# CHAPTER ONE

# INTRODUCTION

## 1-1 General view

Diabetes mellitus is a serious disease that affects not only the patient's internal organs , circulation system and eyesight, but also his entire life[1]. Instruments now used for the self-monitoring of blood glucose (SMBG) are almost all invasive types that require a drop of blood to be withdrawn from a fingertip or other measurement site on the body by a need to puncture. This leads the diabetic patient to suffer pain and also involves a risk of infection. There is a need for a glucose monitoring system that can provide detailed information on glucose patterns throughout the day. In addition, such a system provides an opportunity to sound alarms for rapid declines in blood glucose values, in order to reduce the risk of hypoglycemic events. A number of alternative strategies, including implanted glucose sensors, tissue fluid sampling and non-invasive technologies, are being under development to allow pain free glucose monitoring. Non-invasive glucose monitoring is clearly the most attractive approach for patients with diabetes, allowing more frequent, at best even continuous, measurements without any pain or sensation[1]. The integration between continues – non invasive – measurement instruments and telemedicine techniques can improve the health care quality for diabetic patients and provide them with better life style.

## 1-2 Problem Statement

Diabetes of all types can lead to complications in many parts of their body and can increase the overall risk of dying prematurely. Optimum insulin dosage requires continuous complete monitoring of blood glucose level , currently available glucometers do not address this requirements. Continuous monitors do exist , but they need to be implanted under the skin - causing trauma while being implanted - and they need to be replaced every week , also they don't include all the role players in the monitoring process which can lead to decrease the efficiency of the overall medication process .

## 1-3 Objectives

The general objective is to Design and implementation of a painless, portable and affordable monitoring system for diabetic patients that gives continuous measurement of glucose concentration and help in providing better monitoring and better lifestyle for the patients.

The specific objectives are to provide minimum pain and Minimum discomfort , Connecting the role players in the medication process and to take advantage from the smart phones in analyzing and displaying the sensed data .

## 1-4 Methodology

This research had been divided into two sections , designing a continuous glucose measurement sensor and designing an android application for the role players in the medication process. The sensor included an IR laser source and acoustic transducer which works depending on photoacoustic phenomena , the sensor had been connected to the android application using Bluetooth module and both the sensor and the application obtained an acceptable results **.**

## 1-5 Thesis layout

The research consist of six chapters , chapter one introduces general view for research, problem statement and objectives **,** while chapter two represents the literature reviews ,chapter three represents the theoretical background. System design and implementation have been illustrated in chapter four **,** chapter five shows results and discussions and chapter six includes conclusion and future recommendation.

# CHAPTER TWO

# LITERATURE REVIEWS

## 2-1 Remote Online Vital Signs Processing For Patient Monitoring and Diagnosis M. Abo-Zahhad*, Sabah M.Ahmed, O. Elnahas,2015[13]

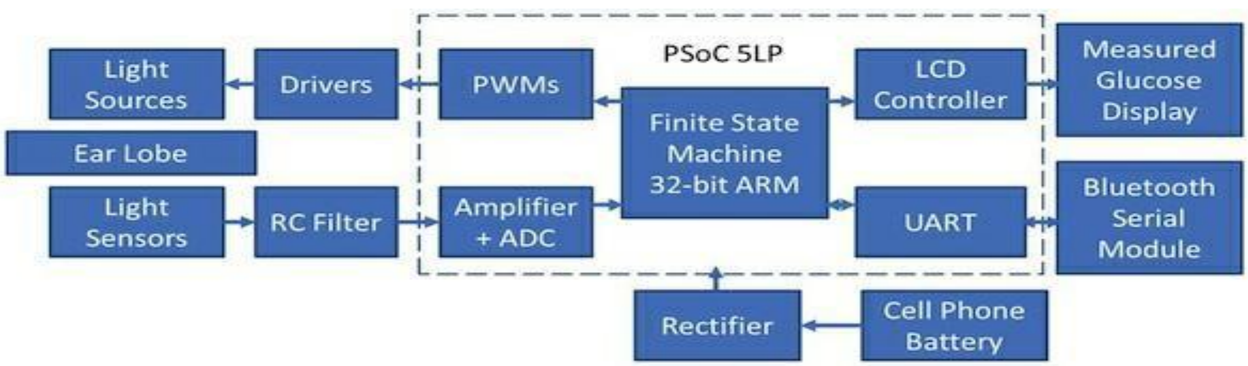
The objective of this study is to design a Remote patient monitoring system which is based on a combination of advanced remote monitoring devices, telecommunication technology, and innovative software and hardware. As mobile phones become more powerful and perform more complex interactions between mobile devices to resident software and other server based software, they have been recognized as effective tools for telemedicine. So, the merging of the Internet and mobile computing, introduce new opportunities and challenges in the telemedicine sector. This study describes the development and implementation of an Android based smart phone in the home monitoring health care system. The system utilizes Android devices as mobile access terminals for patient-monitoring services.

The main goal is subsequently divided into two parts: in the first part we establish a reliable connection between mobile device and a sensor to collect continuous data from patients. In the second part we provide

ElectroCardiGram (ECG) and Photo-PlethysmoGraphy(PPG) signal filtering and processing, feature extraction, detection of any abnormalities in ECG and calculating heart rate using the most familiar and multi-purpose MATLAB software.

## 2-2 Noninvasive prediction of glucose by near-infrared diffuse reflectance spectroscopy, S.F. Malin,(2000),[11]

This study focuses on near Infrared transmittance spectroscopy which is used across the ear lobe to measure glucose. Transmittance spectroscopy involves a light source and a light detector positioned on either side of the ear lobe. The amount of near infrared light passing through the ear lobe depends on the amount of blood glucose in that region. The ear lobe was chosen due to the absence of bone tissues and also because of its relatively small thickness . Near Infrared (NIR) light is applied onto one side of the ear lobe, while a receiver on the other side receives the attenuated light. This attenuated signal is then sampled and processed. Two LEDs from Thor Labs (LED 1550E) were used as the light source. Since conventional silicon photodiodes have limited spectral bandwidth, they cannot be used for receiving near infrared light; therefore other types of photodiodes must be considered.




**Figuer(2.1)** shows a high level system diagram of the complete process.

## 2-3 Mid-infrared spectroscopy (Mid-IR), O.S. Khalil,(2004),[9]

Mid-infrared (Mid-IR) spectroscopy is based on light , in the 2500–10,000 nm spectrum . The physical principle is similar to that of NIR. When compared to NIR, due to the higher wavelengths, Mid-IR exhibits decreased scattering phenomena, and increased absorption. For this reason, the tissue penetration of light can reach a few micrometers , in the case of human skin, that corresponds to the stratum corneum. As a consequence, only reflected, scattered light can be considered, there is no light transmitted through a body segment. On the other hand, a possible advantage of Mid-IR compared to NIR is that the Mid-IR bands produced by glucose, as well as other compounds, are sharper than those of NIR, which are often broad and weak. Mid-IR is less studied technique compared to NIR for glucose measurement, probably due to the strong limitation in penetration. Studies are reported related to finger skin and oral mucosa.

## 2-4 Electromagnetic sensing, M. Gourzi,(2003),[10]

This technique detects the dielectric parameters of blood. In the former an electric current is used, while in the latter the electromagnetic coupling between two inductors is exploited. The inductors are turned around the medium under study  an invitro context, the system can be described by the sketch reported in Figure bellow. The tubes, simulating the human veins, contain blood. To make the experiment more realistic, the tubes can be covered by gelatin, which simulates (although roughly) the tissues surrounding blood vessels in the in vivo context. The electromagnetic coupling of the two inductors is modified by variations in the dielectric parameters of the solution, i.e. blood in this case. However, depending on the temperature of the investigated medium, there exists an optimal frequency, where the sensitivity to glucose changes reaches the maximum For instance, at 248C optimal frequency is 2.664 MHz

The temperature has a strong effect on the Measurement; since it also influences the optimal investigation frequency, temperature measurement has to be performed and the information properly considered. Furthermore, the blood dielectric parameters depend on several components other than glucose.

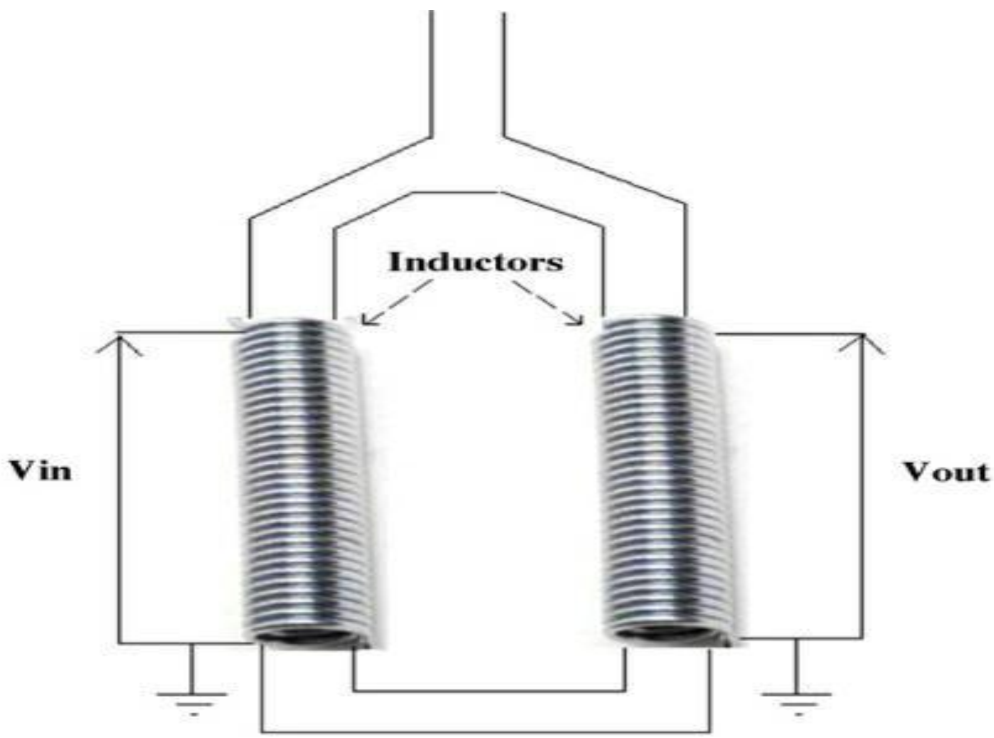



**Figure (2.4)** Sketch of the electromagnetic sensing system

## 2-5 Monitoring blood glucose changes in cutaneous tissue by temperature-modulated localized reflectance measurements, S.J. Yeh, C.F. Hanna,(2002),[12]

This study is based on the observation that temperature changes causes variations in the tissues refractive index (which influences the light scattering),but on the other hand the entity of these changes depend upon glucose concentration . More specifically, the temperature modulation of the localized reflected light due to scattering is analyzed. Glucose concentration is estimated with localized reflectance signals at 590 and 935 nm. In some studies, a probe was placed in contact with the skin and the probe temperature was varied between 22 and 38 8C. After each variation, skin was equilibrated for some minutes. During each of those intervals some light packets were collected, related to glucose concentration. Several parameters can affect this kind of measurements, both physiological and technical (such as the probe position). Also a peculiar health status, such as an inflammatory state with possible fever condition, can in fact affect the measurement.

