SIMULATION STUDY OF FOOTSTEP POWER GENERATION USING PIEZOELECTRIC SENSORS AND RFID FOR CHARGING

16MCL81 – PROJECT

Submitted by

DEEPAK DHARSHAN .P.N - 18BMC032

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Pollachi - 642003

An Autonomous Institution

Affiliated to Anna University, Chennai - 600 025

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Dr. Mahalingam College of Engineering and

Technology Pollachi - 642003

An Autonomous Institution

Affiliated to Anna University, Chennai -600 025

BONAFIDE CERTIFICATE

Certified that this project report, “SIMULATION STUDY OF FOOTSTEP POWER GENERATION USING PIEZOELECTRIC SENSORS AND RFID FOR CHARGING” is the bonafide work of

DEEPAK DHARSHAN .P.N - 18BMC032

Who carried out the project work under my supervision.

Pollachi – 642003 India

Dr.I. Rajendran
HEAD OF THE DEPARTMENT SENIOR PROFESSOR
Mechatronics Engineering
Dr. Mahalingam College of Engineering and Technology, NPT-MCET Campus

Ms.R.Renugadevi
SUPERVISOR
ASSISTANT PROFESSOR
Mechatronics Engineering
Dr. Mahalingam College of Engineering and Technology, NPT-MCET Campus
Pollachi – 642003 India

Submitted for the Autonomous End Semester Examination

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ABSTRACT

Utilization of power turns to be necessary for every work in today's world. An advanced footstep power generation system proposed here uses the piezoelectric sensors. To generate a voltage from footstep the piezo sensors are mounted below the platform. To generate maximum output voltage the sensors are placed in such an arrangement. This is then forwarded to our monitoring circuitry. The circuit is the microcontroller based monitoring circuit that allows users to monitor the charges and voltage a connected battery to it and this power source has many applications. It also displays the charge generated by our footstep and displays it on an LCD. Also, it consists of a USB mobile phone charging point where a user may connect cables to charge the mobile phone from the battery charge. The current is distributed using (radio-frequency identification) RFID cards so that only an authorized person can use the generator for charging. Thus we charge a battery using power from footsteps, display it on LCD using a microcontroller circuit and allow for mobile charging through the setup. Our project model cost is effective and easy to implement and also it is green and not harmful to the environment.

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LIST OF ABBREVIATIONS

RFID - Radio Frequency Identification. PZT - Piezoelectric.

PVDF - Polyvinylidene Fluoride.

DC - Direct Current.

LED - Light Emitting Diode. LCD - Liquid Crystal Display. USB - Universal Serial Bus. PWM - Pulse Width Modulation.

CHAPTER - 1

Introduction

Day by day, the population of the country increased and the requirement of the power is also increased. At the same time the wastage of energy also increased in many ways. So reforming this energy back to usable form is the major solution. As technology is developed and the use of gadgets, electronic devices also increased. Power generation using conservative methods becoming deficient. There is a necessity arises for a different power generation method. At the same time the energy is wasted due to human locomotion and many ways. To overcome this problem, the energy wastage can be converted to usable form using the piezoelectric sensor. This sensor converts the pressure on it to a voltage. So by using this energy saving method that is the footstep power generation system we are generating power. The Footstep energy generation can be an effective method to generate electricity. Walking is the most common activity in human life.

When a person walks, he loses some energy to road surface in the form of impact, vibration and sounds etc. due to transfer of his weight on to the road surface, through foots falls on the ground during every step results in losing kinetic energy. This kinetic energy can be tapped and converted in to useable form .This procedure contains number of simple configurations that are fitted under the walking floor. Walking on this platform, body weight compresses the piezoelectric transducers that produce electric power. The current generated is stored in the battery and later distributed through RFID cards. Greater circulation of people will generate more power. A piezoelectric transducer is an electrical generator that produces electric charges when pressure is applied upon.

In this we are generating electrical power as non-conventional method by simply applying pressure on floor. Every person will walk. When a person walks, he or she loses

energy. That energy can be used and convert into usable form such as power. There are many places where there is no electricity so we are generating electrical power by means

of renewable energy, by simply applying pressure on the floor where foot step is arranged non-renewable energy is very less so renewable energy is very much in demand now a days. As the availability of conventional energy reducing day by day, there is need to find alternate energy sources. All most all countries and states are facing this problem; they are unable to provide the power according to the demand. The power and that power can we can know how much power stored in the battery by using Node MCU.

CHAPTER - 2

Literature Review

"Tom Jose V, Binoy Boban, Sijo M T" proposed that that manufactured a model made from stainless steel, recycled car tires and recycled aluminum, also includes a lamp embedded in the pavement that lights up every time a step is converted into energy. The average square of pavement produces about 2.1 watts of electricity [1].

"Joydev Ghosh, Amit Saha, Samir Basak, Supratim Sen" proposed that the design methodology of electrical power generation using foot step for urban area energy applications [2].

"Vipin Kumar Yadav, Vivek Kumar Yadav, Rajat Kumar, Ajay Yadav" proposed that the study of electricity generation through the step mechanism. For obtaining the electricity through the step mechanism a prototype model is developed and studied. The electrical power generation system is configured to generate electric power via movements of the humans [3].

"Julie Borah" proposed that how piezoelectric effect enables us to convert the kinetic energy produced by the human footsteps to electrical energy that can be used for various applications [4].

