THE MULTIPHYSIOLOGICAL PARAMETER MONITORING SYSTEM

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Abstract:- *The Physiological Monitoring System, which is commonly known as Patient Monitors, in hospital environment, finds a great use in modern era. These type of monitoring systems facilitate the measurement or monitoring of human vital signs such as ECG, Heart rate, Temperature, NIBP and SpO2. These monitors are mainly used in all Intensive Care Units, Critical Care Units, Operation Theatres, Post-operative wards, Emergency wards, etc., In additional to these parameters, there are also some essential parameters to be monitored every instant, in order to eliminate sudden complications and illness. Though there are rising demands in need of patient monitors at almost all departments, there are also some special needs by some departments. The existing monitors measure only these parameters irrespective of the department being used. The monitors which are used in ICUs are similar to where they are used in wards. To design special monitors, some parameters can be added. Here are some of the most required parameters, in which the patient must be regularly monitored:* ***Glucose, pCo2 and Hemoglobin.*** *An additional advantage is that, these parameters are to be measured in* **Non-Invasive** *technique, to satisfy patient comfort.*

Index terms: *Non-invasive, Near Infra-red, Micro controller, Glucose, Hemoglobin, pCo2.*

1. INTRODUCTION:

The existing patient monitoring systems finds various uses in all departments of a hospital, as they possess some good features such as: they are easily portable, they possess less weight, all vitals of a person can be measured less than a minute. The patient monitor measure a person's ECG, Heart rate, NIBP, Respiration rate, Temperature and SpO_2 levels. According to the target parameters, these monitors can be modified and can be used for various purposes.

1.1. Cardiac monitoring

Involves the measurement of cardiac related parameters such as ECG, Heart rhythm, Heart rate continuously for a particular period of time, and is capable of recording the results. This kind of equipment is commercially known as 'Holter monitor', a small monitor which can be worn by an ambulatory patient. Cardiac output can also be measured by an invasive method, with the help of SwanGanz catheter.

1.2. Hemodynamic monitoring

Involves the measurement of blood pressure and blood flow. The blood pressure can be measured by both invasive and non-invasive techniques. In invasive method, a blood pressure transducer assembly is used and in non-invasive method, an inflatable blood pressure cuff is used.

1.3. Respiratory monitoring

Involves the measurement of SpO_2, $ETCO_2$ and Respiratory rate. The SpO_2 can be measured non-invasively via an Infrared sensor. $ETCO_2$ can be measured invasively, which is popularly known as capnography. The Respiratory rate can be measured non-invasively with the help of a thoracic transducer belt.

1.4. Neurological monitoring

Involves the measurement of intra-cranial pressure, anaesthetic concentrations, bi-spectral index and most importantly the EEG. The first three measurements are incorporated into anaesthesia machines. A typical neurological unit must contain EEG, as it plays a major role in determining the activities of brain at various states.

3. EXISTING SYSTEM:

A general block diagram below, represents the overall functioning of a physiological monitor.

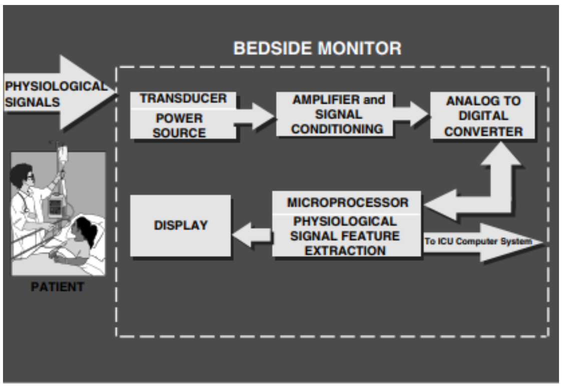

Fig.1 *Block diagram representing the functioning of a patient monitor.*

As discussed before, a Patient monitor can measure 5 vital parameters:

