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# Smart Wearable Body Sensors for Glucose Monitoring

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**Abstract :** Currently, diabetes has emerged as a major healthcare problem in India. Today approximately 8.3 % of global adult population is suffering from diabetes. Patients are recommended to monitor their blood glucose level via an invasive finger tip stick method, this way will inevitably bring patients pain and infection. In our work, a painless measurement of glucose is introduced which is said to be non invasive. Non invasive glucose monitoring is to predict the glucose level of the patient without finger pricking. The different parameters like blood pressure, temperature and heart rate of the patient is to be monitored remotely and under the control of dosage of medicine provided. The measurements are being done through several sensors and these sensors send the measured values to the clinicians for diagnosis and the control action will be taken by doctor urgently. It is depending upon the sensors response and the message which is received by doctor. This method is also needed for monitoring the blood glucose levels frequently to prevent the complications of diabetic patients related to the disease. This system also provides the wearable monitoring and can be used as a portable device where the data can be received as a message in mobile. In the proposed system a completely reliable, accurate and efficient monitoring system will play an important role in providing the better patient care which is pain free.
**Keywords :** Diabetes, Sensors, Glucose, Blood, Measurement.

## Introduction

Diabetes is the major metabolic disorder when normal glucose level (70-100 mg/dl) is either decreasing or increasing to the abnormal level. Detecting the level through invasive methods will cause pain and gives an uncomfortable state to the patient. So the non invasive wearable device is going to be an excellent alternative to the blood pricking system. Non-invasive glucose monitoring in patients with type 1 diabetes is a multi sensor system combining sensors for dielectric and optical characterization of skin[1]The variations of blood glucose will differ depending upon the skin factor of the patients. So ten patients with type 1 diabetes are taken under testing. When applying the multi sensors the glucose level were administered. The major disadvantage of this paper was that sensitivity of glucose measurements were sufficiently reduced. The signal magnitude has irregularity which resulted in poor sensitivity and less accuracy.

Non invasive blood glucose measurement[2]is completely clinical trial based system where measurements were analyzed with the patients who are all having type 1 diabetes and type 2 diabetes by placing the probe on finger's root. The main drawback of this system was that been completely based on the scattering property. Thus it resulted in generation of incomplete profiles of the blood glucose fluctuations.

An embedded system for non-invasive blood glucose measurement in glucose tolerance test [4] was to reduce the repeated puncturing of skin. To predict glucose level of patients, it needs up to ten finger pricks and

so the near infrared light of wavelength was used to detect the glucose level. This system is completely based on placed on placing probes in various parts of body like finger, earlobe, palm, arm, forearm etc. The major drawback of this paper is complex hardware which was losing the positioning of sensing unit. First glucose level is measured with invasive method, later it is detected with non invasive method using about ten finger pricking.

Non invasive glucose monitoring using scattering spectroscopy[5]is non invasive salivary glucose monitoring based on the nano biosensor. Here ultra violet spectrometer is used for clinical accuracy where it is completely ignores the usage of pricking blood and it detects the level with the use of salivary glands. Though this is the non invasive salivary glucose monitoring providing the painless testing methodology with disposable electrodes. But it has only the way of detecting glucose before and after fasting based on the electrodes. It needs to fabricate several electrodes and sensors having high risk of cost and components or else prediction with high accuracy is difficult.

A Novel Method for Blood Glucose Measurement by Noninvasive Technique Using Laser[10]is based on the system of laser having monochromatic source. When forefinger is placed on the unit of laser, the trans illuminated optical is observed and the result is obtained by taking difference of those readings. It gives the final result as the blood glucose concentration level. The drawback is that some problem had occurred due to mode interference occurring in the laser cavity which was used to detect the blood glucose concentration.