# CHAPTER THREE

# THEORITCAL BACKROUND

## 3-1 Diabetes

Diabetes is a condition in which the pancreas of the body ceases to produce insulin, which controls blood glucose levels. The causes of diabetes in humans are not yet fully understood, but the widely accepted hypothesis is that it may be genetic and may be caused by a high sugar intake as part of a daily meal serving [4]. Once diabetes is diagnosed, the blood sugar level needs to be continuously monitored in order to facilitate medicinal insulin intake. Patients with hyperglycemia, in which continuously high blood glucose levels are exhibited, may require continuous blood glucose monitoring [4]. People who think they might have diabetes must visit a physician for diagnosis. They might have SOME or NONE of the following symptoms:

1. Frequent urination.
2. Excessive thirst.
3. Unexplained weight loss.
4. Extreme hunger.
5. Sudden vision changes.
6. Tingling or numbness in hands or feet.
7. Feeling very tired much of the time.

8. Very dry skin.
9. Sores that is slow to heal.
10. More infections than usual.

At present, no cure is available for diabetes but if patients adhere strictly to a proper diet, exercise, medication and make frequent measurements of blood glucose, they are able to maintain their health, and indeed, lead relatively normal lives. If simple, inexpensive, reliable tests were available, they could make those measurements as well and as often as required. The measurement of blood glucose by any technique is inherently complex because of the wide range of potentially interfering components. For a noninvasive technique, not only are there many analytics within human blood that could interfere with the measurement, but there are also other problems such as the variability and inhomogeneity of human skin and the constantly changing human physiology. The invasiveness of the testing procedure for diabetes plays a contributing role to the fact that nearly one-third of the population with diabetes goes undiagnosed. It is for this reason that a method for noninvasively monitoring glucose levels is highly desirable for patients with diabetes which would allow for more frequent and possibly continuous monitoring without the pain that is associated with current commercial glucose monitors. According to the World Health

Organization[2]. "As per facts about diabetes, 90 to 95% of the world diabetics have diabetes type 2,They get it around age 40[2]. It is an alarming fact that, of late, this global epidemic has started coming up in children too. More alarming is that 90% of them are also obese. What is dangerous about diabetes type 2 is that more than 15% of those do not know that they have it. It comes up silently without showing its symptoms. According to the World

Health Organization, 170 million people have diabetes worldwide and this number may well double by the year 2030. If a family history of diabetes exists; there is a more likely opportunity to develop diabetes[2].

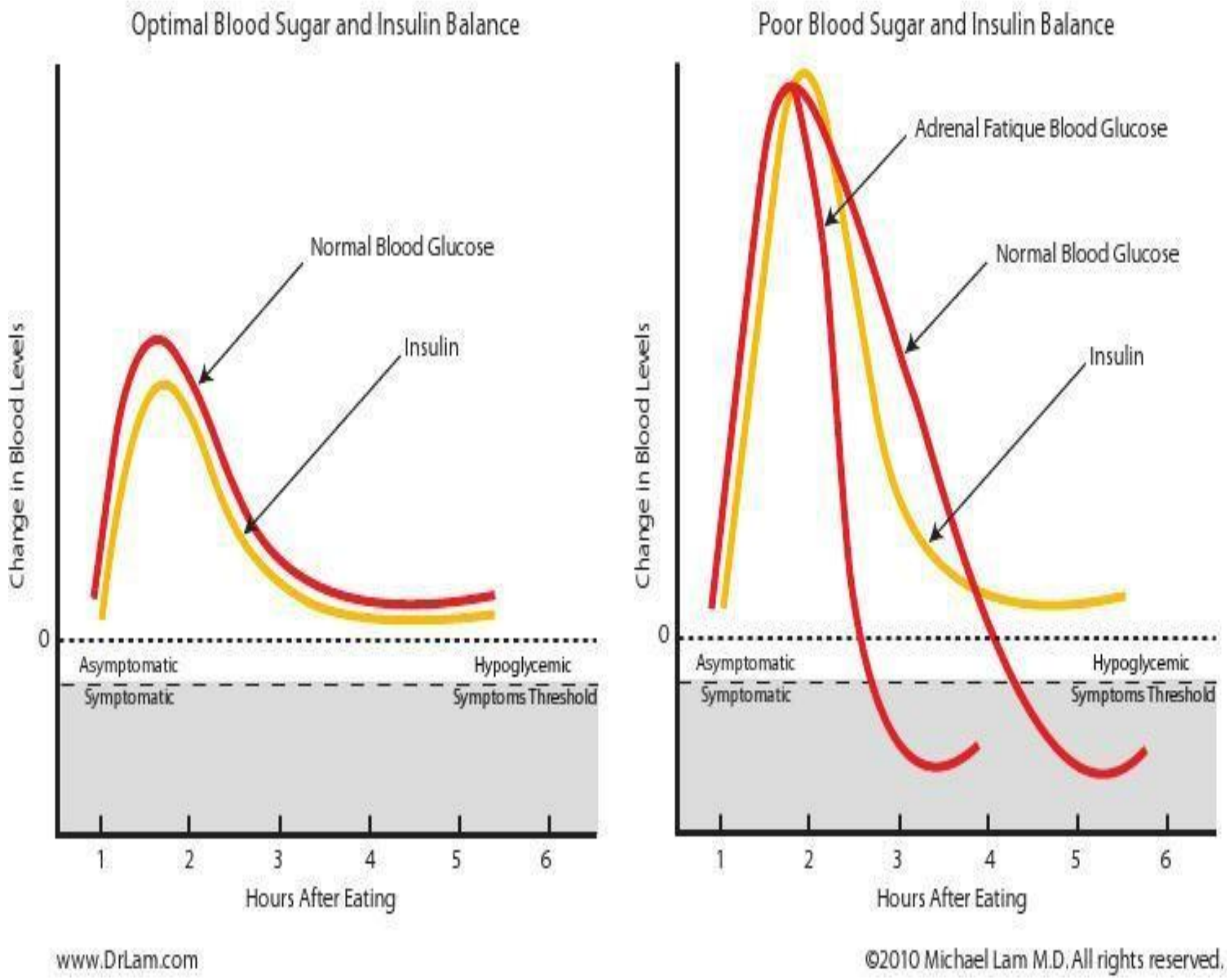



**Figure (3.1):** The normal cycle of glucose and insulin .

## 3-2 Glucose measurement

Blood glucose monitors are used to measure the amount of glucose in blood, especially of patients with symptoms or a history of abnormally high or low blood glucose levels. Most commonly, they enable diabetic patients to administer appropriate insulin doses. The availability of home-use glucometers, as opposed to clinical-use equipment, has greatly improved the quality of life of such individuals [3]. There are two ways to control blood sugar for diabetics and are:

**1. Invasive glucose measurement**

Measurement are done by pricking a finger and extracting a drop of blood which is applied to a test strip composed of chemicals sensitive to the glucose in the blood sample. An optical meter (glucometer) is used to analyze the blood sample and gives a numerical glucose reading.

**2. Noninvasive glucose measurement**

Refers to the measurement of blood glucose levels (required by people with diabetes to prevent both chronic and acute complications from the disease) without drawing blood, puncturing the skin, or causing pain or trauma. All non-invasive optical methods utilize a beam of light to irradiate some selected part of the human body, such as a finger, the forearm, tongue, lip, thigh or abdomen and so on. Light that is transmitted through, reflected or scattered out of the skin comprises information about the composition of the illuminated tissue. This light is then received by optical detectors and analyzed to determine the concentrations of certain analytes, such as oxygen or hemoglobin.

## 3-3 Photo-acoustic spectroscopy (PA spectroscopy)

Photo-acoustic spectroscopy is the measurement of the effect of absorbed electromagnetic energy (particularly of light) on matter by means of acoustic detection. The discovery of the photo-acoustic effect dates to 1880 when Alexander Graham Bell showed that thin discs emitted sound when exposed to a beam of sunlight that was rapidly interrupted with a rotating slotted disk. The absorbed energy from the light is transformed into kinetic energy of the sample by energy exchange processes. This results in local heating and thus a pressure wave or sound. Later Bell showed that materials exposed to the non-visible portions of the solar spectrum. The photo-acoustic effect can be used to study solids, liquids and gases.

Modern photo-acoustic detectors still rely on the same principles as Bell's apparatus, however to increase the sensitivity the following modifications have been made:

1. Use of intense lasers instead of the sun to illuminate the sample since the intensity of the generated sound is proportional to the light intensity.

2. The ear has been replaced by sensitive microphones. The microphone signals are further amplified and detected using lock-in amplifiers.

## 3-4 PA technique

The alternative technique of pulsed laser photo-acoustic spectroscopy. In this technique, short pulses of laser light are directed into the tissue. The resulting acoustic signal depends on the optical and physical characteristics of the sample and may be the basis of determining blood glucose concentrations noninvasively. Recent developments in optoelectronic technologies give the photo-acoustic method of measurement the potential for portability and long component life with the use of piezoelectric and compact electronics and diode lasers with levels of optical radiation that are several orders of magnitude below pain or tissue damage thresholds.

