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Footfall Stress for Piezoelectric Energy Harvesting and Power Generation through PZT Materials

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ABSTRACT

In today's world, energy and electricity are one of the most essential requirements. Because the need for energy is growing by the day, the most effective way to address these issues is to use renewable energy sources. The goal of this project is to generate electricity from footfall as a renewable energy source that we can receive by walking on specified arrangements such as pathways, stairs, and platforms, and these systems may be implemented anywhere, especially in densely populated places.

The use of piezoelectric materials to harvest energy from people walking vibrations for generating and collecting energy is described in this project study. The piezoelectric effect is at the heart of the "power generation utilising piezoelectric cell" concept. The electrical energy created by the pressure is gathered by floor sensors and transformed to an electrical charge when the flooring is constructed with piezoelectric technology. These sensors are positioned in such a way that they produce the highest possible output voltage. This signal is sent to our monitoring circuitry, which is a microcontroller-based circuit that allows users to monitor voltage and charge a battery. This power source has a wide range of uses.

KEYWORDS— *Piezoelectric cell, force or pressure, Power*

I. INTRODUCTION

The ability to conduct labour is what energy is. Energy harvesting, also known as power harvesting [4] or energy scavenging, is the process of collecting and storing energy from external sources such as solar power, thermal energy, wind energy, salinity gradients, and kinetic energy for small, wireless autonomous devices such as wearable electronics and wireless sensor networks. For low-energy electronics, energy harvesters deliver a very little quantity of electricity. While the input fuel for some large-scale generators (oil, coal, etc.) is expensive, the energy source for energy harvesters is abundant and free.Temperature gradients, for example, result from the functioning of a combustion engine, while radio and television transmission emit a huge quantity of electromagnetic radiation in urban areas.

There has been a surge of attention in transferring mechanical energy from human motion into electrical energy over the last two decades. This electrical energy can then be used to power small scale, low-power circuits or to recharge batteries in electronic devices. Hand-crank generators (for powering torches, radios, and recharging mobile devices) and pedal generators are two examples of commercial devices that employ human power to generate energy (that can be used to power larger electrical devices typically generating between 100 and

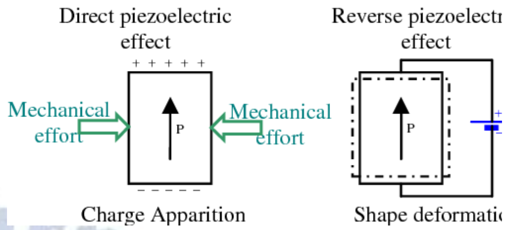
1000W).These generators, on the other hand, necessitate sustained human effort for long periods of time, which may prevent the user from performing other tasks. While the user is conducting his or her duties, it is desirable to scavenge or harvest energy from human movement. Walking is by far the most prevalent human activity. The average person may walk between 3,000 and 5,000 steps each day. Walking wastes energy in the form of vibrations on the ground. The piezoelectric effect can be used to transform this wasted energy into electricity. The piezoelectric effect occurs when mechanical vibrations, pressure, or strain are applied to piezoelectric materials such as quartz, lead zirconate titanate (PZT), Polyviny

lidene fluoride (PVDF), Rochelle salt, Mica, and other piezoelectric minerals. The properties of piezoelectric material (PZT) are superior, and the series-parallel combination is shown to be more effective. The properties of piezoelectric material (PZT) are superior, and a series-parallel combination is determined to be more suited. The system's efficiency can be improved by employing rechargeable nanotechnology batteries, and the voltage can be effectively boosted by employing a Boost converter.More electricity can be created by employing synthesised piezoelectric crystals and a better location for installation.

