

DEVELOPMENT OF OPTIMAL PHOTODIODES BASED HEART PULSE  
DETECTOR

NOOR AZLIN BT ZAINAL ABIDIN

This report is submitted in partial fulfillment of the requirements for the award of  
Bachelor of Electronic Engineering (Industrial Electronics) With Honors'

Faculty of Electronic and Computer Engineering  
Universiti Teknikal Malaysia Melaka

June 2011



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

**BORANG PENGESAHAN STATUS LAPORAN**

**PROJEK SARJANA MUDA II**

**Tajuk** : **DEVELOPMENT OF OPTIMAL PHOTSENSORS**  
**Projek** : **BASED HEART PULSE DETECTOR**

**Sesi** :  
**Pengajian** : 

1	1	/	1	2
---	---	---	---	---

Saya ..**NOOR AZLIN BINTI ZAINAL ABIDIN**.....  
mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (  $\checkmark$  ) :

**SULIT\***

\*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

**TERHAD\*\***

\*\* (Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

**TIDAK TERHAD**

Disahkan oleh:

\_\_\_\_\_  
(TANDATANGAN PENULIS)

\_\_\_\_\_  
(COP DAN TANDATANGAN PENYELIA)

**“ I hereby declare that this report is the result of my own work expect for quotes as cited in the references”**

**Signature :.....**

**Author : NOOR AZLIN BINTI ZAINAL ABIDIN**

**Date :.....**

**“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Industrial Electronics) with Honors”**

**Signature : .....**

**Supervisor’s Name: NIK MOHD ZARIFIE BIN HASHIM**

**Date : .....**

*This thesis had dedicated to my parents and my supervisor who have supported me all the way since the beginning of my study. Other than that, this thesis also dedicated to my friends who had been a great source of motivation and inspiration.*

## ACKNOWLEDGEMENT

The success of any project depends on the encouragement and guidelines from many peoples. By inferiority, I would like to express a lot of thanks and great appreciation to the people who had been instrumental in the progressive to complete this project.

Special thanks to my supervisor, Nik Mohd Zarifie Bin Hashim and Khairul Muzzammil Bin Saipullah for guiding me towards the journey of completing this project. Gaining knowledge on various things has greatly increased my confidence in doing this project. The co-operation is much indeed appreciated.

My grateful also to my family and friends for giving me full support towards the end. Your supports have motivated me in many instances. Without your full supports and cooperation, it would be impossible to prepare this report.

Thank you all.

## ABSTRAK

Pembangunan 'Photosensors yang Optimal Berasaskan Pengesan Denyutan Jantung " adalah satu projek yang terdiri daripada 'photosensor' yang digunakan untuk mengukur denyutan nadi dengan mengukur perubahan dalam aliran darah. Tahap kesihatan yang optimum adalah sangat penting. Melalui degupan jantung pelbagai maklumat berkaitan dengan tahap kesihatan boleh diperolehi. Kadar denyutan jantung yang normal pada waktu rehat biasanya antara 60 hingga 100 BPM. Walau bagaimanapun, denyutan jantung ini bergantung pada umur dan tahap kecergasan seseorang individu. Tujuan projek ini dilaksanakan untuk membantu dan membolehkan orang ramai untuk memantau kesihatan mereka secara berterusan tanpa perlu untuk pergi ke klinik atau hospital bagi membuat sebarang pemeriksaan kesihatan. Hal ini lebih memudahkan, khususnya kepada warga tua dan golongan kurang upaya. Dari senario ini, skop projek telah diperolehi di mana litar mikroelektronik telah digunakan sebagai pemprosesan isyarat dan unit mikro pengawal. Idea untuk projek ini adalah mereka bentuk instrumen yang selesa dan hasil yang tepat bagi menyukat nadi jantung dengan berlandaskan kepada faktor kos yang rendah. Projek ini bermula dengan membuat kaji selidik daripada projek sebelumnya. Seterusnya, kajian untuk membina litar, ujian litar dan juga menganalisis hasil keluaran dilakukan. Komponen-komponen projek dipilih dan elemen-elemen kawalan diprogramkan menggunakan mikro pengawal. Akhir sekali, projek akan dibuat dengan litar sebenar dan menggunakan sensor yang optimal.