"Md.Azhar, Zitender Rajpurohit, Abdul Saif, Nalla Abhinay, P.Sai Chandu" proposed that Bridge type full wave rectifier is used to rectify the ac output of secondary of 230/12V step down transformer[5].

"Patel Kamlesh, Pandya Krunal, Patel Ronak, Prajapati Jaydeep, Mr. Sorathiya Mehul" proposed that the force energy is produced by human foot step and force energy is converted into mechanical energy by the rack and pinion mechanism [6].

"Mrs. Krupal Dhimar, Miss. Krishna Patel, Miss. Zeel Patel, Miss. Nisha Pindiwala" proposed that there for possible solution for this to provide sufficient amount of power using renewable energy. Among these resources, human population is the only far and away and all weather resource that has not been utilized [7].

"A.R.Kotadiya, B.D.Parmar" proposed that to produce power through footsteps as a source of renewable energy that we can obtained while walking or standing on to the certain arrangements like footpaths, stairs, plate forms and these systems can be install specially in the more populated areas [8].

"Akshat Kamboj, AltamashHaque, Ayush Kumar, V. K. Sharma, Arun Kumar " proposed the design ofpower generation using footstep based on available piezoelectricsensors. Human race requires energy at very rapid rate for theirliving and wellbeing from the time of their arrival on this planet [9].

"Muhammad AamirAman, Hamza Umar Afridi,Muhammad ZulqarnainAbbasi, Akhtar Khan,Muhammad Salman " proposed The production of electric power from the foot step movement of the peoples andthe pressure exerted during walking which is fritter away. The mechanical power transformation into electrical power as the pressureexerted by the footstep and by using transducers [10].

CHAPTER - 3

Objective

To develop a power generation system using piezoelectric sensors which generates power with the help of human footsteps. 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 in a battery. The power which is stored in the battery is then used to charge a mobile phone using RFID module. 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.

The remaining sections consisting of chapter, which deals with the detailed study of piezoelectric effect and its various applications. The chapter consisting of methodology which describes the details about the sensing materials, sensor arrangements, arduino controller, LCD and RFID module. And also it provides the detailed study about the simulation model of piezoelectric sensors and its various arrangements. And coming to chapter, which provides the results and observations of the simulation model of different piezoelectric arrangements.

CHAPTER – 4

Proposed Methodology

4.1. Piezoelectric Effect

Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. The word Piezoelectric is derived from the Greek word "piezein", which means to squeeze or press, and "piezo", which is Greek for "push". One of the unique characteristics of the piezoelectric effect is that it is reversible, meaning that materials exhibiting the direct piezoelectric effect (the generation of electricity when stress is applied) also exhibit the converse piezoelectric effect (the generation of stress when an electric field is applied).

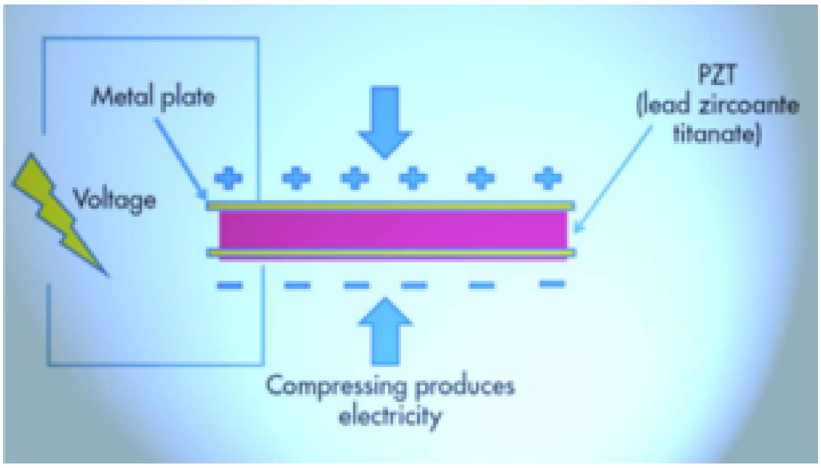


Fig.1: Piezoelectric Effect

When piezoelectric material is placed under mechanical stress, a shifting of the positive and negative charge centers in the material takes place, which is then results in an external electrical field. When reversed, an outer electrical field either stretches or compresses the piezoelectric material as shown in Fig.1. The piezoelectric effect is very useful within many applications that involve the production and detection of sound, generation of high voltages, electronic frequency generation. The microbalances, and ultra-fine focusing of optical assemblies. It is also the basis of a number of scientific instrumental techniques with atomic resolution, such as scanning probe microscopes

(STM, AFM, etc.). The piezoelectric effect also has its use in more mundane applications as well, such as acting as the ignition source for cigarette lighters

4.2. Applications of Piezoelectric Effect:

Due to the intrinsic characteristics of piezoelectric materials, there are numerous applications that benefit from their use:

Sensors

The principle of operation of a piezoelectric sensor is that a physical dimension, transformed into a force, acts on two opposing faces of the sensing element. The detection of pressure variations in the form of sound is the most common sensor application, which is seen in piezoelectric microphones and piezoelectric pickups for electrically amplified guitars. Piezoelectric sensors in particular are used with high frequency sound in ultrasonic transducers for medical imaging and industrial nondestructive testing.

