ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 19, April 2017

PIEZOELECTRIC POWER SOURCE FOR PACEMAKER

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1. ABSTRACT

The current technology used in the artificial pacemaker has some major shortcomings. One of the main problem in the Pacemaker is its battery. The battery used now a Day's has a lifetime of 10 to 15years. Patients who underwent an Operation in a very early age have to repeat the procedure number of times during their entire life. Our proposed project aims to alleviate the trouble and nightmare every time a patient has to face during the procedure of operation. Our project replaces the battery with the PIEZO ELECTRIC CRYSTAL which can covert the vibrations of the heart produced during the contraction and relaxation. Every time the heart beats the vibration is harvested by the crystal. The vibration is converted into electrical energy by applying it to the mechanical axis of the crystal. Piezoelectric crystals has the ability to convert the mechanical energy into electrical energy and vice versa. Hence by replacing the battery with the piezoelectric crystal can prolong the life time of the pacemaker for a long haul and remove the pain and pang of the patient.

General word: Self-sustaining pacemaker

Key word: piezoelectric crystal

2.INTRODUCTION

Batteries used in Implantable cardiac pacemakers-present unique challenges to their developers and manufacturers in terms of high levels of safety and reliability. In addition, the batteries must have longevity to avoid frequent replacements. Technological advances in leads/electrodes have reduced energy requirements by two orders of magnitude. Micro-electronics advances sharply reduce internal current drain concurrently decreasing size and increasing functionality, reliability, and longevity. It is reported that about 600,000 pacemakers are implanted each year worldwide and the total number of people with various types of implanted pacemaker has already crossed 3 million. The implanted cardiac pacemaker uses nickel-cadmium rechargeable battery, later on zinc-mercury battery was developed and used which lasted for over 2 years. Lithium iodine battery made the real impact to implantable cardiac pacemakers. This battery lasts for about 10 years and even today is the power source for many manufacturers of cardiac pacemakers. The proposed project uses a piezoelectric transducer which converts the mechanical vibrations of the heart into electrical energy which in turn powers the pacemaker. This paper briefly reviews the alternative to lithium iodine battery for the near future.

2.1 Pacemaker

The pacemaker unit delivers an electrical pulse with the proper intensity to the proper location to stimulate the heart at a desired rate. The cardiac pacemaker comprises of a pulse generator and a lead system. The pulse generator houses electrical components responsible for generating the pulse (via output circuits) at the proper time (via timing and control circuits) based on events sensed (via sensing circuits). It also contains a power supply (battery) and may include other elements such as telemetry for testability and programmability and memory (ROM or RAM) to store data for diagnostic purposes.

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Impulses are transmitted to the heart by means of a lead, which is attached to the pulse generator via the connector block. A lead is either unipolar or bipolar; a unipolar lead contains one insulated coil, whereas a bipolar lead contains two coils, separated by an inner insulation. An outer insulation shields a lead from the environment. The tip of a lead, which contains an electrode, is implanted into the inner, endocardial surface of the heart, the actual location depends on the type of pacemaker. The pacemaker unit is usually implanted in the pectoral region, with the lead running through the right subclavian vein to the internal surface of the heart. A pacemaker is programmed by means of a programmer, a computer with a special user interface for data entry and display, and with special software to communicate with the pacemaker. The telemetry head is placed above the location of the pacemaker; information from the programmer to the pacemaker, and back, is transmitted by means of telemetry.

The casing of the pulse generator functions as housing for the battery and all other electronic and electrical circuits. A connector block, made of polyurethane, (glass materials were used to comprise the connector block in earlier models) is located at the top of the pacemaker. It serves to attach the pacemaker to the pacemaker lead(s). The present day pulse generator case is made of titanium, a metal that is ten times as strong as steel, but much lighter. Titanium and two of its alloys, niobium and tantalum, are biocompatible, they exhibit physical and mechanical properties superior to many other metals. The modulus of elasticity (measure of stiffness) of titanium and its alloys range between 100-120GPa. Extreme resistance to corrosion and durability make titanium and its alloys ideal materials for hermetically sealed pulse generator cases for cardiac pacemakers. Titanium replaced ceramics and epoxy resin with silicone rubber, which were used for encapsulation of some pacemakers in the past.

