CONTINUOUS PATIENT MONITORING USING WEARABLE BIOSENSORS

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Abstract - Real time patient monitoring has been one of the greatest challenges faced by clinical authorities. Traditional health monitoring systems are time consuming and require human intervention. The increased occurrences of various critical health hazards these days has necessitated the integration of technology and automation in the medical field. During the last few decades, there have been significant developments of patient monitoring systems that employ efficient electronic equipment and biosensors for clinical diagnosis and treatment of patients. The main objective of patient monitoring system is to monitor and assess basic and vital health parameters of a patient including pulse rate, body temperature, blood oxygen level, ECG, etc. The system monitors these vital signs continuously using biosensors and updates all the related patient data to an online database platform(cloud) which the medical professionals can view or access anytime.Also,the alarm system connected to the system gives an audio- visual warning signal to the doctors or nurses in case patients data is out of the critical range and indicated that the patient immediately needs attention. This system enhances patient treatment and care and reduces the chances of risk and emergencies.

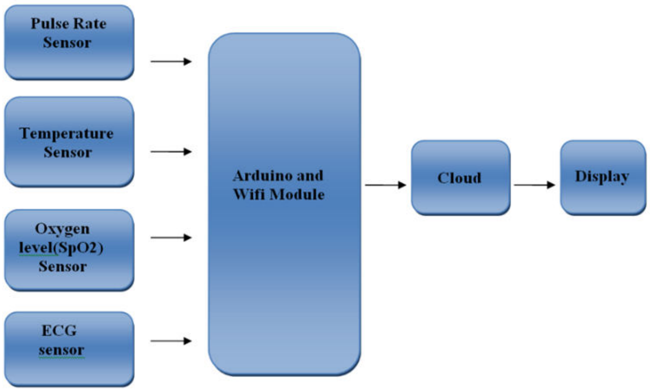
1. INTRODUCTION

A lot of advancement have been recently made in medical electronic systems and significant research work is being carried out. Modern health care systems allows continuous patient health monitoring and helps in faster diagnosis and in providing proper treatment and care for patients with potential health hazards. Continuous health Monitoring systems use special wearable devices called “biosensors” to monitor biological vital signs of the human body including pulse rate, body temperature, oxygen level and ECG. Biosensors consist of a sensing element called bioreceptor and a transducer. The bioreceptors are designed in such a way that they are capable of sensing the required analyte of interest for a particular vital sign. The transducer converts the actual signal sensed by the bioreceptors and converts into suitable form. The function of these biosensors is to timely measure the basic vital signs of patients taking the recommended examining rate of the signal. These biosensors are interfaced with a programmable device (Ex-Arduino/Raspberry Pi) and the patient data received from sensors is later uploaded to cloud for live data streaming and analytics. This data can be accessed easily by concerned medical professionals.

There have been several advancements in wireless communication systems to transfer the patient data monitored by using sensors in a suitable readable format to the concerned medical professionals.

The major benefit of patient monitoring system with suitable data processing is that it allows medical professionals to view or access multiple patient's data easily on an online platform(Cloud).Also, doctors or nurses are immediately notified or indicated(with the help of an alarm system) in case the patient's data is beyond the critical range. This reduces the chances of risk and extremely critical health conditions. Such systems can also be used by common aged people to keep a check on their general health on a daily or weekly routine basis. This can minimize the frequency of hospital visits and reduce the work load of doctors and paramedics staff in the OPD.

2. BLOCK DIAGRAM AND WORKING



This system is compact, light-weighted and low-power consuming vital signs monitoring system. This system consists of bio sensors that monitor important biological vital signs like pulse rate, body temperature, blood oxygen level and ECG .

The following biosensors are used-

- Pulse Sensor
- Temperature Sensor-DS18B20
- Oxygen Level Sensor (SpO2)-MAX30100
- ECG Sensor-AD8232

These sensors are interfaced with programmable Arduino and Wifi Module(ESP8266).The sensor output data that is available is uploaded to the cloud from arduino and wifi module and is later displayed on a device.At any time, any of the doctors or nurses can log on the CPMS and check the history of the observed critical parameters of any of the patient attached to the network.

3. COMPONENTS DESCRIPTION

Components used in the system are as follows:

1. Biosensors
   - Pulse Sensor
   - Temperature Sensor-DS18B20
   - Oxygen Level Sensor (SpO2)-MAX30100
   - ECG Sensor-AD8232
2. Arduino Uno
3. Wifi Module-ESP8266
4. Cloud
5. Display Device

3.1 PULSE SENSOR

Pulse sensor is an electronic device which gives digital output of the heart beat when a finger of a human body is kept on it. This pulse sensors has in particular two segments or surfaces. On the first surface, is a light emitting diode and an ambient light sensor. Similarly, on the second surface, is a circuit connected which plays an important role in cancelling of noise and amplification. The operating voltage of this sensor ranges from +3.3V to +5V. This sensor has a current utilisation of 4mA.

