NON-INVASIVE BLOOD GLUCOSE MONITORING USING IOT

Project report submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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UNDER THE GUIDANCE OF

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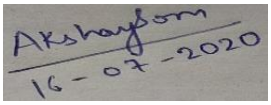
DECLARATION

We hereby declare that the work reported in the B.Tech Project Report entitled **"Non-Invasive Blood Glucose Monitoring using IoT"** submitted at **Jaypee University of Information Technology, Waknaghat, India** is an authentic record of our work carried out under the supervision of **Dr. Emjee Puthooran.** We have not submitted this work elsewhere for any other degree or diploma.



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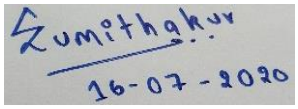

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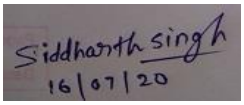

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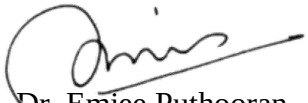

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ACKNOWLEDGEMENT

It’s always delightful to remind the people for their genuine advice we have received to complete this project successfully. Firstly, we would like to thank our parents who gave us immense motivation, zeal & an invaluable assistance, without which, we might not be able to finalise this project. Furthermore, we might want to expand our appreciation to our supervisor Dr. Emjee Puthooran for giving us this opportunity to do this project as well as for his guidance and support. Besides, we would also like to gratify our friends as well as colleagues who helped us in completion of this project in whichever way they could.

LIST OF ACRONYMS AND ABBREVIATIONS

1. MODY – Maturity Onset Diabetes of The Young
2. IRDS – Infantile Respiratory Distress Syndrome
3. WHO – World Health Organization
4. NIR – Near Infra-red
5. SNR – Signal to Noise Ratio
6. CNT – Carbon Nanotubes
7. FRET – Fluorescence Resonant Energy Transfer
8. LED – Light Emitting Diode

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ABSTRACT

Diabetes is by far the most non-communicable diseases which hampers people's health. Diabetes, if left uncurbed, can give rise to problems resulting in the liver failure or heart-attack or loss of eyesight. To circumvent these complications, glucose level must be monitored regularly. Methods (conventional in nature) of glucose measuring (invasive) employs a sharp needle which results in loss of blood with a possibility of infections and leads to biological wastes as well. To control problems like the ones mentioned above, a “non-invasive glucose monitoring system” is essential. In this project, we describe the method of measurement of non- invasive glucose measurement by "NIR Spectroscopy” technique. In addition to this, ESP8266 (wifi module) is attached to this system to permit the facility of data sharing without utilizing wires i.e. wireless. The results that are obtained can be communicated easily to the family doctor for the purpose of examination. The results can also be stored for future records and to analyze variations in blood glucose level. According to the variation in glucose level, adjustment in the dosage of medicines can be done. Maintaining a healthy blood glucose is recommended for the elimination of this disease. The aim of this project is to propose a non-invasive method for measurement of blood glucose concentration levels. Near-Infrared LED was placed over the fingertip for evaluating blood glucose optically and the glucose concentration of the blood was calculated depending upon the intensity of the light. The signal was then filtered and amplified. At a later stage, it is fed to the Arduino to be shown on an LCD. The person’s glucose level was anticipated based on the analyzed voltages received. The glucose readings were forwarded to the cloud using Wi-Fi module interfaced with the Arduino too.

CHAPTER 1
INTRODUCTION

Introduction to Diabetes

Diabetes can be defined as a type of disease which happens when the blood sugar level in the bloodstream is way higher than the normal levels. Insulin hormone i.e. produced by the pancreas is strongly accountable for the regulation of blood sugar levels in the body. However, when the body isn't ready to create adequate measure of insulin or the body isn't apt to utilize the insulin quite well then a person gets encountered with the diabetes.

If the blood sugar level remains beyond the normal blood sugar levels, then it may lead to various set of health problems. Some of them include:-

- Heart diseases
- Chronic kidney diseases
- Eyes damage
- Problems related to foot (foot ulcer)

Epidemiology

In 2017, four hundred and twenty five million people had diabetes over the world, with a gradual increase from an estimated three hundred and eighty two million people in 2013 and from one hundred and eight million in 1980. The prevalence of diabetes is about 8.8% among adults. Type-2 diabetes makes up for most of the total cases. Some data indicates that men & women are equally affected, but it has been found that males are the most affected and majorly due to Type-2 diabetes [8].

According to the reports, diabetes resulted in around one & half million deaths in the year 2012, making it the eighth leading cause of death worldwide. If reports are to be believed, then it's estimated that the rapid prevalence increase will occur in continents like Asia & Africa, where majority of diabetes struck people will live in 2030.

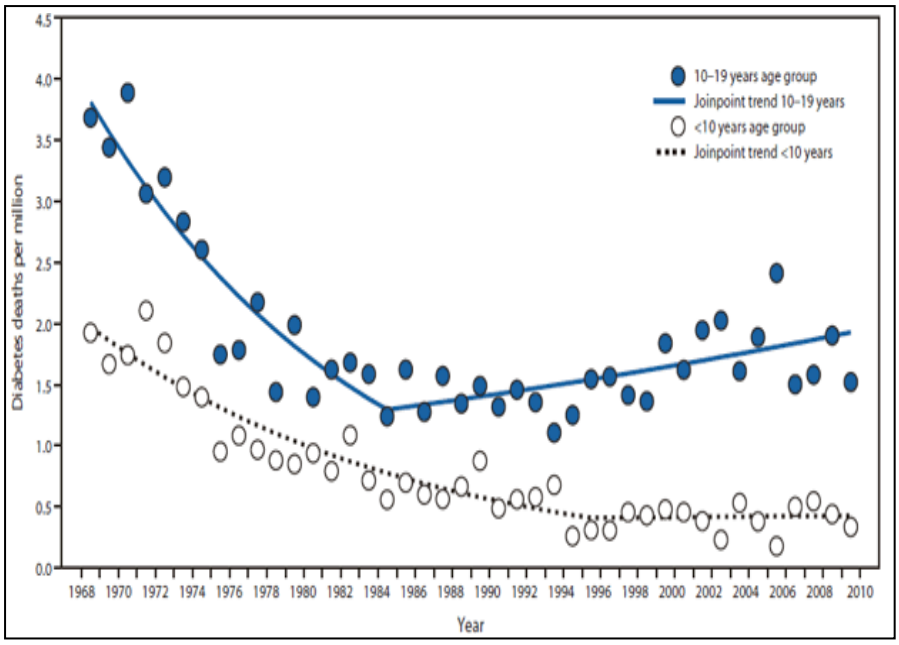


Fig. 1.1 Deaths due to diabetes (in USA) [8]

Universal Symbol for Diabetes

The blue circle has been chosen as the universal symbol for diabetes. Now, the question that comes to our mind is that why a circle and that too a blue one denotes diabetes. Well, here's the answer. It has been observed the circle occurs quite frequently in nature. Also, in some cultures it embarks life & health. Moreover, the circle symbolizes unity. Further, blue color was chosen as a reference to the blue color of the flag of United Nations which itself is an organization representing unity among nations [9].

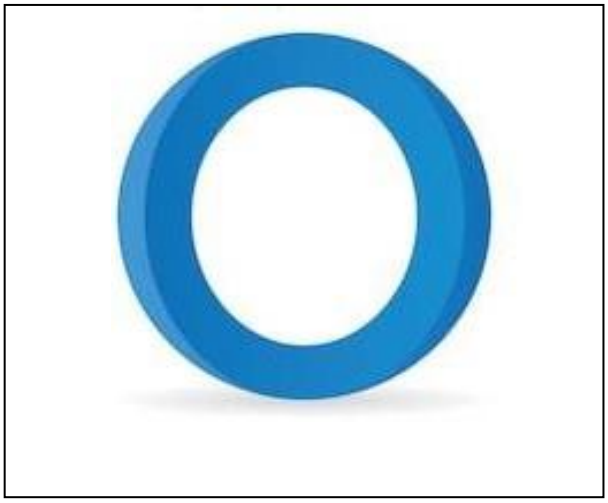


Fig 1.2 Universal Symbol for Diabetes [9]

Complication of Diabetes

All its types, be it type-1, type-2, gestational or MODY affect human body in some way or the other. However, its effects aren't seen gradually but possess a threat in the long run. Diabetes majorly attacks blood vessels which in turn hampers the well-being of eyes, kidneys and nerves. Due to diabetes, blood vessels of the eyes are damaged. As a result, the person is prone to loss of vision and sometimes even complete blindness. This disease also targets the kidneys, resulting in urine protein loss and other chronic kidney diseases. Sometimes, the situation is so severe that it requires for the processes like dialysis as well. Further, it also affects the nervous system of the body. Primary affects include: numbness, tingling, altered pain sensation, etc. Further, it also has an impact on the feet of one affected with diabetes causing a disease called as foot ulcer which is quite difficult to treat and requiring amputation at times as well [8].

Symptoms of Diabetes

There are numerous signs & symptoms that marks the start of diabetes. Some of them are developed quite rapidly as in case of type-1 diabetes, while some of them develop over time or not at all as in the case of type-2 diabetes. Some basic symptoms include: drastic loss in weight, increase in appetite, increased frequency of urination, increased thirst. Others include: blurring of vision, higher time for the healing of wounds, headache [8].

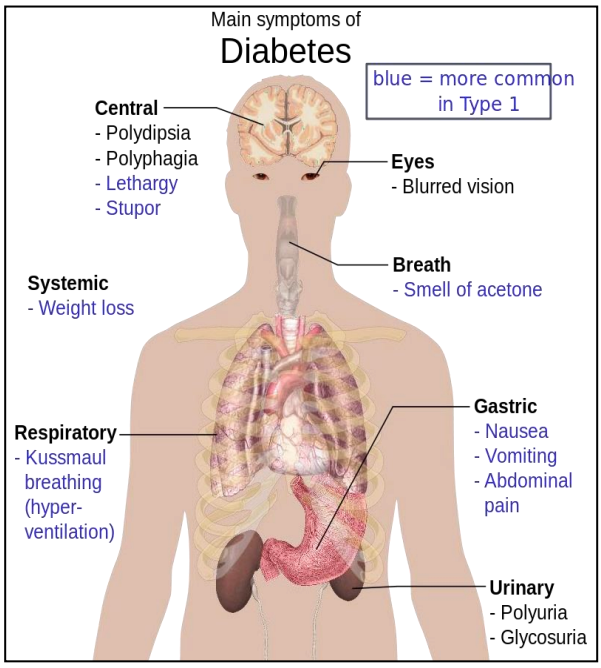


Fig 1.3 Diabetes and its Symptoms [8]

Types of Diabetes

Diabetes can be classified into 3 types as shown in the below given diagram:-

a) Type-1 Diabetes
b) Type-2 Diabetes
c) Gestational Diabetes
d) Others (MODY)

