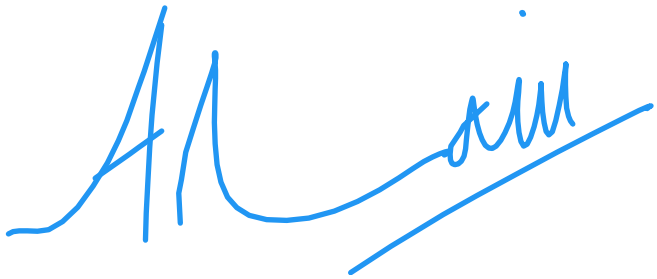

Non-Invasive Mobile Blood Glucose Spikes Monitoring System

by Dr. Abdul Jalil

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Chapter 1

Introduction

1.1 Diabetes

The amount of diabetic people rises to 400 million in 2014. Predominance has been rising all the more quickly in low-and middle salary nations than in top level pay nations. It is a major cause for kidney disappointment, visual impairment, heart failures, stroke and lower appendage removal. Somewhere in the range of 2000 and 2016, there was a 5% increment in untimely mortality from diabetic 2019, an expected 1.5 million deaths were honestly taken due to diabetes. Another 2.2 million deaths happen due to high blood glucose in 2012 [1]. A solid eating regimen, ordinary actual work, keeping a typical body weight and staying away from tobacco use are approaches to forestall or postpone the beginning of type 2 diabetes. Diabetes can be treated with proper diet workout. Diabetes is a constant infection that happens either when the pancreas doesn't secrete satisfactory insulin or when the body can't utilize the insulin it produces. Insulin controls glucose. Hyperglycemia is a typical influence of unrestrained diabetes and over the long run prompts honest harm to a major number of the body parts, particularly the nerves and veins.

In 2014, 8.5% of people aged 18 years old and more suffers from diabetes. In 2019, diabetes was the immediate reason for 1.5 million passing [1]. To introduce a more precise image of the passing causes by diabetes, notwithstanding, passing due to higher-than-ideal blood glucose through cardiovascular infection, constant kidney sickness and tuberculosis ought to be added. In 2012 (year of the most recent accessible information), there were another 2.2 million people died because of high blood glucose.

Somewhere in the range of 2000 and 2016, there was a 5% increment in untimely mortality from diabetes. In major league salary nations, the untimely death rate because of diabetes diminished from 2000 to 2010 yet then, at that point expanded in 2010-2016 [1]. In lower-center pay nations, the untimely death rate because of diabetes expanded across the two time frames.

Paradoxically, the likelihood of kicking the bucket from any of the four principle no communicable infections (cardiovascular sicknesses, malignancy, persistent respiratory illnesses or diabetes)

between the ages of 30 and 70 diminished by 18% universally somewhere in the range of 2000 and 2016 [1]. There are three types of diabetes.

1.1.1 Type 1 diabetes

Type 1 diabetes is described by absent of insulin formation and requires day by day organization of insulin. Neither the reason for Type 1 diabetes nor the way to predict it are identified. Signs integrate pointless release of pee (polyuria), thirst (polydipsia), consistent yearning, weight reduction, vision changes, and weakness. These indications may happen suddenly. [1]

1.1.2 Type 2 diabetes

Type 2 diabetes (once in the past called non-insulin-ward, or adult beginning) results from the body's incompetent use of insulin. Maximum of people with diabetes have type 2 diabetes. This kind of diabetes is usually the import of excess body weight and actual inertia.

Signs might be like those of type 1 diabetes, however are regularly less marked. Thus, the disorder might be examined quite a while from start, after difficulties have effectually emerged.

As this kind of diabetes was seen uniquely in mature yet it is currently likewise happening progressively much of the time in young people.

1.1.3 Gestational diabetes

Gestational diabetes is hyperglycemia with blood glucose regards better than average however below those analytic of diabetes. This type of diabetes occurs during pregnancy.

Ladies with gestational diabetes are at a prolonged threat of intricacies during pregnancy and at delivery. These ladies and perhaps their kids are additionally at extended risk of type 2 diabetes later on.

Gestational diabetes is analyzed through pre-birth screening, are different to through announced manifestations.

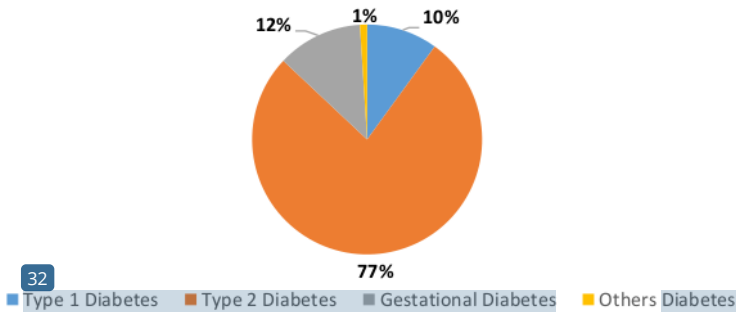


Figure 1. Diabetes Percentage

1.2 Problem Statement

Finger-pricking, notwithstanding, has a few detriments. Numerous individuals detest utilizing sharp items and seeing blood, there is a danger of contamination, and, over the long haul, and this training can bring about harm to the finger tissues. Given these real factors, the benefits of a noninvasive innovation are effortlessly perceived. The finger-prick glucose meter is an isolated glucose approximation gadget that isn't sensible for nonstop detection of blood glucose. The insufficient rates of hyperglycemia or hypoglycemia between estimations may be very difficult to record. In this manner, the resultant checking can't completely address the blood glucose design.

The control of blood glucose levels depends on blood glucose estimation. Diabetic patients, regardless of whether Type 1 or Type 2, are urged to check their blood glucose levels a few times each day; presently, the most widely recognized method for checking is by utilizing a finger-prick glucose meter. Along this, diabetic patients can acquire an unmistakable image of their blood glucose levels for treatment enhancement and for insulin measurement change for the individuals who need every day injections.

1.3 Problem Solution

The noninvasive idea was dispatched over 30 years prior. In any case, one might say that the vast majority of the noninvasive innovations are as yet in their beginning phases of advancement.

Numerous noninvasive advances have been portrayed in the writing, and there is an expanding volume of late exploration results. Staying aware of the flow circumstance requires steady updating. The after effects of a Web search give a lot of data on this subject, for example, outlines of noninvasive technology, the future improvement of meters and screens for diabetes, data about research communities that are fostering this technique. Nonetheless, the extent of gadgets is wide to the point that no single website can keep up. Subsequently, a significant part of the data is outdated along these lines, the point of this research based project is to introduce the such a noninvasive glucose meter which wipes out the agonizing pricking experience, hazard of disease, and harm to finger tissue for diabetic patients. It will portray the advances being utilized, innovations being developed, gadgets being utilized, and the organizations creating these gadgets.

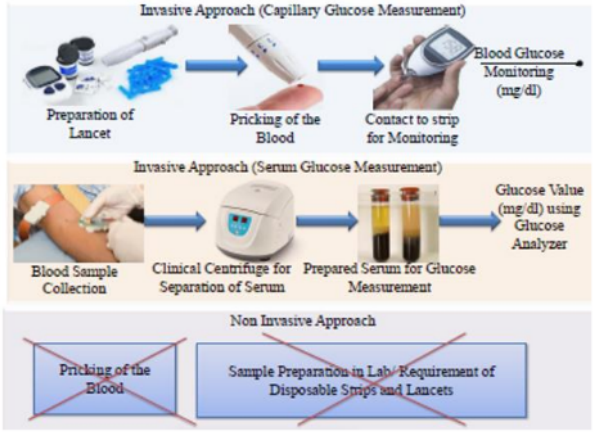


Figure 2. Comparison of Invasive and Non-Invasive Approach

1.4 Difficulties Beforehand for Noninvasive Glucose Monitoring

Different noninvasive improvements were examined. Plainly, many exam bunches are investigating a huge collection of approaches, trying to foster a blood glucose estimation device which could supply constant and stable results, advantageously and monetarily.

Many exploration bunches are chipping away at this issue, trying to foster new estimation advances and techniques to quantify blood glucose noninvasively. One of the number one motives is that modern-day improvements, like assimilation spectroscopy, are fairly bad in signal-to-clamor share

similar to blood glucose recognition and spectra reaction. Because of the massive anticipated marketplace for a fruitful, noninvasive glucose checking device, the race for studies corporations to foster extra genuine and particular spectroscopic equipment is warmed. In addition, multivariate getting ready strategies are regularly applied with inside the quantitative research that the expectancy version is facts subordinate, at the same time as the explicitness of estimation isn't always now no longer tough to handle. Albeit in his addition evolved method is explored for quantitative exam which could enhance the connection of the spectroscopic residences of the glucose atom with glucose fixation in blood, extra exertion has to be made to very well stretch out the technique to noninvasive blood glucose monitoring. In addition, alignment of spectroscopic devices is vital, because of factors like mild electricity, which can also additionally have an impact on the expectancy version. As the huge majority of the noninvasive advances rely upon a few type of optical detecting method, a postpone can also additionally appear among estimations of blood glucose content material from diverse portions of frame, that can gift adjustment mistake. Furthermore, the electricity of the estimation location can also additionally have an impact on the deformity of the touch factor of the tissue. This problem may be addressed with the aid of using making use of regular electricity to the estimation location; be that because it can also additionally, it might be going to create a helpless expectation end result after an intensive stretch of time. This is considering the fact that diverse disfigurements of the tissues can also additionally reason diverse ingestion or mirrored image properties, alongside those traces have an impact on the following sign. Temperature can also additionally have an impact on the forecast end result, in particular for optical detecting innovation, considering the fact that adjustments of some tiers can also additionally basically effect the power stage of ingestion content material. In particular, the physiological effect of the man or woman is the primary component in noninvasive glucose checking. Physiological contrasts might have an impact on the unwavering excellent of diverse advancements, as they're for the maximum element due to man or woman digestion, blood segments, and different herbal liquid publications for frame guideline. The assimilation spectroscopy basically acknowledges the glucose particle, and glucose may be observed anywhere with inside the human frame. Henceforth, it's miles difficult to have an all-inclusive expectation version in place of a solitary patron forecast version, which can also additionally require non-stop self-adjustment.

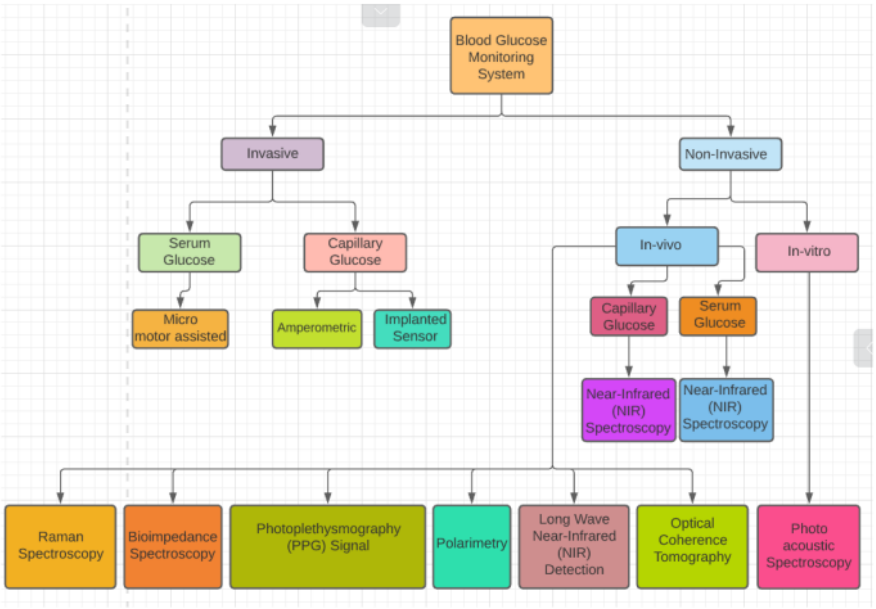


Figure 3. Invasive & Non-Invasive Glucose Monitoring Techniques

1.5 Project Characteristics

Why non-invasive mobile blood glucose spike monitoring system is Best?

