DESIGN AND DEVELOPMENT OF ANDROID BASED WIRELESS HEART RATE AND BODY TEMPERATURE MONITORING SYSTEM

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Abstract - *This paper reports the design and development of an android based wireless heart rate and body temperature monitoring system remotely controlled via Bluetooth using microcontrollers on Arduino Uno modules. A heart rate sensor and body temperature sensor pick up signals from a patient's body using the Infra-red (IR) transmitter and receiver. The signals are being amplified and further processed by the Arduino Uno module and displayed on a liquid crystal display (LCD) on the device. Notably, the device is also controlled remotely from an android based mobile phone via Bluetooth communication. The mobile phone, in addition to the LCD, displays the results. The results have a minimum error of about ± 0.4°C for the temperature sensor reading and ± 4 for heart rate sensor reading compared to the conventional digital thermometer and manual pulse rate readings. Hence, there were no significant differences in the results.*

Keywords: Heartbeat Sensor, LM35, HC-05, ATmega328 microcontroller.

1. INTRODUCTION

One major challenge in our society today is human health. People spend lots of money to restore their health in the advent of challenges, but if detected early, many health problems can be managed and treated accordingly [1]. Heart rate and body temperature are vital signs that indicate the human body system's physiological condition and have the advantage of non-invasiveness. Meanwhile, heart-related problems such as acute myocardial infarction in younger patients are increasingly being diagnosed [2]. This may be because of atherosclerosis's high-risk factors [2], [3]. Vital signs are usually measured by health caregivers to determine initial abnormalities before prescribing major clinical investigations. The heart rate is a function of the heart's contraction and relaxation per unit time - typically per minute [4]. For normal human adolescents and above, the normal resting heart rate is around 72 beats per minute (bpm) depending on the gender; for babies, it is usually about 120 bpm, while older children have a heart rate around 90 bpm [5]. Bradycardia is a condition whereby the heart rate is lower than usual, while a higher than normal heart rate indicates a condition known as tachycardia. In like manner, normal body temperature also varies among individuals and fluctuates throughout the day, depending on environmental conditions. For instance, the lowest body temperature is recorded early in the morning and the highest in the early evening. However, the normal body temperature is about 37° C or 98.6 ° F but can be low as 36.1° C (97°F) in the early morning and high as 37.2° C (99° F); this can still be considered normal. Due to the significance and the contributions of vital signs measurement to initial diagnosis and monitoring of some health problems, an accurate, affordable, effective heart rate and body temperature measuring device is essential for acting promptly [6]. Remote patient monitoring is a technology that allows us to monitor the patient from a distance [7], thereby increasing patients' access to health care facilities at a reduced cost. This technology also increases efficiency and reliability by reducing consultation time with healthcare givers within healthcare [4].

This work aims to provide a portable, affordable, and efficient way of monitoring heart rate and body temperature at the same time. It will also provide easy access to health caregivers using Android phone-based wireless communication (Bluetooth) with a unique application installed. This will help monitor patients' vital signs, especially in the intensive care unit (ICU), ward, accident, and emergency (A&E). Furthermore, the results are displayed on a liquid crystal display (LC D) screen and the doctor's mobile phone.

2. Hardware Components of the Design

The system design mainly consists of the following components, as illustrated in Fig 1: Heartbeat sensor, Temperature Sensor (LM35), Bluetooth module (HC-05), Arduino ATmega328 microcontroller, LCD, Power Supply.

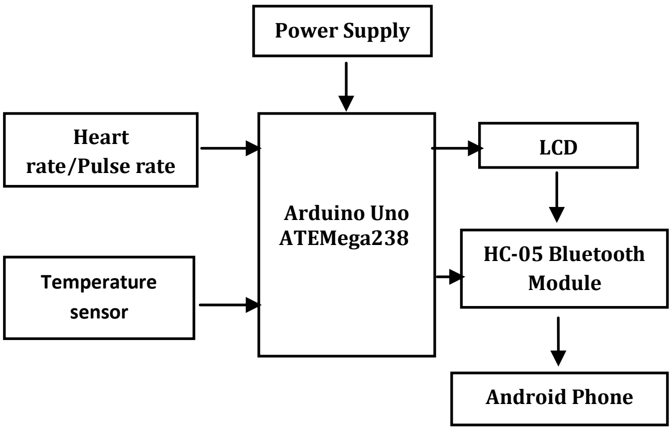

Fig 1: System block diagram of the Heartrate and body temperature monitoring device

2.1 Heartbeat Sensor

The Heartbeat sensor (Fig. 2) is designed to give a digital output when a finger is placed on it based on the principle of light modulation by blood flow through the finger at each pulse. The sensor consists of a super bright green LED and a light detector. The LED must be super bright as the maximum light must pass through the finger and be detected by the sensor. The detector signals vary with each heart pulse. This variation is converted to an electrical pulse, amplified, and triggered through an amplifier that outputs a +5V logic level signal. The optical sensor and the combination of the infrared light-emitting diode, also known as IR LED and IR photodiode, senses the patient's heartbeat and finally produces a weak output signal.

