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Application of Piezoelectric Sensor in Energy Harvesting Technology for Pathway Sustainability

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Abstract: **Nowadays, the power sector is giving many changes in order to maintain an effective power flow. Even though renewable or non–renewable energy sources are present in the power market, some countries could not overcome the power demand due to an increase in the human population. In order to avoid such issues, power can be generated using alternating techniques. At the same time, a certain amount of energy is wasting from human pavements (footsteps). So, this wasted energy can be reformed into useful electrical energy. In this way, the paper is focused on the energy harvesting technology through the human footsteps using a piezoelectric sensor. On each footstep, the Piezo sensor disc pressed and converts mechanical energy into electrical energy. As a single Piezo sensor not enough to generate a sufficient amount of energy, so we connect Piezo sensors in series/parallel combinations for more power output. It is also useful for domestic, office purposes, or commercial purposes (ex: Mobile charging, Laptop charging, Fan, Street Lighting, etc). This project is designed for simple drive of DC (Mobile Charging, LED) and AC load (LED Bulb) and simultaneously the generated voltage status will display using microcontroller (ATMega328P).**

Keywords: Energy Harvesting System - PZT Model - Materials and Methodology - V, I and Power relations - Results (DC and AC Loads).

1. INTRODUCTION

Energy harvesting has been the subject of controversy and research since the 1970s. Discovering and exploiting new energy sources has become a need due to ever-increasing and demanding energy demands. It is the process of electrical power gathering from an external resources and either driving equipment directly or capturing and storing it for later use. The use of energy sources has grown by leaps and bounds since the invention of technology. Figure 1 depicts the energy gathering scheme. Piezoelectric Energy Harvesting is a novel and forward-thinking approach to energy harvesting. Because there have been few studies in this subject to far, extracting energy from piezo-crystals is a difficult task.

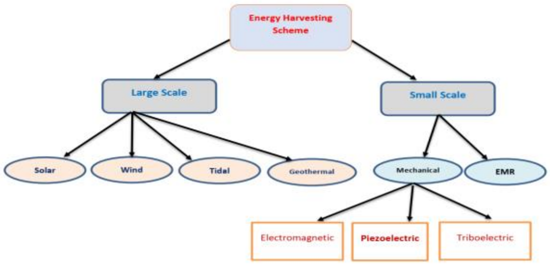

Figure 1: Energy Harvesting Scheme

1.1 Problem Statement:

To keep prices down, alternative kinds of energy are currently being used in areas such as airport terminals, railway stations, stadiums, schools, shopping malls, night clubs, religious auditoriums, and automobile parks around the country. As a result, the usage of piezoelectric devices put in these places will allow for the capture of kinetic energy from foot traffic. This energy can then be utilized to counterbalance part of the main grid's power.

1.2 Objectives:

To preserve a healthier environment for future generations, cleaner and more sustainable types of electrical power are required to maintain healthy and productive connections with industry and other relevant areas. Such a source of electricity may also be utilized to power streetlights and other tiny electrical devices such as phones and torch lights. This will aid in further reducing energy use and environmental effect.

2. BACKGROUND

The piezoelectric energy harvesting technology is based on the material's ability to generate an electric field when subjected to mechanical force. The direct piezoelectric effect is the name given to this phenomenon. Piezoelectric transducers come in a variety of forms and materials, making them appropriate for a wide range of applications. A model is required to study the behavior of piezoelectric devices in the temporal and frequency domains in order to maximize their utilization in applications [1, 3].

The fundamental operation of footstep power generation is based on piezoelectric sensors. When the flooring is designed using piezoelectric technology, the electrical energy generated by the pressure is recorded by floor sensors and transformed to an electrical charge by a piezo-electric transducer**.** These sensors are positioned in such a way that the greatest output voltage is generated. This output is sent into our monitoring circuitry, which is a microcontroller-based circuit that allows the user to monitor the voltage and charge a battery, and this power source has a wide range of uses [2, 4, 5 and 7].

The crystalline structure of piezoelectric crystals allows them to transform mechanical energy (stress and strain) into electrical energy. Based on a novel

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prototype of a PZT, the energy harvesting from floor tile [8].

Harvesting Energy is independent as one of the most promising technologies for approaching the world. Energy problems without depleting natural resources. Energy harvesting technology on the road Infrastructure is a new field of research, including technology to absorb waste collect the energy generated on the sidewalk and store it for later use. [6].