- Accuracy and Affordable
- Mobile Application Connectivity
- Patient's Data Recovery
- Diet Plan Suggestion and Designing
- Exercise

1.6 Project Block Diagram

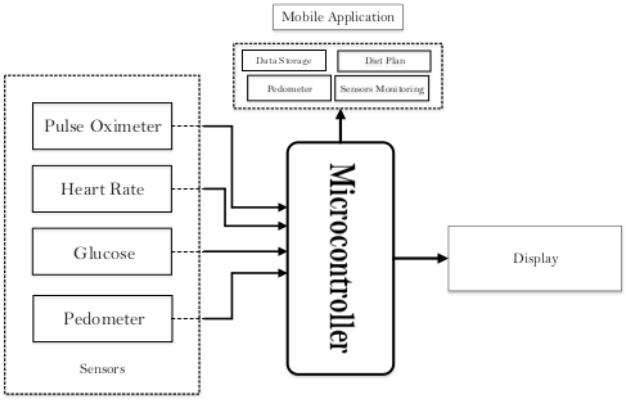


Figure 4. Project Block Diagram

Chapter 2

Literature Review

One approach for painless intermittent glucose management is to replace blood with other fluids containing glucose containing fluids, such as tears saliva, sweat, or urine [3], [4]. Continuous monitoring, on the other hand, was only possible via direct measurements of bodily tissues like cornea, skin, tongue or oral mucosa [5], [6]. Non-invasive glucose transducers should be capable of recording weak blood signals even they pass through tissues (bone, fat, skin, etc.), as well as distinguishing glucose information from that of other overlying components of greater concentrations (hemoglobin, water, urea etc.).

Non-invasive studies employing methods like thermal emission, electromagnetic, metabolic heat conformation, reverse iontophoresis, light absorption, photoacoustic, polarimetry, Raman, ultrasound, and bio impedance spectroscopy have already been reported. Along with the technique and sample location, the characteristics of the measurement environment should be considered. Ambient temperature, blood flow, breathing artefacts, body, body motions, sample length, tone of skin, unevenness of surface, sweating, width of tissue, and pressure for example, all impact transdermal monitoring findings [7], [8].

Table 1 depicted the most referred to techniques of non-invasive, target tissues and reference.

Table 1. Non-Invasive Blood Glucose Study Group

Company	Technology	Target tissue	URL
Abbott	Fluorescence	Contact lens – tears	http://www.abbott.com
Animas Technologies	Extraction of interstitial fluid	Wrist skin	http://www.glucowatch.com

Biocontrol Technology	NIR spectroscopy	Forearm skin	http://www.mendosa.com/painless.htm
Biopeak Corporation	Fusion Spectroscopy	Wrist skin	http://www.biopeak.com
BioTex	NIR spectroscopy	Skin	http://www.biotexmedical.com
Calisto Medical	Bio-electromagnetic resonance	Wrist skin	http://www.calistomedical.com
Ciba Vision	Light spectroscopy	Contact lens – tears	http://www.devicelink.com/ivdt/archive/03/05/008.html
Fluent Biomedical Corp.	Light spectroscopy	Skin	http://www.fluentbio.com
Fovioptics	Light spectroscopy	Retinal	http://www.diabetesnet.com/diabetes_technology/fovioptics.php
GlucoLight Corporation	Optical coherence tomography	Not available	http://www.glucolight.com
Glucon	Photoacoustic	Forearm skin	http://www.glucon.com
Infratec	Thermal emission spectroscopy	Tympanic membrane	http://www.diabetesmonitor.com/meters.htm

Inlight Solutions	NIR spectroscopy	Skin	http://www.inlightsolutions.com
Integrity Applications	Ultrasound, conductivity and heat	Ear lobe skin	http://www.integrity-app.com
Instrumentation Metrics	NIR spectroscopy	Skin	http://www.instrumentationmetrics.com
KMH	Extraction of interstitial fluid	Wrist skin	http://www.glucall.net/english_html/main/index_english.jsp
Life Trac	Light spectroscopy	Skin	http://www.sugartrac.com
Light Touch Medical	Raman infrared spectroscopy	Skin	http://www.lightouchmedical.com
Medicontract (Diabetic Trust)	NIR spectroscopy	Skin	http://www.medicontract.com
NIR DIagnostics	NIR spectroscopy	Skin	http://www.nirdiagnostics.com
Optiscan Biomedical Corporation	Mid infrared spectroscopy	Skin	http://www.farir.com
Orsense	Occlusion optic spectroscopy	Fingertip skin	http://www.orsense.com
Pindi	Radiomolecular magnetism (RMM)	Not available	http://www.pindi.com

PreciSense	Fluorescence resonance energy transfer	Skin	http://www.precisense.dk
Q Step Technologies	Polarized light	Eye iris	http://www.qstep.com
RetiTech	Fluorescence	Retinal	http://www.diabetesnet.com/diabetes_technology/retitech.php
Samsung fine Chemicals Company	Electromagnetic radiant ray	Finger skin	http://www.sfc.samsung.co.kr/en
Sensys Medical	NIR spectroscopy	Skin	http://www.sensysmedical.com/home.html
Sentek Group	Crystalline colloidal array	Eye	http://www.diabetesnet.com/diabetes_technology/sentek.php
Solianis Monitoring (Pendragon)	Bio impedance	Wrist skin	http://www.solianis.com
Sontra Medical (Bayer Diagnostics)	Ultrasonic–electrochemical	Skin	http://www.sontra.com
SpectRx	Laser incorporation	Skin	http://www.spectrx.com
Spire	Laser spectroscopy	Skin	http://www.spirecorp.com

Heinz Nixdorf-Chair for Medical Electronics (TUM)	Mid infrared Spectroscopy and bio impedance	Fingertip skin	http://www.lme.ei.tum.de
VeraLight	Fluorescence spectroscopy	Forearm skin	http://www.veralight.com
Visual Pathways	Visual pigment bleaching	Anterior chamber of the eye	http://vispath.com
VivoMedical	Electrochemical sweat measurement	Fingertip skin	http://www.vivomedical.com
Biocontrol Technology, Incorporated	NIR spectroscopy	Forearm skin	http://www.americandiabetes.com/diasensor.htm
Hitachi	Metabolic heat conformation	Fingertip skin	http://www.hitachi.com/New/cnews/040223.html

2.1 Reverse Iontophoresis

For many decades, iontophoresis has been utilized to move charged pharmaceutical compounds through the skin using an electrical current. Non-invasive monitoring, on the other hand, employs glucose transport in the direction opposite to the conventional medication, giving rise to the term "reverse iontophoresis" [9]. A wrist-watch glucose management device, the GlucoWatch from Animas Technologies which uses this method having two separate potentiostat circuits. [10]. It is feasible since neutral substances like glucose to be removed from epidermal surface and transported to the iontophoretic cathode through electro-osmotic flow alongside sodium ions.

Because glucose value obtained via the body with mA currents are in M ranges, the amperometric circuit must identify glucose between 50 $pmol$ to 200 $pmol$. This electrode accumulated blood sugar in hydrogel discs having the enzyme glucose oxidase (GOx). On regular basis replenished hydrogels serve as the electrolyte of an amperometric biosensor, which detects $H2O2$ produced

by the glucose oxidase-catalyzed process using nA currents [11]. Following the withdrawal and quantity of solutes, mathematical procedures forecast the value of glucose as a result. This processing takes into account the biosensor response as well as changes in temperature of skin and sweat using thermo transducers and conductivity sensors built into the device [12]. Glucose levels can be measured after10 minutes for up to half a day using this technology. Correlation coefficients among biographer and finger-stick readings are around 0.865, despite FDA clearance for an auxiliary technique that does not replace painful control, such as device is no longer accessible due to its inadequate response. Recently introduced technology's drawbacks consist of a time interval linked to blood readings, skin discomfort, errors in outcomes, lengthy standardization processes, and a 2–3 h period of warm-up [13], [14]. The GluCall from KMH Company is another reverse iontophoresis device that takes 70 minutes of warm up then monitors glucose levels after20 minutes for up to fourth part of day.

2.2 Absorption Spectroscopy

While light strikes biological tissues, it will be reflected, scattered, or transmitted depending on the shape and model chemical composition. Because of potential of molecular difference, major efforts in continuous glycemic monitoring are concentrated on the glucose optical signature spectrum.

There are numerous studies are conducted on spectroscopic in the near infrared (NIR) and visible ranges, specifically 2120–2380 nm [18], 1212–1850 nm [15], [16], [17], and 590–950 nm [19]. Such spectra are selected because the measurement signal is high in energy, water absorption is low, and a large range of marketable light transducers are accessible. Such range of wavelengths fall within the therapeutic window (600–2500 nm), permitting reflectance to be used for artificial layer studies while transmission is used for deep tissue measures [19].

However, using middle infrared spectra (mainly from $8382\,nm$ to $9708\,nm$) yields quite identifiable glucose spikes. Moreover, due of their low light penetration, these spectra cannot be used in transmittance measurements. Attenuated total reflection (ATR) measurement, which uses a beam of light directed through a crystal by total refractive index, an alternative of improving optic diffusion. When crystal surface comes into touch with the skin, the reflected light's electromagnetic field strikes the dermis, where the interstitial fluid holds the majority of glucose

of skin [20]. As a result, variations in beam absorption should mirror the optical properties of blood sugar. The presence of squalane oil at the crystal boundary appears to advance numerical forecasting [21].

Table 2 provides a wavelengths summary and optic spectroscopy objectives. Some organizations have decided to test with laser diodes to compensate for the tissue's high absorption. SugarTrack ($650-880\ nm$, $940-1300\ nm$) and Sensys ($750-2500\ nm$) , two most effective optical devices for continuous glucose tracking. According to the company Orsense, another method for improving measurements is occlusion spectroscopy. This technique uses light projections at $610\ nm$ and $810\ nm$ to temporarily stop blood flow at the fingertip [22].

Table 2. Non-invasive Glucose Light Spectroscopy Study

Research group (year)	Target site	Wavelength (nm)
Cho et al. (2004)	Finger skin	470–950
Baba et al. (2003)	Eye	532 and 635
Cote et al. (1992)	Eye	633
Gabriely et al. (1999)	Finger skin	780–2500
Saratov et al. (2004)	Skin	590, 750 and 950
Yeh et al. (2003)	Forearm skin	590, 660, 890 and 935
Heinemann et al. (1998)	Skin	800
Zhao et al. (2002)	Finger skin	905
Robinson et al. (1992)	Finger skin	870–1300
Fischbacher et al. (1997)	Skin	950–1200
Tenhunen et al. (1998)	Finger skin	1500–1850
Maruo et al. (2003)	Forearm skin	1600
Kasemsumran et al. (2006)	Forearm skin	1212–1805

Burmeister et al. (1999)	Tongue	1612, 1689 and 1731
Schrader et al. (2004)	Eye	1859–1528 and 1394–909
Olesberg et al. (2006)	Skin	2040 and 2380
Malchoff et al. (2002)	Tympanic membrane	8500 and 9600
Kajiwara et al. (1993)	Oral mucosa	3424, 9259 and 9708
Tamura et al. (2004)	Finger skin	5714–10526

2.3 Photoacoustic Spectroscopy

It uses ultrasonic vibrations caused by pulsing light absorption in tissue [23]. Heat is produced as a result of Collison of laser beam with cells which cause fluctuations of pressure in the model. Such auditory waves can be observed with a piezoelectric transducer then reflect the optical characteristics of glucose in blood at specific incidence wavelengths [24]. Non-invasive glucose monitoring systems from PAS, such as the Glucon Aprise, are already available. Though the technique has been exposed to associate with glucose levels, but it still needs to be improved in terms of repeatability and sensitivity in order to reduce drug interference.

2.4 Polarimetry

The route parameters of the crossing sample, such as thickness, temperature, and concentrations, can spin the linear polarization vector of light. As a result, polarimetry has long been utilized in the nutritional and pharmaceutical sectors for measuring the concentration of substances like glucose. Several researches have been conducted to try to utilize this method in non-invasive glycemic tests. Though skin is not the safest choice because great scattering coefficients cause full beam depolarization. As a result, many researchers concentrate their efforts on the eye's aqueous humour, as it provides a clear optical medium with a suitable route a time lag and length of less than 5 min. in connection with glucose value [25]. Typical width of a human eye's anterior chamber is 1 centimeter, resulting in anticipated spin of 4.562 milli degrees at a wavelength of 633 nm for regular glucose levels (5.55 $mmol/L$) [26].