To assemble the pulse generator, the hybrid circuits and the battery are placed in the titanium case (ASTM Grade 1) in a specially designed clean room that has no static charge (less than 1% moisture) and no dust in it. Once the hybrid circuits and the battery are in the casing, the casing is welded shut with a high-powered laser beam. This laser beam gives the pulse generator a hermetic seal, which means that the device is airtight and liquid-tight. After welding, the top, or header of the pacemaker is attached and the entire device is covered in a thin layer of plastic (epoxy plastic). This plastic coating further seals the pacemaker.

The casing is a given a kind of elliptical shape and a typical pacemaker diagram is shown in figure 1. This upgrade to titanium allowed patients to safely use appliances such as microwave ovens because titanium helps to shield the internal components and reduce the external electromagnetic interference. In addition, titanium casing shields from ground level cosmic radiation.

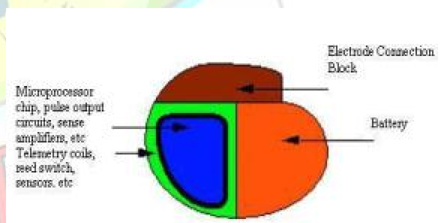

Fig1. pacemaker

2.2 Piezo electricity

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied

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mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field). For example, lead zirconate titanatecrystal will generate measurable piezoelectricity when their static structure is deformed by about 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their static dimension when an external electric field is applied to the material. The inverse piezoelectric effect is used in the production of ultrasonic sound waves.

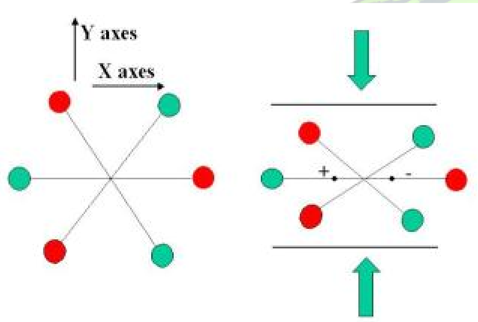

Fig2.mechanism of piezoelectricity

2.3 Proposed system

The idea of replacing or recharging the batteries is based on the fact, that the piezoelectric material is charged by the hearts own operation. This means that the generator is loaded by harmonic pressure. The pacemaker or implantable cardio defibrillator is programmed depending on the heart condition. Therefore it is necessary to store the generated energy in a capacitor and then use it at a time when the heart needs stimulation. Classical implantable devices don't have such storages of energy because they run on batteries. This function can be seen in fig.

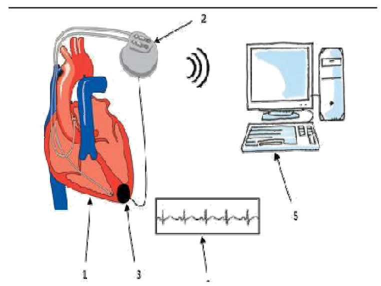

Figure 3: Pacemaker charged by heart (1-heart, 2-implantable device, 3-piezoelectric material, 4-heart beat action, 5-processing computer)