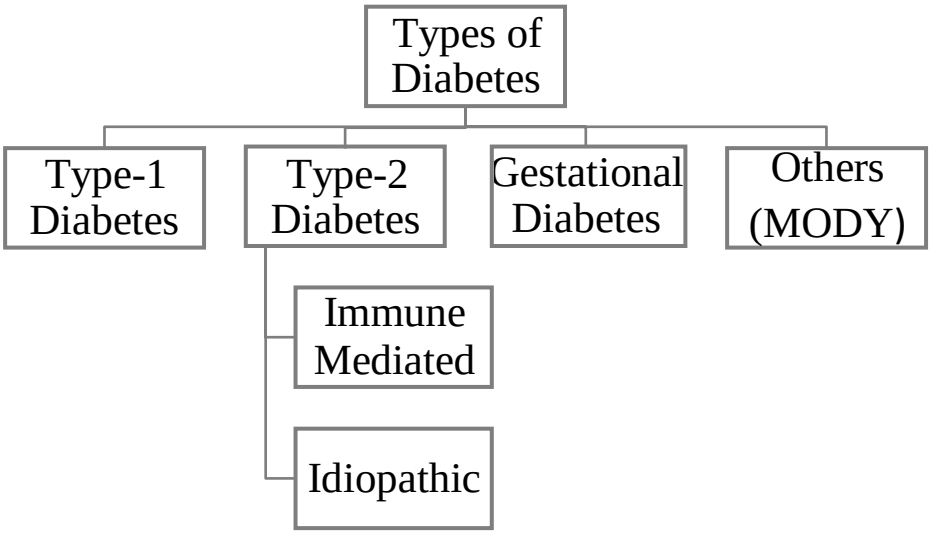


Fig 1.4 Types of Diabetes

Type-1 Diabetes

This is caused when the human body, in particular, pancreas is inefficient in production of sufficient amount of insulin which is due to the fact that there's been a loss of insulin delivering β-cells of the pancreatic islets.

Type-1 diabetes is mainly caused due to the inheritance of genes and can occur at any age. However, the onset of this type is usually found among children or kids [8].

It can be further classified into two types:-

- Immune-mediated
- Idiopathic

Immune Mediated:-

Most of the people having type-1 diabetes have immune-mediated diabetes. It is the one in which an auto-immune attack first results in the loss of the beta cells , which in turn , are accountable for the loss of insulin.

Idiopathic:-

This is the one which results due to sudden or gradual increase in blood sugar levels with the reason behind it being unknown. In other words, it ca be said this type of diabetes occurs spontaneously.

Type-2 Diabetes

A large portion of the people have Type-2 Diabetes. This type of diabetes mainly revolves around the concept of "insulin resistance", i.e. a condition in which the human body isn't able to either respond to insulin or make use of insulin effectively. Its main causes are lifestyle factors along with genetics. Lifestyle factors include obesity, lack of exercise, high consumption of white rice, sweetened drinks, high amount of stress, inappropriate diet, etc [8].

Table 1.1 Comparison b/w Type-1 & Type-2 Diabetes [8]

Parameters	**Type-1 Diabetes**	**Type-2 Diabetes**
Begins	Suddenly	Gradually
Age of beginning	Children	Adults
Type of Body	Normal	Mostly overweight
Prevalence	Ten Percent	Ninety Percent

Gestational Diabetes

Gestational Diabetes is encountered by some of the women during the times of pregnancy. This diabetes usually disappears (when baby is born). [8] However, if a person has ever been diagnosed with gestational diabetes, there is a high chance of him/her becoming a Type-2 diabetic person in the long run. If proper medical care is given during pregnancy, gestational diabetes can be cured.

Untreated gestational diabetes can prove to be vicious for health of the new-born baby. Some of the consequences could be high birth weight, abnormalities in nervous system, muscle malformations, infantile respiratory distress syndrome (IRDS), etc.

Others (MODY)

MODY abbreviation for "Maturity Onset Diabetes of The Young" is another type of diabetes but is very rare. It constitutes about 1-2% of the total cases of the diabetes. It is mainly caused by several gene mutations leading to lesser or inappropriate insulin production in the body. [8] This type is controllable without making use of insulin injections.

Diagnosis

As per the WHO diabetes diagnostic criteria, [8]

- People with fasting glucose reading < 110 mg/dl and 2-hour glucose reading (after 2 hours of having a 75 gram oral glucose) less than 140 mg/dl are normal.
- People with fasting glucose reading > = 110 mg/dl and less than 126 mg/dl and 2-hour glucose reading (after 2 hours of having a 75 gram oral glucose) less than 140 mg/dl are considered to be pre-diabetic(impaired fasting glycaemia).

- People with fasting glucose reading < 126 mg/dl and 2-hour glucose reading (after 2 hours of having a 75 gram oral glucose) > = 140 mg/dl are considered to be pre-diabetic(impaired glucose tolerance).

- People with fasting glucose reading > = 126 mg/dl and 2-hour glucose reading (after 2 hours of having a 75 gram oral glucose) greater than or equal to 200 mg/dl are considered to be diabetic.

Table 1.2 WHO Diabetes Diagnosis Criteria [8]

Condition	2-hour glucose (in mg/dl)	Fasting Glucose (in mg/dl)
Normal	Less than 140	Less than 110
Impaired Fasting Glycaemia	Less than 140	Greater than or equal to 110 & Less than 126
Impaired Glucose Tolerance	Greater than or equal to 140	Less than 126
Diabetic	Greater than or equal to 200	Greater than or equal to 126

Prevention

Over the years, there has been no known measure for its prevention. But type-2 diabetes can be controlled if following preventive measures are taken into account:-

- No or minimal intake of sugary foods like sweets, sweetened drinks, etc.

- No indulge in tobacco smoking

- Increased exercise or physical activity

- Having a meal that is balanced (incorporates all essential nutrients)

Motivation and Scope of the Project:-

This project makes use of the NIR & transmittance spectroscopy for the measurement of concentration of glucose in human body. Based upon transmittance, data analysis will be done for creation of a finest model that predicts glucose concentration levels to a greater extent.

Statement of Problem

Technologies used these days for measurement of body glucose concentration levels are invasive in nature i.e. they require a specimen of blood to obtain a reading. This is often agonizing for the person & is often undesired for the measurement of body sugar levels. Moreover, they require test strips that are not only expensive but also hard to find for a diabetic person & also contributes in the biological waste. The people not having diabetes don't need to use them. But with dearth of health monitoring as well as poor eating habits the onset of diabetes is more likely to be. Hence, it's suggesting that if even people who aren't ill periodically check health, they be well.

Methodology of Solution

Our main objective is to come up with a process for measuring blood glucose levels that is non-invasive in nature. Such methods would not only be pain free but can also be made use by people for ceaseless monitoring of their health. Therefore, the solution would be making use of NIR for measuring blood glucose concentration levels. This is because it would be painless & wouldn't require tedious amounts of test strips for measurements. As a result, it may easily be recommended to keep a check on their health such that they can adjust their eating habits accordingly.

Non- Invasive Methods of Glucose Measurement Techniques

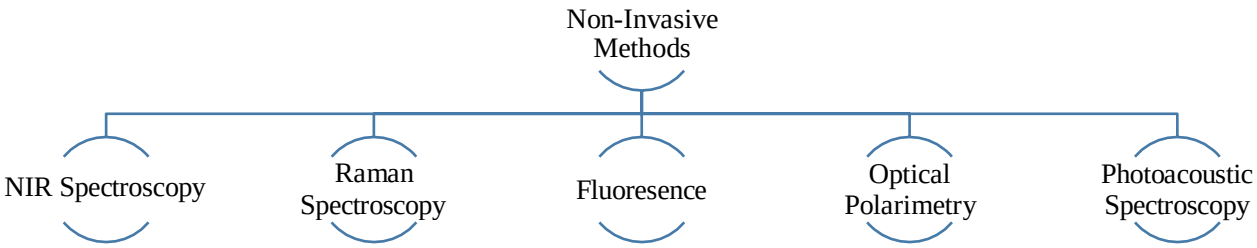


Fig 1.5 Types of Non-Invasive Methods

Near Infrared Spectroscopy

It is the study of interaction of matter with the EM radiation (typically the near infra-red region of the EM spectrum ranging from about 780 nm to 2500 nm). These measurements helps investigation of depths of tissue from 1 mm to 100 mm. Here, penetration depth and wavelength portray an inverse relationship i.e. when wavelength is increased, penetration depth decreases.

This method simply involves the transmission of NIR waves through lobe of the ear, cuticles or web of the finger among others to measure blood sugar levels. The near infra-red diffuse reflectance measurements demonstrate a good correlation with the blood glucose with an error of about 10%.

It is dependent upon the absorption spectrum of the tissue with the help of αspectrometer. First, NIR emission is done on a tissue. As a result, some portion of the light is absorbed partially while rest of it is scattered due to its interaction with various components present in the tissue. Later, the light that has been reflected from the person's tissue is passed through the pair of optical detectors. Further, an analysis is carried out on the changes in the intensity of light upon reflection from the tissue along with making use of numerous techniques of calibration to know about the blood sugar levels of the person.

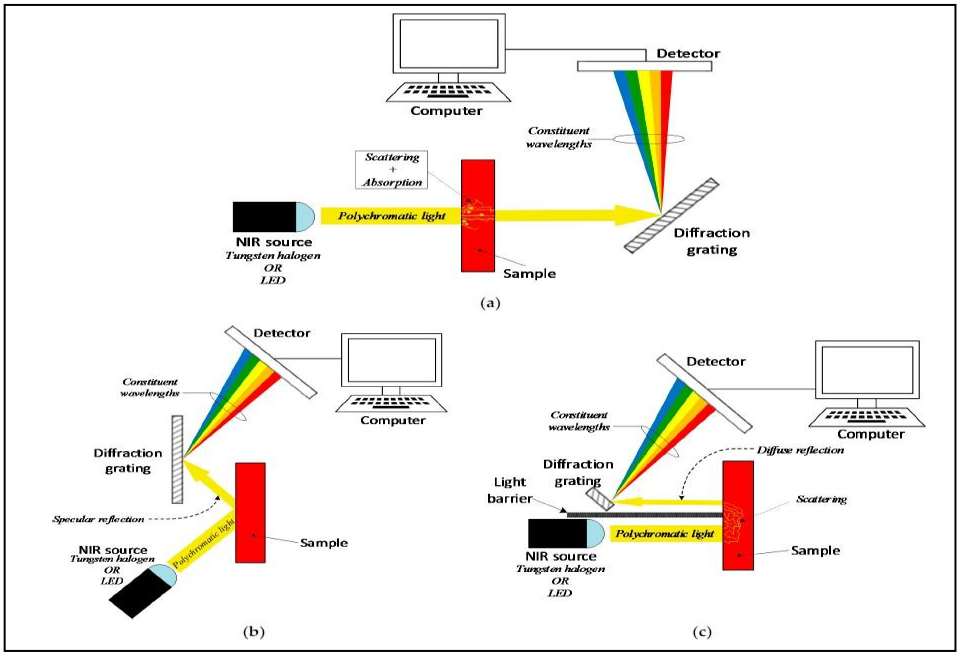


Fig. 1.6 Three modes of Near IR Spectroscopy: a) Transmittance Mode b) Reflectance Mode c) Interactance Mode [10]

Advantages:-

1. Makes use of low cost materials.
2. Intensity of the signal α concentration.
3. Water Transparency in the Near Infra-red band.
4. No or minimal sample preparation is required.

