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PIEZOELECTRIC ENERGY HARVESTING FLOOR MAT FOR LOW POWER APPLICATIONS

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ABSTRACT

The goal of this work is to harness the wasted power from footsteps using piezoelectric sensors. Piezoelectric sensor is a transducer that produces electrical energy when mechanical energy is applied on it. In this work, thirty five piezoelectric sensors are connected in series/parallel and covered with a wooden board to form a foot mat which generates AC voltage when people step on it. Since the output is not continues, it is rectified and stored in a battery. The system has found significant use on roads, parks and variegated public space where energy from footsteps can be harnessed and transformed into harvested power.

Keywords: Piezoelectric, Energy Harvesting, Electromechanical.

I. INTRODUCTION

To supply low-power electronic devices and wireless sensor nodes in applications such as environmental monitoring, Building monitoring and control, Precision agriculture, Medicine and health care, Industrial process control, Automotive and traffic control, Security and surveillance batteries are utilised, however, there are several issues regarding traditional battery-powered methods such as limited lifespan and energy storage capacity of the batteries (He et al., 2019). Because kinetic energy is numerous in our everyday activities, traditional batteries can be substituted with kinetic energy harvesters (Ceponis et al., 2019). It is extremely desirable to harvest kinetic energy from the surrounding environment in order to give these gadgets long-term power. It's also critical to develop newer energy harvesting mechanisms as a way to bolster such self-powered systems that may be deployed remotely (Covaci & Gontean, 2020). Such energy harvesting devices possess the prospective to notably decrease the dangers and impact of greenhouse gas emissions while also preserving the ecology of the environment in which they are used. Numerous attempts have been undertaken to harvest energy from the ambient environment using various techniques such as electromagnetism, electrostatics, Tribo-electrics, and piezoelectrics. By virtue of its characteristics, piezoelectric transducers transform any mechanical strain into electrical energy based on it simple structure which is composite of various crystalline materials with includes Barium titanate, quartz, tourmaline, Rochelle salt. they transform mechanical stress depending on the degree of intensity into electricity based on applied pressure. Piezoelectric materials can be sub-divided into two basic categories piezopolymer and piezoceramics. The latter provides high energy conversion rate with a larger electro-mechanical coupling constant, but found little use in piezoelectric transducers due to their brittle nature, it is expensive in terms of cost and it is impossible to produce in large areas. Conversely, the piezopolymer has a very high flexibility but the major challenge is that the electromechanical coupling constant is smaller in comparison with the piezocreamic. Some of the clean energy sources is the transformation of kinetic energy from human footsteps to electric power. Various studies have been undertaken, with more in the pipeline, in order to offer clean and sustainable energy. Ang et al., (2019) developed a mechanical foot step power generator that uses a rack and pinion system to convert kinetic energy from foot steps into energy and store the output in a battery. A flywheel attached to a gear wheel rotates the shaft that is coupled with the Permanent Magnet D.C Generator to generate DC current that is stored in the batteries in an another development (Aman, 2018). Nworji et al., (2020) proposed a piezoelectric method for powering small electrical appliances and electronic gadgets at dance club centers using the beats of human feet. A piezoelectric energy harvester of any geometrical size and shape was proposed using a more straightforward and readily available organic polymer material. PVDF (Polyvinlidene Floride) is a constituent of the material, which is also known as a mono-axial stretch of PVDF foils. The low dielectric permittivity and great flexibility of this unusual PVDF material were factors in its selection. The amount of energy gathered is determined by the pretreatment of the piezoelectric films, as well as the thickness of the film and the mechanical loads it can withstand (Bischur & Schwesinger, 2014). The longitudinal piezoelectric effect was used in the suggested study, which refers to the forceful contraction of the piezoelectric material that causes the transmission of surface charges via a surface electrode to be converted into electrical energy. As a result, mechanical energy is changed to electrical energy. The PVDF – foil was used to apply mechanical strain to the electrodes on the surfaces in a perpendicular direction for this study. The amount of surface charge released is determined by the piezoelectric coefficient value; additionally, more surface