Implantable Cardioverter Defibrillator with Wireless Charging and IOT Applications

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***Abstract*—Implantable cardioverter defibrillator is battery powered life saving device with multiple functions such as monitoring heart function, pacemaking and defibrillation. The ICD can deliver small electrical impulses and macro shocks to the heart of a congestive heart failure or a hypertrophic cardiomyopathic patient to maintain a suitable heart rhythm. The ICD monitor the heart rhythm and its patterns to detect the abnormality. When the ICD detect an anomaly it delivers the required (pacemaking) signals to the heart and maintain its natural rhythm. At worst conditions such as arrhythmia, ICD is programmed to deliver macroshocks that cause fibrillation and helps to regain the normal rhythm. The in-heart exclusive parameters such as accurate systolic and diastolic pressures are measured by the device. Since integrating all these applications can drain the ICD battery so fast, wireless charging technology is implemented in the device so that the battery replacement surgery can be avoided along with the risks and costs associated with the surgery.**

I.INTRODUCTION

An implantable cardioverter defibrillator (ICD) is a device that monitors and responds to heart activity. ICDs have modes for pacing, wherein the device periodically sends a small electrical stimulus to the heart, and for defibrillation, wherein the device sends a larger shock to restore normal heart rhythm. A physician surgically implants the ICD below the patient’s clavicle and close to the skin. The physician also implants electrical leads that connect the ICD to the heart muscle. This leads delivers the electrical charge to the muscles of the heart and can also conducts the signals from the heart and delivers it to the ICD. The sensors integrated in the ICD can detect the heart signals and transfer it wirelessly to the external reception module .Post-surgery; a health care practitioner can use an external programmer to perform diagnostics, read the private data. The operations such as monitoring, pacemaking, defibrillation and wireless transmission drains the battery much faster than normal pacemaker does. So for compensating the battery drainage issue wireless charging technology is implemented in the device so that the device can be charged wirelessly. The wireless charging mechanism can exclude the needs for frequent battery replacement surgeries along with its costs and risks associated with the surgery.

II.PROPOSED SYSTEM.

The defibrillation, pacemaking and wireless charging are already existing technologies. We propose a system that integrates all these technologies together to make device that is highly useful for the health industry. The conventional pacemaker can only deliver pacemaking signals to the heart on demand or continuous pacemaking in rare case. But in the case of cardiac arrhythmia, the pacemaker fails to maintain the cardiac rhythm. Moreover the pacemaking signal while cardiac arrhythmia can even prove fatal. So a defibrillator has been implemented in the device which works in parallel with cardiac pacemakers. When the heart experience an arrhythmia, the ICD detects the condition and supply macro shocks to the heart. This fibrillates the heart and reorganizes the heart beat and maintains its normal rhythm. The data regarding the anomaly is being recorded by the device and is programmed to send the reports wirelessly to the external receiver module.

A. Pacemaker

Pacemaker is a small device that's placed in the chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate.Pacemakers are used to treat arrhythmias (ah-RITH-me-ahs). Arrhythmias are problems with the rate or rhythm of the heartbeat. During an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm.

A heartbeat that's too fast is called tachycardia (TAK-ih-KAR-de-ah). A heartbeat that's too slow is called bradycardia (bray-de-KAR-de-ah).During an arrhythmia, the heart may not be able to pump enough blood to the body. This can cause symptoms such as fatigue (tiredness), shortness of breath, or fainting. Severe arrhythmias can damage the body's vital organs and may even cause loss of consciousness or death.A pacemaker can relieve some arrhythmia symptoms, such as fatigue and fainting. A pacemaker also can help a person who has abnormal heart rhythms resume a more active lifestyle.

B. Defibrillator

Defibrillation is a treatment for life-threatening cardiac dysrhythmias, specifically ventricular fibrillation (VF) and non-perfusing ventricular tachycardia (VT). A defibrillator delivers a dose of electric current (often called a countershock) to the heart. This depolarizes a large amount of the heart muscle, ending the dysrhythmia. Subsequently, the body's natural pacemaker in the sinoatrial node of the heart is able to re-establish normal sinus rhythm. In contrast to defibrillation, synchronized electrical cardioversion is an electrical shock delivered in synchrony to the cardiac cycle. Although the person may still be critically ill, cardioversion normally aims to end poorly perfusing cardiac dysrhythmias, such as supraventricular tachycardia.

