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A NEW APPROACH OF THE ECG LOGGER DESIGN USING MICROCONTROLLER

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ABSTRACT

There is a need to remotely monitor fully mobile heart patients in their natural environments. The Monitoring of a patient's ECG waveforms in different conditions can track the diagnosis of a heart disease, which can further be treated to help prolong and improve the life of the patient. If a patient must be monitored without any delay that is associated with delivering data which is stored on a recording device, biotelemetry is necessary. Biotelemetry consists of measuring the biological waveforms to a remote area for recording and processing. Due to the limitations of the currently popular methods of biotelemetry, this paper proposes the use of the microcontroller based hand held ECG logger. It consist of the Isolated circuit that is comprising of an ECG preamplifier and protection circuit with two channels of ECG data, a right-leg drive, low and high pass filters, a gain stage, A/D converter, and the Isolation circuit for the signal lines. This extremely low powered device is designed to consume less than 5mA of power in full operation and Powered by a lithium polymer battery. The device will be very small in size, handy and thickness will also be very less. The topic of this paper is to design the Isolated circuitry of an ECG recorder, and an Wireless link (Transmitter and Receiver) for use in a portable ECG device for cardiac investigation.

KEYWORDS: *ECG, data compression, data recording, logger, microcontroller*

I. INTRODUCTION

In the past few years electronic pacemaker systems have become extremely important in saving and sustaining the lives of cardiac patients whose normal pacing functions have become impaired. To retrieve normal sinus rhythm of a disabled heart Pacemakers are widely used as an important therapeutic tool. Normally pacemakers are powered by a battery to be implanted in a patient for a long duration of time. For this reason a pacemaker should have very low power consumption and at the same time wide functionalities. A pacemaker task is not computationally intensive, since a heart typically beats at 70 beats per minute and any general purpose microcontroller with a frequency of 500 kHz or above can accomplish this task. Pacemaker systems need to be very low power consumption microcontrollers. Typically pacemaker companies use custom designed processors to implement pacemaker's programmability. Nowadays advancements in technology have introduced the microcontrollers that are available with ultra low power consumption which can satisfy power constrains for the pacemaker design.

In this paper discussion of the electrical physiology of the heart, a cardiac pacemaker, general purpose microcontrollers and its CPU architecture is presented.

Cardiac pacemakers are medical devices widely used to treat heart diseases. Modern pacemakers are ultra low power embedded systems with programmable functionalities, which include acquisition of heart signals samples and statistical histograms of paced, sensed and other events. This programmability is commonly offered by an internal custom-designed processor for the application. These custom-designed processors increase product cost and time to market. Research on pacemakers has been limited because of the lack of information available in open technical literature. This paper presents a pacing system implemented in a general purpose low power microcontroller, the msp430f1611. Furthermore, a methodology for the development of the whole pacing system, including software flowcharts and control software source code is presented. Techniques to achieve low power consumption by the software are offered. The software consumes a maximum of 10 µA, with a typical value of 5 µA. Pacemakers are widely used today as a therapeutic tool to reestablish normal pacing of a diseased heart. A total of 300,000 are implanted every year, which indicates the popularity of these devices. Traditionally these devices have been powered by a battery to be implanted in a patient for a long period of time. For this reason a pacemaker should have very low power consumption and at the same time wide functionalities.

A pacemaker task is not computationally intensive, since a heart typically beats at 70 beats per minute and any general purpose microcontroller with a frequency of 500 kHz or above can accomplish this. However, pacemaker systems need very low power consumption microcontrollers. Typically pacemaker companies use custom-designed processors to implement pacemaker's programmability. Custom-designed processors increase the cost of the system significantly and also increase the time to market. A few years back a survey for a general purpose processor to be used for the design of a pacemaker was conducted. However, the survey did not found any microcontroller that satisfies the requirements of a pacemaker application. Currently, advancements in technology have made new microcontrollers available with ultra-low power consumption that can satisfy power constrains for the pacemaker design. If pacing software can be developed using a general purpose microcontroller, it will reduce significantly cost and time to market. However, as noted in, there is little available information in open technical literature regarding the design details of cardiac circuits and even less, or non-existent, for control software source codes. This is probably due to the "closed" characteristics of the pacemaker industry (few companies with a long tradition) and the high competition among these companies.