charge can be gained as a function of the active material thickness; the increased force generated increases the intensity of the pressured force. All of these elements influence the amount of charge transported from the surface to the energy bank. PVDF modules were characterized experimentally in terms of the applied mechanical force and the amount of electrical energy generated. The resistance values and voltages were calculated for a single mechanical load cycle, but the load cycle was enlarged to six different loading cycles and a variable number of PVDF layers. In addition, a public test floor was set up to illustrate the amount of energy changed as a function of module size and horizontal geometry alignment utilizing a parquet floor system. With respect to a constant increase in mechanical force, the amount of energy produced is a multiple function of the number of PVDF-layers utilized. Furthermore, Panthongsy et al., (2018) presented the framework and testing of an energy harvesting system established on the concept of unimorph PZT piezoelectric cantilevers, which converts kinetic energy from human mechanical movement into electric energy from floor tiles. Panthongsy et al., 2018) investigated the optimal advantages of low plucking speed and long operational life time and efficiency with harvesting energy with frequency up-conversion strategy, taking into account the fundamental challenges in the reduction in continuance of the piezoelectric cantilever when incorporated with a contact frequency up-conversion mechanism to harness energy. The method of up-converting the low frequency of the PZT unimorph cantilever's lower vibrations into a high frequency vibration between the electromechanical elements of an iron bar and a permanent magnet was used as the technique. The cushion linking the iron bar and the permanent magnet greatly reduces the magnetic force that attracts the iron bar to a value of zero, which generates the greatest output energy from the oscillating PZT cantilever, according to experimental data included with both Finite Element Method. The enormous dimensions of the energy harvesting floor may have limited overall energy output, and thus the curvature difference of the PZT cantilevers were the research's main limits during the assessment process. Furthermore, the level of mechanical stress applied to the floor tile produced enough energy to power some low-power wireless sensor nodes, according to the findings. Due to the constraints of the cantilever beam mechanism, which requires too many sub-layers for optimal energy harvesting, (Malakooti & Sodano, 2015) presented an energy harvesting technique based on the shear mode operating concept. Its concept was based on the material property that piezoelectric materials have high electromechanical coupling properties. Lead Zirconium Titanate (PZT) has the property of efficiently converting ambient vibrations in a system or its environs from an induced in-plane strain rather than the cantilever beam mechanism from mechanical energy to electrical energy. The Timoshenko beam hypothesis was created to project the power and output voltage of a beam placed between two other beams and subjugated to base harmonic excitation. The quantity of power generated is slightly larger than other models employed, according to experimental data. Output power is primarily depending on load resistance. Cha et al., (2016) developed a hypothesized framework for energy harvesting that incorporates the inverted kinematic structure of parallel joints on a robot's fingertips and the electromechanical coupling characteristics equation of a piezoelectric material. Cha et al., (2016) used a piezoelectric material PVDF inserted in a glove and attached to the robot fingers as a transducer. An L-shaped piezoelectric energy harvesting technique was introduced having the goal of increasing the bandwidth frequency limits for which energy can be harvested (Liu et al., 2017). The strategy is intended to tackle the problems associated with the amount of power harvested from a cantilever beam, such as the fact that the optimized energy harvested can only be obtained over a narrow frequency bandwidth, implying that only when resonance is achieved can the optimal energy be harvested. Another constraint is that with cantilevers, sections closer to the clamped end are subjected to greater mechanical force strain than other regions, resulting in poorer power density because energy cannot be gathered throughout the entire beam length. A principal beam is straightly energized at one end of the L-shaped structure, similary an auxiliary beam is coupled to the other end of the main beam, as well as corner and end masses. The L-shaped structure can be calibrated to have its first two natural frequencies close to one another in order to broaden the bandwidth; thus, the goal of the proposed technique was to draw comparisons with the harvested energy intensities relative to the output voltage and power between a conventional cantilever beam and an L-shaped composition with corner and end masses.

