**

Chapter: 5

COMPONENTS

5.1 Introduction

In this chapter, the components used in the hardware of Smart Nose for buildings and houses are presented and explained in detail.

5.2 Description of Components

5.2.1 Microcontroller

A micro-controller can be compared to a small standalone computer; it is a very powerful device, which is capable of executing a series of pre-programmed tasks and interacting with other hardware devices. Microcontroller contains a memory to store the program to be executed, and a number of input/output lines that can be used to interact with other devices.

***Figure 5-1*: Microcontroller IC.**

PIC 16f877A

The basic pin configuration of PIC-16f877A is shown below

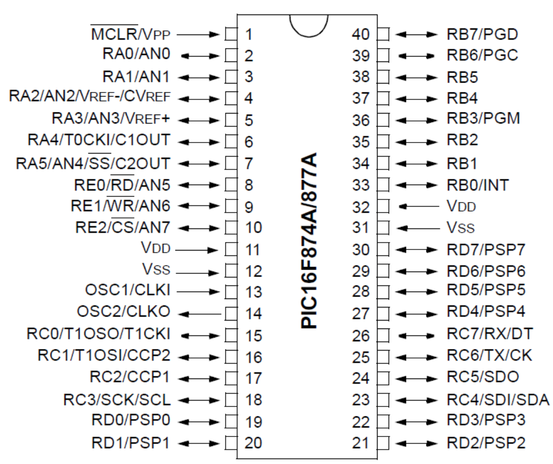


Figure 5-2: Pin configuration of PIC 16f877A

The key features of PIC16f887A are given in table below taken from data sheet

Table 5-1: Feature of PIC 16f877A

Key Features	PIC16F877A
Operating Frequency	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	8K
Data Memory (bytes)	368
EEPROM Data Memory (bytes)	256
Interrupts	15
I/O Ports	Ports A, B, C, D, E
Timers	3
Capture/Compare/PWM modules	2
Serial Communications	MSSP, USART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	8 input channels
Analog Comparators	2
Instruction Set	35 Instructions
Packages	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

5.2.2 Voltage Regulator LM7805

The L7805CV +5V positive voltage regulators can deliver over 1A ofregulated output current (subject to adequate heat sinking). Althoughdesigned primarily as fixed voltage regulators, these devices can beused with external components to obtain adjustable voltages andcurrents.

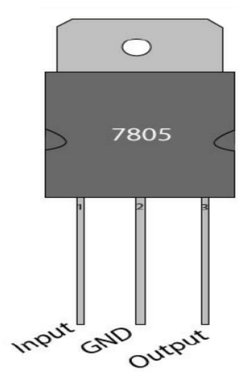


***Figure 5-3*: Voltage Regulator**

Main features of LM-7805 IC are given below taken from data sheet

- Primary Input Voltage: 10V
- Output Voltage Fixed: 5V
- Dropout Voltage V_{do}: 2V
- No. of Outputs: 1
- No. of Pins: 3
- Output Current: 500mA
- Voltage Regulator Case Style: TO-220
- Operating Temperature Range: 0°C to +150°C
- SVHC: No SVHC (19-Dec-2011)
- Base Number: 7805
- IC Generic Number: 7805
- Input Voltage Max: 35V
- Input Voltage Min: 7V
- Operating Temperature Max: 150°C
- Operating Temperature Min: 0°C
- Operating Voltage Tolerance +: 4%
- Output Current Max: 1.5A
- Output Voltage: 5V
- Output Voltage Max: 5V
- Package / Case: TO-220
- Packaging Type: Tube
- Supply Voltage Max: 20V
- Supply Voltage Min: 8V
- Termination Type: Through Hole
- Voltage: 5V
- Voltage Regulator Type: Positive Fixed

5.2.3 Stepdown transformer 220V to 12V

The circuit will be supplied 220V AC which will be down converted to 12V AC using step down transformer.

Figure 5-4: **Transformer**

5.2.4 SIM908

Designed for global market, SIM908 is integrated with a high performance GSM/GPRS engine and a GPS engine. The GSM/GPRS engine is a quad-band GSM/GPRS module that works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz.

With a tiny configuration of 30*30*3.2mm, SIM908 can meet almost all the space requirements in user applications, such as M2M,smart phone, PDA, tracker and other mobile devices.

5.2.4.1 SIM 908 functional diagram

The following figure shows a functional diagram of SIM908:

- The GSM baseband engine
- The GPS engine
- Flash
- The GSM radio frequency part
- The antenna interface
- The other interfaces[36]

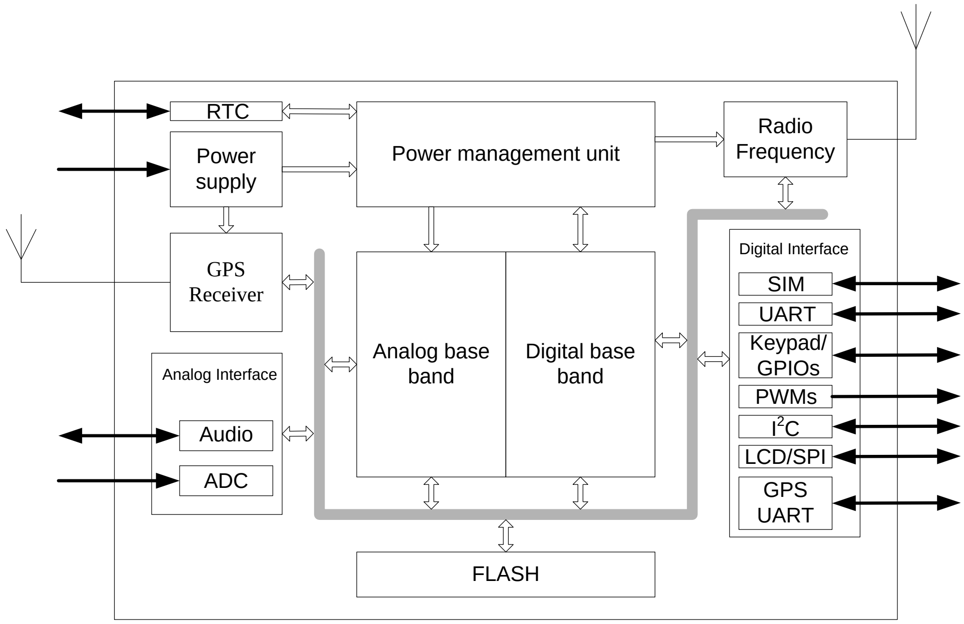


Figure 5-5: **SIM908 functional diagram**

5.2.5 Relay

The main operation of a relay comes in places where only a low-power signal can be used to control a circuit. It is also used in places where only one signal can be used to control a lot of circuits. We are using it for connecting/switching 220 volt appliances.

5.2.5.1 Internal Circuit of Relay

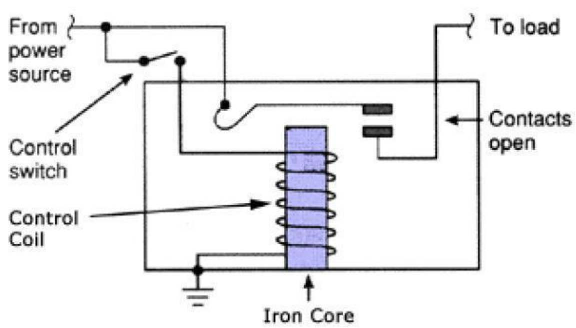


Figure 5-6: **Inside relay**

Fig 5-6 shows an inner section diagram of a relay. An iron core is surrounded by a control coil. As shown, the power source is given to the electromagnet through a control switch and through contacts to the load.

When current starts flowing through the control coil, the electromagnet starts energizing and thus intensifies the magnetic field. Thus the upper contact arm starts to be attracted to the lower fixed arm and thus closes the contacts causing a short circuit for the power to the load. On the other hand, if the relay was already de-energized when the contacts were closed, then the contact move oppositely and make an open circuit.

