*International Journal Of Engineering Research And Development*
*e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com*
*Volume 20, Issue 7 (July, 2024), PP. 573-579*

# Design and Implementation of Cost Effective Patient Monitoring Device

Abubakar Abdullahi[1], Yasin Mamatjan[2] Visa M. Ibrahim[3], S. Y. Musa[4].
[1,2]*Electrical-Electronics Engineering Department, Zirve University, Gaziantep, Turkey*
[3,4]*Department of Electrical and Electronics Engineering, Modibbo Adama University, Yola Adamawa state*

**Abstract—** *Heart attacks and Stroke are becoming the highest cause of death globally. The research conducted by World Health Organization (WHO) in 2012, report that 15 million people suffer stroke worldwide in each year. According to this report 5 million people die and another 5 million people are permanently disabled [1]. The impact of stroke is pervasive and far reaching, affecting individuals and communities not only physiologically but also economically and socially. Families lose their most productive members to this disease, leaving children and elderly people without means of support. Due to such problem a research on building a device that will use to monitor an individual in case of any sudden changes feels by that person and display the result through a mobile Smartphone. The data can be saved and send to hospital or the people concern through SMS or Email .It also used to monitor an elderly people health status periodically. Although before stroke happen the human body undergoes some certain abnormalities such as temperature changes, high blood pressure etc. This research work specifically deals with the signal conditioning and data acquisition of six vital sign; temperature, heartbeat, ECG, blood oxygenation, airflow and patient position. The temperature sensor will measure patient body temperature and pulse sensor will count the number of heartbeat. Electrocardiogram sensor (ECG) will provide the mechanical activity of the heart while blood oxygen sensor will measure the percentage of oxygen saturation on the patient body. The airflow sensor will measure the number of breathing per minute while the position sensor shows the position of the patient such as sitting, standing or the type of lying on the bed e.g. supine, prone. The aim of this research work is to design and implement a portable wireless device, non-invasive that is cost effective to improve the health care and reduce the rate of mortality and disability so that a common man can afford it and the research was successfully achieved.*
***Keywords***—*Electrocardiography (ECG), Temperature, Heartbeat, Stroke, IOIO-OTG development board.*

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Date of Submission: 20-07-2024 Date of Acceptance: 03-08-2024

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## I. INTRODUCTION

The sudden interruption in the blood supply to the brain is known as Stroke while the loss of sensation and functioning in some part of the human body is called paralysis. Most strokes are cause by an abrupt blockage of arteries leading to the brain (Ischemic stroke). Other strokes are cause by bleeding into brain tissue when a blood vessel burst (hemorrhagic stroke). Because stroke occurs rapidly and requires immediate treatment, it is also called brain attack. When the symptoms of a stroke last only a short time less than an hour is called a transient ischemic attack (TIA) or mini stroke [2]. Therefore, the clinical need for continuous monitoring of critical care patients in hospital is a beside solution that provide an alerting in a case of sudden changes of the state of the patient's health and a follow-up of the monitoring of the therapy. Early information will improve the care cycles and lowers the side effects and also timely therapy avoid disabilities or reduce the grade of disabilities.

Many approaches have been made by others to design vital sign monitoring device. A Wireless Body Area Networks (WBAN) system for ambulatory monitoring of physical activity and health status was developed by Jovanov *et al*. They developed a standard platform with common off-the-shelf wireless sensor platforms like ZigBee-compliant radio interface, an ultra low-power microcontroller, accelerometer c ultra-low-power microcontroller, accelerometer circuit, and bio amplifier for ECG monitoring [9]. Anliker *et al*. developed a wearable multi-parameter medical monitoring and alert system. The system is a wrist worn remote monitoring device with a single lead ECG monitoring. Also oxygen saturation, temperature and Blood pressure were measured using this device. All the measured data was send to an online medical mission control station using a global system for mobile (GSM) communication protocol [10]. Mr. Amr Abd EL-Aty. Developed a wireless wearable body area network (WWBAN) for elderly people long-term health monitoring. In his design he used heart rate and blood oxygen sensors to measure heartbeat and blood oxygen saturation. He also used IOIO board as his microcontroller unit to interface with android smart phone via Bluetooth connection [11].

The aim of this study is to build a cost-effective, non-invasive, potable and ubiquitous biomedical sensor system that will be used to monitor patients and elderly vital signs (heart bit, respiratory rate, blood oxygenation, temperature, EKG) remotely without supervision, relay vital information in real-time to hospitals through a Smartphone, tablet or a custom-built wireless device, and warn medical staff automatically in the case of physiological state changes in patients through specially designed patient monitoring software system. The scope of this project is to build a device for individuals over the age of 25years. This limitation is added in order to simplify our project and ensure the accuracy of the components of the system, and also they are the victims of heart attack and stroke.