As seen in Figure 5, there are two potential optical pathways for eye polarimetric testing. The initial employs a transmittance arrangement in which polarized light is passed across the cornea [27]. The incident beam on the cornea in the second approach goes through the eyeball, reflects in the retina, then gives info on the glucose content in the liquid humour [28].

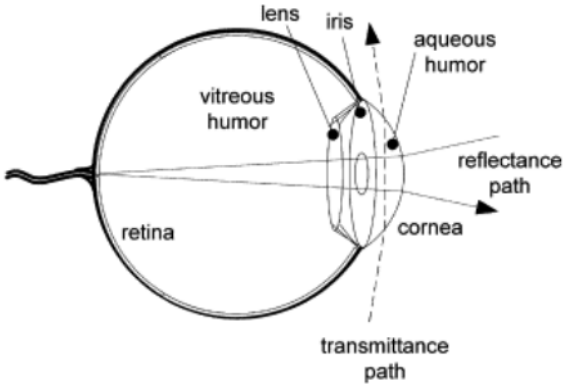


Figure 5. Transmittance and reflectance optical paths for polarimetric tests in the eye

Even though temperature and pH variations have little effect on polarimetry techniques, several issues must be addressed for effectively concentrations measurement in-vivo [29]. Some constraints include eye safety requirements, motion artefacts, optical disturbances from other substances, and the development of methods for measuring tiny angles. Recent experiments utilized a Faraday rotator using a single-mode flint glass fiber in order to increase the system's sensitivity of optic, yielding a glucose spin of approximately 0.55 $mmol/L$ [30]. Lastly, an improved liquid-crystal polarization modulator and intraocular lens controlled by a sinusoidal signal were suggested to permit in-vivo readings of the human eye [31], [32].

2.5 Fluorescence

Well understood that tears glucose concentrations correspond to blood concentrations. As a result, fluorescence is frequently used as a painless monitoring sensor [33]. This device can monitor glucose of blood using a 30-minute lag time and is unaffected by variations in the light intensity of its surroundings. Polymerized crystalline colloidal is used in photonic sensing.

The sensor may be throwaway colorless contact lenses, which would need detecting and excitation equipment. Recent findings from in-vivo tests using such transparent lenses stimulated at 488 nm

revealed that the results correspond with managed glucose levels. Long-term investigations of comfort and harmfulness, on the other hand, are still required [34]. Using colored contact lenses, extra equipment may be removed. Patients can relate the sensor color to a recalibrated color strip in a mirror if it changed color in result to the glucose concentration in their tears [35]. Colorimetric assays continue to have several drawbacks, including low resolution, short life spans, and biocompatibility [36].

2.6 Raman Spectroscopy

Raman effect describes the mechanism through which a tiny proportion of scattered light has wavelength's that differ from those of the stimulating beam. This form of spectroscopy employs laser light sources ranging from visible to MIR in order to measure feeble signals in clear as crystal like materials. The identified photons often have a lower intensity (103 times) than the original light and a lengthier wavelength, necessitating longer collecting times compare to other optical techniques [37]. As water has low scattering indices, therefore interference from this material has little effect on the Raman tests. In addition, unlike absorption spectroscopy, the resultant bands are so fine and have identifiable peaks, making signal separation easier. A recent study used a 785 nm laser source to detect glucose in aqueous humour. The beam was focused on the anterior chamber of pig eyes using an optical fiber, and the resultant spectrum was received using an optical fiber. The results indicate that Raman signals from glucose in the MIR region may be detected using discussing technique. Nonetheless, before addressing human testing, one should assess the risk of photo thermal damage in non-invasive ocular measures [38].

2.7 Metabolic Heat Conformation

This technique includes measuring physiologic indicators such as hemoglobin concentrations, flow rate of blood and HBO2 concentrations, all of which must relate to blood glucose levels [49]. Because such a technique is susceptible to significant influence from environmental factors, it is mainly utilized as supplemental glucose measurements statistics.

The initial experiments employed three distinct temperature readings (background radiation, ambient room, and surface finger) obtained from the fingertip over the course of 10 seconds. Furthermore, multi wavelength spectroscopy with six wavelengths

(470 nm, 535 nm, 660 nm, 810 nm, 880 nm, and 950 nm) was done, which aided in the improvement of glucose signals. In laboratory settings, the first metabolic heat conformation (MHC) prototype, illustrated in Figure 6, 0.91 of correlation value [39].

Figure 6. Metabolic heat conformation blood sugar monitoring device

2.8 Thermal Emission Spectroscopy

It detects infrared signals produced in the body of human as an outcome of variations in glucose content. A possible use of such sort of technology employs principle alike of regular clinical used thermometers, but using the inclusion of particular glucose fingerprinting wavelengths (9.8 m and 10.9 m). This information of membrane is significant since it gives a blood supply along with the hypothalamic temperature regulating center. Furthermore, from this organ blood vessel signals in this organ must travel a shorter distance compared to signals from skin or mouth. A calibrated and tested porotype, exhibiting repeatability along with accurately forecasting glucose value with an error of approximately 0.638 $mmol/L$ [40] . The most important sources of noise in this technique are body motions and ambient temperature.

2.9 Bio Impedance Spectroscopy

Caduff's group, in 2003, reported the earliest research of a non-invasive continuous glucose monitoring device using bio impedance spectroscopy. This research encouraged the firm

Pendragon in created the Pendra wearable wrist glucose display, which gathers data from an LC resonance circuit ranging in frequency between $1\,MHz$ to $200\,MHz$, using skin acting as a dielectric from the capacitor. A drawback of discussing study is that it necessitates an equilibration period in which the patient rest 60 minutes before beginning measurements is required [41].

Pendra was authorized by the Conformite Européenne (CE) in May 2003 and was briefly available on the market for around €3000. When compared to a lancet device, a pre-marketing research found an alteration of 52% (which is 4.3 percent of results in the hazardous E zone from the Clarke error grid) [42]. As a result, this equipment is only appropriate for a restricted set of clients with local dielectric skin properties that exhibit a smallest resonance frequency [43]. Pendragon was shuttered in 2005, although Caduff's impedance work is currently being studied by the business Solianis Monitoring [44].

2.10 Ultrasound

Reverse iontophoresis isn't the only way to collect non-invasive molecules of glucose from body. Sonophoresis is often used to improve transdermal medication delivery, can also be used for this purpose. This approach employs a piezoelectric transducer to generate ultrasonic (US) at a frequency of $20\,kHz$, which improves interstitial fluid cutaneous permittivity, allowing to delivered glucose to the epidermal. Analyze concentrations thus be measured using conventional electrochemical glucose sensors. Early in-vivo laboratory studies predicting glycemic levels in rat skins have been published [45].

2.11 Electromagnetic

Such sensors are built on Eddy currents capable to sense variations in blood dielectric properties, which can also be produced by changes in glucose content [46]. In static and moving samples, blood conductivity discovery within a plastic pipe was achieved at a $2.664\,MHz$ of resonant frequency , with $4.4\,mmol/L$ of glycemic sensitivity [47]. Magnetic glucose tests can also be used to characterize studies from the z group. This study found that even localized nuclear magnetic resonance (NMR) can accomplished in identifying glycogen metabolism in the human brain. [48]

Chapter 3

Circuit Simulations and Integrations

3.1 Glucose Forecasting

The supreme essential way to treat diabetes is to regularly monitor your glucose levels. This enables you to see what reasons your numbers to climb or drop, like eating different foods, proper medication, or physical exercise. As a result of acknowledging the relevance of continuous glucose monitoring, we conducted a thorough review of research articles that employed various methods for glucose monitoring. We determined four circuits after studying the results of this poll.

3.1.1 Basic Principle of Glucose Monitoring

Beer-law Lambert's expresses the connection between absorbance and the concentration of absorbance through which it travels. When infrared light strikes a substance, some of it is absorbed by the molecules in the material. The absorption of infrared light varies with wavelength. Beer-law, Lambert's as seen here, expresses absorbance:

$$A(\lambda i) = \text{Log}10\ (Li / Lt)$$

Where Li and Lt are Intensity of incident light and attenuated light respectively.

In terms of concentration absorbance is also expressed as:

$$A(\lambda i) = \epsilon CD$$

Where, D is optical path length, ϵ is molar absorption coefficient, Ci is concentration of material and A is (λi) absorbance of material.

According to the rule, light absorption is proportional to substance concentration. The amount of light absorbed is determined by the number of molecules with which it interacts. Because light is absorbed by material molecules as it travels through the material, its intensity decays exponentially. As a result of Beer-law, Lambert's a single wavelength is chosen for determining glucose concentration.

3.1.2 Wavelength Selection

There are several peak points where glucose absorption is extremely high. These wavelengths are 935nm, 1150nm, 1450nm, and 1536nm. As a result, a wavelength of 940nm was chosen for investigation. Above 1550nm, the penetration depth of human tissue is quite considerable, while light absorption by water in blood increases significantly.

3.1.3 Circuit Selection

After doing a great literature review we have finalized four circuits which are discussed below:

Circuit 01

Circuit 01 outlines a very basic possible design and development for a non-invasive blood glucose monitoring device. The suggested method transmits and receives rays from the finger using a near infrared sensor. The amount of glucose may be anticipated by evaluating the intensity fluctuation in the received signal using a photo-detector on the opposite side of the finger.

Block Diagram of Circuit 01 is given in Figure 7.

Figure 7. Block Diagram of Circuit 01

Simulations

As a student, I use Altium Designer for simulation. The software's extensive library and project management capabilities make it simple to use. The schematic diagram of circuit 01 is given in Figure 8.

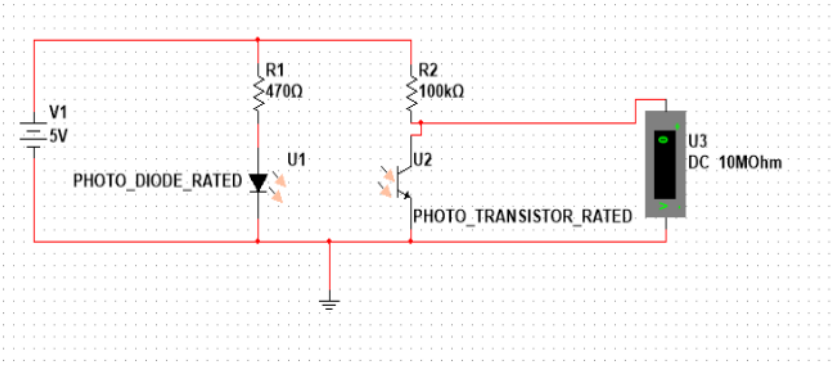


Figure 8. Schematic Diagram of Circuit 01

In simulation results a constant voltage of 0.48m is get at the terminal of photodiode as shown in Figure 9.

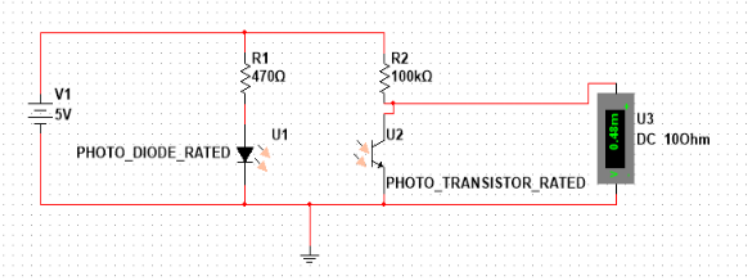


Figure 9. Simulation Results of Circuit 01

From the schematic we know that this circuit works as some voltage is get at terminal of photo-diode. Now it's time to check whether this circuit fits for glucose monitoring.

Hardware Development

The primary goal is to analyse infrared spectra from glucose human samples in order to predict blood glucose levels. The approach employed is to emit infrared light via the finger. The photodiode on the other side of the IR emitter receives the attenuated light.

An NIR LED, also known as an NIR transmitter, is a type of LED that transmits infrared light. LEDs of this type are often constructed of gallium arsenide or aluminum gallium arsenide. They feature a current carrying capacity of 100mA and a voltage carrying capacity of 1.5v2.5v.

Analog to digital conversion is conducted and saved in the buffer after receiving the signal from the photodiode. For programming, the Arduino IDE software is utilized. A linear regression model is used for analysis, which is done with the help of a dataset. The dataset was created by examining individual patients using the Certzer gluco-meter and a custom-built hardware configuration.