3.1 ECG:

ECG refers to the recording of the electrical activity of heart for a particular period of time, with the help of electrodes/leads placed on skin. The leads are placed according to Einthoven's principle: Einthoven's triangle is the imaginary formation of a triangle, in which, the two sides belong to the right and the left shoulders and the third side belong to the pubis. Thus, the shape forms an inverted triangle, with the heart at its centre. Generally, both limb electrodes and surface electrodes are used to measure ECG, but the existing patient monitors use only 6 (V_1 to V_6) surface electrodes. V_1 is placed at the right sternal border of 4th intercoastal space, V_2 is placed at the left sternal border of 4th intercoastal space, V_3 is placed at the halfway between V_2 and V_4, V_4 is placed at the 5th intercoastal space at the mid-clavicular line, V_5 is placed at the left anterior axillary line on the same horizontal plane similar to V_4, V_6 is placed at the left mid-axillary line on the same horizontal plane as V_5.

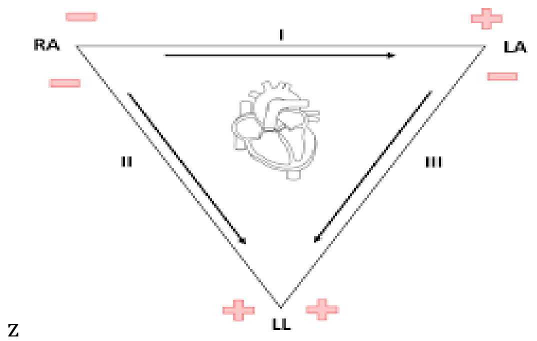

Fig.2 *Lead placement based on Einthoven triangle to record ECG.*

The ECG wave consists of PQRST peaks.

P wave represents atrial depolarization, QRS complex represents ventricular depolarization, T wave represents ventricular repolarization.

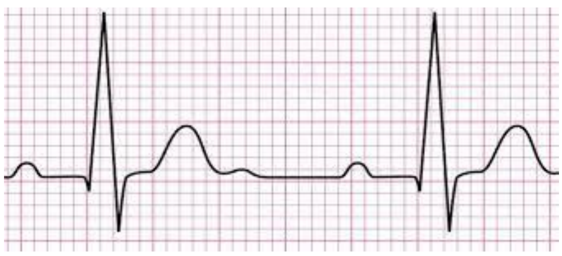

Fig.3 *Normal ECG waveform.*

3.2 Heart Rate:

Heart rate can also be calculated with the help of ECG waveform, with the help of a formula:

Rate = 60/(R-R interval) bpm.

The R-R interval is calculated from the ECG waveform.

The normal range for heart rate is 60-100bpm. If the heart rate is above 100 bpm, it indicates Tachycardia and if the heart rate is below 60 bpm, it indicates Bradycardia.

3.3 NIBP:

Non-invasive Blood Pressure monitoring enables the continuous measurement of blood pressure. High blood pressure does not usually give any warning signs. Though you experience high blood pressure, you might feel perfectly well. The only way to determine whether you have high blood pressure is to have it checked regularly. Non-invasive blood pressure measurement usually involves the use of an inflatable-cuff which is wrapped around the limb of a test subject. The cuff is inflated and deflated at a controlled rate and hence the physical parameters are observed. The auscultatory and oscillometric techniques are well known non-invasive methods. These methods are indirect because they do not couple directly to the artery. Modern NIBP monitors now use oscillometric technique to measure pressure.

The oscillometric technique monitors the changes in cuff pressure caused by the flow of blood through the artery. The monitor inflates the cuff to a pressure that occludes the artery. Even when the artery is occluded, the pumping of the heart against the artery can cause small pressure pulses in the cuff baseline pressure. The monitor lowers cuff pressure at a controlled rate. As the cuff pressure decreases, blood starts to flow through the artery. The increasing blood flow causes the amplitude of the pressure pulses in the cuff to increase. These pressure pulses continue to increase in amplitude with decreasing cuff pressure until they reach maximum amplitude, at which point they begin to decrease with decreasing cuff pressure. The cuff pressure at which the pressure pulse amplitude is the greatest is known as Mean Arterial Pressure (MAP).