C. Pacemaker defibrillation integration.

Pacemaker and defibrillator were two independent devices until implantable cardioverter defibrillator was invented. In this proposed system, pacemaker is an independent device which delivers continuous square wave signals known as pacemaking signal and defibrillator delivers shock to the heart muscles which helps to tackle fibrillation. While integrating both pacemaker and defibrillator, the patient has more survival chances from cardiac arrests compared to other patients without the ICD.

D. Wireless charging

The existing system of an Implantable cardioverter defibrillator consists of a battery which has to be replaced at least in every 15 years which approximately. If ICD with the existing technology has been implemented to a ten year old kid, then the battery has to be replaced at least more than three times (considering life expectancy of minimum 50 years.). The battery replacement surgery is obviously costly and the risk associated with the surgery is very high. So the main difference of the proposed system with respect to the existing system is the implementation of wireless charging in the ICD.

E. Block Diagram.

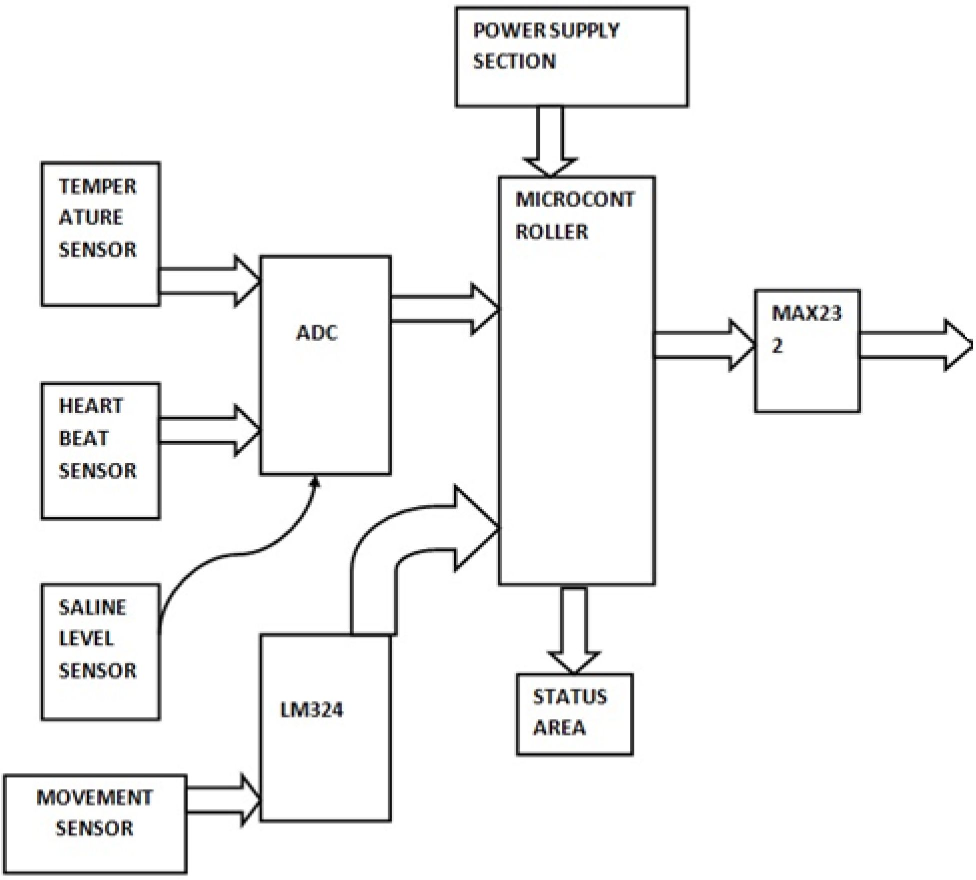

Fig 1

F. Circuit Diagram.

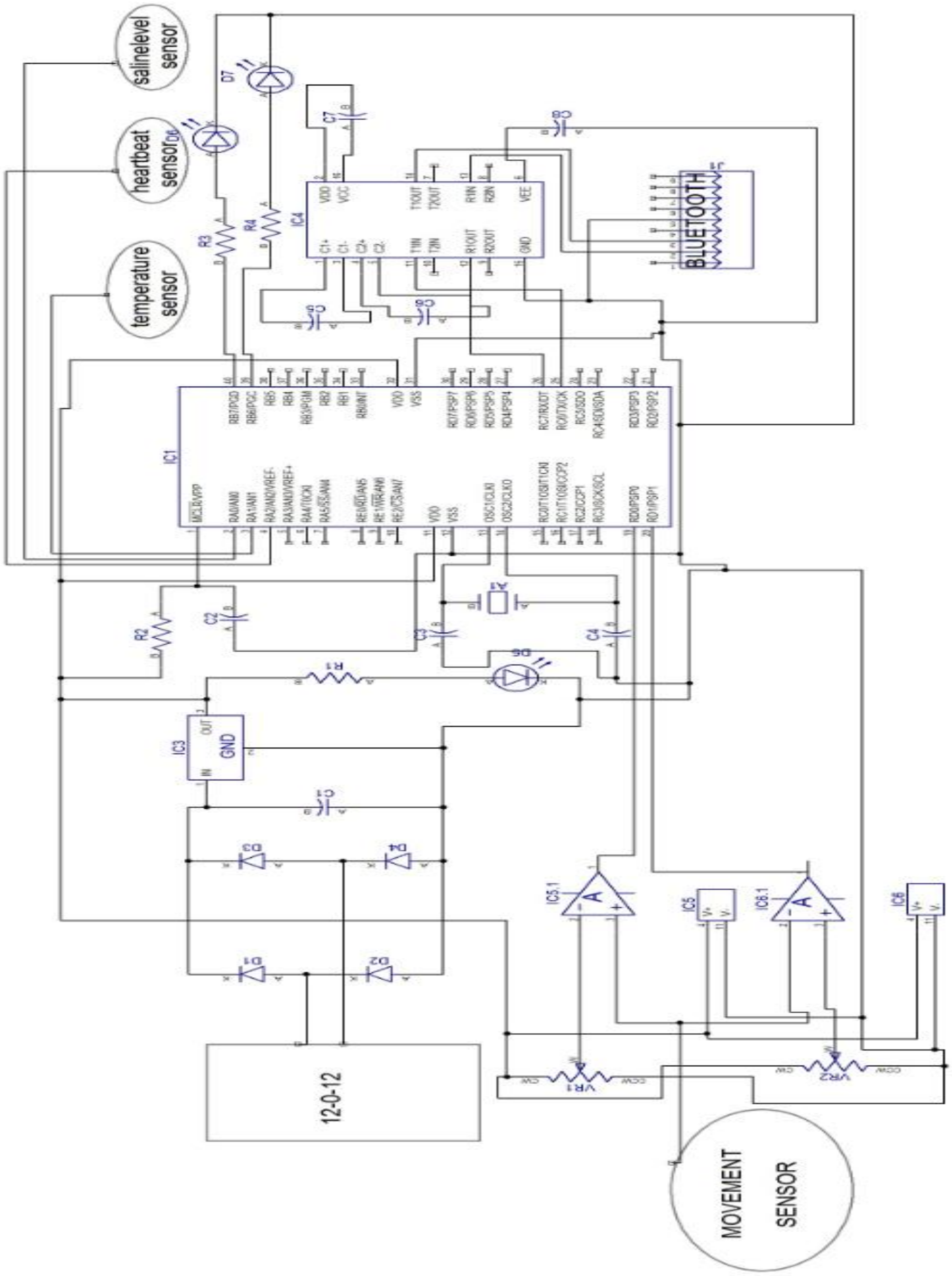

Fig 3