Hardware implementation and Results

After purchasing all of the required components, a hardware implementation is completed, as illustrated in Figure 10.

Figure 10. Hardware Implementation of Circuit 01

This circuit gives us a resultant voltage of 4.96 to 4.99 as shown in Figure 5.

From this voltage using linear regression model a glucose value is predicted which is shown as "analog voltage in mg/dl" in Figure 11.

Figure 11. Hardware Implementation Results of Circuit 01

Circuit 01 Rejection Reason:

Different people's glucose levels were tested, but this circuit showed approximately 89 mg/dl for everyone. It is unable to properly forecast glucose levels. This circuit indicates that some filters and amplifiers should be added to it.

Circuit 02

The work of Circuit 02 is likewise based on the NIR optical technology. As illustrated in Figure 6, an NIR emitter and an NIR receiver (photodetector) positioned on both sides finger. When NIR light passes through the finger then relates with the molecule of glucose, a portion of the beam is absorbed depending on the glucose concentration in the blood, while the remainder is passed through the finger. The quantity of NIR light which passes through the finger is proportional to the levels of blood glucose.

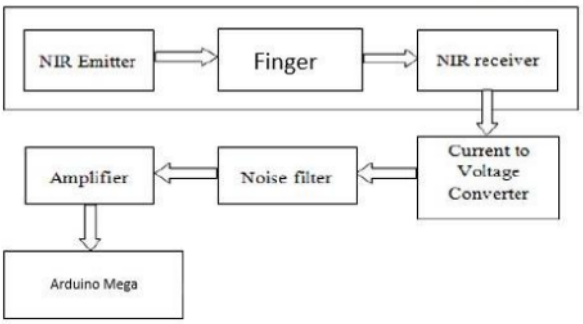


Figure 12. Block Diagram of Circuit 02

The photodetector detects the transmitted signal. The photodetector's output current is transformed into a voltage signal, which is subsequently filtered and amplified. This signal is amplified and sent into the Arduino microcontroller. The received analogue signal is then converted to digital form using an ADC. Linear regression is used to process this signal and to predict glucose level.

Circuit 02 Simulations

The schematic diagram of circuit 02 is given in Figure 13.

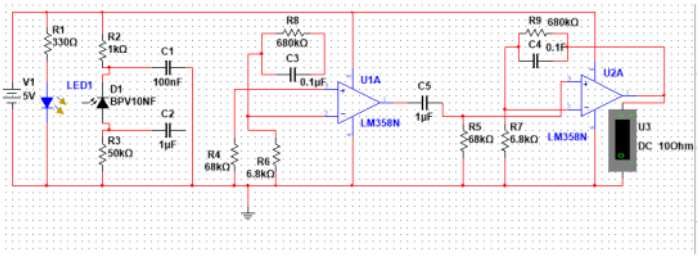


Figure 13. Schematic Diagram of Circuit 01

In simulation results a constant voltage of 40.4mV is obtained as shown in figure 14.

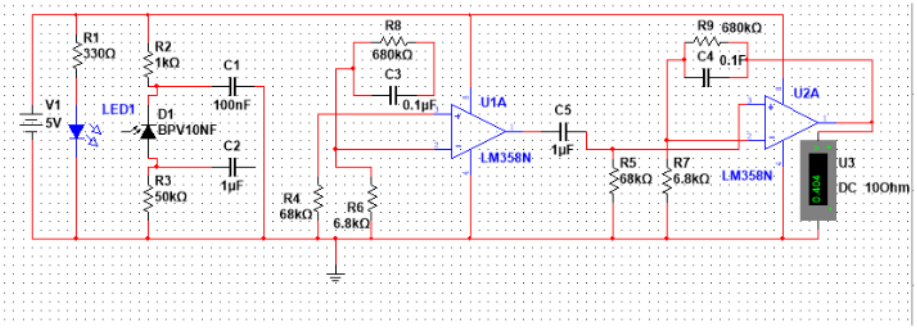


Figure 14. Simulation Results of Circuit 02

From the schematic we know that this circuit works as some voltage is obtained. Now it's time to check whether this circuit fits for glucose monitoring.

Hardware Development

The developed system's circuit schematic includes a filtering stage and an amplification stage. By connecting the load resistance to the anode side of the photodiode, the electrical current acquired from the photo detector is transformed into voltage. The corners frequency of the low and high pass filters are also chosen.

The increased output voltage is linked to an analogue pin on the Arduino Mega microcontroller, which converts the analogue data to digital values. The glucose level is represented by this digital number. The real glucose level is calculated using a linear regression algorithm based on this digital number. This equation is derived from laboratory glucose levels obtained by invasive measurement.

After acquiring all of the components specified in the system design, we built a bread board circuit to see whether this circuit would work for us as shown in Figure 15.

Figure 15. Hardware Implementation of Circuit 02

A code for Arduino is created to determine the glucose level for a given analogue signal. The photo detector's continuous analogue voltage readings are collected by putting the finger between the NIR emitter and the photo detector.

```
analog voltage in mmol/l =
0.07
analog voltage in mg/dl =
1.23


analog voltage in mmol/l =
1.65
analog voltage in mg/dl =
29.65


analog voltage in mmol/l =
0.03
analog voltage in mg/dl =
0.53
```

Figure 16. Hardware Implementation Results of Circuit 02

Circuit 02 Rejection Reason

This circuit gives very random or abrupt values of glucose. For this we provide a common ground to circuit and work a lot on its ground but all in vain. But we get a clue that if some high pass filter is added then there is some chances that we can get some satisfied results.

Circuit 03

The essential principle of this circuit is that when power is applied to the IR sensor, resistor, capacitor, and diodes, the LED begins to produce light radiations. If the surface is white, it reflects 100% of the radiations. The white surface reflects all radiations that strike it, but the black surface absorbs them. As these radiations strike the photodiode, which is linked in reverse bias, the resistance of the photodiode rapidly drops, as does the diode voltage drop. Pin 3 voltage starts to rise, and when it is more than the voltage at Pin 2, a high value is resulted at output of comparator. Even if the LED emits light on the black surface, it is not reflected, thus the photodiode does not detect anything and its resistance is infinite. As a result, the comparator will provide a low output. The IR sensor emits light every seven seconds, and the values are computed.

The block diagram of this concept is given in Figure 17.

Figure 17. Block Diagram of Circuit 03

Circuit 03 Simulations

The schematic diagram of circuit 03 is given in Figure 18.

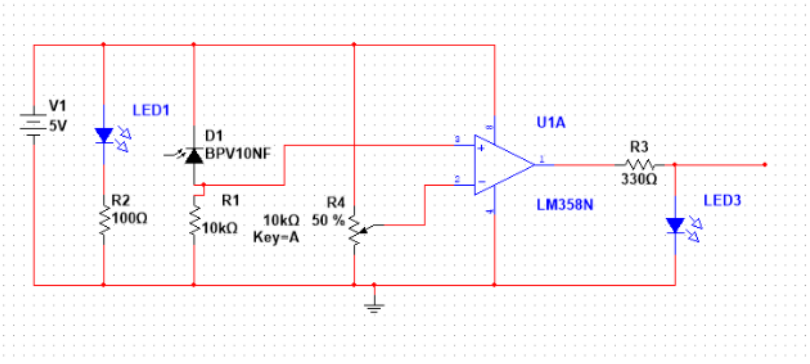


Figure 18. Schematic Diagram of Circuit 03

In simulation results a constant voltage of 31.6 mV is obtained as shown in figure 19.

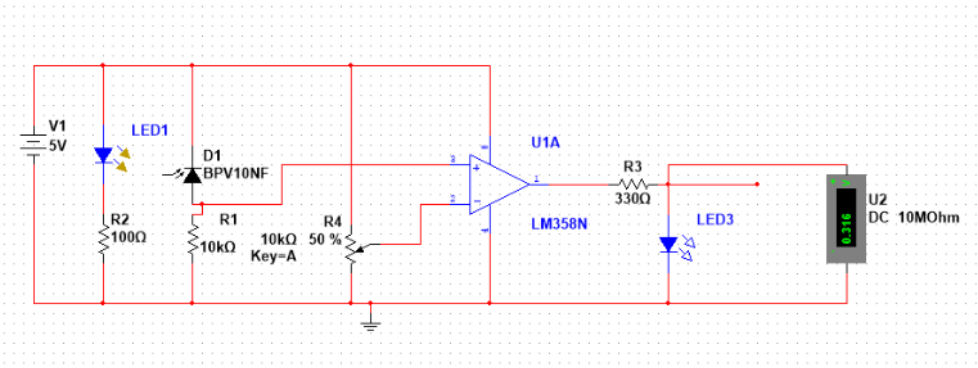


Figure 19. Simulation Results of Circuit 03

From the schematic we know that this circuit works as some voltage is obtained. Now it's time to check whether this circuit fits for glucose monitoring.

Hardware Development

Infrared radiation is emitted by a light-emitting diode. The emitter's job is to transform electrical energy into light energy. A photodiode is a p-n junction diode that is biased in the opposite way. This detector's job is to convert light energy into electrical energy. In this circuit, an Operational Amplifier serves as a comparator.

When we analyzed this circuit then we get an idea that this is IR proximity sensor circuit. So in Pakistan there are two sorts of proximity sensor available as shown in Figure 20.

(a)

(b)

Figure 20 (a) Proximity Sensor 1

(b) Proximity Sensor 2

Arduino IDE is used to write a code for these modules.

Results obtained Proximity Sensor 1 as shown in figure 21.

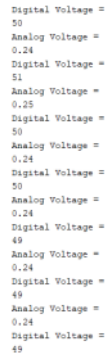


Figure 21 Proximity Sensor 1 Results

Our observations for Proximity Sensor 1 are as follows: when the finger travels near the IR Sensor, the voltage increases; when the finger goes away from the sensor, the voltage drops; and a voltage range of 37V to 60V is seen.

Results obtained from Proximity Sensor 2 is shown in Figure 22

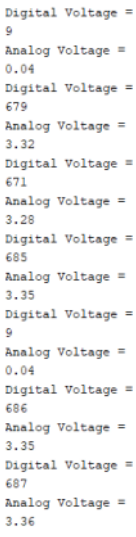


Figure 22 Proximity Sensor 2 Results

From our observation this sensor works really well for obstacle avoiding but not suited for glucose monitoring

Circuit 03 Rejection Reason

This circuit gives us really stabilized results but when we apply linear regression on it and compare its results with invasive glucometer then very low accuracy is obtained. It's very obvious that when finger moves near to this sensor then voltage increase which decrease the value of glucose [voltage glucose relationship paper] and inversely. This sensor or circuit only detect any material near to it but cannot predict glucose level in human body.

Circuit 04

Figure 23 depicts the block diagram of Circuit 04.

Figure 23. Block Diagram of Circuit 04

The system's overall configuration is divided into sections. Optical transmitter's light is first transmitted through a finger. A photodetector detects the transmitted light, which converts it into voltage. The output of photodetector is then filtered and amplified. A Photoplethysmography signal is achieved after filtering. A Photoplethysmography signal is then transformed to a digital signal. Peak to peak voltage of Photoplethysmography signal is identified, and linear regression is implemented to predict glucose value. The predicted glucose level is then displayed on the TFT LCD screen.

Circuit 03 Simulations

When we verified the simulation of circuit 04, we got a voltage of 3.566 V. It is now time to test it for glucose prediction by implementing the hardware setup.

Hardware Development

As an IR sensor, an optical transmitter and receiver are used. When light is transmitted through the finger, then photodetector response is passed through a capacitor, which removes the DC component. The DC component is superimposed on top of Photoplethysmography signal, which is caused by vein, artery and tissue. Generally, the heart rate of human ranges from 30 to 120 beats per minute. The term bpm refers to the number of beats per minute. So, this means that it ranges from 0.5Hz to 2Hz. To achieve this, a band pass filter must be designed in order to obtain a PPG signal.

After calculating Gain capacitors and resistors values we started to design a circuit as shown in Figure 24.

Figure 24. Hardware Implementation of Circuit 04

This filtered signal is fed in A10 pin of Arduino MEGA for ADC conversion as shown in Figure 25.

```
analog voltage in mmol/l =
1.91
analog voltage in mg/dl =
34.40


analog voltage in mmol/l =
1.82
analog voltage in mg/dl =
32.82
```

Figure 25. Hardware Implementation Results of Circuit 04

Why This Circuit is finalized?