## ABSTRACT

The ‘Development of Optimal Photosensors Based Heart Pulse Detector’ is one project that consists of a photosensor which is used to measure the pulse by measuring the change in blood flow. Normal heart rate at rest is usually between 60 to 100 BPM. However, the normal value for heart rate depends on the age and the fitness level. The purpose of this project is to help and allow the people to monitor their health constantly without need to visit the clinic or Hospital for a checkup, especially for the elderly. From this scenario, the scope of this project is available. This project used microelectronic circuit that is used as a signal processing and microcontroller unit. The idea of this project is to design a comfortable instrument, which is reliable with accurate result to develop a heart pulse detector using low cost equipment. This project begins with the research from previous project. The next part is the experiment to construct circuit, test the circuit and analyze the output is necessary. After that, the components of this project tenses. The control elements were programmed using the microcontroller. The project will be constructing the actual circuit with using the best sensor.



## TABLE OF CONTENTS

CHAPTER	DESCRIPTION	PAGE
	Project Title	i
	Approval	ii
	Pages of Admission	iii
	Supervise Conformation	iv
	Dedication	v
	Acknowledgement	vi
	Abstrak	vii
	Abstract	viii
	Table Of Contents	ix
	List Of Figure	xiii
	List Of Table	xvi
	List Of Abbreviations	xvii
<b>1</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1 Review of electromagnetic spectrum	1
	1.2 Visible light	2
	1.3 Infrared radiation	4
	1.4 Photodetector	5
	1.5 Significant of Oxygen Saturation	6
	1.6 Project background	7
	1.7 Objective of Project	7
	1.8 Project statement	8
	1.9 Scope of project	8
	1.10 Flow of the project	9
	1.11 Thesis outline	10

<b>2</b>	<b>LITERACTURE REVIEW</b>	<b>12</b>
	2.1 Introduction	12
	2.2 Previous Work	13
	2.2.1 Case 1	13
	2.2.2 Case 2	14
	2.2.3 Case 3	15
	2.2.4 Case 4	16
	2.2.5 Case 5	17
	2.2.6 Case 6	18
	2.3 Comparison result for case study	19
	2.4 Present work	25
	2.5 Summary	26
<b>3</b>	<b>METHODOLOGY</b>	<b>28</b>
	3.1 Introduction	28
	3.2 Flow chart of the project process	29
	3.2.1 Explanation	30
	3.3 Hardware Development	30
	3.3.1 Finger probe positioning	30
	3.3.2 Microcontroller	32
	3.3.3 PIC16F877A	34
	3.3.4 PIC programmer	36
	3.3.5 Operational amplifier	37

	3.3.6 LM358 low power dual operational amplifier	41
	3.3.7 Circuit heartbeat sensor	42
	3.3.8 LCD display	43
	3.4 Software Development	45
	3.5 Summary	49
<b>4</b>	<b>RESULT AND ANALYSIS</b>	<b>50</b>
	4.1 Circuit Simulation	50
	4.1.1 Simulation of circuit PIC 16f877A and LCD	50
	4.1.2 Simulation of circuit LM358	51
	4.1.3 Simulation of circuit power supply	53
	4.1.4 Simulation of probe sensor	54
	4.2 Result and Analysis	55
	4.2.1 Test LDR sensitivity	55
	4.3 Experiment using MATLAB	57
	4.4 Result from Oscilloscope	60
	4.5 Product	67
<b>5</b>	<b>CONCLUSION AND RECOMMENDATION</b>	<b>68</b>
	5.1 Conclusion	68
	5.2 Problem	69
	5.3 :Recommendation	70

References	71
Appendix's	
Appendix 1	72
Appendix2	73
Appendix3	74
Appendix4	74
Appendix5	75
Appendix6	77

## LIST OF FIGURES

<b>NO</b>	<b>TITLE</b>	<b>PAGE</b>
Figure 1.1	Electromagnetic spectrum	2
Figure 1. 2	Visible Light	3
Figure 1.4	Overview Of Photodetector	5
Figure 1.10	Flow of the project	10
Figure 2.2.1	Block diagram of the measuring devices	13
Figure 2.2.2	Technique the finger position	14
Figure 2.2.3	Combination of Red LED And IR Sensor as Transmitter	15
Figure 2.2.4	Block diagram of the data system	16
Figure 2.2.5.a	Diagram by using Reflectance Photoplethysmogram	17
Figure 2.2.5.b	Reflectance mode PPG	18
Figure 3.2	Flowchart of the project	29
Figure 3.3.2.1	Hardware Circuit	32
Figure 3.3.2.2	Schematic PIC microcontroller	33
Figure 3.3.3.1	PIC 16F877A	34
Figure 3.3.3.2	The PIC 16F877A pin diagram	35
Figure 3.3.4	Connection of cable to box header	37
Figure 3.3.5.1	Basic op-amp	38
Figure 3.3.5.2	Inverting op-amp circuit:	39
Figure 3.3.5.3	Non-inverting op-amp circuit:	40
Figure 3.3.5.4	Unity follower op-amp circuit:	40
Figure 3.3.6	LM 358 pin diagram	41
Figure 3.3.7	Circuit for heartbeat sensor	42
Figure 3.3.8	Connection of LCD display	43