## II. METHODOLOGY

*Design Overview*

The design basically consists of the hardware and the software design

**2.1 Hardware Design: -**The design of this system device consists of sensors, microcontroller unit, power source, Bluetooth module and Smartphone (Android). The sensors are design to collect raw signals from a human body and send to microcontroller unit. The microcontroller unit will transmit the data through Bluetooth dongle to the Smartphone which will display the output values graphically or numerically. The data can also be stored on SD card of the phone and send to the hospital or relatives concern of the patient. These sensors can be analog or digital sensor, but we prefer analog sensor because of simplicity in writing the program that will establish communication between the sensor and microcontroller and also analog are cheaper than digital sensor. The power source was two lithium batteries each of 3.7V connected in series and gives a total of 7.4V. The IOIO board has input voltage ranges from 5V – 15V, and also it has output of 3.3V and 5V. Therefore, to have constant output of 5V, we need the input voltage to be above 5V.

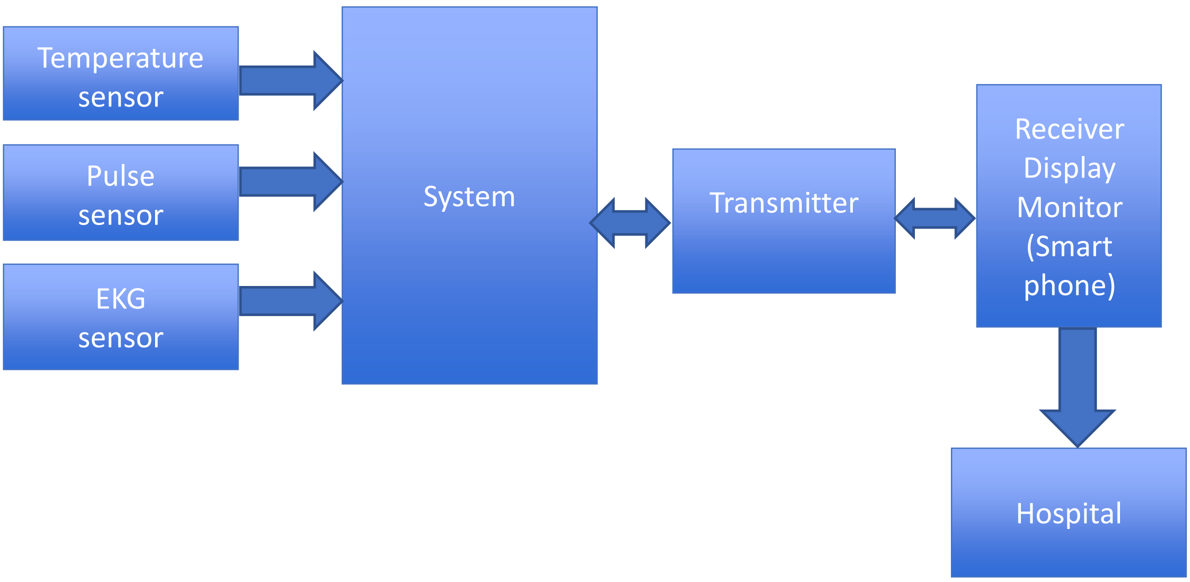



Fig.1. Proposed System Diagram

2.1.1 Electrocardiogram (ECG) sensor

The Electrocardiogram is process of measuring the electrical activity of the heart. When the heartbeat, the cells of the heart depolarize. When depolarization occurs, positively and negatively charged ions ($Na^{+1}$, $Ca^{+2}$, $K^{+}$, and $Cl^{-}$) move in and out of the heart cells. This movement of ions creates electrical charges on the surface of each cell. The myocytes that are depolarizing are causing microscopic electrical charges at each individual cell. Adding up all those microscopic charges, you get a total electrical charge. It is this total charge that can be measured from the skin as ECG.

The electrocardiograph sensor is an analog sensor which can be used to monitor the activity of the heart. The output fluctuating voltage of the ECG was illustrated graphically. To measure any electrical activity you need at least two electrodes (a positive and negative) in order to form an electrical circuit. If using defibrillator paddles to obtain a trace, you are making use of this principle. So we have one electrode ''looking'' between itself and the other electrode. By changing the position of either of these electrodes we alter the angle at which we are viewing any activity. The ECG sensor we use here is using three lead ECG system electrodes; the standard twelve lead ECG systems were modified and reduce to different numbers of electrode.