**Methodology**

**Existing method**

A noninvasive blood glucose measurement system based on multi-sensors and mixture of experts was designed. In the noninvasive blood glucose monitoring system based on distributed multi-sensors information fusion of multi wavelength NIR, this system was designed on the purpose of continuous blood glucose monitoring for patients at home and hospital. The near infrared spectroscopic fusion needs to have a molecular structure of glucose and specialty of absorption. The absorption frequency must exist between 1100 nm and 1300 nm. Trigger occurs due to the special components in such as hemoglobin and water which are containing group of hydrogen. Here water absorption is distributed with two wavelengths. One is between 1440-1460 nm and another one is 1940-1960 nm. When absorbing wavelength between 1400-1800 nm, water absorption occurs at 1787 nm and there is no peak absorption for fat and protein. So, the wavelength for near infrared spectroscopic fusion should be 1400-1800 nm.

The measurement site should be exposed outside and the difference in age, gender and physical state should be reduced. The measurement site is desired with rich blood so that interference between other components will be low, then near infrared light will be passed into the measurement site easily. This non invasive method is based on distributed multi sensors and measurement sights are right ear lobe, left ear lobe and the right hand part between thumb and index finger where glucose level of the patient is to be measured.

Two circuits such as laser driving circuit and photo electronic amplification circuit used to maintain the laser to be operated with output power of 5 mW and current of 50 mA. Forward current will be in the range of 0-120 mA. The spectral signal should be amplified to 3V so that operational amplifiers, potentiometers, resistors and capacitors are used. The amplified signal is then transferred to plug seat which is connected to analog to digital converter. The amplified spectral signal is first transferred to AD converter because it supports the LabVIEW. The converted data will be transferred to LCD and displayed on the screen which is programmed by LabVIEW language. These are all under the control of major processing unit.

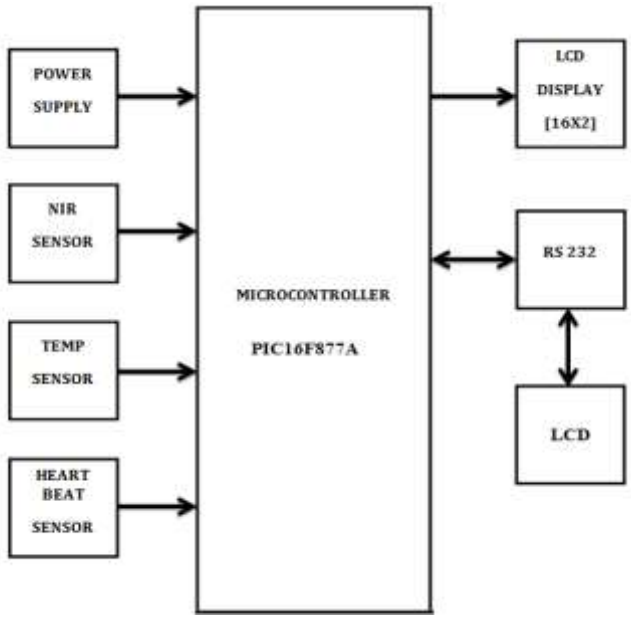
To measure the accurate glucose level samples are to be taken. The samples should be taken in quartz crystal of 5 mm and the temperature maintenance should be about 37 degree celsius. Twenty samples were prepared varying concentrations, ranging from 10 to 200 mg/dL in 10 mg/dL steps. 20 output values of predicted blood glucose concentration were received at the output layer. This is termed as the sample experiment model. Another model is Blood pressure artificial neural network where reference blood glucose value is taken with 120 samples. Here prediction error can be minimized.

In this noninvasive blood glucose monitoring system, two new measurement ideas were employed, which are continuous monitoring and distributed multi-wavelength measurements. The experimental result has

proved that this system has an improved advantage in blood glucose prediction, and the multi-wavelength information fusion model has also contributed greatly to the monitoring property. The major drawback of this system was that more number of samples have to be taken for glucose measurement. Prediction accuracy is to be improved a lot. Time consumption for taking more number of samples with reference is very high. Two different circuits were used and it need a separate experimental set up for amplification and displaying through screen. Multi wavelength property is to be changed for high accuracy of glucose measurement.

