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Energy Harvesting From Human Body Using Thermoelectric Generator

P.Mahalakshmi¹, S.Kalaiselvi²

PG Scholar [EST], Dept.of EEE, Sri Muthukumaran Institute of Technology, Chennai, Tamilnadu, India¹

Assistant Professor,Dept. of EEE, Sri Muthukumaran Institute of Technology, Chennai, Tamilnadu, India²

ABSTRACT: A powerful approach to the characterization of cellular electrical activity is electrical recording from cells or living tissues. In this paper, we propose a new approach to feed implantable system, the system designed is an energy harvesting circuit that supplies a power to battery of implantable medical devices through wireless communication module. A thermoelectric generator is employed to harvest energy from the human body. The major issue to overcome in the design of a system that is aimed at being reduce the multiple surgeries.

KEYWORDS: Thermoelectric generator, seebeck effect, MOSFET, Wireless(RF), pacemaker, GSM.

I.INTRODUCTION

The need for ubiquitous electronics that helps the human being in everyday life, is rapidly growing with increasing features and possibilities of modern mobile terminal devices. One last drawback is the demand for power supplies that allow unlimited operating and stand-by times. A solution to tackle this problem relies on the development of devices and circuits which transform energy from the user's environment or directly from human power into electricity to supply electronic circuits and systems. This paper is focused on energy harvesting from human power. At this point, it is possible to draw a distinction between active and passive harvesting methods. The active powering of electronic devices takes place when the user of the electronic device has to undertake additional actions to generate power. On the other hand, passive energy harvesting assumes that the user is not forced to change his habits in order to generate energy. Thus, the power is harvested from the user's everyday actions [10]. There are several approaches to the energy harvesting scenario. The most common are electromagnetic, thermoelectric, electrostatic or piezoelectric generators. The major challenge of these energy autarkic systems relies in the optimization of the energy harvesting source parameters as a function of the human activity employed. Additionally, it is essential to match the generator to the load and to consume the transferred energy in an economical manner[6]. Biomass burners and firewood furnaces are used in domestic and industrial heating and burning processes. Many of these systems require electric energy support for full performance. By applying thermoelectric generators to these heat sources it is possible to develop independent electric energy source, which start generation in the moment when there will be temperature difference on their sides. Thermoelectric generators are devices that use Seebeck effect – converting heat (temperature differences) directly into electrical energy. As the heat flows from hot side to cold side, free charge carriers – electrons or holes – in the material are also driven to the cold end. The resulting voltage is proportional to the temperature difference via the Seebeck coefficient. The thermoelectric generator will generate DC electricity as long as there is a temperature difference across the module. The more electricity will be generated when the temperature difference across the module increases, and the efficiency of converting heat energy into electric energy will also increase[2]. The human body continuously radiates heat. Devices with direct contact to the human body can harvest this wasted energy by means of thermogenerators (TEGs). This valuable technology for self-sustaining power supplies consists of a thermocouple module that employs the temperature gradient between the hot (body) and cold (ambient) side of the thermopair to generate electrical energy. A significant constraint of this solution relies on the relative low temperature gradient in the range of 5 °C-10 °C, or even lower, between the human body and the environment. Therefore, low voltage differences are provided at the output of the TEG. Specific step-up DC-DC converters have to be used by a power management



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unit to supply an electrical load. Temperature differences, hence electrical energy, are not constant over the operating time, such that two scenarios can be distinguished[1]. On one hand, the electrical load (e.g. a wireless communication module) is supplied only as long as TEG-power is available. On the other hand, accumulators in the form of capacitors or batteries can be employed to ensure continuous power. Energy harvesting gives the possibility to build autonomous microsystems. Especially, energy harvesting would be ideal for implantable microsystems because it can supply the electrical energy without replacement of the battery[5]. Among various energy harvesting methods, thermoelectric energy harvesting on human body has advantages that human body heat is steady and large [4]. However, from the viewpoint of the curvature of the human body, typical TEGs may be not suitable for applying to human body because most typical TEGs are composed of thermocouples on a rigid substrate. On the other hand, flexible TEGs transduce the human body heat efficiently since the flexible TEGs can be tightly attached on the skin [7]. Finite electrical battery life is encouraging companies and researchers to come up with new ideas and technologies to drive wireless mobile devices for an enhanced period of time. Batteries add to size and their disposal adds to environmental pollution. For mobile and miniature electronics devices, a promising solution is available in capturing and storing the energy from external ambient sources, a technology known as energy harvesting. Other names for this type of technology are power harvesting, energy scavenging and free energy, which are derived from renewable energy [12]. In recent years the use of wireless devices is growing in many applications like mobile phones and sensor networks [3]. This increase in wireless applications has generated an increasing use of batteries. Many research teams are working on extending the battery life by reducing the consumption of the devices. Other teams have chosen to recycle ambient energy like in Micro electromechanical Systems (MEMS) [8], solar power satellite [9], the SHARP System [13], but only a small amount can be scavenged in the real environment. The rest is dissipated as heat or absorbed by other materials. RF power harvesting technique is also used in Radio Frequency Identification (RFID) tags and implantable electronics devices. Most commonly used wireless sensor nodes consume few μW in sleep mode and hundreds μW in active mode. A great factor contributing for energy harvesting research and development is ultra-low-power components. The management of power available for sensor nodes has been dealt with to an extent using Ant Based Routing [11], which utilizes the behavior of real ants searching for food through pheromone deposition while dealing with problems that need to find paths to goals.