Disadvantages:-

1. False readings may be obtained due to non-homogeneous (or heterogeneous) distribution of glucose sample.
2. In order to get accurate results, glucose concentration required is low.
3. Selectivity problems for the determination of glucose.

Raman Spectroscopy

Raman scattering is observed when a radiation i.e. monochromatic in nature is incident upon an optically transparent medium. When a monochromatic radiation strikes a target, there is a production of scattered light in all the directions. Most of the radiation has the same wavelength as that of the monochromatic transmission portraying elastic scattering (or Rayleigh scattering). However, there is some portion of scattered light that has wavelength that is different from the wavelength (of monochromatic transmission).This is Raman Scattering. The difference between the wavelength of scattered radiation and initial monochromatic radiation is known as "Raman Shift". This Raman Shift denotes the variation b/w the initial & final states of the molecules. [5]

For glucose molecules, vibration modes of C-H , C-O and C-C bands centered around 2900, 800 and 1300 cm^{-1} respectively are the most representative ones.

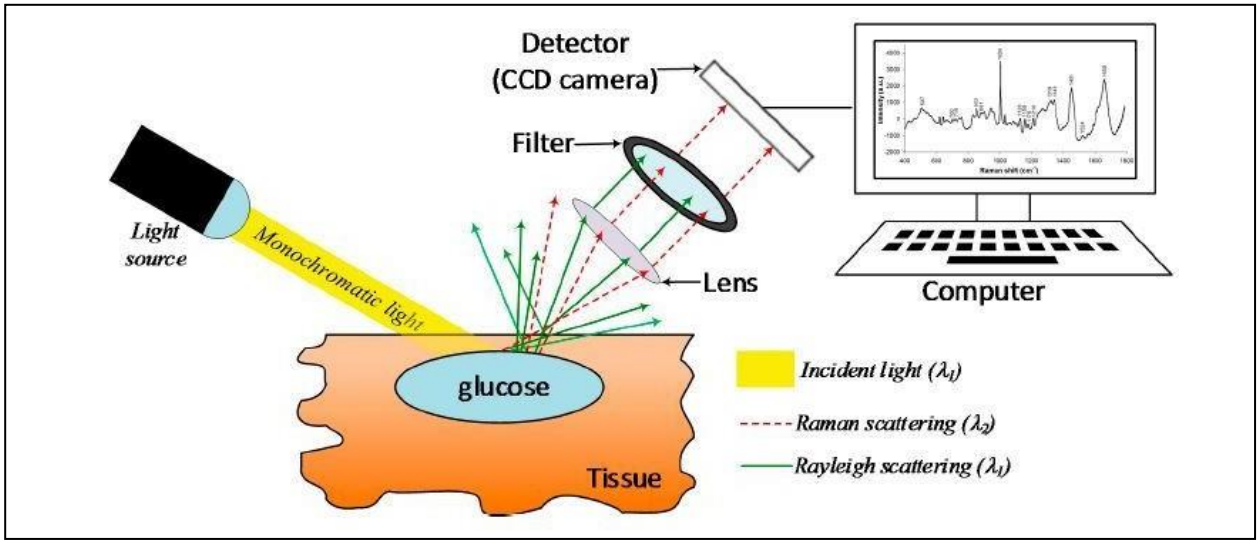


Fig. 1.7 Representation of Raman's Spectroscopy [10]

Advantages:-

1. Can be carried out on any surface.
2. It has a high specificity.
3. It's less sensitive to water and temperature changes.

Disadvantages:-

1. It’s prone to interference from other molecules.
2. Takes a long period of time for collection.
3. Gives a low SNR (signal to noise ratio).

Fluoresence

This technology is based upon making use of fluorophones. [4] Some of the fluorophones bound to the glucose molecule very well. However, there is a need of receptors (which bind to glucose more efficiently) due to the issues like low selectivity, irreversibility, interference, etc. from the former case. Few examples of receptors may include: quantum dots, boronic acid derivatives, glucose binding proteins, CNT (carbon nanotubes) etc.There exists a lot of techniques but FRET technique has garnered much attention. FRET stands for fluorescence resonant energy transfer. As in the case of glucose, when glucose attaches itself to acceptor molecule, the acceptor&donor link is ruptured. This results in less sharing of electron and increased fluorescence.

Advantages:-

1. It is very sensitive to even small glucose concentrations
2. Since molecules possess unique optical properties therefore this technique has high specificity.
3. It’s immune to light scattering.
4. Analyte concentration can be measured in terms of intensity of the fluorescence.

Disadvantages:-

1. It’s prone to interference due to oxygen levels.
2. Shorter lifespan of fluorescence.
3. Prone to auto-fluorescence.

Optical Polarimetry

It depends on the ideas of atoms that are chiral. Chiral particles can be characterized as those atoms that have the property to pivot the plane of spellbound light. Glucose, all things considered, is a chiral particle. It can turn the polarization plane of a light bar by alpha a clockwise way. The measure of pivot that the glucose particle produces is reliant on the grouping of the glucose just as the frequency of the laser pillar that has been utilized.

Due to its high scattering in the skin and tissue this technique is unfit for application on the skin and tissue of a person to measure body sugar levels. [6] However, it can be employed in the aqueous humor (in the eye) since it possesses excellent optical properties.

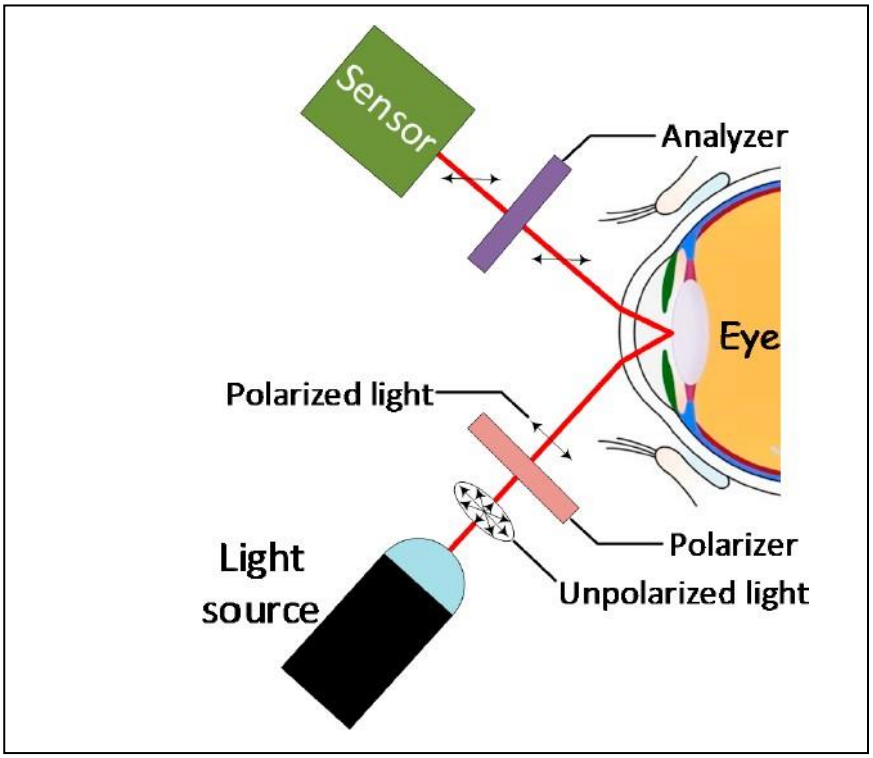


Fig 1.8 Representation of Optical Polarimetry (OP) [8]

Advantages:-

1. It has a very high resolution.
2. Optical components can be miniaturized easily.

Disadvantages:-

1. It’s very sensitive to change in the temperature & motion.
2. Lag time could be upto half an hour.

Photoacoustic Spectroscopy

This procedure utilizes short laser beats with a frequency for example consumed by a particular atom in the liquid to deliver minute limited warming. Because of the assimilated heat, there's a development in the volume of the atom, and prompts age of a ultra-sound wave that is later recognized by a weight sensor. Presently, investigation of the sign is done to connect it with the convergence of body sugar levels.

It works in two modes: consistent wave and beat mode. While the previous utilizes an adjusted Continuous Wave, bringing about a solitary recurrence in the distinguished range and a high SNR (sign to commotion proportion) the last utilizes beats (with terms in ns).

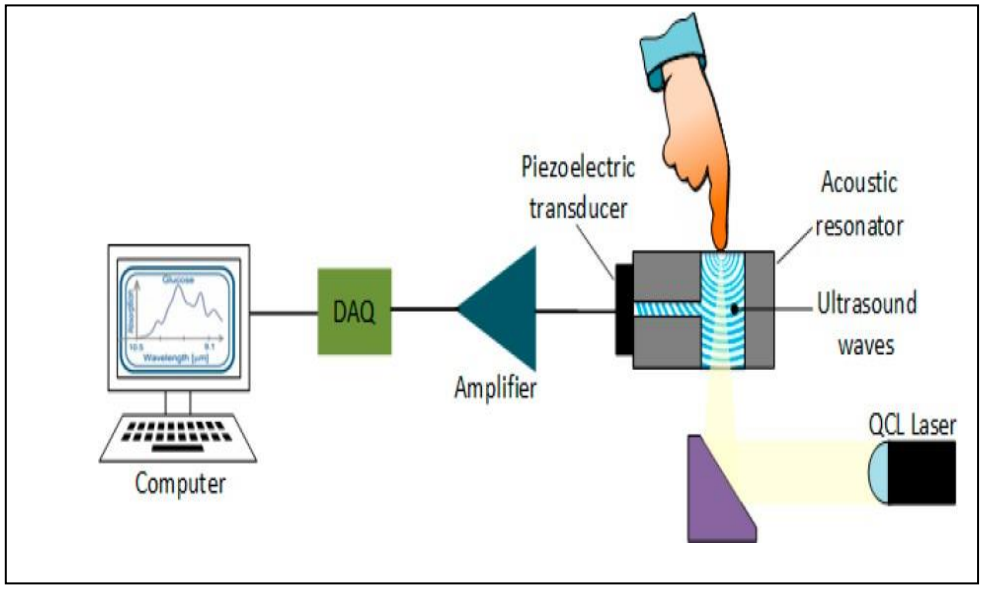


Fig1.9 Photoacoustic Spectroscopy [6]

Advantages:-

1. It's a simple method.
2. It's immune to distortion of H_2O.
3. It's not influenced by the scattering particles.

Disadvantages:-

1. Prone to interference from changes in temperature and motion.
2. Provides low SNR.

Properties of the Glucose ($C_6H_{12}O_6$)

It is the most simple form of sugar (often called or referred to as monosaccharide) found in nature. A monosaccharide is a carbohydrate that can't be hydrolysed to give simpler unit of ketone. It is produced by the process of photosynthesis carried out in the plants using sunlight as a source of energy. It is regarded as the most important "source of energy" in all of the organisms present.[7] Depending upon the number of carbon atoms present and the presence of either aldehyde or ketone group, different types of monosaccharides can be named as follows:-

Table 1.3 Monosaccharides and its different types [7]

Carbon Atoms	**General Form**	**Aldehyde**	**Ketone**
Three	Triose	Aldotriose	Ketotriose
Four	Tetrose	Aldotetrose	Ketotetrose
Five	Pentose	Aldopentose	Ketopentose
Six	Hexose	Aldohexose	Ketohexose
Seven	Heptose	Aldoheptose	Ketoheptose

Since the glucose has six number of carbon atoms and possesses an aldehyde group, it's called an aldohexose.

