ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 6, Issue 5, May 2018

Solar Powered Non-Invasive Pulse Oximeter and Heart Rate Meter

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ABSTRACT: Use of technology in healthcare is growing importance as a result of the tendency to acquire chronic disease like heart attack and high blood pressure. Heart rate and blood oxygen saturation is a couple of such biometrics that is monitored in this project to provide information regarding the health of the body.
Pulse Oximeter is a non-invasive medical diagnostic device used to detect the oxygen saturation of the blood. Heart rate meter detects the number of beats per minute of the patient, normally referred to as bpm.

Our proposed pulse oximeter and Heart Rate Meter device is designed using the MAX30100 chip, integrated with Arduino Uno and an LCD keypad shield. The chip acts as an integrated pulse oximetry and heart-rate monitor sensor solution.
The goal of the project is to develop a low cost, small in size, easy to use, pulse oximeter and heart rate meter powered by solar energy. The idea was conceptualized due to the fact that the oxygen saturation of blood is one of the most important parameter to be monitored, and the pulse oximeter being low cost and solar powered, allows it to be accessed by the developing and under developed nations.

KEYWORDS*:* Pulse Oximeter, Solar Energy, Micro-controller, Arduino uno, Hear-rate and SPO_2 Sensor.

I. INTRODUCTION

Measurement of heart rate and pulse oximetry are very important factors to access the condition of human cardiovascular system. Heart rate is formerly measured by placing the thumb over the arterial pulsation, and counting the pulses usually in a 30 second period. Heart rate is then found by multiplying the obtained number by 2. This method although simple, is not accurate and can give errors when the rate is high. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement, and Electrocardiogram (ECG). ECG is one of frequently used and accurate methods for measuring the heart rate. But ECG is not economical. The heart rate of a healthy adult at rest is around 75(+-15) (or greater for females) beats per minute (bpm).

Pulse oximetry is a noninvasive method for monitoring a person's oxygen saturation (SO_2). Though its reading of SpO_2 (peripheral oxygen saturation) is not always identical to the more desirable reading of SaO_2 (arterial oxygen saturation) from arterial blood gas analysis, the two are correlated well enough that the safe, convenient, noninvasive, inexpensive pulse oximetry method is valuable for measuring oxygen saturation in clinical use.

In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. The device passes two wavelengths of light through the body part to a photodetector. It measures the changing absorbance at each of the wavelengths, allowing it to determine the absorbances due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish.

Less commonly, reflectance pulse oximetry is used as an alternative to transmissive pulse oximetery described above. This method does not require a thin section of the person's body and is therefore well suited to a universal application

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such as the feet, forehead, and chest, but it also has some limitations. Vasodilation and pooling of venous blood in the head due to compromised venous return to the heart can cause a combination of arterial and venous pulsations in the forehead region and lead to spurious SpO_2 results.

II. RELATED WORK

Looking back at the history of the oximeter, the first device to measure the oxygen saturation by transilluminating it with colored light " red and green filters", was invented in 1935 by a German physician called Karl Matthes (1905-1962). To include both the venous and capillary blood, an attempt was made in the period of the Second World War as a part of a project to investigate the problem of the loss of consciousness by the American physiologist Glenn Allan Milikan (1906-1947). However, the transmitted light through the ear is not attenuated by the arterial, venous and capillary blood only, it is also attenuated by the skin whose pigmentation and because of that the absorption properties varies from one person to another. In 1964, Shaw was able to assemble the world's first absolute reading ear oximeter. The device uses eight wavelength of light to obtain the absolute O2 saturation level in the blood. The device was commercialized by Hewlett-Packard. The device's use was limited to pulmonary functions and to the sleep laboratories because of its cost and size. The first pulse oximetry was developed in 1972 by two Japanese Bioengineers, Takuo Aoyagi and Michio Kishi who were working at Nihon Kohden Corporation. The device used the ratio of red to infrared light absorption of the pulsating the components in the measuring site. After that, the device was commercialized by Biox and Nellcor (which is now part of Corvidien Ltd.) in 1981 and 1983 respectively. The invention of the pulse oximeter was a breakthrough which helped doctors and especially surgeons to get quick but yet an accurate reading to the patient's oxygen saturation levels. Due to its quick and accurate readings, the pulse oximeter was directly used in the operating rooms to monitor the patient's oxygen level. This encouraged Biox to shift their attention from initially being concerned with respiratory care towards expanding their marketing resources to focus on operating rooms market in late 1982. In 1983, Nellcon started to compete with Biox for the U.S operating room market. By 1987, the standard of care in the administration of anesthetic decided to include the pulse oximeter in all the operating rooms across the U.S. After the operating room, the use of the device spared into being used in the recovery rooms and then into the intensive care units. In 2009, Nonin Medical Inc. introduced the world's first fingertip pulse oximeter with Bluetooth technology [3][4][5]. The main purpose for that was to help with the increasing need for the remote disease management.