3. BLOCK DIAGRAM

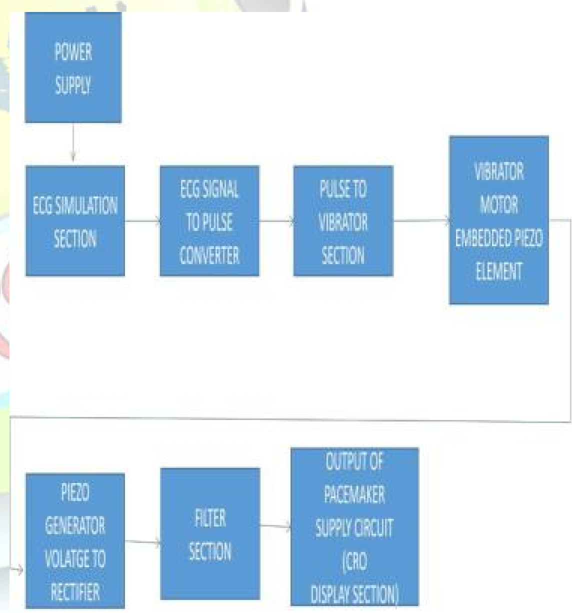

Fig4.Block diagram

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3.1 Power supply

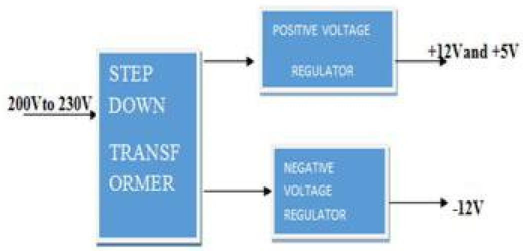

Fig5.Power supply

As all circuit needs a power supply, Hence the power supply of 200V to 230V voltage from the main is first step down by using a 24V-0-24V step down transformer. The output of the transformer is given to a diode 4007 rectifier which converts the AC voltage to DC voltage which is given to positive voltage regulator for which we use IC7812 which provides +12V regulated power supply we only need to use four capacitors ,two on the input and two on the output two obtain clean voltage output and even these capacitors are optional to use.it has built in over heat and short circuit protections which makes it a good choice for making power supplies and a IC7805 provides +5V regulated power supply with provisions to add heat sink as well. The +12V and -12V input is given to the operational amplifiers and trimpot in the further sections and +5V and -5V input is given to the ECG simulation section.

The rectified DC voltage input is also given to the negative voltage regulator for which we use the IC7912 as which can supply -12V regulated power supply.

3.2 ECG simulator

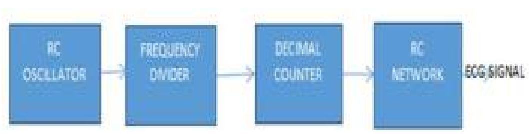

Fig6.ECG Simulator

As it is not possible to use a real heart for testing the proposed concept we are using an ecg simulator to display the functioning of heart. An ECG simulator replicates the cardiac waveform that can be measured by attaching three electrodes (RA, LA, RL) to the patient's chest. This ECG signal is only a few millivolts in amplitude. The circuit consist of an RC oscillator section which generates a frequency signal of 1Mhz whose output is given to the IC1-CD4521which is a CMOS 24-stage frequency divider and it generates a square wave pulse which is given as clock input to theIC2-CD4071 which is a decimal counter given a dc 5 volt as input whose output is given to a RC network which generates a PQRST WAVEFORM as shown in the below .