Preparation of Glucose

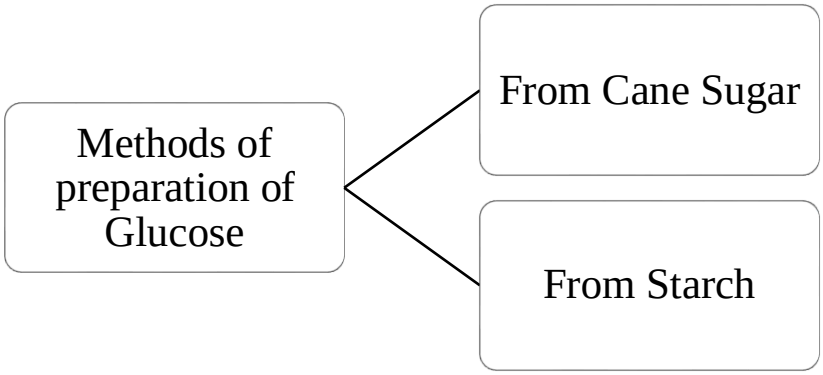


Fig 1.10 Different methods for preparing glucose

From Cane Sugar (Sucrose)

When the mixture of dilue hydrochloric acid (HCl) or Hydro sulphuric Acid (H_2SO_4) is made to boil with cane sugar (or sucrose) it leads to formation of glucose and fructose. However, both of them are produced in equal amounts. [7]

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

(Cane Sugar) (Glucose) (Fructose)

From Starch

Hydrolysis of Starch by boiling it with dilute H2SO4 at 393K also results in the production of Glucose.[7]

$$(C_6H_{12}O_5)_n + nH_20 \longrightarrow nC_6H_{12}O_6$$

Comparison between Glucose & Fructose

People often seem to be confused between Glucose and Fructose as both of them have same chemical formula. However, they are way different from one another. Their differences can be demonstrated as follows:-

Table 1.4 Glucose v/s Fructose [5]

Parameters	**Glucose**	**Fructose**
Functional Group	Aldehyde	Ketone
IUPAC Name	2,3,4,5,6 – Pentahydroxyhexanal	1,3,4,5,6 – Pentahydroxy-2-hexanone
Commercial Production	Produced by hydrolysis of starch	Produced from sugarcane
Solubility in H_20	Less soluble	Most soluble sugar
Glycemic Index	High	Lowest
Sweetness	Less	More

Different Structures of Glucose

Following are the three different structures of Glucose namely: Haworth Projection, Chair Form & Fischer Projection. [7]

a)

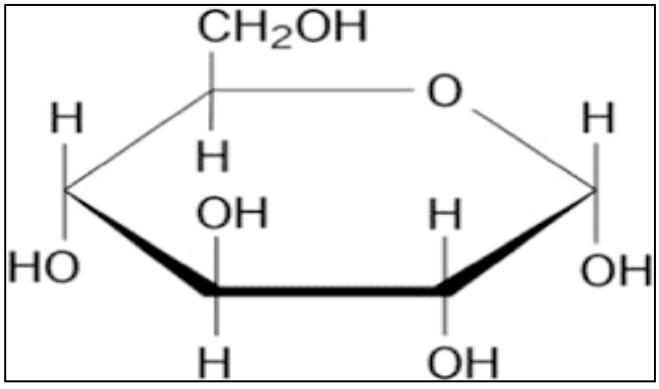


Fig 1.11 Haworth Projection of Glucose [7]

b)

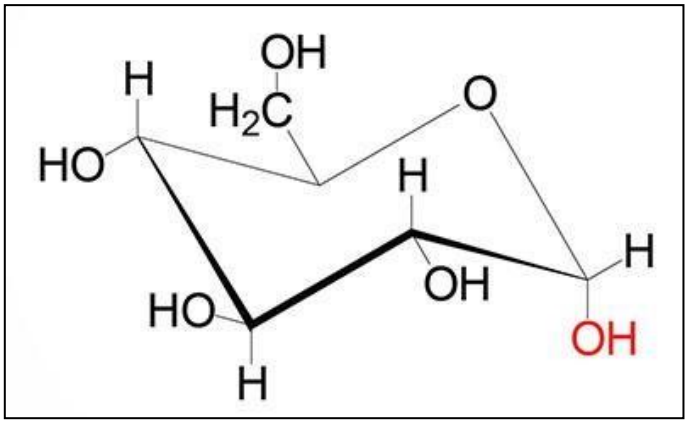


Fig 1.12 Chair Form Of Glucose [7]

c)

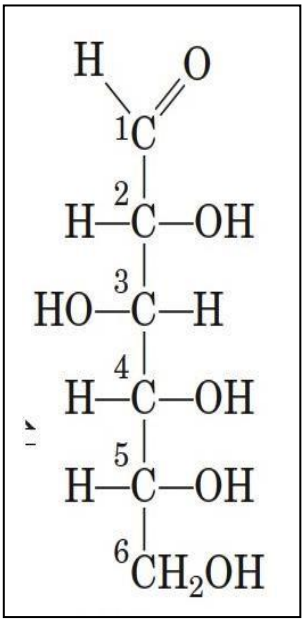


Fig 1.13 Fischer Projection of Glucose [7]

CHAPTER 2

LITERATURE REVIEW

General Approach

For measurement of body sugar levels, the device makes use of NIR emission as well as its absorbance when it passes through the glucose concentration. [4] For implementation of such a device all the basic properties (both chemical and physical) were examined. Further, the absorption of glucose at various wavelengths was also taken into consideration. Moreover, appropriate choices for selection of hardware and software were also made. Non-invasive blood glucose operation can be shown with the help of schematic as shown:-

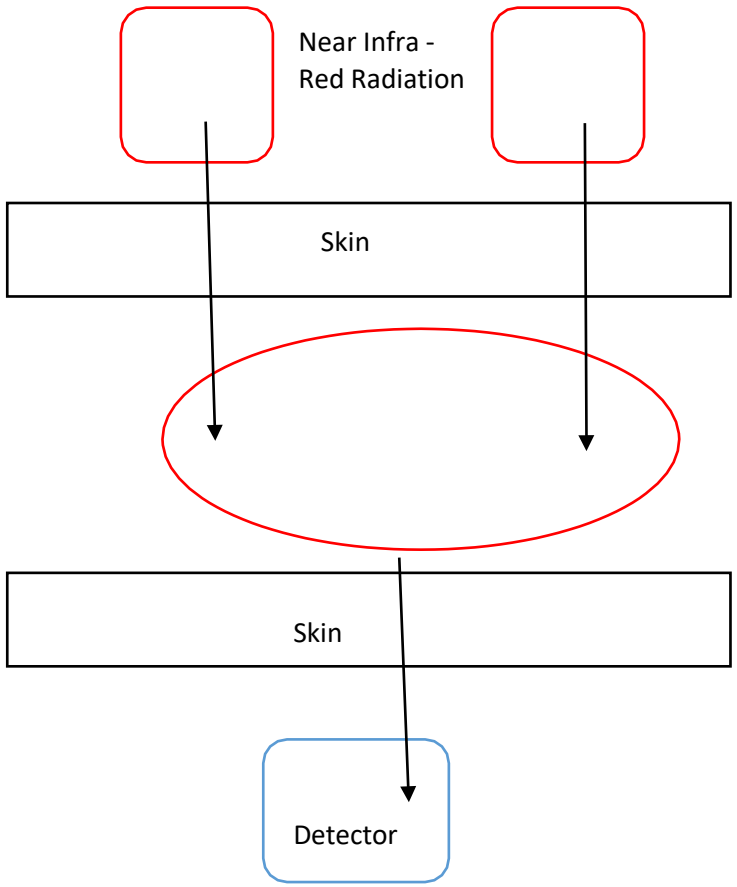


Fig. 2.1 NIR glucose monitoring schematic overview [2]

Comparison of transmittance and reflectance

Near infra-red spectroscopy can be made use to measure body sugar levels by taking into consideration either reflectance measurements of transmittance measurements. [2] Both transmittance and reflectance differ from one another. While the former requires measurement of recordings after light has passed via it latter requires measurements of readings based on the ability of the sample to reflect light. In this project, we're making use of transmittance to measure body sugar levels.

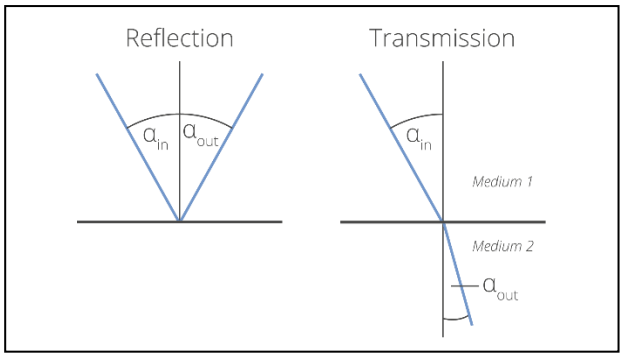


Fig 2.2 Reflection vs Transmission [2]

Basic Principle

The basic principle we made use of is that of Beer-Lambert law. It demonstrates the relationship the concentration of analyte with the absorbance or attenuation of light of different wavelengths as they pass through the sample. [2]

