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AN APPROACH TO GENERATE ELECTRICITY USING PIEZO ELECTRIC SENSORS

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Abstract: Generation of electrical energy has become more n vital factor in power system because of incremental demand. Different technique to generate electrical energy are fuel consuming approaches New technique of electrical energy generation using piezo electric sensors form pressure or vibrations .The obtained energy can be stored in batteries for furher usage or it can be consumed directly for loads. Piezoelectric sensors have the unique ability to generate electricity when subjected to mechanical stress or pressure, making them suitable for power generation applications. The generated electricity can be used in a variety of applications, such as harvesting energy from vibrations in machinery or from the movement of people walking on floors or sidewalks. However, the amount of power generated by piezoelectric sensors is typically small, which poses a challenge for practical use. This has led to the development of new techniques to improve the efficiency of piezoelectric power generation. Research in this area has focused on exploring new piezoelectric materials and developing new designs and configurations that can increase power output. Additionally, advancements in microelectronics and wireless communication technologies have enabled the development of energy-efficient and autonomous systems that can operate on small amounts of power. Piezoelectric power generation has the potential to provide a renewable and sustainable source of energy that can be used in a wide range of applications. However, there are also challenges to be addressed, such as the sensitivity of piezoelectric materials to environmental factors, which can affect their performance. Ongoing research in this field will continue to explore new applications and technologies that can improve the efficiency and reliability of piezoelectric power generation.

I. INTRODUCTION

Piezo electric generation s a new approach to generate electric energy from sensing cum converting equipment /device called piezo sensor/piezo buzzar .It works on the principle of piezo electric effect which is converting pressure energy on crystalline material to electrical energy

The use of piezoelectric materials for power generation dates to the early 20th century. In 1921, the first practical application of piezoelectric power generation was demonstrated by the German scientist, Woldemar Voigt, who used a quartz crystal to power a radio transmitter. Since then, research in this area has continued, and piezoelectric power generation has been used in a variety of applications. One of the earliest applications of piezoelectric power generation was in phonograph pickups. In the 1930s and 1940s, piezoelectric crystals were used to convert the mechanical vibrations of sound waves into electrical signals that could be amplified and recorded. This technology is still used today in some high-end audio equipment. In the 1960s, piezoelectric power generation was used in spacecraft. The Apollo moon landings used piezoelectric crystals to power the seismometers that were used to study the moon's surface. In recent years, there has been growing interest in using piezoelectric power generation for energy harvesting applications. For example, piezoelectric sensors have been used to harvest energy from the vibrations of machinery, the movement of people walking on floors or sidewalks, and event he motion of waves in the ocean. Advancements in microelectronics and wireless communication technologies have enabled the development of energy-efficient and autonomous systems that can operate on small amounts of power. This has opened up new opportunities for piezoelectric power generation in a variety of applications, from powering wireless sensors and devices to generating electricity in remote or off-grid locations.

Piezoelectric power generation has the potential to provide a renewable and sustainable source of energy that can be used in a wide range of applications, from powering small sensors and devices to generating electricity on a larger scale. Piezoelectric power generation is based on the principle that when a piezoelectric material, such as quartz or lead zirconate titanate (PZT), is subjected to pressure or mechanical stress, it generates a voltage difference across its surface. This voltage difference can be used to generate electricity, either by directly connecting the material to an electrical load or by using it to charge a battery or capacitor. The amount of power generated by piezoelectric sensors depends on the size and type of the piezoelectric material, as well as the amount and frequency of the mechanical stress or pressure.

