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Article

ZIGBEE BASED WIRELESS PATIENT TEMPERATURE AND PULSE MONITORING SYSTEM

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Abstract: Many health monitoring systems exist due to the fact that health monitoring is paramount as it is useful to indicate life in the human body. Despite the many systems that exist, life is still being threatened as low sensitivity and accuracy devices are still being used. Also, many health institutions in developing countries like Nigeria are still faced with the challenge of remotely monitoring unstable and critical patients. This project describes the design and implementation of a human pulse rate and temperature monitoring device based on zigbee technology. It presents the use of high sensitivity and accuracy devices such as the thermistor for temperature monitoring and the use of disposable ECG electrodes for pulse rate monitoring. The system consists basically of the transmitting and the receiving units. Zigbee technology is used for wireless transmission and results are displayed via a Liquid Crystal Display (LCD). Subsequently, as a means to measure performance, three samples collected from available results were used and compared with the results obtained from project. The results show 87.2%, 89.5% and 88.1% accuracy for temperature measurement and 98.39%, 97.23% and 98.58% accuracy in pulse rate measurement for the three samples. The device remotely measures human temperature and pulse in real time and can be used in especially small scale hospitals and clinical environments. The device is also user friendly and cost effective.

Keywords: Wireless, Monitoring, ECG, Pulse, Temperature, Transmitter, Receiver

1. INTRODUCTION

Body temperature represents the balance between heat production and heat loss in the body. It is a chief indicator of normal functioning and health of the body. Normal human body temperature depends upon the place in the body from which the measurement is made and the time the body temperature is taken, it also depends on the level of activity of the person. Typical body temperature is 37.0˚C ± 0.4˚C (98.6˚F ± 0.7˚F)[1]

For temperature measurement, extremes of temperature are easier to interpret. It is estimated that accompanying every 1˚C rise in the body temperature is a 10% rise in the rate of enzyme controlled chemical reactions (Marieb*et al*, 2010). At 43˚C and above, cells are irreparably damaged and enzymes denatured, rendering death a certainty. As temperature drops, cellular processes become sluggish and metabolic rate falls[2]

Generally, the body is more tolerant to lower than higher temperatures. Body temperature in critical patients should be measured and recorded regularly with precision, consistency and diligence. Patients' temperature serves as a useful indicator of change in their clinical condition, Therefore, practitioners should always beaware of it. None of the methods for measuring temperature at the bed side is perfect but once a site and a method have been selected, they must be used consistently to ensure accuracy and patient safety .[3]

Just as temperature is very important, so also is pulse in the human body. Although pulse rate and heart rate differ in their definitions, their values are always the same. Therefore, pulse rate is also known as heart rate. Heart rate means the number of times the heart beats per unit of time and it is usually expressed as beats per minute (bpm). Human heart pounds to pump oxygen rich blood to muscles and carry cell waste products away from tissues. Heart rate can vary according to the demand of muscle to absorb oxygen and excrete carbon dioxide, such as during exercise or sleep. It also significantly varies between individuals and is based on the fitness, age and genetics. Pulse rate also serves as a useful indicator for health of the human body.

In the recent years, advances have been made for health monitoring. Many devices have been developed with different approaches to be used for patients health monitoring [4]. Existing systems use wireless sensors networks (WSN) for remote monitoring and real time display of results. Wireless networks have been employed to reduce stress of health workers and to increase efficiency. However, the accuracy of some of these pulse monitoring systems pose a major challenge as they are based upon the principle of pulse oximetry. Pulse oximeters are affected by dyshemoglobinemias, translucency (nail polish and coverings), poor flow and irregular heart rhythm, low temperature of the body and many other factors [4].Thus, producing false results. Also, temperature monitoring devices require high sensitivity to be able to detect the slightest change in readings. Some of the existing systems have been known to make use of low sensitivity monitoring devices such as the LM35 which has an accuracy of 0.5°C guarantee able (at +25°C) and less accuracy at higher temperatures (National Semiconductor, 2000).

To solve the problem of accuracy in pulse readings and use low sensitivity temperature monitoring devices, the work uses the disposable ECG pulse electrodes for pulse readings and the thermistor for temperature reading which can provide more accurate readings. Also, the system would also include PIC microcontrollers, Zigbee technology based radio transceivers for remote monitoring and Liquid Crystal Display (LCD) for display.

1.1 Health Monitoring Problem

Health monitoring systems have always been targeted towards saving lives and improving efficiency in the heath institutions, but despite the many patient health monitoring systems that exist, human lives are still being threatened as some of these systems remain unreliable. Low accuracy and low sensitivity monitoring devices are being us

The aim of this work is develop a real time wireless human temperature and pulse rate monitoring system based on Zigbee technology displaying results through a Liquid Crystal Display (LCD).