II. IMPLANTABLE CARDIAC PACEMAKERS

In the past few years electronic pacemaker systems have become extremely important in saving and sustaining the lives of cardiac patients whose normal pacing functions have become impaired. A device capable of generating artificial pacing impulse and delivering them to heart is known as a pacemaker system and consists of a pulse generator` and appropriate electrodes. A cardiac pacemaker is an efficient treatment to patients suffering from bradycardia. Furthermore, implantable pacemakers have helped to expand the knowledge of the electrical behavior of the heart by acquiring Electro-cardiograms.

2.1 The human heart

The rhythmic beating of the heart is due to the triggering pulses that originate in an area of specialized tissue in the right atrium of the heart. This area is known as sino-atrial node.

The heart has four chambers: two atria (singular: atrium) and two ventricles. Figure 2.1 shows all the components of the heart. The SA node sends electrical impulses at a certain rate, but heart rate may still change depending on physical demands, stress, or hormonal factors [3]. The rhythmic sequence of contractions is coordinated by the sinoatrial (SA) and atrioventricular (AV) nodes located at the upper and lower walls, respectively, of the right atrium.

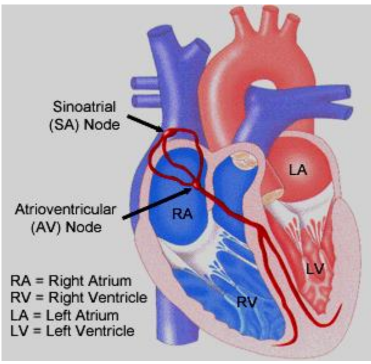

Figure 1: The Human Heart.

The contractions of the heart are controlled by electrical impulses. These electrical impulses fire at a rate which controls the beat of the heart. The cells that create these rhythmical impulses are called pacemaker cells, and they directly control the heart rate. If damage to the body's intrinsic conduction system occurs, an artificial device also called pacemaker can be used to produce these impulses synthetically.

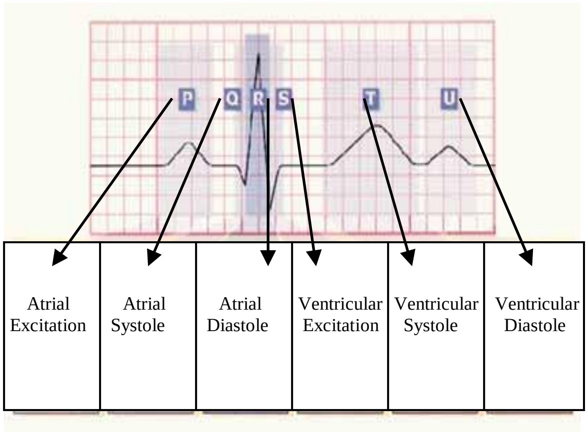

Figure 2: EWCG waveform parameters

P wave: Identify the wave of depolarization that spreads from the SA node throughout the atria. It typically has 80-100 ms in duration.
P - R interval: It normally lasts from 120 to 200 ms. It represents the time between the onset of atrial depolarization and the onset of ventricular depolarization. If the P-R interval is >0.2 sec, there is an AV conduction block. It is also termed as a first-degree heart block if the impulse is still able to be conducted into the ventricles.
QRS Complex: The QRS complex represents the ventricular depolarization. It is the most prominent amplitude of the ECG. It can be used to diagnose bundle branch blocks or abnormal pacemaker site located in the ventricles. This can be detected when the QRS complex is prolonged above 100ms.
ST Segment: The ST segment is measured from the onset of the S wave to the onset of the T wave. The T wave represents the repolarization of the ventricles. The ST segment is the time at which the entire ventricle is depolarized. The ST segment is important in the diagnosis of ventricular ischemia or hypoxia because under those conditions, the ST segment can become either depressed or elevated.
QT interval : The Q-T interval represents the time for both ventricular depolarization and repolarization to occur. Therefore, it roughly estimates the duration of an average ventricular action potential. This interval can range from 200 to 400 ms. In practice, the Q-T interval is expressed as a "corrected Q-T (QTc)" by taking the Q-T interval and dividing it by the square root of the R-R is the time between two consecutive R waves.