III. LITERATURE REVIEW

Pulse oximetry and heart rate monitoring has become most commonly used tools in the clinical environment for assessing patients' oxygenation status. It is employed almost continuously in critical care areas and frequently in the general ward environment. Although it is a much better tool for determining hypoxia than the human eye, its use is limited if clinicians do not understand relevant physiological principles, such as the oxyhaemoglobin dissociation curve and the inherent limitations of the device.

1. According to Handbook of Biomedical Instrumentation by R.S. Khandpur, techniques of measuring heart rate are:

Average Calculation: An average rate is calculated by counting the number of pulses in given time. This method does not show changes in time between beats and thus does not represent the true picture of hearts response to exercise, stress and environment

Beat To Beat Calculation: This is done by measuring the time (T) in seconds, between two consecutive pulses, and converting the time into beats/min, using the formula beat/min = 60/T.

Combination Of Beat To Beat Calculation With Averaging: This is based on four or six beats average. The advantage of this technique over the averaging techniques is its similarity with beat to beat monitoring system. Pulse oximetry relies on measurement of physiological signal called photoplethismography, which is an optical measurement of the change in blood volume in the arteries. Pulse oximetry acquires PPG signals by irradiating two different wavelengths of light through the tissue, and compares the light absorption characteristics of blood under these wavelengths. These

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absorptions obey Beer Lamberts law. According to Beer Lamberts law transmittance of light through the tissue can be calculated using:

$$I_{out} = I_{in}\, e^{A} \qquad (1)$$

Where I_{out} is the light intensity transmitted through fingertip tissue, I_{in} is the intensity of the light going into the tissue and A is the absorption factor.

2. According to Yousuf Jawahar, Pulse oximetry can be done by two methods :

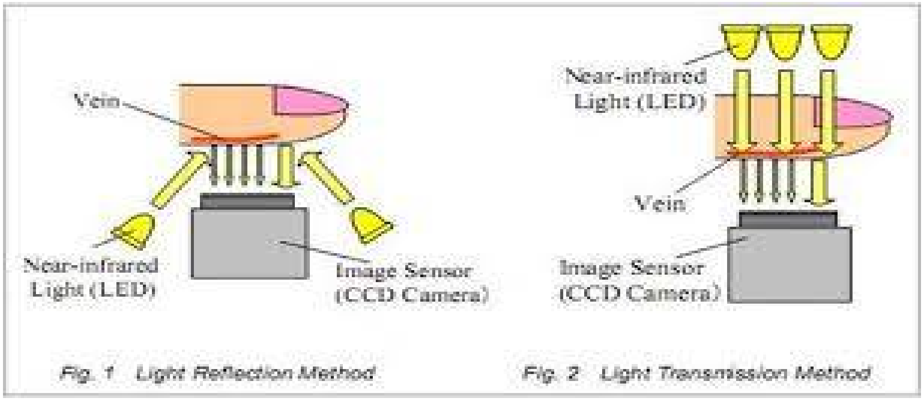

Fig 1: Light Reflection Method   Fig 2: Light Transmission Method.

Transmittance Method: In this method, light is transmitted through tissue using the LED and is detected on the other end using a photo-detector. It is more suited to the areas of body that lend themselves better to light transmittance through them, e.g. fingers or ear lobe. This configuration cannot be used in other areas of body when there are obstacles such as bones or muscles.

Reflectance Method: In reflectance pulse oximetry it uses a photo detector on the same side as the LED to detect the light reflected by the tissue. This method is more useful where the vasculature is available close to the surface of skin e.g. forehead, wrist, forearm.

IV. METHODOLOGY

The hardware design for this project can be divided into four major parts; sensor, amplifier-filter, microcontroller and power supply.