As soon as the coil current is off, the movable armature will be returned by a force back to its initial position. This force will be almost equal to half the strength of the magnetic force. This force is mainly provided by two factors. They are the spring and also gravity. Relays are mainly made for two basic operations. One is low voltage application and the other is high voltage. For low voltage applications, more preference will be given to reduce the noise of the whole circuit. For high voltage applications, they are mainly designed to reduce a phenomenon called arcing. [37]

5.2.6 Optocoupler PC817

An optical coupler is an electronic device which is designed to transfer electrical signals by using light waves in order to provide coupling with electrical isolation between its input and output. The main purpose of an optocoupler is to prevent rapidly changing voltages or high voltages on one side of a circuit from distorting transmissions or damaging components on the other side of the circuit. An optocoupler contains a light source often an LED which converts electrical input signal into light, a closed optical channel and a photo sensor, which detects incoming light and either modulates electric current flowing from an external power supply or generates electric energy directly [38].

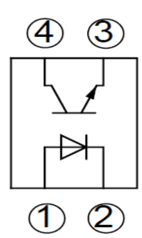


Figure 5-7: **Internal connection diagram of PC817**

5.2.7 LCD Display LM016L

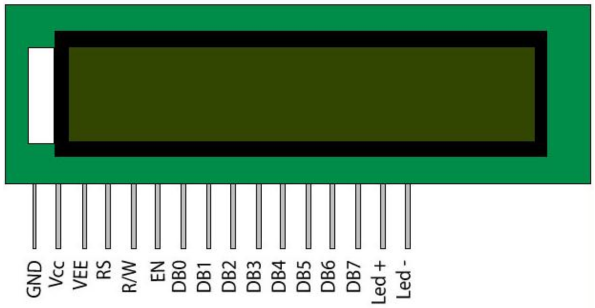


Figure 5-8: **LCD Display**

5.2.7.1 Pin Configuration and function of each pin

The table below shows the pin configuration and function of each pin of LCD display [39].

Table 5-2: Pin configuration of LM 016L

Pin no.	**Function**	**Name**
1	Ground (0V)	Ground
2	Supply voltage 5V (4.7-5.3) V	VCC
3	Contrast adjustment through a variable register	VEE
4	Selects command register when low and data register when high	Register select
5	Low to write to the register. High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	enable
7	Data pin	DB0
8	Data pin	DB1
9	Data pin	DB2
10	Data pin	DB3
11	Data pin	DB4
12	Data pin	DB5
13	Data pin	DB6
14	Data pin	DB7
15	Backlight V_{CC}(5V)	Led +
16	Backlight Ground (0V)	LED -

5.2.8 Gas Sensors

Features of the sensors used are given in table below

Table 5-3: Features of MQ-4,MQ-7,MQ-136 and MG-811 Gas Sensors

GAS SENSOR	FEATURES
MQ-4 Methane sensor	High sensitivity to CH4，Natural gas. Small sensitivity to alcohol, smoke. Fast response Stable and long life Simple drive circuit[40]
MQ-7 Carbon-monoxide sensor	High sensitivity to carbon-monoxide Stable and long life[41]
MQ-136 Hydrogen Sulfide Sensor	Good sensitivity to Long life and low cost Simple drive circuit[42]
MG-811 Carbon-dioxide Sensor	High selectivity to CO2 Compact size Low dependency on humidity Long life and low cost Low power consumption[43]

5.2.9 Keypad

A 4X4 Hex keypad is used to enter or delete the phone numbers on which the text message would be sent. The hex keypad is a peripheral that connects to the DE2 through JP1 or JP2 via a 40-pin ribbon cable. It has 16 buttons in a 4 by 4 grid, labeled with the hexadecimal digits 0 to F. An example of this can been seen in Figure 5-9, below.

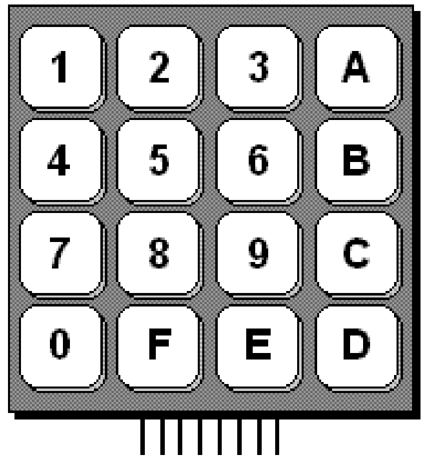


Figure 5-9: **Keypad layouts**

5.3 Summary

To summarize, this chapter contains the description of the components like microcontroller, voltage regulator, Relay, LCD, sensors and keypad.

Chapter: 6

GSM

6.1 Introduction

This chapter describes the carrier frequencies and basic functional components of GSM network structure which is used for sending and receiving messages from Smart Nose.

6.2 GSM (Global System for Mobile Communications)

GSM is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (or "2G") digital cellular networks. Developed as a replacement for first generation analog cellular networks, the GSM standard originally described a digital, circuit switched network optimized for full duplex voice telephony. In our project we use GSM modem SIM 908 for the transmission of SMS to the desired destination.

6.2.1 GSM Carrier frequencies

GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G), with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead (for example in Canada and the United States). In rare cases the 400 and450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems. Regardless of the frequency selected by an operator, it is divided into timeslots for individual phones to use. This allows eight full rate or sixteen half-rate speech channels per radio frequency. These eight radio timeslots (or eight burst periods) are grouped into a TDMA frame. Half rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833 kbit/s, and the frame duration is 4.615 ms. The transmission power in the handset is limited to a maximum of 2 watts in GSM850/900 and 1 watt in GSM1800/1900.

6.2.2 Network Structure

The GSM network architecture as defined in the GSMspecifications can be grouped into four main areas described below:

6.2.2.1 Mobile Station (MS)

Mobile stations (MS), mobile equipment (ME) are the section of a GSM cellular network that the user sees and operates. In recent years their size has fallen dramatically while the level of functionality has greatly increased. A further advantage is that the time between charges has significantly increased. There are a number of elements to the cell phone, although the two main elements are the main hardware and the SIM. The hardware itself contains the main elements of the mobile phone including the display, case, battery, and the electronics used to generate the signal, and process the data receiver and to be transmitted. It also contains a number known as the International Mobile Equipment Identity (IMEI). This is installed in the phone at manufacture and "cannot" be changed. It is accessed by the network during registration to check whether the equipment has been reported as stolen. The SIM or Subscriber Identity Module contains the information that provides the identity of the user to the network. It contains are variety of information including a number known as the International Mobile Subscriber Identity (IMSI).

6.2.2.2 Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) section of the GSM network architecture that is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

6.2.2.2.1 Base Transceiver Station (BTS)

The BTS used in a GSM network comprises the radio transmitter receivers, and their associated antennas that transmit and receive to directly communicate with the mobiles. The BTS is the defining element for each cell. The BTS communicates with the mobiles and the interface between the two is known as the Um interface with its associated protocols.

6.2.2.2.2 Base Station Controller (BSC)

The BSC forms the next stage back into the GSM network. It controls a group of BTSs, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs, allocates channels and the like. It communicates with the BTSs over what is termed the Abis interface.

6.2.2.3 Network Switching Subsystem (NSS)

The GSM network subsystem contains a variety of different elements, and is often termed the core network. It provides the main control and interfacing for the whole mobile network. The major elements within the core network include:

6.2.2.3.1 Mobile Switching Service Centre (MSC)

The main element within the core network area of the overall GSM network architecture is the Mobile switching Services Centre (MSC). The MSC acts like a normal switching node within a PSTN or ISDN, but also provides additional functionality to enable the requirements of a mobile user to be supported. These include registration, authentication, call location, inter-MSC handovers and call routing to a mobile subscriber. It also provides an interface to the PSTN so that calls can be routed from the mobile network to a phone connected to a landline. Interfaces to other MSCs are provided to enable calls to be made to mobiles on different networks.

6.2.2.3.2 Home Location Register (HLR)

This database contains all the administrative information about each subscriber along with their last known location. In this way, the GSM network is able to route calls to the relevant base station for the MS. When a user switches on their phone, the phone registers with the network and from this it is possible to determine which BTS it communicates with so that incoming calls can be routed appropriately. Even when the phone is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position. There is one HLR per network, although it may be distributed across various sub-centres to for operational reasons.

6.2.2.3.3 Visitor Location Register (VLR)

This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided. The VLR can be implemented as a separate entity, but it is commonly realized as an integral part of the MSC, rather than a separate entity. In this way access is made faster and more convenient.

6.2.2.3.4 Equipment Identity Register (EIR)

The EIR is the entity thatdecides whether given mobile equipment may be allowed onto the network. Each mobile equipment has a number known as theInternational Mobile Equipment Identity. This number, asmentioned above, is installed in the equipment and is checked bythe network during registration. Dependent upon the informationheld in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case itsproblems.

