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Design and Simulation of a Low Signal Wireless Communication System: An Application to Biomedical Engineering

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Abstract

The design and simulation of a low signal wireless communication system for detecting, measuring and analyzing heart rate (pulse) is proposed. A composite personal health monitor solution bridges the gaps between patients and doctors/health personnel. The system is user friendly and can use optical technology to detect the flow of blood through wrist. The phases that were adopted include pulse detection, signal extraction, pulse amplification and broadcasting through readable output, alarm and text messages. The information are log and can be monitored and retrieved at any time for analysis. This system is an effective means of preventing sudden death by timely response, improving and providing an easy-access and convenient human health monitor solution, critical information can be shared on large scale coverage within a short time to prevent sudden emergency.

Keywords: Broadcast; Microcontroller; Pulse; Signal; Simulation

Introduction

The heart rate or heart pulse is the speed of the heart beat measured by the number of times the heart pounds per minute, i.e., beats per minute (bpm). Heart rate varies as the body's need to absorb oxygen and excrete carbon dioxide changes during exercise or sleep. This can be used by the medical expert in diagnosis and monitoring the health condition of a Patient [1]. The normal resting adult human heart rate ranges from 60-100 bpm [2]. Heart rate tends to be slower during sleep typically between 40 and 50 which is considered normal and during exercise; it can as well increase above 100.

Heart rate varies from person to person [3]. It is also one of the major factors to determine a physically fit person. Slow or high heart rate in resting conditions may pose a threat; slow heart rate can lead to dizziness, blood clotting and an inefficient circulation of blood in the vessel while high heart rate can lead to heart attack.

Heart rate indicates the soundness of our heart and helps assessing the condition of cardiovascular system [4]. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement, and Electrocardiogram (ECG) [5,6] but it can be measured in home environment also [7]. Our heart pounds to pump oxygen-rich blood to our muscles and to carry cell waste products away from our muscles. The more we use our muscles, the harder our heart works to perform these tasks- means our heart must beat faster to deliver more blood. A heart rate monitor is simply a device that takes a sample of heartbeats and computes the Beats per Minute (bpm) so that the information can easily be used to track heart condition. There are two types of methods to develop heart monitors-electrical and optical methods. The electrical method has an average error of 1 percent and average cost of $150.00. The optical method has an accuracy rating of 15 percent and an average cost of $20 [5].

The average resting human heart rate is about 70 bpm for adult males and 75 bpm for adult females. Heart rate varies significantly between individuals based on fitness, age and genetics. Endure athletes often have very low resting heart rates. Heart rate can be measured by measuring one's pulse. Pulse measurement can be achieved by using specialized medical devices, or by merely pressing one's fingers against an artery (typically on the wrist or the neck). It is generally accepted that listening to heartbeats using a stethoscope, a process known as auscultation, is a more accurate method to measure the heart rate [5]. There are many other methods to measure heart rates like Phonocardiogram (PCG), ECG, blood pressure wave form [4] and pulse meters [8,9] but these methods are clinical and expensive. There are other cost-effective methods that are implemented with sensors as proposed in [10,11] but they are susceptible to noise and movement of subject and artery. It is therefore of a great advantage to have a device that can continuously measure the heart rate of a patient independently, to advice the patient of possible dangers and also to take necessary measures in case the heart rate go to the extremes.

This paper design and simulate a system that will broadcast the state of the heart rate (pulse). A microcontroller is programmed to count the pulse. The heart rate is digitally displayed on a LCD controlled by the same microcontroller that counts the pulse. A text message will be sent and the information will also be logged at intervals simultaneously. The paper is divided into different sections: Section 4 presents the design approach which includes the pulse detection, signal extraction, pulse amplification, information broadcasting and logging; section 5 shows the simulation while the result and conclusion drawn is presented in sections 6 and 7 respectively.

Design Approach

The device is a wrist mounted heart rate monitor, it acquires the required data and process it for transmission to a remote location, the data transmitted will involve the state of the heart rate, a microcontroller is programmed to count the pulses obtained, logs the information, Display the heart rate on a LCD, and send a text message should the heart rate goes beyond normal.