Piezoelectric Motors

Because very high voltages correspond to only tiny changes in the width of the crystal, this crystal width can be manipulated with better-than-micrometer precision, making pies crystals an important tool for positioning objects with extreme accuracy, making them perfect for use in motors, such as the various motor series offered by Nano motion.

Regarding piezoelectric motors, the piezoelectric element receives an electrical pulse, and then applies directional force to an opposing ceramic plate, causing it to move in the desired direction. Motion is generated when the piezoelectric element moves against a static platform (such as ceramic strips).

The characteristics of piezoelectric materials provided the perfect technology upon which Nano motion developed our various lines of unique piezoelectric motors. Using patented piezoelectric technology, Nano motion has designed various series of

motors ranging in size from a single element (providing 0.4Kg of force) to an eight element motor (providing 3.2Kg of force). Nano motion motors are capable of driving both linear and rotary stages, and have a wide dynamic range of speed, from several microns per second to 250mm/sec and can easily mount to traditional low friction stages or other devices.

The operating characteristics of Nano motions motors provide inherent braking and the ability to eliminate servo dither when in a static position.

4.3. Piezoelectric Sensor:

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge. The prefix piezo- is Greek for ’press’ or ’squeeze’. A piezoelectric transducer has very high DC output impedance and can be modeled as a proportional voltage source and filter network. The voltage V at the source is directly proportional to the applied force, pressure, or strain. The output signal is then related to this mechanical force as if it had passed through the equivalent circuit. Piezoelectric sensors have several benefits such as:

• They offer very high frequency response that means the parameter changing at very rapidly can be sensed easily.

• High transient response as they are able to detect the events of microseconds and also give the linear output.

• They offer a high output that be measured in the electronic circuit. They have small dimensions and have rugged construction which means they are easy to handle.

4.3.1. Sensing Material:

Three main groups of materials are used for piezoelectric sensors: piezoelectric ceramics, single crystal materials and thin film piezoelectric materials. The ceramic materials (such as PZT PVDF ceramic) have a piezoelectric constant/sensitivity that is roughly two orders of magnitude higher than those of the natural single crystal materials.

In order to understand the output corresponding to the various forces applied, the V-I characteristics of each material namely, PZT and PVDF were plotted. Voltmeters are connected across both of them for measuring voltages and an ammeter is connected to measure the current. As varying forces are applied on the Piezo material, different voltage readings corresponding to the force is displayed. For each such voltage reading across the sensor, various voltage and current readings of the Piezo test material are noted

The voltage from PZT is around 2 V where as that of PVDF is around 0.4V. So we can thus conclude that better output is obtained from the PZT than the PVDF as show in the Fig: 1.2.

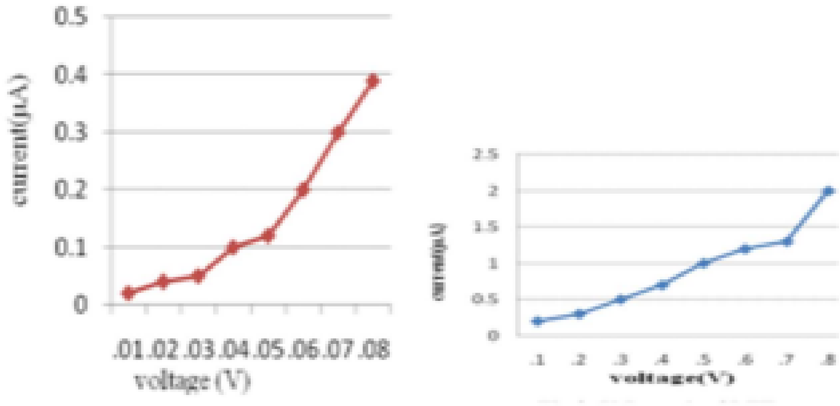
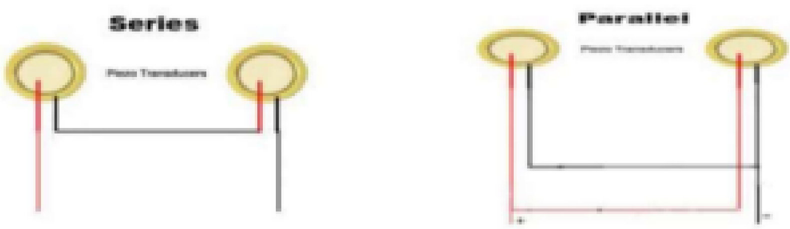


Figure 1.2: V-I graph of PVDF & V-I graph of PZT

4.3.2. Sensor Arrangement:

The piezo sensors can be used in series parallel combination depend upon our required current or voltages values. For obtaining maximum current output and voltage



output, following arrangements of sensors are used;- 1. Series Combination 2. ParallelCombination 3. Series-Parallel Combination 1. Series Combination:

Figure 1.3: Series Combination & Parallel Combination

In this type of combination, sensors are connected in such a way that current flowing through all sensors is same and voltage is different Veq =V1+V2+V3+....Vn.

Parallel Combination:

In this type of combination shown in Fig 1.3, Voltage across each sensor remains the same while current flowing through each sensor is different. Ieq= I1+I2+I3+...In.

Series-Parallel Combination:

In series-parallel combination both voltages and currents are maintained to get the required value. In our project, we have utilized the 3rd combination of sensors as given in figure 1.4 to get the most extreme output productivity. For this reason, the series parallel combination is chosen to be the ideal one for our project.