6.2.2.3.5 Authentication Centre (AuC)

The AuC is a protected databasethat contains the secret key also contained in the user's SIM card.It is used for authentication and for ciphering on the radiochannel.

6.2.2.3.6 Gateway Mobile Switching Centre (GMSC)

The GMSC is the point to which a ME terminating call is initially routed, without any knowledge of the MS's location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station Roaming Number) from the HLR based on the MSISDN (Mobile Station ISDN number, the "directory number" of a MS) and routing the call to the correct visited MSC. The "MSC" part of the term GMSC is misleading, since the gateway operation does not require any linking to an MSC. SMS Gateway (SMS-G): The SMS-G or SMS gateway is the term that is used to collectively describe the two Short Message Services Gateways defined in the GSM standards. The two gateways handle messages directed in different directions. The SMS-GMSC (Short Message Service Gateway Mobile SwitchingCentre) is for short messages being sent to an ME. The SMSIWMSC (Short Message Service Inter-Working Mobile Switching Centre) is used for short messages originated with a mobile on that network. The SMS-GMSC role is similar to that of the GMSC, whereas the SMS-IWMSC provides a fixed access point to the Short Message Service Centre.

6.2.2.4 Operation and Support Subsystem (OSS)

The OSS or operation support subsystem is an element within the overall GSM network architecture that is connected to components of the NSS and the BSC. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system. [44]

6.3 Summary

To summarize, this chapter discusses the basic GSM architecture and its functional components.

SIMULATIONS AND RESULTS

7.1 Introduction

In this chapter, the code and circuit schematic is tested on Proteus and the Simulations are shown. The project was implemented on hardware and the screenshots of results are displayed.

7.2 Proteus Simulations

The following figure shows the LCD screen of Proteus Simulation when project is turned on.

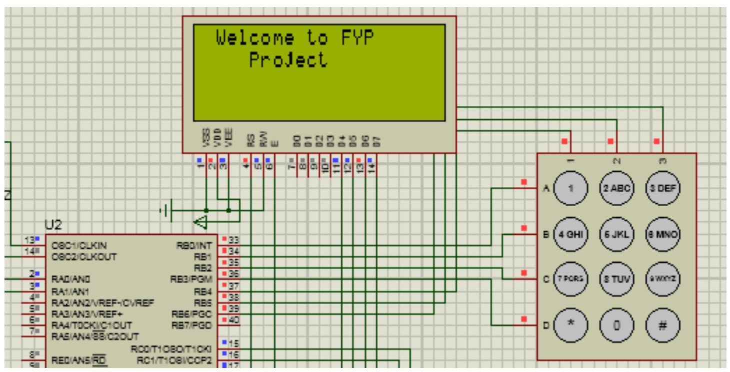


Figure 7-1: **Project turned on**

The following figure shows main menu for the user to add delete or check the numbers added along with green LED on as no gas is detected.

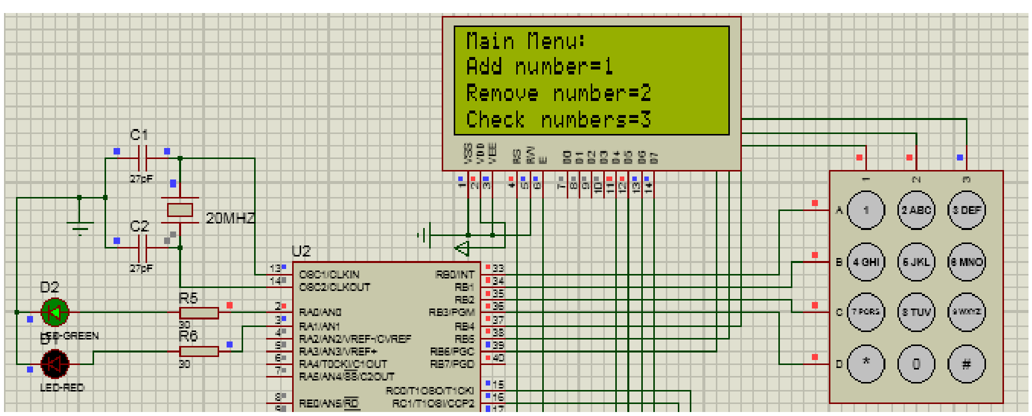


Figure 7-2: **Main menu displayed**

The following figure shows the display when first option is selected and 1 is pressed to add number.

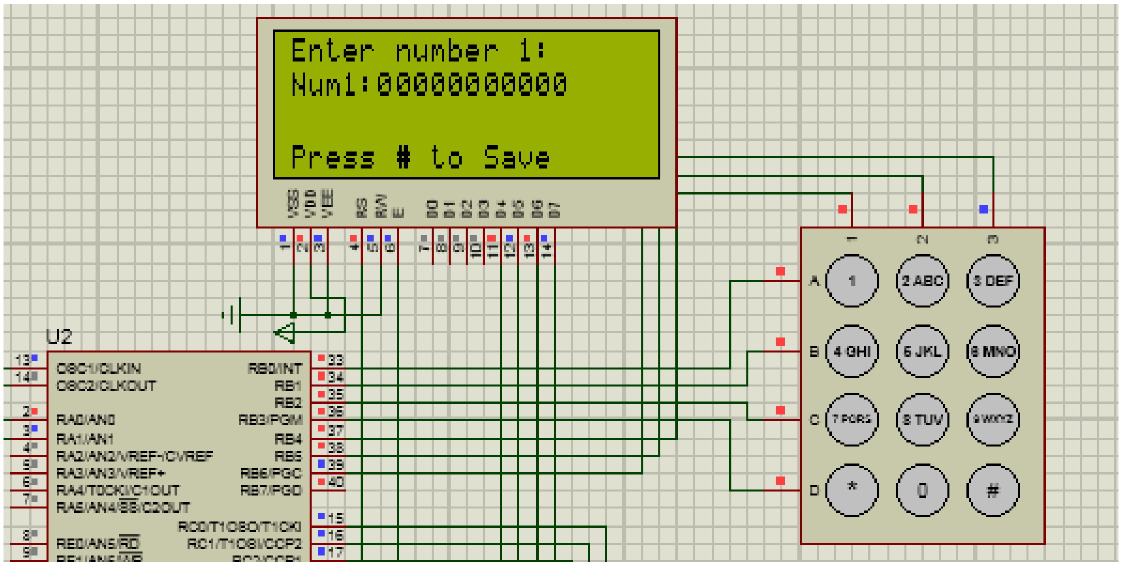
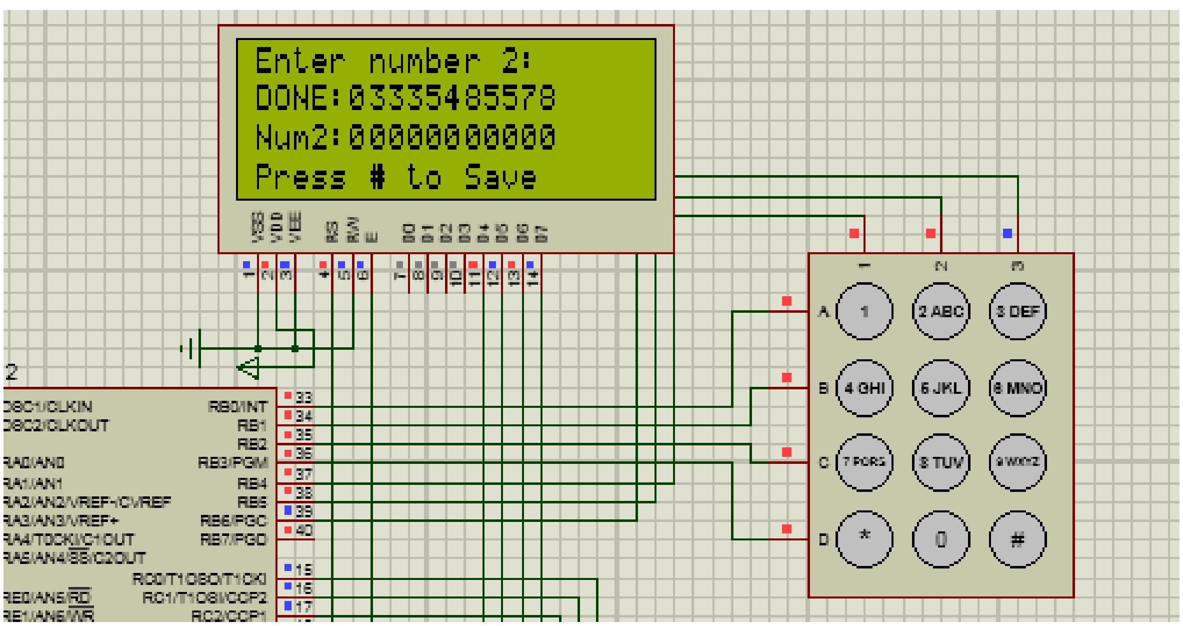


Figure 7-4: **Option 1 selected**

When # is pressed to save number



The following figure shows the display when 3 is pressed to check the numbers saved.

