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Piezoelectric Harvesting Smart Charging

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ABSTRACT: In this research article, we suggest a cutting-edge technology for harnessing the power of human footsteps using piezo sensors. The technology allows for the placement of a platform for feet. To produce voltage from footfall, the piezo sensors are positioned underneath the platform. The sensors are arranged in this way to produce the highest output voltage possible. After that, this is delivered to our monitoring circuitry. On an LCD panel, it also shows the charge that was generated. Additionally, it has a USB charging port for smartphones where users may attach cables to recharge their devices' batteries. As a result, we use user footsteps to power a battery charge, a microcontroller circuit displays it on an LCD, and the system supports mobile charging.

KEYWORDS: Piezoelectric Sensors, Batteries, Footsteps to electricity, RFID Module and Sensors, Arduino Compilers.

I. INTRODUCTION

Wastage of energy is also increasing in many ways nowadays. So, reforming this energy back to usable form is the major solution. In this footstep power generation project, we are generating power with the help of human's footsteps, this power is then used to charge the battery.[1] The power is stored in a battery that can be used to charge a mobile phone using an RFID card. This system is powered by a mega 328 microcontroller, which consists of Arduino IDE, RFID sensor, USB cable and LCD. When we power on the system, the system enters into registration mode. We can register three users. Once all the user is entered in the system then the system asks to swipe the card and connect the charger. Initially all the user is given 5 minutes of charging time as default. When we swipe the card and if the user is authorized, the system turns on for charging and will charge the Mobile phone. If the user is unauthorized then the system will display as unauthorized user. Just in case if the user wants to stop the charging midway then the user needs to swipe the card again. As soon as the card is swiped again, the remaining time balance is displayed and the charging stops. In order to recharge a card, we need to press the recharge button which is on the system, and then the system will ask to swipe the card. Once the user swipes the card, it adds 5 more minutes to the particular card of the user.

Paper is organized as follows. The author first states the Problem that they are trying to address. The next section describes the methodology and components used in the working of the system. The Final section of the paper presents the conclusion of the project and the possible future application for the same.

II. LITERATURE SURVEY

Piezoelectric material generates electrical energy when it is under mechanical stress, vibration, force, pressure etc. The energy conversion property of piezoelectric transducers makes it suitable for energy harvesting applications. Different types of piezo-electric materials used in the energy harvesting process are: single crystal, lead-based piezo

ceramics, lead-free piezo ceramics, piezo polymers etc. Depending on the configuration, the piezoelectric transducers are classified as: a) Cantilever beam type, b) Diaphragm type, c) Cymbal type, d) Stack type.

A. Cantilever beam type Piezo-electric transducer:

The piezo-electric cantilever-beam type transducer consists of a fix-base, a cantilever beam, tip-mass and thin piezoelectric layers. The cantilever beam is fixed at one end, which helps to operate in its flexural mode. Its simple geometry helps in generating high strain. The cantilever piezoelectric transducers are categorized into unimorph and bimorph type depending upon the number of piezo-electric layers bound with the cantilever-beam. The bimorph piezoelectric transducers are well-liked in piezo-electric energy harvesting (PEH) systems, as it generates almost twice the electric energy generated by uni-morphs without changing the volume of the transducer. M. Wisheke developed a piezo-electric cantilever energy harvesting system (PCEHS) using a cantilever piezoelectric transducer and mounted it on a rail track. More than 500 passing trains were detected and the system was monitored for 3 to 5 minutes in every one-hour interval. It was reported that around 395 μJ of energy could be generated from the vibration generated by one passing train. PZT-5H stack cantilever type composite with MC nylon packaging was used to harvest roadway energy.

B. Diaphragm type piezoelectric transducer:

The diaphragm piezo-electric transducer consists of three layers. The core part or inner layer is electrode, middle layer is piezo-electric material & the outer layer is the metal shim. The tip mass is affixed to the core/electrode of the diaphragm, to enhance the output power and its low frequency performance. E. Minazara et al. performed an experiment using piezoelectric diaphragm for vibration-energy-harvesting. They noted that a power of 0.65 milliwatt was produced at 1.71 kilohertz resonance frequency across 5.6 K Ω resistances and 80 N forces. They used a specially designed electronic circuit using “Synchronized Switch harvesting on Inductor” to improve the generated power to 1.7 milliwatt.

