

Non-invasive Optical Blood Pressure Sensing and Measurement

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Abstract: The paper presents design and development of optical blood pressure sensing kit based on Microcontroller and Bluetooth transmission. Blood pressure is one of the important vital signs that need to be monitored for personal healthcare. The aim of this project is to construct an optical system and to monitor blood pressure continuously without use of any cuff or supervision. It is a monitoring system that uses an IR light source and a luminosity sensor to measure the blood pressure. The optical pulsatile method of blood pressure measurement is used to gather pulse data obtained from various parts of body. Blood pressure readings are calculated with the help of developed algorithm and transmitted via Bluetooth module to the computer. Numerical reading values of systolic and diastolic blood pressure are recorded and displayed on the computer.

Keywords —Blood pressure, optical, IR, PWTT, Bluetooth, monitoring system

I. INTRODUCTION

Blood pressure (BP) is one of the health parameters that affect us or it can be said that it is a sign of healthiness of a person. Measurement of blood pressure is significant for detecting hypertension, which is strongly related to cerebral strokes and heart failure. BP if not monitored, may lead to blood vessel damage, stroke, heart or kidney failure. Also, a continuous blood pressure monitoring is required for patients of diabetes and hypertension. Fig.1 gives a range value of blood pressure, and their classification.

In India, every government allopathic doctor serves a population of over 11,000 people i.e. their percentage is hardly 0.009%, with Bihar and Maharashtra having the worst ratios. Yet in other developed countries such as Norway this metric goes up to 4.16%. This disparity between the number of people and the available health workers limit the effectiveness of the healthcare system.

Blood Pressure Category	Systolic (mm Hg)	Diastolic (mm Hg)
Normal	less than 120	less than 80
Prehypertension	120-139	80-89
Hypertension (Stage 1)	140-159	90-99
Hypertension (Stage 2)	160 or higher	100 or higher
Hypertensive Crisis	Higher than 180	Higher than 110

Figure 1 Classification of Blood Pressure readings

As the costs of medical treatments and amount of money spent towards treatment increase, the quality of treatments also increases, but the number of people who can afford such healthcare services decreases.

Most non-invasive BP measuring methods are based on oscillometric method, which are widely accepted and used worldwide but they restrict patients' mobility. They require uncomfortable cuffs and are not suitable for home-care and continuous long term monitoring applications. Continuous monitoring of BP can be done hassle free by an accurate and inexpensive device independent of patient's movement and which does not require supervision of a trained person or any physician.

These requirements can be satisfied using a monitoring system that uses an IR light source and a sensor to measure the blood pressure. The optical pulsatile method of blood pressure measurement is used to gather pulse data obtained from various parts of body. This data collected can be used to track one's health, prevent illness and can be sent to doctors for analysis using an App. The main advantage of this system is its portability and ease of use after learning some basic instructions. Readings taken by this system are designed to match readings taken by standard instruments with some minimal amount of deviation. By providing this data to both patients and doctors, we hope to facilitate and augment the throughput of doctors' efforts.

II. LITERATURE REVIEW

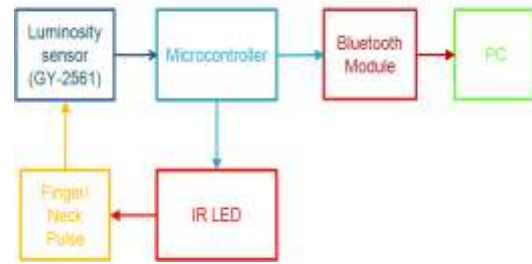
A. The report of University of Maryland states that, health is multi-factorial and complex; influenced by several things including our age, family history, employment and living conditions. Today's hectic lifestyle, lack of

physical activity, obesity, stress, smoking, excess consumption of salt and alcohol lead to hypertension. High blood pressure is a silent killer, because it produces no symptoms until vital organs like heart, brain and kidneys are damaged.[1]

- B. There are various methods to measure the blood pressure. The standard instrument used to measure blood pressure is called a sphygmomanometer. [2]
- C. The sphygmomanometer is not a seemly device for household monitoring of the blood pressure; as it requires someone's help to place the cuff and pump the meter. It may not be suitable for continuous monitoring as it restricts patient mobility. Continuous measurement of BP for home care requires an inexpensive method that is independent from patient movement and does not require continuous care by a practitioner. [3]
- D. Abu Zneid, et al [4] designed a system using Photoelectric Plethysmography (PPG) technique, a simple non-invasive method to measure relative changes in pulse blood volume in the tissues. It uses the reflectance sensor that contained infrared light source. The light source illuminates a part of tissue like fingertip, toe, ear lobe and photo detector receives the returning light. The waveform obtained from this technique represents the blood volume pulse which can be used to measure blood pressure. Two stage bandpass filters are used to remove DC components from the signal detected by light sensor and then amplified. The systolic and diastolic readings of blood pressure were displayed on the LCD.
- E. Vinee Sinha, et al [5] developed a blood pressure monitor using oscillometric, impedance plethysmography (IPG), Photoplethysmographic (PPG) and Electrocardiographic (ECG) modules, oscillometric module facilitate spot or periodic measurement of blood pressure whereas other modules yield various hemodynamic parameters to obtain beat to beat pressure. Linear multivariate equations have been used for this purpose.
- F. Pulse wave transit time [PWTT] parameter was used to indicate change in blood pressure. PWTT is measured by continuous monitoring of ECG and pulse wave. The measurement device for detecting pulse wave consists of infrared LED for transmitted light illumination, pin diode as detector, amplifier and filter. [6]

III. BLOCK DIAGRAM

The block diagram of the proposed idea is as shown in figure 2.