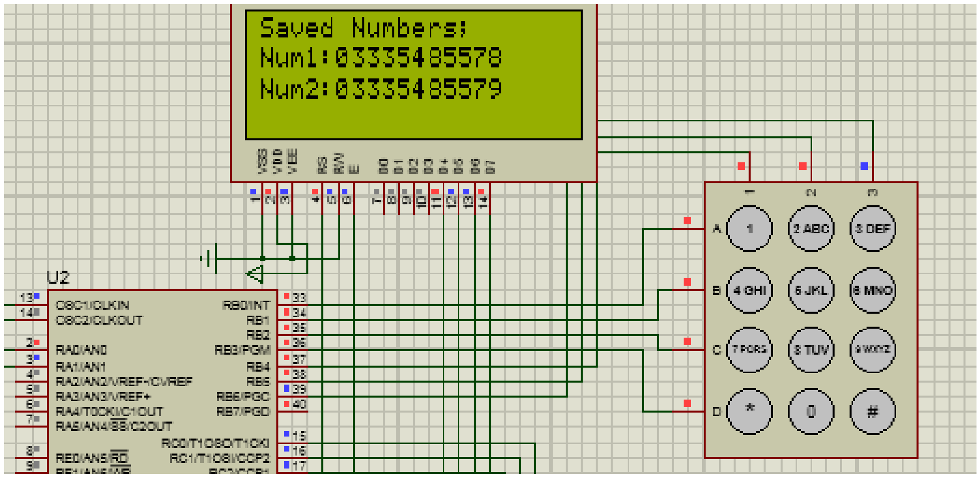
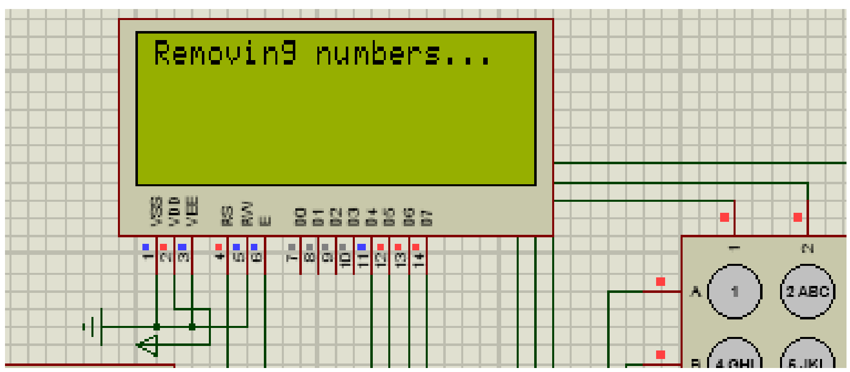
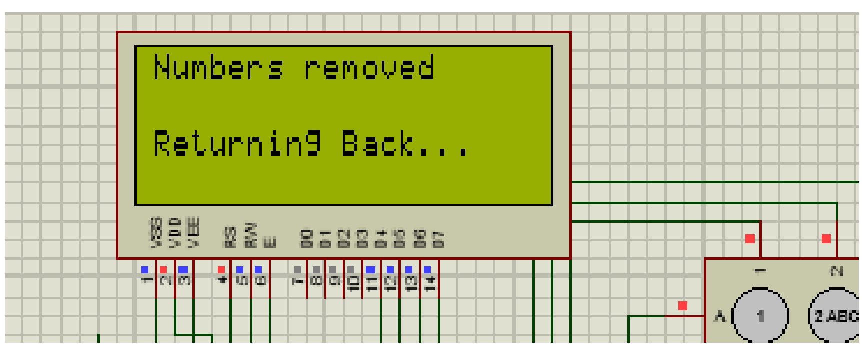


Figure 7-5: **Option 3 selected**

Following is display shown when 2 is pressed to remove numbers.





When gas is detected name of gas is displayed and red LED is turned on

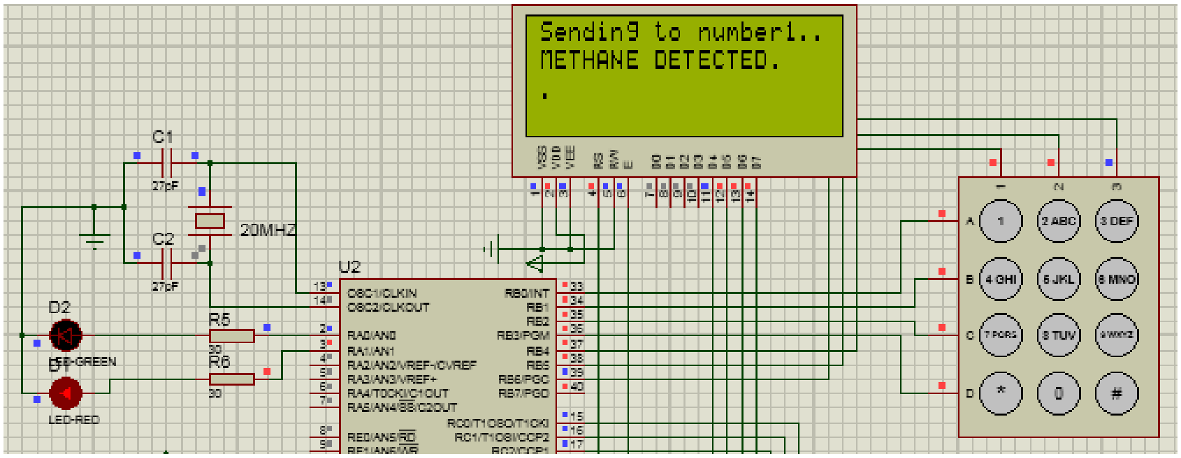
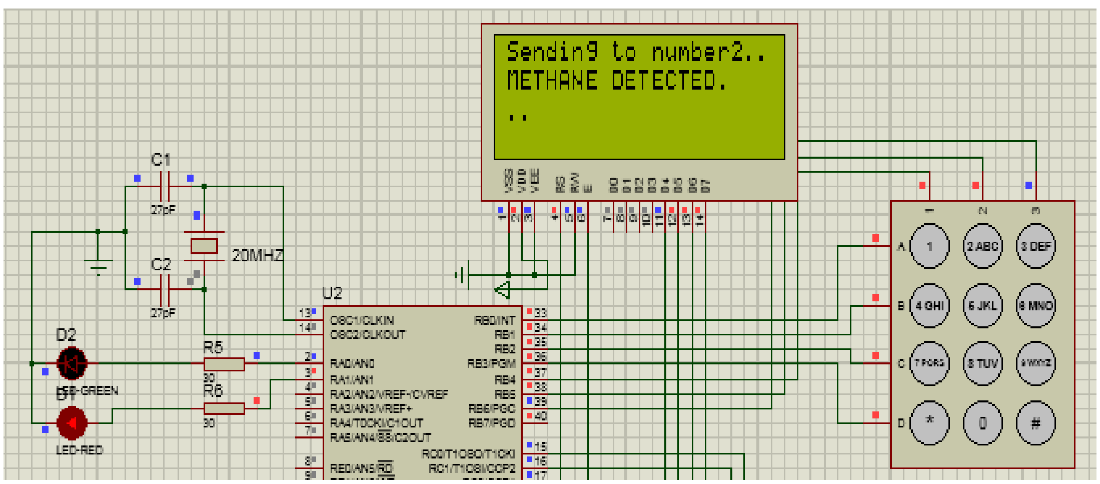