Mathematically, it can be expressed as follows:-

$$\mathbf{A(\lambda) = \log_{10}(I_i/I_o)}$$

Where I_i = Incident Light's intensity

I_o = Attenuated Light's Intensity

In terms of concentration, it can also be expressed as:-

$$A(\lambda) = \varepsilon CD$$

Where D = optical path length

C = Material's concentration

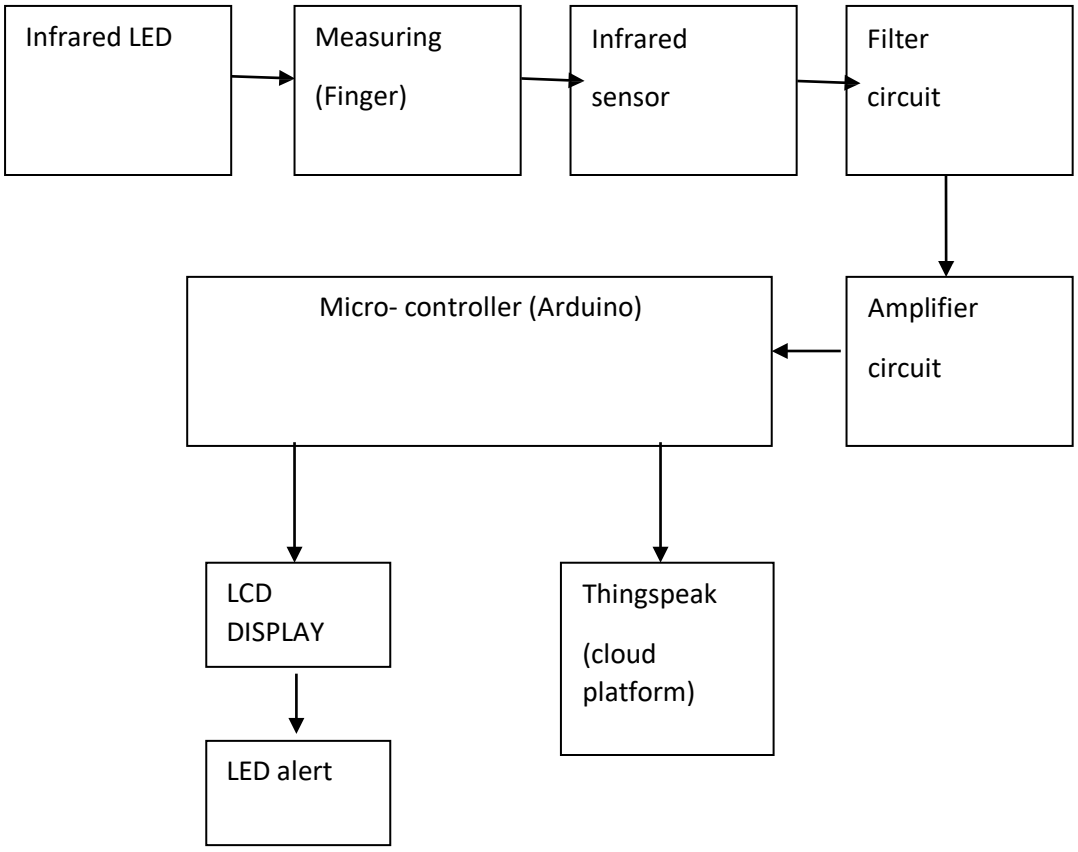
ε = Molar absorption coefficient

Therefore, as the light penetrates through the sample the intensity of light decreases as the light is absorbed by various molecules present in the sample. Further, the relationship between attenuation of light and concentration of the sample has been established by making use of Beer-Lambert's law.

CHAPTER 3
METHODOLOGY

System Architecture

Algorithm flowchart of the system



Selection of Wavelengths

Light for example lying between 700 nanometres to 2500 nanometres falls in the NIR which associates with the tissue with a generally low vitality radiation. 600 nanometres to a thousand and 300

nanometres is considered as the close infrared window. The scope of frequencies where light has its most extreme entrance profundity in tissue is alluded as NIR window. For example, glucose has light ingestion tops at frequencies of 940 nm, 970 nm, 1197 nm. In any case, at 940 nm frequency the constriction of optical signals by different constituents of the blood like H2O, platelets, RBCs (red platelets) and others is least. Subsequently, an ideal profundity of infiltration can be accomplished and genuine degree of glucose can be evaluated accurately.

System Hardware

Our fundamental goal is the investigation of IR (infra-red) range through an individual's glucose test for estimation of blood glucose. The strategy utilized is by emanation of Infra-Red light through the finger fingernail skin or ear flap. The constricted light is then gotten by the photodiode in the contrary side of Infra-Red producer. A Near Infra-Red LED, is a unique reason LED that transmits infrared beams. These are generally made of GaAs or AlGaAs. They have the capacities of hundred milli amps of present and around 3/2 to 5/2 Volts. A consistent current circuit is planned by utilizing operational intensifier for emanation of NIR light to diminish the present's variance through the NIR. The sign molding stage contains 4 phases which are talked about underneath.

Current streaming by means of the photodiode is relative to the measure of light occurrence on the photodiode. first stage comprises of trans-impedance speaker which is liable for the transformation of little changes in the current to the individual voltage. Signal is influenced because of electrical cable impedance at the yield of photodiode.

Thus, to evacuate the DC commotion and high recurrence flags, the LPF and HPF are utilized in the subsequent stage. The third stage is to keep the increase of speaker circuit in the scope of zero to hundred. At the last stage a support speaker is associated with move the impedance level of circuit for interfacing to A/D Converter. After gathering of the sign, A/D change is performed.

System Software and microcontroller

Before the glucose reading can be shown on the LCD display, the received signal must first undergo a signal conditioning stage of filtering and amplifying to filter out noise and to amplify the weak signals. The signal is then fed into the microcontroller to be converted to digital signal. The microcontroller we've used in this project is "Arduino Uno". The control algorithm coding was done in C language & developed in the open-source Arduino Software i.e. (IDE) Integrated Development Environment.

Arduino Uno

8-piece ATmega328P microcontroller structures the premise of this. It's likewise comprised of different parts, for example, a precious stone oscillator, sequential correspondence voltage controller alongside others to help the microcontroller. It has around fourteen computerized I/p and o/p pins (out of which 6 can be utilized as PWM yields), six simple info sticks, a USB association followed by a Power Barrel Jack and an In Circuit Serial Programming header alongside a reset button. [10]

Table 3.1 Various pins of Arduino Uno & its functions[11]

Pin Category	Pin Name	Details
Power	Vin, 3.3 Volts, 5 Volts, GND	Vin: I/p to Arduino when utilising external source. 5V: Regulated power supply used for micro-controller & other constituents. 3.3 Volts: 3.3 Volts supply generated by on-board voltage regulator. GND: ground purpose
Reset	Reset	Microcontroller is reset using it.
Analog Pins	A0 – A5	Provides analog i/p between zero and five Volts
Input/Output Pins	Digital Pins 0 – 13	Can be used as i/p or o/p pins.
Serial	0(Rx), 1(Tx)	Receives & Transmits TTL serial data.
External Interrupts	2, 3	Triggers the interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM o/p.
SPI	10(SS),11(MOSI),12	Used for SPI communication.

	(MISO) and 13 (SCK)	
Inbuilt LED	13	For turning LED ON.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	Provides reference voltage for i/p

Using Arduino Board

The fourteen digital input/output pins can be used as i/p or o/p pins [by using pinMode(), digitalRead() and digitalWrite() functions in arduino programming language]. Each pin operates at a voltage level of five volts and can provide or receive a maximum of forty milli amps of current, and has an internal pull-up resistor of twenty to fifty kilo Ohms which are disconnected. Functions of some pins are given as:-

- Serial Pins 0 (Rx) and 1 (Tx): Rx and Tx pins are used to receive and transmit TTL serial data.
- External Interrupt Pins 2 and 3: These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM Pins 3, 5, 6, 9 and 11: These pins provide an 8-bit PWM output by using analogWrite() function.
- SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK): These pins are used for SPI communication.
- In-built LED Pin 13: When this pin is high, LED is turned ON else it's OFF.
- Along with fourteen Digital pins, there are six analog i/p pins, each of which provide ten bits of resolution, i.e. a thousand and twenty four different set of values. They measure from zero to five Volts. With the help of AREF, this can be increased.
- Analog pin 4 (SDA) and pin 5 (SCA) also used for TWI communication using Wire library.

Arduino Uno has some other pins as well. They're explained below:-

- AREF: Provides reference voltage for analog inputs with analogReference() function.
- Reset Pin: It resets the micro-controller when the i/p is low.

Communication

Arduino can be made to speak with a PC or another Arduino board or other smaller scale controllers. The ATmega328P microcontroller gives UART TTL (5V) sequential correspondence which should be possible utilizing pin zero (Rx) and pin one (Tx) the two of which are advanced in nature.

An ATmega16U2 on the board channels this sequential correspondence over USB and shows up as a virtual com port to programming on the PC. The ATmega16U2 firmware utilizes the standard USB COM drivers, and no outside driver is required. Nonetheless, on Windows, an .inf document is required. The Arduino programming incorporates a sequential screen which permits basic printed information to be sent to and from the Arduino board.

There are two RX and TX LEDs on the arduino board which will streak when information is being transmitted by means of the USB-to-sequential chip and USB association with the PC. A "SoftwareSerial" library takes into account sequential correspondence on any of the Uno's computerized pins. The ATmega328P additionally bolsters I2C (TWI) and SPI correspondence. The Arduino programming incorporates a Wire library to improve utilization of the I2C transport.

Arduino programming

Arduino program’s structure is quite easy. They have atleast 2 blocks,

preparation & execution

```
void setup( )
{

Body
```

```
}
void loop ( )
{
Body
}
```

Here, setup ( ) and loop ( ) is preparation & execution block respectively. The former function is the 1st to execute, and it's called only once. The latter function is used for initialising the pin modes and to start the serial communication.

After the setup ( ) function is executed, the execution block runs next. It hosts statements like reading inputs, triggering outputs, checking conditions etc.

loop ( ) function is a part of execution block.

IR Sensor

An IR sensor detects IR radiation falling on it. Proximity sensors, contrast sensors and obstruction counters/sensors are some of its applications.

Principle of Working

An Infra-Red sensor involves 2 sections, the producer and beneficiary circuit. This is inside and out known as a Photo-Coupler.

The producer is an Infra-Red Light Emitting Diode and the indicator is an Infra-Red photodiode. [1] The IR phototdiode is delicate to the Infra-Red light radiated by an Infra-Red LED. In relation to the Infra-Red light got, the photograph diode's opposition and yield voltage changes. This is the essential working guideline of the Infra-Red sensor.

The sort of occurrence can be either immediate or circuitous. In direct occurrence, the IR LED is set before a photodiode with no obstruction in the middle. In backhanded rate, both the diodes are put neighboring each other with a hazy article before the sensor.

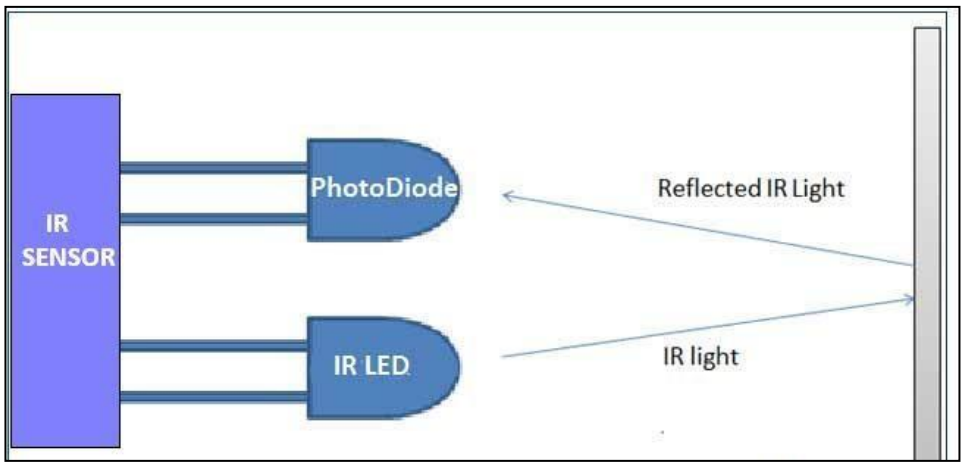


Fig 3.1 Schematic Diagram of IR Sensor

Experimental and Design Procedures

An Infra-Red computerized sensor that gives an IR radiation of around 1550 nm frequency which infiltrates through the tissue and the lessened sign which we get thusly are distinguished by photograph locator. The advanced sensor with inbuilt ADC (Analog to computerized converter) itself has IR (infrared) transmitter &receiver. The sensor is utilized on either the fingertip or ear cartilage to gauge glucose levels. The sign is gone through the RC channel to expel clamor and afterward signal is intensified and prepared by microcontroller (Arduino) and yield is appeared on the LCD. What's more, the information can additionally be shared by fusing the Wi-Fi module and can be spoken with the specialist for additional examination. The Wi-Fi module associated with the microcontroller tracks the area of patients and when the blood glucose levels of patients are not right, it shares the blood glucose report of the patient with the specialist.