G. Coil design.

The transmitter and receiver coils are the key part of the whole device, which decide whether the system operates well. To make the two coils coupled stronger, we designed the bi-layer coil. Compared to the monolayer coil, the bi-layer coil has fourfold inductance and only twice resistance than the monolayer coil. Then the bi-layer coil has twice power factor than the monolayer coil, thus the coupling of the two coils elevated. The two coils are made by printed circuit board (PCB), so their inductances are stable and easier to compensate. The transmitter coil is the regular plane circle design, while the receiver coil needs to fit the surface of the pacemaker, so its shape is irregular, Furthermore, the receiver coil applies the special flexible print circuit, which can bend in 360°, so it can better fit the surface of the pacemaker.

1.Circuit design

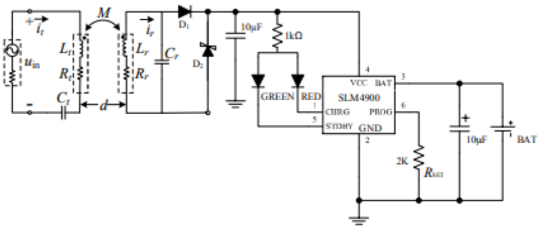

Fig. 2 circuit of the wireless charging device

The circuit of the wireless charging device is shown in Fig. 2. The primary and secondary coils are separated by an 8mm air gap. The whole device consists of four parts. The first part is energy source, containing a signal generator and a signal amplifier, which provides a 200 kHz sinusoidal voltage to power the system.