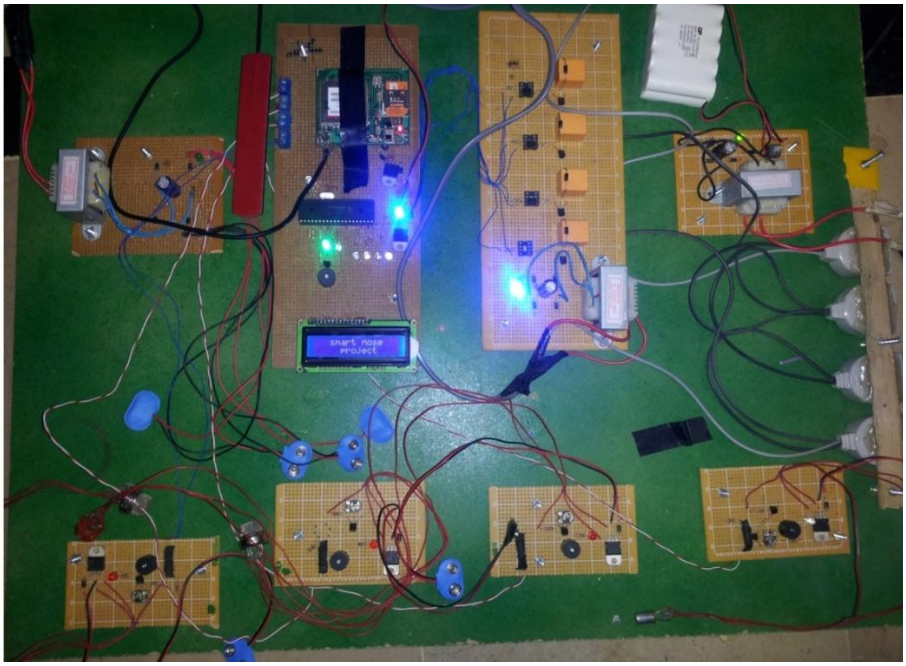
Figure 7-6: **Display when gas is detected**



7.3 Practical Results

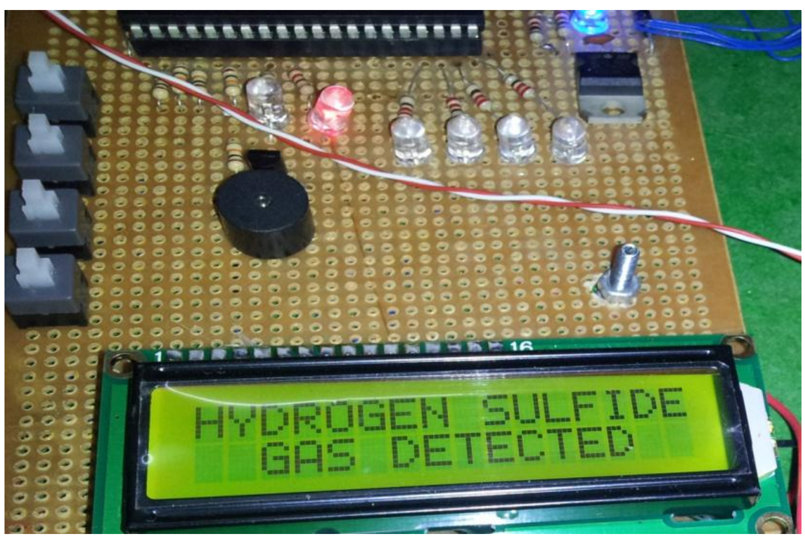
7.3.1 When Smart Nose is turned on

Smart Nose is turned on but as no gas is detected now, so green LED is on.

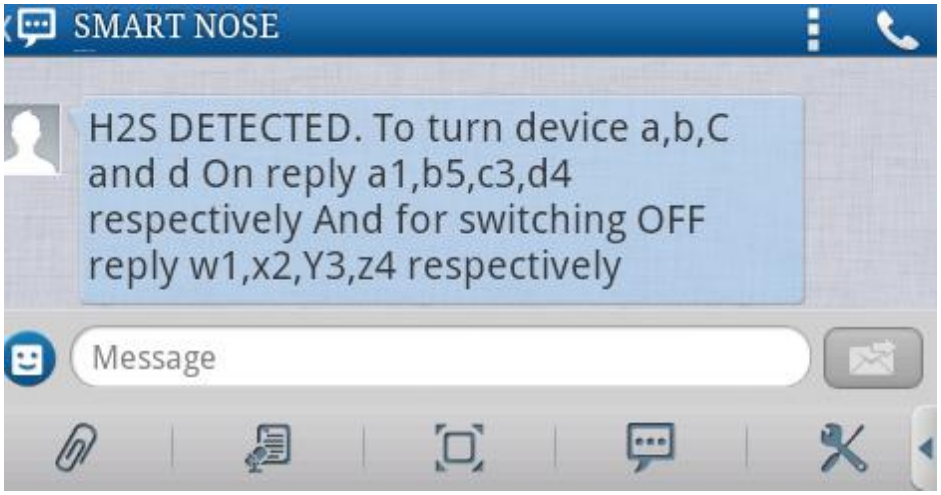


7.3.2 Visual Indications when Gas (e.g Hydrogen Sulfide) is detected

Red LED is turned on and green LED is turned off and message is displayed on LCD screen as gas is detected.



7.3.2 Message received when gas is detected



7.3.3 Devices turned on and off via text message and status check

7.4 Summary

In this chapter, results simulated on proteus and practical results of implemented circuits was shown.

Chapter: 8

FUTURE WORK AND APPLICATIONS

8.1 Introduction

This chapter includes the future work that can be done for the improvement of Smart Nose along with application of Smart Nose to a variety of commercial industries, including the agricultural, biomedical, cosmetics, environmental, food, manufacturing, military, pharmaceutical, regulatory, and various scientific research fields.

8.2 Future work

The smart nose as FYP was designed at domestic level keeping in mind the modern airtight structure of houses. A single unit device was developed to be placed centrally in a house. Bigger houses with multiple units will require more than 1 device. For example, different devices will be installed in garages, basements, servant quarters, pantry, storage areas and near geysers. All these devices may or may not be wirelessly connected to the central device containing GSM module.

Industrialization:

For industries, it can be advanced by using:

- Different Gas Sensors
- Multiple Microcontrollers
- Complex Coding
- External Memory

The central device can be installed in any management office and can be controlled from there. Different gas sensors can be used for different gases according to industry’s threat calibrated to required measurement threshold of these gases. Multiple microcontrollers can be wirelessly linked (via complex coding) to each other for device management and monitoring system. External memory can be installed to keep and maintain a record log of numerous contacts. Similarly this can also be done for residential building like flats and also in hotels.

8.3 Applications

Electronic noses have provided a surfeit of benefits to a range of commercial industries, including the agricultural, biomedical, cosmetics, environmental, automobile, food, packaging, drug, analytical chemistry, manufacturing, military, pharmaceutical, regulatory, and various scientific research fields. More research have enhanced product attributes, uniformity, and consistency as a result of increases in quality control capabilities afforded by electronic-nose monitoring of all phases of industrial manufacturing processes.

8.3.1 Industries

Atmospheric air contains many kinds of chemical species, some of which are essential to our life while many others are more or less harmful. Gas sensors are used to manage the quality of the surrounding atmosphere. Smart nose systems have been designed specifically to be used for numerous applications in many different industrial production processes.

The significance of smart nose is constantly growing and it permits us to watch our surrounding that was not possible a few years ago. With the time, the concentration of gases in the atmosphere has been rising widely since the Industrial Revolution and has now reached dangerous levels not seen in the last 3 million years

Figure 8-1. **Industrial waste producing dangerous gases**

Safety of personnel and plant is our responsibility, so it's necessary to have the perfect detection module for the protection of the industry and employees and facilities from these hazards is important to keep people safe. Atmospheric hazards are common in a range of industrial applications.[45].

Now a day, use of substances like toxics and combustible gases in industries are very common. Certainly, occasional escape of gas occurs, which create a potential hazard to the living nearby. Worldwide incidents involving asphyxiation, explosions, and loss of life are a constant reminder of this problem.

