4.1. Introduction - Pulse Oximetry

The oxygenation and deoxygenation of blood is a process for every breath, when a human being breathes, about 20% of breathe is oxygen. The oxygen rich in air travels down to the lungs where it is exchanged across a membrane into oxygen depleted hemoglobin. The oxygenated hemoglobin then flows through the arterial system to the heart where it is distributed throughout the body to the tissues. Oxygen is utilized by tissues to metabolic process, in the same way the waste products present in the tissues is carried back through the venous system and heart. The carbon dioxide present in the lungs can be expelled from the body by exhaling process which occurs with every breath is shown in Figure 4.1. [1].

![Figure 4.1: Oxygenation and deoxygenation of blood in the body.](image)

Oxygen is carried in the blood attached to hemoglobin molecules and its saturation [2] is a measure of how much oxygen in the blood is carrying as a percentage of the maximum it could carry. One hemoglobin molecule can carry a maximum of four molecules of oxygen. If the 100 hemoglobin molecules were carrying 380 oxygen molecules they would be carrying 95% of the maximum number of oxygen molecules that could carry and so together would be 95% saturated. Oxygen saturation is referred as a SpO₂ or SaO₂ is the amount of oxygen in the hemoglobin. It is 1.39 milliliters of oxygen per milligram of hemoglobin. Functional
Oxygen saturation is defined as the amount of oxygen that the hemoglobin is carrying as a percentage of the maximum that particular specimen could carry.

When someone lacks sufficient oxygen in their blood supply that they are said to have hypoxia. There are varying degrees of hypoxia based on how low the oxygen levels in the blood. The patient symptoms can be analyzed based on hypoxia levels. The subtle effects of hypoxia are poor judgment and loss of motor function. Hypoxia can cause death, because not enough oxygen is being transported from the bloodstream to the tissues of the body. The most sensitive tissue to hypoxia in the body is the brain. The condition that occurs when the brain does not receive enough oxygen is called cerebral hypoxia. Five minutes is all it takes for a brain cell to die in the absence of oxygen. If the hypoxia lasts for prolonged periods it can lead to “coma, seizures, and even brain death. In brain death, basic life functions such as breathing, blood pressure, and cardiac function are preserved, but there is no consciousness/response to the world around.”

The four main variations of hypoxia include stagnant hypoxia, hypemic hypoxia, histotoxic hypoxia, and hypoxic hypoxia. Stagnant hypoxia occurs when the blood flow is restricted to an area of the body cutting off the oxygen supply. The hypemic hypoxia occurs when the functional hemoglobin count is low, thus not having enough hemoglobin to transport the oxygen throughout the body. The histotoxic hypoxia occurs when tissue cells become poisoned and can’t properly use the oxygen. This might occur due to carbon monoxide poisoning. Hypoxic hypoxia [3] occurs due to lack of oxygen available to breathe in. This occurs at high altitudes and is of major concern to pilots. [4] [5]. There are physiological causes for hypoxia, one of which is due to complications during anesthesia. During anesthesia there can be many factors that can occur to induce the onset of hypoxia. They include: low cardiac output, pulmonary edema, pulmonary embolism, airway obstruction, and endobronchial intubation [6].

There are many times when it would be useful to be able to monitor the blood oxygen levels in a person to find and treat hypoxia before it can effect and harm the individual. These situations include: in the operating room during anesthesia, in an ambulance while being transported to the hospital after a cardiac or pulmonary episode, and in the neonatal care unit to closely monitor a newborn’s vital signs. By
using a device to monitor the oxygenated hemoglobin levels, the physician can overcome the complications. It is for these reasons that pulse oximetry has become more prominent.

**Pulse oximetry** [7] is a non-invasive and continuous method of determining the amount of oxygenated and deoxygenated hemoglobin in a person’s blood supply. It is a direct method for the measurement of oxygen levels in hemoglobin because it is able to be determined in real time while causing no discomfort to the patient. Pulse oximetry data is necessary whenever a patient's oxygenation is unstable, including intensive care, critical care, and emergency department areas of a hospital [8]. Pulse oximeter measurements either from the finger or lobe.

### 4.2. Anatomy & Physiology of the Heart and Lungs

The pulse oxygen levels in the blood are combinational functions of both heart and lungs. Hence the anatomy and physiology of lungs and heart are important in the development of Pulseoxymeter for the measurement of pulse oxygen in blood.

Breathing is an important process because body needs the oxygen in the air and generate energy to keeps you alive. When fresh air is breathed in through the nose and mouth, it is pulled through the windpipe or trachea and into the lungs [9]. As humans have two lungs, with the right lung being slightly larger than the left lung. From the windpipe, the air moves through two large passageways, called the bronchi. A complex system of much smaller tubes or bronchioles branch out from human bronchi to carry oxygen to the "working parts" of the lungs — the millions of air sacs or alveoli. These small sacs (like tiny folded balloons) have very thin walls that are full of blood vessels. The walls are so thin that the oxygen in the air can pass through them to enter human bloodstream and travel to cells in all parts of human body. The larger bronchi divide into smaller bronchi, which divide further into the bronchioles. The bronchioles are very narrow and have a diameter of 1mm or less. The bronchioles eventually lead into small sac-like structures called the alveoli. The anatomy of the lungs is as shown in figure 4.2.

The lungs are divided into lobes. The right lung has three lobes (upper, middle, lower) and the left lung has two lobes (upper and lower). Membranes called fissures divide the lungs into lobes.
Each bronchiole ends in a group of tiny sac-like structures, each one called an alveolus. Each lung has about 300 million alveoli. They are very small and cannot be seen easily with the naked eye. Each alveolus is surrounded by a capillary blood vessel. Gases, e.g. oxygen and carbon dioxide, move across the alveolar membrane into the blood vessels and vice versa. A continuous exchange of gases takes place between the alveoli and the capillary blood vessels that surround them. The gas exchange and function of lungs is as shown in figure 4.2.

The function of the lungs - exchange of oxygen and carbon dioxide

When we breathe in, inhaling of oxygen, which is the “fuel” to make our body cells work? And when we breathe out, we are exhaling the byproduct of our body cells’ work – a gas called carbon dioxide, which is often called "used" air. Carbon dioxide, is exhaled with every breath blown out of our lungs.

The main function of the lungs is to keep the correct amount of oxygen and carbon dioxide in the blood. In order to do this we breathe air into the airways of the lungs. The air then moves all the way down to the sac-like endings of the airways called the alveoli. In the alveoli, the oxygen from the air moves into the blood stream which surrounds each tiny alveolus. This vital oxygen is now available for the body's needs. Carbon dioxide, which is a waste product from body tissues, is carried in the blood stream to the lungs. In the lungs, the carbon dioxide is moved across the alveoli into the airways and then breathed out. The exchange of gases can be increased or decreased by breathing at a faster or slower rate, or by breathing more deeply. The
body can increase the amount of oxygen and decrease the amount of carbon dioxide in
the bloodstream by breathing at a faster rate or more deeply.

4.3. Review of Earlier literature - Pulseoxymeter

The first pulse oximeter was designed in the late 1930’s by German
researchers whose objective was to measure the oxygenation of “high altitude pilots”
[10].

Kramer [11], Matthes [12] [1935] developed the 2-wavelength ear O₂
saturation meter with red and green filters, later switched to red and infrared filters.

Wood [13] [1949] added a pressure capsule to squeeze blood out of ear to
obtain zero setting in an effort to obtain absolute O₂ saturation value when blood was
readmitted. The concept is similar to today's conventional pulse oximetry but suffered
due to unstable photocells and light sources. This method is not used clinically.

Shaw [1964] assembled the first absolute reading ear oximeter by using eight
wavelengths of light. Commercialized by Hewlett Packard [14], its use was limited
to pulmonary functions and sleep laboratories due to cost and size.

Aoyagi [15] [1972] developed Pulse oximetry at Nihon Kohden using the
ratio of red to infrared light absorption of pulsating components at the measuring site.
It was commercialized by Biox [1981] and Nellcor [1983]. Biox was founded in
1979, and introduced the first pulse oximeter to commercial distribution in 1981. Biox
initially focused on respiratory care in operating rooms to monitor oxygen levels.
Nellcor [16] Incorporated in 1982. With the introduction of pulse oximetry, a non-
invasive, continuous measure of patient's oxygenation was possible, revolutionizing
the practice of anesthesia and greatly improving patient safety.

4.4. Principle and operating modes and Experimental Techniques of
Pulseoxymeter

PulseOximetry is based on the fractional change in light transmission during
an arterial pulse at two different wavelengths. In this method the fractional change in
the signal is only due to the arterial blood itself and therefore the complicated and
nonpulsatile and highly variable optical characteristics of tissue are eliminated. [17]
Figure 4.3: Typical pulse oximeter sensing configuration on a finger.

Figure 4.3 shows typical pulse oximeter sensing configuration on a finger. Two light emitted diodes produce beams at red and infrared frequencies and there is a photo detector on the other side. The oxygen saturation is estimated by measuring the transmission of light through the pulsatile tissue bed. This is based on the Beer-Lambert law is a combination of two laws describing absorption of monochromatic light by a transparent substance through which it passes.