1.2 PULSE RATE

The pulse rate is one of the many vital signs of the body. The pulse is how many times a minute that our arteries expand and contract in response to the pumping of the heart. This rate exactly equals the rate of heart contractions and these contractions invariably cause increase in the pressure of blood and pulse in the arteries. Therefore, taking pulse reading is the same as taking the heart rate reading. The normal heart rate varies in response to some conditions like body size, body exercise, body temperature, body position and emotion. Abnormal heart rates are life threatening and can lead to death if not attended to. Changes in heart rate/rhythm, or weak pulse, or a hard blood vessel may be caused by heart diseases or another problem [4].

1.3 Pulse Rate Monitoring

The pulse rate is one of the many vital signs of the body. The pulse is how many times a minute that our arteries expand and contract in respond to the pumping of the heart (MNT, 2015). This rate exactly equals the rate of heart contractions and these contractions invariably cause increase in the pressure of blood and pulse in the arteries. Therefore, taking pulse reading is the same as taking the heart rate reading. The normal heart rate varies in response to some conditions like body size, body exercise, body temperature, body position and emotion. Abnormal heart rates are life threatening and can lead to death if not attended to. Changes in heart rate/rhythm, or weak pulse, or a hard blood vessel may be caused by heart diseases or another problem. [4]

The resting pulse value is a credible value metric to determine fitness level and cardiovascular health. Resting Pulse Rate (RPR) varies from person to person but according to the American heart foundation, the average resting pulse should be between 60 to 80 beats per minute (bpm). But any value less than these do not mean a person is unhealthy as athletes or people who perform various cardiovascular activities have a resting pulse rate of close to 40bpm. The heart is a muscle and the more one works it, the stronger it gets. A stronger heart means more blood with each beat [5]. Heart attacks can result when the heart needs more beats to do the same amount of work.

Pulse rate not only measures the heart rate but also the heart rhythm and the strength of the pulse. In the body, it can be observed that arteries run closely under the skin at the wrist and neck making pulse measurable at these points. Therefore, pulse can be checked on a patient particularly on the wrist, inside the elbow, side of the neck and the top of the foot [5]. Checking the pulse at the wrist and at the neck are the two most common ways of checking for pulse. This is so because the pulse at this point is very palpable and the ease at which they are located. The radial artery is located at the wrist and the carotid artery at the neck. At the foot, pulse should be checked to ensure that blood flows conveniently to the legs. Peripheral Arterial Disease (PAD) is the narrowing or blockage of the arteries (HealthWise, 2015). High cholesterol, high blood pressure in patients and smoking all contributes to the buildup of plague inside of the arteries. An absent or weak pulse on the foot is a sign of PAD and so should be checked.

1.4 Abnormal Heart Beats/Rhythms

The heart has its own electrical conduction system as shown in figure 2.1. The conduction system sends signals throughout the upper and lower chambers of the heart known as Atria and Ventricles respectively to make it beat in a regular and coordinated rhythm. The sinus rhythm is the normal rhythm of the heart [9].

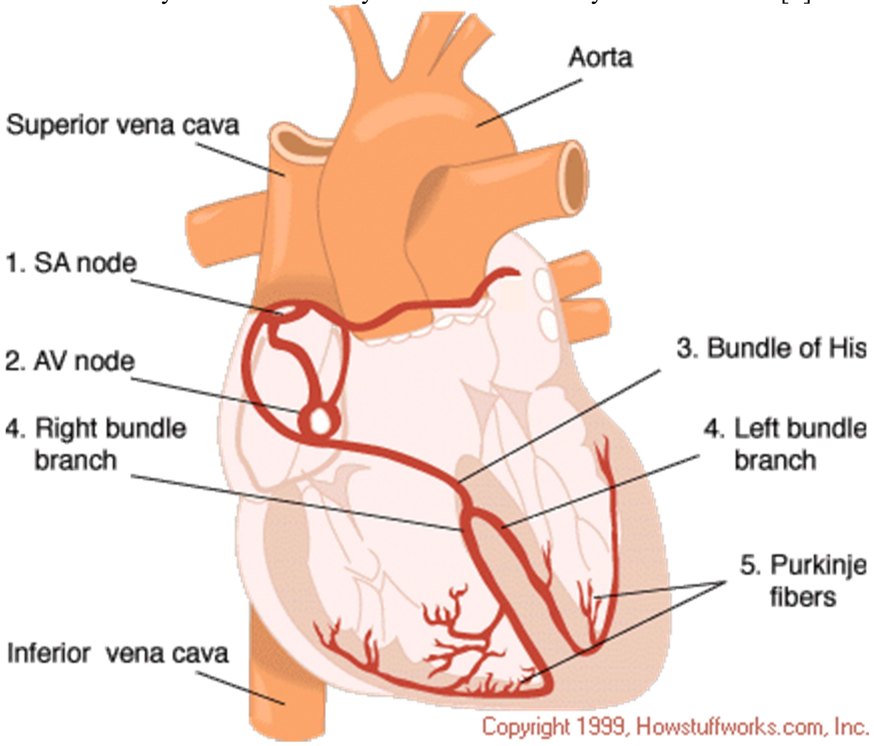

Figure 1 Electrical system of the heart.