II . RESEARCH ELABORATIONS

STUDY OF PIEZOELECTRIC SENSORS

Piezoelectric materials are increasingly being explored because they are odd materials with unique and compelling features. In fact, these materials have the ability to convert mechanical energy into electrical energy, for example, by converting vibrations into electricity.Energy harvesters are a sort of device that can be used when external power isn't accessible and batteries aren't a viable option. While recent research have indicated that these materials could be employed as power generators, the amount of energy generated remains modest, necessitating more optimization.The direct and reverse effects of piezoelectric materials are defined. When mechanical stress is applied to some materials, they produce an electric change on their surface, but when an electric charge is produced, they develop mechanical stress.The piezoelectric sensor requires an external source since it has a very high frequency response and is self-generating. Because of their compact dimensions and large measuring range, they are simple to use. [1]



III . BLOCK DIAGRAM

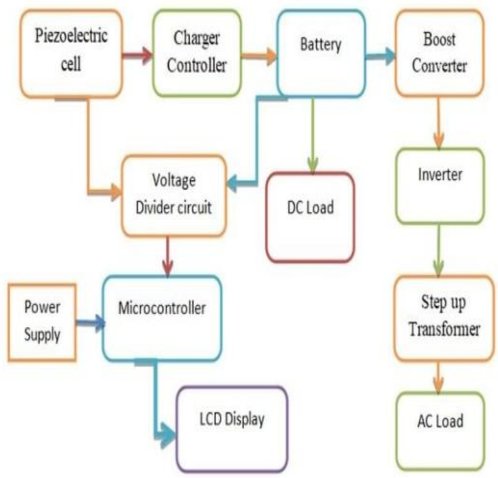


Fig1: block diagram representation

IV. WORKING PRINCIPLE

The pressure supplied to the piezoelectric cell is converted into electrical energy by the piezoelectric material. The source of pressure can either be the weight of driving automobiles or the weight of individuals walking on it.The piezoelectric material's output is not constant. To transform this variable voltage to a linear one, a bridge circuit is employed. An AC ripple filter is utilised once more to filter out any further output variations. A rechargeable battery is used to store the output dc voltage. Due to the low power output of a single piezo-film, a combination of a few Piezo films was investigated. There were two types of connections tested: parallel and series. The voltage output from the parallel connection did not increase significantly. Additional piezo-film results in an increase in voltage output when connected in series, but not in a linear proportion.So, in order to provide a 40V voltage output with a high current density, a hybrid of parallel and series connections are used. To avoid voltage and current fluctuations, a boost converter is connected to the battery. To connect the dc load, battery provisions are provided.A boost converter connects an inverter to the battery, allowing it to connect to an AC load. A LCD may display the voltage generated across the tile. The ATMega328P microcontroller is utilised for this purpose. The microcontroller is powered by a crystal oscillator. The microcontroller's output is subsequently sent to the LCD, which shows the voltage levels. [3]

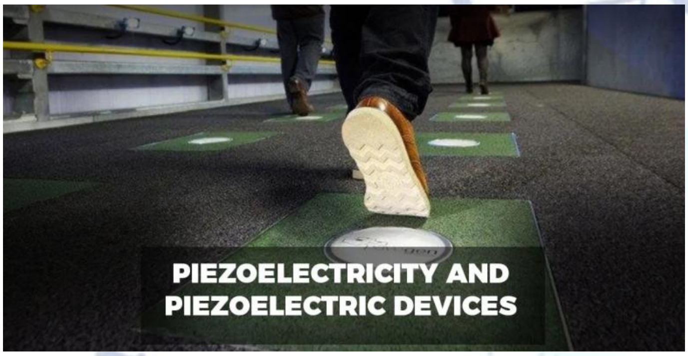


Fig2: Piezoelectric device

A. PIEZOELECTRIC SENSOR

A piezoelectric sensor, in general, is a transducer that converts applied stress into electrical energy. Simply stated, it is a device that transfers energy from one form to another. It transfers physical stress into electrical energy, in other words. The stress can be in the form of a force, pressure, acceleration, or any other potential contact. Not every substance has piezoelectric properties. Piezoelectric materials come in a variety of shapes and sizes. Natural single crystal quartz, bone, and artificially made materials such as PZT ceramic are only a few examples of piezoelectric materials.

B . CHARGE CONTROLLER

A charge controller circuit that is utilized as a unidirectional current controller allows only one direction current to flow through some devices.