When I compared this noninvasive circuit results with invasive circuit results then both glucometer values are so close. We tested this circuit at five different time with invasive glucometer obtained results are mentioned in Table 3.

Table 3 Comparison of Invasive and Non-Invasive Devices results

Sr. No.	Date	Invasive Results	Non-Invasive Results
1	21st June	127	123
2	24th June	115	125
3	25th June	81	76
4	2nd July	107	102
5	14th July	138	136

As our target is to replace invasive glucometer with non-invasive glucometer so our accuracy as compared to invasive glucometer is 82%. So we selected Circuit 04 to add in our device for glucose monitoring.

We added some additional features in this device like pulse oximeter, heart rate monitoring and pedometer. In this device we have used RTC module along with multi-color attractive touch screen display.

3.2 Pulse Oximeter and Heart Rate Monitoring

Pulse oximeter is a painless and noninvasive device that detects your oxygen saturation level, or the amount of oxygen in your blood. Pulse oximetry measures the magnitude of reflected red and infrared light to assess blood oxygen saturation. By measuring the time series response of reflected red and infrared light, pulse oximeters may also approximate heart rate. The pulse oximeter used in this project is an Arduino-compatible, low-cost sensor that allows heart rate to be calculated using the method mentioned above.

3.2.1 Why we added pulse Oximeter in Our Device?

Pulse oximeter is used to determine how successfully a heart is pushing oxygen throughout a body. It may be used to observe the people health who have any disease which can influence their oxygen levels, specifically if they are in the hospital or in ICU. These situations contain:

- Asthma
- Anemia
- Cancer of Lungs
- Heart Attack
- Pneumonia

The heart rate monitor allows anyone a report of how hard one is working out, allowing anyone to make modifications to develop a most effective workout routine. Monitoring one's heart rate during exercise can help all exercisers to retain aerobic target regions and fat-burning based on their aims.

3.2.2 Pulse Oximeter Working

Oximeters operate on the principles of spectrophotometry: the systolic component of the absorption waveform's relative absorption of red and infrared light corresponds to arterial blood oxygen saturations. Small laser beams travel through the finger to measure the quantity of oxygen. This is accomplished by observing variations in light absorption in oxygenated or deoxygenated blood. As a result, the pulse oximeter will be capable to update you about your heart rate as well as oxygen saturation levels.

3.2.3 Pulse Oximeter Readings and setup

Pulse oximeter is a relatively accurate device, when utilizing good tools like that set up in most hospitals or medical offices. It regularly produces findings that are within a 2-percentage point of what they actually are. For most healthy people, a 95% oxygen saturation level is claimed as normal.

According to the Centers for Disease Control and Prevention, a person's goal heart rate for moderate-intensity physical exercise should be 50% to 70% of his or her maximal heart rate.

The hardware Implementation of Pulse oximeter is shown in figure 26.

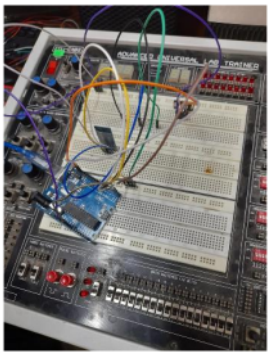


Figure 26. Pulse Oximeter Hardware Implementation

The Bluetooth module, a transparent wireless serial communication device, is utilized here to link this pulse oximeter to our mobile application. Its functionality becomes visible to the user once it is linked with a tablet or android phones. All statistics received via the serial input is referred over the air instantaneously. When wireless data is reached to module, it immediately directs it out through the serial interface. In the user microcontroller programme, no Bluetooth module-specific user code is required. The mobile application that displays spO2 and BPM values is shown in Figure 27.

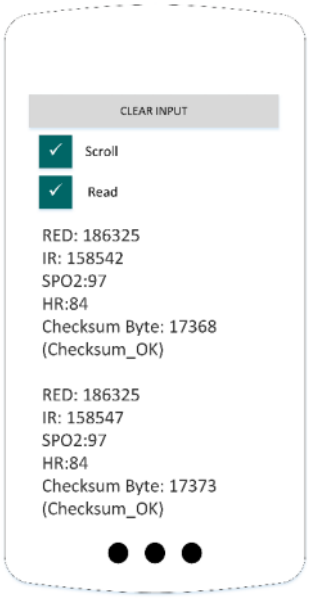


Figure 27. Mobile Application showing Oxygen & Heart Rate values

Where in Figure 21 HR is heart rate with units of BPM (beats per minute) and SpO2 is the Oxygen saturation level expressed in percentage (%).

3.3 Pedometer

Pedometers are designed to detect vertical hip movement and so measure the number of steps taken as well as offer an estimate of the distance walked.

3.3.1 Why we add Pedometer in our device?

The single most important advantage of using a pedometer is that it is an excellent motivator for improving physical activity and fitness awareness among diabetes patients. Stanford researchers discovered that walkers who used pedometers finished approximately 2,000 extra steps per day than walkers without pedometer. Users of pedometers improved their overall physical activity level by 27%. Pedometers are incredibly beneficial for measuring your daily activity in an objective and accurate manner. You may believe you are taking sufficient steps, but the majority of people emphasize their real steps number. You can easily detect when you are falling short of your daily goal and make the necessary changes. Pedometers, which offer an exact readout of your steps and calorie consumption, might provide that extra motivation to meet your daily target.

3.3.2 Pedometer Working

A pedometer estimates a person's total number of steps by using the three components of motion: forward, vertical, and side. An accelerometer is used by the pedometer system to obtain this information. After a predetermined number of samples, the accelerometer constantly updates the maximum and minimum values of the 3-axis acceleration. The dynamic threshold level is the average value of these three axes (Max + Min)/2, and it is utilized to determine whether or not the step is made.

3.3.3 Pedometer Reading and setup:

To begin, the pedometer begins calibration as soon as it is switched on. Then it begins to continually collect data from the X, Y, and Z axes. The total acceleration vector from the beginning position is then calculated by taking the square root (x2+y2+z2) of the X, Y, and Z-axis values.

The average acceleration data are then compared to the threshold values to determine the step number. If the acceleration vector reaches the threshold value, the step count is increased; otherwise, the faulty vibrations are discarded. Figure 28 depicts the pedometer hardware configuration.

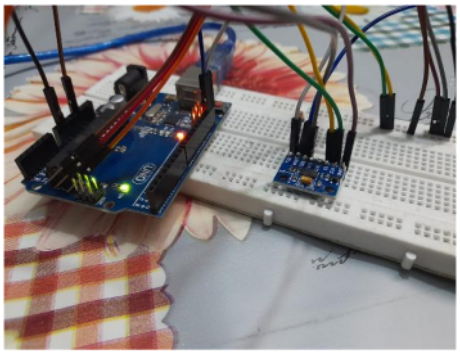


Figure 28. Pedometer Hardware Setup

Here Bluetooth module, which is transparent wireless serial communication device, is also used to connect this circuit with our mobile application. Its process becomes user visible once it is paired with a tablet or smartphone. All statistics received via the serial input is transmitted over the air immediately. So, when wireless data touched the module, it immediately sends it out via the serial interface. Mobile Application which is showing X, Y and Z axis values and steps count are shown in Figure 29.

Figure 29. Mobile Application showing Steps

3.4 Overall Integrations

At the end pulse oximeter and heart rate module, pedometer module and glucose monitor circuits are integrated all together to move towards the PCB. This overall circuit is powered by using fast quick charger circuit board. The view of overall integration is shown in Figure 30.

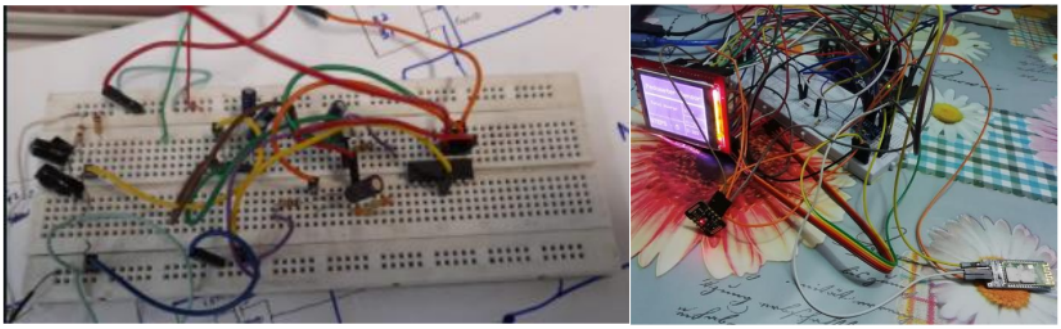


Figure 30. Full Device Integration

Chapter 4

PCB Designing

4.1 PCB Designing Software

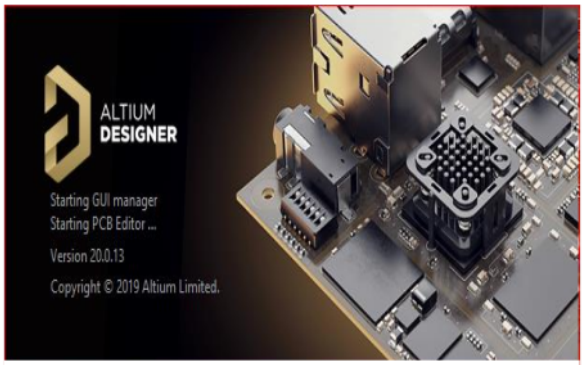


Figure 31. Altium Designer Software

Altium Designer is likely the most well-known of today's high-quality PCB plan programming kits. Altium Restricted is the company that produced it and promotes it. It supports track length editing and animation demonstrating by including a schematic, PCB module, an auto-switch, and differential pair guiding highlights.

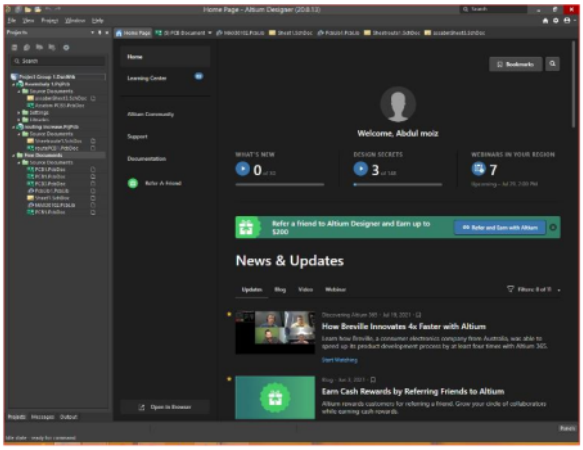


Figure 32. Altium Designer Interface

Altium Planner includes tools for all circuit configuration tasks, including HDL and schematic capture, circuit replication, signal integrity analysis, PCB design, and embedded framework design and development based on FPGA. In addition, the Altium Architect environment can be customized to meet the needs of all types of clients. Altium develops user-friendly software.

4.2 Project Schemetic Diagram

Figure 33. shows the Schemettic diagram of pulse oximeter and pedometer.

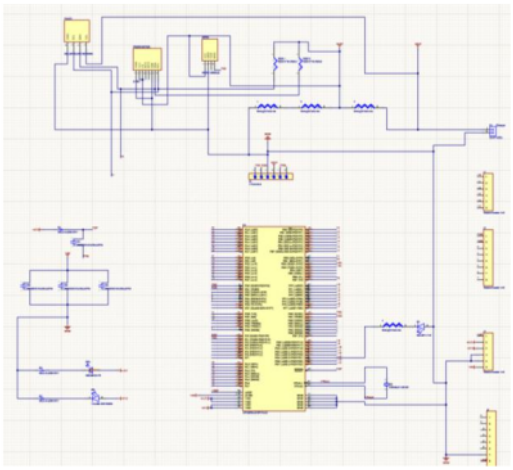


Figure 33. Pulse Oximeter & Pedometer Schematic Diagram

Figure 34. shows the Schemettic diagram of Glucose Meter with RTC Module.