Harvesting Energy is one of the most promising approaches to addressing the global energy crisis without diminishing natural resources. Energy harvesting methods from road infrastructure are a new research area that includes technology that catch lost energy at pavements, gather it, and store it for later use. Their most appealing feature is that they already have extensive paved areas. Paved surfaces with conductive pipes, PV sound barriers, Nano materials or Phase Change Materials, piezo sensors and thermoelectric generators, and induction heating techniques are only a few of the most recent examples [2, 4, and 10].

With the weight applied to the tile the corresponding voltages generated are examined. It turns out that there is a linear relationship. Especially suitable implementation in crowded areas. This can be used on the road lighting without long power lines and also be used in charging station, lighting of sidewalk buildings [9, 10].

2.1. Basic concept of Piezo electric sensor:

The term is derived from the Greek word ‘piezien’, which meaning "to press or squeeze." Alternator converters or the well-known dynamo are frequently used to convert mechanical energy into electrical energy. Other physical processes, such as piezoelectricity, can also transform mechanical motion into electricity [1, 5]. The piezoelectric effect is a phenomenon that occurs when a force is applied to a piezoelectric material, resulting in the generation of an electric charge. The direct piezoelectric effect defines a material's ability to convert mechanical strain into electrical charge, whereas the inverse effect explains a material's ability to convert an applied electrical potential into mechanical strain energy (Figure 2).

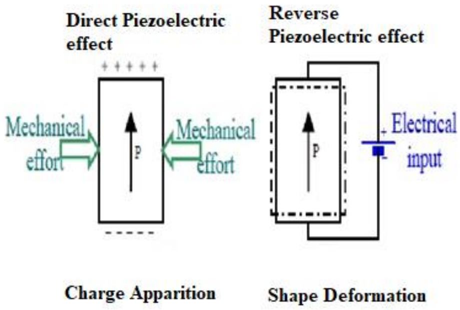


Figure 2: Electromechanical conversion via Piezoelectricity phenomenon

The mechanical and electrical properties of piezoelectric materials can be modelled using two linearized material equations. These equations have two mechanical and electrical variables. The following matrix equations can be used to mimic the direct and adverse effects [3, 4]:

For Direct Effect: $D = d.\ T + \varepsilon T.\ E$ ……………………….(1)

For Converse Effect: $S = sE.\ T + dt.\ E$ …………………..(2)

Where D = the electrical displacement vector,
T = the voltage vector,
εT = the permittivity matrix at a constant mechanical stress,
sE = a matrix of flexibility coefficients at a constant electric field strength,
S = the strain vector,
d = the piezoelectric constant.
E = the electric field vector.
dt = transpose matrix.

As a result, the piezoelectric properties must include a sign convention to support this ability to recover potential. The direct piezo effect contributes to the ability of the material to act as a sensor (Figure 3), and the inverse piezo effect contributes to its ability as an actuator [1, 7].

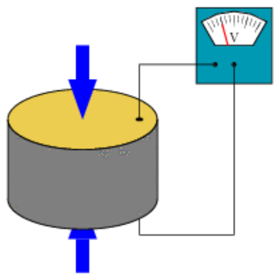


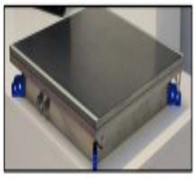
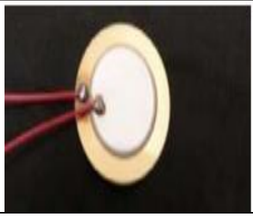
Figure 3: Voltage Generation from Piezo electric

2.2. Types of Piezoelectric Technology in Energy Harvesting:

Natural piezoelectric materials such as quartz do not have attractive properties for power generation. Table 1 shows how piezoelectric technology types are grouped based on the major technical applications [2, 4, and 6].

Table 1: Types of Piezoelectric Sensors

Technology	Application	Structure
Way energy Floor	• Indoor/outdoor applications. • Footfall surfaces, Transport stations, Pathways.	