**Beer’s Law**: The intensity of transmitted light decreases exponentially as concentration of the substance increases.

**Lambert’s law**: The intensity of transmitted light decreases exponentially as the distance traveled through the substance increases.

The pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. These two wavelengths are chosen because Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through it. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band and Absorption spectra of two wavelengths are shown in figure 4.4. Once the absorption levels are detected, it is possible to determine the ratio of the absorption between the oxygenated and deoxygenated hemoglobin at the different wavelengths.

The two light sources are switched on in sequences that allows compensation for ambient light. The microcontroller analyses the changes of light absorption during the arterial pulsatile flow and ignores the non-pulsatile component of the signal (which results from the tissues and venous blood). The photo detector generates a voltage proportional to the transmitted light. The AC component of the wave accounts for between 1-5% of the total signal. The high frequency of the diodes allows the
absorption to be calculated many times per second. This reduces movement effects on
the signal then the microcontroller analyses both the DC and AC components at 660
and 940 nm.

Figure 4.4: Absorption levels of oxygenated & deoxygenated blood at different
wavelengths.

The concentration of oxygen [18], the absorption of the light transmitted
through the blood (medium) can be calculated using the Beer-Lambert Law as follows

\[ I_{OUT} = I_{IN} e^{-A} \]  

(1)

Where \( I_{OUT} \) is the intensity of the light transmitted through the medium,
\( I_{IN} \) is the intensity of the light going into the medium, and
\( A \) is the absorption factor.

**Isobestic point**

This is the point at which two substances absorb a certain wavelength of light
to the same extent. In oximetry, the isobestic points of oxyhemoglobin and
ddeoxygenated hemoglobin occur at 590 and 805 nm. These points may be used as reference
points where light absorption is independent of the degree of saturation. The oxy
meters corrected hemoglobin concentration using the wavelength at the isobestic
points.

The intensity of light that is transmitted across the fingertip varies as shown in
fig4.6. The light absorbed by non-pulsatile tissues is constant (DC). The non-constant
absorption (AC) is the result of pulsatile blood pulsations. The attenuation of light by
the body segment can be split into the three components: arterial blood, venous blood
and tissues shown in figure 4.5. The AC and DC components of oximetry are as
shown in figure 4.6.
Figure 4.5: (a) Transmission of light through the finger when the attenuation of light is caused by arterial blood (A), venous blood (V) and tissues (T).

Figure 4.6: AC and DC components of oximetry

The increase in attenuation of light is caused only by the inflow of arterial blood into the fingertip. The oxygen saturation can be calculated from the arterial blood by subtracting the DC component of the attenuation from the total attenuation, leaving only the cardiac-synchronous pulsatile component for the dual-wavelength determination of oxygen saturation. The AC component of the figure 4.6 is the pulsatile waveform that interested in. This waveform represents the pulsing of the blood in the arteries and each individual pulse can be seen, representative of the heart rate. This waveform is gathered for both light frequencies, in this case infrared and red light. In order to obtain the pulse oximeter saturation, these AC and DC components from each of the wavelengths need to be measured and taken as a ratio as follows

$$ R = \frac{[AC_{\lambda_1}/ DC_{\lambda_1}]}{[AC_{\lambda_2}/ DC_{\lambda_2}]} $$

This ratio is then used in a calibration curve based on studies of healthy individuals to determine the $SaO_2$. This value will end up being a percentage, which will tell the physician whether or not everything is as it is supposed to be. A normal
saturation level is between 87-97%. This method of pulse oximetry has been practiced using extremities of the body such as fingers, toes, and ear lobes. For neonatal purposes the pulse oximeter is used on the palm of the hand or the foot.

**Review of Pulseoximetry Experimental Techniques**

The Bio-Medical Instrumentation implies measurement of biological variables. Prefix Bio- denotes connected with life. Many instruments were developed as early as the nineteenth century. The Bio-Medical measurements are two types. They are

1. Invasive or In vitro technique and
2. Non-invasive/In vivo techniques

**Invasive instruments** where the invasion of instruments into the biological systems for sake of measurements will be implemented. **Noninvasive** biomedical instruments do not need physical invasion into the biological specimens. The noninvasive instrumentation is always preferable in clinical practice, because it does not have any pain or physical disturbance to the patients. Pulseoxymeter come under both techniques

In Invasive oximetry, the blood is withdrawn from the subject under anaerobic conditions and measurements for oxygen saturation are made at a later time in the laboratory, the procedure is referred to as in-vitro oximetry. For discrete blood samples, a spectrophotometer measurement of oxygen saturation can be made by either a Transmission method or a Reflection method.

In the in Non-Invasive Oximetry/vivo oximetry [20], the oxygen saturation of blood is measured while the blood is flowing through the vascular system or it may be flowing through a cuvette directly connected with the circulatory system by means of a catheter. The blood in this case is unhemolysed. Both the techniques, **Reflection** and **Transmission** are utilized for in non-invasive oximetry [21].

**4.4.1. Transmission Oximetry**

Measurement of the degree of oxygen saturation of the blood can be made by spectrophotometric method. In spectrophotometric, the concentrations of substances held in solution are measured by determining the relative light attenuations that the light absorbing substances caused at each of several wavelengths.
4.4.2. Reflection Oximetry

Reflection oximetry [19] is based on the scattering of light by the erythrocytes. For the light scattered from the unhemolysed blood sample, oxygen saturation is given by

\[ \text{Oxygen saturation} = \frac{\text{Ir}(\lambda_2)}{\text{Ir}(\lambda_1)} + \text{br} \]

Polanyi and Hehir (1960) showed experimentally that a linear relationship exists between \( \frac{\text{Ir}(\lambda_2)}{\text{Ir}(\lambda_1)} \) and oxygen saturation. They computed the relationship as follows

\[ \text{Oxygen saturation} = 1.13 - 0.28 \times \left[ \frac{\text{Ir}(805)}{\text{Ir}(650)} \right] \]

The AO (American Optical, USA) oximeter II is a typical example of an instrument, which measures the oxygen saturation of unhemolysed blood on samples as small as 0.2ml by using a micro-cuvettee.

Brown (1980) describes the details of IL 282 Co-oxymeter, a completely automated instrument for the simultaneous analysis of total hemoglobin, %oxyhemoglobin, % carboxyhemoglobin, %methemoglobin and oxygen content in a sample of blood. The measurement of these parameters is critical and essential for oxygen respiratory therapy, measuring the effects of CO from sources like pollution and determining the effects of drugs and poisons etc. The key design feature in the instrument is the use of a servo controlled hollow cathode lamp as a spectral line source for the measurement of these hemoglobin parameters. Thus, the analytical wavelengths (535.0, 585.2, 594.5 and 626.6nm) could be precisely fixed.

4.5. Hardware development of Pulseoxy measurement system

The hardware of the Present developed pulseoxy measurement system mainly consists of the following two units. They are

1. Analog subsystem (front end)
2. Digital Subsystem

**Analog subsystem**

The analog subsystem details on the phenomena of signal detection and signal processing for the digital interface with analog to digital conversion. The digital data is transferred to micro controller after that it is transferred to Raspberry Pi using
Embedded Linux program for oxygen saturation and pulse rate measurement. The figure 4.8 shows detailed block diagram of the embedded based clinical pulse oxymeter. The system consists of sensing unit, Analog Front End and Raspberry Pi.

The functional approaches for the system are described below. The AFE4490 is a complete Analog Front-End (AFE) solution for pulse-oximeter measurement. The device consists of a low-noise receiver channel, an LED transmit section, and diagnostics for sensor and LED fault detection. The device communicates to an external microcontroller using an SPI interface. Figure 4.7 shows a detailed block diagram for the AFE4490. The blocks are described in detail in the following sections.

![Detailed Block Diagram of AFE4490](image)

**Figure 4.7: Detailed Block Diagram of AFE4490**

The photodiode circuitry embedded into these devices can amplify currents below 1 μA with 13 bits of resolution. It is ultralow- power (<4 mW) and has a programmable TIA.

The transmit stage contains two sections: the LED driver and LED current control section. In LED Driver, there are two LEDs, one for the visible red wavelength and another for the infrared wave length. The LED1_ON and LED2_ON signal decide which LED to turn on. In LED Current Control section the current source (I_{LED}) locally regulates and ensures that the actual LED current tracks the specified reference. The LED1 and LED2 reference current can be independently.
The Receiver Stage consists of a differential current to voltage transimpedance amplifier that converts the input photodiode current into a voltage. The feedback resistor of the amplifier ($R_f$) is programmable to support a wide range of photodiodes currents. The differential voltage at the TIA output includes the pleth component (the desired signal) and a component resulting from the ambient light leakage

$$V_{TIAOUT} = 2 \times (I_{PLETH} + I_{AMB}) \times R_f$$

The feedback resistor $R_f$ and feedback capacitor $C_f$ form a low-pass filter for the input signal current. The low-pass filter should have sufficiently high bandwidth because the input current consists of pulses.

