VOL. 14, NO. 3, FEBRUARY2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

POWER GENERATION USING DIAPHRAGM MOVEMENT FOR PACEMAKER

H. Ajay, Aliasgar Zakir, Abhishek Patil and Deepa Madathil
School of Electronics Engineering, Vellore Institute of Technology, Vellore, India
E-Mail: deepa.m@vit.ac.in

ABSTRACT

Nowadays, battery life plays an important role in the productivity of a pacemaker. Whatever might be the case because soon after, a surgery needs to be carried out to replace those batteries? An alternative source for the power requirement for the implant has been discussed here wherein the power is generated using just the body movements, specifically area efficient diaphragm in this case. The voltage requirement for a pacemaker battery is around 2-3V hence by the use of piezo films made of PVDF, this range of power is obtained. The film array is placed on the thoracic region where normal breathing creates a scenario similar to that of the diaphragm.

Index terms: battery life, alternative power source, pacemaker, body movements, diaphragm, PVDF.

1. INTRODUCTION

Current studies involve several alternate methods for power generation with the help of human physiological systems to potentially replace batteries, which include mechanical, chemical, electrical, as well thermal processes [1]. One such process uses the mechanical process of diaphragm movement while breathing. The diaphragm is a dome shaped sheet of inner skeletal muscle in humans that serves as the main muscle of respiration and plays a vital role in breathing process. Hence, its convex upper surface forms the floor of the thoracic cavity and the concave lower surface forms the roof of the abdominal cavity. During inhalation, diaphragm plays a big role by contracting as it allows air to be drawn in the lungs. As soon as the inhalation process ends, air is exhaled due to recoil of the thoracic tissues and the lungs. In this, the abdominal muscles also help by acting antagonists. The intra-gastric pressure at the end of a quiet expiration was 5-15 cm H_20 above atmospheric pressure. In most subjects there was a slight respiratory variation which took the form of a rise during inspiration and a fall during expiration [2].

Pacemaker is a new life to the heart patients whose heart cannot generate impulses on its own. Pacemaker was first implanted on 8^{th} October, 1958 [3]. Contemporary pacemakers, like other implants, are powered by the batteries and, the batteries are needed to be replaced whenever the battery dries out. Pacemakers' replacement needs surgeries which can be dangerous for the person's health. Battery less pacemakers that harvest energy inside the body may overcome these limitations. There are about 3 million people worldwide with pacemakers and each year 600, 000 pacemakers are implanted [4]. With a rare exception, implantation of a pacemaker does not change the recipient's activities or lifestyle. To overcome such limitations, power can be generated from the physical and thermal changes in the body. One such movement is the diaphragm movement. While breathing, the pressure exerted by the diaphragm can be converted into voltage using the piezoelectric properties of material. Once the voltage is generated by the material then it is used as the power source for the pacemakers.

2. MATERIALS AND METHODS

Principle of piezoelectricity has been used to generate the required power to supposedly aid in the working of the biomedical device such as the pacemaker. It has been found that the battery of the pacemaker has a voltage between 2 to 3 volts [4]. So, the basic attempt would be to generate that kind of power with the help of body movements.

Figure-1. Piezoelectric diaphragm array placed on the belt.

Initially, an array of piezoelectric crystals was created with three in row in series connection and then three rows in parallel connection. This was achieved after several trial and error method of forming different combinations and was found that this design gives desirable voltage and current output. The array is then placed on the belt and the belt on to the abdominal region to provide the required pressure. The voltage and current after the crystals are pressed are visualized using LabVIEW as shown in the Figure-2.

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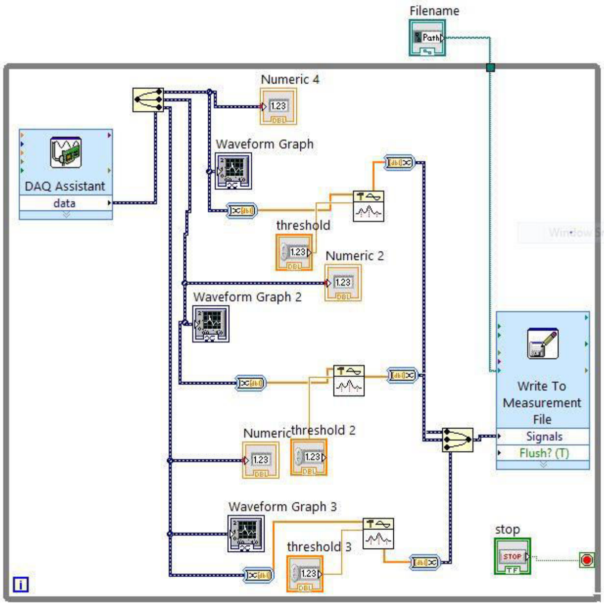

Figure-2. The above figure shows the LabVIEW circuit to store the voltage, current and the strain produced from the array when pressure is exerted.