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The design is divided down to four different building blocks which are:

i. Pulse Detection

ii. Pulse Extraction

iii. Pulse Amplification

iv. Information broadcasting and logging

Pulse detection

There exist various ways by which the human pulse can be measured, of all the kinds, only ECG and PPG is suitable for our design because it can be made relatively smaller. But ECG requires at least two electrodes connected at differently positions on the body which can make it unsuitable for continuous uncontrolled measurement. So we are left with PPG.

Photoplethysmography is a non-invasive process of measuring changes in blood volume in a blood vessel. It consist of generally two types, which are the Trans missive and reflective. The pulse are detected by shining a beam of light on the surface of the skin, the reflected or transmitted light is picked up by an photodiode, Due to changes in the blood volume level as the heart pumps blood to the vessels, the light intensity falling on the photodiode changes in the same rhythm as the heart pulse. This makes the pulse detection stage.

Signal extraction

After the pulse has been detected by the varying amount of light reaching the photodiode, the light is converted to voltage; this voltage contains a lot of DC components which are not useful to the wanted measurement. Therefore, The DC component of the signal is filtered out by using blocking capacitor. The capacitor blocks the DC and allows only the AC component to move through it. So after this stage we have a raw and weak PPG signal to be further processed.

Pulse amplification

The PPG signal (Figure 1) obtained after extraction is very weak and unusable by the microcontroller. Therefore, an amplifier is employed to further boost the signal to an acceptable level. The first amplifier U1 involve a high pass filter made of C2 and R11 and a low pass filter made of C3 and R13. The high pass filter cut-off frequency is given by

$$f_0 = \frac{1}{2\pi RC} = \frac{1}{2 \times 3.142 \times 220000 \times 1 \times 10^{-6}}$$

$$f_0 = 0.72 Hz$$

The cut-off frequency of the low pass filter

$$f_0 = \frac{1}{2\pi RC} = \frac{1}{2 \times 3.142 \times 47000 \times 22 \times 10^{-6}}$$
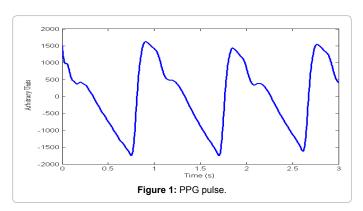
$$f_o = 6.5 Hz$$

The second amplifier U2 is a programmable gain amplifier, i.e., the gain of the amplifier can be controlled by the microcontroller. The signal is then converted to pulses which are then counted by the microcontroller.

Information broadcasting and logging

A program is written on the MCU to count the number of pulses for 15 s, it then multiply the number of pulses acquired within that timeframe by 4. This gives the heart rate. The value obtained and the

state of the pulse rate is displayed on a LCD simultaneously. Also the information is logged with timestamps on a memory card. A GSM/GPRS (Global System for Mobile Communication/General Packet Radio Service) module will also be installed with alongside the MCU. This is to call the attention of the medical personnel in charge to a patient by sending an SMS and alarm if the heart rate is not normal [12]. The message sent will contain, the patients Identification number, the state of the heart, the time of measurement and the actual heart rate as shown in Table 1.

The Simulation

The computer simulation for the heart rate monitor is done in

Figure 1: PPG pulse.

Patient Identification (name, room number, bed number etc.)		
Time	Date	Pulse rate
13:02:41	23/07/15	70
13:02:42	23/07/15	70
13:02:43	23/07/15	75
13:02:44	23/07/15	80
13:02:46	23/07/15	81
13:02:47	23/07/15	79
13:02:48	23/07/15	78
13:02:49	23/07/15	78
13:02:50	23/07/15	78
13:02:51	23/07/15	72
13:02:52	23/07/15	72
13:02:54	23/07/15	72
13:02:55	23/07/15	72
13:02:56	23/07/15	72
13:02:57	23/07/15	72
13:02:58	23/07/15	72
13:02:59	23/07/15	72
13:03:00	23/07/15	72
13:03:02	23/07/15	72
13:03:03	23/07/15	72
13:03:04	23/07/15	72
13:03:05	23/07/15	72
13:03:06	23/07/15	72
13:03:07	23/07/15	72
13:03:09	23/07/15	72
13:03:10	23/07/15	75
13:03:12	23/07/15	75
13:03:13	23/07/15	75
13:03:14	23/07/15	75
13:03:16	23/07/15	75