The manner in which the pulse amplitudes vary is often referred to as a pulse envelope. The envelope is an imaginary line that connects the peak of each pressure pulse and forms an outline. The shape of the envelope is observed by different monitors using a variety of techniques to determine the diastolic and systolic blood pressures.

The normal range of NIBP is **120/80 mmHg.** The top, larger number is called the systolic pressure. This is the pressure generated when the heart contracts. It reflects the pressure of the blood against arterial walls. The bottom, smaller number is called the diastolic pressure. This reflects the pressure in the arteries while the heart is filling and resting between heartbeats.

3.4 Pleth or SpO_2:

SpO_2 is measured with the help of pulseoximeter. Pulse oximetry is a simple non-invasive method of monitoring the percentage of haemoglobin (Hb), which is saturated with oxygen. The pulse oximeter consists of a probe attached to the patient's finger, toe, ear lobe or forehead, which is linked to a computerised unit. The unit displays the percentage of Hb saturated with oxygen together with an audible signal for each pulse beat, and calculated heart rate. A pulse wave related to flow is displayed graphically.

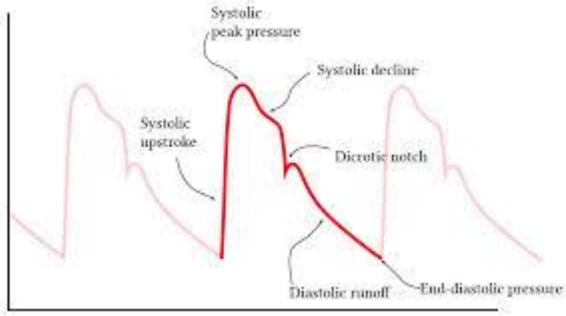

Fig.4 *Normal pleth waveform.*

The measurement of SpO_2 is done with the help of a probe, which consists of two beams of light: red light of wavelength 600-750 nm and infrared light of wavelength 850-1000 nm. It is purely based on the concept that, oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through.

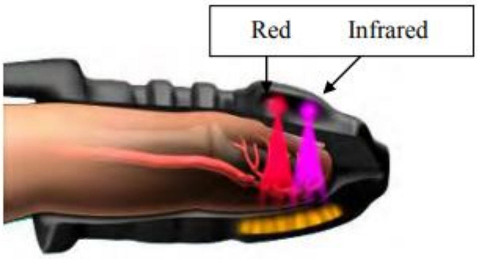

Fig.5 *SpO_2 measurement probe assembly.*

The red/infrared ratio is calculated and then compared with the look-up table and finally converted to SpO_2 value. The normal SpO_2 value ranges from 95-100%.

3.5 Temperature:

The body temperature plays a vital role in maintaining the hemostasis, as temperature plays a vital role in biochemical reactions. The normal temperature of a human is 97 to 99 F. The temperature above the normal range indicates Hyperthermia and the temperature below normal range indicates Hypothermia.

These parameters make up together into a complete module.

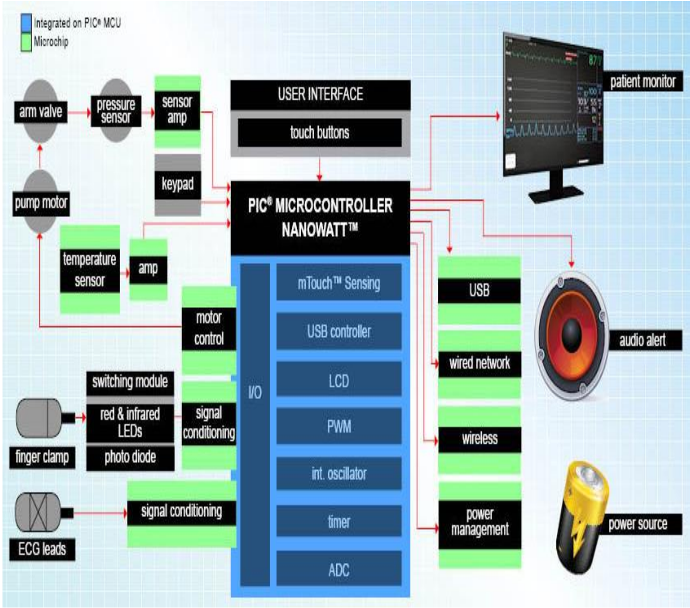

Fig. 6 *Internal Diagram of a patient monitor.*

4. UNSATISFACTORINESS IN THE EXISTING SYSTEM:

Though, these monitors provide a continuous measurement of most of the vital parameters, there are also some vitals, which must be measured continuously, in order to avoid risks.