In addition, (Kim et al., 2018) used a blending of variegated material (PZNxC) to build a sophisticated piezoelectric energy harvesting floor tile for smart homes, which increased the harvested power. The smart system was proposed, which can harvest energy from floor tiles and provide enough energy to wirelessly communicate information to control electrical appliances. Energy harvesting systems are being incorporated into normal human schemes to power a range of appliances, according to some researchers (Covaci & Gontean, 2020). It was proposed that piezoelectric materials be used in the manufacturing of stair devices to power emergency lights in buildings (Puscasu et al., 2018). The concept of putting piezoelectric materials into roadways in order to create electric current as the mass of motor vehicles deforms the piezoelectric surface has been proposed by (Data, 2004). He et al., (2019) proposed a double-layer squeezing structure as an energy harvesting floor structure that uses a force amplification method. PZT-based piezoelectric transducers have improved ferroelectric properties, such as a lower coercive field, greater dielectric constants, and a higher Curie temperature, in contrast to BST (Barium Strontium Titanate) (Izyumskaya et al., 2007). The fundamental idea behind this study is to transform surplus energy from surrounding systems, such as when people walk, jump, or dance, into electrical energy. Under insulating material, piezoelectric sensors are placed (piezoelectric mat). A modest ac voltage is generated when the mat is strained by a force such as a footstep. A rectifier circuit converts the ac voltage to dc, while a capacitor stores the charges generated. The voltage is boosted and stored for later use in a battery.

II. METHODOLOGY

Working Principle

The pressure applied to the piezoelectric material is converted into electrical energy. The source of pressure can either be the weight of driving automobiles or the weight of individuals walking across it. The Piezo electric energy harvesting (PEH) device generates an alternating voltage. The AC is transformed to DC voltage using a rectifier. The piezoelectric material's output is not continuous. A rechargeable battery is used to store the output dc voltage. As shown in Figure 1

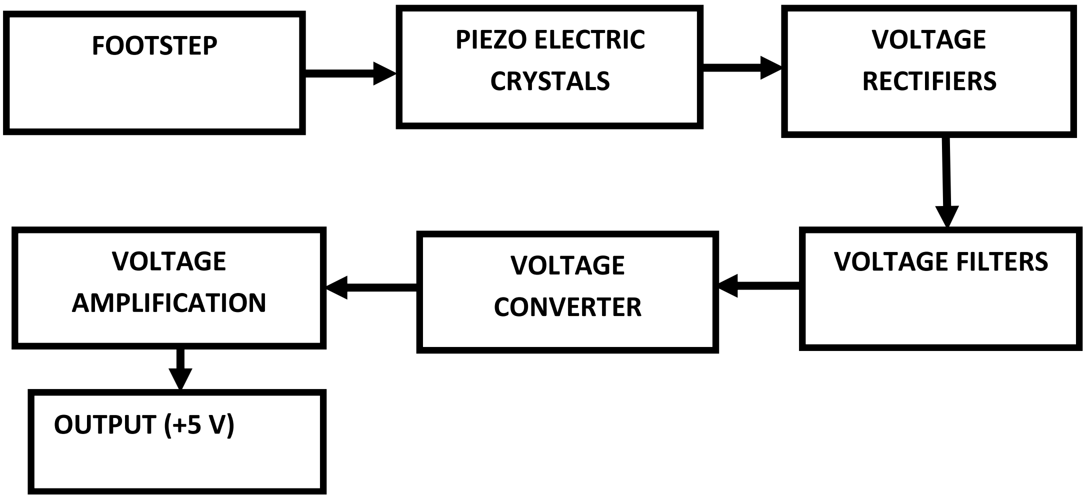
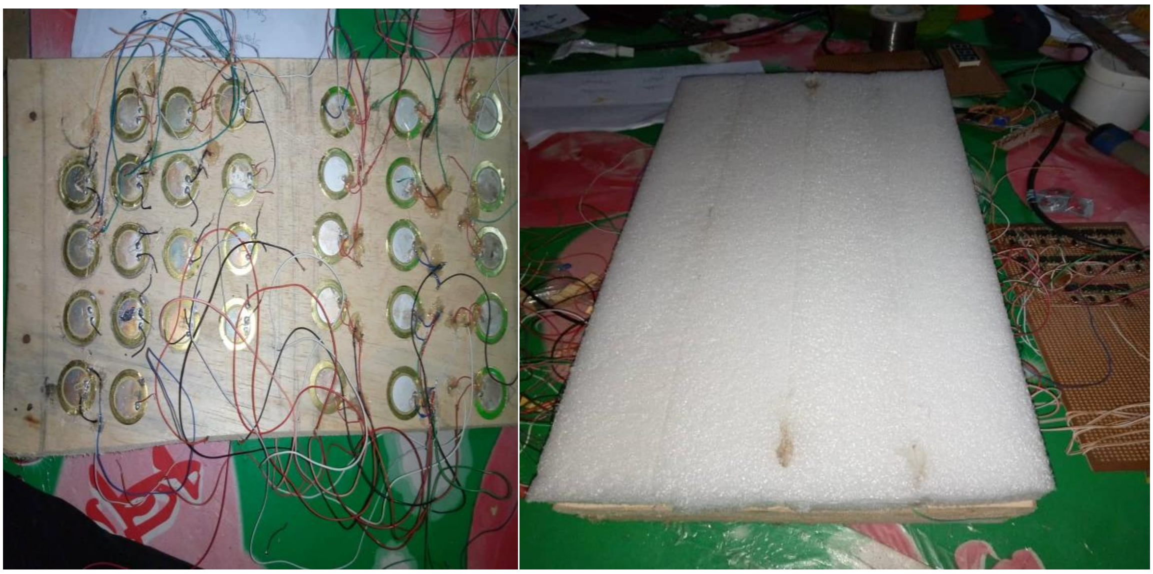