Third largest source of gas emission is from industrial sector. This produced 20% of fossil fuel related gas emission in 2010. The industrial sector consists of manufacturing, construction, mining, and agriculture. Manufacturing can be broken down into 5 main categories: paper, food, petroleum refineries, chemicals, and metal/mineral products. These categories account for the vast majority of the fossil fuel use and gas i.e. CO2 emissions by this. Manufacturing procedure directly uses fossils to create heat and steam needed at various stages of production. For example factories in the cement industry, have to heat up limestone to 1450°C to turn it into cement, which is done by burning fossil fuels to create the required heat.

To generate steel, the carbon content of iron is lowered by smelting and refining. This process uses oxygen to combine with the carbon in iron which creates carbon-dioxide. On average, 1.9 tonnes of CO_2 are emitted for every tonne of steel produced [46].

Petrochemical products like plastics, solvents, and lubricants are created using petroleum. These products evaporate, dissolve, or wear out over time releasing carbon-dioxide.

So Smart Nose, helping the prevention of the above-mentioned problems, plays an important role in various modern technological processes, where power and analysis of these four harmful gases are necessary and monitor toxic gases present in the atmosphere due to industrial emissions. It can control the concentration of the gases in the engine and gas boiler, to guarantee the highest possible efficiency of the combustion process. The same concept can also be applied to power plants, as the energy is generated by combustion [47].

8.3.2 Indoor Air Quality

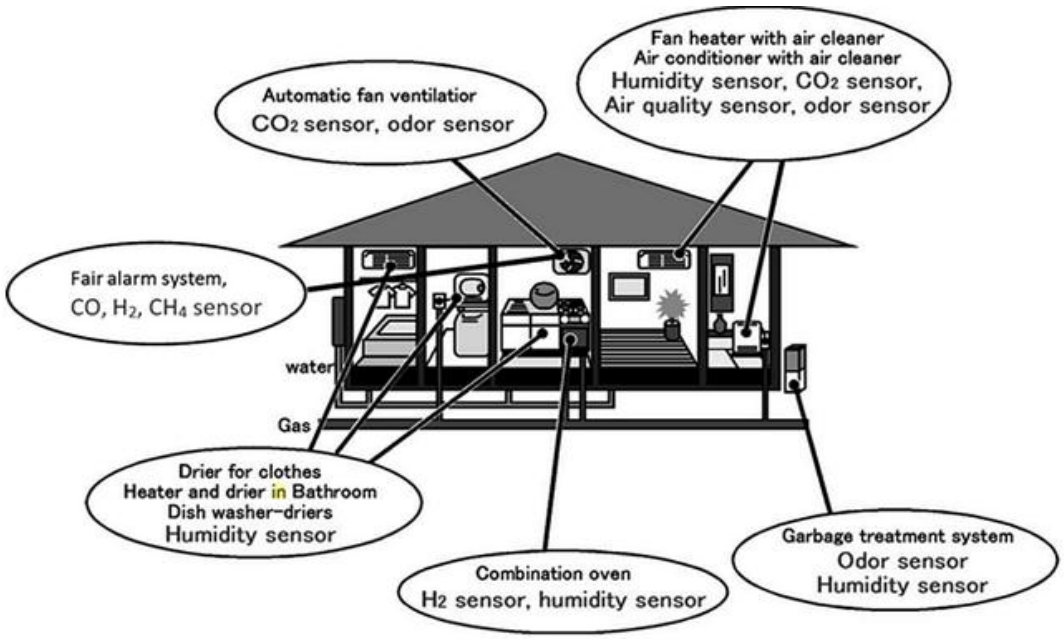


Figure 8-2: **Various kind of gases present in our homes that require sensor to detect different gases**

As seen in the figure a lot of gas sensors are required in a domestic house for safety, but with the use of Smart Nose only one module which is used to monitor CO_2, air quality, ventilation control. It may be used to detect toxic gases in continuous monitoring and alarm system both outdoor and indoor. Smart Nose is able to detect a gas leak and can interface with a control system so that a process can be shut down automatically. A gas detector can also sound an alarm to inform the user about the place where leak of gas is occurring, thus it can prevent accidents due to gas leakages, thereby saving lives and equipment. It can also be used to detect combustible and flammable gases. This type of devices can be suitable in a variety of locations such as on oil rigs, gas containers, and trunk gas pipelines; they may therefore also be used in firefighting.

Natural gas occurs as a colorless, odorless gas formed over millions of years within the Earth. It is composed after the decomposition of organic compounds as fossil fuels were formed. Consumers access natural gas by extracting the hydrocarbons from their earthen reservoirs, and after removing impurities transport it as mostly methane gas. In a home a gas stove have about five to 15 parts per million of natural gas in the air. More than 30 parts per million crosses into dangerous levels of natural gas and indicates a faulty stove. The risk of carbon-monoxide poisoning from methane peaks during the winter because we heat our homes. Often, houses aren't ventilated in the winter to retain that heat. To avoid carbon-monoxide poisoning, particularly in the wintertime, you can install a module to detect these harmful gases.

While natural gas used indoors can create health risks. Since more than 2 million miles of natural gas pipeline funnels the fuel underground in the United States, you must take caution when digging in your yard. [48].

So in short we can control indoor air quality, monitor toxic gases in a working environment for instance in a factory where dangerous chemicals are used by using Smart Nose also used in the detection of poisonous gases or smoke in households, due to accidents such as fires and explosion, intelligent refrigerator or oven; fire alarm; natural gas heating; leak detection; air purifiers; cooking control.

8.3.3 Car Parking

With increasing electricity bills people are all looking for ways to reduce our carbon footprint and ongoing costs. As per Australian Standards, if gas detection module is mounted in car parking area then it is not essential to turn on the fans installed in that area for ventilation purpose 24 hours a day, as a result we save money on the running costs, but the maintenance costs associated with the ventilation system are also greatly reduced.

It also enables the operators to run their tunnels at financially efficient levels and protect from the vehicle pollution effects [49]. So we can use Smart Nose for city traffic control and management , air quality monitoring in tunnels or underground parking garages , it control the ventilation ,gasoline vapor detection .

8.3.4 Food

8.3.4.1 Food freshness, Quality, Ripeness and Shelf-life:

The age of fruits (ripeness or maturity level) determines the shelf life and future rate of quality loss due to changes in flavor, firmness and color. So fruit quality can be analyzed by different techniques such as the starch conversion index and flesh firmness or pressure test but it cause harm to the fruit too. Therefore, a method is required that do not harm the fruits but it calculate the self-life and also enhance the marketability. Shaller*et al.* [49] gave assessment about the e-nose that how we get benefit out of it to differentiate among types of foods.

It is observed that the odor of fruit determiner the maturity of all other factors that includes that self-life etc. To discriminate among different types of coffee beans in coffee production process e-nose is used, also it spot its brands and separate samples of it [50, 51, 52]. So a lot of advantages are there that helps to maximize corporate profits and optimize customer satisfaction.

8.3.4.2 Milk and Dairy Products

Dairy products contain off-flavor compounds made by the use of natural as well as artificial microbial enzymes and other such type of chemical reaction.

In cheeses, quality, flavor and taste are closely connected to the ripening process which depends on the growth of bacteria, lipid degradation and oxidation, and proteolysis. Use of e-nose is becoming popular in these applications now days.

A NIR spectrum (Near Infrared Spectroscopy) measures only the chemical changes takes place at storage [53] but e-nose analysis was more helpful as it also determine self-life and other important information of use.

8.3.4.3 Meat Products

Use of e-nose to detect the quality of meat products in food industry is also very common now days. The electronic nose results were compared with those obtained by microbiological, sensory, and headspace GC analyses [54]. The e-nose shows better results as it discriminates the broiler chicken and fresh chicken by consuming less time. Hence e-nose is more capable of detecting even early signs of spoilage in modified atmosphere packed poultry meat [55].

8.3.4.4 Fish and Seafood Products

In the judgment of freshness of fish again e-nose play very important role by distinguishing the aroma of spoil and fresh fish and also detect when food start to rot or it’s no longer good for use[56]. Therefore this module helps in fast quality control determinations of freshness evaluation in smoked salmon products [57].

8.3.4.5 Stored Oysters

Xiaopei Hu, Parameswara Kumar Mallikarjunan(2008) have studied the effectiveness of two electronic nose systems and trained sensory panel evolution system to review the quality of on live oysters stored at 4 and 7ºC for 14 days. According to results Cyranose 320 e-nose can identify with 93% accuracy while second system has accuracy of 22 %. Correlation of sensory panel scores with e-nose data revealed that e-nose has demonstrated potential as a quality assessment tool by mapping varying degrees of oyster quality. The developed methodology to evaluate the odor of oysters was able to produce a distinct smell-print of oysters stored at two temperatures for various time periods [58].