Fig 2. A photographic image of the pulse sensor

2.2 Beer-Lambert law of transmittance

The Beer-Lambert law illustrates the linear relationship between absorbance and concentration of an absorbing species. It states that 'the absorbance of a material sample is directly proportional to its thickness.'

The mathematical expression is as follow:
$I = I_o e^{-\sigma Cx} = Ie^{-\mu x}$

Light intensity decreases exponentially with the thickness of the material, and this is referred to as linear attenuation, usually expressed in Cm^{-1}

μ is a function of wavelength $\Longrightarrow \mu = \mu(\lambda)$

Beer-Lambert Law is also a function of λ, i.e.

$$I(\lambda) = I_o(\lambda) e^{-\mu(\lambda)x}$$

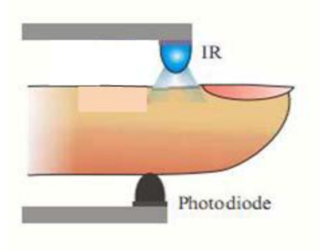

Fig 3. An illustration of Beer-Lambert's law as applicable to the pulse sensor

Transmittance is defined as $T = \frac{I(\lambda)}{I_o(\lambda)}$

A quantity called *absorbance 'A'* is defined as

$$A = log\left[\frac{I(\lambda)}{I_o(\lambda)}\right] = log\left[\frac{I(\lambda)}{I_o(\lambda)e^{-\mu x}}\right] = \log\left(e^{-\mu x}\right)$$

$$A = \mu x \log(e) = 0.4343\mu x$$

This definition includes both absorption and scattering

A further definition is extinction coefficient ε
$\varepsilon = 0.4343\sigma$

So,

$$A = \varepsilon Cx$$

2.3 Temperature sensor (LM35)

The temperature sensor was designed to detect any change in temperature and produce a digital output. The LM35 series are precision integrated-circuit (ICs) temperature sensor devices with an output voltage linearly proportional to the Centigrade temperature.

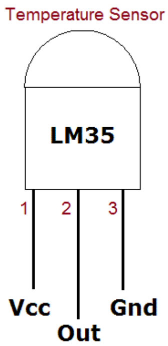

Fig 4. A schematic of the LM35 Temperature sensor

It does not require external calibration or trimming to provide typical accuracies of ±¼ °C at room temperature and ±¾ °C over a full temperature range from −55°C to 150°C. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device make it easy to interfere with the readout or control circuitry. The device uses a single power supply or plus and minus supply. Since the LM35 device draws only 60 µA from the supply, it has a very low self-heating capacity of less than 0.1 °C in still air.

2.4 Bluetooth Module (HC-05)

HC-05 Bluetooth module is an easy to use SPP (Serial Port Protocol) module designed for transparent wireless serial connection setup. Its communication is through serial communication, which makes an interface with the controller or PC HC-05. Bluetooth module and provides switching mode between master and slave mode, which means using either receiving or transmitting data. The serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with a complete 2.4GHz radio transceiver and baseband. It uses the CSR BlueCore 04-External single-chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature) [5].

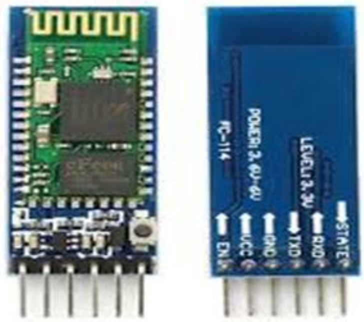

Fig 5. A photographic image of the Bluetooth module (HC-05) after purchase

2.5 Liquid Crystal Display (LCD) 16x2

A 16x2 LCD was used as a display unit to view the result of the measured data. The 16x2 LCDs display two lines of 16 characters each. It also has two registers, which are Command and Data. The command register usually stores command instructions specific to the LCD. A command is an instruction given to LCD to execute a predefined task such as initialization, clear the screen (CLS), setting the cursor position, controlling the display, etc. The data register stores the data to be displayed on the LCD. The character's ASCII value is displayed on the LCD, consisting of tiny rod-shaped molecules sandwiched between a flat piece of glass and an opaque substrate. These rod-shaped molecules between the plates align into two different physical positions based on the electric charge applied to them. When an electric charge is applied, they form an alignment that blocks the light entering through them. But, when no charge is applied, they are transparent. Light passing through causes the desired images to appear [6]. This is the basic concept behind LCDs, and they are widely used because of their benefits over other display technologies. They are thin and flat and consume minimal power compared to LED displays and cathode ray tubes (CRTs).