It is possible that the rhythm of the heart changes as result of the conduction pathway being damage or blocked or an extra pathway exists. The heart beating too quickly is known as tachycardia and the heart beating too slowly is called bradycardia. All these conditions may affect the ability of the heart to pump blood around the body. These heart beats which are abnormal in nature are known as arrhythmias which can occur in the Atria or Ventricles.

1.5 Body Temperature

Sensing and regulating body temperature is a key feature of human survival. Resting temperature rate is about 37ºC. A deviation from the resting temperature by±3.5˚C can result in psychological impairments and fatality. Normal human body temperature is referred to as Normothermia or Euthermia and it depends upon the place on the body at which the measurement is made, the time of day and the level of activity of the person. There is no single number that represents a normal or healthy temperature for all people under all circumstances using any place of measurement [10].

1.6 Telemedicine

Telemedicine is defined as the use of telecommunications technology to allow health care workers and professionals to evaluate, diagnose and treat patients in remote locations [8]. Telemedicine has grown to include a growing variety of applications and services using two-way video, email, smart phones, wireless tools and other forms of telecommunications technology (ATA, 2013). Telemedicine involves remote training, intensive care, remote diagnosis and guidance (between patient and doctor),

1.7 Electrocardiogram (ECG)

An electrocardiogram is also called ECG or EKG which is used to monitor the heart. Each heart beat is triggered by an electrical pulse which is normally generated from special cells in the upper right chamber of the heart (Mayo clinic, 2012). It translates the heart's electrical activity into tracing lines on a paper. All the spikes and dips in the line tracings are called waves. Mostly, the ECG is done to check for the heart's electrical activity. It is done find out if a patient is hypertrophied that is, the walls of the heart chambers are too thick, to check whether any disease condition of the heart is present. Example of the disease include; hypertension, high cholesterol and diabetes (WebMD, 2014).

Figure. 2 Watch shaped Pulse Oximeter (Itamar Medical Ltd, 2015)

In 1856, Kollicker and Muller discovered that the heart could produce electrical activity. Using a siphon instrument, Muirhead in London recorded the first ECG in man in 1869. Also, Waller recorded an ECG in 1887 with a capillary electrometer. The Einthoven's string galvanometer was a huge breakthrough in 1906. The readings were voluminous and unpredictable but also very precise. His invention was in use not until RumeElmqvist invented the direct writing inkjet recorder demonstrated at the congress of cardiology in Paris in 1950. His invention has since been in use till date but with various modifications and design but basically the same concept the Rume used . ECG became more used to diagnose various heart diseases like coronary heart diseases, myocardial ischemia and so on. Fetal and comparative ECG provides important scientific and clinical information. The ECG has continued to be developed. The modern ECG (as shown in figure 3.

Figure 3 modern ECG device (Tower pharmacy, 2015)

2 Wireless Sensor Network (WSN)

A wireless sensor network is a collection of sensing devices that can communicate wirelessly where each device can sense and process signals (Puccinelli and Haenggi, 2005). Typically, a WSN consists of various target sensor nodes and also, centralized collection point exists in the network to collect all the processed signals which is also a sink or base station as shown in Figure. 2.6

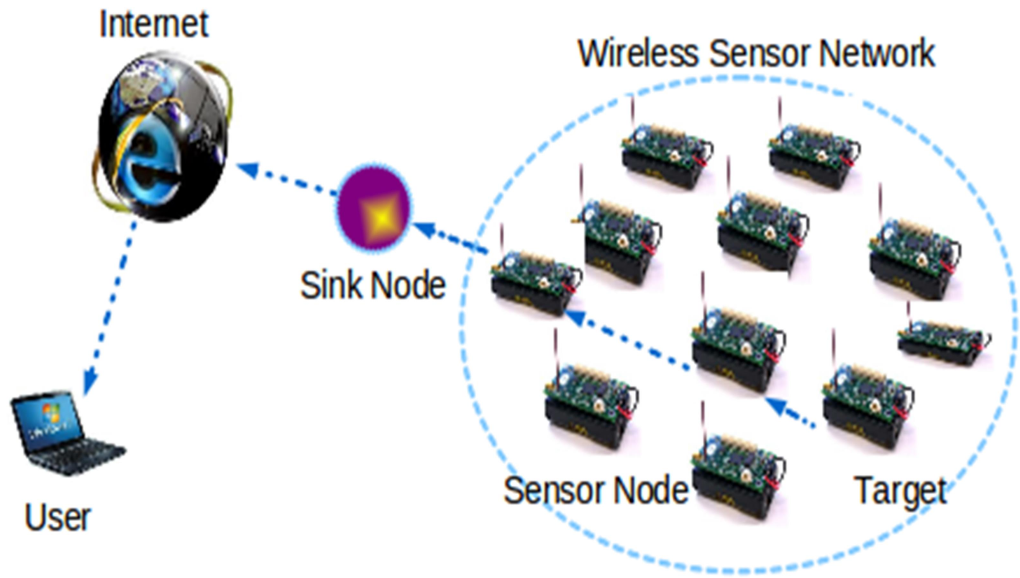

Figure 4 Wireless Sensor Network (Nex- G WSN training, 2014)

WSN enhances productivity, reduces cost and also saves lives. Advances in semiconductor, material science technologies and networking have driven the ubiquitous deployment of large scale wireless sensor networks (WSNs) and the combination of these technologies have combined to enable a new generation of WSN that differ vary greatly from wireless network developed as recently as 5 to 10 years ago.