With only three leads available, it is important that lead placement is optimized to produce the most useful information. The bipolar leads involve measurement and display of the difference in electrical potential (from the heart) between two points on the body surface. Conventionally, the three limb leads are utilized, lead I, lead II and lead III. Lead I measures the difference in potential between right arm and left arm, lead II right arm and left leg, lead III left arm and left leg. The three leads include two that are "active" and one that is "inactive" (earth). The former two may be placed to record leads I, II, or III, the inactive lead being placed anywhere on the body surface [12].

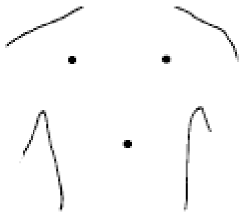
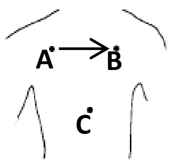
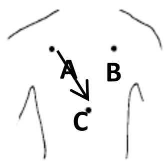


Fig.2. Electrode position on the body[3]

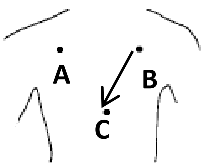
There are two electrode that are placed on the chest and one placed at left bottom of the stomach. From these three points, 3 leads are generated; each lead is simply an electrical comparison of two points on the chest. [3] Figure2 below shows the points at which each lead will be measured. The three bipolar leads form Einthoven's Triangle. When an action potential starts on the right proceeds toward the left side of the heart, a positive inflection will be seen on in lead one. This holds true for all leads. Whenever a current proceeds toward a positive electrode, an upright inflection is seen on the EKG tracing.[8] Lead I measures electrical potential between right arm (-) and left arm (+). Lead II measures the electrical potential between right arm (-) and left leg (+). Lead III measures electrical potential between left arm (-) and left leg (+). [6][7]




Lead I




Lead II




Lead III

Fig.3. Lead measurement positions [3]

2.1.2. Pulse sensor

The Heartbeat Sensor provides a simple way to study the heart's function. It monitors the flow of blood through earlobe or fingertip. As the heart forces the blood through the blood vessels in the ear lobe or fingertip, the amount of the blood in these parts will change with time. The sensor shines a small incandescent light through the earlobe/fingertip and measure the light that is transmitted. The signal is amplified, inverted and filtered using a designated circuit on this sensor. The heart rate can be determined and also some details of the pumping action can be observed by graphing this signal. This pulse sensor was made essentially with a photo plethysmograph, which is a well-known medical used for non-invasive heart rate monitoring. The heart pulse signal that comes out of a phot plethysmograph is an analog fluctuation in voltage, and it has a predictable wave shape as shown in the figure 4. The depiction of the wave is called photoplethysmogram, or PPG. This latest hardware version, pulse sensor Amped, amplified the raw signal of the previous pulse sensor, and normalizes the pulse wave around V/2 (midpoint in a voltage). Pulse Sensor Amped responds to relative changes in light intensity. If the amount of light incident on the sensor remains constant, the signal value will remain at or close to 512 midpoint of ADC range.

More light and the signal go up, less light go down. The Light from the green LED that is reflected back to the sensor changes during each pulse.

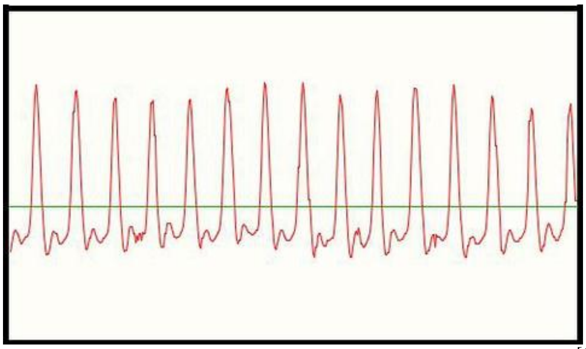


Fig.4 Raw analog signal voltage with peak percentage [13]

2.1.3. Temperature sensor

The TMP36 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature. It is a low voltage, precision centigrade temperature sensor. It also provides a voltage output that is linearly proportional to the Celsius (centigrade) temperature. The TMP36 do not required any calibration to provide typical accuracies of $\pm$ 1℃ at +25℃ and $\pm$ 2℃ over the -40℃ to +125℃ temperature range [5]. The TMP36 has 3pins. $V_{in}$ is the input voltage, $V_{out}$ the analog output voltage and GND which is the ground pin. It is easy to measure temperature with TMP36 temperature sensor, simply connect the left pin to power (2.7V – 5.5V) and the right pin to ground. Then the middle pin will have an analog voltage that is directly proportional (Linear) to the temperature. The analog voltage is independent of the power supply.