1. Diode
2. Thristors

C . BATTERY

Separately linked or individually interconnected and contained in a single unit, a lead acid battery (electricity) is a collection of electrochemical cells for electricity storage. An electrical cell is composed up of one or more electrochemical cells that convert chemical energy into electrical energy.Batteries can be used once and then discarded, or they can be refilled and used in standby power applications for years. Hearing aids and wristwatches are powered by miniature cells, while larger batteries provide backup power for telephone exchanges or computer data centres.

D . BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter that increases voltage while decreasing current from its input (supply) (load). It's a type of switched-mode power supply (SMPS) that has at least two semiconductors (a diode and a transistor) and at least one energy storage element (a capacitor, an inductor, or both).Filters built of capacitors (occasionally in combination with inductors) are typically added to such a converter's output (load-side filter) and input (input-side filter) to reduce voltage ripple (supply-side-filter). One of the most basic types of switch mode converter is the boost converter.It takes an input voltage and boosts or enhances it, as the name implies. An inductor, a semiconductor switch, a diode, and a capacitor are the only components. A source of a periodic square wave is also required. This could be as simple as a 555 timer or as complex as a special SMPS IC like the well-known MC34063AIC.

E . INVERTER

A power inverter, often known as an inverter, is a device or circuitry that converts direct current (DC) to alternating current (AC) (AC). The frequency of the generated AC is determined by the equipment used. Inverters work in the opposite direction of converters, which are huge electromechanical devices that convert AC to DC.The design of the specific device or circuitry determines the input voltage, output voltage and frequency, and overall power handling. The inverter does not generate any power; instead, the DC source provides it.

F . STEP-UP TRANSFORMER

A step-up transformer is one in which the output (secondary) voltage is greater than the input (primary) voltage. The step-up transformer reduces the output current to balance the system's input and output power.

G . VOLTAGE DIVIDER CIRCUIT

The voltage is lowered to the level of a microcontroller using a voltage divider circuit. We can't supply 12 volts to the microcontroller directly. The voltage is divided using a voltage divider. The microprocessor then reads the analog inputs and displays it on the LCD after that.If you're not sure how to measure dc voltage with a microcontroller, the dc voltmeter with microcontroller project can help you learn. [5]

H . ARDUINO

It's a free and open-source prototyping platform with simple hardware and software. Arduino boards can take inputs like light from a sensor, a finger on a button, or a Twitter post and turn them into outputs like turning on a light, triggering a motor, or publishing anything online.By providing a set of instructions to the board's microcontroller, you may tell it what to do. You may do this by using the Arduino programming language (which is based on wire) and the Arduino software (IDE), which is based on Processing.

I . LIQUID CRYSTAL DISPLAY (LCD)

The output of the battery and the output of piezoelectric sensors are displayed on a liquid crystal display (LCD), which is a tiny, flat panel used for electronically displaying information such as text and sensor outputs.

J . DC MOTOR

Any rotary electrical motor that transfers direct current electrical energy into mechanical energy is known as a DC motor. The most common varieties rely on magnetic fields to produce forces. Almost all DC motors contain an internal mechanism, either electromechanical or electronic, that changes the direction of current in a section of the motor on a constant schedule.

V . HARDWARE IMPLEMENTATION

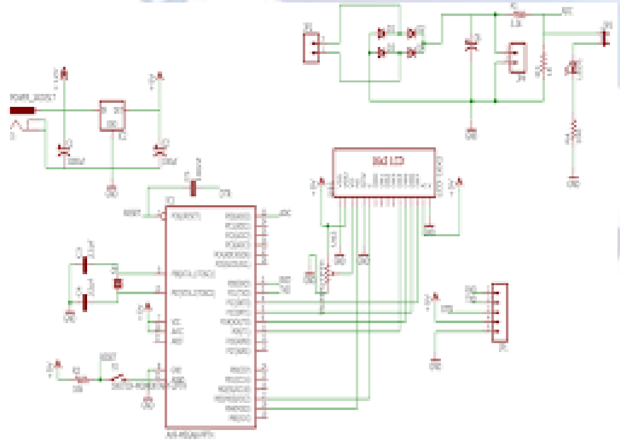


Fig 3 : hardware implementation schematic

The schematic diagram is depicted in the image above. A piezo material tile generates voltage across a piezo tile, which is sent to a bridge rectifier circuit to acquire DC voltage, which is then sent to a rechargeable battery, which charges the battery and can be used to drive both DC and AC loads. The battery in this case is a 12V lead acid battery. A microcontroller is connected to an LCD. The ATMega328P microcontroller is utilised in this project, and it has a 16Hz speed and an 8-bit, 32kb flash with 1k RQM.The voltage generated by the piezoelectric tile is displayed using a 16x2 LCD. A clock signal is generated by connecting a crystal oscillator to a microcontroller. Power is supplied to the microprocessor and LCD via the power supply unit. The IC7805 in this unit converts 12V to 5V. [5]