Figure 1: Block diagram of the piezoelectric energy harvester

Construction of the foot mat

On a hard wooden board measuring 300 mm x 300 mm x 25 mm thick, a sheet of plywood measuring 400 mm x 200 mm x 5 mm thick was laid. In view of the fact that power output from a single piezoelectric film was determined to be quite inadequate; thirty-five piezoelectric sensors were mounted on this board (figure 2 a). The PZT-5 sensors, on the other hand, were chosen for their excellent piezoelectric capabilities (table 1 gives the specification of the sensor). The 35 piezoelectric devices in the shape of a circular diaphragm were connected in series/parallel to enabling energy to flow down numerous channels to its destination, reducing the number of probable failure spots.



a) b)

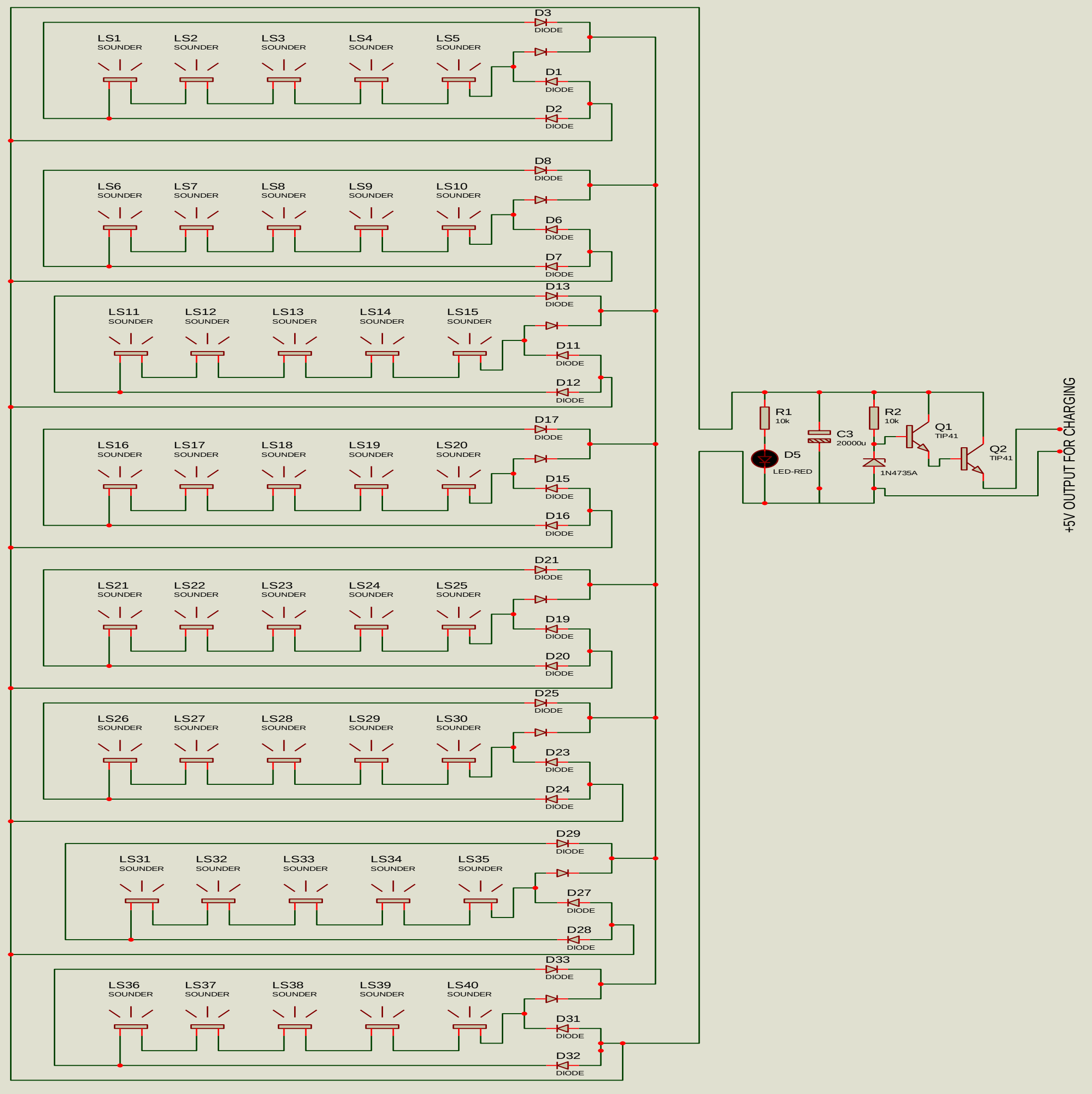
Figure 2: Construction of the energy harvester