The photo-acoustic process involves the conversion of optical energy into acoustic energy by a multistage energy Conversion process. The fraction of incident optical energy that is absorbed is determined by the optical absorption coefficient the photo-acoustic pulse consists of an isolated pressure wave comprising a compressive pulse followed by a rarefaction. Generally, the peak-to-peak amplitude of the detected photo-acoustic pulse is used for analysis and is directly proportional to the absorbed energy. Accordingly, an energy measurement is used to normalize the peak-to-peak measurement.

## 3-5 Photo-acoustic effect

The photo-acoustic effect is a conversion between light and acoustic waves due to absorption and localized thermal excitation. When rapid pulses of light are incident on a sample of matter, they can be absorbed and the resulting energy will then be radiated as heat. This heat causes detectable sound waves due to pressure variation in the Surrounding medium.

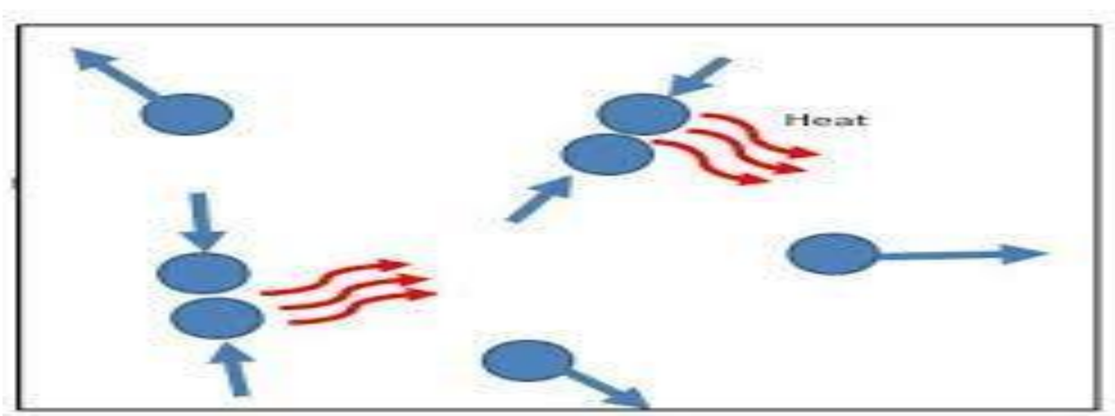



**Figure (3.5):** Visualization of the photo-acoustic effect First, pulsed light that is incident on a sample is absorbed and the constituent molecules become thermally excited. Periodic heat flow from the sample to the surrounding gas causes pressure waves that are in turn detected by an acoustic sensor.

## 3-6 The mechanisms of PA generation

All modulated energy beams, such as those comprised of electromagnetic radiation, x-rays, electrons, protons, ions and other particles are capable of generating an acoustic Sound when they interact with matter, However, the most popular method of producing PA waves is modulated light energy. Light consists of non-ionizing radiation, which is not harmful to the human body, and there is an unlimited supply of diversified, Convenient, cheap and effective optical sources and devices.

In liquids, the generation of PA waves is generally the result of two different Mechanisms: optical absorption followed by thermal de-excitation, as in thermal expansion and liquid boiling, or non-thermal de-excitation, as in the case of photochemical processes and breakdown. In addition, optical non-absorption, such as electrostriction and radiative pressure, may also produce acoustic waves. The thermal elastic expansion mechanism is an interesting choice for material characterization and medical diagnosis for a variety of reasons:

1. Firstly, it does not break or change the properties of the object under study.

2. Secondly, it has a linear or a definite relationship with many of the physical parameters of diverse materials.

3. Thirdly, it is non-destructive or non-invasive in application such as materials test and medical diagnosis.

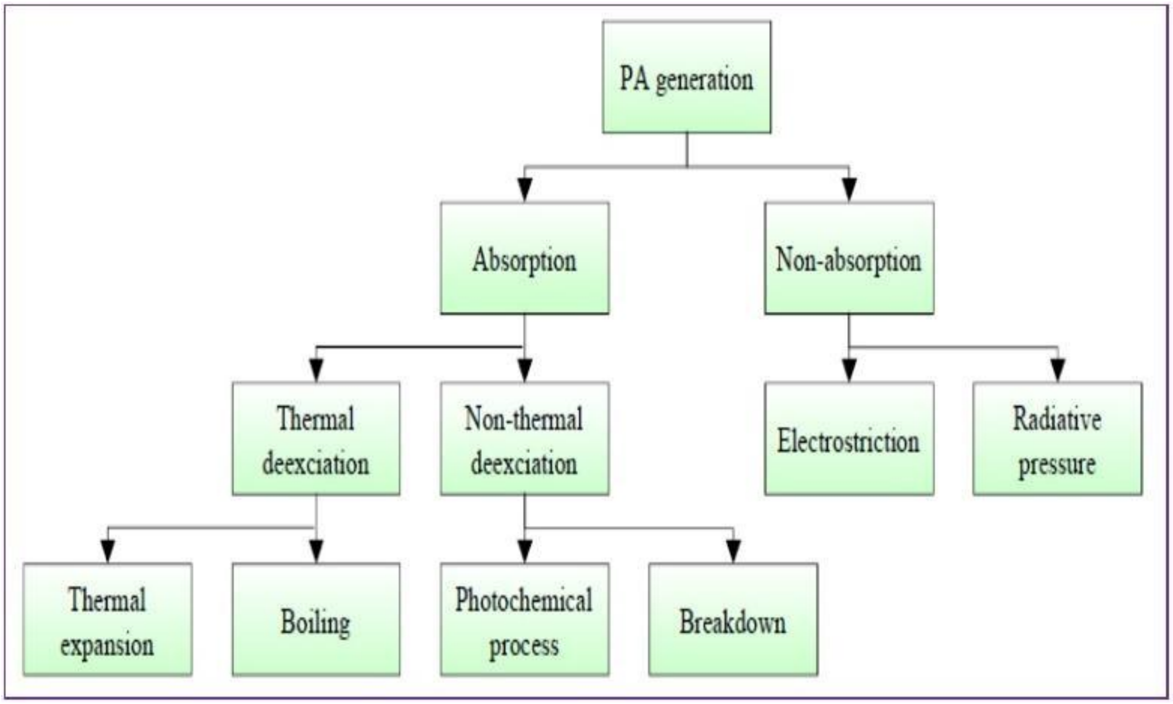



**Figure (3.6):** Mechanisms for generating Photo-acoustic Waves.

### 3-6-1 Thermal elastic expansion

When a modulated light source, such as laser, irradiates an absorbing medium; the ion specific absorption in the illuminated region produces heat due to non-radiative relaxation. This heat causes the region to expand. If the pulse duration of the laser is short enough or its modulated frequency rapid enough, the thermal expansion will be exceedingly fast. Such modulated thermal expansion causes the illuminated region to extend and compress, owing to inertial effects within the medium. As a result of this action, an acoustic wave is generated and propagated outside. This wave is subsequently detected by an acoustic transducer.

### 3-6-2 Vaporization and boiling

If the absorbed laser energy density within the absorbing region of a medium exceeds a certain threshold determined by the optical and thermal properties of the medium, the generated heat may cause the temperature to rise. If the medium gets hot enough, the result will be vaporization and internal boiling. This process involves a momentum exchange between the ejected molecules or particles and the liquid sample consequently, produces shock waves with pressure amplitudes these shock waves may be used to destroy sick tissue [6].

### 3-6-3 Dielectric breakdown

Dielectric breakdown is caused by the interaction of a medium and an optical beam with a very high optical intensity, generate a strong acoustic wave this mechanism is the most efficient process for converting optical energy into acoustic energy .

### 3-6-4 photo-chemical process

Some mechanisms based on photochemical effects are capable of generating acoustic emission [7], that gas evolution or consumption may produce a larger PA signal than the thermal expansion mechanism, and that a photochemical chain reaction may cause an extremely large and prolonged PA emission.

### 3-6-5 Electrostriction

The electrostriction effect can be explained by the electric polarizability of molecules which causes them to move within the illuminated region such that a density gradient is produced in the medium a change in the density gradient will form an acoustic wave. (Very weakly absorbing media subjected to an electric field with high field strength).

### 3-6-6 Radiative pressure

When light irradiates the surface of a medium, the maximum radiative pressure caused by the change in the momentum of the light beam on reflection is equal L to 2I/c, where I is the intensity and c the velocity of light in the medium. Fast modulated light produces a modulated pressure change and emits an acoustic wave. Nevertheless, the thus generated acoustic wave is considerably smaller than that produced by other PA mechanisms.

## 3-7 Thermal-elastic direct PA generation by pulsed excitation mode

Several mechanisms can produce PA effects, but in terms of liquid analysis, thermal elastic expansion is of particular relevance. Compared with radiation pressure and electrostriction, the thermal elastic mechanism produces a large PA response. In addition, unlike dielectric breakdown, evaporation and the photochemical process, it does not break or change the properties of the sample. Moreover, the thermal elastic PA process exhibits a simple proportional relationship between the signal amplitude and thermal physical parameters (such as thermal expansion coefficient), For the high sensitivity and convenience it offers for practical applications.

## 3-8 Thermal and acoustic properties

In addition to the optical parameters of a medium, PA generation also affects such thermal and acoustic parameters as the thermal expansion coefficient; thermodynamic methods are used to measure the expansion coefficient.