2.1 Base Technologies of Medical Applications

The rapid growth of the technologies extends the potential for exploitation of wireless medical application market. Nowadays, thanks to the large scale wireless network and mobile computing solutions such as cellular 3G and beyond, WiFi mesh and WiMAX, caregivers can access vital information anywhere and at any time within the health care network as shown in Figure 5. It shows a doctor in the medical environment viewing the report of patient vital through a GSM link or web based transmission on a personal computer.

The presence of pervasive computing of RFID, Bluetooth, Zig-bee and wireless sensor networking gives innovative medium for data transmission for medical applications. With a number of advantages over wired alternatives, including: ease of use, reduced risk of infection, reduce risk of failure, reduced patient discomfort, enhance mobility and low cost of care delivery, wireless applications bring forth exciting possibilities for new application in medical market.

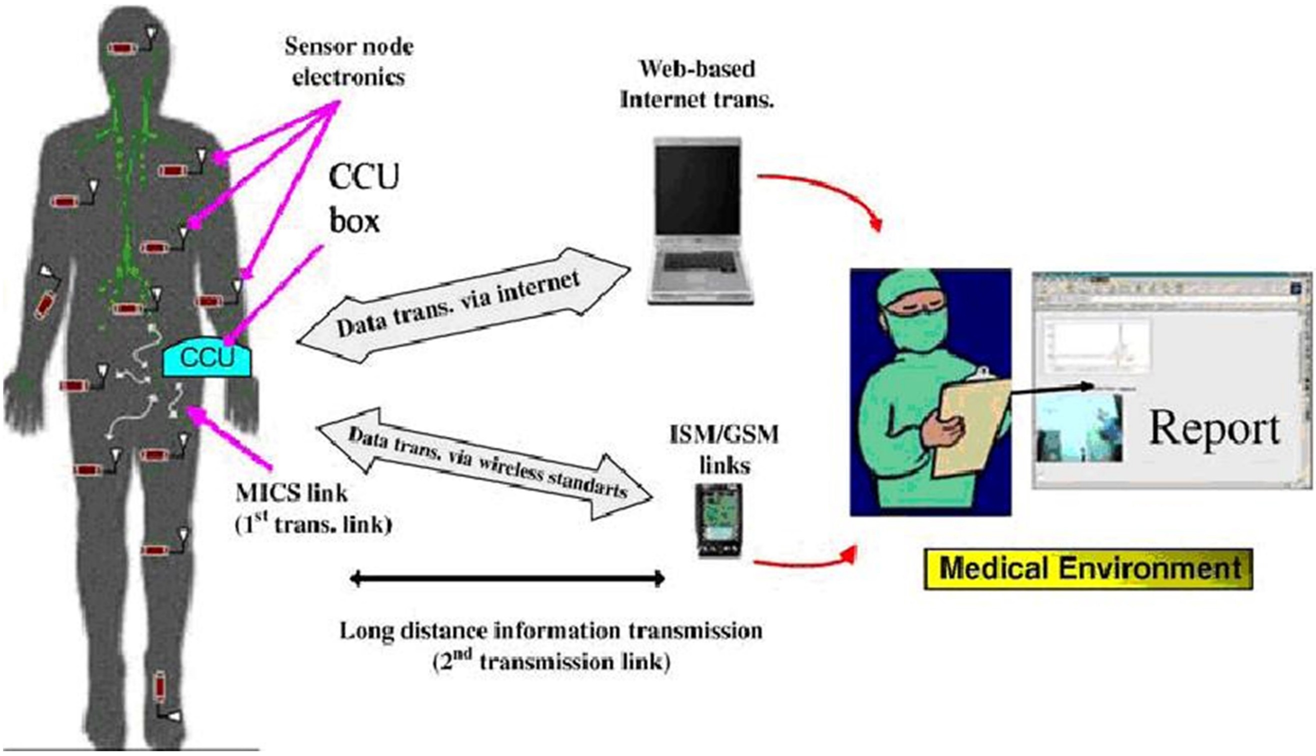

Figure 5 WSN for health monitoring (Yuce, Steven, Naung, Jamil, Wentai, 2007)

2.2 Wireless Body Area Network (WBAN)

Recent technological developments in low-power integrated circuits, wireless communications and physiological sensors promote the development of tiny, light weight, ultra-low-power monitoring devices. A body-integratable network (WABN), can be formed by integrating these devices. WBAN with sensor consuming extremely low power is used to monitor patients in critical conditions inside the hospital. Outside the hospital, the network can transmit patient’s vital signs to their physicians over internet in real-time.