The TIA is followed by the digital-to-analog converter (DAC) that sources the cancellation current and an amplifier that gains up the pleth component alone. The current DAC ($I_{CANCEL}$) has a cancellation current range of 10 uA with 10 steps (1 uA each).

The receiver provides digital samples corresponding to ambient duration. The microcontroller uses these ambient values to estimate the amount of ambient light leakage. The microcontroller must then set the value of the ambient cancellation DAC. Using the set value subtracts the ambient component and gains up only the pleth component of the received signal.

The output of the ambient cancellation amplifier is separated into LED2 and LED1 channels. When LED2 is on, the amplifier output is filtered and sampled on capacitor $C_{LED2}$. When LED1 is on, the amplifier output is filtered and sampled on capacitor $C_{LED1}$. In between the LED2 and LED1 pulses, the idle amplifier output is sampled to estimate the ambient signal on capacitors $C_{LED2-AMB}$ and $C_{LED2-AMB}$. The sampling duration is termed the Redeive sample time. The Redeive sample time is used for all dynamic range calculations; the minimum time supported is 50μs.

A 22-bit ADC converts the sampled LED2, LED1, and ambient signals sequentially. Each conversion takes 25% of the pulse repetition period and provides a single digital code at the ADC output. Four data streams are available at the ADC output (LED2, LED1, ambient LED2, and ambient LED1) at the same rate as the pulse repetition frequency. The ADC is followed by a digital ambient subtraction block that additionally outputs the (LED2–ambientLED2) and (LED1–ambient LED1) data values.
The Serial Peripheral Interface-compatible serial interface consists of four signals. The SCLK is the serial peripheral interface (SPI) serial clock. SCLK shifts in commands and shifts out data from the device. Data are clocked in on the SPISIMO pin.

The SPISOMI - SPI serial out master in pin is used with SCLK to clock out the AFE4490 data. The SPISIMO - SPI serial in master out pin is used with SCLK to clock in data to the AFE4490. The SPISTE -SPI serial interface enable pin enables the serial interface to clock data on the SPISIMO pin in to the device.

The microcontroller is used to calculate the heart rate and oxygen saturation using AFE data. The microcontroller should have specific features including the ability to measurement with limited power because it will be continuously running.

The present designed non-invasive pulseoxymeter use optical plethysmography [22] using the MSP430F5529 Micro controller (MCU). The pulseoxymeter consists of a peripheral pulseoxy probe combined with the MCU displaying the oxygen saturation and pulse rate on a Raspberry Pi. The same sensor is used for both heart-rate detection and pulseoxygen in this application. The probe is placed on a peripheral point of the body such as a fingertip, ear lobe or the nose. The probe includes two light emitting diodes (LEDs), one in the visible red spectrum (660nm) and the other in the infrared spectrum (940nm). Measuring the intensity from each frequency of light after it transmits through the body and then calculating the ratio between these two intensities work the percentage of oxygen in the body.

The Pulseoxymeter [23] is a medical instrument for monitoring the blood oxygenation of a patient. This type of monitoring is especially useful during surgery. This present design report demonstrates the implementation of a portable pulseoxymeter using the ultra low power capability of the microcontroller MSP430F5529. Because of the high level of analog integration, the external components can be kept to a minimum. Furthermore, by keeping ON time to a minimum and power cycling the two light sources, power consumption is reduced.

In a pulseoxymeter, the calculation of the level of oxygenation of blood (SaO2) is based on measuring the intensity of light that has been attenuated by body
tissue. SaO2 is defined as the ratio of the level oxygenated Hemoglobin over the total Hemoglobin level (oxygenated and depleted)

\[
\text{SaO2} = \frac{\text{HbO2}}{\text{Total Hemoglobin}}
\]

Body tissue absorbs different amounts of light depending on the oxygenation level of blood that is passing through it. Two different wavelengths of light are used, each is turned on and measured alternately. By using two different wavelengths, the mathematical complexity of measurement can be reduced.

\[
R = \log(lac) \lambda_1 / \log(lac) \lambda_2
\]

\[
\text{SaO2} \propto R
\]

Where \( \lambda_1 \) and \( \lambda_2 \) represents the two different wavelengths of light used.

There are a DC and an AC component in the measurements. It is assumed that the DC component is a result of the absorption by the body tissue and veins. The AC component is the result of the absorption by the arteries. In practice, the relationship between SaO2 and R is not as linear as indicated by the formula.

**Block diagram of Pulseoxymeter**

![Block diagram of Pulseoxymeter](image)

**Figure 4.8 : Pulseoxymeter Block Diagram**
Circuit diagrams of Pulseoxy measurement System

Figure 4.9(a) : AFE4490 Schematic Diagram for pulse oxymeter

Figure 4.9(b): Schematic Diagram for pulse oxymeter

The implementation of pulse oxy meter is by cascading several stages as shown in the figure4.8, which depicts the system block diagram and figure 4.9(a) &4.9(b) describes the schematic diagram of Pulseoxymeter. The system requires a pulse oxygen sensor, Analog Front End, Integrated Mixed Signal Micro controller unit with USB serial link and Raspberry Pi.

The system can be practically implemented by incorporating the following components. The design consists of hardware and software sections. The device hardware mainly consist of following parts namely

1. Sensor unit- Pulse oxy probe
2. Signal conditioning unit - Analog Front End (AFE)
3. Mixed Signal Micro Controller
4. Graphical LCD Display - AT070TN92
5. Output display unit
6. GSM MODEM - SIM500

4.5.1. Sensor unit - Pulseoxy probe

The sensor unit consists of a pulseoxy probe. The pulseoxy probe senses the signals from the patient and transmits the sensing signals to next stage, signal-conditioning unit which can be processed in next stage.

In present system, finger probe is the heart of the instrumentation system. The sensor unit of pulseoxy probe [24] of a pulse oximeter consists of two major parts. The first part of the probe is having a pair of light emitting diodes (LED’s), which emit visible red light, and infrared light. The second major part is a photo detector opposite the LED’s. The two light sources emit their respective frequencies of light through the extremity that the pulse oximeter is attached to.

Deoxygenated hemoglobin absorbs large amounts red light (640nm) while also absorbing infrared light (910nm). On the other hand, oxygenated hemoglobin absorbs the same amount of infrared light while absorbing a decreased amount of red light. This difference in intensity on the photo detector between the two light sources shows the amount of deoxygenated hemoglobin with respect to the oxygenated hemoglobin. This sensor unit can also measure the pulse by counting one heartbeat for every systolic reading.

Figure 4.10: Nelcore DS-100A pulseoxy sensor, DB9 Connector Pin Outs
In present work, Nellcore DS-100A is used as a pulseoxy sensor, which is designed from Nellcore. This probe has a finger clip integrated with sensors and is convenient to use. The input to the probe is a D-type 9 pin connector. The DB9 pulse oximeter connector pin-outs are shown in Figure 4.10. The description of the pin-outs is shown in Table 1.

**Table 1: DB9 based PulseOximeter Connector pinouts**

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Pin Name</th>
<th>Pin Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>TX_LED_P</td>
<td>Anode of the IR LED, cathode of the red LED</td>
</tr>
<tr>
<td>3</td>
<td>TX_LED_N</td>
<td>Cathode of the IR LED, anode of the red LED</td>
</tr>
<tr>
<td>5</td>
<td>DET_N</td>
<td>Phototransistor anode</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td>Cable shield</td>
</tr>
<tr>
<td>9</td>
<td>DET_P</td>
<td>Phototransistor cathode</td>
</tr>
</tbody>
</table>

The LED’s transmit red light and infrared light through the tissues to the photodetector, which captures changes in light absorption by hemoglobin. In the probe, these two LEDs are connected back to back. To turn them on, an H-Bridge arrangement is used. The signal-conditioning unit uses information from the sensor to calculate oxygen saturation in arterial blood and also measures average pulse rate.

Pulse oximetry monitoring sensor Nellcore DS-100A can apply to a finger, toe, forehead, nose and earlobe as long as perfusion is adequate. If you’re using a finger, remove any nail polish. Some shades of polish can block light transmission, resulting in an inaccurate reading and Place the sensor on an unpolished nail.

The heart beat of the patient is to be monitored accurately. Pulse oxy meter measures heart beat by sensing the difference in absorbance of infrared radiation by blood during systolic and diastolic activities of heart. The volume of blood flowing through arteries varies widely during each heart beat. Hence if infrared radiation is incident on it, the absorbance of IR also varies according to the heart beat. These variations are sensed using a photo detector to determine the heart beat.

**Nellcore probe DS-100 Features**

- Reusable Sensor, Easy-to-use
- Built-in shielding protects signal from electronic noise
- High quality LEDs maximize tracking capabilities
• Sensor head design optimizes signal and shields detector from ambient light

4.5.2. Signal conditioning unit

The instrumentation systems consist of various units staring from sensors to data representation units. Among that signal conditioning is a vital process. This system consists of Amplifiers, Filters, ADC, and DAC …etc. the Bio-Medical instrumentation consists of signal conditioning and processing for very low frequencies. During study of these signals, noise interference is a major problem. In this present work, signal conditioning is complex system.