### 3-8-1 Measurement of the expansion coefficient

There are equation to the expansion coefficient as by the change in temperature sample and the change in volume.

$$\beta = \frac{\Delta V}{V} \cdot \frac{1}{\Delta T}$$

………………………………………………………………... (1)

Glucose solutions with different concentrations , the relationship between the relative change of the expansion coefficient and the concentration of the solutions. ($\Delta\beta\ \beta/$ equals about 1.2% per percent change in glucose concentration)

$$\frac{\Delta\beta}{\beta} = 1.2C$$

……………………………...……………………………………….. (2)

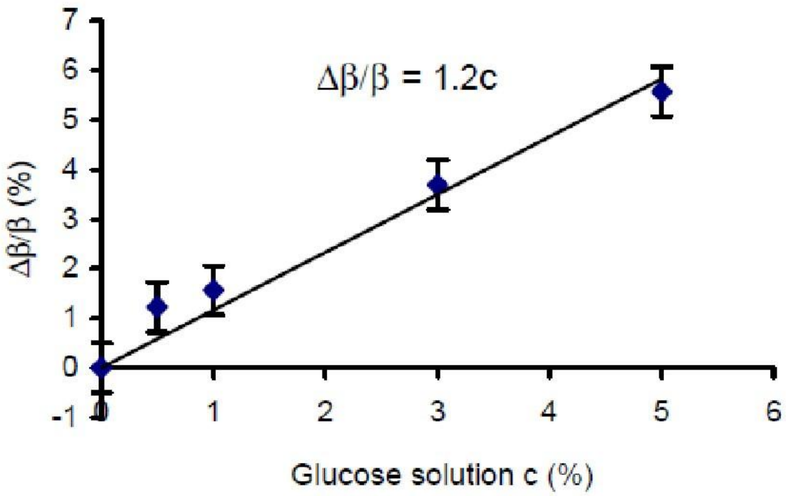


**Figure (3.8):** Relative Change of the Expansion Coefficient with Glucose Concentration.

### 3.8.2 Measurement of the specific heat:

The specific heat can be calculated by:

$$Cp = \frac{QE}{m \cdot \Delta T} \quad \text{.......................................} \quad (3)$$

Where :

$Cp$: is specific heat

$\boldsymbol{QE}$: is the electrical energy dissipated in the heater

**m** : is the sample weight

$\Delta\boldsymbol{T}$: $is\ the\ temperature\ rise\ in\ the\ sample$

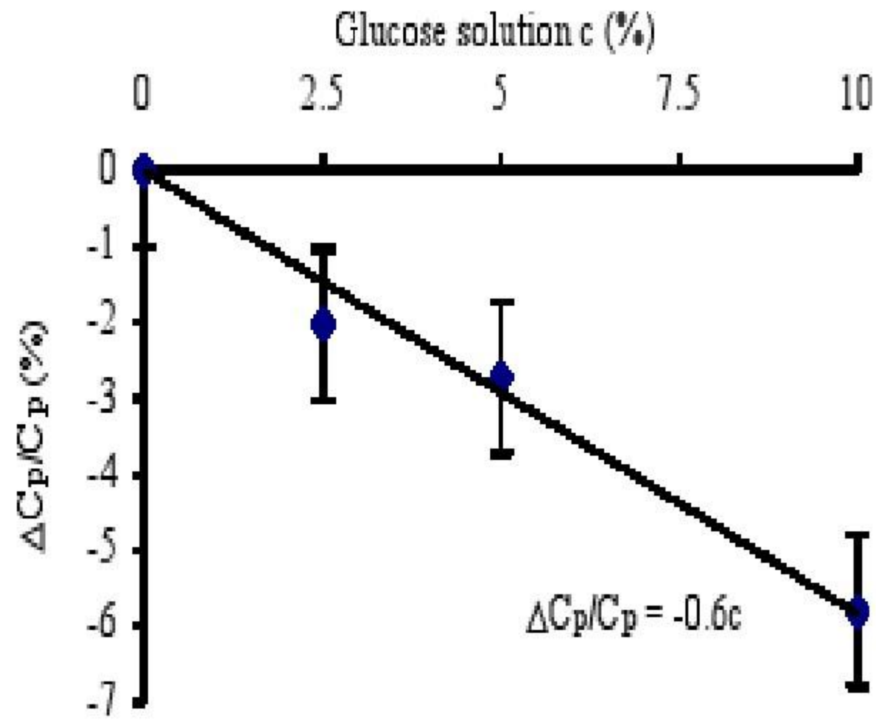



**Figure (3.8.2):** Relative change of specific heat with Glucose concentration.

**3-8-3 Measurement of sound velocity**

The relative change of sound velocity can be expressed by:

$$\frac{\Delta V}{V} = \frac{Vs - Vo}{Vo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The lower case s and 0 indicate the relative parameters of solution and the water.

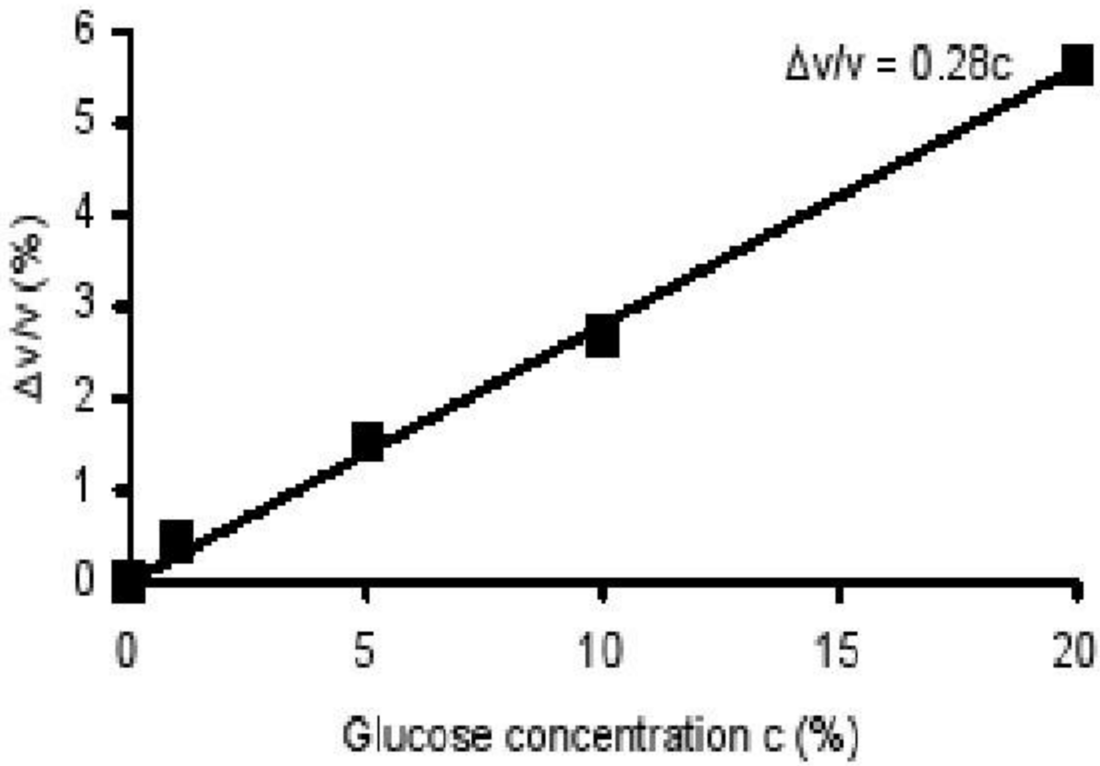



**Figure (3.8.3):** Relative change of sound velocity with Glucose concentration.

**Table (3.1)** Physical parameters of blood that play an important role in PA generation and propagation

| Thermal expansion coefficient: (10-4/C) | Specific heat (J .kg-1 .K-1) | Density (kg/cm3) | Acoustic velocity (m/s) |
|---|---|---|---|
| 2.5 (15 ~ 20 C) 3.5 (25 ~ 30 C) 4.0 (35 ~ 40 c) | 3950 - 7.24H (H: hematocrits %) 3624 (37.5C) | 1052 ~ 1064 | 1584 (37C) temperature coefficient: 2.0 m/sC-1 (29 ~ 40C) |

## 3-9 Laser sources

PA waves can be generated by any radiation energy source with a short duration. Thermo elastic generation, however, requires a high power radiation source, due to the low efficiency (< 0.0001) of optical to acoustic transformation. Pulsed laser sources have some advantages over continuouswave modulating sources in terms of PA techniques. Pulsed lasers offer higher detection sensitivity owing to their high output power producing a correspondingly strong PA signal.

In spite of their high output power, pulsed laser are free of convection currents.

Unlike continuous-wave lasers, PA signals generated by pulsed lasers exhibit no complex dependence on the thermal diffusion length and chopping frequency

## 3-10 Selection of wavelength and transducer material

Absorption of light by tissue causes localized heating, which causes expansion and subsequent contraction, which gives rise to a PA signal. As composition of blood is quite complex and has various constituents, wavelength needs to be chosen judiciously. Figure (3.10) shows how optical properties of tissue vary over the wavelength with respect to melanin, water and oxy-hemoglobin [2]. It can be seen that absorption by water, melanin, and oxy-hemoglobin is less in red and NIR region. This region extending from 600nm to 1300nm is known as optical window of biological tissue. Also, in this region the depth of penetration of light in tissue is several millimeters.