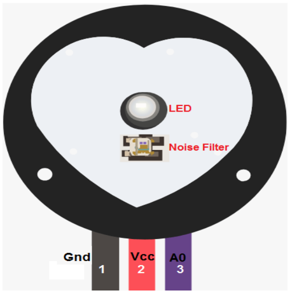


Fig.3.1.1 Pulse Sensor

PIN	PIN NAME	DESCRIPTION
1.	GROUND	Power Supply Ground
2.	Vcc	Power Supply +5 Voltage
3.	OUTPUT	Analog Outupt

Table3.1.1 Pin Configuration of Pulse Sensor

The LED is exactly located below the vein in a human finger, on the fingertip. Once the LED is located on the vein, the LED starts emitting light towards the vein on the fingertip. Once the heart pumps blood, there will be significant flow of blood in the veins. Heart rates can be checked by measuring the flow of blood in veins. As the heart pumps blood, the volume of blood increases and as a result, the LED rebounces back. This rebounced light is absorbed by the ambient light sensor. So, this time difference of emission and absorption obtained by the LED can be used to measure the pulse rate.

3.2 TEMPERATURE SENSOR - DS18B20

The **DS18B20 sensor** is a 1-wire programmable temperature sensor which measures temperature ranging from **-55°C to +125°C** with a significant error of **±5°C**. This sensor consists of variable resistance material that operates according to variations in temperature. The temperature is calculated by the circuit by measuring the change in resistance accordingly as in, when the temperature rises, then the voltage also rises. The DS18B20 temperature sensor has a built in 12 bit ADC, hence showing the digital value of the measured temperature.

It can be conveniently connected to an Arduino digital input pins. The communication of DS18B20 sensor can be done through a one-wire bus protocol which uses only one data line to communicate with an inner microprocessor, while the other 2 wires are used for supplying power.

Fig.3.2.1DSB18B20

Power Supply	3V to 5.5V
Current Consumption	1mA
Temperature Range	-55 to 125°C
Accuracy	±0.5°C
Resolution	9 to 12 bit (selectable)
Conversion Time	< 750ms

Table3.2.1 Specifications of DS18B20

3.3 OXYGEN LEVEL SENSOR - MAX30100

The MAX30100 is a sensor which is a pulse oximeter and also a sensor monitoring heart rate. This sensor is mainly used to measure or find out the oxygen level(SpO2) content in human blood. This sensor basically comes with two LED's, a photodetector, optics which are optimized and a processing unit with low noise which is required to detect the required pulse rate signals and oxygen content in blood. This MAX30100 sensor operates between the voltage levels of 1.8v-3.3v. so any supply giving out this range of voltage supplies can turn the sensor on.

Fig.3.3.1 MAX30100

Out of the two LED's as mentioned above one emits red light and the other emits Infrared light.To measure the heart rate of a patient the requirement is only the infrared light. But to measure the oxygen content in blood, both the infrared light and the red light are required. When the process of pumping blood is performed by heart, the oxygenated blood increases which means that there is an increase in blood in human body. But, as the heart relaxes, there is a decrease in the volume of oxygenated blood. The heart rate of a human is measured by taking the difference between the time of increase and decrease in oxygenated blood because, infrared light is more absorbed by oxygenated blood and more of red light is passed through it but red light is absorbed by deoxygenated blood and more of infrared light is passed through deoxygenated blood. This is how the MAX30100 functions by reading the levels of absorption of both the light sources and both the conditions and uses a buffer to store them which can be further read by I2C.

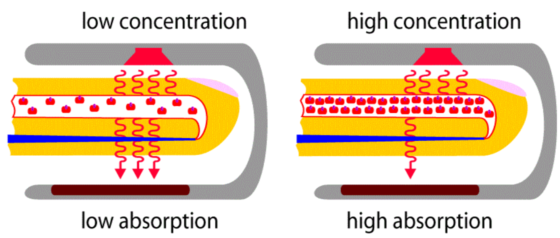


Fig.3.3.2. MAX30100 Working

3.4 ECG SENSOR – AD8232

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The AD8232 is basically an operational amplifier that is used to monitor the heart activity.The output of this sensor is charted as EDC(electrocardiogram) ,that is the analog reading.The output of this sensor is an amplified one with good clarity and free of noise.