Also, it has been found that the sensitivity of the crystal is quite low and along with that, the output voltage per unit of stress is below satisfactory. So instead, we resorted to using piezofilms made of PVDF for the purpose. It has good sensitivity for low pressures and also the output per unit stress is much greater than what the crystals offer [5].

The combination of piezofilms is arranged on two wood pieces where it is held tightly by the ends for its efficient working. When the film is bent, it generates voltage than in the crystal where it needs to be pressed to get the voltage. Hence the film serves as an ideal source in the sense that it will bend when diaphragm imparts pressure on the film than being pressed as the pressure to be exerted by the diaphragm in it is quite low.

This wooden arrangement is wrapped around the person such that the films are placed on the abdomen region. The idea of this placement is to simulate the working movement of the diaphragm in the sense that the thoracic region expands while breathing so the stomach moves forward and backward during the process. So, the pressure exerted by the abdominal region is somewhat similar to what diaphragm exerts on the abdominal organs.

Figure-3. Setup for a single film.

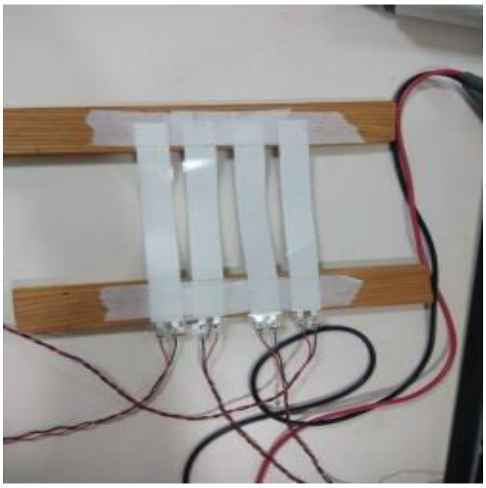

Figure-4. Setup for four films.

3. RESULTS

From LabVIEW, it was seen that at low pressure the piezoelectric crystal produces negligible voltage output. To counter this, piezofilms are brought in. Piezofilms have good sensitivity at low pressure which can be put to use efficiently[5].

It was found that when the films are connected in a parallel combination, the output voltage can be increased with each film added in the array. For one film only, the output reached was in range of 1V to 1.2 V. With two films connected in parallel, the output voltage was in the range of 1.6V to 1.8V, and for four, it reached upto 3V.

Table-1. Output depending on the number of piezofilms.

Number of piezofilms (s)	**Output** (V)
1	1 - 1.2
2	1.6 - 1.8
4	2.8 - 3.1

Figure-5. Output taken from a single film.

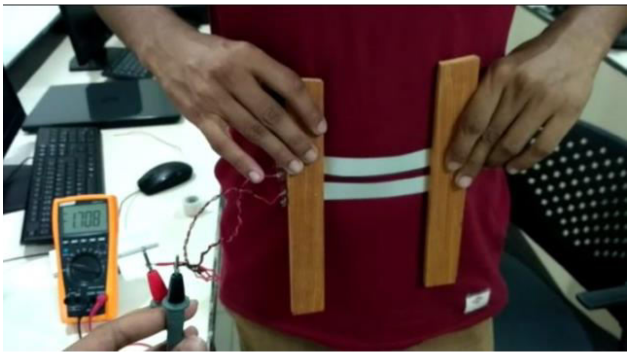

Figure-6. Output from two films.

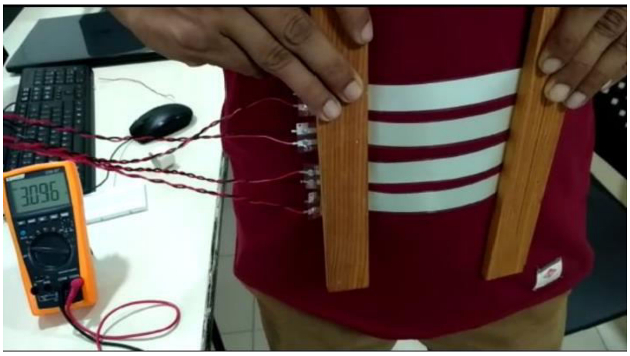

Figure-7. Output taken from four films.

4. CONCLUSIONS

The above results show that from the diaphragm movement enough power is generated to power the pacemaker device without any power source required. The purpose of the study was to try and create an alternative power source for the biomedical implants that currently require battery for their operation. Initially the crystals were used for the study but it came with several roadblocks such as less power, being too bulky, less sensitivity for low pressures, etc. Then, piezofilms were considered. The reported results suggest that piezofilms generate a reliable power that can be utilized as a source of power for several biomedical appliances such as pacemaker, implants, etc. To develop the study in a future perspective, the films can be customized according to the need such as the core material, desired properties such as sensitivity, output requirements, etc. and also the whole system be biocompatible. The potential to eliminate batteries or, at least, the need to replace them frequently represents a source of motivation for continued work in these and related directions.

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