Close infrared (NIR) spectroscopy lies in the scope of around 750-2500 nanometres range. This spectroscopy permits the estimation of glucose in tissues in the scope of one to hundred millimeters of profundities, with a diminishing of entrance profundity for expanding of frequency esteems. [2] The light transmitted onto the body part will be in part consumed and dispersed because of the cooperation with the concoction structures inside the tissue. The glucose fixation can be evaluated by the light power of the transmitted and reflected light.

System Implementation

Arduino Uno Microcontroller

The open-source Arduino IDE is used to write code on the sketch and the sketch is then uploaded on the Arduino board. Arduino collects the information from the 14 digital i/p or o/p pins and Analog PORT pins. It compiles the code before it has been uploaded. The Arduino boards are featured with the serial communication or COM port for displaying the output of the sensors. After the compilation and uploading is verified, the output can be viewed through the serial monitor.

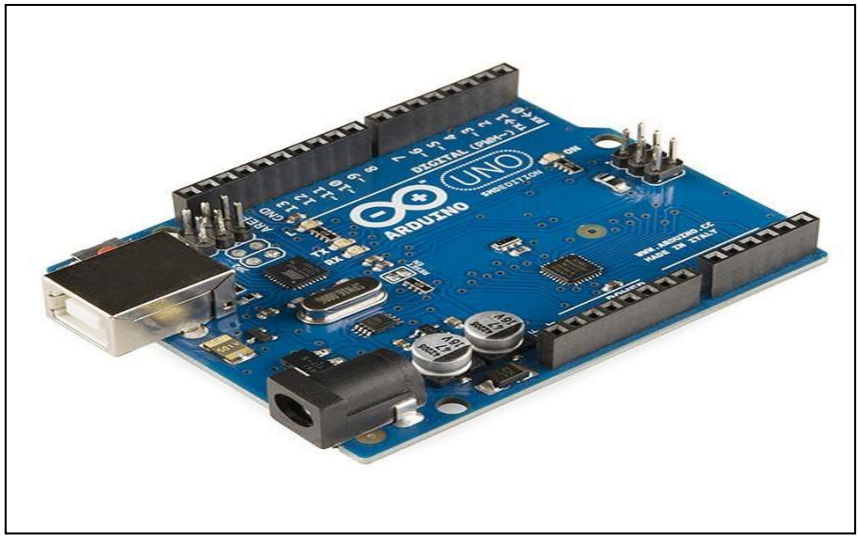


Fig 3.2 Arduino Uno Microcontroller [11]

Analog to Digital Conversion and Sensor Interface

Arduino has 6 different A/D conversion pins. These pins are connected to six different Analog output product sensors. Output from the sensor is an analog value which varies from 0 to 1023. Only the machine level language is supported by the Arduino controller. The binary value of 0 to 1023 can be considered as an output voltage varying from zero to five Volts. In our process, we are using the IR digital sensor. It has three pins (GND, V, OUT).V pin of sensor is connected to 5V of Arduino. GND pin of IR is connected to GND of Arduino. Interface OUT pin is connected to 2nd pin of Arduino Uno.VCC and GND is a supply power of the sensor. While, VCC is connected to the 5V of Arduino, GND is connected to the ground. VOUT provides the output of the sensor values of the test cases. The Analog to Digital Converter in Arduino is a “ten-bit ADC” meaning it is capable of detection of upto one thousand and twenty four discrete analog levels.

LCD 16*2 display:-

The output of the body sensor values are shown in the LCD. All the output pins from the Arduino are connected to the LCD to display the output values. When it comes to displaying of output on the LCD, the values are generated by the program which is been mentioned in the Arduino IDE.

Fig 3.3 A 16*2 LCD Display

IoT Monitoring and Connection Details

The Internet of Things (IoT) checking is for the most part dependent on the Communication Protocol Operation. Through the simple port, Arduino gathers all the sensor esteems. They can be changed over to computerized sign and afterward they can be put away in an Arduino controller. This put away sensor esteems are sent to the ESP8266 by means of the activity of correspondence convention. Along these lines of association is called TTL association (Transistor-Transistor-Logic).In Arduino microcontroller, TX and RX (Pin number 0 and 1) are utilized as a correspondence port. These pins are utilized for sending and accepting the detecting information to different gadgets. To screen the sensor esteem, TX pin of the Arduino controller is associated with the RX of the observing convention gadget. To control any object or burden gadget, TX pin of the controlling convention gadget associated with the RX pin of the Arduino.

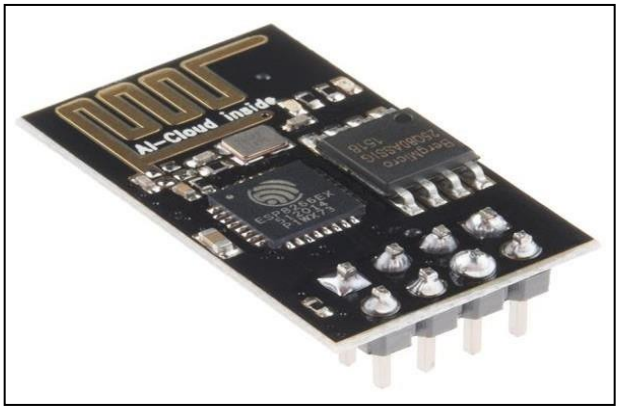


Fig 3.4 ESP 8266 Wi-Fi Module

Scope of the Project

This task involves the utilization of NIR with the end goal of estimation of the fixation levels of C6H12O6. Investigation of the information will be accomplished for the development of a model to best examine the glucose levels.

Chapter 4

Another Methodology

Humidity & Temperature Sensor:-

It comprises of three components which are as follows:

- humidity sensing component
- thermistor (NTC)
- integrated chip on its back

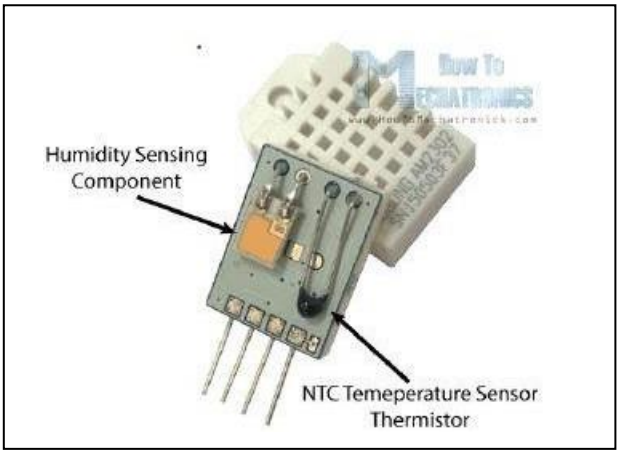


Fig 4.1 Internal Diagram of DHT11 Sensor [12]

In order to measure the humidity, it makes use of the humidity sensing component. This humidity sensing component comprises of "two electrodes" having a substrate that holds moisture between them. Any change in humidity levels results in change in either the conductivity of the substrate or the resistance between the two electrodes present. The integrated chip present in it is responsible for measurement of the change in resistance as well as its processing which can further be made use by a microcontroller.

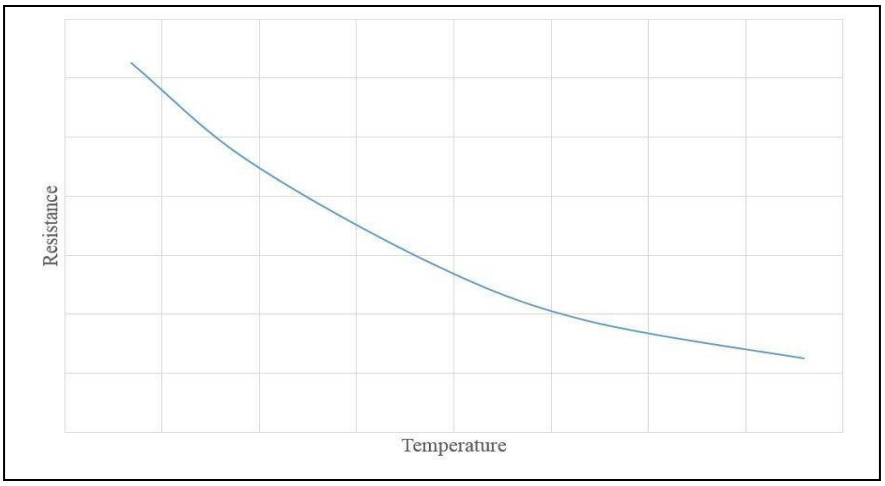


Fig 4.2 Working Principle of Temperature Sensor

For measurement of the temperature, it makes use of a NTC i.e. Negative Temperature Coefficient Sensor. A thermistor is basically a gadget that shows change in obstruction comparing to changes in temperature.

Sintering of ceramics or polymers results in their production which enables them to provide a higher resistance change even if a little change in temperature. NTC embarks the decrease in resistance for increase in the temperature.

The humidity and temperature sensor (DHT11) consists of four pins VCC, GND, data pin as well as a no connection pin which is of no use. A pull-up resistance varying from five kilo-ohms to ten kilo-ohms is there for provision of two purposes. First, in order to communicate between the sensor and the Arduino and secondly, for keeping the data line high.