Figure 3.4.1	Interface of CCS C Compiler	45
Figure 3.4.2	Create new file	47
Figure 3.4.3	Writing the code	47
Figure 3.4.4	Compile the code program	48
Figure 3.4.5	Compile selection File	48
Figure 4.1.1	Simulation of circuit PIC 16f877A and LCD	50
Figure 4.1.2	Simulation of circuit LM358	51
Figure 4.1.3	Power supply simulation	53
Figure 4.1.4	Probe sensor simulation part	54
Figure 4.2.1	Sensitivity of a Photosensor	55
Figure 4.3.1	Example pulse from the probe sensor (WR_5mm)	58
Figure 4.3.2	Digital signal probe sensor with finger	58
Figure 4.3.3	Digital signal probe sensor without finger	59
Figure 4.3.4	Delay test for 10ms	59
Figure 4.3.5	Signal from probe sensor after complete connection	60
Figure 4.4.1	Graph result from LED (red color) and LDR photosensor	60
Figure 4.4.2	Graph result from LED (green color) and LDR photosensor	61
Figure 4.4.3	Graph result from Infrared (IR) and Photodiode	61
Figure 4.4.4	No finger on the sensor	62
Figure 4.4.5	Movement factor	62
Figure 4.4.6	Some testing during the project analysis	64
Figure 4.4.7	Chart of the heartbeat from the data collection	66

Figure 4.5

Product design

67

## LIST OF TABLES

NO	TITLE	PAGE
Table 1.1	Range of wavelengths color in the visible spectrum	4
Table 2.3.1	The advantage and disadvantage of each Case Study	19
Table 2.3.2	The finger position of each Case Study	21
Table 2.3.3	Comparison between each photosensor heart pulse detector	24
Table 3.3.1	Finger probe positioning criteria	31
Table 3.3.3.1	Specification of PIC 16F877A	35
Table 3.3.3.2	PIN name and their application	36
Table 3.3.8	Pin connection of LCD display	44
Table 4.2.2	Table shows the output from the LM358	52
Table 4.2.1.1	Sample measurement result from various type of LED and IR sensor	56
Table 4.2.1.1	Test using three types of paper color	57
Table 4.4	Data collection of heartbeat	65



**LIST OF ABBREVIATIONN**

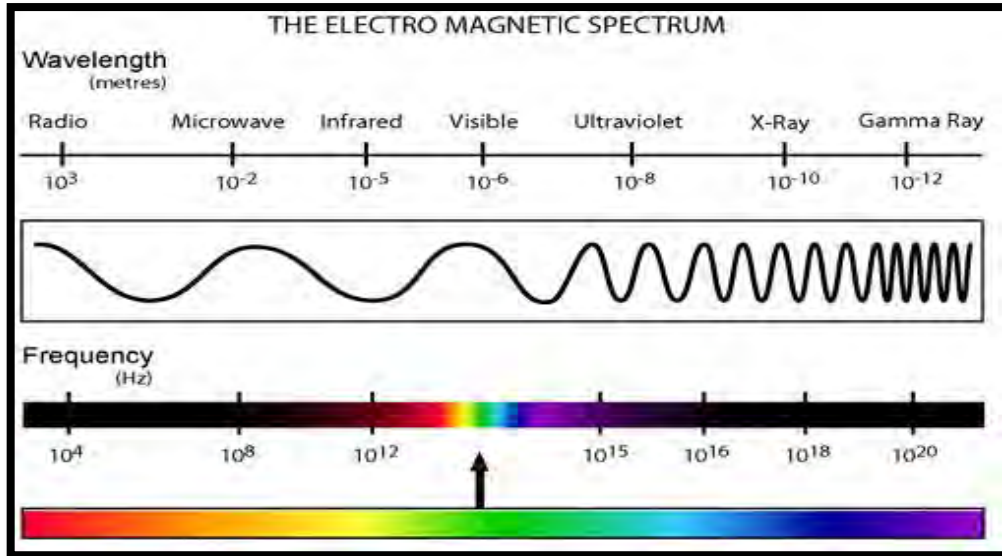
PIC	Programmable Integrated Circuit
LCD	Liquid Crystal Display
Bpm	Beat per minute
HR	Heart Rate
LED	Light Emitting Diode
IR	Infrared
LDR	Light Dependent Resistor
PIR	Passive Infrared
ADC	Analog to Digital signal
OSC	Oscilloscope
ECG	Electro-cardiogram
IEEE	The Institute of Electrical and Electronics Engineers
HBMD	heart beat monitoring device
PPG	mode Photoplethysmography
CdS	Cadmium Sulfide
CO	Carbon Monoxide
O <sub>2</sub>	Oxygen