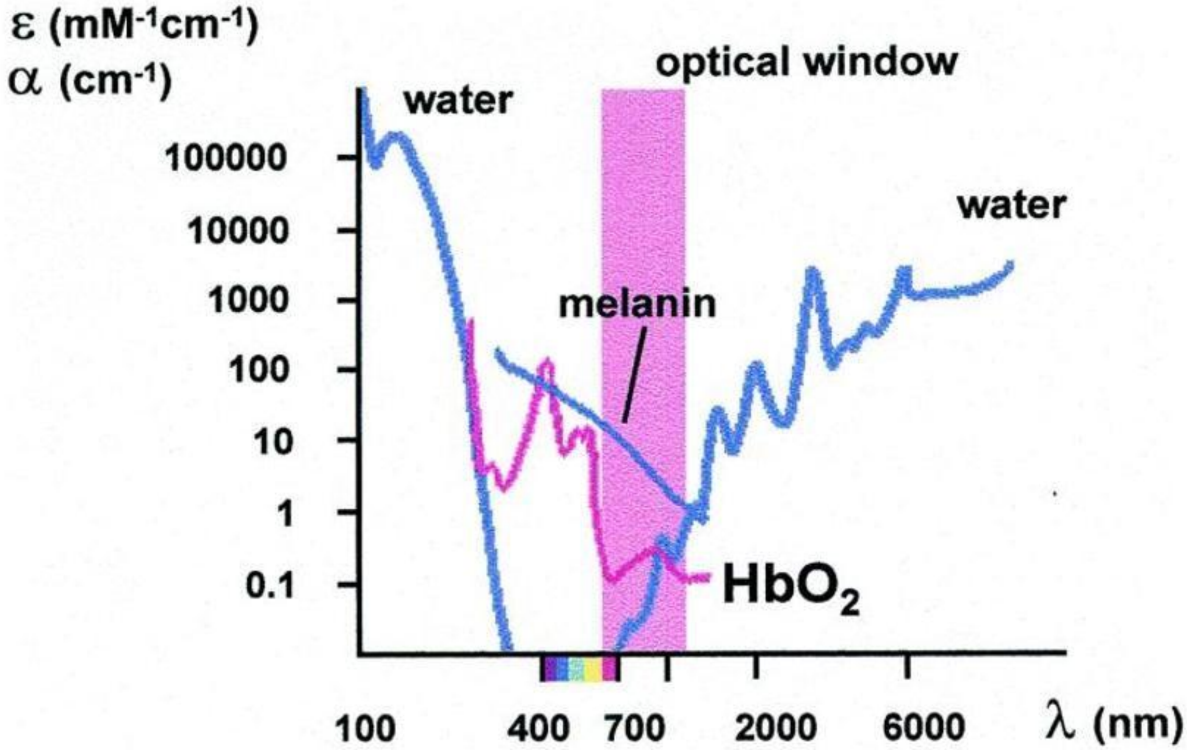



**Figure (3.10):** Absorption spectra of tissue

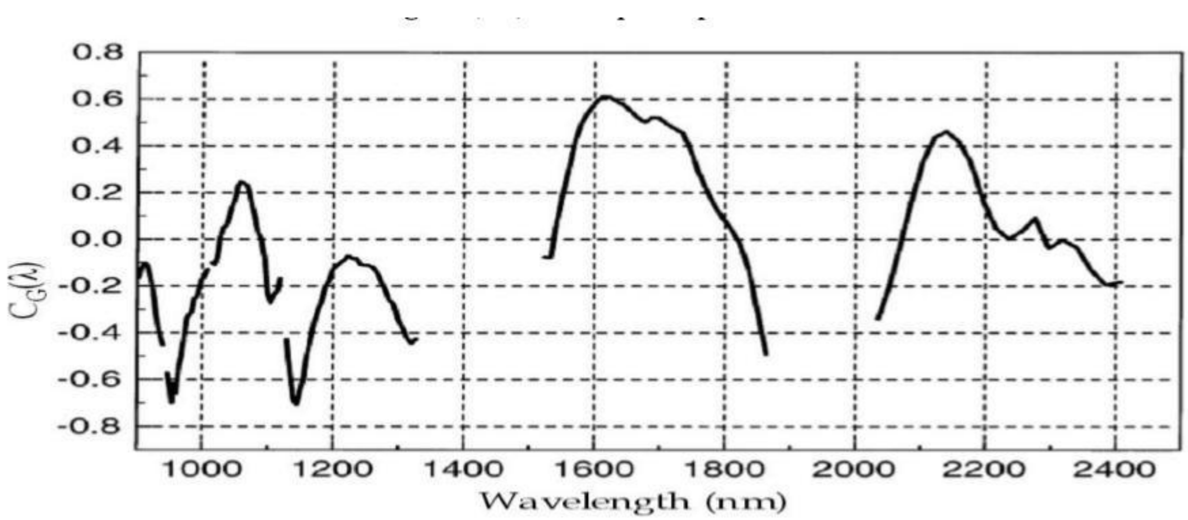



**Figure (3.10.2)** Optical absorption spectra for glucose showing absorption peaks

One more fact that needs to be considered is that, in wavelengths ranging from 1000nm to 1200nm absorptions for oxy-hemoglobin and doxy-hemoglobin are different, whereas this difference is fairly small at around 900nm. This may lead to errors as light absorption will change with the changes in amount of blood oxygenation. Considering the above phenomena tissue's optical window (wavelength around 900nm) is the most suitable for glucose detection. Although glucose has relatively lower absorption around this wavelength, but due to minimum attenuation of optical signal by other constituents, desired depth of penetration can be achieved with substantial energy available for absorption by the glucose. Commercial availability of pulsed laser diode at 905nm has leaded us to use this wavelength for the experiments. Excitation signal has nanosecond pulse duration and hence microphone cannot be used due to its limited bandwidth. PZT (Lead Zircon ate Titan ate), being a highly sensitive material is selected for detection of PA signal.

## 3-11 Acoustic detectors

Several different types of acoustic detectors are available for PA detection. They include microphones, piezoelectric transducers, capacitance transducers, fiber-optic sensors, noncontact optical detectors, and so on [7].The choice of detector for a particular application is mainly based on factors such as detection style, sensitivity, response time, bandwidth, impedance matching, noise, size and ruggedness. In the PA study of condensed matter, the most common detectors are the piezoelectric transducer and the non-contact optical detector. The former has a good acoustic impedance match while the latter can requires no contact with the object of study or form all optical device.

## 3-12 Telemedicine

Telemedicine provides interactive healthcare by utilizing the ability of computer networks to transmit medical information from one site to another via electronic communication in order to help improve patients' health status when traditional face-to-face consultations aren't an option. It assists patients who do not have access to certain care, and doctors from around the world can help or inform the existing physician in the area to that certain care. It can be a very helpful in an emergency case. Patients don’t have to wait for specialists to get an opinion and treatment. They can get immediate attention and treatment without any delay. It can help to save thousands of lives. In rural areas people are dying every day because they don’t get the right treatment at the right time. It is a cost effective alternative. People can’t visit the specialist because of their high fees and long waiting for appointment. They can get treatment through video conferencing. It is a two way communications between the patient and the physician or specialist. If the doctor is out of town for some reason the patient can still get treated through video- conferencing Also it makes patients feel more comfortable with nurses and can ask questions when need about any health concerns. Most often telemedicine allows patients to "visit" their physician live to receive immediate attention or to take medical images to be sent and analyzed by a physician. A few of the most common services include specialist referrals, patient consultations, remote patient monitoring as well as it facilitates medical education. This form of medicine is useful for patients and physicians living in rural communities or in remote locations where the nearest health clinic is hundreds of miles away. Telemedicine allows doctors or physicians to do video conferencing to communicate remotely and can discuss any situations they have about surgeries, medicine, and even previous patients that need transferring. A doctor can introduce his fellow physician about a new patient, if they have troubles with them, they can communicate the needs of the patients and what they could do to be better. Doctors can do diagnosing of patients who are in different areas of the world where they do not have time to visit. For example doctors can send pictures or vital statistics to the physicians located at that area to help them out. Health Information Technology and telemedicine is vastly expanding and will definitely a prominent factor in the field of medicine.

# CHAPTER FOUR
# SYSTEM DESIGN

## 4-1 Block diagram

The block diagram below represents the components used in designing the system .

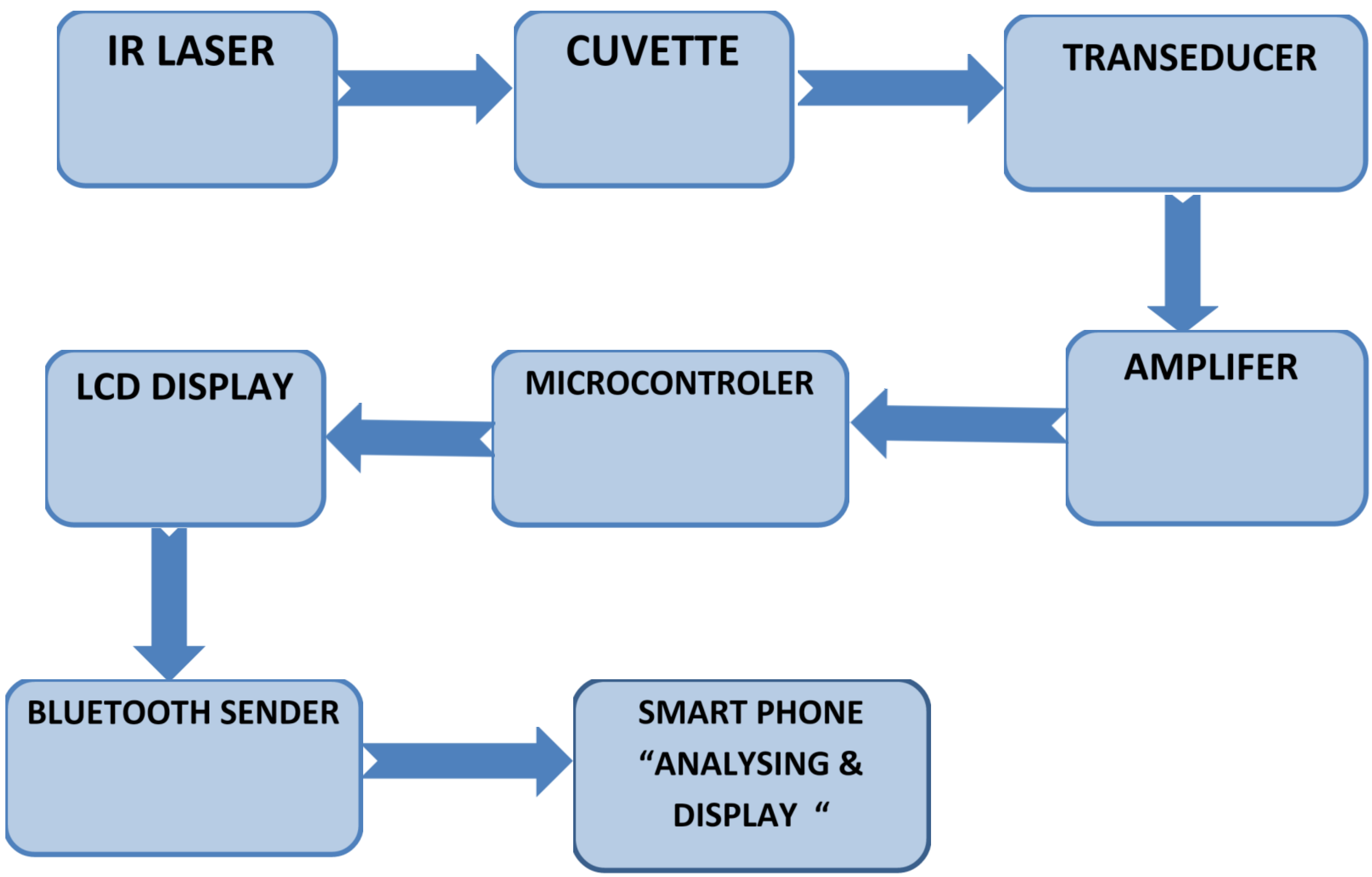



**Figure (4.1):** Design block diagram

## 4-2 IR Laser source

The design has been tested in the LASER institute (biomedical and biological applications department), using the LASER device: Omega XP, 200mW/ 950nm Probe. Near Infrared Transport in Biological Tissue This section describes the mechanisms that govern Near Infrared transport through physical media and identifies the components of biological tissue that are responsible for these processes [15].

