Sustained Pacemaker System Powered From PIEZOELECTRIC TRANSDUCER

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Abstract. It endeavours to postulate a smart, economical power supply system for pacemakers based on the principle of power harnessing using piezoelectric effect, on the contrary to the existing battery powered system, resulting an enormous reduction in pacemaker cost. The proposed system will use heart vibrations to generate power from piezoelectric transducer and provide a steady DC output to the pacemaker system, reducing or omitting the need of pacemaker replacement. The proffered system also has a scope of providing a warning by pre-detecting the possible threat of future heart-disease. The general objective of the project is to replace the need of expensive battery by harnessing power from heart vibrations to drive the pacemaker system to measure the real-time Blood Pressure of the patient and to produce an alarm by pre-sensing the probability of possible heart-failure or heart-disease.

Keywords: PIEZOELECTRIC TRANSDUCER, pacemaker, Piezoelectric Effect

1. Introduction. Piezoelectricity occurs due to the electric charge that gets accumulated in some solid materials because of the application of mechanical stress to it (a 1 cm³ of quartz crystal produces approximately 12500V on application of 1kN of force) [1]. In this scenario, the piezoelectric transducer is designed to sense heart vibrations (Expansion and contraction of the auricle and ventricle) and generate power spikes (AC voltage), which in turn gets rectified, filtered and regulated to provide the same voltage and current rating as of the pacemaker battery.

Pacemakers are one of the most common life supporting tools for patients with abnormal or irregular heart rhythms [2]. Pacemakers are too expensive in consideration to middle earning people and also have an average lifetime of 10 years i.e. surgery is required for replacement in every 10 years [3-5]. Lithium iodide batteries are contained in the currently available pacemakers. Mercury zinc batteries are also used in some cases. Mercury zinc batteries have shorter lifespan as compared to the lithium iodide batteries. While great improvements have been made, there are still flaws. Complications leading to death may sometimes occur due to the corrosive nature of the batteries [6]. However a typical pacemaker battery may last for seven to eight years depending on its respective qualities [1]. Battery replacement surgeries are costly and increase the difficulty of the patient [6]. The specialized battery used to achieve longer lifespan incurs the most of the manufacturing cost. Whereas the piezoelectric pacemakers will be working efficiently throughout the entire lifespan of the patient without any battery. In addition to this the blood pressure of the patient can be measured and the possibilities of heart diseases can be predicted.
As shown in Figure 1, Piezoelectric Effect occurs when electric charge gets concentrated in some solids because of the applied mechanical stress to it.

The use of piezoelectric transducer as power source does have the potentiality not only to replace the need of such batteries, but also to eliminate the need of periodic surgeries for pacemaker replacement, thus offering a vast reduction in manufacturing cost and broadens the accessibility of mediocre people during medical emergency.

![Figure 1: Piezoelectric Effects](image)

The pacemaker system powered from piezoelectric transducer will replace the need of expensive battery, by harnessing power from heart vibrations to drive the pacemaker system. To measure the real-time Blood Pressure of the patient and produce an alarm by pre-sensing the probability of possible heart-failure or heart-disease.

The piezoelectric crystal is easily available and also really convenient to design. With the use of piezoelectric transducer and ultra-low power VLSI circuitry, the size of the pacemaker can be reduced significantly as the battery consumes more than 70% space. Subsequently, the manufacturing cost will be extremely low helping large scale production. Also, as future replacement of the pacemaker is not required, the risk of heart surgery is absent. The proposed design would also be reluctant to damages from radioactive field emissions unlike conventional ones.

2. Materials and Methodology

This system will use heart vibrations to generate power from piezo transducer and provide a steady DC output to the pacemaker system.