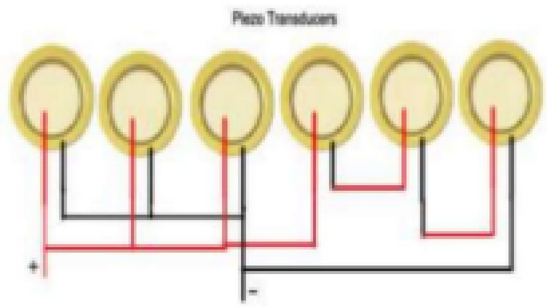


Figure 1.4: Series-Parallel Combination

4.4. Bridge Rectifier Capacitor:

Piezo sensor produce ac output so to convert it to dc we use bridge rectifiers that convert the piezo voltage to dc which are later used for charging the battery. Bridge rectifier will not give pure dc (some ripples comes) to get pure dc we use capacitor which removes the ripples and give us pure DC as shown in Fig 1.5. So in our project bridge rectifier and capacitor are used to get the maximum output.

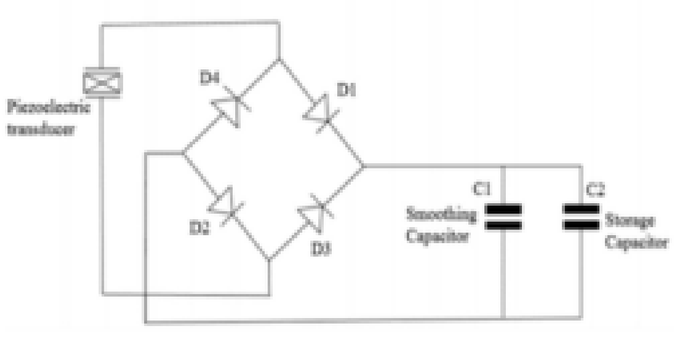


Figure 1.5: Full-wave bridge rectifier with smoothing and storage capacitor.

4.5. Arduino Controller:

The Arduino can be a small board with a brain (called a microcontroller) that could be customized. An Arduino is an open-source microcontroller advancement board. Basically, this stage passes on an approach to manufacture and program electrical modules. The Arduino programming language is a learner's modifying language from the programming dialect C/C ++, in view of which is called Arduino "sketches" utilizing basic programming structures, factors and capacities. At that point these are changed over in a C ++ program. This enables us to download programs code for this gathering, which can connect with things in this present world, you can make gadgets that react and respond to the world with this. It interfaces with LEDs, sensors, engines, LCDs, ringers, and so on for this real world. The Arduino encoding dialect is a fundamental type of C/C++. On the off chance that you know C, as encoding the Arduino will be recognizable. In a case that you don't know C, there are just some fundamental directions that are required to perform significant capacities.

A key component of Arduino is that you can assemble controller programming on your PC and it will definitely be downloaded to Arduino. Unplug the connector from the USB link, and the program is continually running from starting when you press the reset button. On the off chance that you interface the battery, at that point it executed last put away program. This tells you can connect the Arduino to the PC to build your

program and repair, however once this is done, you needn't bother with a computer to run the program.

It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with USB cable or power it with an AC to DC adapter or battery to get started.

4.5.1. Arduino's Input Yield Pins:

One of the 14 advanced sticks on the Arduino UNO can be utilized as info or yield utilizing the "pin Mode ()", "digital Write ()" and "digital Read ()" capacities. They all work at 5 volts. Each pin can get up to 40 mA and furthermore give an inner draw up resistor of 20-50 kilo ohms in Fig.1.6.

• Serial: pin 0 (RX) and pin 1 (TX). Used here to receive (RX) and transfer (TX) TTL serial data.

• External Interrupts: pin 2 and pin 3. These are designed to trigger an interrupt on a low bit, a rising or falling edge, or a change in value.

• PWM: Pin number 3, 5, 6, 9, 10 and 11. These provide 8bit PWM output with analog Write () function SP1: Pin number 10 (SS), 11 (MOSI), 12 (MISO), 13(SCK). They provide support SPI communication. LED: Pin 13, there is an in-built LED associated to digital pin number 13. When pin as value is 13 LED turns on and vice versa. A ref: Reference voltage for inputs. Used with "analog Reference ()".Reset: Bring this line LOW to microcontroller. Normally used to add reset button which block the one on the board. * Reset Pin: Used to reset Arduino board. Voltage Pins: This pin gives voltages to outer circuits. Microcontroller: ATMEL ATmega328 microcontroller is used here.

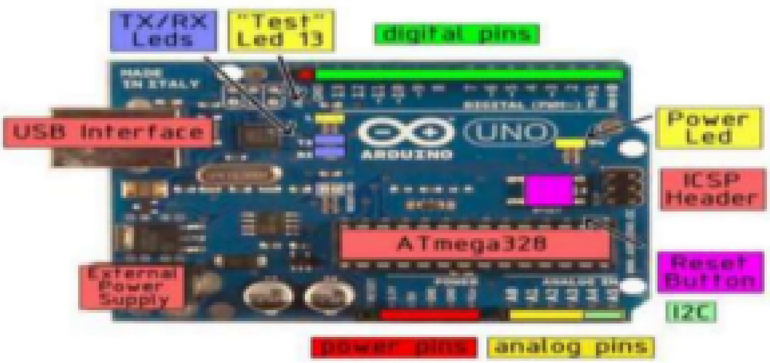


Figure 1.6: UNO Atmega 328

4.5.2. LCD:

To observe electrical parameters, we are using 16*2 alphanumeric LCDs. A 16x2 alphanumeric network can show 224 distinct characters and symbols. It requires +5V for input control supply. This LCD is equipped for handle 8 bits at once. It has up to 14 pins as shown in Fg.1.7 from which 8 pins are information pins and utilized for sending and getting information to LCD as numbers or characters. Three control pins are described below:

- Reset pin: It is used for resetting the display.
- Reset pin: It is used for resetting the display.
- Read Write Pin: This x pin is set as (1) for reading operations and (0) for writing Operations
- Enable pin: Used to enable or disable the LCD.

