

Footstep Power Generation using Piezoelectric Sensor and Distribution using RFID

Dr. Meena Chavan¹, Sachin Chauhan², Maanvendra Singh³, Archie Tripathi⁴

¹Professor, Dept. of Electronics, College of Engineering, Bharati Vidyapeeth (Deemed to be University), Pune, Maharashtra, India

^{2,3,4}(Student B.Tech final Year) Dept. of Electronics, College of Engineering, Bharati Vidyapeeth (Deemed to be University), Pune, Maharashtra, India

Abstract - The electrical power consumption is increasing exponentially. Therefore, the need of a fool-proof and economically viable power generation and distribution system demands a certain interest. This paper proposes utilization of human locomotion energy which, although extractable goes mainly to waste. This paper proposes a model that uses human walking, jumping and running as a source of energy and store it for essential use. Such a model is apt in a demography that of a country like India which has such a huge pedestrian population. This paper illustrates a method for harvesting this human locomotion energy with the use of piezoelectric sensor and demonstrates an application with the stored energy i.e. to charge a mobile phone securely using RFID. The ground reaction force (GRF) exerted from the foot, when converted to voltage by piezoelectric sensors is capable enough to power up a device. Successive exertion leads to aperiodic voltage build up which with proper circuitry can be used to charge a storage battery. The power produced by this technique can also be employed in basic application such as street lighting, notice boards, gyms and other areas of public domain. It also promotes green energy and environment friendly approach towards energy generation. In this paper we have provided the basic concept and design details of this model and a basic implementation of the same.

Key Words power generation, human locomotion energy, piezoelectric sensor, RFID, ground reaction force, battery, green energy.

1. INTRODUCTION

As the demand of energy is increasing day by day, so the ultimate solution to deal with these sorts of problems is just to implement the renewable sources of energy Humans are using the renewable energy which are solar, wind etc. but we still could not satisfy our power needs, because of that we have to generate electricity through each and every possible ways. The objective of this work is to produce power through footsteps as a source of renewable energy that we can obtain while walking or standing on to the certain arrangements like footpaths, stairs, plate forms and these systems can be installed specially in the more populated areas.

In this project the energy is produced by the ground reaction force generated due to human foot step and this energy is

focused on an array of piezoelectric sensor; which further converts this to electrical energy which can be stored and utilized.

2. Piezoelectric Materials and Its Effects

2.1 Piezoelectric Effect

Piezoelectric Effect or Piezoelectricity is the ability of certain materials to generate an AC voltage when subjected to mechanical stress or vibration. This effect is shown by materials such as:

- Berlinitz ($AlPO_4$),
- Quartz (SiO_2),
- Tourmaline Barium Titanate ($BaTiO_3$)
- Gallium orthophosphate ($GaPO_4$), various other solids.

Piezoelectricity has both direct and converse effects i.e. mechanical stress results in AC voltage generation and vice-versa.

2.2 How it Works?

The nature of piezoelectric materials is closely linked to significant quantity of electric dipoles within these materials. A dipole is a vector, so it has a direction and a value in accordance with the electrical charges around. These dipoles tend to have the same direction and are altogether called Weiss domains.

The reason why piezoelectric materials create a voltage when a mechanical stress is applied, because the crystalline structure is disturbed and it changes the direction of the polarization of the electric dipoles. This change might be caused due to re-configuration of ions within the crystalline structure or by re-orientation of molecular groups. As a result, the bigger the mechanical stress, the bigger the change in polarization and the more electricity is produced.

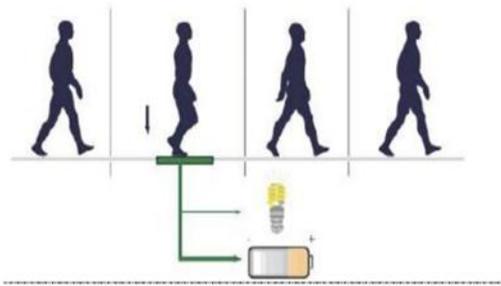


Fig- Schematic representation of the working model

The principle of operation of this sensor can be described as a physical quantity, transformed into a force, which acts on two opposite face of sensor element. The pressure variations can be used via different application. The most common used in the form of sound, seen in piezoelectric microphones and piezoelectric pickups for electrically amplified guitars.