II. THERMO ELECTRIC GENERATOR

Thermoelectric devices are basically solid state devices that can convert energy from heat to electricity or vice versa. Devices are normally made up of semiconductor materials, the most common being bismuth telluride. A typical configuration of a thermoelectric module consists of many leg pairs made of semiconductor pellets, joined together using contact tabs made of high conductivity materials. The principle behind the working of the thermoelectric module is the Seebeck effect. In 1821 Thomas Johann Seebeck observed that when two dissimilar metals with junctions at different temperatures are connected in a circuit, a magnetic needle would be deflected. Seebeck initially attributed this phenomenon to magnetism. However, it was quickly realized that it was an induced electrical current that deflects the magnet. In a thermoelectric module, the two dissimilar conductors are connected electrically in series and thermally in parallel. When the two junctions are maintained at temperatures T_H and T_C respectively, and $T_H > T_C$, an open circuit electromotive force is developed between the junctions.

The voltage produced is proportional to the temperature difference between the two junctions. This is given by:

$$V_0 = \alpha N (T_h - T_c) / (1 + 2rL_c / L) \quad (1)$$

$$I_0 = \frac{\alpha A (T_h - T_c)}{2\rho(L + n)} (1 + 2rL_c / L) \quad (2)$$

$$P_0 = \frac{\alpha^2}{2\rho} \cdot \frac{NA}{(L + n) \cdot (1 + 2rL_c / L)^2} \cdot (T_h - T_c)^2 \quad (3)$$

The proportionality constant, α , is the difference between the Seebeck coefficients of the two materials forming the junction. This is known as the overall Seebeck coefficient, and often referred to as the thermoelectric power or thermo

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power. The Seebeck voltage does not depend on the distribution of temperatures along the material between the junctions.

Where, $n = 2qC/q$, $r = k/kC$, a is the TE material Seebeck coefficient (V/K), q is electrical resistivity (X cm), qC is electrical contact resistivity, N is the number of the thermo element in the module, A is the cross-sectional area of the thermoelements (mm)², L is the length of the thermo element (mm), L_c is the thickness of the contact layer (mm), T_h is the temperature at the hot side, T_c is the temperature at the cold side, k is the thermal conductivity of the thermo element and kC is the thermal conductivity of the contact layer.

The most important parameters in a thermoelectric material are the “Seebeck coefficient” and “figure of merit.” The Seebeck coefficient is a measure of the transported entropy per charge carrier. The figure of merit is a non-dimensional measure of performance of the material. It gives the theoretically possible maximum efficiency of a thermo electric. The figure of merit (ZT) is expressed as

$$ZT = \frac{\alpha^2 \sigma}{k} T \quad (4)$$

The figure of merit varies directly with the Seebeck coefficient and electrical conductivity and inversely with thermal conductivity. An increase in electrical conductivity reduces the losses caused due to Joule heating. A decrease in the thermal conductivity would limit the amount of heat passing through the module without being converted into power. The theoretical maximum efficiency of thermoelectric material depends on the figure of merit, and there are no theoretical upper limits for the figure of merit. Most materials currently used have thermoelectrics of approximately one or less.

III. THERMOELECTRIC MODULE CHARACTERISTICS

In this paper, we are used the module of TEPI-1264-1.5 thermo electric generator for power generation from human body. The power module is used for converting heat source directly into electricity. The module is Bi-Te based thermo electric module that can work at the temperature of as high as 330 °C (626 °F) heat source continuously and up to 400 °C (752 °F) intermittently. The thermoelectric module will generate DC electricity as long as there is a temperature difference across the module. The more power will be generated when the temperature difference across the module becomes larger, and the efficiency of converting heat energy into electricity will increase therefore. The module is stuck with the high thermal conductivity graphite sheet on its both sides of the ceramic plates to provide low contact thermal resistance, hence you do not need to apply thermal grease or other heat transfer compound when you install the module. The graphite sheet can work well in extremely high temperature.