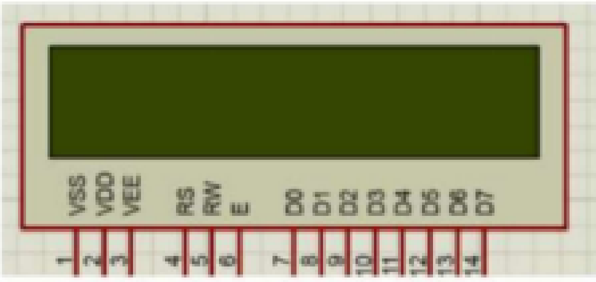


Figure 1.7: LCD Pins

4.5.3. Interfacing of LCD with Arduino UNO:

LCD is used to show the parameter like voltage of piezo sensors and current, also give battery voltages and charging percentage of battery shown in Fig.1.8.

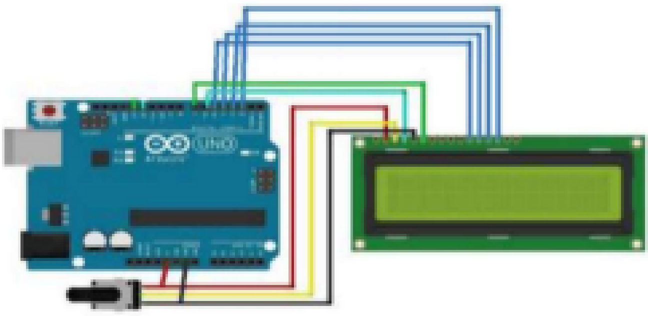


Figure 1.8: Interfacing of LCD with Arduino UNO.

4.6. RFID Module:

RFID is Radio Frequency Identification. FID module consists of RFID reader and RFID tag. It is an ADC (Automated Data Collection) technology that:

- Uses radio frequency waves to transfer data between a reader and a movable item to identify, categorize, track..etc.
- Is fast and does not require physical sight contact between reader/scanner and the tagged item.
- Performs the operation using low cost components. *Attempts to provide unique identification and integration that allows for wide range of applications.

4.6.1 RFID Reader:

RFID reader consists of a microcontroller, signal generator and signal detector. RFID signal generator generates radio waves which are transmitted using the antennae. Also to receive the feedback signal coming from the tag the rfid reader have a receiver /signal detector. To process the information which is send by the rfid tag this rfid reader also have a microcontroller shown in Fig.2.

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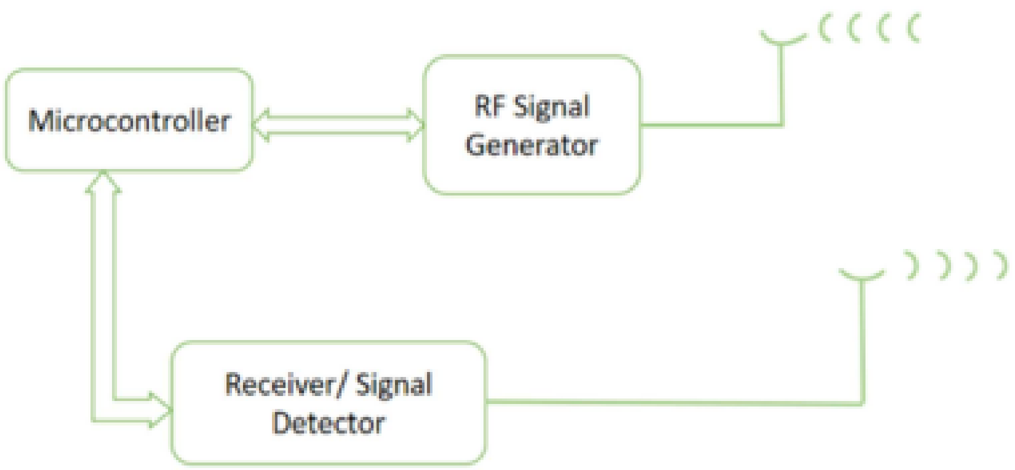

Figure 2: RFID Reader

4.6.2. RFID Tag:

Energy that is coming from the radio waves is stored across the capacitor and this energy is used as a supply for the controller and the memory element inside the RFID tag. The transporter receives the radio waves from the reader and sends the feedback signal back to the reader denoted in Fig.2.1.

