A Proposal on the Design of Battery-less Cardiac Pacemakers

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ABSTRACT

Cardiac Pacemakers are used to monitor the rate and rhythm of the heart. Also they provide electrical simulation when the heart beat is too slow or doesn’t beat. Present day pacemakers suffer from the heating of pacemaker leads and moreover they are battery operated. The batteries used in such cardiac IMDs have problems like being in large in size, limited life span and different chemical effects. Due to these problems a lot of people with cardiac Implantable device are facing reliability and safety issues.

The main aim of this work is to provide safety for the Cardiac patients and improve their quality of life. This project proposes a cardiac Implantable Medical Device that continuously monitors the cardiac rhythm and rate of the patient and also it is capable of providing electrical simulation to heart when it doesn’t beat or beats too slowly. The proposed work eliminates the use of batteries in implantable devices by using various techniques like power harvesting with piezoelectric material, inductive coupling link to power up implantable devices. Also this work reduces the complexity of the electronic blocks and various passive components which indeed reduces the size of the device.

This project attempting different challenges and issues like efficient power delivery to the implantable circuits, reliable and fast bidirectional data communication, delivery of safe stimulation to avoid tissue and electrode damage, low noise and low power for the recording part of the system. By taking all these points into consideration and with the knowledge of work done so far, we would like to design a new cardiac Implant Medical Device which can fulfill the requirements of low power, low noise and battery less power up for Implantable device.

1. INTRODUCTION

Cardiovascular disease has been identified as the major health concern in many countries. The statistics shows that around 7.5 million people die every year due to cardiovascular disease. With the reports and studies, World Health Organization (WHO) expected India to be the world capital for Cardiac disorders with more than 60% of cardiac patients in India. Hence it is a need of hour to design and develop bio-medical electronic devices that detect, control and prevent cardiac disorders. In India most of the people with cardiac disorders reach to the hospital after the golden hour from the onset of cardiac arrest. The chances of fast and total recovery of the patient with cardiac related disorders are declined due to the late detection of the symptoms. Therefore, patients investigated with cardiac disorders are those who are at high risk, need continuous Electrocardiography (ECG) monitoring solutions for continuous cardiac monitoring and also need cardiac Implantable Medical devices to treat brad arrhythmia.

Wearable wireless ECG sensor is one of the best methods for continuous monitoring of heart condition where as Pacemakers are used to treat brad arrhythmia. However, the design and development of ECG sensors and Pacemakers using CMOS technology remains more challenging due to the constraints on size, weight and power consumption. Attaining long battery
life or self-powered sensor which is small and flat is the eventual goal as it facilitates continuous recording of ECG signal and cardiac rhythm, providing electrical simulation when hearts beats too slow or doesn’t beat without causing any sort inconvenience to the patient.

2. LITERATURE SURVEY

Gabor C. Temes [1] addressed the design options for battery operated medical device applications which can operate on limited power available in the battery. He also discussed about the implementation of low power data converters which consumes more power in medical devices.

Zhihao Jiang, Miroslav Pajic and Rahul Mangharam [2] developed a virtual model by extracting timing properties of pacemaker and heart for verifying the electrophysiological operation of malfunctioning and functioning of heart during arrhythmia. But proposed model suffers from the implementation issues such as jitter, noise, signal distortion and timing overhead. Louis S.Y. Wong et al [3], developed an IC for pacemaker consisting of switched capacitors and analog transistors operating in sub threshold region. The proposed chip dissipates more power which makes the device with less longevity. Joachins Neves Rodrigues et al [4], developed and implemented Cardiac Event Detectors in digital CMOS. The authors presented how the architecture of pacemaker was modified to achieve power and area efficient silicon implementation. Fernando Silveria et al [5], presented and tested a ultra low power implementation of a sensing channel circuitry. In this work authors had reduced power by combining the architecture of pacemaker with power saving building block techniques and with the characteristics of SOI CMOS technology. Nourhene Ellouze et al [6], discussed various lethal attacks targeting cardiac Implantable Medical devices due to the use of wireless communication and security protocols. The authors also proposed a system for analyzing the lethal attacks targeting Cardiac Implantable devices.

Zhanning Zhu et al [7], proposed a novel switching scheme for implementing SAR ADCs in Cardiac Implementable Medical Devices to achieve low power operation. Also the authors proposed a Prototype of ADC implemented in CMOS technology which occupies less area and consumes less power. In the measurement of energy consumption in wireless sensors, Carlos Fernandez et al [8] designed and proposed a circuit and a method called Self-Energy Meter which has capability of measuring its own device energy consumption. Andreas Demosthenous et al[9], discussed the issues and challenges faced by the designer when creating cardiac Implantable Medical devices such as fast and reliable bidirectional data communication, low power and low noise for the recording part of the system, simulation to avoid electrode and tissue damage.