**Proposed method**

A non invasive patient monitoring system is to provide the information about calculation of insulin units provide for the particular patient by the system itself. Wireless, patient monitoring system and control is used to monitor the different parameters of an ICU patient remotely and also control over medicine dosage is provided. Measurement of vital parameters can be under risk developing situation can be conveyed to the physician with alarm triggering systems in order to initiate the proper control actions. In the implemented system a reliable and efficient real time remote patient monitoring system that can play a vital role in providing better patient care is developed. In this pic16f877a is used because of its simplicity, accuracy, low cost and availability. This system enables expert doctors to monitor vital parameters viz body temperature, blood pressure and heart rate of patients in remote areas of hospital as well as doctor can monitor the patient when the doctor is out of the premises. The system in addition also provides a feedback to control the dosage of medicine to the patient as guided by the doctor remotely, in response to the health condition.




**Block diagram of glucose monitoring**

First glucose concentration is measured using conventional invasive method. After calibrating the proposed device with the first sample measurement, subsequent glucose concentration values are determined without further finger pricking. Thus pricking can be reduced to one while conducting glucose tolerance test. Once the system is turned on, the infrared light propagates through the measurement site. During the propagating phase, NIR light interacts with the molecules present in the medium. A part of light gets absorbed depending on the glucose concentration of blood under test and remaining part is transmitted through the measurement site. The transmitted signal is then detected by the infrared sensitive detector. After amplification the signal is digitized and is processed in the microcontroller to determine the blood glucose concentration. The measured blood glucose concentration is then displayed on the LCD. The time of measurements and the corresponding value of glucose concentration are stored in memory for further analysis.

Two major methods have been used to measure glucose. The first is a chemical method exploiting the non specific reducing property of glucose in a reaction with an indicator substance that changes color when reduced. Since other blood compounds also have reducing properties (e.g., urea, which can be abnormally high in uremic patients), this technique can produce erroneous readings in some situations (5 to15 mg/dl has been

reported). The more recent technique, using enzymes specific to glucose, are less susceptible to this kind of error. The two most common employed enzymes are glucose oxidase and hexokinase.

This project involves a simple principle of displaying the sensed signal from the sensors on the LCD Screen through a microcontroller. The sensed signal will be in milli voltage, so it can't be used directly by the other components. So the signal is amplified to an extent that can be processed by other components. The amplified signal is conditioned for the microcontroller by the signal conditioner. The microcontroller, the signal conditioner and other components are powered by a separate power supply circuit which converts 230V AC to 5V & 12V. The microcontroller is programmed to convert the input signal in volts to the respective glucose value. The computed value is then displayed in the 16x2 LCD screen. Addition to glucose, temperature and heart rate of the patient also measured.

**Sensor Description**

**NIR Glucose Sensor**

This sensor allows continuous measurement of variation in blood glucose concentration. The instrumentation for optical measurements consists of an NIR emitter and receiver of 950nm wavelength which is suitable for glucose concentration measurement.NIR rays emitted by the NIR LED passes through the measurement site and the transmitted rays are received by NIR receiver. It measures the insulin level which should be in the range of 70-110 mg/dl. After amplification output signal from the sensing unit is given to the microcontroller. The microcontroller has an inbuilt analog to digital converter that converts the analog electrical signal into digital values. The digitized values are then processed in microcontroller to determine the corresponding blood glucose concentration.

For proper measurement site selection two factors should be considered that the measurement site should be easily accessible and NIR light should easily transmit through the measurement site. Hence ear lobe or finger web is selected as suitable measurement site. The sensing unit must be fixed in proper position during entire measurement period. It is designed in such a way that the detector is placed exactly opposite and in line to the NIR light source for detecting maximum amount of transmitted light. The light source and detector should be placed as close as possible to the measurement site in physical contact with the skin

A biosensor can be defined as a "compact analytical device or unit incorporating a biological or biologically derived sensitive recognition element integrated or associated with a physiochemical transducer". There are three main parts of a biosensor, the biological recognition elements that differentiate the target molecules in the presence of various chemicals and a transducer that converts the bio recognition event into a measurable signal and a signal processing system that converts the signal into a readable form. The molecular recognition elements include receptors, enzymes, antibodies, nucleic acids, micro organisms and lectins. The five principal transducer classes are electrochemical, optical, thermometric, piezoelectric, and magnetic. The majority of the current glucose biosensors are of the electrochemical type, because of their better sensitivity, reproducibility, and easy maintenance as well as their low cost.