C. Cymbal type Piezoelectric Transducer

The cymbal transducers comprise a piezoelectric disc with metal capping on top and the bottom. The displacement of a cymbal is due to both flexure and rotational motion of the end caps. The cymbal is preferred for traffic energy harvesting systems because of its higher displacement, high stability, high contact surface and its lesser fabrication cost. From their simulation study, concluded that the piezoelectric traffic model using multiple piezoelectric cymbal transducer arrays can produce a total of 170 KW electric power for a 1-kilometer stretch considering the traffic rate as 600 vehicles/hour.

D. Stack type Piezoelectric Transducer

Stacked piezoelectric transducers are the multi-layer piezoelectric transducers stacked over each-other. The poling direction of the layers is the same as the direction of applied force. The stack type piezoelectric transducers are mostly used in high-pressure applications. A.J. Lee et al. used a PZT-stack type piezoelectric transducer to simulate a traffic energy harvesting system on LabVIEW. They predicted that for an impulsive load of 20.8 mN the PZT-stack (SCMAP09-HI00) is capable of harvesting 0.2899 μJ energy.

Energy Harvesting from Vehicular Vibration Sources

The vehicular vibration energy eventually destroys the pavement structures and it is not easy to collect that energy. The mechanical to electrical conversion property of piezoelectric transducers is used to convert the vehicular vibration energy into electrical energy. This electrical energy can be used to feed power to the roadside electric appliances, such as traffic signal lights, advertising boards etc. In 2010, Prof. H. Aramovich and Associate Prof. of Technion Institute of Technology headed a project on piezoelectric energy harvesting (PEH) in roads of Israel. They observed that when the piezoelectric energy generators are installed 6 cm. beneath the road level maintaining 30 cm. distances from each other, the system is able to produce power of 400 kilowatt in one hour for a 1-kilometer stretch assuming the traffic of 600 vehicles/hr. Now-a-days PEH

systems have been implanted in many office corridors, mostly in Japan, to lighten up LEDs when it senses footsteps.

H. Najini and S.A. Muthukumarswamy presented a simulation-based model to advocate the idea of harvesting energy from road traffic using piezo-electric material. From this simulation work, they observed that energy of 137, 255 & 469 kwh can be yielded from a single lane road with vehicle speed of 80,100 and 120 km/hr respectively assuming the traffic of 500 vehicles per hour. Jasim et al. have also reported numerical simulation model of PEH system for roadways application. They conducted an experimental study on piezoelectric roadways energy harvesting systems.

They concluded that out of PZT-4, PZT-8 and PZT-5H, the PZT5H possesses a high voltage, high relative dielectric constant and high capacitance when load frequency is more than 5hz. It is able to produce comparatively more power under the same load. Hence, it is more suitable to be used in piezo-electric boxes for pavement energy harvesting. They Designed a piezo-electric power generation unit using stacked array piezo-electric transducer with MC nylon as packaging material for road vibration energy harvesting. They proved the practical significance of the system by performing on-site tests. M.V. Rodriguez et al. used PZT and lead-free PIC-700 for designing traffic-energy-harvesting systems. They concluded that the relative error in practical implementation of the theoretical model is around 3% in both ways, by using PZT and PIC-700.

With a view of future prospects in case of densely populated nations, the optimum use of energy wasted is of very much importance.

1. Japan is one of the first liners to use electric principle for generating mechanical energy from flooring tiles i.e., by using these plates on bus stairs. When someone steps in the energy is generated which leads to an increase of steps as well as energy also increased.
2. Secondly, Europe is setting another milestone in the field by using such plates on dance floors, so if anyone steps on to these tiles and dances again the energy is released with which even one can charge their mobile and other handy gadgets.