Fig.3.4.1. AD8232

Board Label	Pin Function	Arduino Connection
GND	Ground	GND
3.3v	3.3v Power Supply	3.3v
OUTPUT	Output Signal	A0
LO-	Leads-off Detect -	11
LO+	Leads-off Detect +	10
SDN	Shutdown	Not used

Table3.4.1. AD8232 Connections

The output graph consists of repetitive waveforms.Each cycle of the waveform consistes of three parts- P, QRS, and T waves.Impulse propagation time to atria is indicated by the P wave,electrical impulse propagation from atria back to ventricles is indicated by PR segment. The ECG graph contains repeating waveforms or repeating cycles. Each cycle is divided into three parts: P, QRS, and T waves. A P wave provides information regardingthe impulse propagation time to the atria (2 in number) of the heart. This is followed by a PR segment which is a flat trend, which provides information about the electrical impulse propagation from the atria to the ventricles. This is then followed by a complex QRS.Ventricular systole is indicated by QRS segment.

ECG lead placement-

It is crucial to place the sensor leads in proper position to ensure an accurate ECG reading. The three lead ECG cable has three leads colors in green, yellow and red.

- The green electrode should be placed below the pectoral muscles, near the lower edge of the left rib cage, on the left side of the subject.
- The yellow electrode should be placed near the left shoulder and within the rib cage frame, under the left clavicle of the subject,
- The red electrode should be placed near the right shoulder and within the rib cage frame, under the right clavicle of the subject.

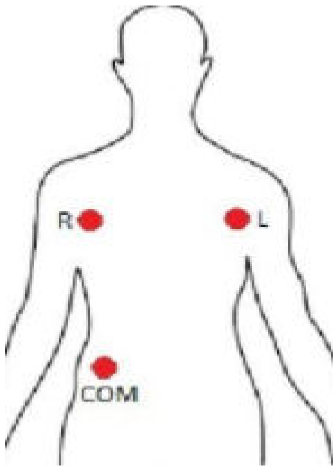


Fig.3.4.2. AD8232 Lead placement

3.5 ARDUINO UNO

The Arduino Uno is basically an open-source microcontroller board which is based on the ATmega328P microcontroller which is a MicroChip and developed by Arduino.cc. The board comes with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board contains 14 digital Input/Output pins where six are capable of Pulse Width Modulation output and 6 analog Input/Output pins.The Arduino board is programmed with the help of Arduino IDE software(Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

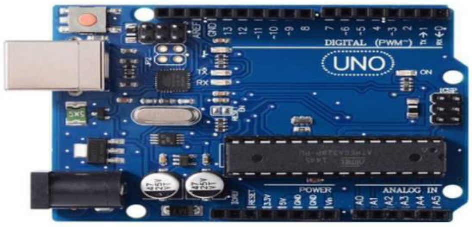


Fig.3.5.1. Arduino Uno

Technical specifications:

- Microcontroller: Microchip ATmega328P
- Operating Voltage: 5 Volts
- Input Voltage: 7 to 20 Volts
- Digital I/O Pins: 14
- UART: 1
- I2C: 1
- SPPI: 1
- Analog Input Pins: 6
- DC Current per I/O Pin: 20 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz

3.6 WIFI MODULE – ESP 8266

The ESP8266 is a system on a chip (SOC) which is also a Wi-Fi microchip based on its applications for Internet of Things (IoT) applications which is designed and manufactured by Espressif Systems.The chip is cheaper in cost, smaller in size and can be adapted and used in many embedded systems, due to all these advantages, the ESP8266 is now widely used extensively across almost all IoT devices. It comes with a complete, it itself contains a networking solutions widely based for WiFi on a single chip. The on-board processor with integrated storage functions as a standalone microcontroller with GPIO, providing an easy and inexpensive way to integrate with sensors and standalone devices. The chip comes soldered to a breakout board with integrated antenna and associated components, making it easy to get up and running.

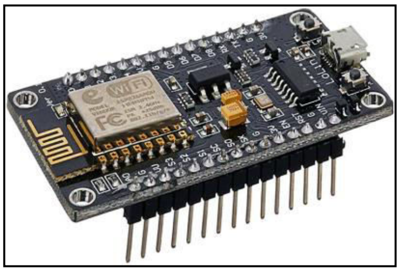


Fig.3.6.1. Wifi Module ESP8232

Pin configuration-

1. GND, Ground (0V)

2. GPIO 2, General-purpose input/output No.2

3. GPIO 0, General-purpose input/output No.0

4. RX, Receive data in, also GPIO 3

5. VCC, Voltage (+3.3 V; can handle upto 3.6V)

6. RST, Reset

7. CH_PD, Chip power-down

8. TX, Transmit data out, also GPIO1

3.7 CLOUD PLATFORM – THINGSPEAK

ThingSpeak is an open IOT platform that allows aggregation, visualization, and analyzation of live data streams in the cloud. ThingSpeak is very helpful for building and implementing IOT solutions. IOT device sensor data can be sent in a few minutes and an instant visualization of data can be created. Thingspeak provides MQTT and HTTP protocol supported **Rest API** to collect data from the device sensor and store data in the cloud and develop IOT applications.Thingspeak **Rest API's** work with Raspberry pi, Arduino and Wifi Module ESP8266. Thingspeak allows to create private and public channels so that information is secure and selective access can be provided to viewers. There is no need to configure large set up in ThingSpeak because all backend service is very well managed by the platform. A ThingSpeak account has to be created and required channels need to be set up.With this, realtime streaming data can be easily visualized with thingspeak matlab widgets. ThingSpeak is free for small non-commercial projects.