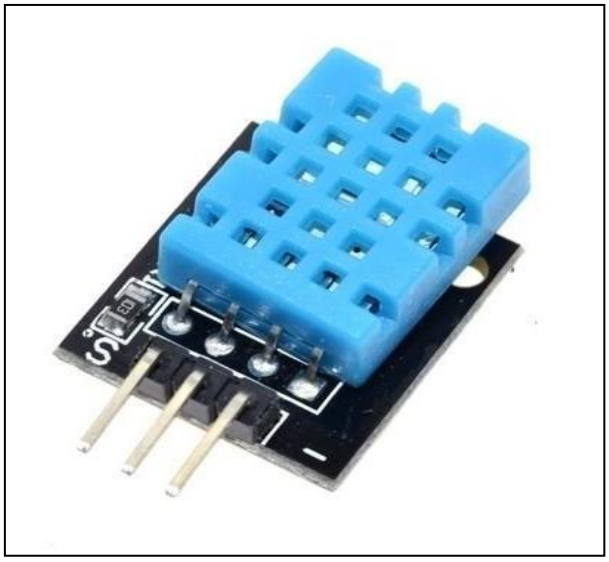


Fig 4.3 DHT11 Sensor

Introduction:-

The disease diabetes has turned out to be a major problem in the world and has increased many folds over the years. When instead of the glucose, the body makes use of fat for providing energy to the body the chemical ketones tend to appear in the body. Further, the testing of ketone is claimed to be an essential part for detection of diabetes, type-1, in particular. Therefore, if an effort is made to detect ketone levels in the body, then the diabetes of a person can be detected as well as regulated. Invasive methods like the blood test among others are very popular for detection of diabetes however, they are too expensive and often painful and sometimes even lead to production of biological waste like syringes which is difficult to dispose off. Acetone , results in the sweet odor of a diabetic person and is also associated with the metabolism of glucose in the body.It has also been reported that the level of concentration of acetone is relatively higher in a diabetic patient.

Procedure:-

FIGARO TGS 822 gas sensor will be made use of for the detection of ketone level (acetone, in particular) in the breath of a diabetic patient. It works in the following way, as soon as a person's acetone level in the breath increases, there is a decrease in the resistance of the gas sensor. This decrease in resistance of gas sensor depends upon the following three factors:-

- Humidity
- Temperature
- Concentration of the gas

Since we wish to get an accurate result a (DHT11) is added. Further, the reading is send to the Arduino module which is thereafter shared via the ESP8266 (Wi-fi Module).

Flow Chart:-

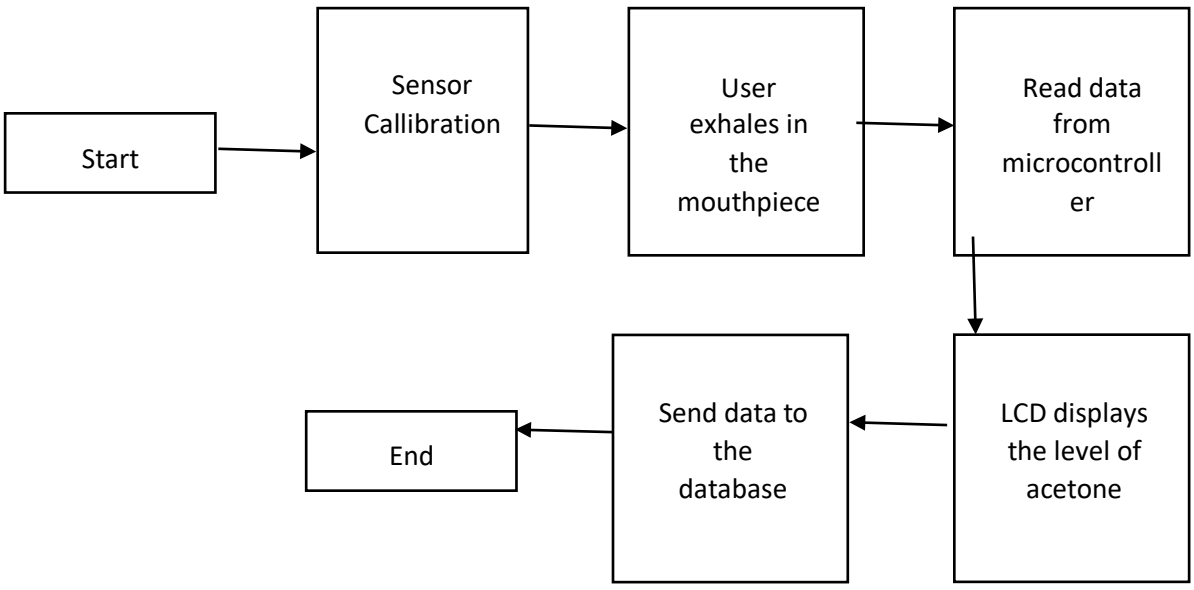


Fig 4.4 Flow Chart for detection of acetone gas level

Figaro TGS 822 sensor is used for the detection of acetone levels in breath. It is connected to the anlog pin 0. There's an obvious requirement for conversion of ketone level from mmol/l to parts per million(PPM) since the sensor reads only values in PPM.

The below given table demonstrates the level of ketone and the action that needs to be taken for a value of level of ketone in the body.

Table 4.1 Level Of Acetone and Action Required

Exhaled Breath Acetone	**Required Action**
Less than three	Normal
Between three and seven	Insulin required
Greater than seven	Immediate medical attention required

Block Diagram:-

Here, we make use of the Figaro TGS 822 acetone gas breath sensors as well as humidity and temperature sensor DHT11 as inputs to the microcontroller which is responsible for data collection from both the sensors. The data is processed upon by the microcontroller and then shared into the web by making use of the Wi-fi Module. Two Arduinos namely Arduino Uno and Arduino Mega have been put to use. While the former has been used to read the value from the sensor, the latter is used to connect to Wi-fi Module. The acetone gas breath sensor Figaro TGS 822 is connected through a ten

kilo-ohm resistance to the analog pin “0” of Arduino to form a voltage divider circuit. The humidity & gas sensor is connected to digital input pin ten of Arduino.[12]

We have made use of two Arduinos since the gas sensor itself consumed a lot of power supply. Since ESP 8266 requires 3.3 Volts hence it can’t be connected directly to the Arduino which drives at 5 Volts. Hence, two different Arduinos have been used for different purposes.

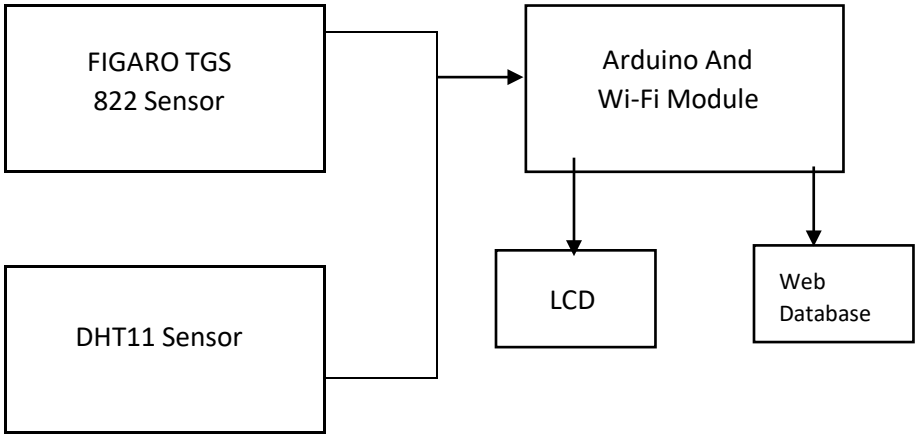


Fig 4.5 Block Diagram of the system

Figaro TGS 822 Gas Sensor

Features Of The Sensor

a) It Has High Sensitivity Towards The Gas Sensor Such As Acetone
b) High Stability And Reliability
c) Low Cost And Long Life
d) It Has A Simple Electrical Circuit

Aplications Of The Gas Sensor

a) Breath Alcohol Detector
b) Gas Leak Detector

c) Solvent Detector For Factories.

Figaro gas sensor is a semiconductor material and the sensing element present in the gas sensor is tin dioxide (SnO_2) semiconductor. It has low conductivity in clean air. However, when a gas is detected, depending on the concentration of the gas in the air, ther is a rapid increase inthe conductivity of the sensor.

The TGS822 sensor is highly sensitive to the fumes of the organic solvents. It's also sensitive to the numerous gases such as CO i.e. Carbon Monoxide.

Fig 4.6 Figaro TGS 822 Sensor [12]

The ceramic base variant of this sensor is highly resistant to harsh surroundings such as temperatures upto as large as two hundred degree Celsius.

Sample E-circuit Diagram

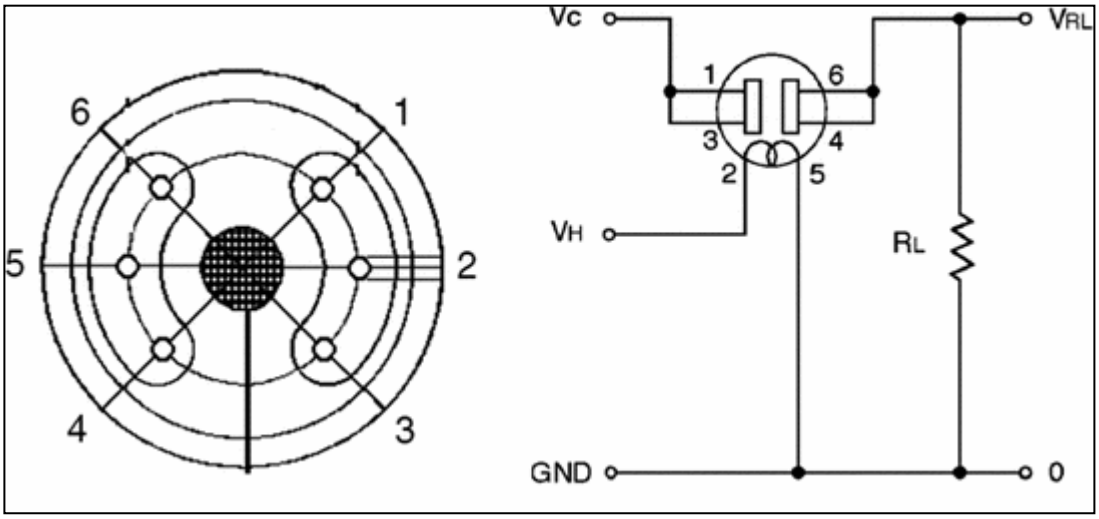


Fig 4.7 Sample e-circuit diagram of the gas sensor[12]

Table 4.2 Pin Diagram explanation of the gas sensor circuit

Pin No. 1 & 3	Vc-24 Volts (Max.)
Pin No. 2	V_H (Heater Voltage) – 5+0.2Volts or 5-0.2Volts
Pin No. 5	Gnd (Circuit Voltage)
Pin No. 4 & 6	V_{RL}(Load Resistance) variable 0.45K (Min.)

