UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PORTABLE HEART RATE MONITOR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree in Electronic Engineering Technology
(Industrial Electronics) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Electronics Industry) (Hons.). The member of the supervisory is as follow:

……

Puan Izadora binti Mustaffa

ABSTRAK

Tesis ini menerangkan tentang pembangunan sebuah pemantau denyutan jantung mudah alih yang digunakan untuk memantau pesakit yang mempunyai kegagalan jantung kongestif (CHF). CHF adalah keadaan, apabila fungsi jantung yang bertindak sebagai pam tidak mampu untuk mengepam darah ke seluruh badan. CHF boleh disebabkan oleh pelbagai jenis penyakit yang melemahkan otot jantung, dan menyebabkan otot-otot pada bahagian jantung menjadi keras dan tebal. Pesakit CHF memerlukan pemantauan jantung yang berterusan dan kerap berjumpa doktor. Oleh itu, satu alat memantau jantung mudah alih dengan penyimpanan data dibangunkan untuk memudahkan pemantauan pesakit, seterusnya meningkatkan kualiti hidup pesakit. Kadar denyutan jantung bole dikira dengan mengukur masa daripada satu nilai puncah R ke nilai puncak R yang seterusnya. Proses pengiraan dilakukan oleh mikropengawal, Arduino Uno R3 dan data berkenaan kadar jantung disimpan di dalam kad mikro SD yang boleh diakses oleh doktor semasa rutin pemeriksaan. Kadar jantung yang dikira juga akan dipaparkan di paparan LCD.

ABSTRACT

This thesis describes the development of a portable heart rate monitor used for monitoring congestive heart failure (CHF) patient. CHF is a condition in which the heart's functuion as a pump is too weak to pump blood to the entire body. CHF patient requires continouos heart rate monitoring and need to visit to the doctor frequently. Therefore, a portable heart rate monitor with data storage is developed to faciliate the monitoring of patients, thus improving the quality of life of patients. The heart rate is calculated by measuring the time difference from one R-peak to the next R-peak. The calculation will be done by a microcontroller, Arduino Uno R3. The heart rate data is stored on an micro SD card which can be accessed by the doctor during routine check-ups. An alarm buzzer is also installed to notify the patient when his/her heart rate reached 110 BPM. The calculated heart rate will also be displayed on the an LCD display.

DEDICATION

I dedicate my thesis work to my family and many friends. A special feeling of gratitude to give to my loving parents, Encik Zaid bin Haji Ali, Puan Badriah binti Omar, Muhammad Firdaus bin Musa and Nur Wahida binti Johari whose words of encouragement and push for tenacity ring in my ears.

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Special thanks to all my peers, my family, and siblings for their moral support in completing this project. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

TABLE OF CONTENT

TABLE OF CONTENT

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ALU	-	Arithmetic/Logic Unit
BPM	-	Beats per Minute
CHF	-	Congestive Heart Failure
CV	-	Cardiovascular
CS	-	Clock Select
DDR	-	Data Direction Register
ECG	-	Electrocardiography
EEG	-	Electroencephalography
GB	-	Giga-byte
GND	-	Ground
GPIO	-	General Purpose input Output
HF	-	Heart Failure
HRV	-	Heart-Rate Value
IC	-	Integrated Circuit
IDE	-	Integrated Development Environment
LCD	-	Liquid-Crystal Display
LED	-	Light-Emitting Diode
LSI	-	Liquid-
MISO	-	Master In Slave Out
MOSI	-	Master Out Slave In
PHRM	-	Portable Heart Rate Monitor
PIN	-	Port Input
PWM	-	Pulse-Width Modulation
RD	-	Read and Write
RS	-	Register Select
RISC	-	Reduced Instruction Set Computing
SD	-	Secure Digital
SPI	-	Serial Peripheral Interface

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

SCK	-	Slave Clock/System Clock
V_{CC}	-	IC power-supply pin

CHAPTER 1
INTRODUCTION

1.0 Introduction

This chapter introduces the background, problem statements, and the objectives. Hence, it is next followed with scope of works, project significance and thesis outline. Each sub-topic relates each other in order to make the readers understand the flow of the project.

1.1 Background

CHF is the failure or lack of ability for the heart to withstand the cardiac output sufficient for each of the body's need, and almost come from myocardial failure affecting either side of the ventricles, and thus causing fluid; which is mainly water, to leak from capillary blood vessels (Nieminen, 2012). The lack of strength to pump out the blood to the body causes congestion, or known as blockage in the heart. Excessive amount of sodium and water will accumulate in the heart tissue, and leaving a greater burden towards the heart to pump blood on it. A normal heart can pump for at least 60% of its blood volumes in a single beat; CHF lowers the blood volume from 30% to 20%. The blood circulation system becomes sluggish and also

putting more work on the weak heart. With the circulatory system becoming overload, the volume of blood that returns to heart through the vein becomes double (Theresa A., McDonagh, 2011).