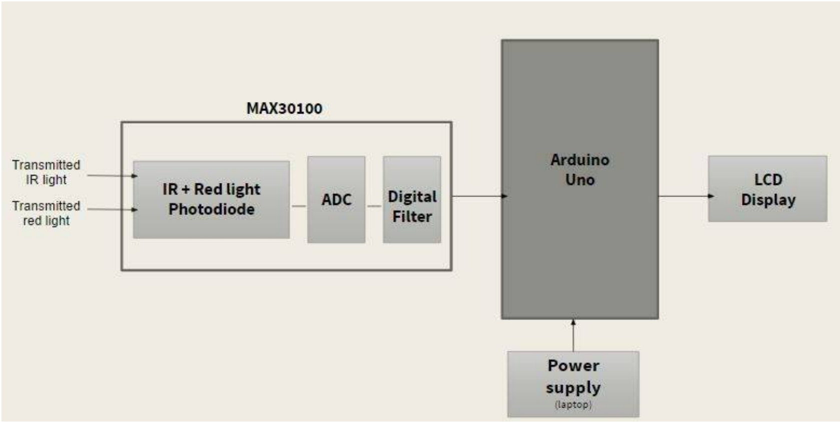

Fig 3: Block Diagram of Solar Powered Pulse Oximeter

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1. Sensor:The MAX30100 chip integrates two LEDs: red and infrared (IR), a photodetector and low-noise signal processing to detect pulse oximetry and heart rate signals. The absorption data for both IR and red light is stored in a FIFO buffer up to 64 bytes. It provides two operating modes; the heart rate mode, and the heart rate and oxygen saturation mode. In the heart rate mode, only the IR LED is switched on, while in the dual mode both IR and red LEDs are switched on. It also has an integrated 60 Hz low-pass filter. While it can filter out power line noise, it still does not account for environmental noise and fluctuations.From the LEDs, red and IR light is transmitted through the finger and the photodetector integrated within the chip senses the light absorption of the two separate wavelengths. In this project, we used both the oximetry and heart rate detection operations with the MAX30100, so we can detect both heart rate and oxygen saturation at the same time.

2. Integrating the MAX30100 to the Arduino: The MAX30100 is an I2C device, therefore through code it requires the Wire library to interface with the Arduino. Physically, the MAX30100 (in this case, the breakout board) is connected to the Arduino through special pins that are able to read data from the SCL and SDA lines, which are A4 and A5. The SCL and SDL lines provide the data signal and the clock signal. The ground and Vin lines are connected to the GND and 5V lines respectively.

3. LCD : The LCD Shield is connected to the Arduino by pins 4-8 so that we can provide a user-friendly display. We can also utilizetwo buttons on the LCD Keypad Shield, which are used to select between two modes: the heart rate monitor and the oxygen concentration monitor.

4. Power Supply: The goal of this project, as mentioned before, is to power this device using solar cells; 12V/1.5W solar panel is used. The output current of the solar panel in bright sunlight is about 120mA. The solar panel is used to charge NimH rechargeable batteries having charge capacity of 2500mA. Batteries are used to power the device during low light or no light conditions, i.e. when the solar panel is not efficient enough to drive the electronic circuit. The output of the solar panel is given to a decoupling capacitor of 0.2uF to filter out the high frequency noise. It is then given to a linear voltage regulator LM340LAZ-5.0 which gives out a constant DC voltage of 5 V. The output is further given to a decoupling capacitor of 0.01uF and later given to a schottky diode IN5817. A diode is very crucial element in the design, as it acts as reverse charge protection, i.e. it will prevent the battery to discharge backwards into the regulator and hence into the solar panel, thus avoiding damage to those. Schottky diode is used due to very low forward voltage drop, i.e. about 0.2-0.3V. The output of diode is about 4.8V and is appropriate in charging the rechargeable batteries. Two switches have been used, one in between the solar panel output and the voltage regulator and second between the output of the batteries and the Vcc terminal of main electronic circuit.

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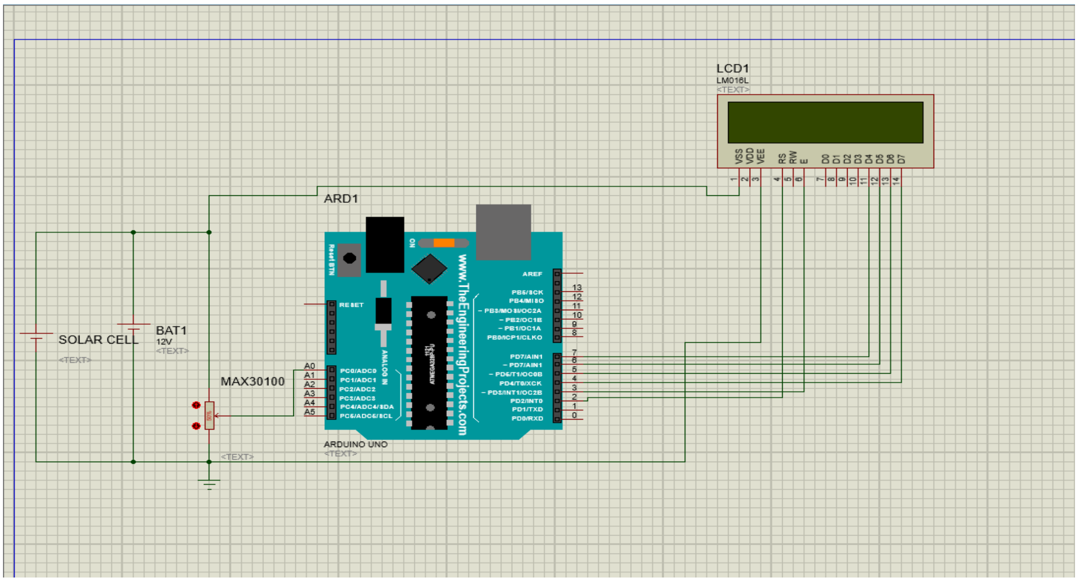

Fig 4: Circuit diagram of pulse oximeter

V. IMPLEMENTATION FLOW

The following flowchart shows the implementation process for finding pulse oximeter values using our project.