A patient's vitals are measured mostly in critical departments, where the patients are at high risk, such as Intensive Care Units, Critical Care Units, Post-operative wards, Operation theatres, Emergency departments, Maternity wards etc., where, not only the above discussed vitals are considered important. There are also some parameters, which are not continuously measured, but at regular time intervals and also involves invasive method, which leads to patient discomfort and sometimes pain, which could not be tolerated.

Glucose, pCO_2 and Hemoglobin values are also necessary for proper functioning of the body. Hence it must also be monitored continuously and also by invasive method, for satisfying patient's comfort.

5. PROPOSED MODEL:

In order to solve the above mentioned issues or in other words, to satisfy the physician's needs, we have considered 3 main parameters, Glucose, pCO_2 and Hemoglobin, which can be continuously measured by non-invasive technique.

5.1 WHY THESE PARAMETERS ARE CONSIDERED?

Here are some reasons, for considering the above mentioned parameters to be added:

1. Any patient, who is recovering from a surgery, may face an alternating blood glucose level, no

matter, whether the patient is a diabetic or non-diabetic. Sometimes, the blood glucose level may reach high or too low. If the glucose values are left unnoticed, it may lead to serious ill effects. In addition to that, the blood glucose level is measured by invasive method, which would be uncomfortable to the patient. Hence, glucose level must be monitored both continuously and non-invasively.

2. A patient, who has undergone a lung surgery, may face with periodic respiratory acidosis or respiratory alkalosis. If these changes are left unnoticed, then it leads to lung failure or even death. To determine the proper functioning of the lungs, pO_2, pCO_2 and pH must be measured. Here, ABG machine, also known as blood gas machine aids in measuring these parameters. It is a painful and invasive technique, which involves drawing of a small amount of blood from the radial artery or femoral artery and then the values are estimated. This again leads to patient discomfort. Hence, in our proposed model, pCO_2 value is estimated both continuously and non-invasively.

3. A patient may face with decreasing hemoglobin levels, after a surgery or after the chemotherapy (for oncologic patients). The decrease in hemoglobin usually lead to fatigue, anaemia and several other complications. The hemoglobin level in blood is also estimated only periodically at regular time intervals and also involves invasive technique. Hence, in our proposed model, the hemoglobin value is estimated both continuously and non-invasively.

5.2 Principle behind the model:

The whole module is built based on the principle of **Near Infra Red (NIR) Spectroscopic Technique.**

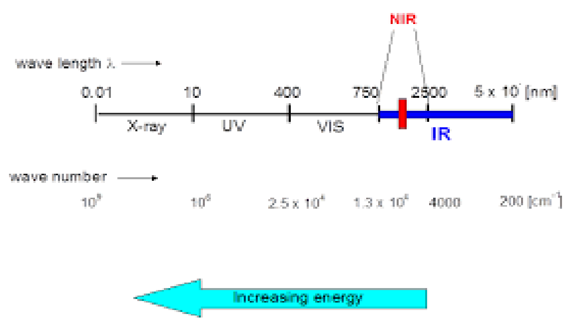

Fig.7 Electromagnetic spectrum.

Near-infrared spectroscopic method uses the near-infrared region of the electromagnetic spectrum which ranges from **780 nm to 2500 nm.** Some applications include medical and physiological diagnostics and research including blood sugar, pulse oximetry, functional neuroimaging, sports medicine, elite sports training, ergonomics, rehabilitation, neonatal research, brain computer interface, urology, and neurology.