Sustainable Energy Floor (SEF)	• Power street lights. • Airports, Sport arenas, shopping malls, Railway stations and office and Apartment blocks.	
Sound Power	• Power Sources for many applications. • Utilizing in the emergency stairs	
Drum Harvesters - Piezo	• Using in low power Sensors and in Microelectronic devices like Bluetooth, GPS modules, microcontrollers	

1. MATERIALS AND METHODOLOGY

3.1 Hardware Components:

- **Piezoelectric sensor:**

These materials are available in a variety of formats. Crystals are the most prevalent, although it may also be found in polymers and ceramics. Piezoelectric sensors of the PZT drum type are employed in this work [2, 5 and 9]. The diameter of the disc is 35 mm. A 100 mW (max-Apprx) power may be acquired from this sort of transducer.

On the foot step plate, 8 discs are utilized. Each disc generates around 1.5 V. As a result, depending on the pressure applied to the foot step arrangement, a maximum of 12 V can be created. Figure 4 depicts an arrangement.

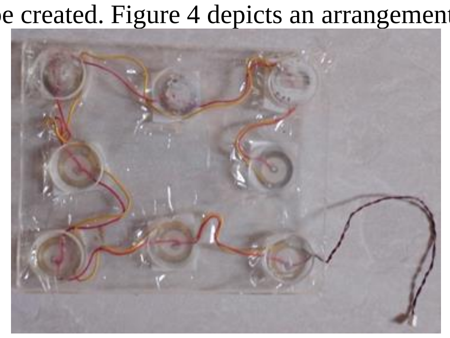


Figure 4: Piezo Foot Step Plate

- ***Microcontroller:***

The ATMega328P is an AVR-based 8-bit microcontroller. At 20MHz, several instructions are completed in a single clock cycle, resulting in a throughput of about 20 MIPS. It is available in a PDIP 28 pin package. In the IC, the following pins are vital role in process.

- **I/O Ports**
- **Communication ports**
- **ADC**
- **Timers**

- ***LCD:***

The 16x2 LCD (Liquid Crystal Display) is used in the project for display purposes (Figure 3.1.3). LCD screens are a type of electronic display module for a variety of uses. The 16x2 LCD is a very simple module and is widely used in a variety of devices and circuits. These modules are most common with 7 parts and various multi-segment LEDs

This LCD contains two registers, command and information. The command register contains LCD command instructions. The command register contains LCD command instructions. Commands are commands issued to the LCD to attempt to perform certain actions, such as screen initialization or cleaning. The information register contains the data displayed on the LCD. The information is the ASCII value of the characters displayed on the LCD

- ***Battery:***

Batteries have become the standard power source for a variety of home and industrial applications. Figure 5 shows that a lead-acid battery (12 V / 1.3 Ah) is used in this work**.** It is used to store the power and as well as the power taken for input source to microcontroller**.**

Figure 5: Battery

- ***Inverter Module:***

In this work, AC load is also provided. So, the DC output voltage is converted into AC source with help of inverter module (Figure 6). This inverter module has 12 V DC to 240 V AC and 600 W features

Figure 6: Inverter Module

- ***Load:***

For electricity, the load can be a group of devices that use electrical energy from the source, battery, or module. In our project, a 5 watt LED bulb will be used as an AC load and a mobile charging system is used as a DC load (Figure 7).

Figure 7: Load

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- **Voltage Regulator (IC 7805):**

7805 Voltage regulator IC is one of the most frequently used regulator ICs. Regulated power supplies are especially important for many electronic devices. In this work, mobile charging is used as DC Load. So, the 5V supply is given to mobile from the regulated IC.

3.2. Software Section:

The software area is another important component of this project. Based on code, the hardware components are connected to the microcontroller unit. After running the code, the parameters will be displayed correctly on the LCD. Initially, the voltage and step count will be displayed as zero value. Therefore, all interface processes with the microcontroller have gone through the programming path. In this project, the display shows the output voltage for each step count. The interface between the LCD and the microcontroller programming code was created using the ANSI-C language.

3.3. Methodology:

In a densely populated country where highways, airports, clubs, shopping malls, schools, universities, religious auditoriums, etc. are crowded and millions of people are watching watches, energy loss due to the power of the feet due to human movement. It is a great idea to waste all of that human / bioenergy when used, and crowd energy farms will be an incredibly valuable source of energy in populated countries [9,10]. The electricity provided by such farms is valuable for local use. A sensor is a device that measures a physical quantity and converts it into a signal that can be read by an observer or device. This project will use a renewable energy plan with a microcontroller (ATMega328p).