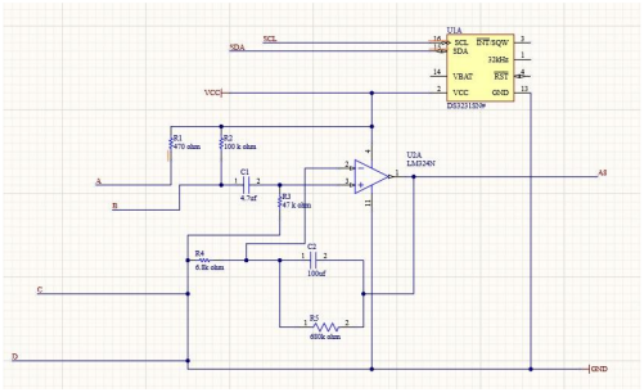
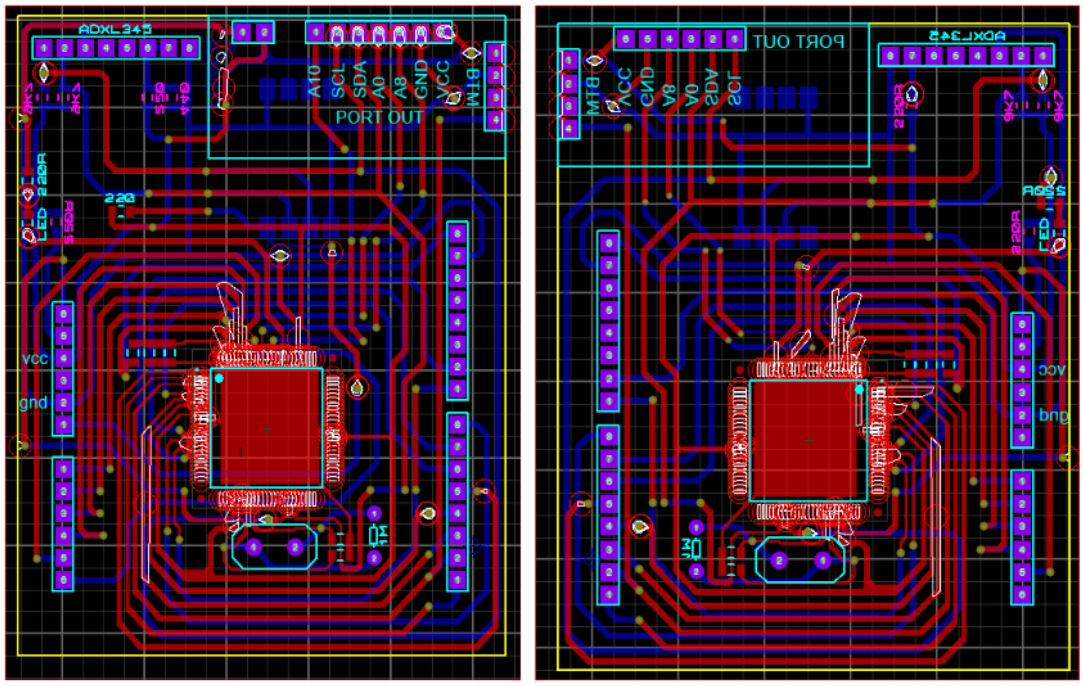


Figure 34. Glucometer Schematic Diagram

4.3 Project PCB Design

Figure 35. , 36. shows the top and flipped view of PCB of pulse oximeter and pedometer.

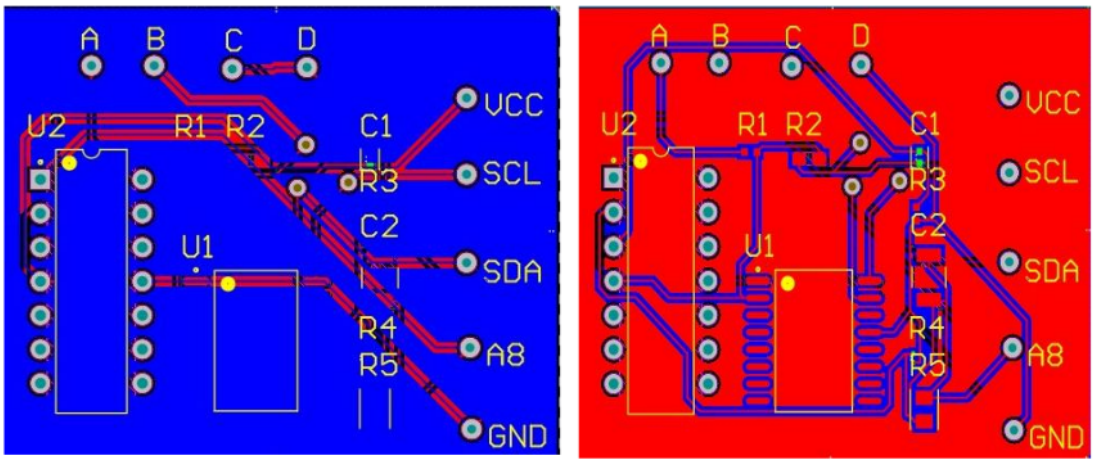


(a) (b)

Figure 35. (a) PCB Top View

(b) PCB Flipped View

Figure 37. , 38. shows the top and flipped view of PCB of pulse oximeter and pedometer.



(a) (b)

Figure 36. (a) Glucometer PCB Top View

(b) Glucometer PCB Flipped View

4.3.1 Atmega 2560

Microcontroller may be the most adaptable and widely used integrated circuit in electronic circuits. The microcontroller is a programmable simple circuit (IC) that can be thought of as a small PC system. Microcontroller ICs usually integrate the focus of the processor, Pummel, ROM, and information/performance peripherals into a set of ICs. Due to its adaptability and convenience, microcontrollers are mainly used for electronic circuits and basically fully mechanized input systems. From home machinery components, office machines, theater layouts, modems and candy machines to satellite systems, microcontrollers are everywhere in today's robots, military equipment, automobiles and airplanes. The best part of microcontrollers is their ability to change, allowing draftsmen to retry their convenience according to their needs. Today, there are a large number of specific microcontrollers on the market with moving part sizes, group sizes, clock speeds, RAM, ROM, I/frames, and other specific details available for inspection. The latest ideal advancing model from Industry 4.0 and the Internet of Things expands the use and meaning of the microcontroller complex.

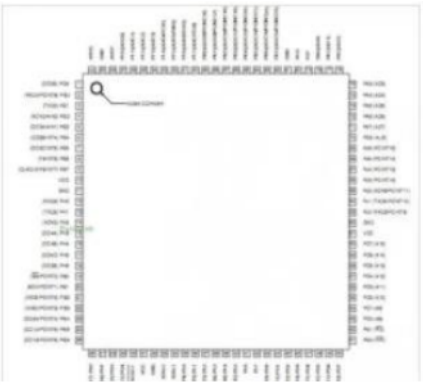


Figure 37. Atmega Chip Pins

The ATMEGA256016AU is a low-power 8-cycle AVR microcontroller from the ATMEL Company. The ATMEGA256016AU microcontroller is a RISC (Reduced Guidance Set PC) architecture with 256kB Blaze memory. There are additionally 4KB of EEPROM, 8KB of internal SRAM, and 86 GPIO connections on the microcontroller IC. Three adaptive clock/counters, a sequential USART, an SPI interface, a 10-bit ADC, and five pros are also included in the device.

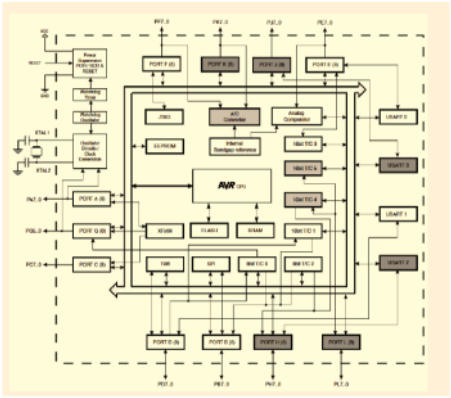


Figure 38. Atmega Internal Circuitry

4.3.2 Max30102 Sensor

This sensor is a combined coronary heart rate and pulse oximetry biosensor module. It is comprised of LEDs, photodetectors, optics, and low-noise electronics with ambient temperature suppression. MAX30102 provides comprehensive machine options to simplify battery and portable device design technology.

The MAX30102 uses a technique called photo plethysmography to grade someone's coronary heart rate. This focal point emits a faint light on the skin and measures blood perfusion. One of the practical components of this method is that it is very feasible to distinguish soft meditations with the help of different additives from the blood from the arteries (which produces AC output) and from the framework including bones and tissues (which produces DC output). The photodiode inside the sensor then smoothly converts it into a contemporary, which we use as understandable data.

To counter problems which includes pores and skin tone variations LEDs with one of a kind wavelengths are used. In the MAX30102 there may be an additional inexperienced LED for this purpose.

Another log could be published in a while to offer precision on how we calculate the SP02 and coronary heart-fee from the AC output of the sensor.

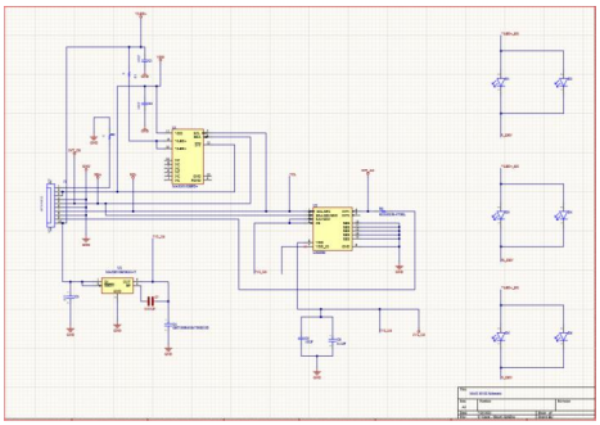


Figure 39. Schematic of MAX30102

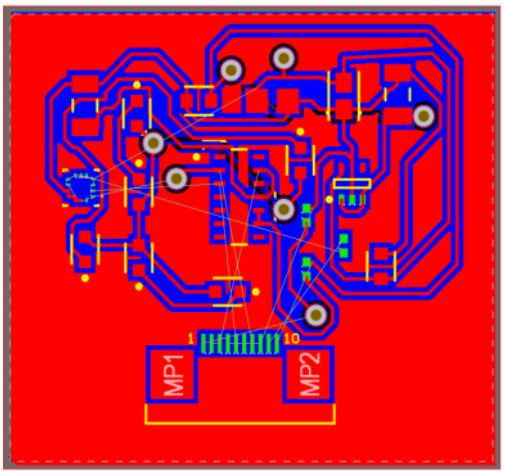


Figure 40. Footprint of MAX30102

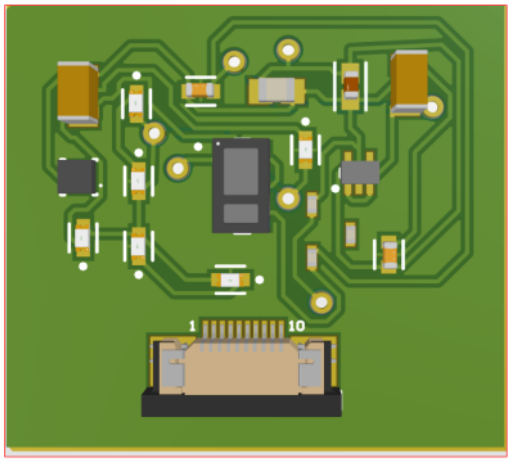
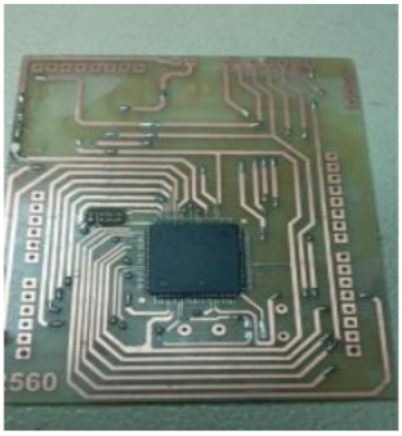


Figure 41. PCB of Max30102

4.4 Project Printed Circuit Board(PCB) Hardware

Figure. 44 shows PCB of Pulse oximeter and pedometer while (b) shows PCB of Glucometer with Rtc module.



(a) *(b)*

Figure 42. (a) Pulse Oximeter and Pedometer PCB

(b) Glucometer PCB

4.4.1 Problem Occurred

Here u unfortunately one problem is faced that atmega solder in the pcb of pulse oximeter and pedometer is not working. When we checed it then find out that crysral oscillator of atmega is not working. So, due to shortage of time it is not possible to again make two layer pcb of project so, we decided to design varrow board for project.