4.5.2.1. Receiver Section

The receiver section [25] consists of a differential current-to-voltage (I-V) trans impedance amplifier that converts the input photodiode current into an appropriate voltage, as shown in Figure 4.11. The feedback resistor of the amplifier (RF)is programmable to support a wide range of photodiode currents.

![Figure 4.11: Internal architecture of Receiver](image)

The RF amplifier and the feedback capacitor (CF) form a low-pass filter for the input signal current. Always ensure that the low-pass filter RC time constant has sufficiently high bandwidth because the input current consists of pulses.

\[
R_F \times C_F \leq \frac{R_X \times \text{SAMPLE TIME}}{10}
\]

The output voltage of the I-V amplifier includes the pleth component (the desired signal) and a component resulting from the ambient light leakage. The I-V amplifier is followed by the second stage, which consists of a current digital-to-analog converter (DAC) that sources the cancellation current and an amplifier that
gains up the pleth component alone. The amplifier has five programmable gain settings: 0 dB, 3.5 dB, 6 dB, 9.5 dB, and 12 dB. The gained-up pleth signal is then low-pass filtered (500-Hz bandwidth) and buffered before driving a 22-bit ADC. The current DAC has a cancellation current range of 10 μA with 10 steps (1 μA each). The DAC value can be digitally specified with the SPI interface. Using ambient compensation with the ambient DAC allows the dc biased signal to be centered to near mid-point of the amplifier (±0.9 V). Using the gain of the second stage allows for more of the available ADC dynamic range to be used.

The output of the ambient cancellation amplifier is separated into LED2 and LED1 channels. When LED2 is on, the amplifier output is filtered and sampled on capacitor CR. Similarly, the LED1 signal is sampled on the CLED1 capacitor when LED1 is ON. In between the LED2 and LED1 pulses, the idle amplifier output is sampled to estimate the ambient signal on capacitors CLED2_amb and CLED1_amb.

The sampling duration is termed the Rx sample time and is programmable for each signal, independently. Sampling can start after the I-V amplifier output is stable. The Rx sample time is used for all dynamic range calculations; the minimum time supported is 50 μs.

A single, 22-bit ADC converts the sampled LED2, LED1, and ambient signals sequentially. Each conversion takes a maximum of 25% of the pulse repetition period (PRP) and provides a single digital code at the ADC output. The conversions are staggered so that the LED2 conversion starts after the end of the LED2 sample phase, and so on. This configuration also means that the Rx sample time for each signal is no greater than 25% of the pulse repetition period. The four data streams are available at the ADC output (LED2, LED1, ambient LED2, and ambient LED1) at the same rate as the pulse repetition frequency. The ADC is followed by a digital ambient subtraction block that additionally outputs the (LED2 – ambient LED2) and (LED1 – ambient LED1) data values.
4.5.2.2. Ambient Cancellation

The receiver provides digital samples corresponding to ambient duration. The microcontroller uses these ambient values to estimate the amount of ambient light leakage. The microcontroller must then set the value of the ambient cancellation DAC using the SPI, as shown in Figure 4.12.

![Ambient Cancellation Loop](image)

**Figure 4.12: Ambient Cancellation Loop**

Using the set value, the ambient cancellation stage subtracts the ambient component and gains up only the pleth component of the received signal, as shown in Figure 4.13.

![Front-End (I-V Amplifier and Cancellation Stage)](image)

**Figure 4.13: Front-End (I-V Amplifier and Cancellation Stage)**

Receiver Control Signals

The receiver control signals consists of the following sample phases, they are **LED2 sample phase (SLED2):** When this signal is high, the amplifier output corresponds to the LED2 on-time. The amplifier output is filtered and sampled into
capacitor CLED2. To avoid settling effects resulting from the LED or cable, program SLED2 to start after the LED turns on. This settling delay is programmable.

**Ambient sample phase (SLED2_amb):** When this signal is high, the amplifier output corresponds to the LED2 off time and can be used to estimate the ambient signal (for the LED2 phase). The amplifier output is filtered and sampled into capacitor CLED2_amb.

**LED1 sample phase (SLED1):** When this signal is high, the amplifier output corresponds to the LED1 on-time. The amplifier output is filtered and sampled into capacitor CLED1. To avoid settling effects resulting from the LED or cable, program SLED1 to start after the LED turns on. This settling delay is programmable.

**Ambient sample phase (SLED1_amb):** When this signal is high, the amplifier output corresponds to the LED1 off time and can be used to estimate the ambient signal (for the LED1 phase). The amplifier output is filtered and sampled into capacitor CLED1_amb.

**LED2 convert phase (CONVLED2):** When this signal is high, the voltage sampled on CLED2 is buffered and applied to the ADC for conversion. The conversion time duration is always 25% of the pulse repetition period. At the end of the conversion, the ADC provides a single digital code corresponding to the LED2 sample.

**Ambient convert phases (CONVLED2_amb, CONVLED1_amb):** When this signal is high, the voltage sampled on CLED2_amb (or CLED1_amb) is buffered and applied to the ADC for conversion. The conversion time duration is always 25% of the pulse repetition period. At the end of the conversion, the ADC provides a single digital code corresponding to the ambient sample.

**LED1 convert phase (CONVLED1):** When this signal is high, the voltage sampled on CLED1 is buffered and applied to the ADC for conversion. The conversion time duration is always 25% of the pulse repetition period. At the end of the conversion, the ADC provides a single digital code corresponding to the LED1 sample.

The Figure 4.14 for a timing diagram detailing the control signals related to the LED on-time, Receive sample time, and the ADC conversion times for each channel.
All timing signals are set with reference to the pulse repetition period (PRP). Therefore, a dedicated compare register compares the 16-bit counter value with the reference value specified in the PRF register. Every time that the 16-bit counter value is equal to the reference value in the PRF register, the counter is reset to '0'.

The ADC conversion signal requires four pulses in each PRF clock period. Timer compare register 11 uses four sets of start and stop registers to control the ADC conversion signal, as shown in Figure 4.15.
Using the Timer Module registers can be used to program the start and end instants in units of 4-MHz clock cycles.

The start and end edges can be positioned anywhere within the pulse repetition period. Care must be taken by the user to program suitable values in these registers to avoid overlapping the signals and to make sure none of the edges exceed the value programmed in the PRP register. Writing the same value in the start and end registers results in a pulse duration of one clock cycle. The following steps describe the timer sequencing configuration:

1. With respect to the start of the PRP period, the sequence of conversions must be followed in order: convert LED2 → LED2 ambient → LED1 → LED1 ambient.
2. Also, starting from t0, the sequence of sampling instants must be staggered with respect to the respective conversions as follows: sample LED2 ambient → LED1 → LED1 ambient → LED2.
3. Finally, align the edges for the two LED pulses with the respective sampling instants.

**Analog to Digital Conversion**

The ADC reset signal must be positioned at 25% intervals of the pulse repetition period (that is, 0%, 25%, 50%, and 75%). After the falling edge of the ADC reset signal, the ADC conversion phase starts. Each ADC conversion takes 50 μs. The averaging mode can average multiple ADC samples and reduce noise to improve dynamic range because the ADC conversion time is usually shorter than 25% of the pulse repetition period. Figure 4.16 shows a diagram of the averaging module. The ADC output format is in 22-bit twos complement. The two MSB bits of the 24-bit data can be ignored.

![Averaging Module Diagram](image)

**Figure 4.16: Averaging Module**
All the ADC digital samples are accumulated and averaged after every 50 μs. At the next rising edge of the ADC reset signal, the average value (22-bit) is written into the output registers sequentially. At the rising edge of the ADC_RDY signal, the contents of all six result registers can be read out.

4.5.2.3. Transmit Section

The transmit section integrates the LED driver and the LED current control section with 8-bit resolution. This integration is designed to meet a dynamic range of better than 105 dB (based on a 1-sigma LED current noise). The RED and IR LED reference currents can be independently set. The current source (ILED) locally regulates and ensures that the actual LED current tracks the specified reference. The transmitter section uses a reference voltage for operation. This reference voltage is available on the REF_TX pin and must be decoupled to ground with a 2.2-μF capacitor. The TX_REF voltage is derived from the TX_CTRL_SUP. The maximum LED current setting depends on the transmitter reference voltage. By default, after reset, this voltage is 0.75 V and supports up to a 150-mA LED current. For higher LED currents up to 200 mA, the reference can be programmed to 1.0 V. An H-bridge drive for a two-terminal, back-to-back LED package is used for two LED driver are supported as shown in Figure 4.17.

Figure 4.17: Transmit: H-Bridge Drive
### 4.5.2.4. Serial Programming Interface

The SPI-compatible serial interface consists of four signals: SCLK (serial clock), SPISOMI (serial interface data output), SPISIMO (serial interface data input), and SPISTE (serial interface enable).