2. PROPOSED PROJECT

4.1 Block Diagram:

Piezoelectric sensor maintains close contact with the source of vibration. When vibration occurs, the piezoelectric sensor produces an electric charge. The AC pulse is determined by the rate of change of these induced charges over time and covert into DC with help of ADC. Then the Dc voltage is stored in the battery. From the regulated source, mobile is charged. Also, AC load is switched ON from the inverter unit. The voltage and step count is displayed in the LCD. A figure 8 shows the block diagram of the project.

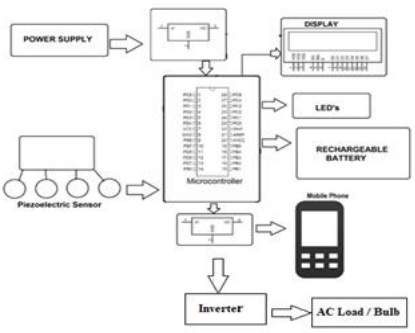


Figure 8: Block Diagram

4.2 Operation:

The process to generate piezoelectricity from a coin-shaped piezoelectric crystal. When a person steps on the scale, the piezo disk is crushed. The crystals are decompressed as soon as you raise your legs. As a result, the quartz disc recognizes a complete vibration and creates a voltage across it. The voltage is recorded and converted by the microcontroller's ADC. The voltage is then shown on the device's display. This voltage is also used to charge the 12V battery. The LED strip is mounted on the setup box and is activated by the 555 timer IC when voltage is applied. A LED strip will glow and off based on the capacitor charging and discharging mode on the circuit board. As a result, the battery is charged each time it passes through the scale, with the voltage reflected on the screen. The DC load of the mobile charger to the charging point to charge it. If AC load is required, to open the AC output switch. A 5 W LED lamp is used for the AC load. The inverter module is used to generate this AC output voltage (12 V DC- 240 V AC). The operation mode is described with a flow chart as shown in figure 9.

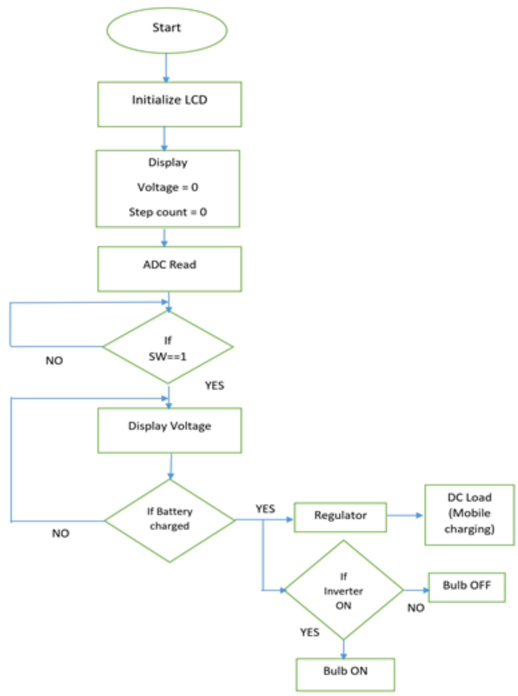


Figure 9: Flow Chart

The display purpose, the ATMega328P is interfaced with LCD. This arrangement is shown in figure 10. Using an ATMega32 to interface with a 16x2 LCD, there are no built-in libraries for the Atmel AVR Microcontroller, programming it with Atmel Studio is a bit more difficult. To address this issue, LCD library that comprises regularly used functionalities. A microcontroller may be interfaced with a 62 LCD in either 8 Bit or 4 Bit mode. In this work, 4 Bit mode only requires four data lines (D4 to D7). To preserve microcontroller pins, the concept of four-bit communication is created [7, 9].