2.3 Piezoelectric Sensor

Piezoelectric Sensor uses piezoelectric effect to measure pressure or mechanical energy by converting all of it to electrical energy signals. It is a substantial tool that could be used for the measurement of varying cause.

It has very high modulus of elasticity compared to other metals and it goes up to $10e6 \text{ N/m}^2$.

Additionally, piezoelectric sensors are rugged, have high natural frequency. This phenomenon is not affected to Electromagnetic fields and other radiations.

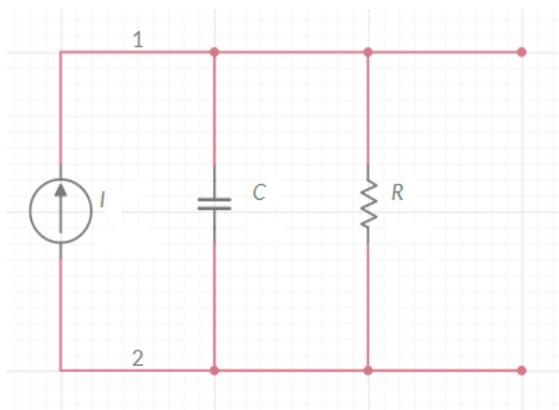


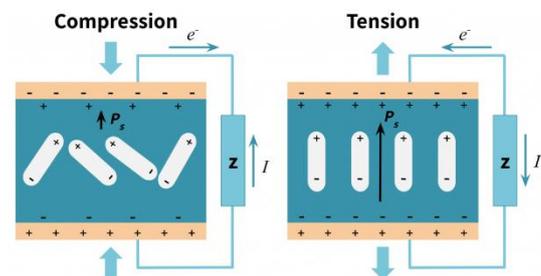
Figure 1 Equivalent circuit of piezoelectric sensor

It converts the mechanical stress to electrical voltage. When mechanical stress is applied onto the sensor, electrical charge is accumulated on the crystal that can be extracted using a wire. When a piezoelectric material is subjected to stress T , it produces Polarization P which is linear function of T : $P = dT$ (d : piezoelectric strain constant). For a dielectric substance, the relationships of electrical displacement D with electric field strength E is given by $D = \epsilon E$.

Basic Piezoelectric Effect equation:

$$D_n = d_{nj}T_j + \epsilon_{nm}E_m \quad (m, n=1,2,3; j, l=1, 2, \dots, 6)$$

Piezoelectric sensor can be considered as a RC Network and an alternating current source I as shown in the fig1.



3. SYSTEM CONFIGURATION

3.1 COMPONENTS

- Piezo Sensor Tile
- Bridge Rectifier
- Buck-Boost Converter
- Rechargeable Batteries
- LCD and Arduino
- RFID module

3.2 Piezo Sensor Array



A Piezoelectric tile is a tile of dimension 25 cm x 30 cm. The thickness of the tile is 0.9 mm. To enforce and safeguard the piezoelectric sensors a double-tape is placed on each sensor. The thickness of the tape is 0.3 mm. On this tile 30 piezoelectric sensors are installed. The output power from a single piezo sensor is remarkably low therefore a

combination of few Piezo sensors is used. The piezo sensors can be installed in two possible combinations:

- Series Connection
- Parallel Connection

When the sensors are connected in a series combination, it emanates an increased voltage output but that voltage is not on a linear scale. On the other hand, when a parallel combination is implemented it did not produce a satisfactory upsurge in the voltage output. If an amalgamation of both parallel and series connection is utilized for producing voltage output with high current density. Springs at the corners are placed on the second tile equivalent to the sensors at the centre of the tile in 5 x 6 pattern. A similar tile is placed on the former tile so that it can be pressed by the foot.