Table 1. Specifications of piezoelectric sensor discs

S/N	Properties	Symbol	value
A	**Physical properties**		
1	Diameter(mm)		10
2	Thickness(mm)		
3	Hardness		Hard
4	Density	P	7.5
5	Curie Temperature(°c)	Tc	225
6	Mechanical Quality factors	Qm,n	70
B	**Dielectric Properties**		
1	Dielectric Constant 1KHz	Kit	2600
2	Dissipation Factor at KHz	Tand	0.02
3	Resistivity	ohm-cm	10-12
C	**Electro-Mechanical**		
1	Planer Coupling Co-efficient	Kc	0.62
2	TransverserCoupling Co-efficient	Kn	0.37
3	Longitude Coupling Co-efficient	-dn	195
4	Piezoelectri Charge Constant	Dn	460
5	Piezoelectri Voltage Contant (10^3 volts/meter newton	-gi	13
		Gi	27

Power supply and monitoring section:

A +6V zener diode, a bridge rectifier, a filtering capacitor, and a voltage amplifier make up the power supply unit. The +6V zener diode was conditioned to output a voltage of +5 V when connected to two TIP 41 transistors which has a voltage drop of 0.7 V each, the first transistor whose base was connected to zener diode takes a voltage drops of 0.7 V leaving the remaining voltage to be 5.3 V while the second transistor whose base was coupled to the base of the transistor also takes a voltage drop of 0.7 V leaving a total voltage of (5.3 V – 0.7 V) to give a voltage of 4.3 V while the two transistors serves also serve as voltage amplifier amplifying the signal if weak before it is connected to the load.



III. RESULTS AND DISCUSSION

The power generation capability of piezoelectric sensors changes with varied mechanical stress (footsteps) and person weights. To evaluate how the readings changed as the frequency of footsteps increased. A Multimeter was used to measure voltages and currents across the board. Variations of voltage readings corresponding to the force were presented as varying forces were applied to the piezoelectric material. Various voltage and current measurements of the piezoelectric material are taken for every voltage reading across the force sensor as depicted in Figure 3.