2.3 Related Works On Wireless Health Monitoring Systems

Pulse and temperature monitoring like other phenomena has been improved to include the wireless technology. A number of devices have been developed that incorporates the wireless network.

Ramanathan.P and PradipManjrejar.P in 2011, developed a wireless sensor network (WSN) for continuous monitoring of a patient's physiological conditions using zigbee. The device consists of the zigbee and the personal computer (PC). The PC collects the measured signal and when the measured signal exceeds the standard value, the PC sends a short message to the care taker via a Global system for Mobile Communication (GSM). The device has its advantages in that there is a wider range of coverage and it is effective for continuous monitoring of patient but has its disadvantages as poor and inaccurate results are gotten from device [4].

Also in 2011, an online health monitoring system was developed by Josephine Selvarani. Physiological signals of humans such as temperature and pulse rate could be measured from a distant location and various abnormalities could easily be indicated via SMS. These measurements obtained from the temperature sensor and heart beat sensors are all transmitted to the programmed microcontroller to the PC through the zigbee transceiver. The personal computer (PC) collects all physiological measurements and sends the SMS, to the indicated Mobile number through a GSM modem. The system proved to be effective for patient monitoring, simple to implement and also inexpensive. But in the case of network failure in the delivery of SMS, patient is at risk of losing life.

In the year 2013, ShahidaKhatoon, Manoj Kumar Singh, And Ahmad Saad Khan developed a Zigbee-Wifi-Wimax hybrid wireless sensor network based telemedicine system. The system uses zigbee, wifi and wimax hybrid sensor to monitor hearth and transmit data over a distance of 20km and the information is transferred to a web server and accessed via laptops and computer having internet connections. The system has low power consumption; efficiently transfers data without significant time delay and is low cost. There has to be internet connection before information can be accessed.

3 SYSTEM DESIGN AND DEVELOPMENT

The real time remote monitoring system for human pulse and temperature consists of two major units: the transmitting unit and the receiving unit. The transmitting unit majorly consists of the temperature and pulse sensors, the amplifying unit, the PIC 18F4550 microcontroller and the transmitter. The receiving unit consists of the receiver, PIC 18F4550 microcontroller and the Liquid Crystal Display (LCD). Both the transmitting and the receiving unit contain power supply units.
The temperature and pulse sensors measure the temperature and pulse respectively and send the result to the microcontroller for processing. The processed result is then sent to the transmitter which is received by the receiver. The transmitter and the receiver form a pair called the transceiver. The receiver in turn sends the result to the microcontroller which is displayed by the LCD. A block diagram representing the system overview is shown in Figure 6 .

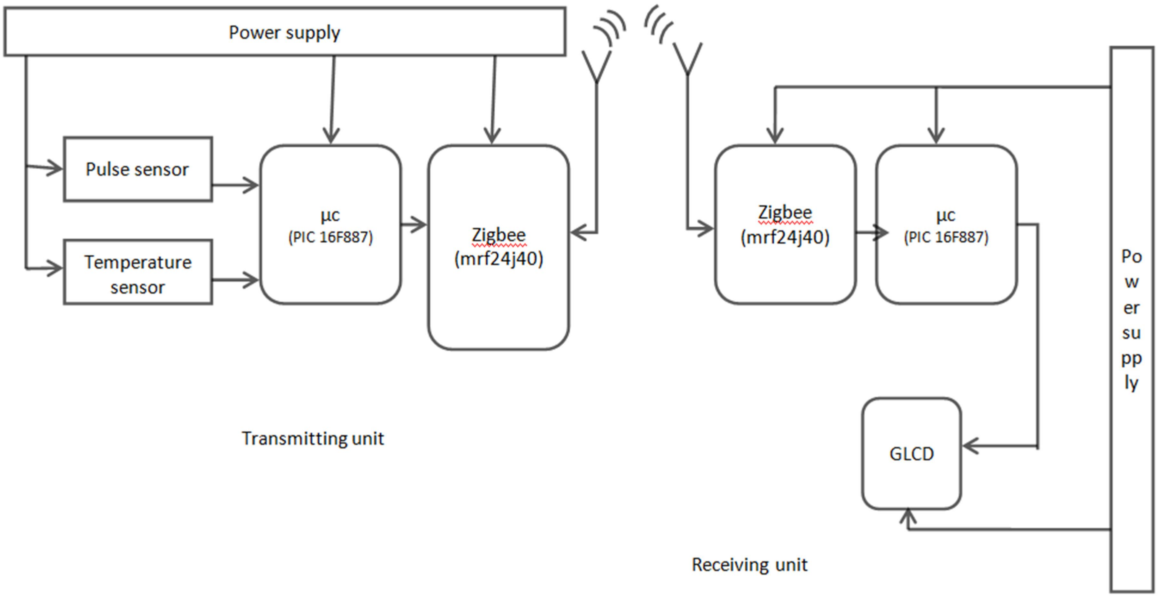

Figure 6 Block diagram of the design of the monitoring system

3.1 Temperature Sensor

The temperature sensor used is the thermistor. More specifically, the Negative Temperature Coefficient (NTC) thermistor is used as it is best suited for precision temperature measurement. The resistance versus temperature configuration operating in the zero power condition for the thermistor is used. The now linearity of the thermistor is corrected using the third order polynomial also called the Steinhart-hart thermistor equation. This equation is an approximation and can replace the exponential expression for a thermistor. Wide industry acceptance makes it the most useful equation for precise thermistor computation. The Steinhart-hart equation states:

$T1/(A_0+ A_1(\ln RT)+A_3 (\ln RT_3)$ (1)
$\ln RT=B_0+B_1/T+B_3/T_3$ (2)
Where:
T is the temperature of the thermistor in kelvin.
A0, A1, A3, B0, B1, and B3, are content provided by the thermistor manufacturer
RT is the thermocouple resistance at temperature T.
With a typical thermistor, this third-order linearization formula provides 0.1^0 C accuracy over the full temperature range. Although the temperature range of the thermistor is a little better than the diode or silicon-based temperature sensor (-55^0C to + 175^0C), it is still limited to a practical range of-100^0C to $+175^0$ C.

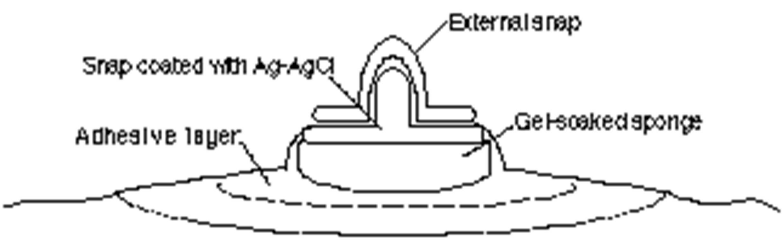

Figure 7 the structure of the disposable ECG electrode (www.cisl.columbia.edu)

3.1.1 IMPLEMENTATION

To take pulse reading, the sensor pair is stuck on the right arm (RA), left arm (LA) and right leg (RL) of the subject as shown in Figure 8. This is known as the Wilson electrode system.

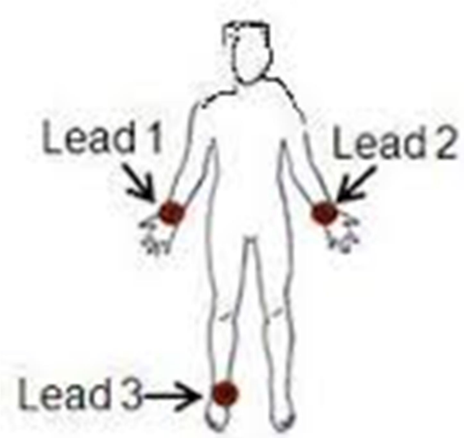

Figure 8 Wilson electrode system[6]

The effect of the arrangement is to force the reference connection at the right leg of the patient to assume a voltage level equal to the sum of the voltages at the other leads. This arrangement increases the common mode Rejection (CMR) ratio of the overall system and reduces noise interference. It also has the effect of reducing the current flow into the right leg electrode.
Because voltage generated by the electrodes is minimal (1mV), an amplifying circuit is required so as to increase the voltage up to its requirement. A Low pass fitter is also required for the signal so as to remove the unwanted signals like noise the frequency range of ECG is 0.04HZ to 150Hz, and so the Low pass fitter is designed with the cut off frequency of 150Hz
The general expression of a Low pass filter is:
Fc =1 /(2πRC)
Where:
Fc = the cut off frequency
Fc = 150Hz
C= 1µf
Therefore:
R = 1/(2*π*C*150) (3)
= 1/(2*π*1*150)
= 1kΩ

3.2 TEST RESULTS AND DISCUSSION

The digital multimeter was used to test individual components of the various units of the system for required voltage level functionality. The oscilloscope was used to observe the constantly varying signal voltages from the pulse electrodes. All the components of the power supply unit which includes the bridge rectifier, voltage regulators and capacitors were tested to ensure proper functionality and the voltage drop across them were measured before connecting with all the appropriate sub systems. Furthermore, the data sheet of the manufacturers for the digital ICs were consulted to identify and check their respective internal configurations and required voltage supplies.
Figure 11,12 and for are pictures of the test carried out to measure the functionality of the system, while figure 13 is the output that for read out of signal at the source (transmitter) and sink(receiver)

3.3 Testing and Results

the following steps were taken in order to check the accuracy of the project

i. Actual values of pulse rate and temperature were obtained from three (3) adults.
ii. The device was used to check for the values of the pulse rate and temperature
iii. The accuracy of the measured parameters were compared against the existing values of the parameters

$$\text{Percentage Error} = \frac{(\text{Actual Value} - \text{measured value})}{(\text{Actual value})} \times 100 \quad \text{.................}4$$

