Development of Optimal Photosensors Based Heart Pulse Detector

N. M. Z. Hashim*[1], N. A. Ali*[2], A. Salleh*3, A. S. Ja'afar*4, N. A. Z. Abidin*[5]

[*] Faculty of Electronics & Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*[1]nikzarifie@utem.edu.my, *[2]alisa@utem.edu.my, *[3]azahari@utem.edu.my, *[4]shukur@utem.edu.my, *[5]naza_alin@yahoo.com

***Abstract*— The development of heart pulse instruments rapidly fast in market since 21st century. However, the heart pulse detector is expensive due to the complicated system and it is used widely only in hospitals and clinics. The project is targeting to develop a significant photosensor to the medical fields that is easy to use and monitor their health by the user everywhere. The other target is to develop a comfortable instrument, reliable, accurate result to develop of heart pulse using low cost photosensors. This project involved both hardware and software with related to signal processing, mathematical, computational, formalisms, modeling techniques for transforming, transmitting and also for analog or digital signal. This project also used Peripheral Interface Controller (PIC) 16F877A microcontroller as the main function to control other elements. Result showed this project functioned smoothly and successfully with overall objectives were achieved. Apart from that, this project give good services for people to monitor their heart condition form time to time. In the future, wireless connection e.g. Global System for Mobile Communications (GSM) and Zigbee would be developed to make the system more reliable to the current world. Furthermore, the system should be compatible to various environments such as Android based OS so that it can be controlled away from the original location.**

Keyword- Colour Wavelength, Heart Rate, Photosensor, PIC 16F877A Microcontroller, Sensor

I. INTRODUCTION

There are many heart pulse instruments in the market nowadays. However the heart pulse detector is expensive due to the system is complicated and it widely used in hospitals and clinics. The percentages of people who have the medical equipment at home are very less. There are many advantages of using medical instrument at home e.g. it will allow the user to monitor their health constantly without going to the clinic for a checkup, especially for the elders. The project consists of a photosensor which is used to measure the pulse by measuring the change in blood flow. The research concern is to review to the best photo-sensor such as Light Emitting Diode (LED), Infrared (IR), and Light Dependent Resistor (LDR), need to use in order to produce significant heart pulse signal detected from human finger. The wide significant between the wavelength is the best of photosensor. Other than that, this project also used microcontroller where the microcontroller will be programmed to calculate the heart rate and control the LCD display to indicate the pulse rate. The heart pulse will be display on a LCD display. Several literature reviews were referred in completing this project.

N. I. Ramli et al [1] designed a simple and low cost microcontroller [2] based heart rate measuring device with Liquid Crystal Display (LCD) output. The pulse of heart rate will be measured from the finger using optical sensors, and displayed on the LCD. The device consists of an infrared transmitter Light Emitting Diode (LED) and an infrared sensor phototransistor. The transmitter-sensor pair is clipped on one of the fingers of the subject. LED will emit infrared light to the finger, the phototransistor then will detect this light, and then the changes of the blood volume will be measured. After that, the microcontroller will count the number of pulses over a fixed time and thus obtains the heart rate.

Research from the articles by K. Padmanabhan [3] measured either by the ECG waveform or by the blood flow in to the finger (pulse method). These heartbeats are counted by using clipping sensor technique, which a small light source on one side of the finger and the other side will observe. The microcontroller IC AT89C2051 (IC2) is used as the hardware in the project. The software will be written in assembly language and assemble using ASM51 co-assemble.

Research by Yun-Thai Li show there were many methods of monitoring heart rate and level of oxygen in the blood system in human body such as using pulse Oximeter [4]. This device uses optical sensor and LEDs emit light at different wavelength. The LED light will emit through a finger and then the transmitted light is detected by using optical sensor. The value of oxygen saturation level can be obtained based on the principle of oxygenated hemoglobin which having a higher absorption coefficient for infrared light and then deoxygenated hemoglobin will observe more red light.