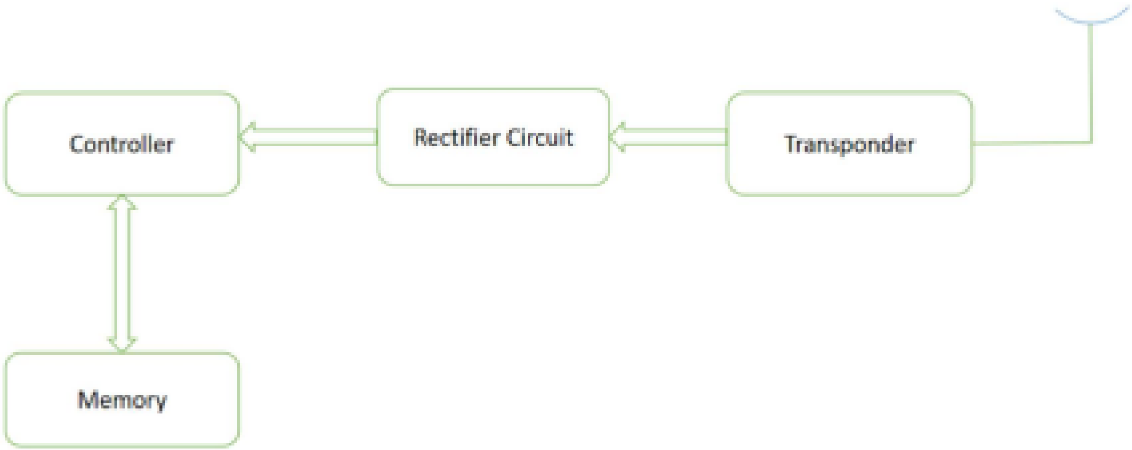

Figure 2.1: RFID Tag

CHAPTER - 5

Simulation

The piezoelectric sensor is modeled and simulated in Sims cape in order to precisely study its elemental behavior for various vibration strengths and ranges. Depending on the passive elements resistance, capacitance, and frequency of vibration, the voltage of the sensor varies at output.

5.1. Electrical Model of Piezoelectric Sensor:

The circuit design of the piezoelectric sensor consists of a capacitor in parallel with the charge source and a resistor. The resistor typically has very high value. The capacitor makes the impedance very large at the output of the sensor compared to the operating frequencies of the data acquisition systems mentioned in Fig.3.

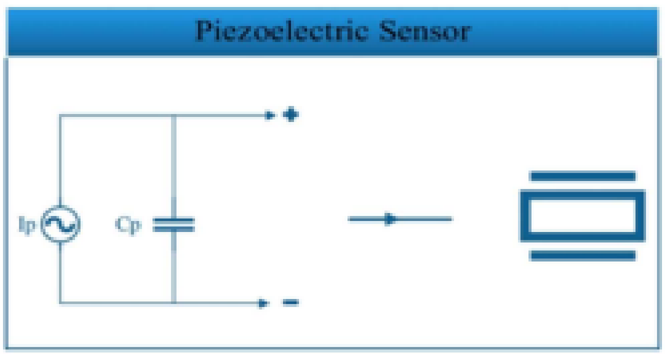

Figure 3: Electrical Model of Piezoelectric Sensor.

5.2. Piezoelectric Sensor: Implementation in Simscape: The piezoelectric sensor model is designed in Simscape using basic electrical elements and an AC source to provide the input current to the circuit. The alternating current (AC) charge source is set in parallel with the capacitor. Additionally, a resistor in series with a DC voltage source is connected in parallel to the sensor in order to model the charge leakage due to the circuit parasitic and for removing unwanted noise.

Hence, it works as a noise reduction component for the circuit. Some other blocks that are required for execution of the model in the software are added to the circuitry in order to get the desired results. The following blocks are included in the model:

• The Solver Configuration: It is used to provide the specification of solver parameters for the start-up of the simulation, i.e. prior to the beginning of the actual simulation. All network blocks in Simscape required to have a single separate solver configuration connected to that block.

• The PS-Simulink Converter: This block is used to change a physical signal into a Simulink output signal. It also provides the related units of the signals that are traced at the output.

• The Electrical Reference block: The Electrical Reference block is used to provide an electrical ground. A model having electrical elements must include at least one Electrical Reference block

. • OP-AMP (Operational Amplifier) block: An operational amplifier is used for the voltage amplification. It shows significant variations in the amplification of output voltage when the inverting and non-inverting inputs are given the signal.

• Voltage Sensor block In the Fig.3.1 is to measure the voltage at the output.

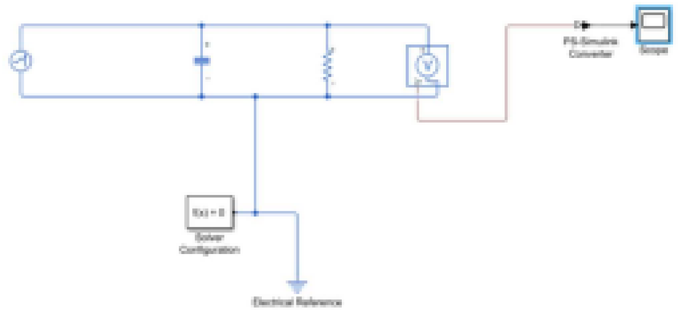

Figure 3.1: Piezoelectric Sensor in Simscape

The voltage achieved in the simulation of piezoelectric sensor is calculated by Vp = Q/(Cp) . Vp is the output voltage of the piezoelectric sensor, Cp is its piezoelectric capacitance, and Q is the charge applied. The Cp and load resistance values are taken 11.12 nF and 10 ohm respectively in the simulations.