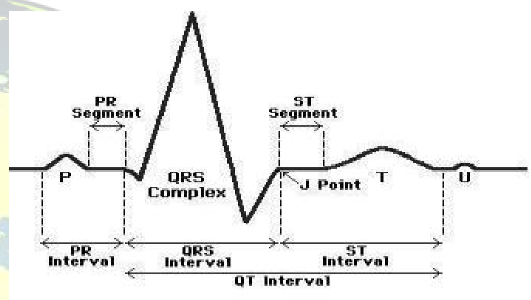

Fig7. ECG waveform

3.3 ECG signal to pulse converter

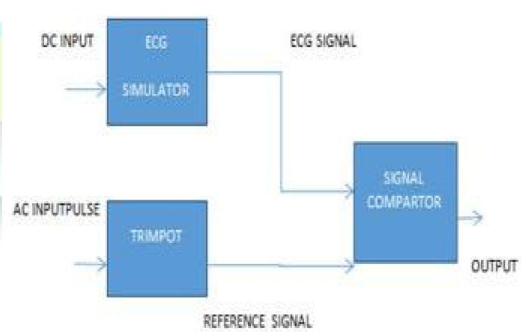

Fig8.ECG signal to pulse converter

Now the ECG signals has to be converted into a pulse since it is not possible to covert these signals into vibrations directly as the heart does, we need to convert these signals into a pulse for which we are using a trimpot which is a potentiometer and used to give a reference signal and the IC741operational amplifier as shown in acts as a signal comparator

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which takes the PQRST waveform as input and also the reference signal and produces a pulse only when the QRS complex is received , it is because the required voltage to drive the vibrator motor in the further section can be obtained only when the QRS complex is encountered and the other waveforms such as P,T are neglected.

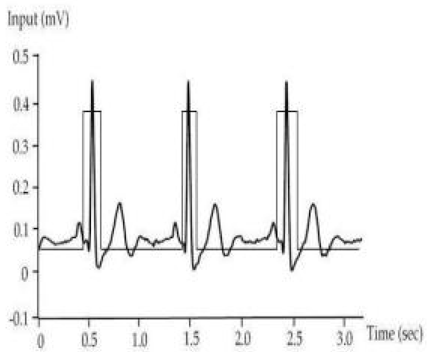

Fig9.waveform depicting the pulse output only when the QRS complex is encountered

3.4 Pulse to vibration section

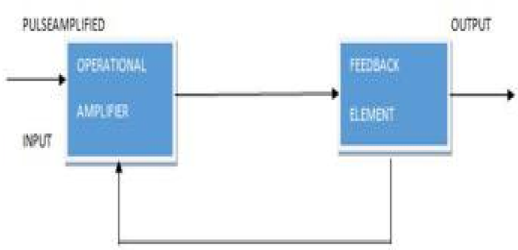

Fig10.pulse to vibration section

The pulse signal has to be amplified before converting it into vibrations. For that purpose IC LM741 is used which is an operational amplifier which can amplify the incoming pulse signal with an outstanding gain of 10 X10^3 or more is maintained over the full output voltage of +-12V.a diode 4007the output of this section is given to the vibrator motor. The transistor IC1351 is used here as a feedback element to the opamp IC741.

3.5 Vibrator motor embedded piezo element

The amplified pulse is given to the transistor to the IC1351 which acts here as a switching element which reduces the delay in the circuit and then it is connected to the diode 4007 which acts here as leakage current blocking element. The pulse is given as input to the vibrator motor which converts the pulse into vibrations.These vibrations are given as input to the mechanical axis of a piezoelectric crystal which generates an AC voltage signal.

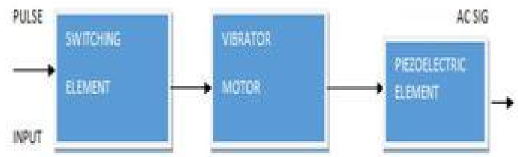

Fig11. vibrator embedded piezoelement

3.6 Piezo generator to voltage rectifier

Fig12.Piezo generator voltage rectifier

The AC signal output is given to the fullwave bridge rectifier consisting of four IN4148 which is a signal diode and it converts the AC voltage produced by the piezoelectric transducer into DC voltage.

3.7 Filter section

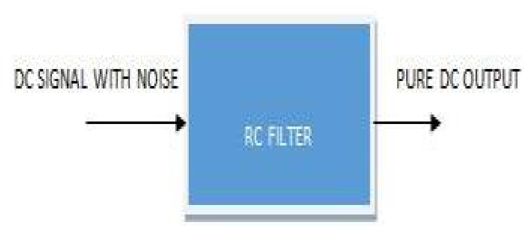

Fig13.filter section block diagram

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The filter section consists of a parallel RC circuit which blocks any residual AC signal and filters out the noise signal and gives pure DC signal as the output. It consists of two resistors R29(10K) and R30(1K) and the capacitors C21(100uF) and C22(1uF) and resistorR28(470K) in parallel connection this circuit filters out any residual AC components and removes the noise and gives out pure DC signal as the output.