# CHAPTER 1

## INTRODUCTION

### 1.1 Review of electromagnetic spectrum

Figure 1.1 shows the wavelength of electromagnetic spectrum. The spectrum could be dividing into two categories which is the wavelength or frequency part and secondly is in term of their physical properties. The wavelength is the distance between peaks where each wave has a certain shape and length. In other hand, frequency is a value of waves in one second. Besides that, Figure 1.1 shows the wavelength of gamma rays, X-rays, ultraviolet, visible light, infrared, microwave and radio. This figure shows that the low frequency will produce a high wavelength.



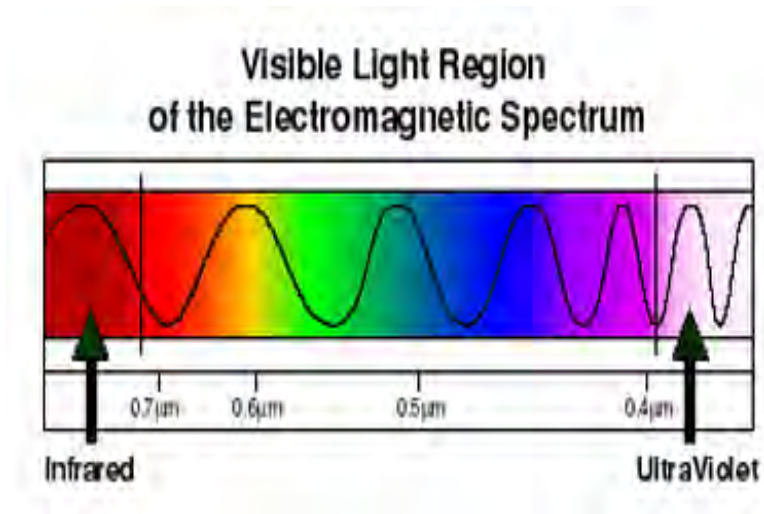
**Figure 1.1 : Electromagnetic spectrum**

Moreover, the electromagnetic waves generated from the motion of electrically charged which called as 'electromagnetic radiation' that produced from oscillating electric and magnetic fields. The wave of energy generated via vibrations moves through the space by using the speed of light. The visible light is one form of electromagnetic (EM) radiation.

## 1.2 Visible Light

Figure 1.2 shows the visible light waves from the Electromagnetic spectrum. The visible light is one of the bands that appear in the electromagnetic spectrum. It is a small range wave that able to seen in the form of light. The colors that available in the visible light are red, orange, yellow, green, blue, indigo and violet. Each color has different

wavelength. The red color has the longest wavelength and the violet color has the shortest wavelength. The combination of all color will produce white color.



**Figure 1.2 : Visible light waves**

Meanwhile, the wavelength of the visible light is around 400-700 nanometers. Human eye is not capable to see radiation wavelength outside of this range. However, it is good factors because a high lighting rate will cause the retina in the human eye become damage. The Table 1.1 below shows an approximate range of wavelengths corresponding to the various colors in the visible spectrum.