Figure 3.2: Piezoelectric Sensor Output Voltage at 35 micro ampere Iin and 60 Hz Frequency, V-T Graph.

The graph in Fig.3.2 demonstrates that the output voltage of the piezoelectric sensor increases linearly with the input charge as per equation.

5.3. Energy Harvester Using Piezoelectric Sensor: This method does not utilize any battery. It gets the capability to start and power the system operations by itself. An energy storing capacitor caches DC voltage. The voltage obtained at the output of piezoelectric sensor is AC. Therefore, an AC-DC rectifier is included to convert the AC voltage into DC voltage. Therefore a capacitor Cp is included in parallel as shown in Fig.3.3 as with the AC-DC rectifier to store this collected power.

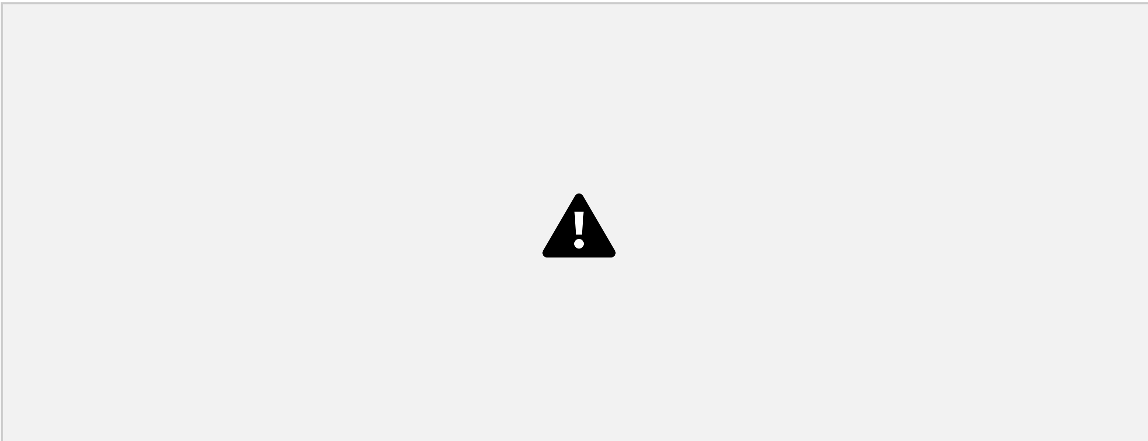

Figure 3.3: Simscape Model of Piezoelectric Energy Harvester.

Harvested current for the average period of time at the rectifier output is given by, $io(t) = 2Ip/\pi - 4(V s + 2)/\pi$

Where Ip is the polarization current of the piezoelectric material, and its value relies on the magnitude of surrounding vibrations, Vcs is the optimal voltage at output, Î´V is the forward voltage drop of the diode, f is the frequency, and Cp is the capacitance of the piezoelectric sensor. Multiplying by the sensor voltage Vs the output power is obtained in Fig 3.4. To collect the maximum power, the optimal voltage value should be,

$$V s(peak) = Ip\ (4f * R * Cp)\ \delta V.$$

Where R is the load resistance. The maximum value of collected power depends on the magnitude of energy vibrations Ip and the frequency.

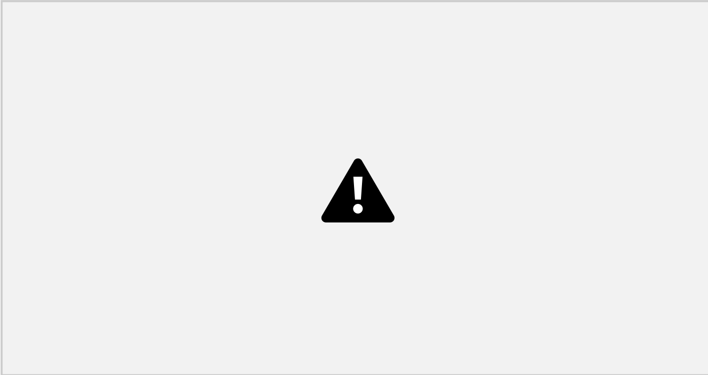

Figure 3.4: Rectified output (ideal case)

CHAPTER - 6

Results and Observations

Voltage Output:

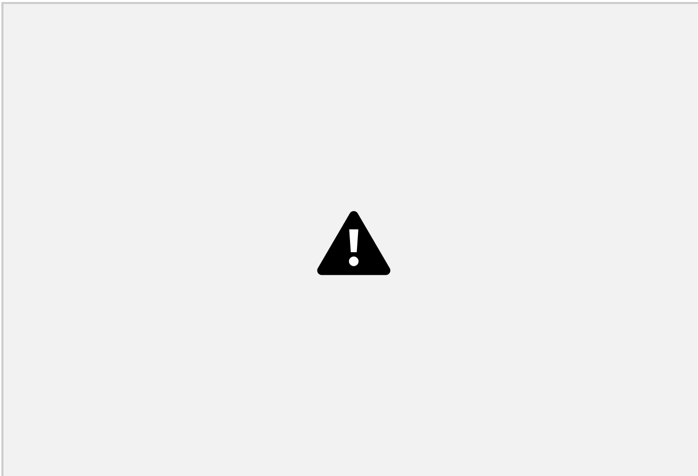

Figure 4: Series Arrangement - Voltage Sensor

- This Fig.4 is the series arrangement of four piezoelectric sensors connected to a voltage sensor to get the voltage output. The Cp and load resistance values are taken 11.12nF and 10amp respectively in simulation.
- This is the V-T graph obtained from the series arrangement of four piezoelectric sensors.
- The output obtained is 1.5mV.