In other search from M. Laghrouche et al indicated that the Wireless pressure pulse system consists of a transmitter, receiver, and a PC, which are used to record online data. The device measured and displayed the

pulse rate and the saturation of hemoglobin in arterial blood. This saturation of hemoglobin is a measure of the average amount of oxygen bound to each hemoglobin molecule. Light is emit by a LED and transmitted through the artery and the resistance of the photoresistor is determined by the amount of light reaching it. With each contraction of the heart, blood is force to the extremities and the amount of blood in the finger increases.

Widdop designed a low cost design of heart beat monitoring using reflectance mode photoplethysmography (PPG) [6] to produce the pulse signal from the finger, which is equivalent to the heart, beat. The device consists of several stages to amplify, filter and digitize the extracted heartbeat and interfacing technique via parallel port to computer is use to calculate and display the heart rate. The device will be simple to use and cost effective.

The reflectance mode PPG used super bright LED and the Light Dependant Resistor (LDR) which placed side by side on the surface of the finger. This PPG Mode allowed red light with viewing angle of 15° (625nm, 20000mcd) to pass through the finger and the transmitted light is detected by an LDR [7], [8]. The LDR (photoconductive cell ORP12) is a photoresistor made up with material called cadmium sulfide (CdS) with its resistance decreases when the intensity of the light detected increases. This type of sensor is used to measure arterial blood volume from many surfaces of the body.

Based on all these review, there are two methods can be performed to measure the blood flow in body either transmission or reflection. After making the classification and study, the technique of transmittance is better because the amount of light transmitted through the tissues is greater than reflectance. There are some improvements to the system as to highlight our contribution to this problem. The improvements of the project are LCD will display the counter heartbeat in unit beat per minute, a specific testing will be shown to prove that each photosensor has differences significant wavelength, the device will consist of hardware and electronic circuit system by using microcontroller and the device will be build with a small size and easy to use for non professional user. Thus, the objectives of this project are to develop simple photosensors that is easy to use and make sure each person can monitor their health everywhere and to develop a comfortable instrument, reliable, accurate result to develop of heart pulse using a low cost photosensors.

II. MATERIALS AND METHODS

Firstly, all related research to this project had been review. All the background study of this project is reviewed and the knowledge and theoretical issues behind this project needs to be determined. The problem statements from all these literature review are listed and then the objectives of this project are determined. After that, the circuit are tested by using an oscilloscope which to view the signal output from the circuit. The microcontroller will be used for this system to control the entire components as the hardware in this project. The flowchart of this project system is shows in Fig.1 below.

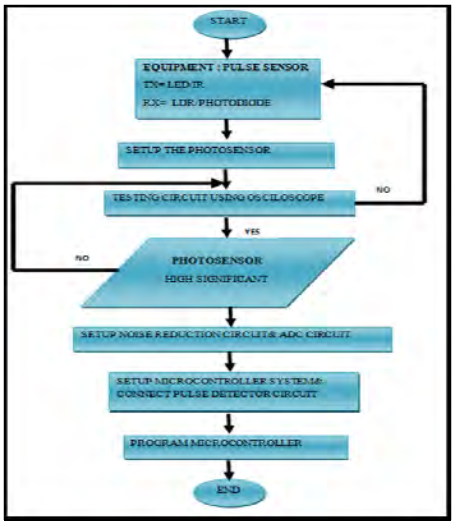


Fig. 1 Flowchart of the project

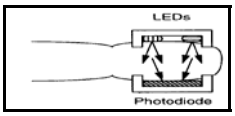
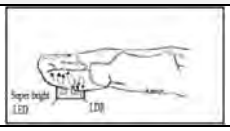
A. Hardware Development

To ensure the right electronic components selected, the process flow of the project must be in detail.

1. Finger probe positioning

To measure the volume of blood in the human body, the Photoplethysmographic technique had been chosen because the unique criteria which need two wavelength that provide from the optical sensor of non-aversive pulse Oximeter. There are two method to perform heartbeat measurement either transmission or reflection modes.