8.3.4.6 Processed Cheeses and Evaporated Milk

Laurent Pillonel et al (2001) investigated, processed cheeses and evaporated milk as reference materials, and observed that data transfer between two e-noses does not require any complicated operations and is very user friendly and simple. They used evaporated milk and air as references for standardization and the results shows that e-nose give best measurements related to self-life and all other parameters of market use [59].

8.3.4.7 Stored Vegetable Oils

N. Shen et al (2001) studied to compare the results of sensory evaluation and e-nose. Canola, corn, and soybean oils were stored at 60°C in the dark until sufficiently oxidized, and results proved that the "electronic nose" is capable of measuring changes in volatile compounds associated with oil oxidation and could be used to increase data obtained from sensory evaluations [60].

8.3.4.8 Authenticity of the Botanical Origin of Honey

S. Ampuero et al (2003) observed an electronic nose based on mass spectrometry to the control of the authenticity of the botanical origin of honey. Different models were built based on groups of samples identified as typical unifloral honey. Following types of unifloral honeys were analyzed: acacia, chestnut, dandelion, lime, fir and rape. Three different sampling modes were tested: static headspace (SHS), solid phase micro-extraction (SPME) and inside needle dynamic extraction (INDEX). The best classification, under the sampling conditions used, was provided by the SPME sampling mode. This method proved to be fast, reliable and powerful for this type of task. Modern methods also use this approach up to some extend [61].

8.3.4.9 Mycotoxins in Wheat

G. Tognon et al (2005) develop the innovative method of the sensorial analysis (based on the use of an "electronic nose"), to evaluate the potential for determination of the levels of mycotoxin contamination in durum wheat[62]. The on-line evaluation of the quality of durum wheat (*Triticum durum*) represents, in terms of health and safety, one of the leading challenges of the milling industry.This study is very helpful regarding safety of humans. [63].

8.3.5 Medicines

Modern medicine faces the problem in the diagnoses in order to start the treatments. Very common means of diagnoses of pathological problems is through the chemical analysis of human biological samples, such as breath, blood, urine, sweat and skin. The "metabolic profile concept" described by Jellum*et al.* [64], is related to the study of the composition of human fluids [65]. As we know that pathogenic microbial species produce a wide range of VOCs, and the diagnostic potential of pathogen recognition through analysis of secondary microbial metabolites was recognized and considered theoretically possible as early as the 1960s [66]. However, the use of VOC chemical analyzers, such as GC or GC/MS, is still very expensive, requires highly-skilled personnel and is time consuming to the extent of precluding early diagnoses. The diagnostic process depends on the difference of aroma of diseased vs. healthy human tissues. Human pathogenesis is supported by studies using the extraordinarily keen olfactory abilities of well trained dogs whose sense of smell is one million times greater than human's in the ability to detect melanoma tissues [67], bladder cancer [68], as well as lung and breast cancers [69].

Many medical researchers presented experimental data related to the viability of using the e-nose to identify many different pathogenic microorganisms through the detection of the VOCs they emit both in vitro and *invivo* [70].. Dutta *et al*. [71] used the Cyranose 320 e-nose for in situ diagnostic analysis to identify three different strains of *Staphylococcus aureus*bacteria responsible for ear, nose, and throat infections and it is proved that the Cyranose 320 e-nose was capable of identifying up to 99.69% accuracy.

Some highly pathogenic gastro esophageal bacteria were correctly discriminated by Pavlou*et al.* [72] whose trials involved successful analysis of headspace volatiles from complex potage cultures of *Staphylococcus aureus*, *Klebsiella spp*., *Helicobacter pylori* (the most common ulcer-causing pathogen) and *Enterococcus faecalis*. More recently, in an other studies the feasibility of recognizing several strains of two anaerobic bacteria and two fecal pathogens by the use of an electronic nose [73,74]. Moens*et al.* [75] were able to dramatically reduce the time between isolation and identification of ten clinically important microorganisms (*Pseudomonas aeruginosa*, *E. coli*, *Klebsiellapneumoniae*, *Enterobacteraerogenes*, *Proteus vulgaris*, *S. aureus*, *Streptococcus pneumoniae*, *E.faecalis*, *Candida albicans*, *Aspergillusfumigatus*) using an electronic nose.

Urinary tract infections have been thoroughly investigated by Di Natale*et al.* [76]. Pavlou*et al*. [73] proposed the use of the electronic nose as a potential diagnostic tool for patients affected with kidney diseases. Aathithan*et al.* [77] analyzed 534 clinical urine specimens of which 21 % had significant bacteriuria indications. The ability of e-nose to get result is 5% more than conventional systems by consuming low cost as well. Boilot*et al.* [78] classified six bacteria responsible for eye infections and ENT (ear, nose and throat) disease with an accuracy of 97.3% and 97.6% respectively using a commercially-available electronic nose.

Lykos*et al.* [79] proposed sensorial analysis as an alternative method to identify bacteria from blood cultures of patients with bacteremia and septicemia instead of the conventional. Blood analysis via the electronic nose was used by Fend *et al.* [80] to monitor and quantify dialysis dosage in patients undergoing regular renal dialysis following kidney failure. E-nose helps in the detection of asthma in young and older patients with mild and severe asthma [81].

The presence of *Mycobacterium* tuberculosis, etiologic agent of tuberculosis and world-wide major public heath problem particularly in developing countries, was investigated by Pavlou*et al.* [82]. One of the most doubtful yet promising application of electronic nose technologies is for the early detection and diagnosis of oncologic diseases, in particular lungs cancer up to accuracy of 100%.

This electronic nose could distinguish between cancer cell and healthy cells [65]. Other applications include the possibility of monitoring microbial metabolites released from superficial wounds and burns [83], upper-respiratory infections in the field of rhino logy [84], the diagnosis of diabetes [85], and to distinguish cerebrospinal fluid from serum [86,87], diagnosis of ventilator-associated pneumonia [88,89,90], detection of cerebrospinal fluid [86,87], identification of bacterial pathogens [91,92], early screening for the presence of many different types of cancers [93,94], and breath analyses for detection of various diseases [95], toxin exposure [96] and radon ingestion [97].

The stronger emphasis on the production of e-nose is the cost that is low and diverse applications as compare to other instruments needed for disease diagnoses. In one line we can say that it helps in the diagnostics (breath analysis, disease detection) ; point of care patient monitoring ; drug monitoring ; artificial organs and prostheses ; new drug discovery. It helps in the detection of particular molecules, which are formed when food starts to rot and it is no longer good for consumption [55].

8.3.6 Agriculture

8.3.6.1 Agricultural Plant Production

Modern agricultural management depend on the information of crop ,soil ,climate ,and environment conditions. The aroma of grains is the primary criterion of fitness for consumption in many countries. However, the sniffing of grain should be avoided as inhalation of toxic or pathogenic mold spores such as from *Aspergillus* species is harmful. Campagnoli*et al.* [98] use the electronic nose for detecting processed animal proteins in feedstuffs and the e-nose was able to discriminate the blank sample from all other samples containing processed animal proteins.

Scientists working in stirpicultural research have verified that the electronic nose can accelerate the selection of new commercial plant cultivar [99], this e-nose proved to be an appropriate tool for the identification of cultivars and was potentially useful for accelerating the selection process.

Paddy fields for rice production are essentially man-made wetlands that create a great environment for methane producing microbes that decompose the organic matter [100].

8.3.6.2 Plant Pathology

The study by Nilsson [101] in 1996 was perhaps the first published attempt to apply an electronic nose technology to plant pathology by discriminating sapwood of Scots pine colonized and decayed by specific wood decay fungi and the results are positive. The problem of moisture effects on sensory outputs was solved by Wilson *et al.* [102-103] by the use of e-noses for plant disease diagnosis applicable to all types of microbial plant pests and phytopathogenic microorganisms up to 95-100% of accuracy.

This work could eventually lead to a simple and effective means of evaluating the structural integrity of standing trees in the urban environment using e-noses in order to prevent or minimize catastrophic property damage and personal injuries attributed to landscape tree failures [57].