**Figure**(4.2) : Omega Xp Mobile

The infra-red probes provide a penetrative, highly effective wavelength for soft tissue and sports injuries, pain relief, acupuncture point stimulation and smoking cessation. These probes encourage fast resolution of musculoskeletal and tendon injuries and substantial relief for arthritic, herpetic, neuralgic and neuropathic pain. An infra-red probe is the choice for treatment of verrucae and general stimulation of immune system response.

## 4-3 Cuvette

A small tube made of “Teflon “with a circular section used to hold the patient finger , transducer & the IR source .

A beam of light can pass through the entering cavity of the cuvette and then the PA wave which generated by the absorbance value can be measured by the transducer .

“TEFLON” had been used in the cuvette due to its properties such as : it has a strong resistance to chemical acid ,It retains physical properties unchanged at temperatures ranging from 270 - to 250 Silesia , it’s an insulating material for electricity & it’s flexible material.

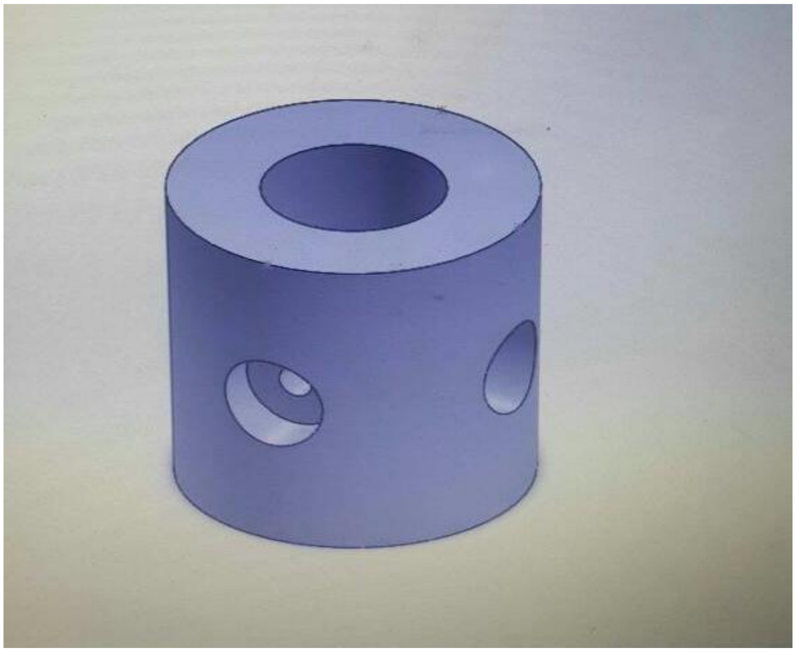


**Figure (4.3)** cuvette structure

## 4-4 Transducer

Audio transducer that convert an acoustic wave generated by pulsed laser which interact with the tissue into electrical signal

**Figure (4.4):** Audio transducer

## 4-5 Operation amplifier

The Operational Amplifier is probably the most versatile Integrated Circuit available. It is very cheap especially keeping in mind the fact that it contains several hundred components. The most common Op-Amp is the 741 and it is used in many circuits. The OP AMP is a 'Linear Amplifier' with an amazing variety of uses. Its main purpose is to amplify (increase) a weak signal. One of 741 advantages is that it is compensated (its frequency response is tailored) to ensure that under most circumstances it won't produce unwanted spurious oscillations.


**Figure (4.5)** 741 operation amplifier

## 4-6 Microcontroller

PIC 16F877A is one of the most advanced microcontroller from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on. The PIC 16F877 features all the components which modern microcontrollers normally have. The figure of a PIC16F877 chip is shown below.


**Figure (4.6**) PIC 16f877a microcontroller

## 4-7 Display

Although the final glucose value can be displayed on a simple LCD, in this design it is also displayed on an smart phone using Bluetooth and internet connectivity. A simple communication protocol was implemented inside the sensing device and the mobile device. When a user asks for a glucose value, the Android platform sends a ‘get’ request to the readings from the Bluetooth module connected to the sensor, which waits for glucose computation , after that it sends the glucose value to the smart phone and an acknowledgement to microcontroller . The Android device displays the glucose value upon receiving it. Our App and Smart Cloud technology delivers personalized advice and alerts, helping the patient to fully manage his condition. Intelligent analytics will use his current and historical data to calculate and forecast immediate trends in his blood glucose levels, allowing him to adjust his food or medication intake according to his activities or feeling.

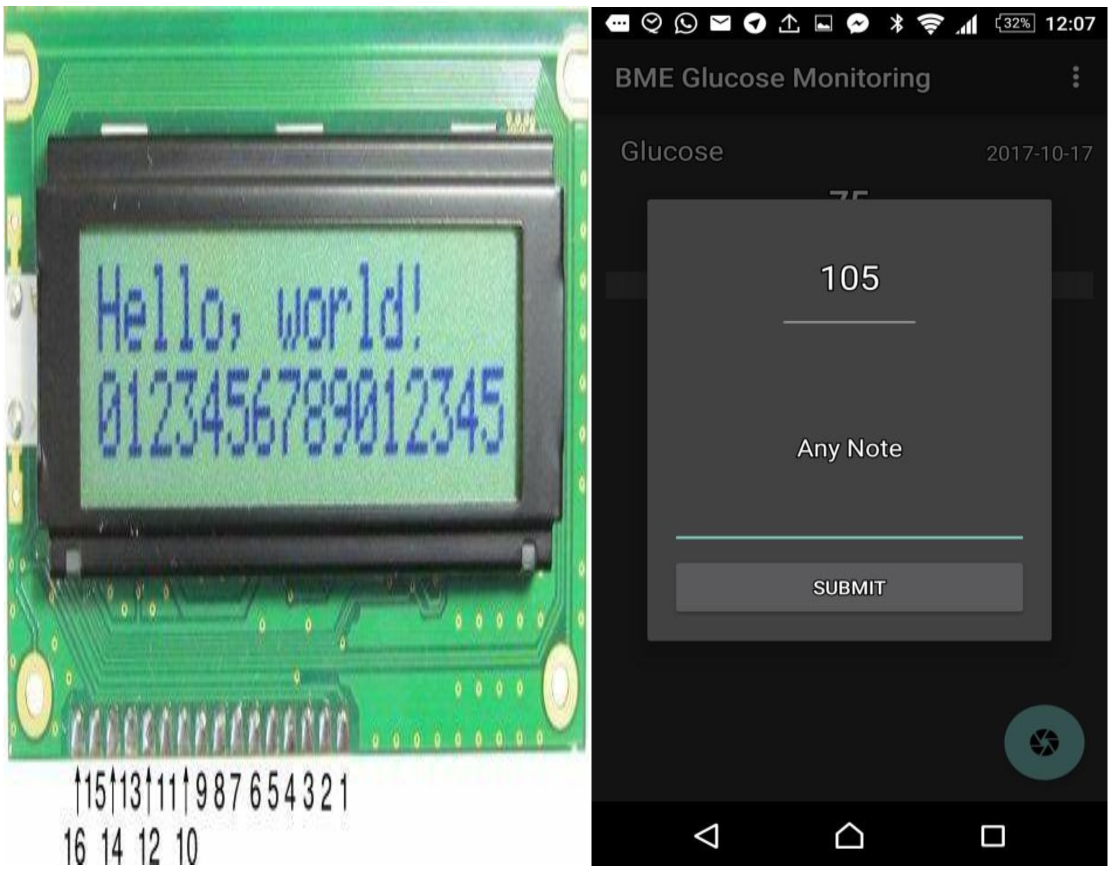



**Figure (4.7)** Display

## 4-8 Bluetooth module

Provide a low range connectivity between the sensor & the patient smart phone , These constantly connected devices can transmit information via base stations and smartphones directly to the patient or to a medical expert over the internet providing immediate diagnosis and feedback.

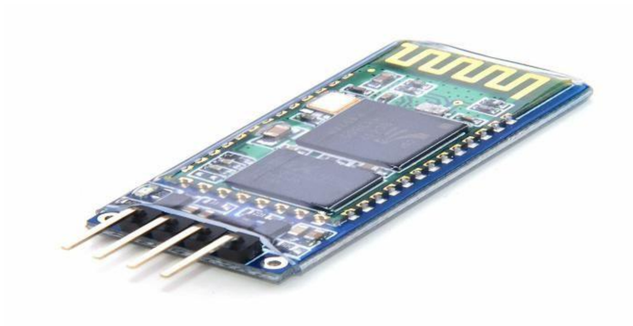


**Figure (4.8):** Bluetooth module

## 4-9 SIMULATION

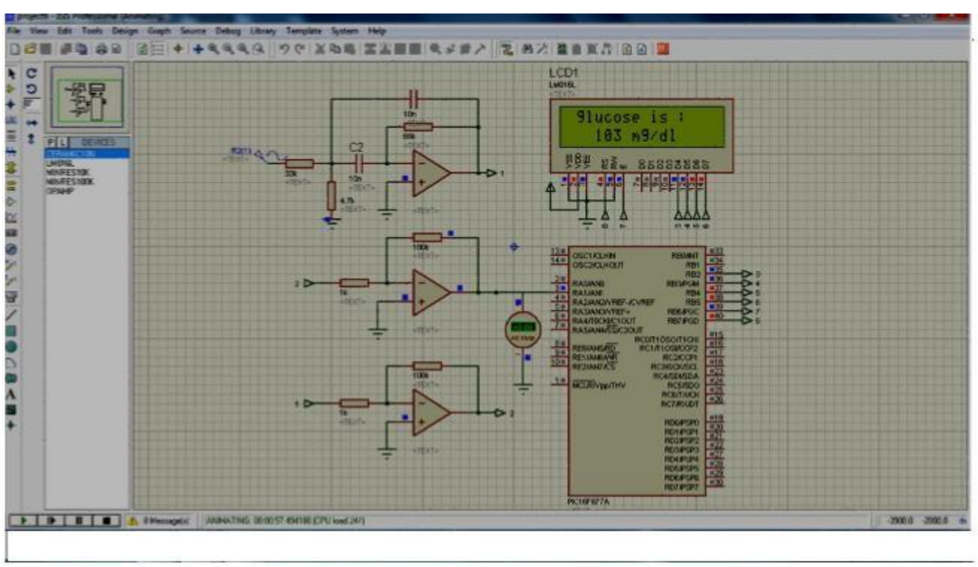


**Figure (4.9)** protus8 simulation

## 4-10 Implementation

The project implementation had been divided into two sections , the sensor design and the android design .