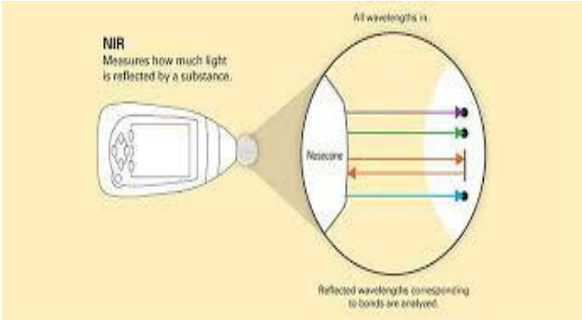

Fig.8 *A simple representation of NIR spectroscopy.*

5.3 COMPONENTS USED FOR BUILDING UP THE MODULE:

The major components required are as follows:

1. Arduino Uno R3
2. Infrared LEDs
3. Quadripple Operational Amplifier (LM324N)
4. Operational Amplifier (TL082)

The above mentioned components play a vital role in estimating the proposed parameters. In addition to these, the following components are also required:

5. Phototransistors
6. Photodiode
7. Resistors and Capacitors
8. USB cable

5.3.1 ARDUINO UNO R3:

The Arduino is a microcontroller board based on ATmega328 microcontroller. It consists of 14 input/output pins, of which, 6 pins can be used as PWM inputs, 6 analog inputs, a 16MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button.

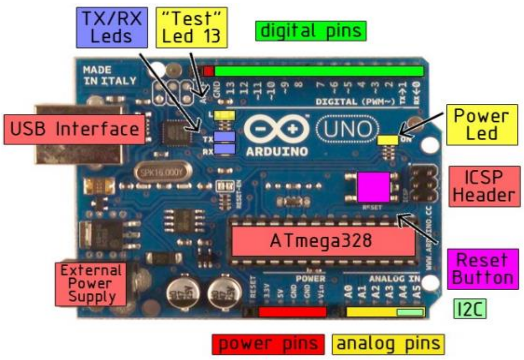

Fig.9 *Arduino Uno microcontroller.*

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External power can come either from an AC-to-DC adapter or battery.

The board can operate on an external supply of 6 to 20 volts. The recommended range is 7 to 12 volts. Out of the above mentioned 14 pins, some pins have specific functions as listed below:

Serial Pins 0 (Rx) and 1 (Tx): Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the ATmega328P USB to TTL serial chip.

External Interrupt Pins 2 and 3: These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

PWM Pins 3, 5, 6, 9 and 11: These pins provide an 8-bit PWM output by using analogWrite() function.

SPI Pins: 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK): These pins are used for SPI communication.

In-built LED Pin 13: This pin is connected with an built-in LED, when pin 13 is HIGH, LED is on and when pin 13 is LOW, it is off.

Power pins:

1. **V_{IN}** refers to the input voltage to the Arduino board when it is using an external power source.
2. **5V:** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the V_{IN} pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board.
3. **3.3V:** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
4. **GND:** Ground pins.

4.3.2 Infrared LEDs:

For detection of Glucose, 700-1100nm of light is capable of absorbing glucose molecules in blood. Similarly, for the detection of pCO_2, 1200-1500nm of light is capable of absorbing pCO_2 present in the blood. The detection of hemoglobin doesn't need any light source, rather, it can be detected with the help of arduino program.

5.3.3 Quadripple Operational Amplifier: (LM324N)

The Quadripple operational amplifier is used here, as a part of the circuit, which estimates the **blood glucose** value.

The LM324 series are low–cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V.

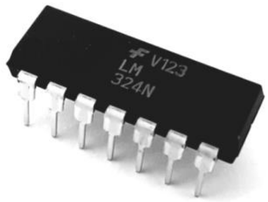

Fig.10 *LM324N*

Features:

1. Internally frequency compensated for unity gain.
2. Large DC voltage gain 100 dB.
3. Wide bandwidth 1 MHz.
4. Wide power supply range: Single supply 3V to 32V.
5. Essentially independent of supply voltage.