3.8 Output of pacemaker supply circuit (CRO display section)

Thepure DC output from the filter circuit can be used to power any pacemaker circuit. The output is displayed in the CRO.

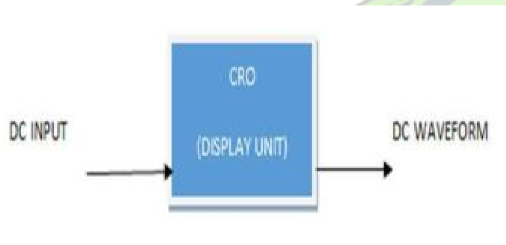

Fig14.CRO display unit block diagram

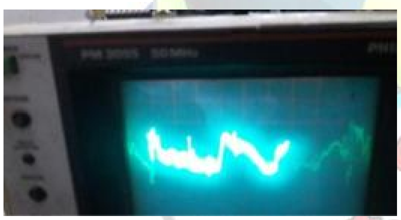

Fig15.ECG waveform output of ECG simulator

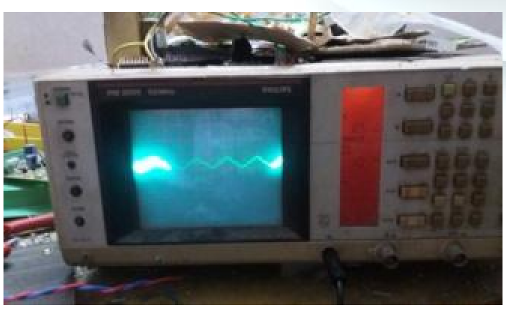

Fig16.AC signal output of piezoelectric transducer

Fig17.DC Output to the pacemaker circuit

4. APPLICATION

This piezoelectric power source can be used to power the internal cardiac pacemakers. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the natural pacemaker is not fast enough or because there is a bock in the heart electrical conduction system.This proposed pacemaker can be used to treat bradycardia (a type of heart diseases in which the heart beat of the patient is below 60 beats per minute. Average BPM should be 72 to 90). It synchronizes the heart beat.Tachycardia (A type of heart diseases in which the heart beat of the patient is above 100 BPM). This condition can be treated by using the pacemaker which reduces the BPM to 72 to 90.The sole use of this pacemaker is to treat arrhythmic conditions of the cardio-vascular system

5. CONCLUSION

Theproposed projectproduces the output of 300 mV which can be increased considerably by using custom made multi layered piezo electric transducer. The power generated is enough to power a pacemaker. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's natural pacemaker is not fast enough, or because there is a block in the heart's electrical conduction system. The condition in which the hearts BPM is lower than normal is called as bradycardia and the condition in which the BPM is higher than normal is called as tachycardia. Pacemaker can be used to treat both the cases of arrhythmias. Modern pacemakers are externally programmable and allow a cardiologist to select the optimum pacing modes for individual patients. Some combine a pacemaker and defibrillator in a single implantable device. Others have multiple electrodes stimulating differing positions within the heart to improve synchronisation of the lower chambers (ventricles) of the heart. The future development of the project includes enclosing a defibrillator inside the pacemaker which helps to revive the patient from the cardiac arrest. We can extend the power to other implants includes brachytherapy and neuro implants . the overall project can be made using the microelectronics and integrated into a single chip.The overall gain of the piezo electric wafer can be improved by using a different kind of substance.

6. ACKNOWLEDGEMENT

We are in deep gratitude to our departmental faculty who has always been supporting us through thick & thin as well as our H.O.D. professor Mr. Sridhar for his engulf support..

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