### 4-10-1 Sensor circuit

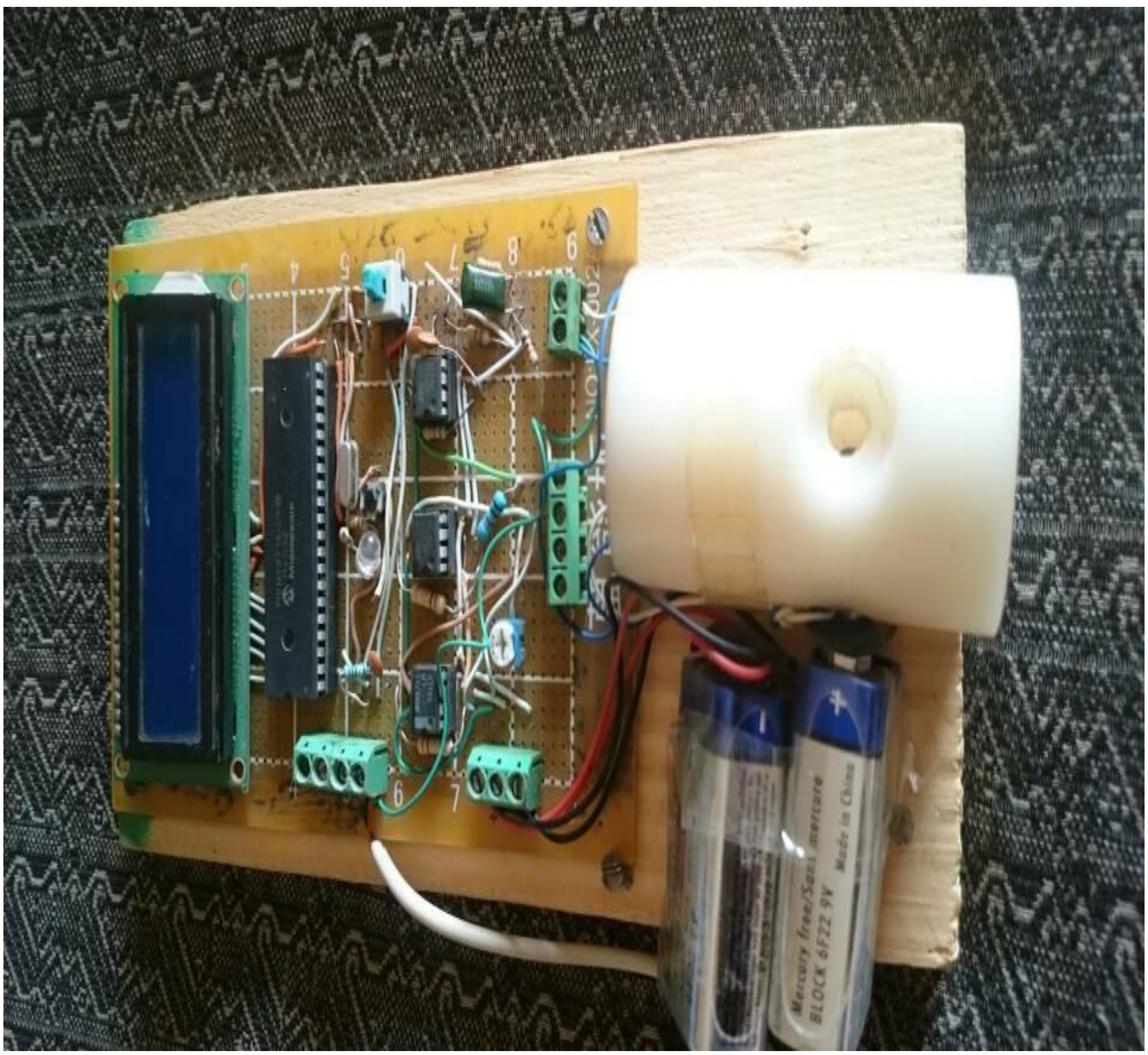
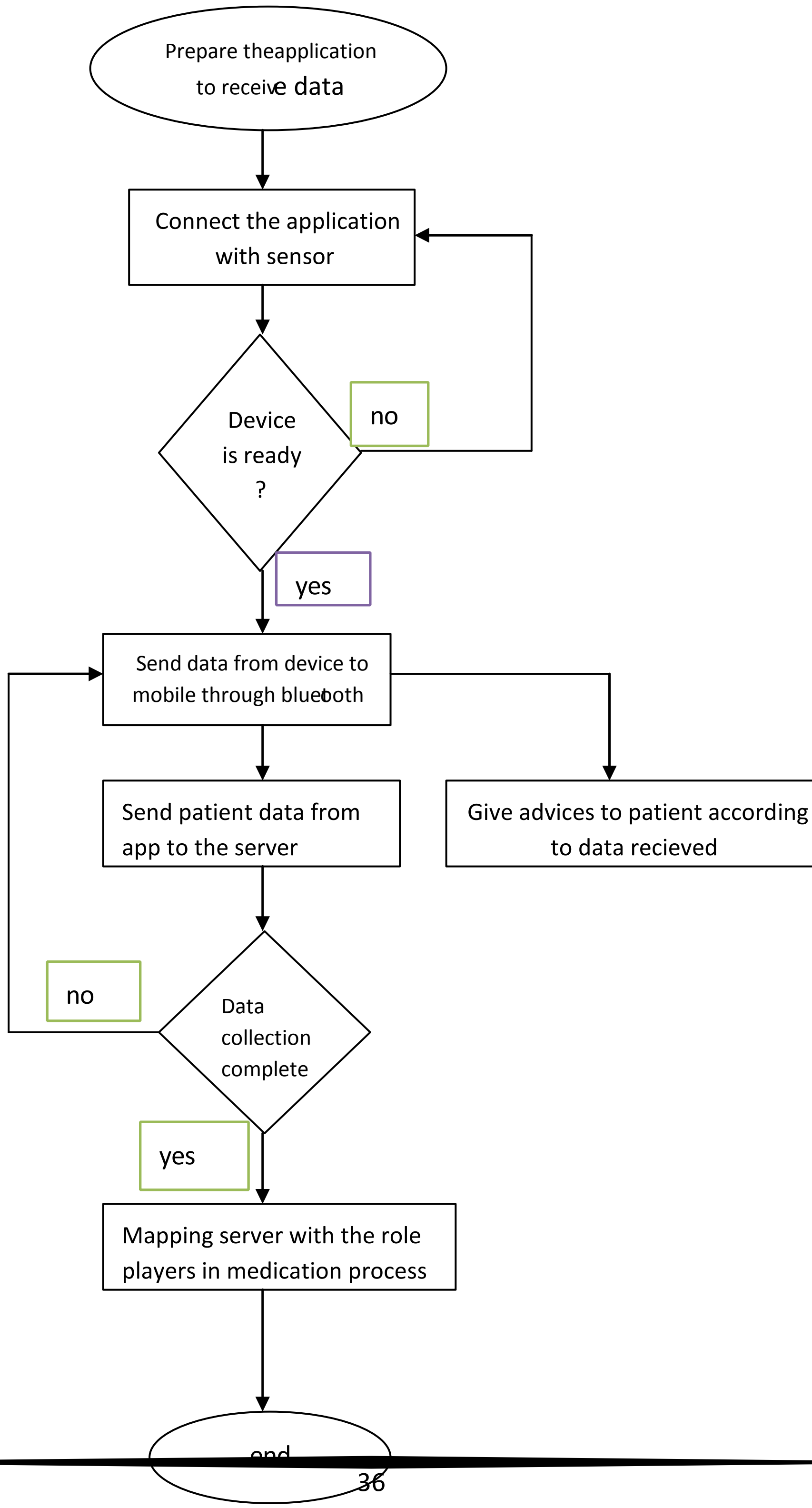


**Figure (4-10-1) electronic circuit**

## 4-10-2 Android application



# CHAPTER FIVE RESULTS AND DISCUSSION

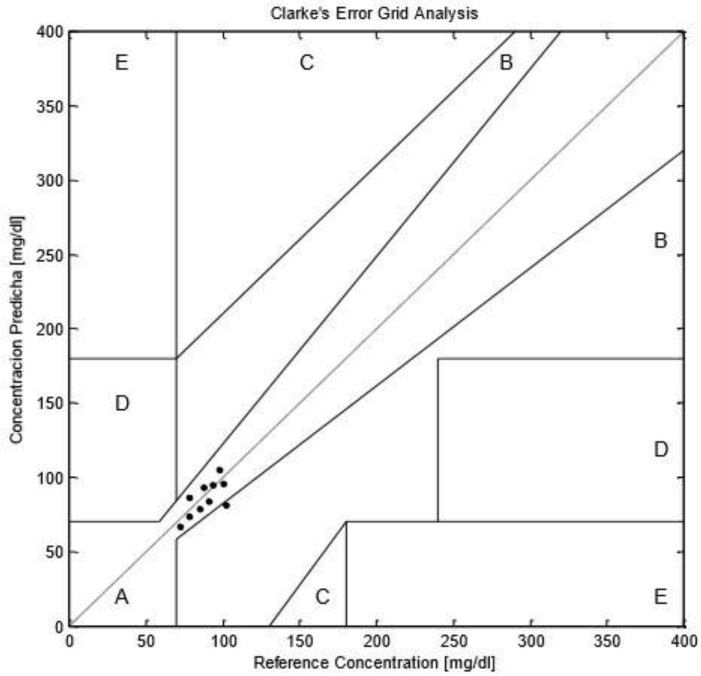
## 5-1 The sensor

To determine the accuracy of the device described above, its readings were compared against an off-the-shelf handheld home-use invasive glucometer available in the market.