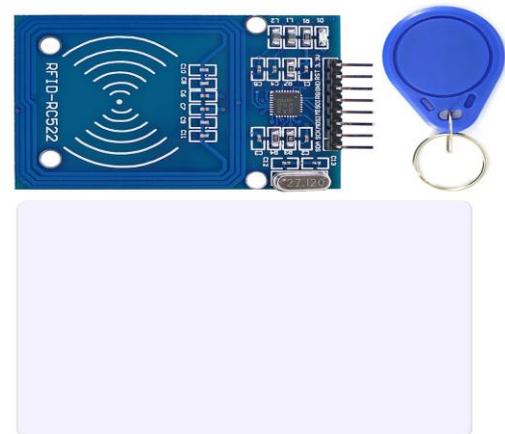
3.3 RFID MODULE AND USER IDENTIFICATION

We choose to use RC522 RFID module because of its facile interfacing and the cost effectiveness. It operates on 13.56MHz which is an ISM band and can be easily configured.

Radio frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. RFID is also called dedicated short-range communication (DSRC). In a typical RFID system, individual objects are equipped with a small, inexpensive tag. The tag contains a transponder with a digital memory chip that is given a unique electronic product code. The transponder emits messages with an identification number that is retrieved from a database and acted upon accordingly. The writable memory is used to transmit information among RFID readers in different locations.

The interrogator, an antenna packaged with a transceiver and decoder, emits a signal activating the RFID tag so it can read and write data to it. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer. The application software on the host processes the data, and may perform various filtering operations to reduce the numerous often redundant reads of the same tag to a smaller and more useful data set.

We used RFID so that authentication of user can be done and the accuracy and functioning of the system is not compromised. This is done to build an economic viable and quality service which can be implemented.



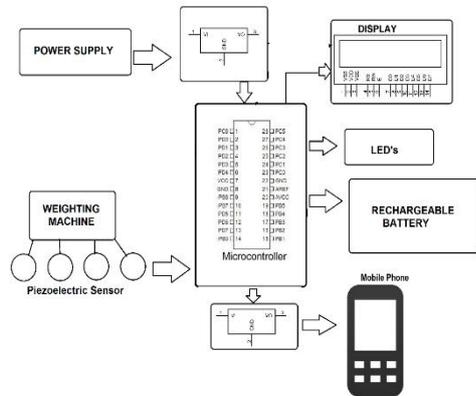
3.4 Arduino Uno

The Arduino MCU is there to provide control over various parts of the proposed system. The MCU upon getting successful authentication signal from the RFID module, relays power from Storage Device to the particular individual. The MCU also displays the remaining charge and Time a user has got based on the capacity of the rechargeable battery.

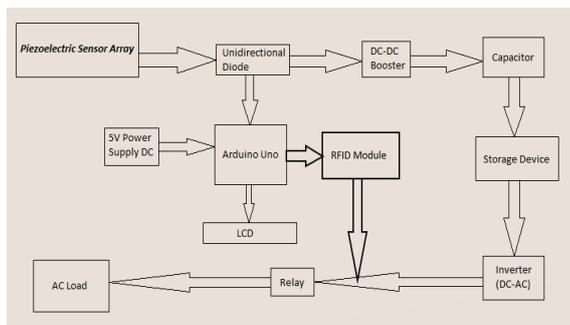
Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button.