4.4.2 Varrow Board Design

So final varrow board design of project is depicted in Figure 45.

Figure 43. Project Varrow Board Design

Chapter 5

Mobile Application

In current world of technology and success there are many software for android application development like Leak Canary, IntelliJ IDEA, Source Tree and Android Studio etc. We use android studio for our application because developing Android apps can be a lot of work so it purpose-built to creates a tool for best-quality applications for Android devices. It helps us to create the maximum demanded applications for every Android device used today. Android Studio is an advance tool for application development. It supports both languages like java and kotlin. It provides both facilities like coding and working on front end. You can work on the front end of layouts as well as the background coding. It supports thousands of different libraries and features and most importantly Its fee of cost you just need to install android studio and began your work without any worry.

5.1 Brief View of Application

Before developing our application, we decided a name for application that was "Glucoxy" that we finalize. Then we created UI's for application using AdobeXD. After developing complete UI's for application we start working with application. Following are the brief introduction to every activity of application.

5.1.1 Activity 1

In this activity there is a Logo we developed for our application and the name of our device is "Glucoxy Meter". After installing, when user open application this activity appears. By clicking on "START" button user moves to next activity

Figure 44. Android Application Activity 1

5.1.2 Activity 2

In this activity user has to write their email and password. This activity does not move to next activity until proper format for email and password is typed. It shows a warning message until proper email syntax is written along with password that should be alphanumerical. Then after pressing the "LOG IN" button it leads to next activity.

Figure 45. Android Application Activity 2

5.1.3 Activity 3

This activity shows login email on top of tab along with Welcome message. This activity contains 4 tabs which are:

- Pulse oximeter
- Glucose
- Rate us
- About App

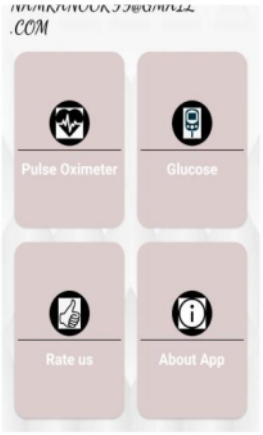


Figure 46. Android Application Activity 3

5.1.4 Activity 4

When we press pulse oximeter tab then it leads to activity that search and connects our mobile application to Pulse Oximeter through Bluetooth module and starts to show sensors values on application.

Figure 47. Android Application Activity 4

5.1.5 Activity 5

From activity 3 if user select Glucose tab then it leads to this activity which is Personal Data. Here patient write its glucose value in mg/dL, weight in Kg, height in feet, Glucose type (either type 1 or 2), Patient age, Gender and also some notes. Then there are 3 different buttons that serve different purpose. "Next" Button Leads to activity 7, "Use Sensors" Button leads to activity 4 where now user can use Glucose sensor instead of pulse Oximeter and connect through HC-06 for data. The "Store Data" button leads to storage activity that is activity 6.

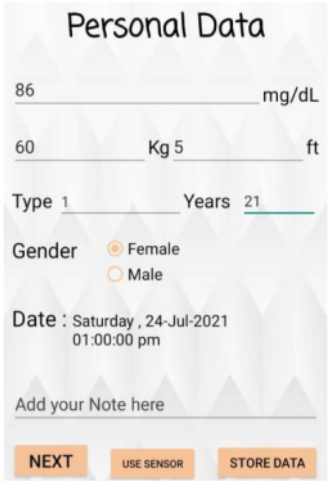


Figure 48. Android Application Activity 5

5.1.6 Activity 6

This activity has values from previous personal data activity and now with the help of four buttons (Store locally, Store on cloud, View Local Data and View Cloud data) we can store these shown values on Aws DynamoDB or mobile storage. And also view this data on application by view buttons.

Figure 49. Android Application Activity 6

5.1.7 Activity 7:

The "Next button leads to this activity. This activity is a fragment activity that has 3 parts, one part (OVERVIEW) show the real time graph for Glucose value. It also shows the date and time when user check his/her glucose value last time. According to glucose value from personal data activity it tells about the current condition of patient either his glucose value is normal, too high or too low. There is also a "GO TO PLANNER" button that leads you to activity 8 that shows diet plan according to diabetes type.

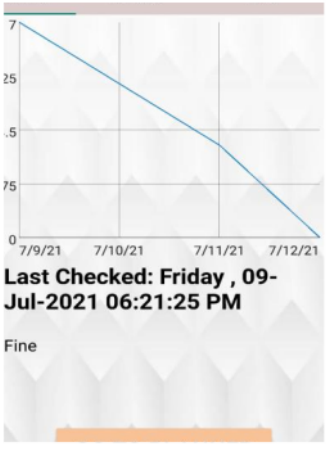


Figure 50. Android Application Activity 7

5.1.8 Activity 8:

This Activity has 3 different diet plans. If glucose value is less than 90, above 126 or between 100 to 125 mg/dL then user can choose diet plan accordingly. There is also a "Calories Burner" tab that connects the application through HC-06 to pedometer that count steps that patient has taken.

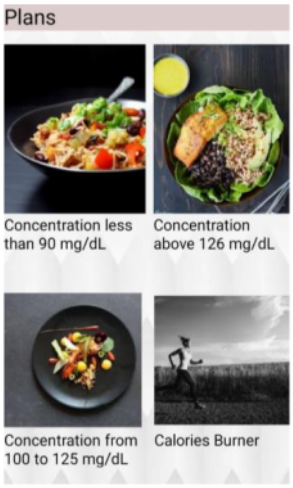


Figure 51. Android Application Activity 8

5.1.9 Activity 9:

This activity contains diet plans. There are 2 diet plans one is weekly plan and other is day plan. There is a "Make your plan" option that allow patient to make their own diet plan.

Figure 52. Android Application Activity 9

5.1.10 Activity 10

Here is activity in which user can make his/her own diet plan from few options given in our application,

Figure 53. Android Application Activity 10

5.1.11 Activity 11:

The "Tip" fragment show some tips about diabetes and importance of exercise for them to remain healthy.

Figure 54. Android Application Activity 11

5.1.12 Activity 12:

The "HISTORY" fragment show runtime data of sensors that application show through HC-06 and save it. This tab show data of sensors stored in device. The data of different sensors show with the names of sensor and date and time when data is stored.

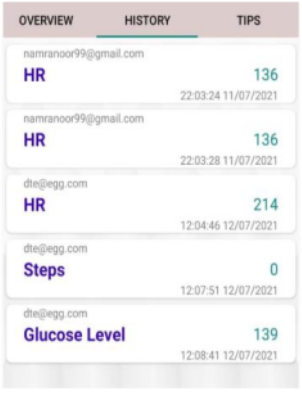


Figure 55. Android Application Activity 12

Chapter 6

Data Storage

6.1 Introduction

The process in which we use a network of remote servers for hosting, storing, managing and transmission of information through the Internet is referred to as **cloud computing**. An alternative way for storing, processing and managing data is a local server or personal computer. Because of the simplicity of use and lower upkeep, many technological applications that were formerly popular as installed software are now favored as cloud apps. Cloud computing, social media, mobile devices, and data analytics provide significant benefits to businesses of all sizes, but according to a recent study, only about 10% of businesses believe the IT infrastructure that they are currently using is fully prepared to manage the proliferation of cloud computing and mobile devices.

6.2 Benefits of Cloud Computing

In today's world consumers and online sellers have acceptance to cloud computing. Internet businesses expand their earning potentials through cloud computing while also providing clients with access of thousands of trump card, and it has numerous advantages over traditional computers. Written below are some advantages of cloud computing:

Scalability - It may be increased or decreased dynamically in response to the demands of online businesses.

Data Security- Because data is saved on a distant server, there will be no loss of data even if the internal network or personal computer fails.

Accessibility - Cloud computing can be used to improve access to resources that are inaccessible on the desktop, even if customers are far away. It is a new way of accessing information which was either inaccessible or locked

Pay-Per-Use- Cloud Computing Services allow user to use as much features as they need and they have to pay for only those things they need and use for their product or services.

6.3 Major Cloud Services

The cloud has various forms of computing according to the service type. It also has public, private and hybrid cloud web hosting surroundings that host and store data. Three major service categories are SaaS, PaaS, and IaaS that are defined below.

SaaS (Software as a Service): It is the worldwide known service between online retailers, through which sellers can run direct sales, they can also run applications like shopping carts in the cloud and they don't need to install or download programs for buying.

PaaS (Platform as a Service): Unusual in the e-commerce industry, PaaS is used for hosting Java-based applications.

IaaS (Infrastructure as a Service): Focus on delivering on-demand data center infrastructure. Netflix, for example, uses Amazon Web Services to store a library of movies and TV shows

6.3.1 Examples

SaaS: Google Workspace, Google Apps, Microsoft Office 365, Dropbox, MailChimp, Salesforce.com, and Hubspot are all SaaS examples.

PaaS: AWS Elastic Beanstalk, Netflix, Windows Azure (mostly used as PaaS), Force.com, Google Kubernetes, Apache Stratos, and Facebook are just a few examples of PaaS.

IaaS: AWS, Microsoft Azure, Rackspace, GCE, Cisco Metacloud, and Magento 1 are all examples of IaaS.

6.3.2 Distinction Between IaaS, SaaS and PaaS

- For hosting custom-built apps and storing data IaaS is the best option because it has the most flexibility.

- PaaS is frequently built on top of an IaaS platform to decrease the need for system administration. It permits you to concentrate on your application expansion rather than infrastructure management.
- Now days majority of SaaS platforms are constructed on infrastructure as a service (IaaS) or platform as a service (PaaS). It delivers ready-to-use, off-the-shelf solutions that address a specific business need (such as website or email).

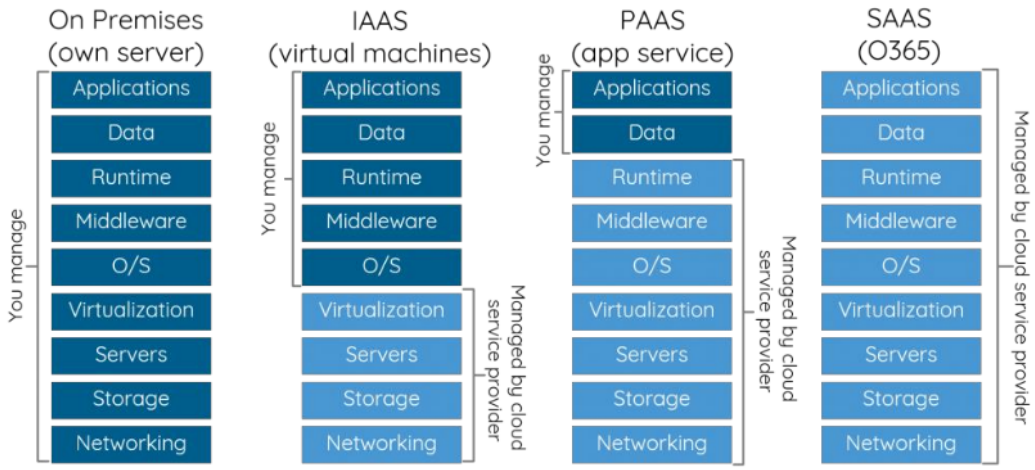


Figure 56: The differences between IaaS, PaaS and SaaS

6.4 Mobile Cloud Computing

To send applications to mobile devices cloud computing is the best tool and for that purpose they use mobile cloud computing. Mobile apps can be deployed remotely with the help of development tools that provide speed and flexibility. Cloud services are the best way to build or update mobile cloud applications. It is not limited to only some specific devices rather it allows a wide range of devices, each with its own operating system, computing tasks, and data storage requirements.

6.4.1 Key Features

- Allow rapid development of mobile applications with shared resources.
- Increase reliability by supporting and saving data in the cloud.
- Because they are cloudy, applications use less power resources.

- The service provided by API architecture is connected to mobile devices.
- Supports a wide range of development methods and devices.

6.5. Why We Use Mobile Cloud?

6.5.1 Speed and Flexibility

Cloud services are used to update and build cloud base mobile applications. These services can be delivered to a variety of devices having different computing task and operating systems.