The serial clock (SCLK) is the serial peripheral interface (SPI) serial clock. SCLK shifts in commands and shifts out data from the device. SCLK features a Schmitt-triggered input and clocks data out on SPISOMI. Data are clocked in on the SPISIMO pin. Even though the input has hysteresis, TI recommends keeping SCLK as clean as possible to prevent glitches from accidentally shifting the data. When the serial interface is idle, hold SCLK low.

The SPISOMI (SPI serial out master in) pin is used with SCLK to clock out the AFE4490 data. The SPISIMO (SPI serial in master out) pin is used with SCLK to clock in data to the AFE4490. The SPISTE (SPI serial interface enable) pin enables the serial interface to clock data on the SPISIMO pin in to the device.

### Reading and Writing Data

The device has a set of internal registers that can be accessed by the serial programming interface formed by the SPISTE, SCLK, SPISIMO, and SPISOMI pins. The SPI_READ register bit must be first set to '0' before writing to a register. When SPISTE is low,

- Serially shifting bits into the device is enabled.
- Serial data (on the SPISIMO pin) are latched at every SCLK rising edge.
- The serial data are loaded into the register at every 32nd SCLK rising edge.

In case the word length exceeds a multiple of 32 bits, the excess bits are ignored. Data can be loaded in multiples of 32-bit words within a single active SPISTE pulse. The first eight bits form the register address and the remaining 24 bits form the register data.

### 4.5.2.5 Mixed Signal Microcontroller-MSP430F5529

The Texas Instruments MSP430F5529 [26] is ultralow-power microcontrollers consist of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with extensive low power modes, is optimized to achieve extended battery life in portable measurement applications.
device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in 3.5μs (typical). The MSP430F5529 microcontroller configurations with integrated USB 2.0, four 16-bit timers, a high-performance 12-bit analog-to-digital converter (ADC), two universal serial communication interfaces (USCI), hardware multiplier, DMA, real-time clock module with alarm capabilities, and 63 I/O pins. The block diagram of MSP430F5529 is as shown in figure 4.18.

![Block Diagram of MSP430F5529](image)

**Figure 4.18: the block diagram of MSP430F5529**

The MSP430 CPU has a 16-bit RISC architecture that is highly transparent to the application. All operations, other than program-flow instructions, are performed as register operations in conjunction with seven addressing modes for source operand and four addressing modes for destination operand.

The CPU is integrated with 16 registers that provide reduced instruction execution time. The register-to-register operation execution time is one cycle of the CPU clock. Four of the registers, R0 to R3, are dedicated as program counter, stack pointer, status register, and constant generator, respectively. The remaining registers are general-purpose registers. Peripherals are connected to the CPU using data, address, and control buses, and can be handled with all instructions. The instruction set consists of the original 51 instructions with three formats and seven address modes and additional instructions for the expanded address range. Each instruction can operate on word and byte data.
The MSP430 has one active mode and six software selectable low-power modes of operation. An interrupt event can wake up the device from any of the low-power modes, service the request, and restore back to the low power mode on return from the interrupt program. The Bootstrap Loader BSL enables users to program the flash memory or RAM using various serial interfaces.

The Universal Serial Communication Interface (USCI) modules are used for serial data communication. The USCI module supports synchronous communication protocols such as SPI (3 or 4 pin) and I2C, and asynchronous communication protocols such as UART, enhanced UART with automatic baud rate detection, and IrDA. Each USCI module contains two portions, A and B. The USCI_An module provides support for SPI (3 pin or 4 pin), UART, enhanced UART, or IrDA. The USCI_Bn module provides support for SPI (3 pin or 4 pin) or I2C.

The ADC12_A module supports fast 12-bit analog-to-digital conversions. The module implements a 12-bit SAR core, sample select control, reference generator and a 16 word conversion-and-control buffer. The conversion and control buffer allows up to 16 independent ADC samples to be converted and stored without any CPU intervention.

The USB module is a fully integrated USB interface that is compliant with the USB 2.0 specification. The module supports full-speed operation of control, interrupt, and bulk transfers. The module includes an integrated LDO, PHY, and PLL. The PLL is highly-flexible and can support a wide range of input clock frequencies. USB RAM, when not used for USB communication, can be used by the system.

By using USB serial link, a serial communication establish between the microcontroller and Raspberry Pi. By using this communication, we can transmit and receive e data between MSP430F5529 to Raspberry Pi. In present study we are transmitting the data for measuring Pulse oxygen and Heart Rate to the Raspberry Pi.

The signals from analog digital converter are processed by using RASPBERRY Pi ARM11J6JZmicro controller. ARM stands for Advanced RISC Machine. The ARM11 is based on the ARMv6 instruction set architecture. The block diagram of the internal architecture of the micro controller ARM11J6JZis shown in
figure 6.12. The Raspberry Pi uses the Broadcom BCM2835 system on a chip (SoC). The Raspberry Pi model B has 512MB of primary memory (RAM). Clock speed is 700MHz. The Broadcom BCM2835 is the specific implementation of an ARM11 processor. The CPU core is the ARM11J6JZF which is a member of the ARM11 family (ARMv6 architecture with floating point). The GPU is a Video core IV GPU. This is mainly consists of the following units embedded inside the chip.

The important features of the ARM11J6JZ core is of the following:

- Eight stage pipeline
- Internal coprocessors CP14 and CP15
- Three instructions sets
  - 32-bit ARM instruction set (ARM state)
  - 16-bit Thumb instruction set (Thumb state)
  - 8-bit Java byte codes (Jazelle state)
- Data path consist of three pipelines:
  - ALU, Shift, Sat pipeline (Sat implements saturation logic)
  - MAC pipeline (MAC executes multiply and multiply-accumulate operations)
  - Load or store pipeline

The ARM Memory Management Unit (MMU) translates virtual addresses to physical addresses using page information. The MMU supports four page sizes: 4KB small pages, 64KB large pages, 1MB sections and 16MB super sections. Address mapping is performed using two levels of translation look aside buffers: the Main TLB and two micro TLBs. The Main TLB backs separate micro TLBs for each of the instruction and data caches. Address translation is first attempted in a MicroTLB. If the address cannot be translated in the MicroTLB, then the Main TLB is tried. If the address cannot be translated through the Main TLB, then hardware page walking is invoked. The functional block diagram of the ARM11J6JZ is as shown in figure 4.19.
The circuit diagram of interfacing motor, filter, memory...Etc to a micro controller is as shown in figure 6.8. In the present design ARM11J6JZF is the central processing unit do the total processing. The micro controller is connected to all external devices like motor’s, filter, amplifier, ADC, USB, Graphical LCD. Every external device has their own input/output lines. The motors, sensor output are connected to the GPIO pins of the micro controller. LCD communicates serially with the micro controller. 5 lines are used to interface with the micro controller. Universal Serial Bus uses Differential lines to communicate between micro controller and Personal Computer. The system having memory interface with an external memory up to 16GB where the system software as well as the application software developed can be stored to execute the operations as small CPU without personal computer. the photograph of Raspberry Pi Central processing unit and its components are shown in Photograph 1.
4.5.2.6 GRAPHICAL LCD DISPLAY (TOUCH SCREEN - AT070TN92)

The output of the device is sent to a liquid crystal display to display the data of systolic and diastolic blood pressure. In present design we are using GRAPHICAL LCD DISPLAY TOUCH SCREEN - AT070TN92 [36]. The pin description and the specification of AT070TN92 are as shown in table 2 and 3. The Graphical LCD interfacing circuit is as shown in fig 6.17.

AT070TN92 is 800x480 dots 7” color TFT LCD module display with OTA7001A controller, optional 5 points capacitive multi-touch panel with connector and 4-wire resistive touch panel screen with connector. A thin-film-transistor liquid-crystal display (TFT LCD) is a variant of a liquid-crystal display (LCD) that uses thin-film transistor (TFT) technology to improve image qualities such as addressability and contrast. A TFT LCD is an active-matrix LCD, in contrast to passive-matrix LCDs or simple, direct-driven LCDs with a few segments. It has superior display quality, super wide view angle and easily controlled by MCU ARM. It can be used in any embedded systems, car, mp4, gps, industrial device, security and hand-held equipment which require display in high quality and colorful image. It supports RGB interface. FPC with zif connector is easily to assemble or remove. The pin description of AT070TN92 is as shown in Table 3

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>I/O Description</th>
<th>Function</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VDD1</td>
<td>P</td>
<td>Power for LCD backlight circuit</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>VDD2</td>
<td>P</td>
<td>Power for LCD backlight circuit</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>VDD3</td>
<td>P</td>
<td>Power for LCD backlight circuit</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>VDD4</td>
<td>P</td>
<td>Power for LCD backlight circuit</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>P</td>
<td>Power ground</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>VDDmA</td>
<td>I</td>
<td>Common voltage</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>VDDmB</td>
<td>I</td>
<td>Common voltage</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>VDDmC</td>
<td>I</td>
<td>Common voltage</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>VDDmD</td>
<td>I</td>
<td>Common voltage</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>VSS1</td>
<td>I</td>
<td>Negative Voltage</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>VSS2</td>
<td>I</td>
<td>Negative Voltage</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>D2</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>13</td>
<td>D1</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>14</td>
<td>D0</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>15</td>
<td>B4</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>16</td>
<td>B3</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>17</td>
<td>B2</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>18</td>
<td>B1</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>19</td>
<td>B0</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>20</td>
<td>G7</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>21</td>
<td>G6</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>22</td>
<td>G5</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>23</td>
<td>G4</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>24</td>
<td>G3</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
<tr>
<td>25</td>
<td>G2</td>
<td>I</td>
<td>Data Bus</td>
<td>Refer to AT070TN92 for more details</td>
</tr>
</tbody>
</table>

Table 3: The pin description of AT070TN92

Four Resistive Touch Screen

Four - wire resistive technology is the simplest to understand and manufacture. It uses both the upper and lower layers in the touch screen “sandwich” to determine
the X and Y coordinates. Typically constructed with uniform resistive coatings of indium tin oxide (ITO) on the inner sides of the layers and silver buss bars along the edges, the combination sets up lines of equal potential in both X and Y. In the illustration below, the controller first applies 5V to the back layer. Upon touch, it probes the analog voltage with the coversheet, reading 2.5V, which represents a left-right position or X axis. It then flips the process, applying 5V to the coversheet, and probes from the back layer to calculate an up-down position or Y axis. At any time, only three of the four wires are in use (5V, ground, and probes).