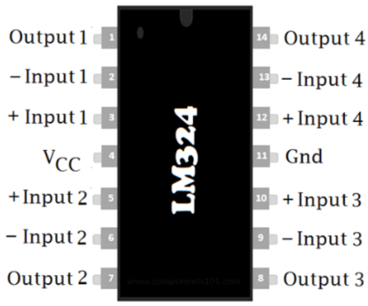

Fig.11 *Pin configuration of LM324N.*

Pin functions:

Pin No.	Function
1	Output of first comparator
2	Inverting input of first comparator
3	Non-Inverting input of first comparator
4	Supply voltage 5V
5	Non-Inverting input of second comparator
6	Inverting input of second comparator

7	Output of second comparator
8	Output of third comparator
9	Inverting input of third comparator
10	Non-Inverting input of third comparator
11	Ground
12	Non-Inverting input of fourth comparator
13	Inverting input of fourth comparator
14	Output of fourth comparator

5.3.4 Operational Amplifier (TL082):

This amplifier is used as a part of the circuit, which estimates pCO_2. TL082 is a low cost, high speed, dual JFET input operational amplifiers with an internally trimmed input offset voltage. They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth.

The devices also exhibit low noise and offset voltage drift.

Fig.12 *TL082.*

Features of TL082:

1. Low Power Consumption: 1.4 mA
2. Wide Common-Mode and Differential Voltage range.
3. Low Input Bias Current: 30 pA
4. Low Input Offset Current: 5 pA
5. Output Short-Circuit Protection.
6.

Pin Configuration:

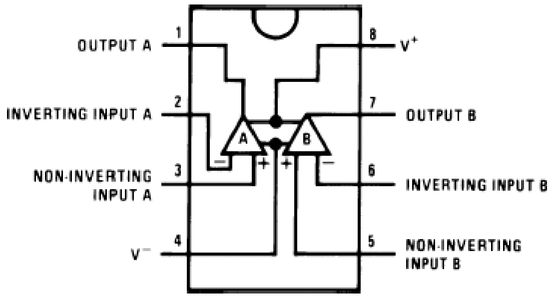

Fig.13 *TL082 pin configuration.*

5.3.5 Photodiode (OPT101):

The OPT101 is a monolithic photodiode with on-chip trans-impedance amplifier. Output voltage increases linearly with light intensity. The amplifier is designed for single or dual power-supply operation, making it ideal for batteryoperated equipment. The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered in discrete designs such as leakage current errors, noise pick-up, and gain peaking due to stray capacitance. The 0.09 x 0.09 inch photodiode is operated in the photoconductive mode for excellent linearity and low dark current.

The OPT101 operates from +2.7V to +36V supplies and quiescent current is only 120μA. It is available in clear plastic 8-pin DIP, and J-formed DIP for surface mounting. Temperature range is 0°C to +70°C.

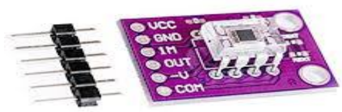

Fig.14. *OPT101*

Pin configuration:

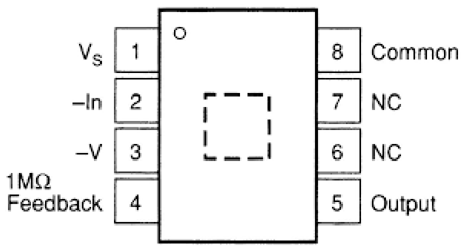

Fig.15 *Pin configuration of OPT101.*

7. BLOCK DIAGRAM:

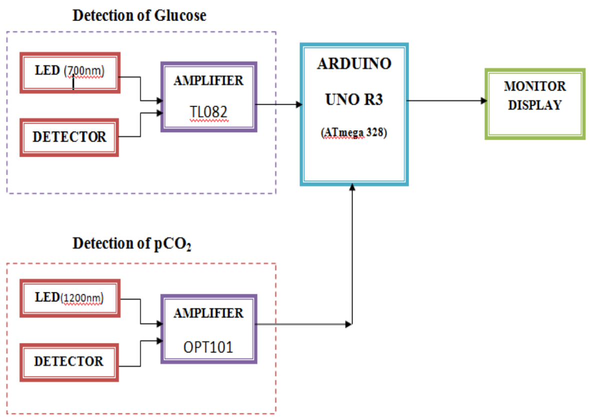

Fig. 16 Block diagram for proposed system.