8.3.6.3 Plant Identification

Electronic nose easily could be used to identify and classify many different kinds of wood and tree species using extracted wood samples. They also were able to discriminate between white oaks from those in the red/black oak group. A lot of applications were known like forest management research and the identification of the roles that wood-inhabiting organisms play in stand dynamics and ecosystem functions [104].

By using an e-nose we use to investigate a problem relating to the quality of pulp and paper. Plant /animal diagnostics ; soil and water testing ; mea

/poultry inspection ; waste / sewage monitoring can also be done by using e-nose [105].

8.3.7 Automobiles

In early days oxygen sensor was the part of car engine to increase its efficiency and to maintain the required ratio of air and gasoline i.e. 14.7:1. If air is less than gasoline, the mixture is called a rich mixture. Rich mixtures are bad because the unburned fuel creates pollution. If there is more air than there is excess oxygen. This is called a lean mixture. A lean mixture tends to produce more nitrogen-oxide pollutants, and, in some cases, it can cause poor performance and even engine damage [106].

The reason why the engine needs the oxygen sensor is because the amount of oxygen that the engine can pull in depends on all sorts of things, such as the altitude, the temperature of the air, the temperature of the engine, the barometric pressure, the load on the engine, etc.

Gas sensors are increasingly used for automotive applications to ensure safety of vehicle by automatically controlling the Heating Ventilation and Air Conditioning (WAC) system. It also helps in conducting breath alcohol test. A breath alcohol test determines how much alcohol is in your blood by measuring the amount of alcohol in the air you breathe out (exhale).

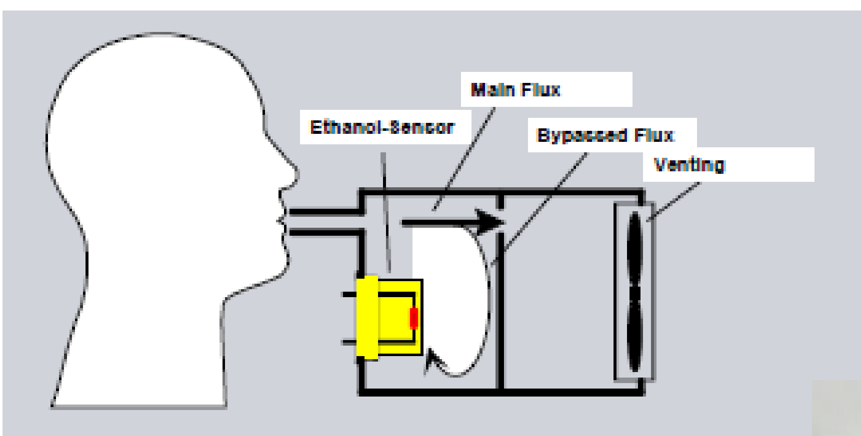


Figure 8-3: **Alcohol breath test**

When the amount of alcohol in the blood reaches 0.02 - 0.03%, you may feel a relaxing "high."And further increase in percentage i.e. 0.05 - 0.10% can damage judgment power. The test may help you make better decisions about driving after drinking [107,108].

8.3.8 Coal Mines

The majority (around 60%) of the coal seams currently being extracted worldwide are so far underground that open cast mining cannot take place and workers have to go underground for their work. One of the major problems that this creates is the dangers from Methane (CH4) gas which occurs in Mine gas. Mine Gas is a natural product, produced during the geochemical conversion of organic substances to Coal (during carbonization). [109].

In blasting operations Carbon-monoxide (CO) and Hydrogen Sulfide can occur in large quantities. The concentration of CH4 depends directly upon the quality and depth of the coal seam. [110].

To keep atmosphere safe some mechanism like e-nose is required that observe, monitor and helps in controlling the levels of gases, like methane, carbon-dioxide, carbon-monoxide etc. No mineworker should enter any underground work place, in particular those places with poor air circulation (e.g. blind headings), unless the air has been checked therein to ensure a safe breathable atmosphere free from levels of hazardous gases [111].

8.3.9 Environmental Monitoring

The field of environmental monitoring encompasses a broad range of activities. Pollution of the environment can occur not only by dumping wastes in water, land, and air, but also by generating noise in the audio and communications frequency ranges.

8.3.9.1 Water

Water quality is threatened when agricultural and industrial concerns allow their waste products to seep into ground water or to flow into streams or rivers. The e-nose can be used in these applications by collecting samples of the effluent and boreholes. Studied have proved that the e-nose can be used as an instrument for monitoring water quality.

Baby et al. [112] used the MOSES II e-nose to measure contaminating residues of insecticides and products from leather manufacture that are often offloaded into streams and rivers. Dewettinck et al. [113] employed an e-nose consisting of 12 metal-oxide sensors to monitor volatile compounds in the effluents of a domestic wastewater treatment plant over a 12-week period and all shows very encouraging results. Van Hege et al. [114] explored the application of evaporative technology for wastewater treatment plant effluents. Evaporation completely removed most inorganic and organic contaminants.

Di Francesco et al. [115] studied the use of an e-nose with conducting-polymer sensors and fuzzy-logic-based pattern recognition algorithms to test wastewater samples. Fenner and Stuetz [116], Stuetz et al. [117], andStuetz et al. [118] employed an e-nose with 12 polypyrrole conducting-polymer sensors to monitor quiescent sewage liquors at three wastewater treatment plants over an 8-month period. The study suggested that it might be feasible to use an e-nose to monitor and/or control the biochemical activities of a wastewater treatment process.

Gardner et al. [119] and Shin et al. [120] developed a system for detecting blue-green algae in potable water. The e-nose system was able to detect 100% of the unknown toxic cyano bacteria using a multi-layer perceptron (MLP) neural network. The results showed the potential for a neural network-based e-nose to test the quality of potable water.

8.3.9.2 Land

Land contamination by toxic and radioactive materials is a big problem around the world. Garbage waste dumps are also a dilemma. Adding specific reagents to the boreholes improve the sensitivity of the e-nose instruments.

This is a talented area for e-nose and there is a possibility of future growth in this segment of the e-nose market.

8.3.9.3 Air

Air quality has been the primary target of e-nose research projects in environmental monitoring [121, 122]. The e-nose can monitor odorous emissions at their near source or remote locations, such as paper mills, animal production sites, power-plant stacks, vehicle exhaust pipes, compost facilities, wastewater treatment plants, animal rendering plants, paint shops, printing houses, dry cleaning facilities, or sugar factories. In most cases irritating atmospheric emissions do not menace public health, and reduce the quality of life [115]. The e-nose offers the promise of being able to make accurate and repeatable measurements of odor profiles at sites of complaint.

Automotive ventilation may also be monitored and controlled by an e-nose. Menzel and Goschnick [123] investigated methods for improving the time response of an e-nose instrument intended for on-line discrimination applications and as a result the error in the detection of pollutants was reduced from the original 25% to only 10% for their new method.

8.3.10 Aerospace

The application of Smart Sensor Systems for aerospace applications is a multidisciplinary process consisting of sensor element development, element integration into Smart Sensor hardware, and testing of the resulting sensor systems in application environments in order to monitor conditions in both space vehicle environments and in aircraft or spacecraft operations [124].

In the detection of fire conditions aboard aircraft and spacecraft e-nose significantly enables an improved understanding of the environment and earlier detection of hazardous events. Likewise, the ability to measure some of the same chemical species such as, CO, CO2, O2, nitrogen oxides (NOx), and, again, H2/HxCy is necessary in jet engine emission monitoring. It is used in some other aerospace applications such as fuel leak detection or environmental monitoring [124,125,126].

8.4 Summary

To summarize, development and utilization of many new electronic-nose (e-nose) applications in the healthcare and biomedical fields have continued to rapidly accelerate over the past 20 years. This chapter includes the applications of Smart electronic Nose in various industries.

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APPENDIX A

USER MANUAL

1. Insert SIM Card in the device.
2. Insert the switch in the socket. Green light will be turned on. Let the device be, it will take some time to warm up the gas sensors.
3. After approximately one minute, a menu will be displayed at the LCD screen. You can now add and remove numbers as well as check the numbers already inserted.
4. To add no, press 1.
5. To remove no, press 2.
6. To check no, press 3.
7. To save, press #.
8. To go back the previous menu, press the white button at the bottom right corner of device.
9. Plug in any 4 gas excavating or security devices you want to control with Smart Nose.
10. Place the device at eye level on any wall in a central area of your accommodation area so that its alarm can be audible easily in case of any emergency.