III. PACEMAKERS

The cardiac pacemaker is an electric stimulator that produces periodic electric pulses conducted to electrodes located on the surface of the heart (the epicardium), within the heart muscle (the myocardium), or within the cavity of the heart or the lining of the heart (the endocardium).The stimulus thus conducted to the heart causes it to contract.
Pacemakers can help in pacing the heart in cases of slow heart rate, fast and slow heart rate, or a blockage in the heart's electrical system. There are different pacemakers. One of them sends pulses to the heart so that it beats to a rhythm that have been determined. This is denominated pacemaker of fixed rhythm and are called asynchronous pacemaker.
Another class can sense the heart's rhythm and turn themselves off when the heartbeat is above a certain level. They will turn on again when the heartbeat is too slow. These types of pacemakers are called demand pacemakers.

3. 1 Functions of a pacemaker

In the past few years electronic pacemaker systems have become extremely important in saving and sustaining the lives of cardiac patients whose normal pacing functions have become impaired. A device capable of generating artificial pacing impulse and delivering them to heart is known as a pacemaker system and consists of a pulse generator` and appropriate electrodes. Internal pacemakers may be permanently implanted in patients whose sino-atrial nodes have failed to function properly or who suffer from permanent heart block because of a heart attack. An external pacemaker usually consists of an externally worn pulse generator connected to electrodes located on or within the myocardium. External pacemakers are used on patients with temporary heart irregularities. Internal pacemaker systems are implanted with the pulse generator placed in a surgically formed pocket below the right or left clavicle.

A modern pacemaker is not only capable of stimulating, or pacing, the heart, but also of sensing the intrinsic activity of the heart. Sensed activity is used as information for the pacemaker to adopt appropriate stimulating activity as therapy.

3.2 Why the Pacemaker is needed?

A normal healthy adult heart has a regular beat, and usually beats 50 to 100 times a minute. If one are going to have a pacemaker fitted, it can be useful to know the basics of how the heart beats. The heart has four ‘chambers’. There are two upper chambers called the atria. (There is a ‘right atrium’ and a ‘left atrium’.) The two lower chambers are called the ‘right ventricle’ and the ‘left ventricle’.(These are shown in the illustration on the next page.)The heart has its own ‘natural pacemaker’. A group of cells on the right side of the heart send regular electrical impulses across the two atria. Where the atria meet the ventricles (the two larger pumping chambers), there is another group of cells called the atrio-ventricular node (or ‘AV node’). As the electrical impulses pass from the AV node to the ventricles, they stimulate a contraction – in other words, a heartbeat.

If body’s natural pacemaker is not working properly, one may need to have a pacemaker fitted.

This could be because:

- One has ‘heart block’
- One have a certain type of irregular heart rate or heart rhythm (heart rate is how often heart beats in a minute and heart rhythm is how regular heartbeat is), or
- One has heart failure.

IV. PACEMAKER DESIGN

The pacemaker software will receive the desired pulse rate from the programmer and use it to pace the fetal heart. In order to conserve battery life which will be monitored constantly by the circuit, the pacemaker will be in sleep mode between pulses. The pacemaker will continue to pace at the set pulse rate until it detects another value from the programmer. It is to be noted that the pulse rate can only be modified before implantation.

4.1 Hardware Design

The pacemaker will have one output which will either receive the pulse length from the programmer or send the pulse output to the electrode. The microcontroller and battery will be encased in a titanium alloy casing. In this hardware design the electrodes will sense the electrical activity of the heart. Then this measured signal will be compared with a pre-fed signal. The programmer will send the pulse length. The microcontroller circuit will determine what amount of pulse strength should be sent to heart.