The process use to convert the voltage to temperature is simply done by the basic formula:

Temp in ℃ $= [(V_{out}\ in\ mV) - 500]/10$

So for example, if the output voltage is 1V that means the temperature is

$[(1000mV - 500)]/10 = 50℃$

2.1.4. IOIO-OTG board

In order to conduct sensor readings, I/O capability is required because different sensors will have a number of output protocols, even though usually we just need to sense analog voltages. The sensor interface must be able to support a number of methods such as pulse width modulation (PWM), Serial peripheral interface (SPI) and Universal asynchronous receiver transmitter (UART). There also need to be an A/D with a high resolution and general purpose I/O for interaction with the arbitrary digital input. For these reason we choose IOIO board as the interface because IOIO API provide capability to do most of these things. IOIO board also supports both USB cable and Bluetooth module; in case of power consumption IOIO consumes little power compare to other boards. It is also the heart of the complete system. It is responsible for all the process being executed. It will monitor and control all the components and peripheral connected in the system. In short the complete intelligence of the project resides in the software code embedded in the IOIO board. The code will be written in java by program and run on mobile smart phone as an application, then the program will install to IOIO by connecting it to the phone via USB cable or Bluetooth dongle.

The Bluetooth adaptor is the one that will establish communication between microcontroller and smart phone wirelessly. The operating range, frequency band, maximum data rate transfer and sensitivity of the Bluetooth will be considered, although not all Bluetooth adaptors are supported by IOIO board.

IOIO-OTG is an input/output prototyping board design for Android devices (OS version 1.5 and greater). The IOIO contains a single PIC24FJ256GB210 family microcontroller that acts as a USB host and interprets commands from an Android application [15].

**2.2 Software Design: -** In order to develop software applications for mobile Smartphone we need Android platform software capabilities. The API provides all the android version operating system, which will be downloaded from Google URL. Eclipse is more preferable for this compilation because of the Android IOIO user guide manual, Eclipse was used. To begin programming IOIO some basic software libraries have to be downloaded. The software application known as *IOIOLib* is a collection of libraries for Android and for PC, which enables user application to control the IOIO board. These libraries expose a set of java interfaces that covered the various features of the board. When a user build an application, *IOIOLib* got parked into the target *.jar* or *.apk*, so that the application is self contained and does not require any further installation of dependent components. Those existing libraries and their purpose in the *IOIOLib* were explained below;

- The *IOIOLibPC* library: - This library has it Eclipse project files under *ioiolib/target/pc*. It used to interface IOIO from a PC.
- The *IOIOLibAndroid* library: - This library has it Eclipse project files under *ioiolib/target/android.* It is the library that user would used to interface IOIO from an Android device.

There are also two additional libraries *IOIOLibBT* and *IOIOLibAccessory* which are complementary to *IOIOLibAndroid*. The *IOIOLibBT* add Bluetooth and *IOIOLibAccessory* add Android Open Accessory functionality as possible connections to the IOIO, respectively. The reason why these two libraries are kept separate is that, the *IOIOLibAndroid* library would work with any version of Android (as early as V1.5), while Bluetooth has been introduced in Android V2.x and Open Accessory is only available on select Android 2.3.4 or later devices. By simply linking any of those libraries (or both) to the application, the IOIO connection will automatically be established over whichever channel, provided that the application is based on the android utility classes.