**Table (5.2):** result for measuring glucose concentration by both Invasive & Noninvasive method for non-diabetic patients

| Invasive | Noninvasive |
|---|---|
| 72 | 67 |
| 78 | 86 |
| 78 | 74 |
| 85 | 79 |
| 88 | 93 |
| 91 | 84 |
| 94 | 95 |
| 98 | 105 |
| 100 | 96 |

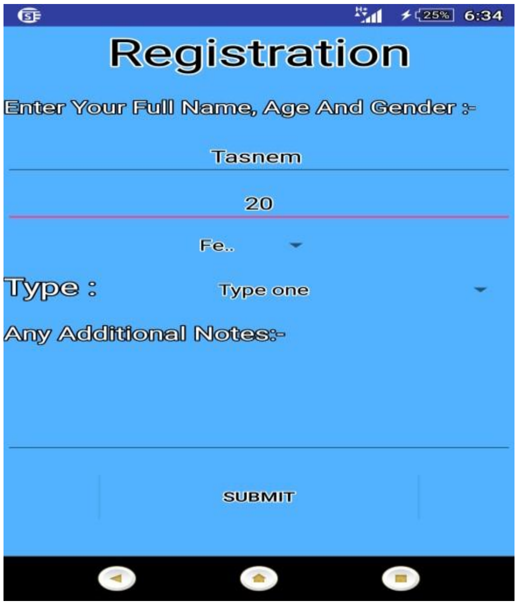
The Clarke error grid[14] approach is used to assess the clinical significance of differences between the glucose measurement technique under test and the venous blood glucose reference measurements. The method uses a Cartesian diagram, in which the values predicted by the technique under test are displayed on the y-axis, whereas the values received from the reference method are displayed on the x-axis. The diagonal represents the perfect agreement between the two, whereas the points below and above the line indicate, respectively, overestimation and underestimation of the actual values. Zone A (acceptable) represents the glucose values that deviate from the reference values by ±20% or are in the hypoglycemic range (<70 mg/dl), when the reference is also within the hypoglycemic range. The values within this range are clinically exact and are thus characterized by correct clinical treatment. Zone B (benign errors) is located above and below zone A; this zone represents those values that deviate from the reference values, which are incremented by 20. The values that fall within zones A and B are clinically acceptable, whereas the values included in areas C-E are potentially dangerous, and there is a possibility of making clinically significant mistakes. A total of 2 persons were tested during the trial period, producing 10 data pairs. Using Clarke error grid analysis, 100% of the readings fell in the clinically acceptable zones A and B, with 90% in the A zone, and 10% in B zone.



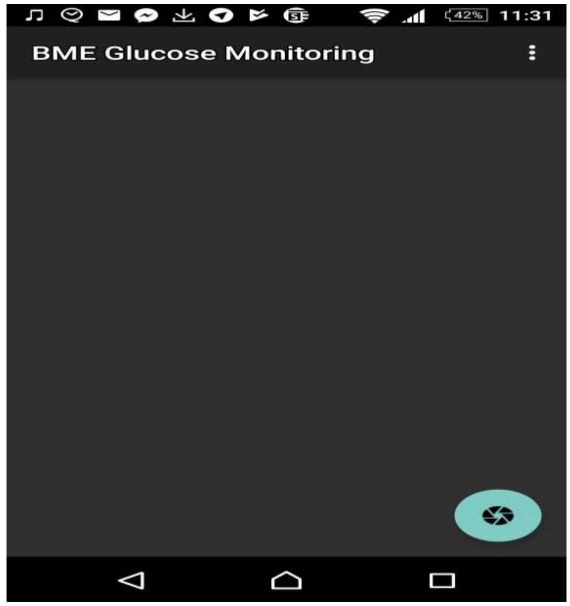

**figure(5-1):** Clarke's Error Grid Analysis

## 5-2The smart phone application

The smart phone application has been attended to perform several functions such as : receiving and displaying the sensor results through the bluetooth module , analyzing the results which has been received from the sensor , give advices to the patient according to these results and send it to the role players in the medication process ( doctor and family ). The application has been developed using java language and tested using several values with different ranges . The application appeared an acceptable results in receiving , analyzing the results and in the connecting process . the stability of the application reached 85% which considered an acceptable stability range.

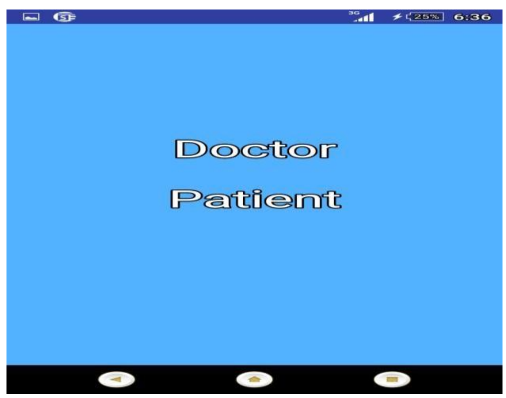



**A :** entering registration info

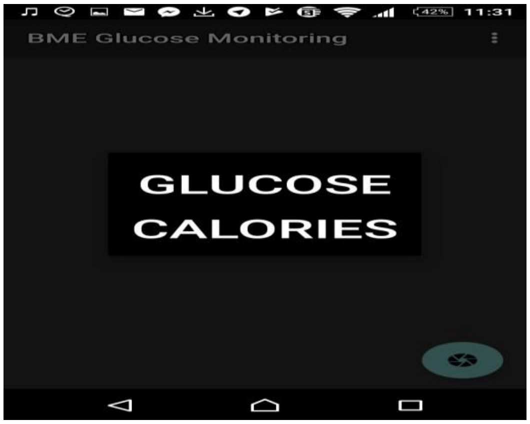



**B:** application home page

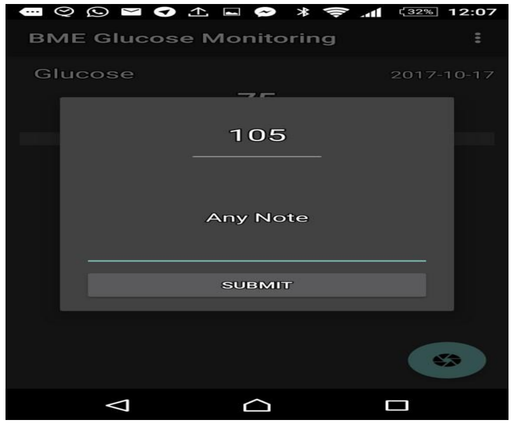

**C:** application icon



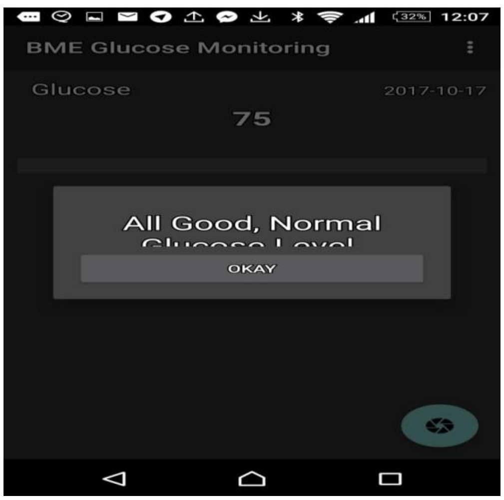

**D:** chose to register as a patient or doctor



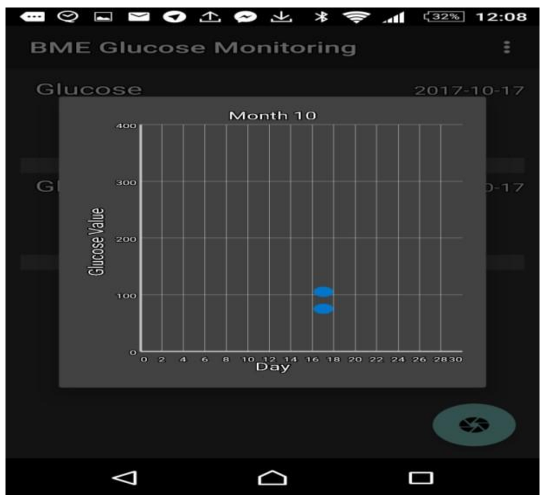

**E:**options of parameters to measure



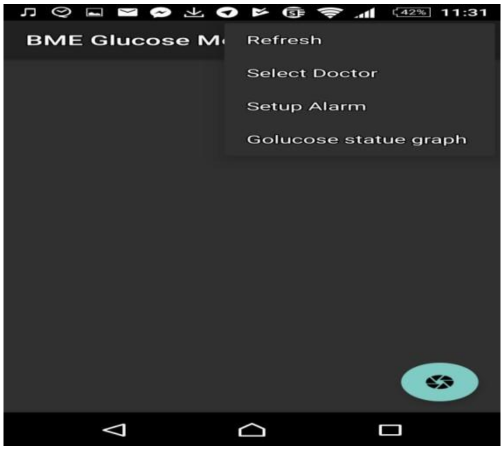

**F:**output of measuring device displayed at the app




**G:** patient feedback**




**H:**golucose status graph




**I:** options panel


**J:**setting alarms

**Figure (5.2)** screenshots taken from the application

****NOTE:** patient feedback determined according to table (4.)

**Table 1. Sliding Scale Insulin Protocol**

| Blood Glucose Level, mg/dL | Human Insulin, IU[a] | Additional Action Requested |
|---|---|---|
| 0-80 | 0 | 1 Ampule of D50, call physician |
| 81-100 | 0 | No action |
| 101-150 | 0 | No action |
| 151-200 | 2 | No action |
| 201-250 | 4 | No action |
| 251-300 | 6 | No action |
| 301-350 | 8 | No action |
| 351-400 | 10 | No action |
| >401 | 12 | Call physician |

SI conversion factor: To convert to millimoles per liter, multiply by 0.0555.
[a] Subcutaneous dose of rapid human insulin to be given.

# CHAPTER SIX CONCLUSION AND RECOMMONDATIONS

## 6-1 Conclusion

In this article we have presented a non-invasive blood glucose meter that can provide glucose measurements painlessly, without a blood sample or finger pricks, within a few seconds. The device can be easily adapted to provide continuous blood glucose monitoring and maintain a history of these measurements, analyze them and share them with all the role players in the medication process.

## 6-2 Recommendations

The recommendations for this project are

1- modify the algorithm to provide other capabilities like heart rate in the same device .

2- Improve the application features such as the feed back mechanism .

3- Increase the application stability by applying more tests in beta period.

4- Design the family application

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