2.1 Flow Chart of the system

As shown in Figure 2, below, the right side of the flow chart gives the electronic model of the piezoelectric transducer. An oscillator has been designed, which will efficiently convert DC signal to AC signal. The oscillator is a wein bridge oscillator of 5Hz frequency. This electronic system will help to create vibrations and realise the heartbeat. The frequency of heart vibration is 5 Hz, which means that in every 200 ms (millisecond) the heart must strike 1 time over the piezo crystal, which is not possible to create by pressing the piezo transducer by hand. Hence this oscillator and the electronic model of the transducer have been designed. The charge is subsequently passed through the trans conductance amplifier and the integrator circuit to get the output of the piezo transducer electronic model.

The left side of Figure 2, below, shows the flowchart of the entire process. The heart vibrations strike the piezo transducer surface, the charges are then passed on from the transducer to the bridge rectifier,
which converts AC current to DC current. From the bridge rectifier the charges are passed to the capacitor filter, the capacitor would store the charge. The DC-DC converter and voltage regulator can be used to increase the chance of accuracy. And finally a stable DC voltage will be obtained as an output.

Figure 2: Flow-chart of the proposed system

2.2. The circuit diagram
The Piezoelectric transducer assembly (mounted on human heart) can be approximated as a trans conductance amplifier along with an integrator as it integrates the charge accumulated during application of force.

The circuit schematic is simulated in NI Multisim 11.0 and results indicates a steady power supply of almost 3V can be realized, verifying the feasibility of the proposed solution [7].

In Figure 3, the electronic model of the piezoelectric transducer has been designed using opamp AD8541, which is a general purpose opamp. The current is then passed through the bridge rectifier, it will convert AC current to DC current. Four schotky diodes(1N4001) have been used to reduce the voltage drops and time delays. Then the current is passed through the capacitor filter. It consists of a 1mF capacitor and a 1KΩ
3. Calculation and Exerted force
The Blood-Pressure measured in Heart’s ventricle & auricle are 80 mmHg & 120 mmHg respectively [2-3] which is equivalent to 1.6 N/cm²
Approximating avg. heart size as 90 cm² [2-4] the force exerted on the transducer will be 144 N, which is enough to generate almost 3V [figure 4].
A heart vibration cycle consists 2 contraction and 2 expansion. Frequency of entire vibration cycle is 1.2 Hz. Hence, frequency of striking the transducer can be approximated as 4 × 1.2 Hz = 5 Hz.
4. Result and Discussion

This system will use heart vibrations to generate power from piezo transducer and provide a steady DC output to the pacemaker system.

As shown in Fig (5), in the piezoelectric materials the displacement in the curve acts as the difference between the displacements paths in the forward stroke when it is being compared to the return stroke. Hence the current is not generally linear in nature. In order to generate the required voltage, piezoelectric materials require sufficient current from the driver or the amplifier [1]. However the voltage generated is directly proportional to the displacement occurred.

![Piezo Hysteresis vs. Driving Voltage](image)

**Figure 5:** Graphical analysis of voltage generated in piezoelectric transducer

As shown in Figure 6 below, NI Multisim 11.0 a stable DC voltage of 4.5 volt is obtained as an output [6]. The orange colour line shows the desired stable DC output voltage. Further this voltage can be passed through the DC-DC converter and voltage regulator to get a smoother curve and a more accurate result.
Figure 6: Simulation result.
The Piezoelectric transducer assembly should have to be designed in a medicated way by Bio-medical or Bio-technical engineers keeping in mind the delegate nature of human-heart. Proper lead-cover of the entire circuit must be applied to protect from any damages while on-mount. The design should be enough ergonomic, standardized and hollow heart shaped to extract maximum efficiency.

5. Conclusion

The Piezoelectric power source endeavours an efficient design replacing the conventional expensive battery powered system, following an enormous reduction in manufacturing cost (approximately 60%). The proposed design has the potentiality of a smart system that can constantly monitor and alerts for a possibility of future heart disease. The proffered circuitry is also reluctant to damages from radioactive field unlike the conventional one. The solution also eliminates the need of replacement of the pacemaker unless faults at circuit level.

6. References

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