% Accuracy = 100 - % error

TABLE 1 PULSE RATE SAMPLES OF ADULTS

Test	Project (bpm)	Existing HRM (bpm)	% Error	% Accuracy
First sample	61	62	1.61	98.39
Second sample	74	72	2.77	97.23
Third sample	71	70	1.42	98.58

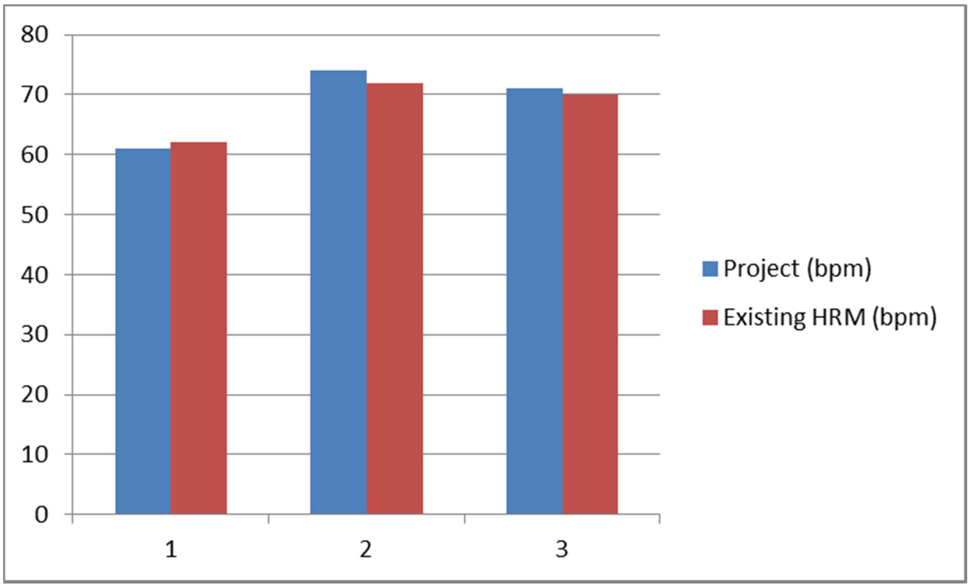

Figure 9 comparison of project and existing HRM pulse rates.

Table 2 temperature samples of adults

Test	Project (°C)	Existing (°C)	% Error	% Accuracy
First sample	34	39	1.28	98.72
Second sample	34	38	1.05	98.95
Third sample	37	42	1.19	98.81

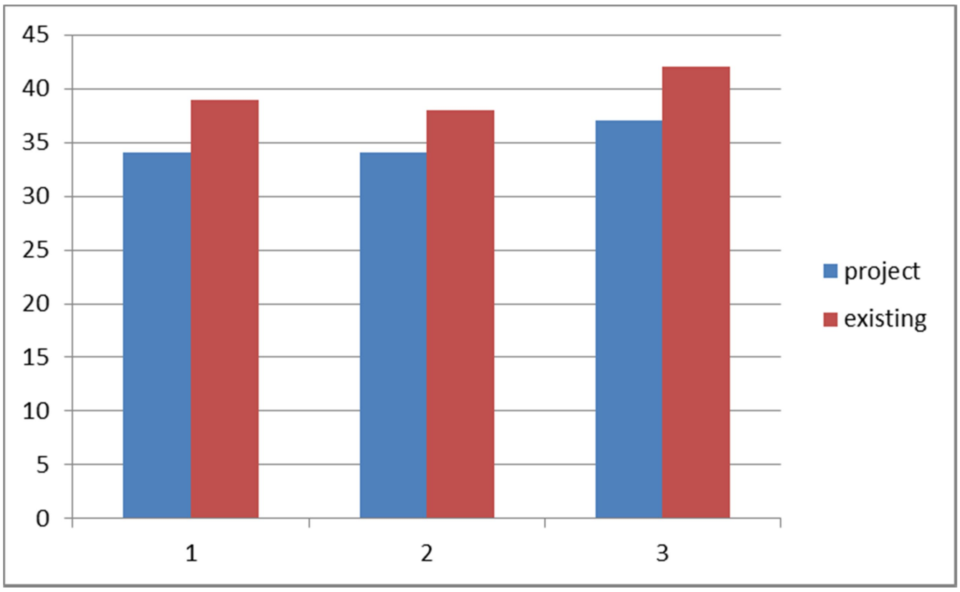

Fig. 10 Comparison of project and existing results of temperature.

An oscilloscope was used to check for the ECG signals before and after amplification. It is shown in Fig. 11 and fig. 12 respectively.

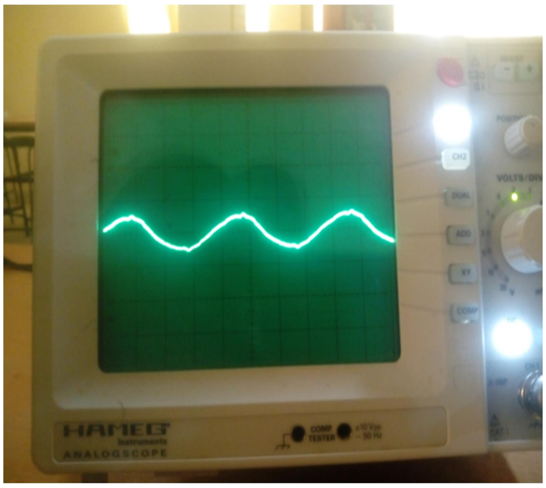

Figure 11 Signal Before amplification.