Conditions of the circuit :-

Table 4.3 Conditions of the gas sensor circuit

Item	Symbol	Related values	Remarks
Higher Voltage	VH	5V	Alternating Current or Direct Current
Circuit Voltage	Vc	Less than twenty four Volts	Direct Current only
Load Resistance (R_L)	R_L	Variable	450 ohm minimum
Earth	GND	0	0

Electrical Characteristic of the circuit:-

Table 4.4 Electrical Characteristics of the gas sensor circuit

Item	Symbol	Condition	Specifications
Sensor's Resistance	Rs	Ethanol at 300 parts per million per air	1kilo ohms - 1000Ω
Change Ratio of Sensor Resistance	Rs/Ro	Rs (Ethanol at 300ppm per air)/ Rs (Ethanol at 50ppm per air)	0.30 to 0.50
Heater Resistance	R_H	at 25 degree C	35 to 41Ω
Heater Power Consumption	PH	V_H WILL BE 5V	660 mW

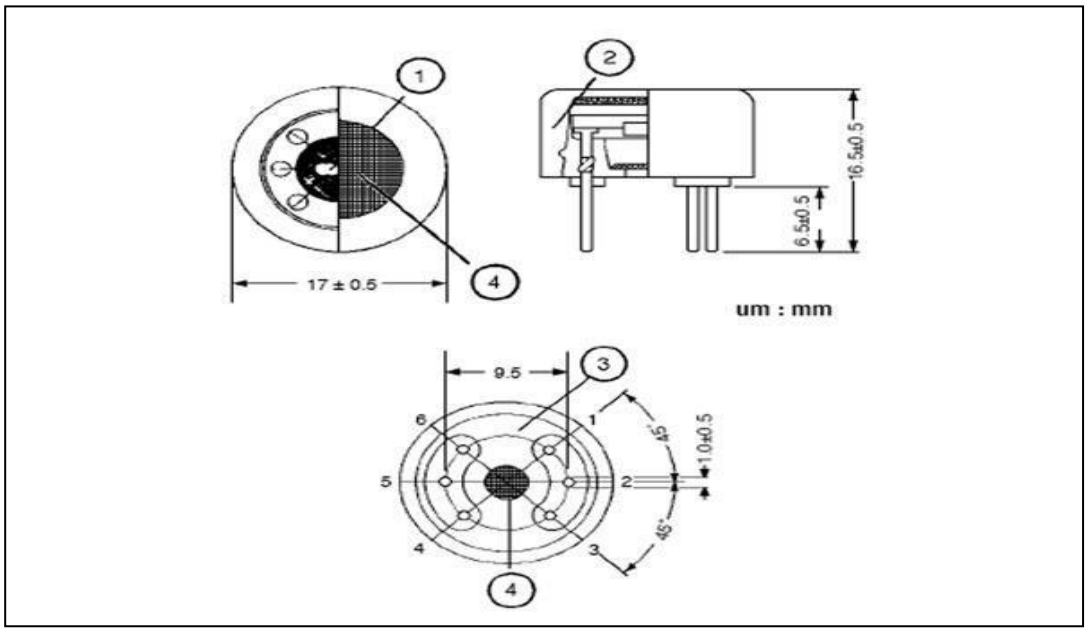


Fig 4.8 Structure and dimension of the gas sensor

The above Figure shows the structure And dimensions of the Gas sensor.

The (1) is the sensing element, (2) is the cap, (3) is the sensor base and (4) is the flame arrestor.

Standard test conditions of the circuit:-

TGS 822 operates with the characteristics(electrical) as mentioned above.

Test Gas Conditions: Eighteen to twenty two degree celsius, 65 ± 5 % R.H.

Circuit Conditions:

VC = 9.9 Volts to 10.1 Volts (AC or DC),

VH = 4.95 Volts to 5.05 Volts (AC or DC),

RL = 10 Kilo ohms ±1%.

Rs is the sensor resistance is calculated by the formula given below:-

$Rs = (Vc/V_R -1)* VRL$

Formula used for the calculation of Power dissipation across sensor electrodes (Ps) is as shown:-

Ps = VC2 *Rs /(RS+RL);

Temperature and humidity dependency

The figure below demonstrates the dependency of the humidity and temperature characteristics. Sensor resistance ratio is embarked on the y-axis and can be calculated using the below given formula:-

Rs = Resistance of the sensor at 300 ppm of ethanol

Ro = Resistance of the sensor at 300ppm of ethanol at 20°C and 65

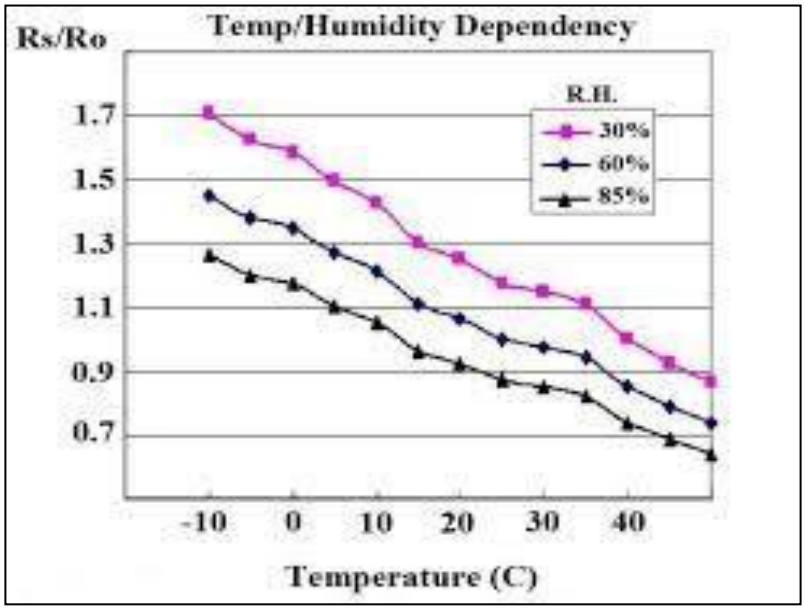


Fig 4.9 Temperature and Humidity dependency of the gas sensor

Analysis and Interfacing

For doing the analysis of level of glucose from the breath, four parameters were considered from the two different sensors which are resistance along with voltage from Figaro TGS822 i.e. acetone gas sensor and humidity&temperature from the DHT11 sensor. All of this data was given to Arduino Uno as shown in fig 4.10.

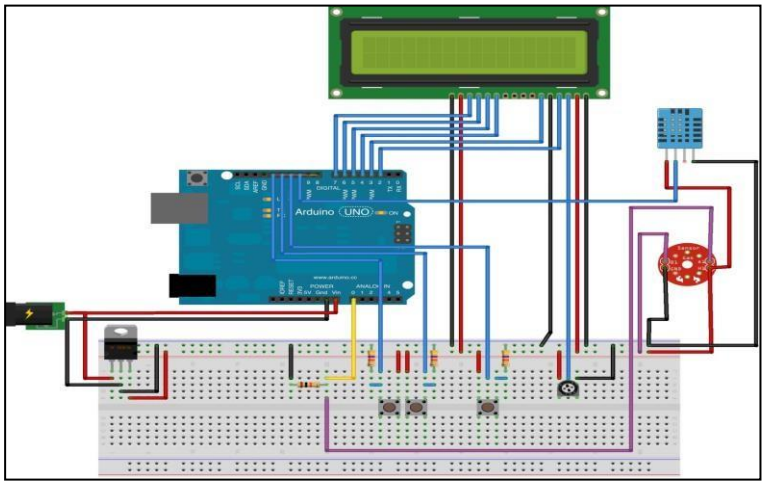


Fig 4.10 Connection of Arduino Uno with DHT11 and Figaro TGS822 Sensor

4.3.1 Connecting DHT11 sensor with Arduino Uno

DHT11 is Micropik'sa Digital Temperature&Humidity sensor. It estimates dampness, ranges from twenty to 90% with a goals of 1% and temperature from zero to fifty degree celsius with a goals of one. It works at 5V DC gracefully.

It sends forty piece information on a solitary information line which incorporates 16 piece Relative-Humidity, 16 piece Temperature (8bit whole number temperature information + 8-piece decimal temperature information) and 8-piece checksum. The 40bit single information line is associated with the microcontroller board peruse the lative Humidity and Temperature sensors.

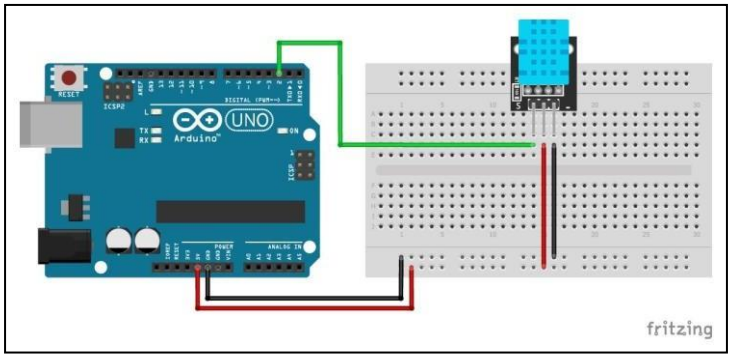


Fig 4.11 Connection of Arduino Uno with DHT11 Sensor

Interface With Microcontroller

The gas sensor is linked to pin zero. Here, the ketone level is in unit of milimoles per litre. Terefore, there's a requirement for conversion of the value of the sensor from parts per million to milimoles per litre. For this we will require the molar weight of acetone which is "fifty-eight". Humidity & temperature are also taken into consideration so that acetone's gas concentration can be predicted correctly.

Coding for the reading of sensor

```
// Sensor read 3 and store values after 5ms delay
float ppmToMmol (int PPM)
 {
float mmolVal = (((float) PPM / 1000) / 58.08);
mmolVal = mmolVal * 1000;
return mmolVal;
}

void sensor1( )
{
```

```
    gasVal1 = analogRead (0);
    Serial.print ("gasVal1");
    delay (5);
    gasVal2 = analogRead (0);
    delay (5);
    gasVal3 = analogRead (0);
    Serial.begin(9600);
}
```

Table 4.5 Range of ketone level condition

Blood β-hydroxybutyrate (mmol/l)	Breath Acetone (ppmv)	Action required
Less than 0.6	Less than 3.0	Normal
0.6 – 1.5	3.0 – 7.0	Requirement of Insulin
1.5 – 3.0	>7.0	Seek medical attention

Interfacing and Working of All Sensors With Arduino Uno

Two sensors are utilized as the I/ps in this framework. Small scale controller plays out the errand of assortment of the information from these sensors. The information in the wake of being prepared is broke down while the smaller scale controller further dipalys the qualities LCD screen. Later,the yield is then sent into the web database through ESP8266.

We will utilize 2 Arduino Unos. While the previous will be utilized to peruse the sensor esteem. Acetone sensor is connected to simple pin zero with a 10 kilo-ohms resistor to shape a voltage divider circuit. Temperature and stickiness (DHT11) sensor is associated with computerized input pin ten. The last will be associated with WI-FI module (ESP8266).

Since the gas sensor expends a ton of intensity two Arduinos will be utilized. On the off chance that lone a solitary Arduino Uno is utilized to join among sensors and ESP8266 (wifi-module), the gadget may get unsteady.

Since the wifi-module drives at 3.3Volts consequently it can't be legitimately gotten together with Arduino as it works at a voltage of 5 Volts. This is the motivation to interface ESP8266 with various Arduinos so the force gracefully for the two sensors and ESP8266 can be given out appropriately.

So as to keep up 3.3V force flexibly the voltage controller isn't sufficient. Hence, voltage divider is made to deliver a voltage that is only a segment of the first. Three point three volts is accomplished by utilizing a voltage divider circuit comprising of three units of 1 Kilo-ohm resistors. The gas sensor's steadiness is exceptionally subject to the estimation of humidity&temperature.

The ketone level perusing is appeared in milimoles per liter. The most noteworthy incentive for the degree of the ketone is taken as the right outcome.

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