III. METHODOLOGY

1. The Footstep power generator works on the principle of piezoelectric effect.
2. Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. [2]
3. Thus, squeeze certain crystals (such as quartz) and you can make electricity flow through them.
4. In most crystals (such as metals), the unit cell (the basic repeating unit) is symmetrical; in piezoelectric crystals, it isn't.
5. Normally, piezoelectric crystals are electrically neutral: the atoms inside them may not be symmetrically arranged, but their electrical charges are perfectly balanced: a positive charge in one place cancels out a negative charge nearby.
6. However, if you squeeze or stretch a piezoelectric crystal, you deform the structure, pushing some of the atoms closer together or further apart, upsetting the balance of positive and negative, and causing net electrical charges to appear.
7. This effect carries through the whole structure so net positive and negative charges appear on opposite, outer faces of the crystal.
8. Normally, the charges in a piezoelectric crystal are exactly balanced, even if they're not symmetrically arranged. [6]
9. If you squeeze the crystal (massively exaggerated in this picture!), you force the charges out of balance.
10. Now the effects of the charges (their dipole moments) no longer cancel one another out and net positive and negative charges appear on opposite crystal faces. By squeezing the crystal, you've produced a voltage across its opposite faces and that's piezoelectricity

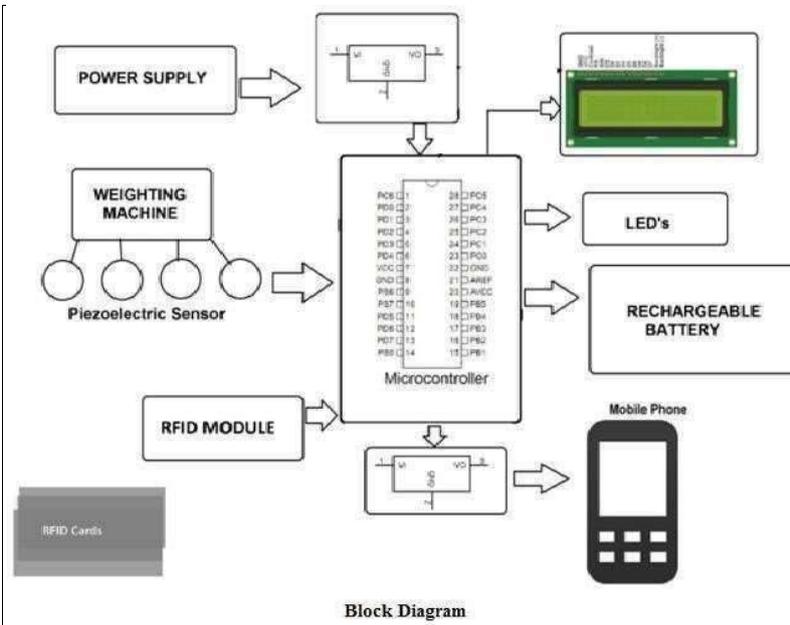


Figure 1: Block Diagram

IV. CONSTRUCTION

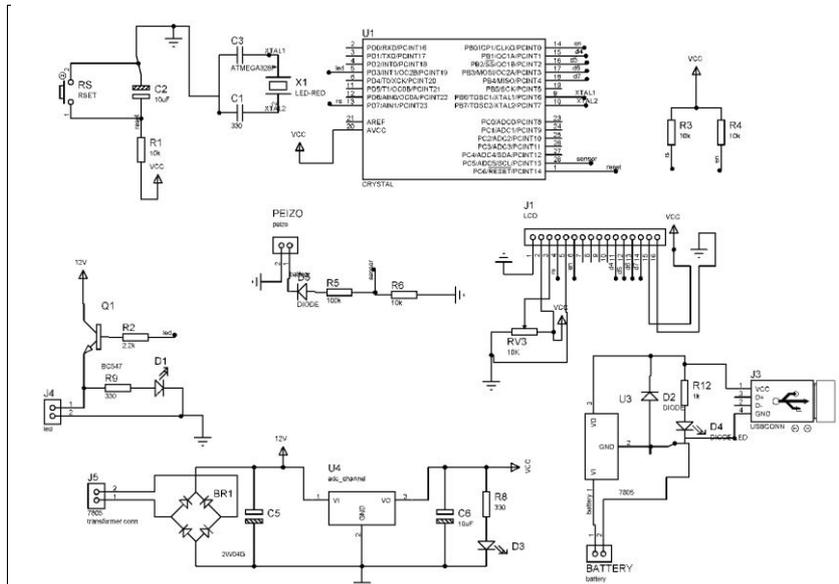


Figure 2: Circuit Design

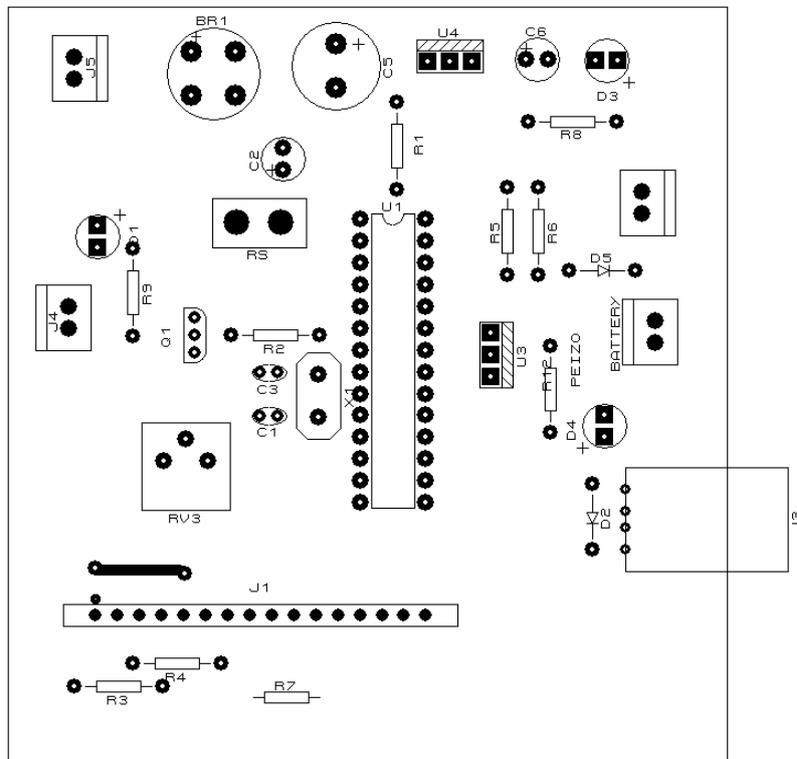


Figure 3: Visual Demonstration of PCB

1) **Hardware Specifications:**