VI. MAXIMUM THEORETICAL VOLTAGE GENERATED

A charge is formed when a force is applied to a piezoelectric material. It's a good bet that it's a perfect capacitor. As a result, it can be subjected to all capacitor equations.On one tile, we link three piezoelectric cells in series and five piezoelectric cells in parallel in this research. When ten piezoelectric discs are wired in series, the corresponding capacitance is:

$1/ C_{eq} = 1/ C1 + 1/ C2 + 1/ C3$

we know, Q=C*

So, C=Q/V

Hence, $V_{eq}/Q = V1/Q + V2/Q + V3/Q$

Thus, $V_{eq}=V1+V2+V3$

Hence, the net voltage generated in series connection is the sum of individual voltages generated across each piezoelectric disc. Output voltage from 1 Piezo disc is 13V.

Thus, $V_{eq}=V1+V2+V3$

=13+13+13

=39V

Thus the maximum voltage that can be generated across the piezo tile is around 39V[1]

VII . ANALYSIS DONE ON THE PIEZO TILE

To test the piezo tile's voltage generating capacity, people weighing between 40 and 75 kilogrammes were forced to walk on it. The graph below depicts the relationship between a person's weight and the amount of power generated.From the graph it can be seen that maximum voltage is generated when maximum weight/force is applied. Thus, a maximum voltage of 40V is generated across the tile when a weight of 75kg is applied on the tile.[1]

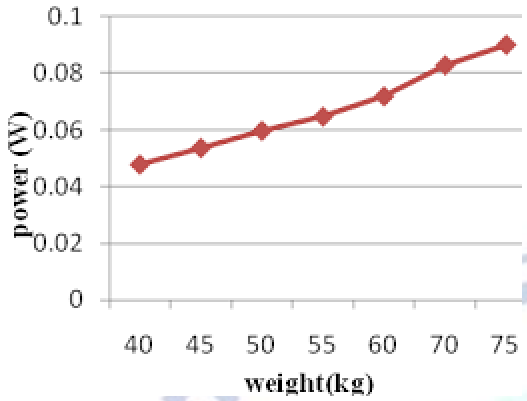


Fig4 : weight V/s power graph of piezo tile

VIII. RESULT AND FINDING

If 30 piezo sensors are employed in a 1 square foot area. Because the power generated by piezo sensors fluctuates with different stages, get 1 V every step as a minimum voltage Each step has a maximum voltage of 10V.If you take an average of 50 kg weight pressure from a single person, the average computation is as follows: To increase the voltage of a battery by one volt, you must do 800 steps.

As a result, to boost the battery's voltage to 12 V,

The total number of steps required is (12 800) =9600.

Because this project is being implemented in a crowded region with available footsteps as a source, an average of two steps per second will be taken. Time required =9600/ (60 2) =80 minutes for 9600 steps. (Approximately)

IX. CONCLUSION

The use of piezoelectric crystals has begun, with encouraging results. More electricity can be generated with additional advancements in the field of electronics, better manufactured piezoelectric crystals, and better selection of installation locations, and it can be seen as a next promising form of generating electricity. It is possible to gather a non-conventional, non-polluting kind of energy while maintaining common people's economic standards. The piezoelectric effect causes mechanical stress on the crystals, which creates the energy needed to charge the battery that powers the streetlights at night, as well as for the city's electricity consumption. Regardless of the outcome of this endeavour, piezoelectric materials have a bright future ahead of them, with research focused on their characteristics and applications in nanotechnology.

As a result, the assembly greatly increases the concern of cost effectiveness, and development continues to improve the system's results.

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