Touch can be defined by three parameters. The first and second parameters are X and Y-position. The parameter relates to “touch pressure” and allows the touch screen to differentiate between finger and stylus contacts Equivalent circuits for touched and untouched touch screens as shown in Figure 4.20.

Touch screen equivalent circuits

All measurement cycles need voltage applied in various combinations. In this project, VDD is put on the touch screen connector by switching the connected PSoC port in the strong drive and setting the logic to a high value. Connecting to ground means setting the port to the strong drive and setting the logic to a low value. The PSoC output stage drain resistance is low and its influence is also low. The calibration algorithm compensates for this discrepancy.

The measurements are performed by an incremental analog-to-digital converter (ADC) through a programmable gain amplifier (PGA). Measurements are made in radiometric mode. The touch screen is powered by the same source that powers the PSoC. The ADC is configured to measure in the GND-VDD range. Hence, measurement does not depend on power supply voltage. X-position is measured as
voltage and applied over the X-plane by connecting XP to Vdd and XM to ground. Voltage measured from the YP or YM touch screen connector is proportional to the touch X-coordinate. Y-position is measured as voltage and applied over the Y-plane by connecting YP to Vdd and YM to ground. Voltage measured from the XP or XM touch screen connector is proportional to the touch Y-coordinate.

Figure 4.21: Touched and untouched touch screens & To measure touch pressure, it is necessary to relate pressure to resistance.

Touch pressure is most often used to determine the presence of a finger or pen touch and not the intensity of the contact, it is not necessary to have high accuracy is an 8-bit ADC instead of the 12-bit resolution used for X- and Y-position (X) and two additional cross-panel measurements (Z1 and Z2) of the touch screen. Voltage is applied to YP (Vdd) and YM (Z2) values.

**Peninterrupt**

If the user does not touch the screen for a long period of time, there is no need for operation or measurement. The touch screen is then put in sleep mode and waits for a pen interrupt. Upon user touch, an interrupt occurs and the touch screen controller wakes up and measures touch parameters.
Fig 4.22 : Peninterrupt

The port pin that is connected to touch screen XP connector is configured to pull-up mode and set to a logic state of high. The port pin connected to the XM connector is configured as a digital input and the interrupt is enabled by falling edge. If the lower screen is still untouched, XM holds the logic in high states. If the user touches the screen, the voltage of XM falls to a low logic level and initiates an interrupt that wakes up the PSoC. Graphical LCD display interface photograph is as shown in Photograph 2.

Photograph 2 : Graphical LCD display interface circuit with RPI
4.5.3 GSM MODEM - SIM500

The Global System [27] for Mobile communications (GSM: originally from Groupe Special Mobile) is the most popular standard for mobile phones in the world. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it may be a mobile phone that provides GSM modem capabilities. The term GSM modem is used as a generic term to refer to any modem that supports one or more of the protocols in the GSM evolutionary family, including the 2.5G technologies GPRS and EDGE, as well as the 3G technologies WCDMA, UMTS, HSDPA and HSUPA.

GSM module is the kernel part to realize wireless data transmission. Wireless communication module SIM500 based on standard of GSM produced by SIMCOM Company is used in the developed application. SIM500 module consists of main frame, antenna, serial communication line, power line. It provides services of wireless modem, wireless fax, short message and speech communication. The short message service is suitable to apply in the situation of frequent transmittance of small data flow.

SIM500 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS1900 MHz. With a tiny configuration of 40mm x 33mm x 2.85 mm, SIM500 can fit almost all the space requirement in your application, such as Smart phone, PDA phone and other mobile device. The physical interface to the mobile application is made through a 60 pins board-to-board connector, which provides all hardware interfaces between the module and customers’ boards except the RF antenna interface. The keypad and SPI LCD interface will give you the flexibility to develop customized applications. Two serial ports can help you easily develop your applications. Two audio channels include two microphones inputs and two speaker outputs. This can be easily configured by AT command. SIM500 provide RF antenna interface with two alternatives: antenna connector and antenna pad. The antenna connector is MURATA MM9329-2700. And customer’s antenna can be soldered to the antenna pad. The circuit of SIM500 is shown in Photograph 3.
The SIM500 is designed with power saving technique, the current consumption to as low as 2.5mA in SLEEP mode. The SIM500 is integrated with the TCP/IP protocol, Extended TCP/IP AT commands are developed for customers to use the TCP/IP protocol easily, which is very useful for those data transfer applications. The leading features of SIM 300 make it ideal for virtually unlimited applications, handheld devices and much more. It is compatible with AT cellular command interface.

The features of SIM500 are

- Tri-Band GSM/GPRS 900/1800/1900 MHZ
- Complaint to GSM phase 2/2+
- Dimensions: 40mm x 33mm x 2.85mm
- Weight : 8g
- Control via AT commands
- SIM application tool kit
- Supply voltage range 3.4 …. 4.5v
- Low power consumption

All hardware interfaces except RF interface that connects SIM500 to the customers’ cellular application platform is through a 60-pin 0.5mm pitch board-to-board connector. Sub-interfaces included in this board-to-board connector are Dual serial interface ,Two analog audio interfaces, SIM interface
SIM500 provides two unbalanced asynchronous serial ports. The GSM module [28] is designed as a DCE (Data Communication Equipment), following the traditional DCE-DTE (Data Terminal Equipment) connection, the module and the client (DTE) are connected through the following signal as shown in figure 4.23. Auto bauding supports baud rate from 1200 bps to 115200bps.

Serial port 1
Port/TXD @ Client sends data to the RXD signal line of module
Port/RXD @ Client receives data from the TXD signal line of module
Serial port 2
Port/TXD @ Client sends data to the DGBRXD signal line of module
Port/RXD @ Client receives data from the DGBTXD signal line of module

![Interface of serial ports](image)

**Figure 4.23 : Interface of serial ports**

The TXD, RXD, DBG_TXD, DBG_RXD, GND must be connected to the IO connector when user need to upgrade software and debug software, the TXD, RXD should be used for software upgrade and the DBG_TXD, DBG_RXD for software debug. The PWRKEY pin is recommended to connect to the IO connector. The user also can add a switch between the PWRKEY and the GND. The PWRKEY should be connected to the GND when SIM500 is upgrading software.

The SIM interface supports the functionality of the GSM Phase 1 specification and also supports the functionality of the new GSM Phase 2+ specification for FAST 64 kbps SIM. Both 1.8V and 3.0V SIM Cards are supported. The SIM interface is powered from an internal regulator in the module having nominal voltage 2.8V. All pins reset as outputs driving low.

The Figure 4.24 is the reference circuit about SIM interface. The 22Ω resistors showed in the figure should be added in series on the IO line between the module and the SIM card for matching the impedance. The pull up resistor (about 10KΩ) must be
added on the SIM_I/O line. The SIM_PRESENCE pin is used for detecting the SIM card removal. We can use the AT command “AT+CSDT” to set the SIMCARD configure. We can select the 8 pins SIM card.