- Power supply
- Mobile
- Atmega 328 microcontroller
- RFID sensor & cards
- Piezoelectric sensors
- USB cable
- LCD 16*2
- Adapter
- Voltage regulator – LM 7805
- Resistor
- Capacitor
- LEDs
- Diode – IN4007



- Battery

Software Specifications:

- Arduino Compiler
- Programming Language: Embedded C

V. PIEZOELECTRIC SENSORS

Piezoelectricity is the electric charge that accumulates in certain solid materials in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure. A piezoelectric sensor is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical signal.

Piezoelectric materials exhibit the unique property known as the piezoelectric effect. When these materials are subjected to a compressive or tensile stress, an electric field is generated across the material, creating a voltage gradient and a subsequent current flow [3]. This effect stems from the asymmetric nature of their unit cell when a stress is applied. As seen in Figure 1, the unit cell contains a small positively charged particle in the center. When a stress is applied this particle becomes shifted in one direction which creates a charge distribution, and subsequent electric field. These materials come in several different forms. The most common is crystals, but they are also found as plastics and ceramics. [4]f

Pressure Sensing

Pressure is sensed by mechanical elements such as plates, shells, and tubes that are designed and constructed to deflect when pressure is applied. This is the basic mechanism converting pressure to physical movement. Next, this movement must be transduced to obtain an electrical or other output. Finally, signal conditioning may be needed, depending on the type of sensor and the application. Figure 8 illustrates the three functional blocks.