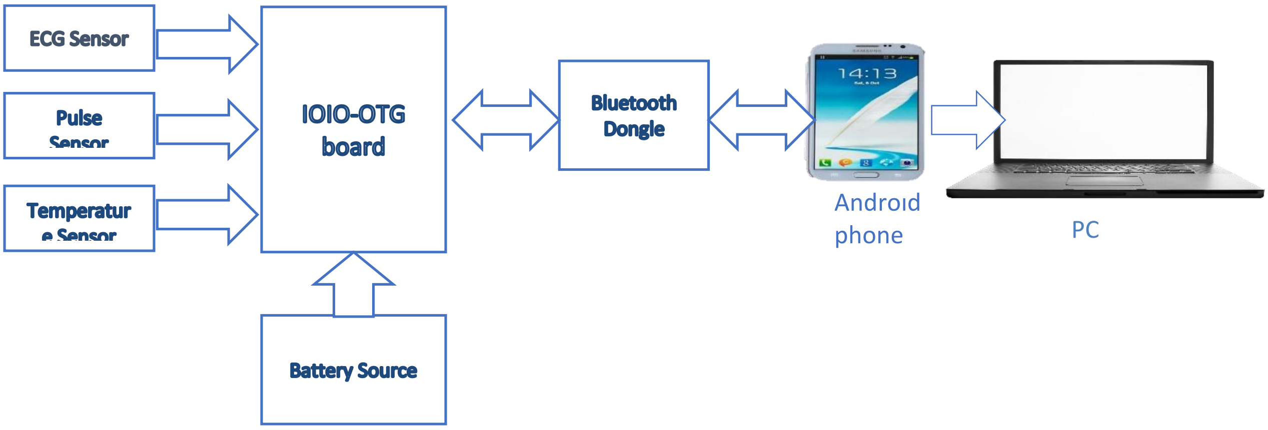



Fig.5. Block diagram of our system

Android SDK is a Google provided a set of tool for accessing Android phone hardware (Camera, Vibration, Bluetooth, etc.) and some libraries for android development. It comes with an Eclipse Plug-in called ADT (Android Development Tool) to add some additional features to Eclipse environment like Emulator to test apps on, some Debug tools to help developers to enhance and fix their apps. In order to access data coming through USB or Bluetooth, we need some protocols for specific USB device. With these protocols can access registers in microcontroller that is connected host PC via USB cable. When we develop protocols we begin to assign some variables to hold address of the microcontroller registers via high level programming language, such as Java in our IOIO protocol.

## III. TEST AND RESULTS

The Patient monitoring device can be used to obtained body temperature and also heartbeat can be obtained graphically and numerically as seen in figure 6 below, a screen short was captured during testing.

ECG also can be used to calculate heartbeat. From the test we conducted many samples of data was been recorded and send to PC via an Email. These data's was been filtered using Mat lab programming and also the samples provide the heartbeat within the normal range i.e. 60bpm to 100bpm. This data can also be analyzed to obtain the PR interval, QRS complex and QT interval. The three ways of calculating heart rate from ECG rhythm can be used; Rule of 300, RR method and the 10 seconds rule. The former two methods are used for regular ECG rhythms pattern while the latter is used for irregular rhythms pattern. Figure7.below shows sample data obtained during testing.

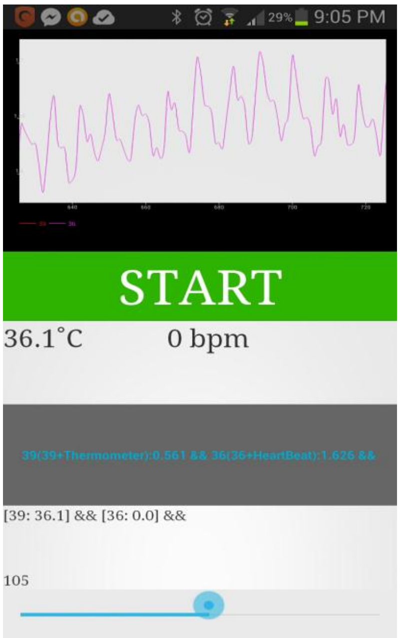



Fig.6. Screen short while testing Temperature and Heartbeat on Android phone.

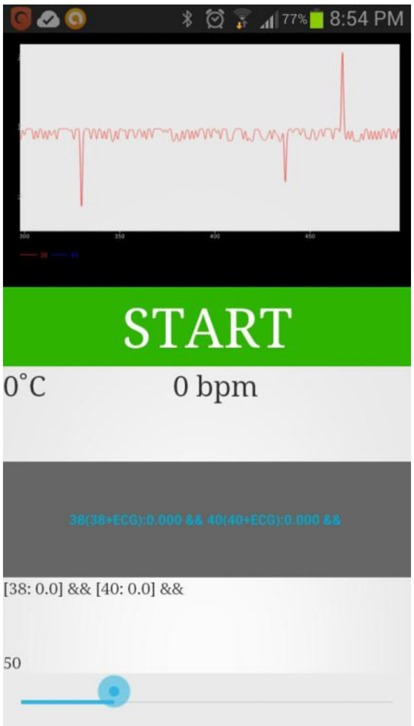



Fig7. Screen short of ECG rhythm during testing.

## IV. Conclusion

The ultimate goal of designing this patient monitoring system was to improve vital monitoring healthcare. Early detection of heart attack and stroke is important to reduce mortality rate. In some countries where the facilities of heart attack and stroke treatment are not enough in their medical sector, this device will help much due to early detection. Also this device can be used as preventive measure by individual. In a countries where the internet is expensive and also the medical health center does not have internet the system can be used either. When an individual found that he obtain the values of his health status out of the normal range he can quickly goes to hospital for more details. As seen in the result, with these solution temperature and heartbeat parameters, waveforms can be obtained easily without any supervision. The patient will be able to send all these information with email to their doctors through their smart phones for further diagnosis without leaving home comfort.

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