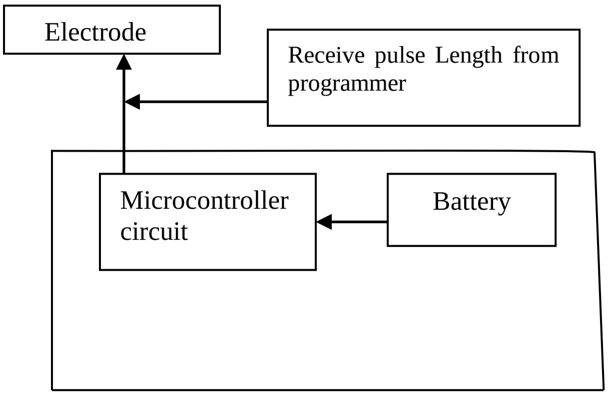

Figure 3: Hardware Layout of Pacemaker

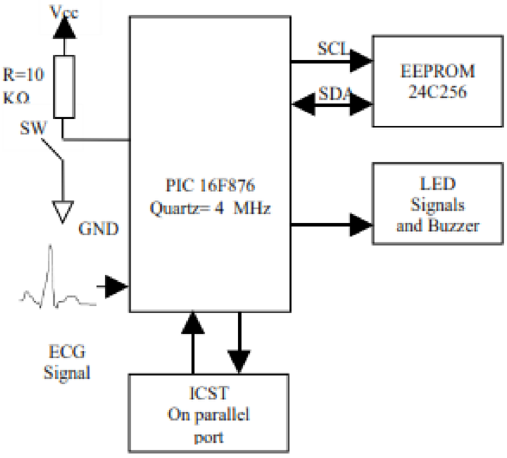

Figure 4: Block Diagram of Pacemaker

In this case, the method consists of computing a cardiovascular rate of the person each minute. A pre-processing step is needed to perform an amplification of the signal and a hardware filtering to eliminate noise. Many algorithms had been investigated to chose the best fit method for the microcontroller [7, 13].The QRS pulse has higher energy and a heart pulse can be detected within five to six zero crossing of the signal as illustrated in Figure 5. The rate counter, representing the number of pulses during one minute, is incremented at detection of a QRS pulse. It is then compared with two references representing bradycardia and tachycardia for adult or children. These referenced values were taken by statistical computation. The adult normal heart rate is in the range of 70 and 90 beats, while that of an infant is in the range of 100 and 170 beats per minute at rest [16]. If the heart rate counter is different from references then a LED indicator is lightened and an audio signal is generated. After a minute, the rate count is stored in the external EEPROM, if it is different from the previous count. This is followed by an internal clock time which should be synchronized with real-time clock. Thus, at every sensitive variation of the pulse rate, three bytes would be stored. These bytes represent the rate count, the hour and the minute of the internal clock.
As aforementioned, a graphic unit interface easy to use by the patient, using Delphy language under Windows as operating system has been developed. The main menu of the application provides the user with acquisition, display and transfert.

4.2 Software Design

The programmer software will ask the user to input the desired heart rate and calculate the pulse rate which will be converted to a binary value. The user will be first asked to confirm the heart rate and subsequently asked to confirm if he/she would like to output the pulse rate to the pacemaker. The programmer will only be able to set/reset the pulse rate of the pacemaker before implantation.

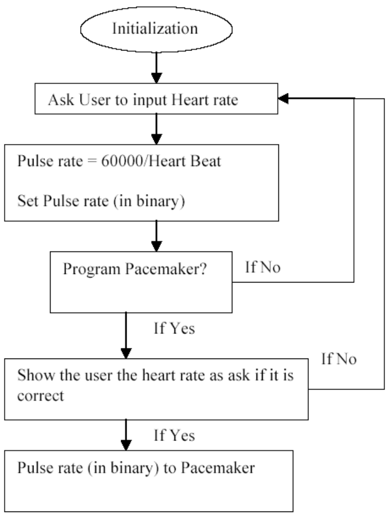

Figure 5: Flow Chart of Pacemaker

V. RESULT & DISCUSSION

The system has been designed to incorporate the ECG signal capability of diagnosis, the real-time ECG processing. The diagnosis capability of the logical algorithm used has been tested using a simulated ECG signal. In addition, the diagnosis bytes associated with each heart signal are being verified but further statistical studies on real ECG signals are required for more evaluation of the system validity. The processing time required for generating and storing the diagnosis byte is 1.25 ms. This is believed to be sufficiently short compared with typical heart signal variation. Hence the system is fast enough to track any changes in heart condition.

VI. CONCLUSION

The principal objective of the pacemaker design is to turn on pacemaker when the heart simulation turn off and with the help of this circuit it is achieved. The designed pacemaker can only detect the heart state, but it cannot sense the changes in the heart frequency .it is also required that pacemaker circuit should be battery operated and the life of battery should be long enough (7 to 10years at least).The pacemaker circuit was tested and it was giving rhythmic pulses. But certain improvements are to be required before actually using pacemaker circuit on subject (human body).

In future, after developing a suitable pacemaker it will be good to investigate to create an implantable system that can be programmed externally. There are many different kinds of pacemaker. The best one depends on what type of abnormality of heart rhythm or heartbeat one have. Most pacemakers are ‘demand pacemakers’ which means that the pacemaker does not produce a beat if the heart beats naturally. Modern pacemakers are comfortable and very reliable. Many people find that having a pacemaker allows them to get back to their normal lifestyle, and greatly improves their quality of life.

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