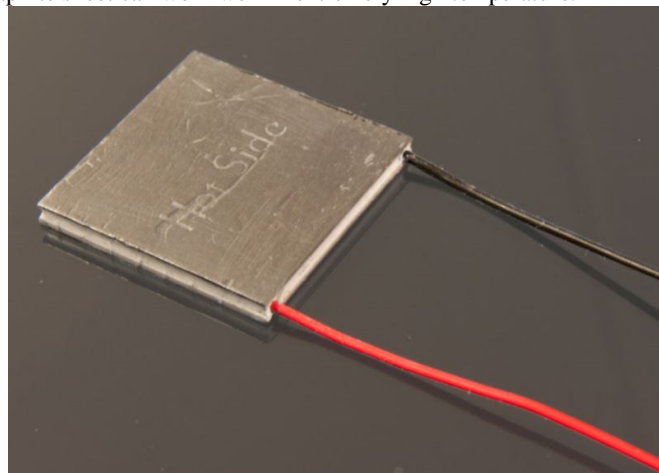


Fig 1. Thermo Electric Generator



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SPECIFICATIONS OF THE MODULE:

Table1.Parameters of the TEG

Hot Side Temperature (°C)	300
Cold Side Temperature (°C)	30
Open Circuit Voltage (V)	9.4
Matched Load Resistance (ohms)	2.8
Matched load output voltage (V)	4.7
Matched load output current (A)	1.56
Matched load output power(W)	7.3
Heat flow across the module(W)	≈ 152
Heat flow density(W cm-2)	≈ 9.5
AC Resistance(ohms) Measured under 27 °C at 1000Hz	1.3 ~ 1.8

TEST DATA

Some electrical testing data for TEP1-1264-1.5 is listed below:

The data is obtained at $T_h=200C$ and $T_c=70C$.

The heat flux under the $T_h=200C$ and $T_c=70C$ is 110Watts

Table2. Test values of TEG

Load Resistance(Ohm)	Output Voltage(v)	Output Current(A)	Output Power(Watts)
Open Circuit	6.28		
0.9	1.44	1.60	2.3
1.4	2.04	1.46	3.0
1.8	2.53	1.4	3.5
2.3	2.88	1.25	3.6
2.6	3.08	1.18	3.65
2.8	3.21	1.15	3.7
3.0	3.28	1.09	3.6
3.2	3.40	1.06	3.6
3.6	3.55	0.99	3.5
3.8	3.61	0.95	3.43
4.4	3.85	0.88	3.4
5.0	4.01	0.80	3.2

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5.6	4.19	0.75	3.14
6.4	4.43	0.69	3.06
8.4	4.7	0.56	2.65
10	4.94	0.49	2.42

IV. BLOCK DIAGRAM

TRANSMITTER SECTION

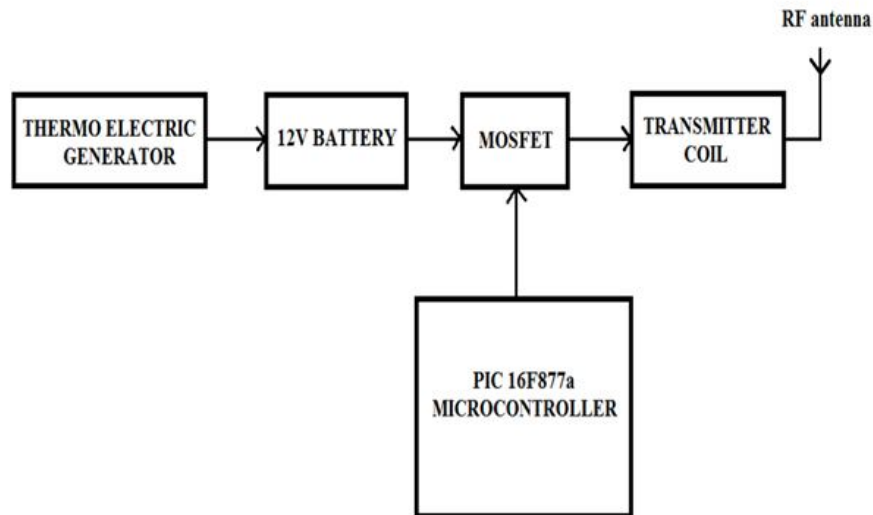


Fig 2. Transmitter part of the harvesting

In the transmitter section, we are used the thermo electric generator for extracting electric power from human body heat, this power module is convert the thermal energy into electrical energy, the extracting voltage is stored in the 12V battery for backup purpose. Here we are using the MOSFET for switching the tiny voltage into high voltage pulses. The PIC16f877a microcontroller is used to operate the MOSFET driver circuit. These pulses are transmitted to the RF Receiver coil through RF waves at 1KHZ frequency. This section is placed outside of the body.