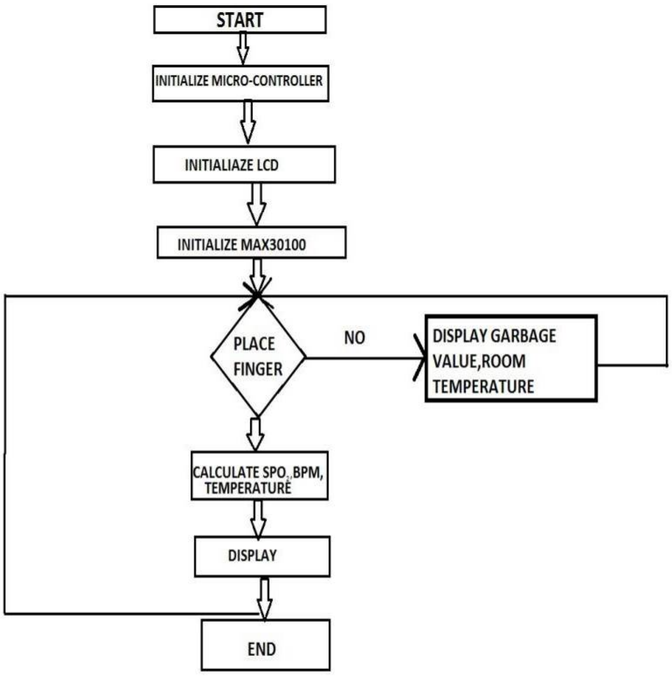

Fig 5: Implementation Flowchart for calculating $Spo_{2,}$ BPM, Temperature

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VI. EXPERIMENTAL RESULTS

The results were checked during panting condition, and the heart rate boosted up to 105, and gradually settled for 75-80 over 5 minutes. The project does not have any safety concerns due to low input power. The product is well fabricated and easy to use, just switch on the power and push your finger in the sensor, the display will show you the readings. The device drew about 60mA of current, and as the charge capacity of the batteries is about 2500mAH, the device will run efficiently for over 40 hours, which is exceptionally good time duration. Also, assuming 120mA of current from the solar panel in bright sunlight, it will take about 20 hours to charge the batteries completely, which is fairly reasonable.

PERSON	AGE	SPO_2 (%)	HEART RATE(BPM)	TEMPERATURE (^{O}C)
Person A	50	97	78	39
Person B	40	98	84	41
Person C	22	96	88	43
Person D	22	98	86	42
Person E	22	97	79	40
Person F	21	98	83	44
Person G	25	97	88	41

Observation Chart: For Analysis of $SPO_{2,}$Heart Rate and Temperature

With our implementation of the MAX30100, we noticed that position and movement of the finger dramatically affect the registered readings. This may be caused by how the measurement of heart rate is greatly dependent on the volume of blood flowing through the finger, and the thickness of skin also comes into play here. If the fingers are moving around, this may cause nonuniform light levels while acquiring a reading.

VII. CONCLUSION AND FUTURE WORK

The Heart rate and SpO2 for me was on an average 80 beats per minute and 98.23% respectively. The heart rate for normal person is about 72 beats per minute and a normal range is about 60-90 beats per minute. The SpO2 for normal person lies between 95-99%. SpO2 below 94% may be fatal and may cause unconsciousness. The device was designed efficiently and met all expectations as set earlier. Due to shortage of time, the charge capacity of the batteries could not be monitored and displayed on the LCD. The current sensor probe is not flexible for a thick finger, and can be made much more flexible. More complex algorithm can be written to change the brightness of the LEDs with variation in the skin thickness. Smaller solar panel could not be bought, and its inclusion will make the project really robust and ready to use in any environment. As mentioned earlier, the device has a capability of running for over 40 hours, which will really revolutionize the health care in under developed and developing nations which has many electricity problems. With higher charge capacity batteries, time duration for its usage can be made longer.

People testing out our project should not move their fingers/hands around in order to acquire a stable reading. This project can be improved by placing the sensor within an actual finger cuff that can further reduce the effects of ambient light and also keep the finger in place, instead of just using a simple Velcro strip.

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