TABLE 1
Finger probe positioning criteria

Criteria	Transmission mode	Reflectance mode
Figure		
Description	• The sensor usually applied at finger ,earlobe, foot • The sensor will place on opposite • The photodiode will detect transmitted	• The sensor usually will put side-by side. • The photodiode will detect reflected instead of light transmission
Advantage	• Light detected area is wide. • The amount of light transmitted through the tissues is greater than the amount of light. • The signal great quality if the strong light intensity is concern to the area.	• Suitable for multiple location of the body.
Dis-advantage	• The signal only depends on the intensity of light. • only able to applied in peripheral areas such as fingers, ear lobes, fingers (adults) and the foot or palm (baby)	• The signal not greatly quality in a strong of light intensity through the finger

2. Microcontroller

PIC 16F877A microcontroller is used as hardware in this project [9], [10], [11]. To enable the microcontroller operate , seven pins need to be connected the PIC which one pin from power supply, four pins from reset pin and another two pins from oscillator. The Fig. 2 below shows the schematics of PIC 16F877A microcontroller.

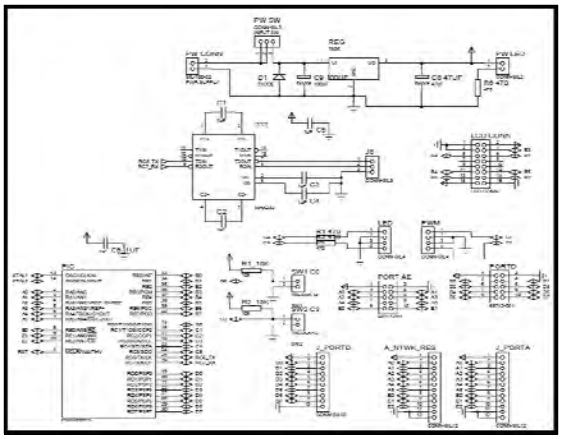


Fig. 2 Schematic PIC microcontroller

3. Circuit Heartbeat Sensor

Fig 3 is a circuit for heartbeat sensor. The signal from the finger is converting into voltage and the signal will amplify by using operational amplifier IC LM358. Signal from the finger will enter to non-inverting input (pin 3). The output from pin 3 will enter to input pin 5 which act for squaring and amplification. The pin 7 of LM358 provided the heartbeat signal and as an input for the PIC .the variable resistance (R13) is used as a sensitivity and R14 as a trigger level setting of the circuit.

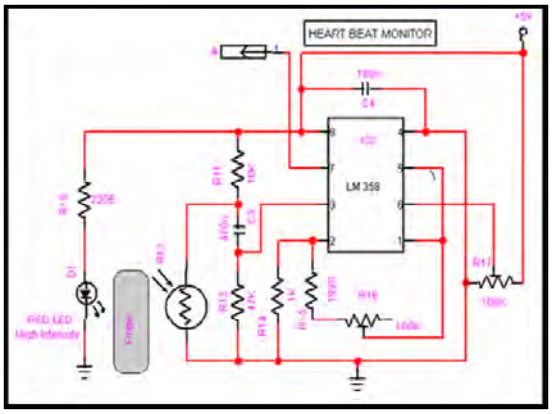


Fig. 3 Circuit for heartbeat sensor

B. Software Development

This project used PIC programming for the software development where the whole program is writing by using CCS compiler and each circuit was drawn at Proteus software. The program will determine the heart rate where. The total of heartbeat can be calculates by using the equation below:

$$\text{Heart Rate (HR)} = 60/RR \quad (1)$$

where RR is determine as the peak of two signals.

1. CCS compiler

The CCS C compiler is a one of the software that has been use in this project, which it is a compiler for Microchip. This software provides a library of built in function, preprocessor commands and easy to used for a beginner programmer. Otherwise, the real time clock, A/D converter, LCD, easy migration from 8-bit processors up to 24-bit processor and many advantages are to the CCS C compiler.