6.5.2 Shared Resources

For cloud-based mobile apps it is not necessary to use cloud for storing and processing, rather we can use cloud to run processes that require more data storage

6.5.3 Integrated Data

Mobile cloud computing allows all the operators to rapidly and securely use, assemble and integrate data from variety of sources, irrespective of the fact that where it is stored

6.6. Cloud Computing with AWS

Amazon Web Services has become world's most widely used cloud platform. It is very comprehensive and has more than 200 full-featured services available in data centers around the world. It has millions of clients, to save costs, enhance agility, and accelerate innovation fast-growing start-ups, big companies, and significant government agencies, rely on AWS.

6.6.1 The leading Cloud Platform

AWS offers more facilities than any other cloud provider, from traditional infrastructure technologies to new technologies. Traditional infrastructure technologies are computing, storage, and databases and new technologies are machine learning and artificial intelligence data lakes and analytics, and the IoT (Internet of Things). This make possible to move every application to the cloud and make it more easily available, cost effective and fast.

6.6.2 AWS as Largest Community

AWS has the most dynamic community with millions of active customers worldwide .Everything that we use now days is somehow linked with AWS, either it is an industry, a startup business or a public sector organization. There are thousands of people worldwide that specialize with AWS services and millions of free software vendors that make up the AWS Partner Network (APN).

6.6.3 More Secure

Today AWS the most secure cloud computing platform on the market. It is designed to be the most secured and adaptive platform. The core infrastructure of AWS was designed such that to meet the security needs of the high-profile organizations and military. With 230 security compliance and governance services and features, this is backed by a comprehensive set of cloud security tools

6.6.4 The Most Rapid Rate of Innovation

We can experiment and innovate more quickly by leveraging cutting-edge technologies with AWS. They're constantly speeding up their innovation to create entirely new technologies that we can use to transform our company. AWS, for example, pioneered serverless computing with the launch of AWS Lambda in 2014, which allows developers to run code without having to provision or manage servers. You can experiment and innovate more quickly by leveraging cutting-edge technologies with AWS. We're constantly speeding up our innovation to create entirely new technologies that you can use to transform your company. AWS, for example, pioneered serverless computing with the launch of AWS Lambda in 2014, which allows developers to run code without having to provision or manage servers.

6.6.5 AWS With Machine Learning

AWS is named a leader in Gartner's Magic Quadrant because of its Cloud Artificial Iintelligence Developer Services. The company is supporting tens of thousands of clients in speeding their machine learning journey. AWS offers the most complete collection of machine learning services and cloud infrastructure, placing it in the hands of any developer, data scientist, and professional practitioner

6.7. Amazon Relational Database Service (Amazon RDS)

Amazon RDS is a web-based tool that allows you to create and manage a database with just a few clicks. It enables you to install managed databases in on-premises settings utilizing the Amazon technology that hundreds of thousands of AWS RDS users rely on. Amazon Aurora is a cloud computing platform that offers scalable and cost-effective capacity while automating time-consuming administrative activities. It frees you up to focus on your applications, allowing you to provide them with the quick performance, high availability, security, and compatibility they require across several database types. There are six well-known database engines to select from, including Amazon Aurora, Postgis, and MySQL.

6.8. Amazon DynamoDB

Amazon DynamoDB is a key-value and document. It's a fully managed, multi-region database. It has built-in security, backup and restore, and in-memory caching for web-scale applications. DynamoDB can handle lots of requests and messages per second. It is very fast efficient and effective. Now days Hundreds of thousands of customers that require low-latency data access at any scale, chose AWS DynamoDB as their key-value and document database for mobile, web, gaming, ad tech, IoT, and other applications. It is very easy and simple all you need to do is create a new table for your application and let DynamoDB handle the rest. Many of the world's fastest growing companies, including Lyft, Airbnb, and Redfin, as well as enterprises like Samsung, Toyota, and Capital One, rely on DynamoDB's scale and performance to support mission-critical workloads. Hundreds of thousands of Amazon Web Services customers have chosen DynamoDB as their key-value and document database for mobile, web, gaming, ad tech, IoT, and other

applications requiring low-latency data access at any scale. Create a new table for your application and leave the rest to DynamoDB.

6.8.1 Getting Started With Amazon DynamoDB

Before beginning we should become acquainted with the fundamental concepts of Amazon DynamoDB. Then proceed to Prerequisites for set up DynamoDB. Then follow these steps:

Step 1: Create a Table

In this step, we create an Amazon DynamoDB table called glucoxy_data. To create the table, we need following information:

Naming your table: For the name of table we should follow the DynamoDB naming conventions. For example, two tables would be diametrically opposed if you set up a People table in the United States East (Northern Virginia) and another in Europe (Ireland).

The primary key: The primary key consists of one partition key and one sort key. We must specify name, role and type of key: HASH (for a partition key) and RANGE (for a sort key). See Primary Key for more information.

Configuration of throughput): For provisioned mode table's initial throughput must be considered for read and write options. These settings can be changed later or we can let DynamoDB handle this trivial task.

Step 2: Using the Console or AWS CLI, write data to a table

You insert two items into the glucoxy_data table in this step.

AWS Management Console

1. First we need to login to DynamoDB console for which we need to go to this link at https://console.aws.amazon.com/dynamodb/.

2. In left side of window there are some options we need to choose **Tables** from the list.

3. Then we need to choose the **glucoxy_data** table from the list, this is the table we created for our Application.

4. For the **glucoxy_data** table we need to choose **item** tab on window screen.

5. Then choose **Create item** option below the overview tab.

Figure 57. Create Item in AWS Management Console

6. Then chose plus symbol from the left side of word "age"

7. Choose the option **Append** from dropdown menu, and then choose the option **Number** that identify the data type for age. Write the name of field as **age**

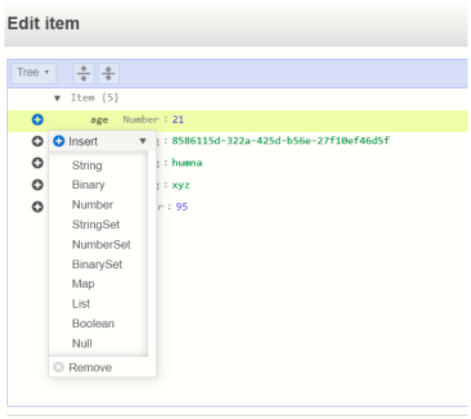


Figure 58. Append Option in AWS Management Console

8. Repeat the above process for patient **Id** that should be of **string** data type

Figure 59. Add patient ID in AWS Management Console

9. For other items of the table chose following options:

   i. For **name**, enter **Humna** as the value.

   ii. For **type**, enter **1**.

   iii. For **value**, enter **95**

10. Choose **Save**.

Step 3: Read Data from a Table

In this step we can read the data from our table we created above. Using the Console or AWS CLI, write data to a table. Whenever we need, we can read or write data from the glucoxy_data table by specifying the id and name in the DynamoDB console or the AWS CLI. We have connected our Glucoxy Application with AWS and the data from application is storing in AWS DynamoDB as shown in figure 61

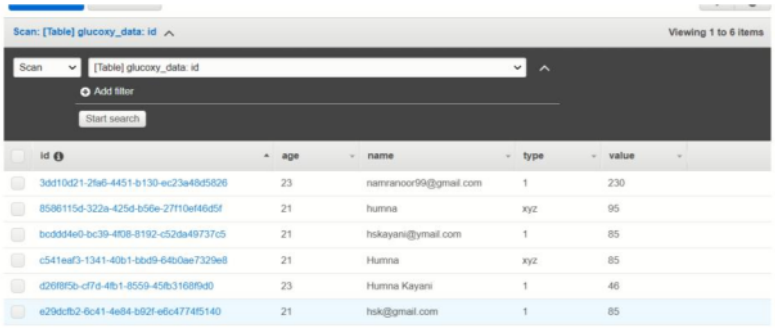


Figure 60. Glucoxy Data in AWS

We can edit this data from our mobile application as well as from the table created on AWS

Dynamo Data Base. We are storing the endpoints of users in dynamoDB in order to send them notifications. This data remains on AWS CLI in the form of table unless we delete it from the table or application. This data does not reset even if we uninstall our mobile application. The data stored in local storage remain in application until we remove the application from device or reset the device but this data remain saved both on cloud and application no matter what. The only way to edit or delete this data is the table.

Chapter 7

Porotype Designing

7.1 Device Prototype

We have made prototype of device in which we made a box using acrylic sheet and place all circuitry of project inside this box as shown in Figure

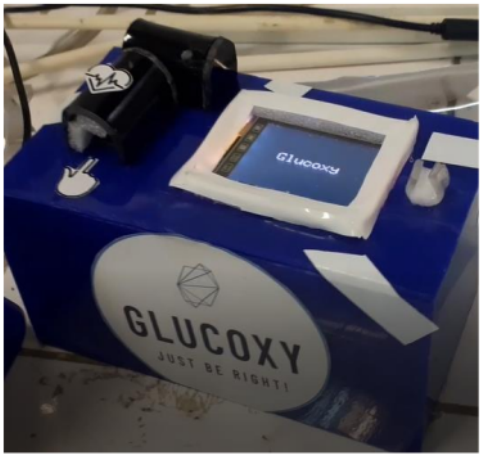


Figure 61. Sensor Prototype

For Sensors we have made cavity, using black acrylic sheet, to stop external rays to interfere, because it will affect the accuracy of device.

Figure 62. Cavity for Pulse Oximeter

Figure 63. Cavity for Glucose Sensor

7.2 Mobile Stand Prototype

Figure 64. Mobile Stand Prototype

7.3 Glucose Multiple Sensors Prototype

Figure 65. Glucose Multiple Sensor Prototype

7.4 Invasive Device Prototype

Figure 66. Invasive Device Prototype

Chapter 8

Conclusions

8.1 Scope

Diabetes is a chronic disease, our body produce insulin through pancreas, that insulin is required for proper function of body. Diabetes happens when the pancreas is unable to produce insulin or the insulin produce is unable to reach different organs of body. According to a survey in 1980, it was estimated to effect up to 108 million people but 2014 survey shows that it affected 422 million people worldwide. This shows that the risk factor has been doubled in past 34 years. But with the increase in the percentage of people being overweight or obese this risk factor is increasing It affect not only adults but also children. Right now even if the technology and medical field has become so advanced yet there's no cure for diabetes

8.2 Summary

The amount of people with diabetes rise from 108 million to 422 million from 1980 to 2014. Diabetes is a major cause for visual impairment, kidney disappointment, cardiovascular failures, stroke and lower appendage removal. In 2014, 8.5% of people aged 18 years old and more suffers from diabetes. Continuous glucose monitoring was only possible through direct measurements of bodily tissues such as cornea, skin, tongue, oral mucosa, or tympanic membrane. The most essential thing you can do to treat type 1 or type 2 diabetes is to regularly monitor your blood sugar levels. This device not only measure glucose value but also have pulse oximeter, pedometer and also measure heart rate. Pulse oximetry is used to monitor the health of people who have any disease that can influence their blood oxygen levels, especially if they are in the hospital. It may be used to determine how successfully your heart is pumping oxygen throughout your body. Pedometers are designed to measure the number of steps taken as well as offer an estimate of the distance walked by people in a day. Non-invasive glucose meters have been around for over 30 years, but no single website can keep up with the latest advances in this field. The research based project aims to introduce a non-invasive glucose meter that wipes out the agonizing pricking experience and hazard of disease.

8.3 Future Work

The initial cost of GlucoTrack is around PKR 3.4 lac, with a recurring cost of PKR 30,000 per 6 months. Once completed, the medical equipment will be extremely useful to our economy and medical department. Some non-invasive blood glucose monitoring devices are available on the market, however they are expensive.

8.4 Conclusions

An evaluation of the most recent non-invasive glucose monitoring methods and devices has been published. Because none of these technologies has resulted in a commercially accessible, clinically reliable device, more work has to be done. Researchers have discovered a novel method for measuring blood glucose levels in the laboratory. They discovered that in the controlled circumstances of research facilities, it is difficult to measure data and identify correlations with blood sugar levels. This necessitates a thorough grasp of the physical and physiological variables that might influence blood glucose measurement. According to a recent study, non-invasive blood glucose monitoring may be used to monitor diabetes in the future. However, it is still far from being able to identify a patient's blood glucose level. There are still technical difficulties to be overcome and that further study is required before it can be used.

Non-Invasive Mobile Blood Glucose Spikes Monitoring System

ORIGINALITY REPORT

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