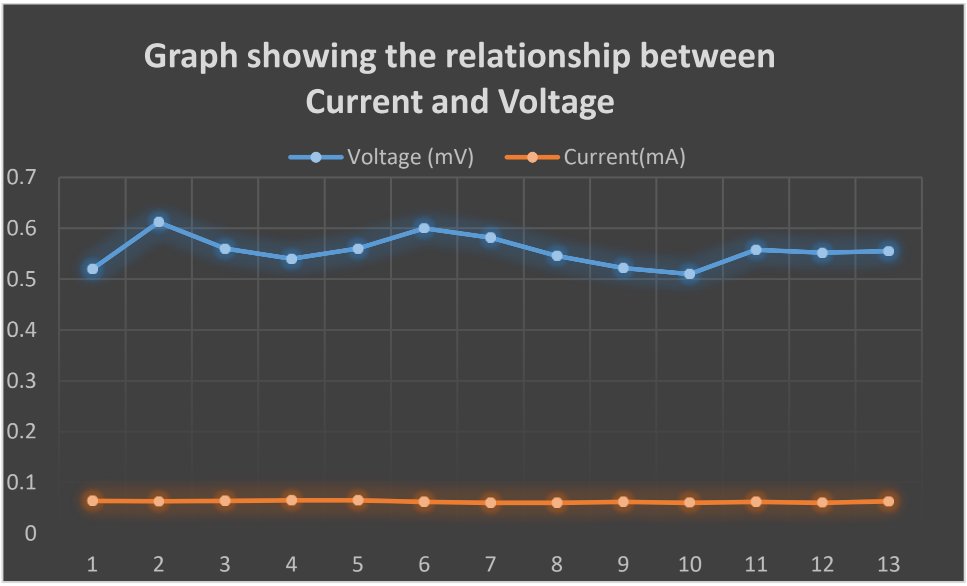


Figure 3: Name of Graph (Font size-10)

The power generation of the piezoelectric sensor fluctuates with different steps. If each foot step produces an average of 0.555 microvolts, 1802 foot steps from the strain of a 50 kg human will be required to charge a battery by one volt. Given the low power output generated, the total number of foot steps required to boost the generated voltage to 6 V in a battery would be 6 by 1802 (equivalent to 10812 steps). Considering this, the project would be applied in an open environment where footsteps are the primary source of strain, an average of 2 footsteps per second will be necessary to collect the requisite voltage.

Despite the fact that piezoelectric materials have the ability to convert mechanical force to electrical energy, building piezoelectric generators proves difficult due to their deficient source attributes (high voltage, low current, high impedance) and low energy output, as illustrated in Figure 4. Those difficulties have previously hampered the successful implementation of piezoelectric generators. The condition of magnifying the current or power from the source to boost our batteries employing piezoelectric sensor is the key restriction of our research. The thickness of the piezoelectric sensor employed in this study is substantially less, and it is constrained in comparison to the piezoelectric crystal material on its surface. As a result, the sensors could be shattered if subjected to too much pressure, and the mechanical construction was finally reinforced to create the requisite strength, resulting in a maximum output in the milliwatt range.

IV. CONCLUSION

This device converts the energy of a footstep, walking, or sprinting into electrical energy. The need for electrical energy is regularly increasing. Nevertheless, conventional power producing resources are no more adequate to provide the whole needs for electrical energy. In such regards, numerous researches are working on clean and renewable energy alternatives. Also, a sustainable non-conventional renewable energy is the foot step piezoelectric system. This strategy employs the piezoelectric transducers to convert energy from mechanical footsteps into electrical power. This power generation method has the potential to become extremely popular in densely populated nations such as Pakistan, China, and India. It can be installed on roads, bus stations, and a various locations on public spaces. Although this system is a little pricey, it has the potential to make a significant difference in the country's electrical power generation. The goal and objective of this study was to transfer the energy of a footstep, walking, or sprinting into electrical energy. It is used to create energy by walking or running on one's feet, which can then be utilized to charge gadgets such as cellphones. The system circuit is connected to a piezoelectric sensor, which is employed as a transducer to transform force energy into electrical energy. It is made up of a huge number of piezoelectric sensors that are wired together in a series. Electrical energy is converted from the kinetic energy of series-connected transducers. To obtain proper output, piezoelectric sensors generate voltages that are fed to circuit parts, through the use of a USB cable, the output energy is stored in batteries.

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