Fig 6. Liquid Crystal Display showing the programmed display after switching it on.

2.6 ATmega328 Arduino microcontroller

The system controller is built around a standard microcontroller ATmega 328. The Atmel AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), enabling two independent registers to be accessed in a single instruction executed clock wisely. Arduino can sense the environment by receiving input from various sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or communicate with software on running on a computer (e.g., Flash, Processing, MaxMSP). It has 14 digital input/output pins (of which six can be used as PWM outputs), six analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

3. TESTS AND RESULTS

The whole circuit was built and tested for a long time and was found to work successfully with minimal error, which shows high reliability. The device was tested on different patients and produced the desired results. The data measured was displayed on the device display unit (LCD), and the data was accessible on an android phone using the developed application, as shown in figure 5.

Fig 7a. LCD display of Heartrate and Body temperature on the fabricated device

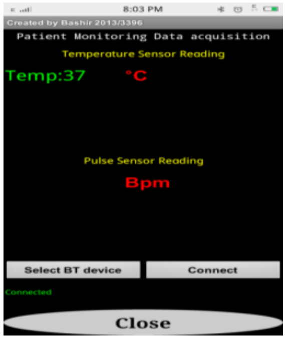

Fig 7b. Display of body temperature and heart rate on android mobile phone transmitted from the device.

This indicates that the device meets the design specifications and objectives required to design and construct an electronic health monitoring system. Table 1 below shows the readings obtained while measuring ten different volunteers' body temperature and heart rate. Compared with the readings obtained from the conventional digital thermometer and manual heart rate readings, we found that the developed device has

Table 1.

	Body Temperature(°C)		Heart Rate(bpm)	
Subjects	Digital Thermometer	Project	Manual Reading	Project
1	35.2	35	66	68
2	34.8	35	58	62
3	36.0	36	57	66
4	35.5	36	71	77
5	35.8	36	65	69
6	36.2	36	70	71
7	36.7	37	66	63
8	35.6	36	59	70
9	34.8	35	74	69
10	36.6	36	68	74

4. CONCLUSIONS

In conclusion, this work led to the development of a system that measures patients' heartbeat and temperature and transmits it to a remote end via a Bluetooth module and a microcontroller at a reasonable cost with significant effect. It utilized biotelemetry system technology, which enabled monitoring patients' vitals non-invasively and continuously from a distance. It can lead to increased access to health care delivery. The device uses two sensors for measuring the heartbeat and temperature of a body. The microcontroller controls these sensors. Optical technology was used to detect blood flow through the finger, and LM35 was used as a temperature sensor in this project, which measures the body's temperature. The heartbeat and temperature are calculated every minute and displayed on LCD. The results are transferred via Bluetooth module and sent to an android phone. Finally, the data is displayed on the mobile screen using a unique application at the receiving end where the specialist or physician can analyze the data and will be able to provide the necessary assistance. The developed system is reliable, portable, affordable, and user friendly.

REFERENCES

[1] W. M. Jubadi and S. F. A. M. Sahak, “Heartbeat monitoring alert via SMS,” in 2009 IEEE Symposium on Industrial Electronics Applications, Oct. 2009, vol. 1, pp. 1–5, doi: 10.1109/ISIEA.2009.5356491.

[2] A. Cengel and A. Tanindi, “Myocardial infarction in the young,” Journal of Postgraduate Medicine, vol. 55, no. 4, p. 305, Oct. 2009, doi: 10.4103/0022-3859.58944.

[3] J. B. Rubin and W. B. Borden, “Coronary Heart Disease in Young Adults,” Current Atherosclerosis Reports, vol. 14, no. 2, pp. 140–149, Apr. 2012, doi: 10.1007/s11883-012-0226-3.

[4] V. R. Parihar, A. Y. Tonge, and P. D. Ganorkar, “Heartbeat and Temperature Monitoring System for Remote Patients using Arduino,” International Journal of Advanced Engineering Research and Science, vol. 4, no. 5, pp. 55–58, 2017, doi: 10.22161/ijaers.4.5.10.

[5] Y. Ostchega, K. S. Porter, J. Hughes, C. F. Dillon, and T. Nwankwo, “Resting pulse rate reference data for children, adolescents, and adults: United States, 1999-2008,” Natl Health Stat Report, no. 41, pp. 1–16, Aug. 2011.

[6] H. Jaiswal, M. Safwan, and H. Rajput, “HEALTH MONITORING SYSTEM BASED ON GSM,” vol. 05, no. 03, p. 3.

[7] Q. Hou, “Research and implementation of remote heart rate monitoring system based on GSM and MCU,” The 2nd International Conference on Information Science and Engineering, 2010, doi: 10.1109/ICISE.2010.5689352.