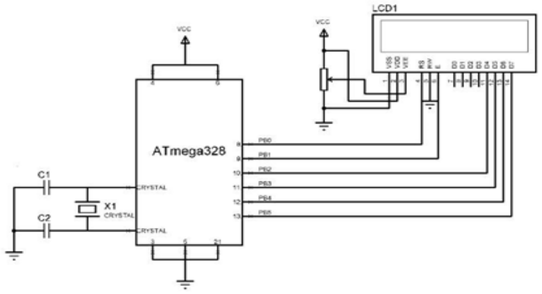


Figure 10: Interfacing Circuit

3. RESULT AND DISCUSSION

5.1 Output Voltage:

From this work, each press of the piezo sensor generates 1.5 volts (Approximate) based on the weight of the body. This energy is stored in the batteries to be used to power the loads. The following table (Table 2) shows the voltage generation from footsteps.

Table 2: Generated Voltage (by 70 Kg of body weight)

Steps	**Generated Voltage (V)**
1	1.5
2	3
3	4.5
4	6
5	7.5
6	9
7	10.85
8	12

The maximum 12 V is observed from 8th footsteps (Figure 11). This output voltage is generated by 70 kg of body weight. This output voltage can be varied based on the body weightage. It normally varies from 40 Kg to 80 kg of body weight.

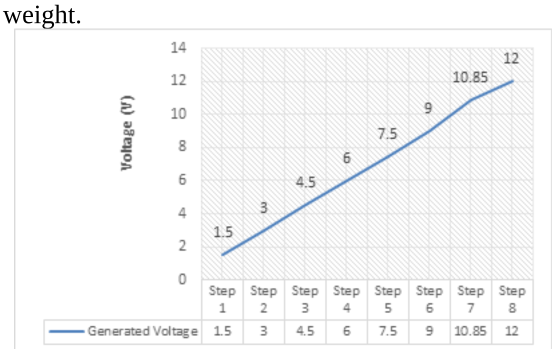


Figure 11: Generated Voltage Curve

5.2 Current and Power Relations:

In this project, 8 piezo cells are connected in series on one tile. When 8 piezoelectric discs are connected in series, its equivalent capacitance becomes [6]:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots\dots\dots \frac{1}{C_8}$$

We know, Q = C * V

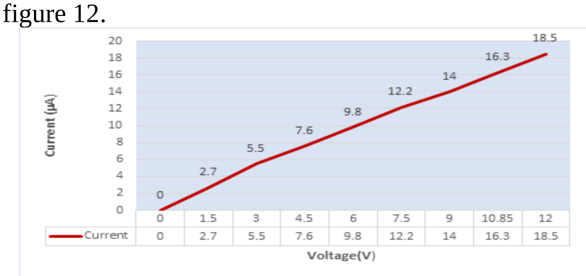
Hence,

$$V_{eq} = V_1 + V_2 + V_3 + \dots\dots\dots + V_8$$

The output voltage from 1 piezo disc is 1.5 V.

Therefore, $V_{eq} = 1.5 * 8 = 12$ V

Thus the maximum voltage that can be generated across the piezo tile is around 12 V. The current and generated voltage also observed from the experimental and shown in the figure 12.



.Figure 12: Current Vs Voltage

From the piezo plate (drum based Piezo sensor), the power is generated based on the body weight as shown in figure 13.

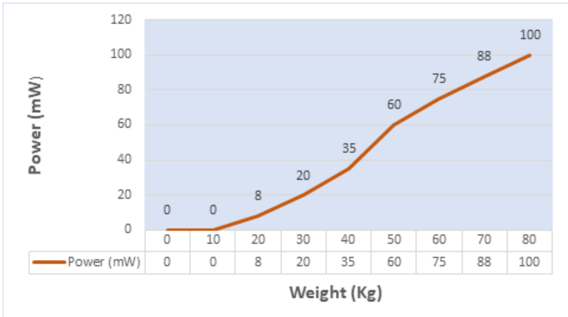


Figure 13: Power Vs Weight

A complete hardware setup made as shown in figure 14**.**

Figure 14: Hardware Setup

4. CONCLUSION

The concept has been thoroughly tested and implemented, and it is currently the most cost-effective and accessible energy option available to the general population. In rural locations where power is limited or non-existent, this can be used for a variety of reasons. Energy management is a big concern in Oman because it is a developing country with a vast population.

The suggestion for utilizing waste energy from human mobility is extremely relevant and important for densely populated or crowded areas. If it is possible to utilize all of the currently squandered human/bioenergy, it will be a fantastic innovation, and crowd energy farms will be extremely valuable energy sources in populated areas/countries

5. CONFLICT OF INTEREST

No Conflict of Interest.

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