Figure 4.1: Parallel Arrangement - Voltage Sensor

- The Fig .4.1 is the Parallel arrangement of four piezoelectric sensors connected to a voltage sensor to get the voltage output. The Cp and load resistance values are taken 11.12nF and 10amp respectively in simulation.

- This is the I-T graph obtained from the series arrangement of four piezoelectric sensors. The output obtained is 0.15mA.

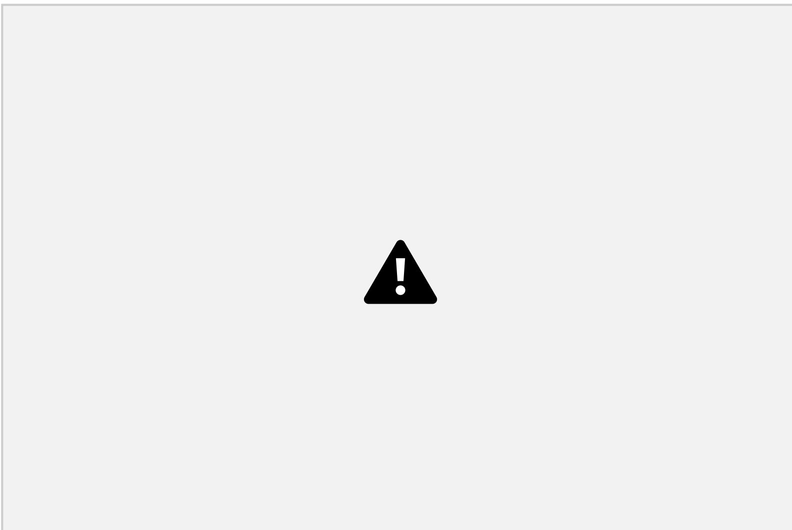

Figure 4.2: Parallel Arrangement: I-T Graph

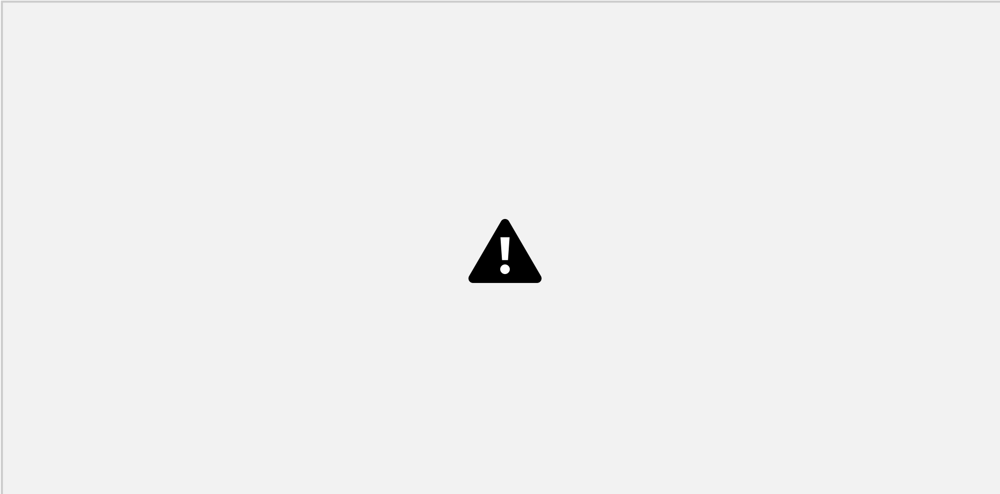

Figure 4.3: Series-Parallel Arrangement - Current Sensor

- The Fig.4.3. is the Series-Parallel arrangement of four piezoelectric sensors connected to a current sensor to get the current output. The Cp and load resistance values are taken 11.12nF and 10amp respectively in simulation.
- This is the I-T graph obtained from the Series-Parallel arrangement of four piezoelectric sensors.
- The output obtained is 0.07mA
- The Output of the piezoelectric sensor depends directly on the vibration input and inversely on the input frequency and the piezoelectric capacitance. • The resulting voltage and current is an AC signal because the magnitude if the input vibrations is varying and considered as an AC current source and voltage source.
- The voltage achieved in the simulation of piezoelectric sensor is calculated by $Vp = Q/(Cp)$.
- Vp is the output voltage of the piezoelectric sensor, Cp is the piezoelectric capacitance and Q is the charge applied.
- Series connection of piezoelectric sensors gives maximum voltage and less current & in parallel connection we get maximum current and less voltage.

CHAPTER – 7

Conclusion

This system that we developed is capable of harnessing human locomotion energy and have implementing 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.

This project is also an attractive approach for obtaining clean sustainable energy and is highly consumer friendly. And also this project is capable of generating more voltage when longer the time taken. The longer the time taken means more footstep/force are applied on the tile.

The linear relation is found between the voltage generated and the time taken. This system is specifically suitable for the implementation in the crowded area such as pavement street, train ticket counter, stairs and dance floor. The system is also suited for the exercise tile such as for skipping or on the treadmill. The power that is generated from this piezoelectric system can be used to power up the light street, light along the stairs and also low power appliances.

CHAPTER - 8

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APPENDIX

System Programming:

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