Munna Padmavathi [10], presented the characteristics of the inductive effective RF link and highly efficient communication systems for data rate over the link. The author also addressed how the powering of the implanted devices is done, as well as the bidirectional communication between the external world and implant that can be simultaneously done via a biotelemetry inductive link. Santosh Chede and Kishore Kulat [11], proposed development of low power processor based implantable cardiac pacemaker and estimation of software related energy consumption. Munna Khan et. Al., [12] presented a low power Implantable solar power supply for battery operated biomedical sensors and implemented using SPICE. The work also demonstrated how the maximum power can be extracted from light to use in biosensors. Md.Kareemoddin [13] addressed the design challenges and strategies of low power SAR ADCs for Cardiac implant devices. The author had designed and implemented dynamic comparator in CMOS technology which consumes more power in SAR ADC.

3. OBJECTIVES AND METHODOLOGY OF RESEARCH PROPOSED

A. Objectives

The objectives of this research work are given below in a simple and obvious way that on attaining this goals will lead to betterment in design of batteryless cardiac IMDs
● To design a cardiac Implantable Medical Device that monitors the heart rate and rhythm and boost the heart rate whenever heart beats too low or doesn’t beat.

● To establish the new approach that eliminates the use of batteries in implantable devices by using various techniques like power harvesting with piezoelectric material, inductive coupling link to power up implantable devices.

● To develop a frame work for the qualitative design that reduces the complexity of the electronic blocks and various passive components which indeed reduces the size of the device.

● Simulational verification of the various blocks in cardiac IMDs and find its performance characteristics in terms of power, speed, area and noise.

B. Methodology:

The methodology is given below as step by step procedure to solve the considered applications.

a) Initialization and Framing the process Flow

Here the required block diagram of the wireless ECG is initialized and processed as follows: The Simplified block diagram of cardiac wearable medical Device and transmission using GSM is shown in figure1 and 2.

The block diagram consists of the important functional blocks as follows.
1) Input side: a sensing system consisting of amplifiers, filters and ADC.
2) Output side: consists of high voltage multiplier and high voltage output pulse generator.
3) Housekeeping side: battery management system, bias and reference generators
4) Logic: algorithms for therapy controls and oscillators.

![Figure 1: Proposed Block diagram Cardiac IMD Outline](image)

![Figure 2: Cardiac Implantable Pacemaker](image)

b) Implementation of the Proposed System

Initially different Implantable device models which work for cardiac applications are going to be designed on commercial EDA-VLSI tools like Mentor Graphics and Cadence. Compact, low power and low noise models will be separated for testing under different circumstances.
designing these models care will be taken in the size and the place occupancy of the IMDs as per the specifications. It is very important for a Pacemaker to sense cardiac signals. The block diagram of pacemaker sensing system is shown in Fig. 3.

![Figure 3: Block Diagram of sensing system](image)

Here the signal from the heart is sensed and it is amplified by a LNA, Voltage gain amplifier, and bandpass filters, and the resultant is digitized by an analog-to-digital converter (ADC). Switched-capacitor (SC) amplifiers and filters are used for accurate frequency response and low power consumption. The block diagram of Monotonic Slope ADC is shown in Figure 4. A high speed local oscillator is proposed in this ADC architecture to make sure that the conversion rate is more than 100S/s.

![Figure 4: A 12bit SAR ADC](image)

Simulation with Prototype Measurement

Performance of the designed Cardiac IMD is much different when it is operated in heart. As our work aim is to develop a battery less operated cardiac IMD, once the design is done a specific prototype is developed and it is tested with different power harvesting techniques. Experimental Investigation of the proposed prototype is carried out by using Microcontrollers and labview software.

Prototyping the cardiac IMD and testing for its reliability

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**4.EXPECTED RESULTS**

The proposed design can be fabricated in 45nm CMOS process. The designed and implementation of the project may occupy a die area of approximately 70µmX70µm. Also the power dissipations will be in terms of few nano watts with a sampling rate of 1kHz. The ON supply current and standby supply current will be in a range of 20nA and 2nA.
5. CONCLUSION

In biomedical applications like cardiac IMDs low power dissipations is the major criterion and also current consumption is carefully considered and used in the IC. In this project, we proposed a batteryless low power cardiac IMD which automatically recharges and thereby reduces the risk of repeated surgeries.

Once the framework is standardized and yielding optimum results we hope to tie up with a group of independent researchers, medical professionals and Healthcare providers who may be interested to use this work for the betterment of society. We aim to utilize the technology developed through this project as a tool to serve the people in need and create awareness among the common people.

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REFERENCES