CHF happens as the heart cannot afford to pump sufficient blood to all of the body as either of the left ventricles, or the right ventricles, or both of muscles has stiffened and thicken. Certain symptoms can be seen for the person that is having CHF, such as difficulties in breathing, leg swelling, weakness and exercise intolerance. Person with CHF is said to take four times risks than a normal citizen to suffer cognitive impairment and demonstrate some diverse pattern of cognitive impairment (Ponrathi Athilingam, 2013). Studies shows that they have extracted out the possible outcomes of efficacy towards the CHF patient are sudden death, cardiovascular death, nonfatal myocardial infarction, stroke, heart failure (HF) hospitalization and the composite of cardiovascular (CV), while the outcomes of safety are hyperkalemia, renal failure, and hypotension. Patients with CHF are advised to have CHF therapy along with follow-ups each 3 months.

There are few symptoms, depend on which area of the body is most involved in the reduced pumping action:

a) When the left side of the heart (left ventricle) starts to fail, fluid collects in the lungs (edema). This extra fluid in the lungs (pulmonary congestion) makes it more difficult for the airways to expand as a person inhales. Breathing becomes more difficult and the person may feel short of breath, particularly with activity or when lying down
b) When the right side of the heart (right ventricle) starts to fail, fluid begins to collect in the feet and lower legs. Puffy leg swelling (edema) is a sign of right heart failure, especially if the edema is pitting edema. With pitting edema, a finger pressed on the swollen leg leaves an imprint. Non-pitting is not caused by heart failure
c) As the right heart failure worsens, the upper legs swell and eventually the abdomen collects fluid (ascites). Weight gain accompanies the fluid retention and is a reliable measure of how much fluid is being retained

Heart failure may develop gradually over several years, or more quickly after a heart attack or a disease of the heart muscle. Congestive heart failure (CHF) is generally classified as systolic or diastolic heart failure and becomes progressively more common with increasing age. In addition, patients with risk factors for heart disease are more likely to develop congestive heart failure. (Davis, 2014). Figure 1.1 explains how the congestive heart failure (CHF) happened:

In Malaysia, CHF is on the rise, from a ratio of 5 per 1000 population/year into 30 cases per 1000 population/year in the general population, and accounts for 10% of medical admissions in Malaysia. A visit to the doctor's office can be quite troublesome. The drive and the long wait can be a burden. The drive and the long wait can be a burden to the heart patient. This is where the motivation of developing a Portable Heart Rate Monitor (PHRM). The device will record the patient's heart condition by recording the heart rate for durations of 2 minutes approximately (Chin, 2006).

1.2 Problem Statement

It is important for a CHF patient to monitor their heart rate continuously. Hospital based monitoring is troublesome and not sufficient. Doctor will only be able to monitor the patient's heart condition during this time and in between 2 to 3 months after the first check-up.

Continuous monitoring of a CHF patient's heart rate may help in predicting future onset of heart failure and its assessment will improve the quality of life of CHF patients.

A continuous monitoring system consisting of microcontroller, which is Arduino Uno R3, which can be implemented with memory storage, is developed. The portable device calculates the heart rate and then stores it in the micro SD card. If the heart beat per minutes (BPM) is more than 110, alarm will be triggered to

notify the patient for immediate action. The stored data of the heart rate can be easily accessed by doctors using Microsoft Office Excel.

1.3 Objectives

A portable continuous monitoring device is developed for CHF patient in order to enhance their quality of life by reducing the amount of time spent at the doctor's office detecting any heart rate abnormality at home. To do so, some objectives need to be achieved at the end of the project.

The device must be able to monitor all the heart rate in a continuous interval length of time. For the device to monitor the heart rate in a continuous interval length of time, it is important for the device to be able to display the information regarding the heart rate to the CHF patient on the liquid-crystal display (LCD) screen as well.

All the heart rate is being calculated in the microcontroller implemented in the device. The microcontroller job is to ensure that the arithmetic logic inside the microcontroller is able to do all the calculation information regarding to the heart rate. This can be seen as another objective need to be achieved at the end of the project, to see that the microcontroller is able to read the signal retrieved and do certain calculation towards the signal

For the device is able to save certain data on the memory storage, the micro secure digital (SD) card will be used to store certain value of heart rate that have been measured. An installation of the micro SD card module is likely to happen on it, as micro SD card is the medium being used to store the heart rate and next being represented by software.