17:00:25	26/07/15	75
17:00:27	26/07/15	75
17:00:28	26/07/15	72
17:00:29	26/07/15	75
17:00:30	26/07/15	75
17:00:31	26/07/15	75
17:00:32	26/07/15	75
17:00:33	26/07/15	75
17:00:35	26/07/15	75
17:00:36	26/07/15	70
17:00:37	26/07/15	65
17:00:38	26/07/15	65
17:00:39	26/07/15	65
17:00:40	26/07/15	66
17:00:42	26/07/15	65
17:00:43	26/07/15	68
17:00:44	26/07/15	68
17:00:45	26/07/15	67
17:09:11	26/07/15	66
17:09:13	26/07/15	69
17:09:14	26/07/15	70
17:09:15	26/07/15	70
17:09:16	26/07/15	70
17:09:17	26/07/15	72
17:09:18	26/07/15	65
17:09:20	26/07/15	65
17:09:21	26/07/15	65
17:09:22	26/07/15	65
17:09:23	26/07/15	70
17:09:24	26/07/15	0
17:09:25	26/07/15	0
17:09:27	26/07/15	0

Table 1: Patient pulse rate measurement.

Proteus Professional Suite [8]. It is suitable for testing of mainly digital circuits and some analog ones before the real construction. The simulation window is shown in figures. Since the system is simulation, we assume the behavior of wireless connections in the real world. The transmitter (Figure 2) is made of the pulse detection stage, pulse amplification and signal extraction. The microcontroller employed – pic16f628a, counts the pulses and send it out via the Serial Peripheral Interface (SPI) terminal, the receiver circuit will read this transmission.
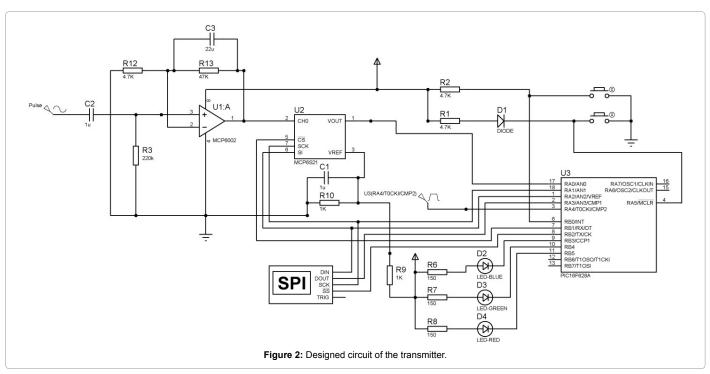
The receiver circuit (Figure 3) consists of the Microcontroller Unit MCU – PIC18F46K22, a multimedia card module, a real time chip, a SPI terminal for data reception, a LCD for display, a virtual terminal for assume behavior of the GSM feature. It takes the pulse transmitted via the SPI terminal; it logs and displays it simultaneously. If the heart rate is too high or low, it sends a message via the virtual terminal.
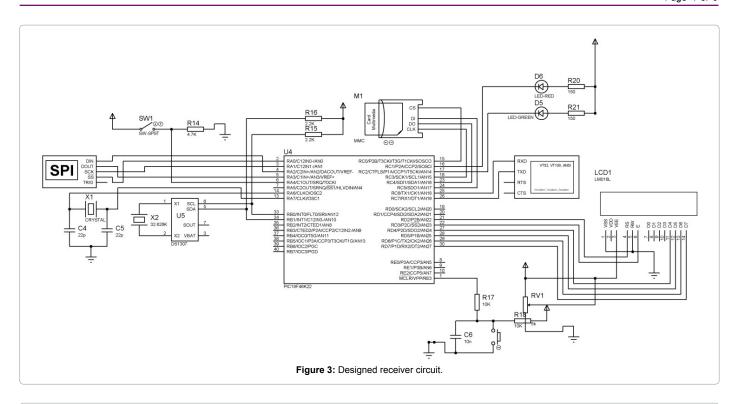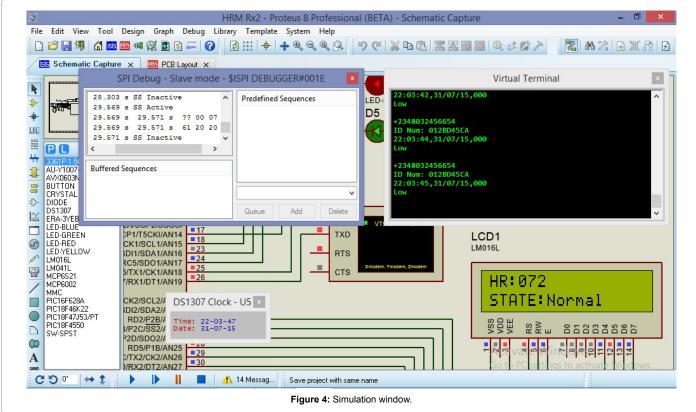
Results and Discussion