7. ESTIMATION OF GLUCOSE:

Some of the optical properties of glucose help us to determine that the NIR wavelength of 950 nm is suitable to estimate the blood glucose level.

Block diagram for glucose:

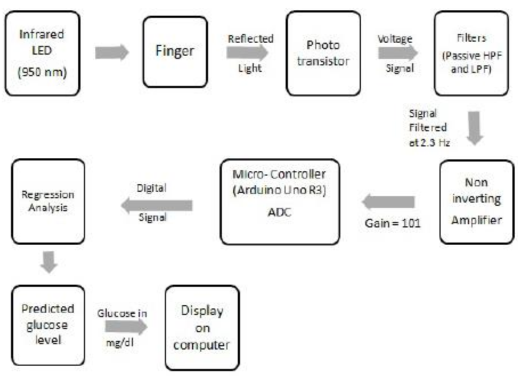

Fig.17 Block diagram for detection of glucose.

The IR source and the detector are hence fixed in the board, and it is covered to eliminate the interference of the environmental light sources.

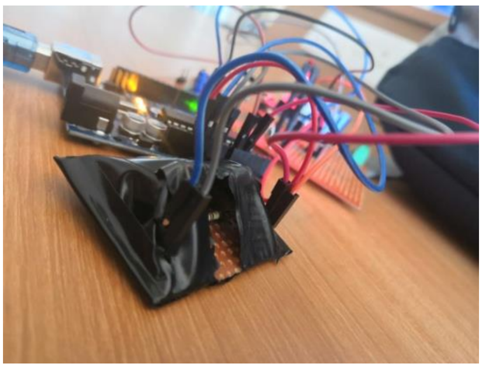

Fig. 18. Assembly of source and detector.

The source and detector are connected to the Arduino Uno for power supply and to read the analog inputs.

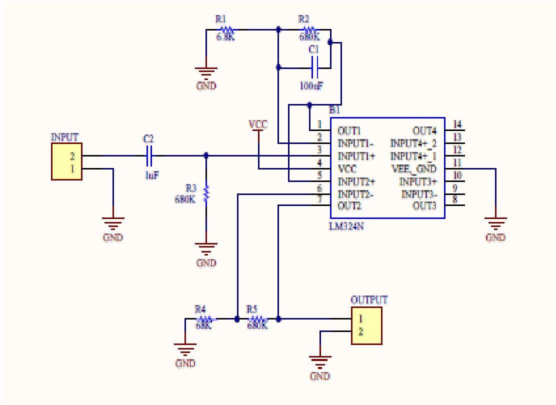

Fig.19 Circuit diagram for estimation of glucose.

The amount of IR source, absorbed by the glucose in the blood is determined by the detector, which is sent as an analog signal to the Arduino Uno. The analog signal is then converted into a digital voltage, by means of algorithm. According to Beer Lambert's law, the absorption of light by the solution is directly proportional to the voltage developed.

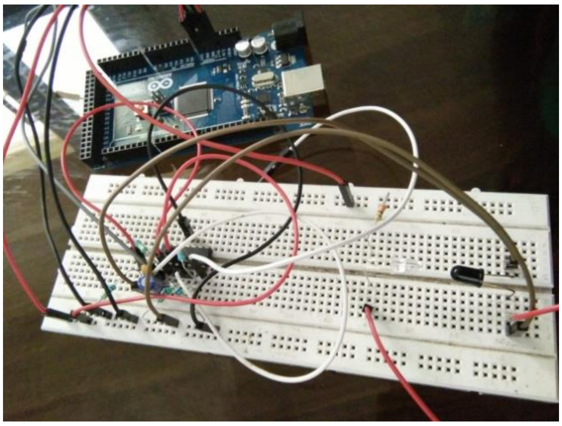

Fig.20. Experimental setup for the detection of glucose.