A. Microcontroller (ATmega328):

Figure 2. Block Diagram

Arduino Nano is a small, complete, breadboard friendly board based on ATmega328, a high-performance Atmel 8-bit AVR RISC-based microcontroller and it has 32KB ISP flash memory onboard with read-while-write capabilities. For other storage, it has 1KB EEPROM and 2KB SRAM. It has 23 GPIO lines, 32 working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented I2C interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The board operates between 1.8-5.5 volts.

B. TIL32 (Infrared LED):

TIL32 is a low cost 3mm IR LED package. It has wavelength of 940 nm. Maximum forward voltage for TIL32 is 1.6V and maximum forward current is 20mA.

C. GY2561 (Luminosity Sensor):

The TSL2561 is a light-to-digital converter that transforms light intensity to a digital signal output capable of direct I2C interface. It combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of



providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel. This digital output can be input to a

microprocessor where illuminance (ambient light level) in lux is derived using an empirical formula to approximate the human eye response. The TSL2561 device supports a traditional level style interrupt that remains asserted until the firmware clears it.



Figure 4. TSL2561 Board

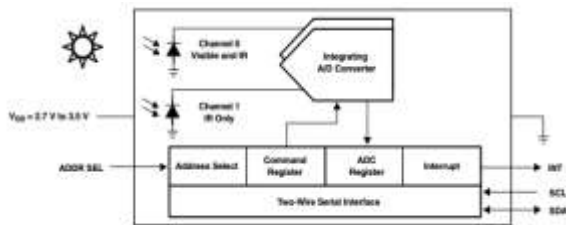


Figure 5. TSL2561 Functional Diagram

D. HC-05 (Bluetooth Module):

HC-05 is a Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH(Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm.

IV. METHODOLOGY

- A. The Arduino Nano excites IR LED for light emission. The light reflected from blood is sensed by the GY2561 sensor.
- B. 5 consecutive readings taken from sensor are stored in 5 variables and their mean is calculated.
- C. The mean value is divided by some factor to obtain optical M.A.P. (Mean Arterial Pressure) value.
- D. M.A.P. is defined as the average blood pressure in a person’s arteries during one cardiac cycle. [7]

$$M.A.P. = (systolic BP \div 3) + 2(Diastolic BP \div 3)$$

- E. M.A.P. is considered a better indicator of perfusion to vital organs than systolic

blood pressure.

- F. Systolic and Diastolic M.A.P. values are derived from optical M.A.P. and sent to PC or mobile via Bluetooth Module.

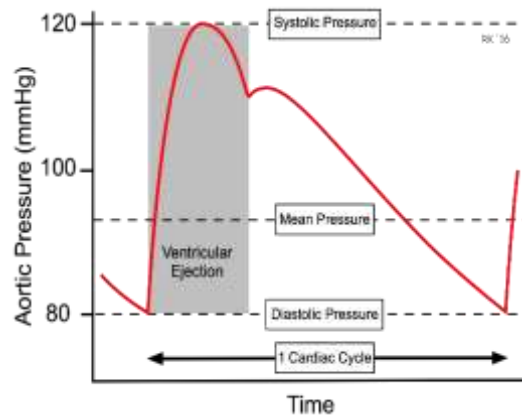


Figure 6. Relation between M.A.P. and BP readings

V. SOFTWARE SYSTEM DESIGN

A. Arduino IDE

The Arduino Integrated Development Environment (IDE) or Arduino Software contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them. Programs written using Arduino software are called ‘sketches’. These sketches are saved with an extension .ino. This editor allows writing, reviewing, and compiling the desired code. Once the code is compiled, it is uploaded to the board using USB connector. In this project, Arduino IDE is used extensively. A program that is used to excite IR LED and get value from light sensor is written and compiled in Arduino IDE. The code to read and send data via Bluetooth is also written in Arduino.

B. Processing IDE:

The Processing IDE or Environment includes an intuitive text editor, a compiler, and a display window. It enables the creation of software within a carefully designed set of constraints. In Processing, a computer program is called a sketch. Sketches can draw two- and three-dimensional graphics.

The purpose of using Processing in this project is that it will receive the serial data from the microcontroller via Bluetooth and it will plot the data graphically on the computer. In this way, understanding the output i.e. blood pressure values will be easier for people with zero technical skills and it will enhance the usability of this system.