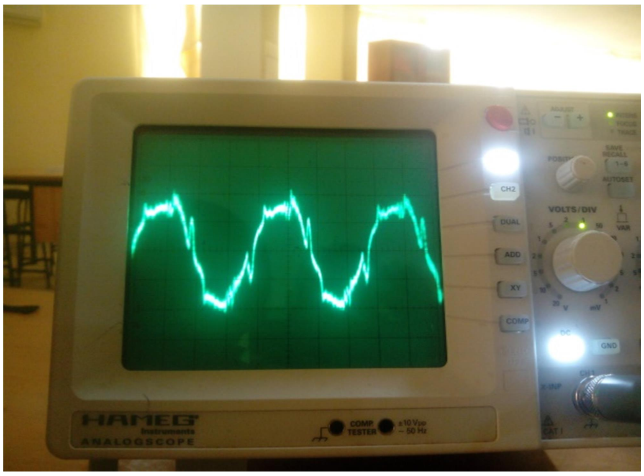

Fig.12 Signal After amplification

Figure 13 Device Being On Test

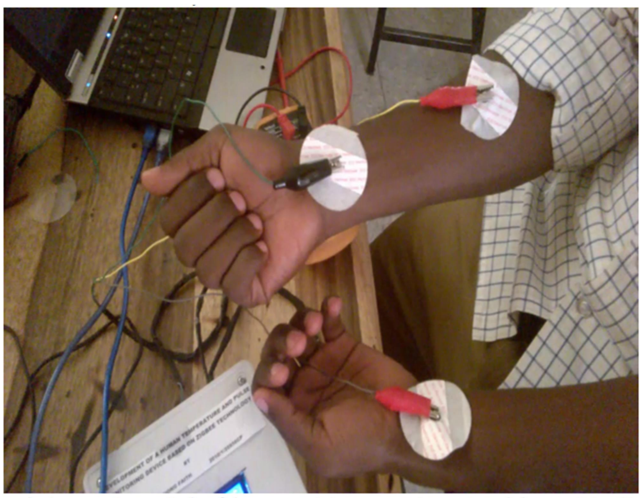

Figure 14 Device Being Test on a Patient B

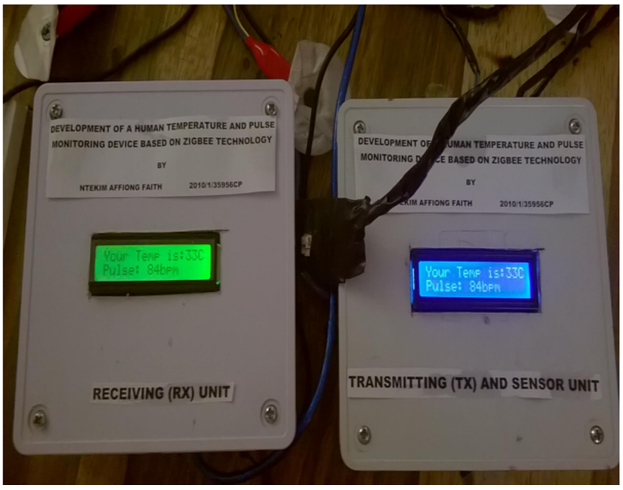

Figure 15 Wireless Transmitter and Receiver

Figure 16 Result Being confirm on output Interface

3.4 Discussion of results

Table 1 shows the results of pulse rates obtained from three(3) individuals compared with existing results while table 2 shows the results of temperature obtained from three individuals compared with existing results. The first sample of table 1 gives a percentage error of 1.61% and an accuracy of 98.39%. The second sample gives a percentage error of 2.77% and an accuracy of 97.23%while the third sample gives an error of 1.42% and an accuracy of 98.58%. The first sample of table 2gives a percentage error of 1.28% and an accuracy of 98.72%. The second sample gives a percentage error of 1.05% and an accuracy of 98.95%. while the third sample gives an error of 1.19% and an accuracy of 98.81%.The readings were varying as noticed. The variation was due to factors body movement of the individual. Also construction error such as soldering and packaging resulted in changes in readings.

4 Conclusion

All areas of technological advancement in medicine have been targeted towards saving lives. Saving lives in the aspect of monitoring is of great importance and is attracting a lot of attention in the area of research. Although several works have been done on this subject, this work presents the use of wireless, high sensitivity and accuracy devices to remotely monitor patient pulse and temperature.

In this work, the design and development of a real time human temperature and pulse monitoring device based on zigbee technology was presented. The device remotely measures human temperature and pulse in real time via wireless communication medium and can be used in especially small scale hospitals and clinical environments. The device is user friendly and cost effective.

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