1.4 Scope of work

For PHRM to calculate the average heart rate beat for the patient and display patient's heart rate; literature review regarding on electrocardiography (ECG), heart rate (HR) calculation algorithm on both MATLAB® and Arduino, memory storage, hardware and microcontroller implementation, display on LCD screen will be done, in order to establish essential knowledge related to the project.

The hardware needed for this project has been identified and acknowledged. They are Arduino Uno R3, Pulse Sensor, LCD display 2x16 and Micro SD Card module, along with other related electronic components. The next step is to construct and develop the hardware into a working PHRM. This involves the usage of software in designing the circuit such as Fritzing, Arduino IDE and Proteus as well.

Algorithm used in HR calculation in Arduino is written using BIOPAC Systems, Inc and the data is stored in SD card for later on. Then, from the working algorithm of the MATLAB®, next it is being compared with the real ECG that has been collected from the PHRM.

The capacity of micro SD card memory and the proper format of file to be saved on the SD card need to be considered as well. Since the data need to be stored continuously for at least 3 months, size of the file format and the type of the file must be sufficient for the micro SD card to hold

1.5 Thesis Outline

Portable Heart Rate Monitor (PHRM) is a combination of five chapters overall that contains and elaborates specific topics such as Introduction, Literature Review, Methodology, Result and Analysis, and Conclusion.

Chapter 1: Introduction of the project. The brief explanation for the project will be given. The objectives of the project will be elaborated. It is followed by the explanation in the scope of project, objective doing this project and also the problem statements.

Chapter 2: Describes electrocardiography (ECG) waveform, heart rate (HR), beats per minute (BPM) and exisiting portable heart rate monitor/

Chapter 3: Methodology of the project. This chapter focusing on how the work scope is carried out and that includes hardware development and software implementation of the project.

Chapter 4: Result and Analysis. This chapter explains the result obtained regarding the performance and efficiency of the system in general term and overall systems operation.

Chapter 5: Conclusion. Conclusion and further development or future recommendation that can be applied in this project are being discussed in this last chapter

1.6 Conclusion

The CHF is a disease due to the failure or lack of ability for the heart to withstand the cardiac output sufficient for each of the body's need. The lack of strength to pump out the blood to the body causes congestion, or known as blockage in the heart. Excessive amount of sodium and water will accumulate in the heart tissue, and leaving a greater burden towards the heart to pump blood on it.

In Malaysia, CHF is on the rise, from a ratio of 5 per 1000 population/year into 30 cases per 1000 population/year in the general population, and accounts for 10% of

medical admissions in Malaysia. A visit to the doctor's office can be quite troublesome. The drive and the long wait can be a burden.

A portable continuous monitoring device is developed for CHF patient in order to enhance their quality of life by reducing the amount of time spent at the doctor's office detecting any heart rate abnormality at home.

Continuous monitoring of a CHF patient's heart rate may help in predicting future onset of heart failure and its assessment will improve the quality of life of CHF patients. For PHRM to calculate the average heart rate beat for the patient and display patient's heart rate; literature review regarding on electrocardiography (ECG), heart rate (HR) calculation algorithm on both MATLAB® and Arduino, memory storage, hardware and microcontroller implementation, display on LCD screen will be done, in order to establish essential knowledge related to the project.

Monitoring the pattern of a CHF patient's heart rate may help in predicting future onset of heart failure and its assessment will improve the quality of life of CHF patients. The development of this device can improve many clinical outcomes as such devices have not been shown to the public before this.

CHF patients do not require frequent medical check-ups but they still need routine check-ups which have long intervals up to 3 months. In between these check-ups, patients have to self-monitor their health status. A self-monitoring device with data storage is very useful in order to have a clear and accurate health assessment during these medical check-ups.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter explains what heart is, alongside with electrocardiography (ECG) signal, heart rate (HR), and beats per minute. Next, this chapter will also explain the existing project used what type of microcontroller, and the Arduino models and its algorithm

2.1 Heart

The heart is a muscular organ about the size of a fist, located behind and slightly left of the breastbone. The heart is one of the toughest muscles that use to pump up blood from it to the entire body. The heart has four chambers; right atrium, right ventricle, left atrium and left ventricle. The right atrium and ventricle are referred as right heart, and the counterparts of it, which are the left atrium and ventricle, are referred as left heart. The average heart will beat at 72 beat per minute and weighs for approximately 300 grams until 530 grams. The heart continuously works, even when our body is resting or sleeping. Figure 2.1 shows the heart and its components (Hall, 2011).