Figure 4 shows the system simulation, the pulse obtained from the Patient is amplified for easy analysis and broadcast using Figures 2 and 3. The essence is to detect pulse(s) that is too high and/or too low, such pulse will be broadcasted to the medical personnel through text messages, visual display and alarm, indicating the status of the pulse rate of the Patient in which the medical expert will be able to interpret and know the next step to take. The Patients pulse rate will be monitored constantly at regular intervals and log accordingly as shown in Table 1, the corresponding plot of heart rate against time is shown in Figure 5. This shows the level of pulse to be monitored, if the pulse is gradually going below or above the threshold, there will be an indicator/alarm and the information will be logged and Short Message Service (SMS) will also be sent to the appropriate quarters. The flowchart of the system procedure is shown in Figure 6.
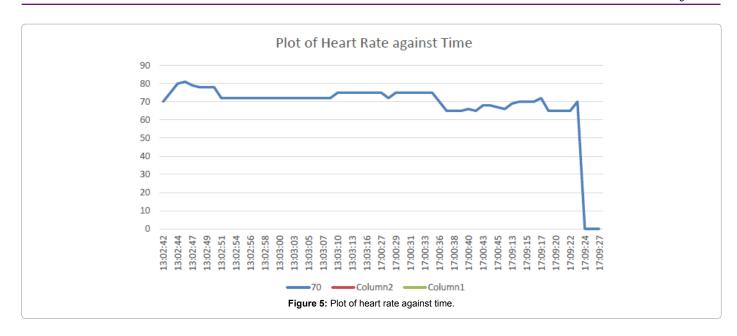
Conclusion

Design and simulation of a low signal wireless communication system has been presented. It's a one way communication system

Figure 2: Designed circuit of the transmitter.

Figure 3: Designed receiver circuit.
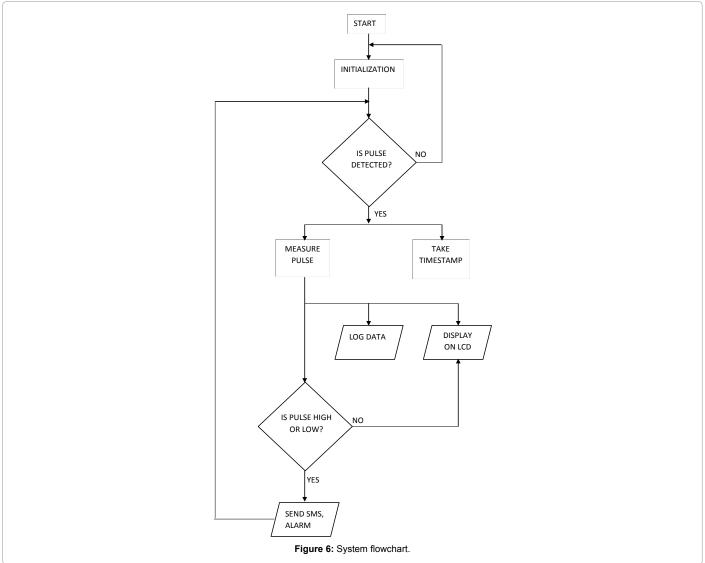

Figure 4: Simulation window.

that transmit low signal to readable outputs. The algorithm that log and broadcast the detected pulse signal and a microcontroller based pulse monitoring system were also presented. The system will prevent sudden death by timely response, Improve and provide an easy-access and convenient human health monitor solution that will bridge the gaps between patients and doctors/medical officers.

Figure 5: Plot of heart rate against time.

Figure 6: System flowchart.

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