4. Block Diagram



5. Working Mechanism

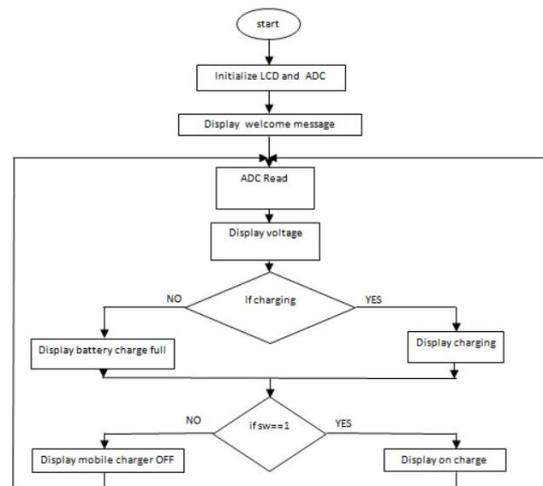


The piezoelectric material gives an output that is not a constant. Therefore, to convert this variable voltage into a linear voltage a bridge circuit is utilized. AC ripple filter is used to filter remaining fluctuations in the output. The output DC voltage is stored in a rechargeable battery. This battery can then be used to charge the mobile using RFID access.

The LCD is interfaced with the microcontroller ATMEGA328P.

When the system is powered on, LCD flashes a welcome message which is read by the ADC that is present in the microcontroller. The 5V power supply is given to the LCD and the microcontroller. The system enters into registration mode. Two users can be registered. After all the users are registered in the system then the system requests to swipe the card and connect the charger. By default, each the users is given 10 minutes of charging time. This time can be modified later on. When the card is swiped the system analyses if the user is authorised, if yes then the system allows charging and will charge the Mobile phone. If the user is unauthorised then the LCD displays unauthorised user. For a card to be recharged there is a recharge button that needs to be pressed which is present in the system.

6. Flow Chart



7. Calculations and Outputs:

Power generated varies with different steps in piezoelectric array that is used.

Based on practical results voltages obtained are:

- Minimum voltage = 1V per step
- Maximum voltage = 8V per step

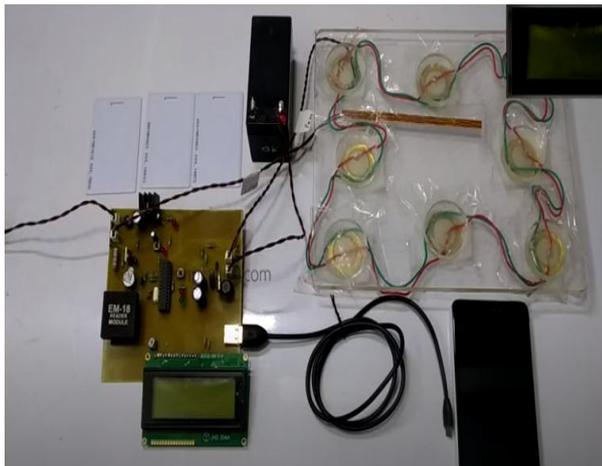
Considering average weight as of the person stepping on the system to be 53 Kg the average calculation is:

Steps are required to increase 1 V charge in battery = 700

To increase 12 V in battery:

Total steps needed = (12 × 700) = 8400 steps

- Considering the implementation of this system in places like college biometrics where footsteps as source is easily available, if:
- Time required for 2 steps is 1 second
- Time required for 8400 steps = 8400 / (60 × 2) = 70 minutes



8. Advantages

- Zero side effect on human body.
- Can be easily used in malls, roadways, or area with frequent locomotion.
- Easy to install.
- The output is proportional to number of steps.
- User friendly and easy-to-go utility.

9. Applications

It can be used to charge large number of devices such as:

- Mobile Phones
- Electric Torch
- Smartwatches

With a simple swipe and charge mechanism it can be easily used by anyone.

The pressure generated by footsteps are stored in the rechargeable batteries for a long time and can be used by multiple users.

The RFID will help keep a track of the usage and the display unit will help better understand the mechanism in the real world.

10. Conclusions

Thus, we have shown a design of a system capable of harnessing human locomotion energy; and have implemented it around a basic application of charging a mobile device. This project promotes an uninterrupted way of using smart phones and other devices. The described system can be built independently and delivers off the grid power for public/private usage.

Lastly, this project is an attractive approach for obtaining clean sustainable energy and is highly consumer friendly.

11. References

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