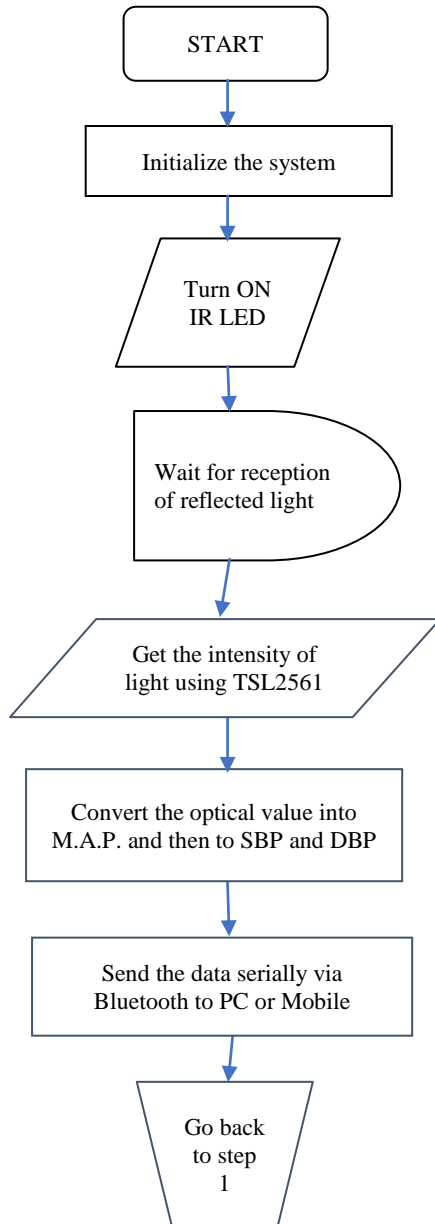


Figure 7. Flowchart of the System

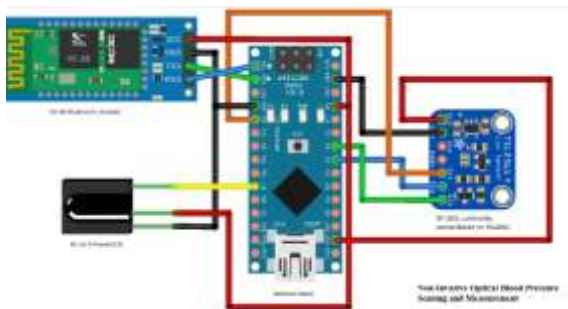


Figure 8. Circuit Diagram

VI. RESULTS

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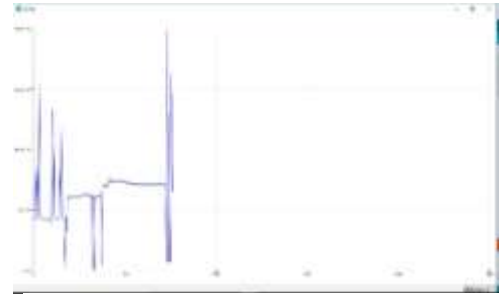


Figure 9. Output of Light sensor plotted on serial monitor



Figure 10 Plot of Mean Arterial Pressure readings taken by Sphygmomanometer Vs the System

SBP	DBP	MAP	Optical Reading	Optical MAP
94	74	80.66	4735	86.88
102	75	84	4765.33	87.43
114	88	96.66	5018	92.07
128	82	97.33	5246.66	96.26

Figure 11. Comparison of Readings Taken from Sphygmomanometer and the System

SBP: Systolic Blood Pressure
 DBP: Diastolic Blood Pressure
 MAP: Mean Arterial Pressure
 Optical reading: Mean reading from sensor
 Optical MAP: Optical reading/MAP factor

VIII. CONCLUSION

This proposed idea aims at reducing the hassle that a patient faces in blood pressure measurement. The main objective is to reduce the need of some doctor or trained personnel in the process of blood pressure measurement by means of a relatively inexpensive yet user friendly device. It is easy to store data which can be accessed by doctors for better analysis.

REFERENCES

- [1] University of Maryland Health Center.
<http://umm.edu/health/medical/reports/articles/high-blood-pressure>
- [2] Sphygmomanometer:
<https://en.wikipedia.org/wiki/Sphygmomanometer>
- [3] Photoelectric Plethysmography (PPG)
<https://en.wikipedia.org/wiki/Photoplethysmogram>
- [4] Basem Abu Zneid, Mohammed Al-zidi, Tareq Al-Kharazi, “Non-invasive Blood Pressure Remote Monitoring Instrument Based Microcontroller”, IEEE Region 10 Symposium, April 2014, Kuala Lumpur, Malaysia.
- [5] Vinee Sinha, R.K. Jain, G.D. Jindal, C.K. Pithwa, CD. Kapse, BhagyashreeSarade, “Non-Invasive Blood Pressure Monitor: Beat to Beat”, TECHNOLOGY DEVELOPMENT ARTICLE, BARC Newsletter 62 , Issue no. 328 , OCT 2012.
- [6] Gu-Yung Jeong, Kee-Ho Yu, Nam-Gyun Kim, “Continuous Blood Pressure Monitoring using Pulse Wave Transit Time.”, ICCAS 2005, KINTEX, Gyeonggi-Do, Korea.
- [7] <http://www.nursingcenter.com>