III. RESULTS/FINDINGS AND DISCUSSION

A simulation is very important to make sure each circuit or parts are doing right. It is a first stage before to make any action. If there is any problem related to the circuit it can be detected earlier before the etching stage completed.

A. Simulation of circuit PIC 16F877A and LCD

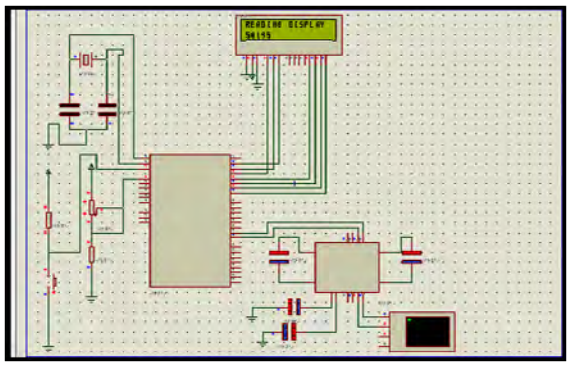


Fig. 4 Simulation of circuit PIC 16f877A and LCD

Fig. 4 shows the connection between the LCD and the microcontroller PIC16f877A. This microcontroller provide 5 port which are PORT A = 6 bit, PORT B =, PORT C, and POTRT D = 8 bits while the PORT E only 3bits. Therefore, the LCD connection uses a PORT B.

B. Simulation of circuit LM358

Fig. 5 shows the connection circuit LM358. This device consists of two stages of amplifier. The first stage of this amplifier is non-inverting amplifier where it can produce a high gain of this amplifier s like a comparator. The input signal at pin 5 provide through the output pin 1 where it will compared by using the variable resistor. Next, the output voltage from stage 1 will be the input for the second amplifier. Finally, the result will trigger at output pin 7. The table below shows the output waveform from the LM358.

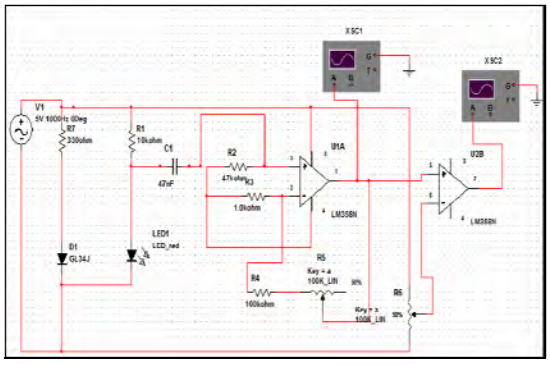


Fig. 5 Simulation of circuit LM358

C. Simulation of circuit power supply

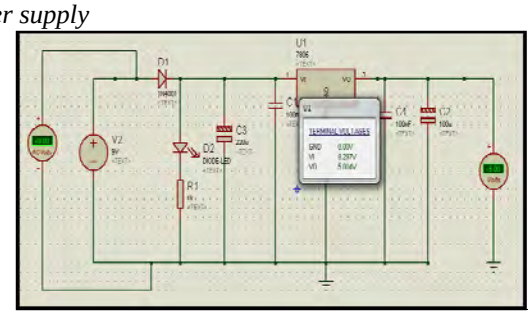


Fig. 6 Power supply simulation

Fig. 6 shows the simulation of the power supply circuit for the project .The supply 9V DC convert to 5V DC by using voltage regulator LM7805. The 7805 voltage regulator comes from 78xx family where there are very popular for many electronic circuits application. 7805 regulator IC have three terminal positive voltages, which pin 1 as input, pin 2 as ground and pin 3 as output. This voltage regulator called as terminal positive voltage because it designed to produce a voltage that is positive relative to a common ground. The simulation approved which the output display is 5 V.