**Heart Rate Sensor**

The Heart Beat Sensor provides a simple way to study the heart's function. This sensor monitors the flow of blood through Finger. As the heart forces blood through the blood vessels in the Finger, the amount of blood in the Finger changes with time. The sensor shines a light lobe (small high bright LED) through the ear and measures the light that is transmitted to LDR. The signal is amplified, inverted and filtered, in the Circuit .By graphing this signal, the heart rate can be determined

**Temperature Sensor**

The skin temperature measurement is done using an integrated circuit, the temperature sensor produced by MAXIM Dallas Semiconductor . The Sensor gives an analog output depending on the measured temperature. This voltage has to be measured by the microcontroller using a 12 bit Analog to Digital converter (ADC) used as temperature sensor. This sensor is mounted within the wrist strap, positioned in such a way that it is in contact with the skin, allowing it to measure the external temperature of the skin. From the skin temperature, the body temperature is estimated. There can be different methods to estimate the exact body temperature from skin

temperature, but with a rough estimation usually the body temperature is 5.1 C higher than skin temperature when the body temperature is measured at the ear by the National DM-T2-A thermometer used by a general practitioner compared to the skin temperature measured at the wrist. Because an exact measurement of body temperature is not required, this method is suitable. Rather, relative changes are monitored within set threshold, which sets off the alarm. This allows the device to detect changes in body temperature.

## Result and Simulation

Temperature and heart beat of the patient have monitored using PIC16F877A microcontroller. Sensors used were temperature sensor and heart rate sensor and coded with Embedded C. The Heart beat Sensor is to study the heart's function. This sensor monitors the flow of blood through finger. As the heart forces blood through the blood vessels in the finger, the amount of blood in the finger changes with time. when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque. With each heart pulse the detector signal varies. This variation is converted to electrical pulse. This signal is amplified and triggered through an amplifier which outputs +5V logic level signal.

The Temperature Sensor gives an analog output depending on the measured temperature. This voltage has to be measured by the microcontroller using a 12 bit Analog to Digital converter (ADC) used as temperature sensor. This sensor is mounted within the wrist strap, positioned in such a way that it is in contact with the skin, allowing it to measure the external temperature of the skin. From the skin temperature, the body temperature is estimated.The glucose level of the patient was measured with the help of glucose sensor and it was made as wearable which can be very easy for the patient to wear and for the doctor to monitor on time.

| **Parameters** | **Threshold value** | **Obtained value** | |
|---|---|---|---|
| **Glucose** | | **Non invasive** | **Invasive** |
| i) During fasting | 72-108 mg/dl | 100 mg/dl | 106 mg/dl |
| ii) After meal | 120-140mg/dl | 130 mg/dl | 134 mg/dl |
| iii) Before meal | 70-99 mg/dl | 80 mg/dl | 81 mg/dl |
| **Temperature** | 37°F | 34°F | |
| **Heart rate** | 60-100 bpm | 71 bpm | |

## Conclusion

The Temperature sensor gives an analog output depending on the measured temperature. This voltage has to be measured by the microcontroller using a 12 bit analog to digital converter (ADC) used as temperature sensor. This sensor is mounted within the wrist strap, positioned in such a way that it is in contact with the skin, allowing it to measure the external temperature of the skin. Thus an innovative, simple and low cost on-chip electrochemical glucose sensing system was developed and from the skin temperature, the body temperature is estimate. Thus temperature and heart rate of the human body has been measured using microcontroller using temperature sensor and heartbeat sensor. Then the glucose level has been measured from the patient body without pricking blood using glucose sensor which is a transmitter and a small external monitor to view the patient glucose levels. Since diabetes is the deadly disease because when the glucose level is very high, it will affect the human heart which leads to coronary heart disease. This disease cause sudden heart attack to the patient. The non invasive glucose monitoring will surely help to secure the life of the patients, not only the diabetic and normal people, This system will enables expert doctors to monitor vital parameters via body temperature, blood pressure and heart rate of patients in remote areas of hospital.

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