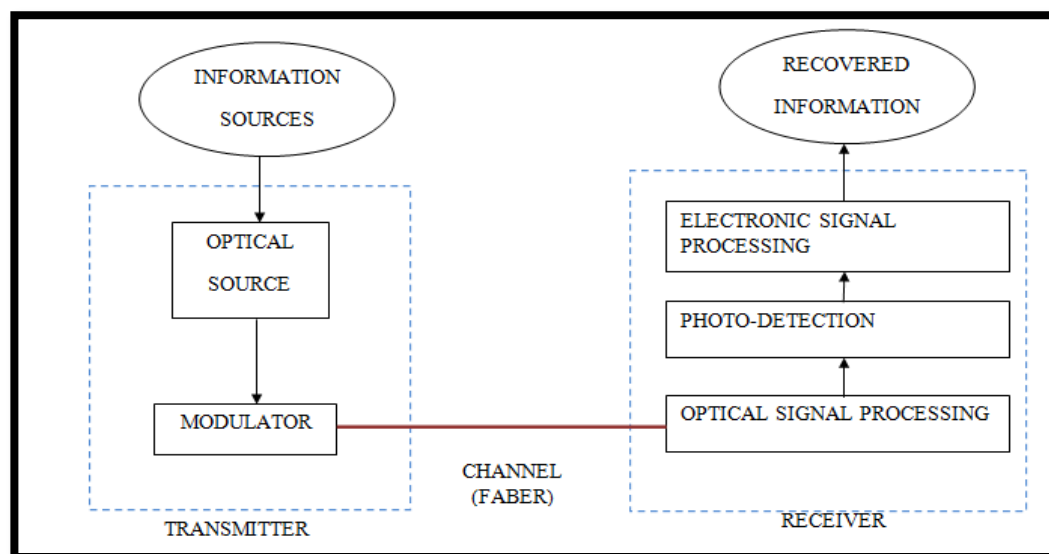
**Table 1.1 : Range of wavelengths color in the visible spectrum**

Approximate Wavelengths of Colors (in <i>nm</i> )											
700	650	650	600	540	590	540	490	490	440	440	400
Red		Orange		Yellow		Green		Blue		Violet	

### 1.3 Infrared Radiation

By referring on Figure 1.1 on the EM spectrum, the visible light is in the middle ranges of the infrared (IR) and ultraviolet. The IR region of the electromagnetic spectrum is also divided into three segments which are near, mid and far- infrared. A near infrared refers to the part of the infrared spectrum that closed to visible light and far-infrared refers to the part that closed to ultraviolet. The mid-infrared is the range between these two categories. Besides, the infrared waves have wavelength longer than visible light and their frequency is lower than visible light.

## 1.4 Photodetector



**Figure 1.4 : Overview of Photodetector**

Figure 1.4 shows the process flow of how to convert optical signal into an electrical signal. In other words, the detectors receive transmitted optical pulse and converted weather to electronic signal processing, photodetection or optical signal processing. Apart from that, the photodetectors are suitable to be use in optical communication system.

A photodetector is an important part in any application of light. It will sense light from photon that used to produce the electrons and it is important for conduction. The photodetector operate by converting the signal into a voltage or current form. The junction that acts as an illumination window will absorb the light photon. Meanwhile, the photodetector have seven basic requirements. These are sensitivity, efficient conversion, fast response, low noise, sufficient area, high reliability and last in term of

cost. From the researched, there are many types of photodetector, which are photoconductive cell, also called as light dependent resistor (LDR) or as photocell. Other types of photodetector are photovoltaic detector, photodiode and phototransistor.

## 1.5 Significant of Oxygen Saturation

Oxygen ( $O_2$ ) is an important part in human body. Without  $O_2$  each cell in the human body cannot function and will be damaged. When the oxygen flows into the lungs, it will pass on into blood. The blood will carry the oxygen to the each organ in human body. For example, the Oximetry is a device that measures the oxyhemoglobin ( $HbO_2$ ) Saturation in blood. It measured by using a basic concept which is the light will transmit through a blood. After that it will determine the amount of light absorbed by oxygenated and deoxygenated hemoglobin. In addition, the oxygenated blood especially red color whereas deoxygenated blood has a dark blue coloration. Physically, the blood was detected when the finger placed on the probe. The light will pass through the finger to reach the detector. The amount of light that absorbed in finger depends on some factors such as concentration of the light, length of light path, oxyhemoglobin and deoxyhemoglobin.

The optical property of blood in the visible and near –infrared spectral regions depends on the amount of  $O_2$  carried by blood. Otherwise, the absorption of the light also depends on the both skin thickness and blood concentration. The change in blood volume can be detects in peripheral parts of the body such as fingertip and earlobe.

## 1.6 Project Background

The ‘Development of Optimal Photosensors Based Heart Pulse Detector’ 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 the best photo-sensor such as Light Emitting Diode (LED), Infrared (IR), and Light Dependent Resistor (LDR), need to be used in order to produce significant heart pulse signal detected from human finger. The biggest 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 for easy monitoring.

## 1.7 Objective of Project

The objectives of this project as below:

- i. To develop a biggest significant between photosensor (LED, IR and LDR) by using a suitable testing.
- ii. To develop a simple equipment that is easy to use and make sure each person can monitor their health everywhere
- iii. To develop a comfortable instrument, reliable, accurate result to develop of heart pulse using a low cost equipment (photosensors).