Based on the Fig. 6, the diode IN4007 which label as D1 roles as protection to the circuit. The diode will be protecting the circuit, when there are a problem that will cause of wrong polarity and unregulated power supply. Meanwhile, the function of the capacitor is different between after and before flowing through the regulator. The capacitor C1 and C3 are functioning to stabilize the value of voltage at the input side. Meanwhile, C4 and C5 are functioning to stabilize the output voltage value. Otherwise, the LED is use to indicate the status of power supply on the circuit. The resistor (R1) is use to avoid the overload current flow through the LED.

D. Test LDR sensitivity

In addition, some experiment of the condition sensitivity of the sensor when having obstacles also had been test. The testing is important to obtain what will be happens when the finger is between the sensors. This experiment conducted using some type of paper color, red, black and gray color. There had been test with two condition either when the paper was on the photosensor as an obstacles or there are no obstacles, the value on the voltage is different. Experiment was carrying out using several pairs of sensors. Table 2 shows the result using various pair of sensor and Table 3 shows the result after testing using three types of paper colors.

TABLE 2
Sample Measurement Result from Various Types of LED And IR Sensor

TX	RX	Normal Condition	Obstacles
RED LED (SMALL)	LDR	2.47	1.98
1R (BLUE)	IR	0.17	3.10
LED(BLUE)	IR	1.72	2.7
LED ORANGE + WHITE	IR	1.2	2.63
IR (WHITE)	1R	1.22	3.32
IR (PURPLE)	IR	0.85	3.33

TABLE 3
Test Using Three Types of Paper Colour

Condition	Measurement
When the obstacles is grey color	1.12V
When the obstacles is black color	1.11V
When the obstacles is red color	1.02V

From the result, it shows that the lowest output voltage is when the obstacle in red colour. Meanwhile, the highest output voltage is obtain when the obstacle in the grey colour. This result might be effect by visible light electromagnetic spectrum. The red colour show the shortest wavelength compares both grey and black colour.

E. Final Product

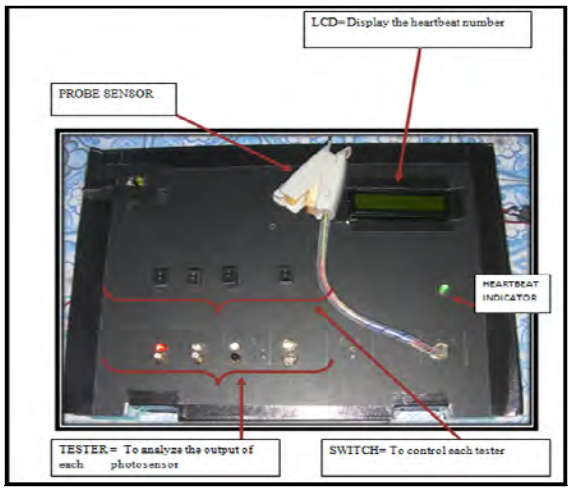


Fig. 7 Final Product

F. Result Analysis

Table 4 below shows the data that provided from 14 persons. The people are age around 22 to 26 years olds where they are in normal hearth.

TABLE 4
Data Collection of Heartbeat

Age	Sex	Heartbeat
22	Female	68
22	Female	84
23	Female	80
24	Male	86
25	Male	89
25	Female	92
24	Female	72
26	Male	80
23	Male	87
23	Male	61
22	Female	72
20	Female	83
23	Female	90
24	Male	83