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RECEVIER SECTION

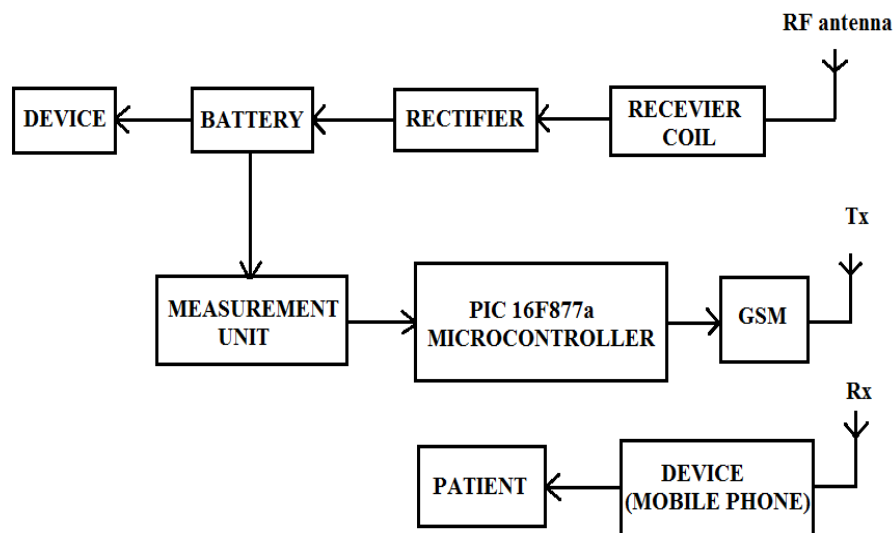


Fig 3. Receiver part of the harvesting

In the receiver section, we receive the generating pulses from the RF transmitter coil. These pulses are converted into DC voltage using bridge rectifier. This DC voltage is used to charge the battery of the implantable devices, such as pacemaker, defibrillator. The charging voltage values are measured by using the voltage MMT. Here the PIC16f877a controller is used for connecting the MMT unit and GSM modem. The voltage values are displayed in patient mobile phone through GSM. They Receiver section is placed into the patient body.

V. HARDWARE DESIGN

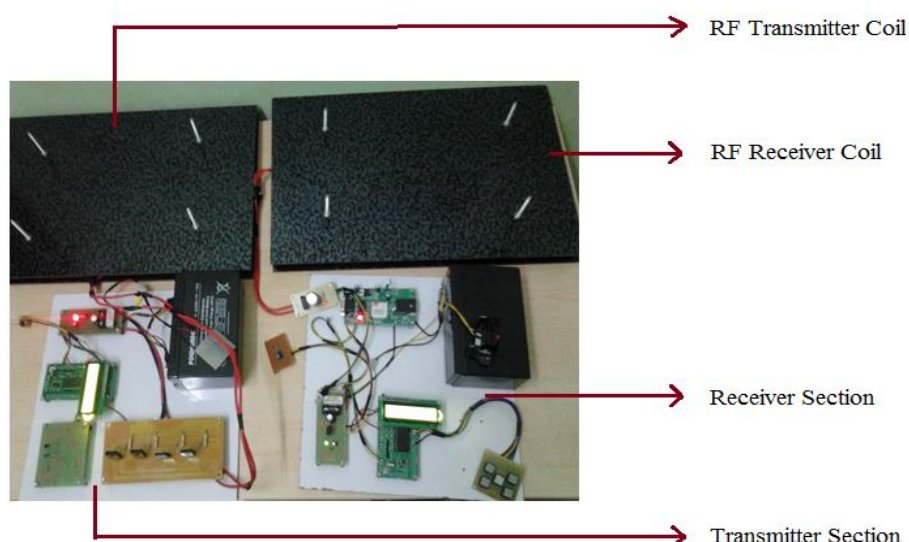


Fig 4. Overview of energy harvesting circuit



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VI .CONCLUSION

We proposed a new approach to feed implantable system, the system designed is an energy harvesting circuit that supplies a power to battery of implantable medical devices through wireless communication module. A thermoelectric generator is employed to harvest energy from the human body. By using the TEP1-1264-1.5 generator, we extract electric voltage from human body. This voltage is enough for low power implantable devices. Such as pacemaker. The major issues to overcome in the design of a system that is aimed at being reduce the multiple surgeries.

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BIOGRAPHY



Mahalakshmi.P completed B.E Electronics and Communication Engineering from P.R Engineering College in 2011, Now doing M.E Embedded System and Technologies from Sri Muthukumaran Institute of Technology in 2012 to 2014.



Kalaiselvi.S completed B.E Electrical and Electronics Engineering from R.M.K Engineering college in 2003 and completed M.E Applied Electronic from Sri Muthukumaran Institute of Technology in 2007, worked at VEL TECH Engineering college from Aug 2004 to Aug 2005 and Now working at Sri Muthukumaran Institute of Technology from July 2007 onwards