Sensing Elements

The main types of sensing elements are Bourdon tubes, diaphragms, capsules, and bellows. All except diaphragms provide a fairly large displacement that is useful in mechanical gauges and for electrical sensors that require a significant movement

VI. WORKING

1. In our project we have used the same phenomenon of producing piezoelectricity from piezoelectric crystal in the form of coin shaped disc.
2. When one steps on the weighing machine the piezoelectric disc gets compressed. After the leg is lifted the crystal is decompressed. [5]
3. Thus a full vibration is sensed by the crystal disc and a voltage across it is produced.
4. This voltage is sensed by the voltmeter and displayed on its display.
5. Also, at the same time this voltage is used to charge the 12VDC Battery.
6. LED's have been mounted under the weighing machine that is switched on by relay through 555 timer IC whenever a voltage is generated.
7. This event is notified by a glowing LED on the PCB. (Also one can hear the switching sound of the relay)
8. Thus, whenever a person walks through the weighing machine the battery gets charged due to the voltage which is also displayed on the voltmeter. [7] This event is notified by glowing LED's beneath the weighing machine.



Figure 4: Working Model

VII. PROPOSED WORK

In 1 square ft. we have used 8 piezo sensors.

As piezo sensors the power generating varies at different steps, hence we get Min volt= 1V per step

Max volt = 10.5V per step

Also, taking an average of 50 Kg weight pressure from a single person.

Likewise considering the steps of a 50Kg weighted single person, the average calculation comes out to be: Increase of 1V charge in the battery it takes 800 steps. So, increment of 12V in battery total steps needed are equal to, $(8 \times 800) = 6400$ steps.

And if implementation of our project is done in a populated area where footstep as source will be available, we took an average of 2 steps in 1 second.

For 6400 steps time needed = $6400 / (60 \times 2) = 53$ minutes. (Approx.)

VIII. CONCLUSION

The project "FOOTSTEP POWER GENERATION" is successfully tested and implemented which is the best economical, affordable energy solution to common people. This can be used for many applications in rural areas where power availability is less or totally absence. As India is a developing country where energy management is a big challenge for huge population. By using this project we can drive both A.C. as well as D.C loads according to the force we applied on the piezo electric sensor. Our prototype demonstrates that a floor generator can be done.

A DC generator can illustrate the concept, but the reliability and durability are questionable, newer technologies could make a very reliable generator.

Proposal for the utilization of waste energy of foot power with human locomotion is very much relevant and important for highly populated countries like India and China. The whole human/ bio-energy being wasted if can be made possible for utilization, it will be great invention and crowd energy farms will be very useful energy sources in crowded countries. Some 28,527 steps, for example, could power an entire moving train for a second. The Crowd Farm could also be used to harness the head-bashing energy at a rock concert. Nonconventional energy system is very essential at this time to our nation.

IX. FUTURE SCOPE OF THE PIEZOELECTRIC HARVESTING SMART CHARGING DEVICE

- Can be broadly utilized as the part of colleges, schools, public transport places and universities.
- This can be actualized in air terminals, transport stations, railroad stations.
- Streetlights can be actualized utilizing this strategy instead of solar in the rainy season. This framework can be actualized in swarmed places like shopping centers, pathways, and so forth.

- Numerous piezoelectric generators with desirable properties specific to applications such as flexibility, stretchability, durability, high piezoelectric performance, biocompatibility, biodegradability, etc. have been developed.
- Flooring Tiles:

Japan has already started experimenting with the use of the piezoelectric effect on generating energy. They implemented a piezoelectric effect on the bus stairs. Thus, every time a passenger steps on the tiles, they trigger the small vibration that can be stored as energy in the battery. The flooring tiles are designed with rubber which can absorb the vibration. This vibration generates when people are running or walking on it. Under these tiles, the piezoelectric material is placed. They can generate electricity when the movement is felt by the material. Simultaneously this generated energy is stored in the battery. The generated electricity can be used for the lighting of a lamp or street light. Energy generated by the step of one human being is too less but if the number of steps increases ultimately energy production also increases simultaneously.

- Dance floors:

Europe is one of the countries which implemented and started experimenting with the use of a piezoelectric crystal for energy generation in nightclubs. The floor is then compressed by the dancer's feet and piezoelectric materials make contact and generate electricity which can be used as the generator in the club. The generated electricity is nothing but 220 watts. It depends on the impact of the dancer's feet. If constant compression of the piezoelectric crystal causes a huge amount of energy.

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