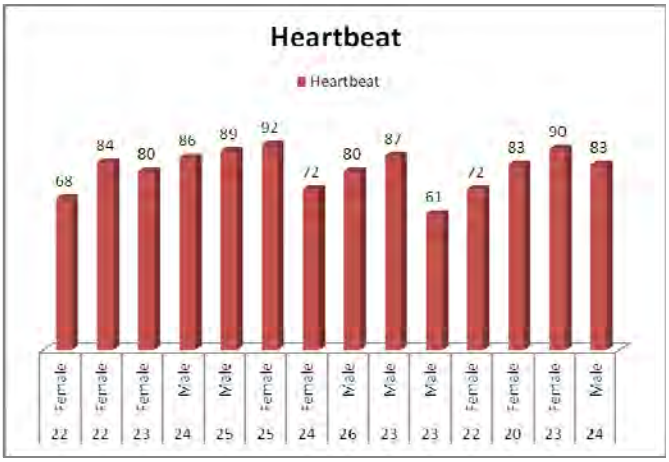


Fig. 8 Chart of the heartbeat from the data collection

The Fig.8 above shows the graph of the heartbeat during normal rest time. For the information, the normal rate for adults is around 60 to 80 BPM. However, this rate depends on the physical fit and age. The reading shows, each peoples in a normal condition because the heartbeat not over the 100 BPM and below the 60 BPM. The result of heartbeat is around 80 shows the people in normal daily activities and less stress.

IV. CONCLUSION

As a conclusion, this project was functioned smoothly and the overall observation for this project was achieved the objectives. Apart from that, this project will give a good service for the people to monitor their heart condition from time to time. Through this project, the device is easy to use, safety and it is suitable to all levels of user. In the future, the research is looking towards to add wireless connection to be the communication methods as the demands of the people nowadays. Furthermore, the system is recommended to be environmental friendly for all Operating System (OS) which are available in market so that it can be used as many users as possible and controlled away from the original location by using the cellular phone.

ACKNOWLEDGMENT

We are grateful to thank Universiti Teknikal Malaysia Melaka (UTeM) for their kind help for supplying the electronic components and giving their laboratory facilities to complete this study.

REFERENCES

[1] Nur Ilyani Ramli, Mansour Youseffi and Peter Widdop, Design and Fabrication of a low cost heart monitor using reflectance Photoplethysmogram, World Academy of science, Engineering and Technology 08 2011,pages 417to 418.
[2] Dogan Ibrahim, Kadri Buruncuk, Heart Rate measurement form the finger using a low cost microcontroller, Near East University, Faculty of Engineering, TRNC.
[3] Prof. K. Padmanabhan, Microcontroller - Based Heart - Rate meter, WWW.EFYMAG.COM, May 2008, pages 58 to 62.
[4] Yun Lai ,Pulse Oximetry, Department of Electronic Engineering ,University of Surrey, Guildford, GU2 7XH, www.surrey.uk , pages 11-15.
[5] M. Laghrouche, S.Haddab, S.Lotmani, K.Mekdoud, S.Ameur, Low –Cost Embedded Oximeter , LAMPA Laboratory, Department of Electronics, Mouloud MAMMERI University, Measurement Science Review, Volume 10 No. 5, 2010.
[6] Widdop, Design and fabrication of a low cost heart monitor using reflectance Photoplethysmogram, World academy of science, Engineering and technology, 2011.
[7] Debra J. Lynn-McHale, Karen K. Carlson, Oxygen Saturation Monitoring by Pulse Oximetry, AACN Procedure manual for Critical Care. Fourth Edition, 2011.
[8] Sandra, Oxygen saturation monitoring by pulse Oximetry, AACN procedure manual for critical care, 2001.
[9] N. M. Z. Hashim, A. S. Jaafar, N. A. Ali, L. Salahuddin, N. R. Mohamad, "Traffic Light Control System for Emergency Vehicles Using Radio Frequency", IOSR Journal of Engineering (IOSRJEN) Vol. 3, Issue 7, pp 43-52, 2013.
[10] N. M. Z. Hashim, M. S. Sizali, "Wireless Patient Monitoring System", International Journal of Science and Research (IJSR) Volume 2 Issue 8, pp 250-255, 2013.
[11] N. M. Z. Hashim, N. A. Ali, A. S. Jaafar , N. R. Mohamad, L. Salahuddin, N. A. Ishak, "Smart Ordering System via Bluetooth", International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7, pp. 2253-2256, 2013.