The second part is the coupled coils and their compensating circuit, the system was in series-parallel compensating model, this model is easy to tune and the secondary part can get higher voltage. The third part consists of a schottky diode and a zener diode for rectifying and being a 5V DC power source for the last part. The last part is the charging circuit achieved by the IC SLM4900 and its application circuit, which can charge a single 4.2V lithium-ion battery.

H. Battery selection

Considering the heat of the coils and the psychological states of patients, the charging process should not last too long. Actually, 30 minutes could be suitable, so the capacity of the lithium-ion battery should be chosen considerately. From the data [13], the 0.92Ah lithium battery for single-chamber pacemaker could last 10.4 years and the 1.3Ah lithium battery for dual-chamber pacemaker could last 11.3 years. So we chose a 1050 mAh lithium-ion battery at last, and we plan to charge the battery when its remaining power decreases to 80%. The battery longevity is shown in the equation (1), / 8766 L = Q I del (1) I is the current output of the pacemaker, usually 10μA [14], L is the battery longevity. From the equation (1), 20% power of our battery can last 2.39 years. Do not confuse "imply" and "infer."

I. Chaging curve

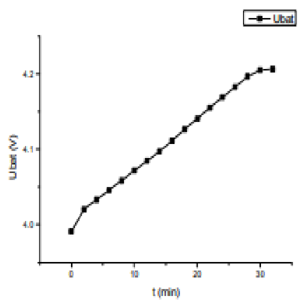

Fig. 4 the charging curve

The frequency of power source was 200 kHz, and the original voltage of lithium-ion battery was 3.9912V. Measured in the experiment, the input voltage uin was 26.3V (peak-peak), the input current i was 4.7A (peak-peak). The charging curve is shown in Fig. 4, the whole process lasted 32 minutes and the voltage of battery increased from 3.9912V to 4.2060V, reaching the expectation.

IV CONCLUSION

Our study focuses on a single ICD, and therefore provides only a small snapshot in the evolution and breadth of ICD technologies and more general implantable medical devices. Nevertheless, we believe that this snapshot is necessary toward assessing the current trajectory of ICD modernization. The exclusion of cost, time and risks was the main objective while we come up with the integration of multiple technologies. The heart disease is the main issue by which the patients die worldwide. The further investigation and optimization to this technology will have a huge impact in patients who suffer from critical heart diseases.

V.REFERENCES

[1] G. Martinelli. Torna a Surriento. [Online].

[2] D. C. Schechter, *Exploring the Origins of Electrical Cardiac Stimulation*. Minneapolis, MN: Medtronic, Inc, 1983.

[3] L. A. Geddes, "A short history of the electrical stimulation of excitable tissue. including electrotherapeutic applications," *Physiol.*, vol. 27, no. 1, p. 47, 1984.

[4] S. Furman, "Early history of cardiac pacing and defibrillation," *Indian Pacing Electrophysiol. J.*, vol. 2, pp. 2–3, 2002.

[5] A. Chaikhouni, "The magnificent century of cardiothoracic surgery. Part 8: Reviving the dead heart views," *Heart Views*, vol. 11, no. 2, pp. 85–91, June–Aug. 2010.

[6] S. Furman, "In memoriam: Clarence Walton Lillehei (1919–1999)," *PACE*, vol. 22, pp. 1566, Oct. 1999.

[7] L. A. Geddes and E. E. Bakken, "Who first performed cardiac pacing: Why, when and where?" *IEEE Eng. Med. Biol. Mag.*, vol. 26, no. 3, pp. 77–79, 2007.

[8] E. Sowton, "Implantable cardiac pacemakers," *British Heart J.*, vol. 30, no. 5, pp. 587–590, 1968.

[9] W. Greatbatch and C. F. Holmes, "History of implantable devices," *IEEE Eng. Med. Biol. Mag.*, vol. 10, no. 3, pp. 38–41, 1991.

[10] L. G. Robinovitch, "Resuscitation of electrocuted animals. Choice of the electric current and method used and application to human beings. Experimental study of the respiration and blood pressure during electrocution and resuscitation," *J. Ment. Pathol.*, vol. 8, no. 2, pp. 74–81, 1907