The normal range of glucose is **100 to 125 mg/dL.**

8. ESTIMATION OF PCO2:

It is experimentally proven by most of the research scholars that, the CO_2 can be absorbed by the near infrared light source of wavelength ranging from 800-2500 nm. Here, a NIR source of wavelength 800 nm is used to estimate the amount of pCO_2 present in blood.

The circuit diagram to estimate pCO_2 concentration is as follows:

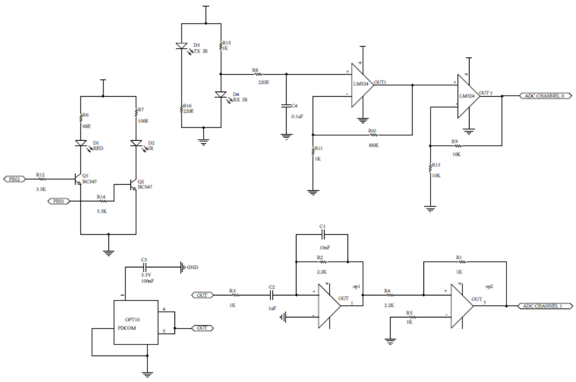

Fig. 21. Circuit diagram for the estimation of pCO_2.

OPT101 plays a major role here to estimate pCO_2. The amount of NIR light, absorbed by pCO_2 molecules, is detected by means of a photodetector, which converts the absorbed light into its corresponding analog voltage. The analog voltage is then converted into digital voltage, which follows Beer Lambert's law.

The normal range of pCO_2 is **38 to 45 mmHg.**

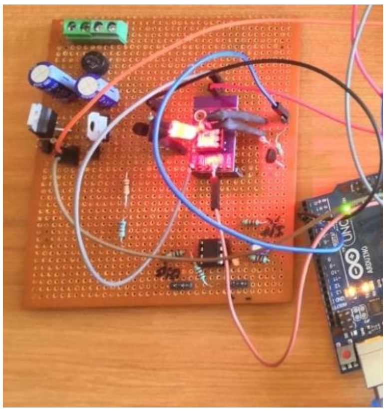

Fig.22 Experimental setup for the detection of pCO_2.

9. ESTIMATION OF HEMOGLOBIN:

The hemoglobin can be estimated by means of simple algorithm, which requires the values of pCO_2 and SpO_2. The common formula to estimate Hemoglobin concentration in blood is:

$$SpO2 = \frac{c_{HbO2}}{c_{HbO2} + c_{Hb}} \times 100\%$$

RESULTS:

All the 3 proposed parameters are combined together and the final setup is given as follows:

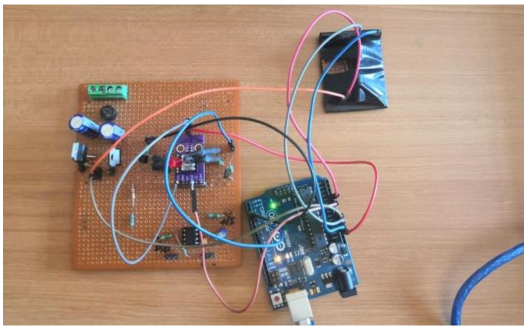

Fig.23 Final circuit for the proposed system.

It has been checked with our faculties and student members, the results displayed are as follows:

The Multiphysiological Parameter Monitoring System\Result 1.png

The Multiphysiological Parameter Monitoring System\Result 2.png

The Multiphysiological Parameter Monitoring System\Result 3.png

10. CONCLUSION:

Thus, among all the invasive parameters, glucose, pCO_2 and hemoglobin were chosen, to detect them purely non-invasive and tried to resolve patient discomfort. This will find a greater advantage in all the emergency and critical care departments. The future works will deal with developing this circuit into a complete module and testing among the general public, thus ensuring that, this module will be safe that they can be used in hospitals.

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