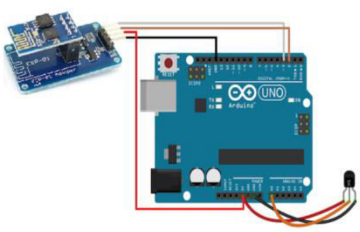
Fig.3.7.1. Data Uploading into ThingSpeak

ThingSpeak Features-

- Collection of data in private channels
- Sharing data though public channels
- RESTful and MQTT APIs
- MATLAB visualizations
- Event scheduling
- Alerts
- App integrations

4. UPLOADING DATA TO CLOUD VIA THINGSPEAK

In order to connect ESP8266 with Arduino, ESP-01 adapter is used. Using this adapter, there is no requirement of voltage divider circuit or any external power, because this adapter has a built-in voltage regulator.



ESP-01	ARDUINO
VCC	5V
GND	GND
TX	PIN 2
RX	PIN 3

Fig. 6.1 Arduino and ESP8266 Connections

ThingSpeak Setup-

Step 1-Creating an account in ThingSpeak. First, go to ThingSpeak.com and click on "Get Started for Free". The sign-up form will come up. Enter the information required and sign up for ThingSpeak.

Step 2-Click on "New Channel" to create a channel to store the information. Enter information about the new channel.

Step 3-Go to the API keys section and copy write API key.

Step 4-Enter the API key into the code.

Step 5- View data of respective channels.

5. APPLICATIONS

- Vital Signs in a human body can be monitored for diagnosing viral infections, like COVID-19.
- Signal quality assessment and control for human vital signs, especially wearable ECG, EEG, blood pressure, pulse, heart sound, respiration, etc.
- Pre-processing the signal waveform and feature extraction methods for long-term vital signs.
- Machine learning, multimodality signal processing, and artificial intelligence for detecting the long-term vital signs.
- Based on signal and image processing, assessment models for an individual's health risk can be determined. (e.g., bone fracture, heart disease, viral infection, brain tumor, skin cancer, and hypertension classification, etc.)
- Sleep and emotional health of a person can be assessed based on long-term vital signs.
- Human tracking, action recognition, navigation, and positioning using sensor and vision data. (e.g., quantity of motion, fall, and abnormality detection)
- Wearable devices can be further developed for the monitoring of long-term and short-term vital signs.

- Healthcare applications for the detection of viral infection, functional decline, cognitive impairment, emotional problems, sleep disorders, chronic illnesses, etc

6. CONCLUSION AND FUTURE SCOPE

"Without proper action at proper time, danger awaits us with a bigger face". It is necessary to act on time when a person is injured otherwise a valuable life might be lost. This project is indeed helpful to the common people. If the health of a person is not monitored regularly, the risk of emergency can occur anytime. Therefore, with the help of this system, the risk of deaths can be decreased to a large extent. In the designed system, the vital signs of a human body is being continuously checked and monitored at regular intervals of time, it allows the medical staffs and the doctor to keep a check on the patient's medical condition regularly, thereby negligence either by the medical staff or the patient is reduced drastically. Also, in case of any irregularities or mismatches in the vital signs, attention is demanded immediately by using an alarm system. This avoids unnecessary delays in attending the patient.

Future work on this project can provide certain improvements. Sophisticated and much more complex machines can be used to monitor other vital signs accurately and precisely. Better algorithm may be employed to track the medical condition of the patient. A push button can be included wherein, the patient can press this button on feeling uncomfortable, pain or needs immediate attention for any cause. Vital signs detection and alert systems are highly relevant in these times and this project aims in developing an effective and low cost solution for the same for the benefit of the society and mankind. This project provides an idea of how we detect the vital signs from a human body and transmit the same to the medical staff in the hospital. It also defines the importance of vital signs detection and alert system, its working and its use to save a life.

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[11] Wearable biosensors for healthcare monitoring

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[13] AN OVERVIEW ON HEART RATE MONITORING AND PULSE OXIMETER SYSTEM ,Esrat JAhan,Tilottoma Barua,Umee Salma

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Risk analysis of a patient monitoring system using Bayesian Network modeling.