![SIM interface reference circuit with 8 pins SIM card](image)

**Figure 4.24:** SIM interface reference circuit with 8 pins SIM card

The GSM 07.05 AT commands are for performing SMS and CBS related operations. The Overview of AT Commands According to GSM07 [29] is listed in Table 2.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT+CMGD</td>
<td>DELETE SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGF</td>
<td>SELECT SMS MESSAGE FORMAT</td>
</tr>
<tr>
<td>AT+CMGL</td>
<td>LIST SMS MESSAGES FROM PREFERRED STORE</td>
</tr>
<tr>
<td>AT+CMGR</td>
<td>READ SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGS</td>
<td>SEND SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGW</td>
<td>WRITE SMS MESSAGE TO MEMORY</td>
</tr>
<tr>
<td>AT+CMSS</td>
<td>SEND SMS MESSAGE FROM STORAGE</td>
</tr>
<tr>
<td>AT+CMSC</td>
<td>SEND SMS COMMAND</td>
</tr>
<tr>
<td>AT+CNMI</td>
<td>NEW SMS MESSAGE INDICATIONS</td>
</tr>
<tr>
<td>AT+CPMS</td>
<td>PREFERRED SMS MESSAGE STORAGE</td>
</tr>
<tr>
<td>AT+CRES</td>
<td>RESTORE SMS SETTINGS</td>
</tr>
<tr>
<td>AT+CSAS</td>
<td>SAVE SMS SETTINGS</td>
</tr>
<tr>
<td>AT+CSCA</td>
<td>SMS SERVICE CENTER ADDRESS</td>
</tr>
<tr>
<td>AT+CSCB</td>
<td>SELECT CELL BROADCAST SMS MESSAGES</td>
</tr>
<tr>
<td>AT+CSDH</td>
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| 4.6 Software development of pulseoxymeter |

The processing unit utilizes the logic implemented in the software for accurate detection of pulse oxygen. The software checks the input signal from the pulse oxymeter from the patient’s body continuously and measures the pulse width of the signal. This width is converted into heartbeat rate by the software. If there is any abnormality in heart beat, it can be detected as a change in the pulse width. As soon as the logic detects a change it triggers the vibrator and the system waits for the response. In the present study the c language used for the development of software having the following features.
The ‘C’ programming language is growing in importance and has become the standard high-level language for real-time embedded applications. PC is the standard for computing the concept of a ‘C’ compiler [30]. To development of C programs for an MSP430F5529 executing on a PC is now familiar with IAR Embedded IDE only. This largely due to the inherent language flexibility, the extent of support and its potential for portability across a wide range of hardware [31]. Specific reasons for its use include

- It is a midlevel with high level features and low-level features
- It is very efficient, it is popular and well understood
- Good well-proven compilers are available for every embedded processor
- Books, training courses, code samples and world wide web sites discussing the use of the language are all widely available

### 4.6.1. The IAR Embedded Workbench IDE

The IAR Embedded Workbench IDE is the framework with all necessary tools is integrated: IAR Embedded Workbench is available for a large number of microprocessors and micro controllers in the 8-, 16-, and 32-bit segments, allowing to development project. The highly optimizing MSP430 IAR C/C++ Compiler

- The MSP430 IAR Assembler, The versatile IAR XLINK Linker
- The IAR XAR Library Builder and the IAR XLIB Librarian
- IAR C-SPY debugger, a state-of-the-art high-level language debugger.

The IAR Embedded Workbench IDE is a flexible integrated development environment, allowing developing applications for a variety of different target processors. It provides a convenient Windows interface for rapid development and debugging. The IAR Embedded Workbench IDE comes with functions that will help to stay in control of all project modules, for example, C or C++ source code files, assembler files, include files, and other related modules.

The MSP430 IAR C/C++ Compiler is a state-of-the-art compiler that offers the standard features of the C or C++ languages, plus many extensions designed to take advantage of the MSP430-specific facilities. The compiler is integrated with other IAR Systems software in the IAR Embedded Workbench IDE.
The IAR C-SPY Debugger is a high-level-language debugger for embedded applications. It is designed for use with the IAR Systems compilers and assemblers, and it is completely integrated in the IAR Embedded Workbench IDE, providing seamless switching between development and debugging. This will make possibilities such as Editing while debugging. During a debug session, corrections can be made directly into the same source code window that is used to control the debugging. Changes will be included in the next project rebuild. Setting source code breakpoints before starting the debugger. Breakpoints in source code will be associated with the same piece of source code even if additional code is inserted.

After creation of project and the program, we download the program for execution of a program micro controller with external hardware interface then we can get the results. If we get wrong results then modify the program and do the same process as above till to get the correct results. Software program for Pulse oximeter is present in Annexure –I.

4.6.2. EMBEDDED Based LINUX - QT Programming

In the present work the software development for the development of Blood pressure meter was developed using the software of embedded Linux and its GUI design developed is QT. Linux itself is a kernel, but ‘Linux’ in day to day terms rarely means so. Embedded Linux generally refers to a complete Linux distribution targeted at embedded devices. There is no Linux kernel specifically targeted at embedded devices, the same Linux kernel source code can be built for a wide range of devices, workstations, embedded systems, and desktops though it allows the configuration of a variety of optional features in the kernel itself. In the embedded development context, there can be an embedded Linux system which uses the Linux kernel and other software or an embedded Linux distribution which is a pre-packaged set of applications meant for embedded systems and is accompanied by development tools to build the system.

The Qt framework first became publicly available in May 1995. It was initially developed by Harvard Nord (Troll tech's CEO) and Eirik Chambe-Eng (Trolltech's Chief Troll). Qt has long been available to non-C++ programmers through the availability of unofficial language bindings, in particular Py.Qt for Python programmers. In 2007, the Kyoto unofficial bindings were released for C#
programmers. In 2007, Troll tech launched Qt Jambi, an officially supported Java version of the Qt API. Since Troll tech's birth, Qt's popularity has grown unabated and continues to grow to this day. This success is a reflection both of the quality of Qt and of how enjoyable it is to use. In the past decade, Qt has gone from being a product used by a select few "in the know" to one that is used daily by thousands of customers and tens of thousands of open source developers all around the World.

The signals and slots mechanism is fundamental to Qt programming. It enables the application programmer to bind objects together without the objects knowing anything about each other. We have already connected some signals and slots together, declared our own signals and slots, implemented our own slots, and emitted our own signals. Let's take a moment to look at the mechanism more closely.

Slots are almost identical to ordinary C++ member functions. They can be virtual; they can be overloaded; they can be public, protected, or private; they can be directly invoked like any other C++ member functions; and their parameters can be of any types. The difference is that a slot can also be connected to a signal, in which case it is automatically called each time the signal is emitted.

Qt provides a complete set of built-in widgets and common dialogs that cater to most situations. We present screenshots of almost all of them. A few specialized widgets are deferred. Main window widgets such as QMenuBar, QToolBar and QStatusBar and layout-related widgets such as QSplitter and QScrollArea. A widget is a user interface component such as a button or a scroll-bar are Reusable, Well defined interface, Uses C++ inheritance, All widgets derive from a common base, Widgets may contain other widgets, Custom widgets can be created from existing widgets or they can be created from scratch. The Qt designer window is as shown in figure 4.25

QT DESIGNER

Written using Qt so it is available on all platforms where Qt is available. Used to speed design of Qt applications. Supports all Qt widgets and can be used to incorporate custom widgets
FEATURES

- Fully object-oriented
- Consistent interfaces
- Rich set of widgets (controls)
  - Have native look and feel
  - Drag and drop
  - Customizable appearance
- Utility classes
- OpenGL support
- Network support
- Database support
- Plugin support
- Unicode/Internationalization support
- GUI builder

Based on the above advantages, we used the Qt software for the present work.

The algorithm and flow chart of the touch screen based electronic voting machine as shown below.

After creation of project and the program, we executed the program. Then executed program is downloaded in to the micro controller. The download program is executed in micro controller with external hardware interface then we can get the results. If we get wrong results then modify the program and do the same process as
above till to get the correct results. Software program for Blood pressure measurement is present in Annexure –I

4.7. Measurement of pulse rate and pulseoxymeter

Photoplethysmograph is a non-invasive technique that measures relative blood volume changes in the blood vessels close to the skin. The pulsatile component of the PPG waveform is often called the “AC” component and usually has its fundamental frequency, typically around 1 Hz, depending on heart rate. This AC component is superimposed onto a large quasi-DC component that relates to the tissues and to the average blood volume. This DC component varies slowly due to respiration, vasomotor activity and vasoconstrictor waves [32] [33]. The time period of each pulse is dictated by the heartbeat and the amplitude by the concentration of various constituent parts of arterial blood and path length of light travelling through the arteries.

After the systole, blood volume increases in the arteries thereby reducing the received light intensity. During diastole, blood volume in the arteries decreases and hence in increasing in light transmission. Thus the PPG signal appears pulsatile in nature at the heart rate [34].

In this work, a low cost miniaturized pulse oxymeter is designed to acquire the real time PPG signal and measure the SpO2 and pulse rate by embedded Linux software

To calculate the SpO2 and HR continuously a sensor is designed to acquire the PPG signal. The proposed design of the pulse oxymeter is give in block diagram. A SpO2 probe containing two LEDs and the light sensor (photodiode) is placed on the finger of the patient. One LED emits red light (wavelengths of 660nm), and the other emits light in the near IR (wavelengths 940 nm) range. The LEDs are rapidly and sequentially excited by two current sources (one for each LED) whose dc levels depend on the LED being driven. The switching of the two LEDs is controlled by the two control signals.

The detector is synchronized to capture the light from each LED as it is transmitted through the tissue. Low power, precision current sources used in pulse oxymeter deliver a few decades of milliamps. The light shining on the photodiode produces a small current that is converted to a voltage by an amplifier, Trans
impedance configuration (I/V). Usually a large resistor is used in the amplifier’s feedback loop, so the circuit is very sensitive to small changes of light. The circuit is used to separate the red and infra red PPG signals, according to the respective control signals. Then both PPG signals are given to the embedded Linux software through the serial port. The two PPG signals are pre-processed for removal of high frequency noise and then SpO2 and heart rate are calculated with specified algorithms.

The PPG signals can be pre-processed in the embedded Linux. The normal frequency range of PPG signal is 0.5 Hz to 5 Hz. So the noise elements are cancelled by using low pass filter of cut off frequency 5 Hz. The PPG signal is highly affected by motion of the patient’s hand. So to get a stabilized reading of SpO2 a moving average filter is implemented with filter [35].

The ADC Capture and Analysis the number of samples and display to volts or codes. Then the filter type is set to Notch filter with the Frequency to 50 or 60 Hz. The captured data can be analyzed in time domain. The ADC Capture data is as shown in Figure 4.24. In the Time Domain plot, the data are displayed in time domain format. The units can be converted from codes to volts. For the time domain plot, the mean voltage, root mean square (RMS) voltage, and peak-to-peak voltage are displayed in the Test Results table. The mean voltage, root mean square (RMS) voltage, and peak-to-peak voltage are calculated for both the Red and IR samples.
Figure 4.26: IR and Red - ADC Capture data

By AC and DC estimator in embedded Linux, the AC and DC component of both Red and IR signal is calculated. By using these values, we calculate the R and then percentage of SpO2 as per equation 5. From calibration results, the constant $K = 98.56$ can be obtained for calculating %SpO2 level.

The calculation of SpO2 using PPG signals. The SpO2 estimation relies on the relationship between the baseline value (referred as DC component) to the fluctuation in the signal (referred to as AC component). SpO2 calculation is based on computing the “ratio of ratios” or Pulse Modulation ratio R which is defined as the ratio of AC/DC of red and IR LEDs.

The PPG signal is normally contaminated with noise which could come from various sources like the power supply noise, motion artifact etc. An essential component as part of the data preprocessing is filtering out the unwanted signal of interest. Since the DC component resides in frequencies below 0.5Hz, a low pass filter with a cutoff frequency of 5Hz can be used for the SpO2 estimation. This filtering stage is left for the user to implement.

Here is an example to estimate SpO2 percentage based on the sample PPG data from figure. The ratio of ratios $R$ for the sample PPG data is computed below,

$$R = \frac{(AC/DC)Red}{(AC/DC)IR}$$
$$= \frac{4mV/(323mV)/25mV/(920mV)}$$
$$= 0.455$$

The $R$ value is the only variable in the SpO2 estimation. The standard model for computing is defined as follows:

$$SpO2 \% = 110 - R \times 25$$

This model is often used in the literature in the context of the medical devices. However, it relies on the calibration curves that are used to make sure that this linear approximation provides a reasonable result. ADC Capture data Codes, ADC Voltages and RED and IR Analysis data for mean, rams, pp for voltage and current are shown in tables 4, 5, 6 sequentially.

For the sample PPG data, % SpO2 is computed as below,

$$SPO_2 \% = 110 - 0.455 \times 25 = 98.6 \%$$
### Table 3: ADC Capture data Codes

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<td>$V_{\text{pp}}$</td>
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<td>$I_{\text{pp}}$</td>
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When we start health monitoring of the patient, the main window of the GSM based Neonatal Intensive Care Monitoring system consists of the following menu for selection. The main window is as shown in photograph2. They are

1. Temperature
2. Phototherapy
3. Pulse oxygen(SPO$_2$) and pulse rate
4. NIBP
5. Total system and
6. Exit

The measurement and control process of the GSM based Neonatal Monitoring system presented with the following photographs.

The Temperature selection button displays the temperature window to display the temperature detail of the neonates. It also set the temperate of the intensive care system using Set temperature button. It also read the body temperature of the body and send temperature to the mobile using SMS button. It also has selection for Air Temperature and Heater value by the concerned persons i.e., Doctor/Nurses who is taking care about the new born baby who required the temperature regulation of the body by setting body set temperature as well as the Air set temperature as the safety and security measures that the temperature should not exceeds the above two limits. The Set Time of the temperature can be set by using the up/down buttons for incrementing/ decrementing of hours, minutes and seconds.
The Phototherapy button open its window to select the voltage and current values to be set for UV therapy required by the neonate for a period of duration as per the instructions of the Doctor. The system also has provision to set the phototherapy duration of time with the help of up/down buttons for incrementing/decrementing of hours, minutes and seconds using touch based buttons to avoid the additional hardware. It also has the count of time with the help of a counter to stop the process accurately with the help of the processor. It also has the reset button to reset the timer and stop button to stop the timer.

The SPO$_2$ button opens the pulseoxygen measurement window. It displays continues monitoring of the oxygen percentage of the patient. It also has the graph display for measured oxygen percentage.

The NIBP selection button selects the monitoring of the Blood Pressure window. It displays the Systolic, Diastolic and Pulse Rate of the patient. The BP displayed in millimeter of Mercury (mmHg) units and pulse rate displayed in Beats per Minute (BPM) units. Measured record stores the systolic, diastolic and pulse rate data of the patient with measured date and time. The meter can store maximum 300 records data. The selected number of records can be displayed on the monitor window with recorded date and time. The recent button displays the current recorded data of the neonate.

The total system button, displays the GSM Based Neonatal Intensive care monitoring system window. It has the four individual displays. They are temperature, phototherapy, SPO$_2$ and NIBP windows. The individual window displays the corresponding reading from individual measurements. The complete records of the patient are transferred to Mobile using SMS service.

The Exit button, close the GSM based Neonatal Intensive care monitoring system window.
Photograph 4.4: Main Window of Neonatal Intensive care Monitoring system

The SPO2 monitoring with pulseoxy probe connected to the patient monitor the oxygen percentage of the patient is as shown in photograph 4.4.

Photograph 4.5: Neonatal Monitoring system for Pulseoxygen

The oxygen percentage measured by connecting pulseoxy probe to the patient figure as shown in photograph 1. When we select the SPO2 measurement of the patient through main window it open the GSM based Pulseoxygen measurement window and start measurement. The GSM based Pulseoxygen measurement photograph is as shown in photograph 4.5.
Photograph 4.6: GSM based Neonatal SPO2 measurement window

The SPO2 measurement window shows the continues oxygen percentage of the patient. The record consists of the oxygen percentage and pulse rate of the patient. The complete measurement records of the patient are stored in the meter for further analysis. The measurement records are shown in photograph 4.6 with the recorded date and time. When the Total button is selected in main window of GSMNICS system then all measurements are displayed on the screen as show in Photograph 4.7 along with the SMS message on the user mobile also.

Photograph 4.7: Total display window with Mobile Phone
4.8. Calibration and Analysis

Instrumentation system employed for the measurement of physicochemical or biological parameters needs systematic calibration. The calibration is utmost important for the measuring instruments. The calibration process involves study of influence of various kinds of parameters on the final measurement systems. Especially in bio-medical instrumentation it is very important, because most of the instruments may be used as life saving instruments. Malfunctioning and bad calibration of the system leads to wrong diagnosis leading to catastrophic results. Hence the calibration regarding to life saving instruments need vast studies and precautions. The present work on pulseoxymeter is based on noninvasive instrumentation principle. The measurement of oxygen saturation in the arterial blood is obtained by photometric method. The oxygen saturation measurement by noninvasive methods encounters problems from pigment of skin, density of flesh, bone nature, thickness of finger etc. hence the calibration processor is more complex involving number of volunteers for the measurements of oxygen saturation. As large number of data being collected before arriving conclusion on the response of oxygen saturation measurement. The measurements we carried out on all age groups. The total measurements we corrected with accuracy with in 98%. The error was not allowed beyond 2%. The actual measurements carried out with designed instrument as well as with standard BPL Pulse oximeter.

The measurements were carried out on the system is good agreement with values measured with standard BPL pulse oximeter. The empirical calibration process, the measurements exhibited slight deviation, but all these measurements we within the tolerance range. The response time of the instrument was also equal with BPL Pulse Oximeter. As the system is compact it can be used at ambulance services also. The measured values are present in table6.
Table 6 : Measured percentage of Pulse oxygen values

<table>
<thead>
<tr>
<th>S. No</th>
<th>Actual pulse oxygen values</th>
<th>BPL Pulseoxymeter</th>
<th>Present designed Pulse oximeter</th>
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</table>

4.9 Results & discussions

The present aim of the project is to develop the pulseoxymeter. Hence the author invariably used analog front end AFE4490 and micro controller MSP430F5529. The benefit of the project is that a lightweight, rugged, low-cost, wearable device. The device will be extremely cost effective since it uses simple sensors and technology for the detection. The sensors are small in size and can be firmly attached to the body. Batteries can last long as the device consumes only little energy. The device doesn’t restrict the movement of the patient. The system is easily expandable paving the way to incorporate much more sophisticated devices like medical detector in the future Standalone application