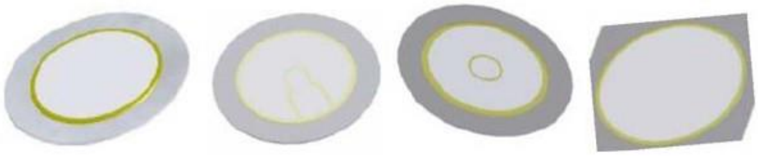
II. LITERATURE REVIEW

In 2005, piezoelectric materials were primarily used as sensors and actuators, but their potential for electrical generation was not well-established. However, they showed great promise for remote applications such as MEMS devices and distributed networking in the communication field. In 2006, new power conversion circuits were developed to interface with piezoelectric power generation. This was driven by the increasing demand for portable and lightweight electronic devices that required high efficiency. The goal was to harness the electrical energy generated by piezoelectric materials effectively.In 2011, piezoelectric materials were incorporated into fiber-based flexible piezoelectric composites. These composites offered significant advantages for energy harvesting and locomotion purposes. They were efficient and capable of silent transmission over a wide range of frequencies, although they were not necessarily light weight. In 2017, there was the development of footstep power generation using piezoelectric sensors. This technology aimed to capture the energy generated by human footsteps, considering the significant energy requirements of human life. Footstep power generation could be implemented in public places with high human population or areas visited by large numbers of people, although it had limitations in terms of efficiency.

III. PIEZOELECTRIC SENSORS AND ITS EFFECT

Piezoelectric Sensor

A piezoelectric sensor is a valuable device that utilizes the piezoelectric effect to convert mechanical energy or pressure into electrical signals. It is commonly employed for measuring various factors that exhibit variation. One notable characteristic of piezoelectric sensors is their high modulus of elasticity, which can reach up to 10e6 N/m2, surpassing that of many other metals.Furthermore, piezoelectric sensors are known for their durability and high natural frequency. They possess a rugged design that allows them to withstand harsh conditions. Another advantage is that these sensors are unaffected by electromagnetic fields and other types of radiation. They effectively convert mechanical stress into an electrical voltage. As mechanical stress is applied to the sensor, the crystal accumulates an electrical charge that can be extracted using a wire. Piezoelectric energy is a technology which converts mechanical energy into electrical energy. When an external force is applied to the piezoelectric system, electric charge is generated by drawing the charge generator in the system. Using this principle, it is being applied in various fields such as ecofriendly energy like sun, wind, wave, and vibration. The unimorph piezoelectric device applied to this experiment has a circular thin piezoelectric ceramic plate attached on the metal diaphragm, although there are various types of piezoelectric devices with various applications The Figure 1shows the various models and types of piezo electric sensors



a) b) c) d)

Figure 1 Types of Piezo electric sensors

a) Two terminal circular type b) Three terminal circle with brim feed back c) Three terminal circle with centre feed back

d) Three terminal square type with centre feed back

Piezoelectric effect

- Piezoelectricity, also known as the Piezoelectric Effect, refers to the ability of certain materials to generate an alternating current (AC) voltage when subjected to mechanical stress or vibration. *Piezo electric materials form transducer that are able to interchange electrical energy and mechanical motion or force. Therefore can be used as mechanism to transfer ambient motion(or vibration)into electrical energy that may be stored and used to power other devices Piezo electricity is defined as change in electrical polarization with a change in applied stress as shown in figure 2a.The converse piezo electric effect is the change of strain or stress in a material due to applied electric filed as shown in figure 2b*

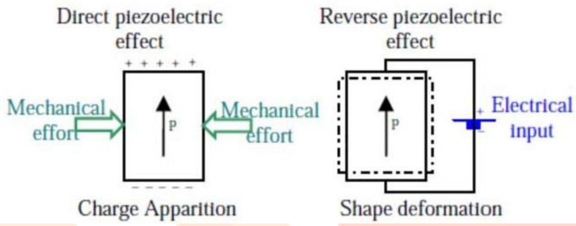


Figure 2 a) Piezo electric mechanism b) Converse Piezo mechanism

The Piezoelectric Effect demonstrates two fundamental characteristics: the direct effect and the converse effect.

- The direct effect refers to the generation of an AC voltage when mechanical stress is applied to a piezoelectric material. In other words, when the material is deformed or subjected to pressure or vibration, it produces an electrical voltage.
- Conversely, the converse effect occurs when an AC voltage is applied to a piezoelectric material, causing it to deform or vibrate. This means that the material exhibits a mechanical response in the presence of an electrical voltage.
- Both the direct and converse effects of piezoelectricity are utilized in various applications, such as sensors, actuators, and energy harvesting systems. These materials play a crucial role in converting mechanical energy into electrical energy and vice versa, enabling a wide range of technological advancements.

Mechanism of Operation:

Mechanical compression or a stress on a poled piezo electric ceramic element changes the dipole moment , creating a voltage . Compression along the direction of polarization or tension perpendicular to the direction of polarization genets voltage of the same polarity as the polling voltage shown in figure 3

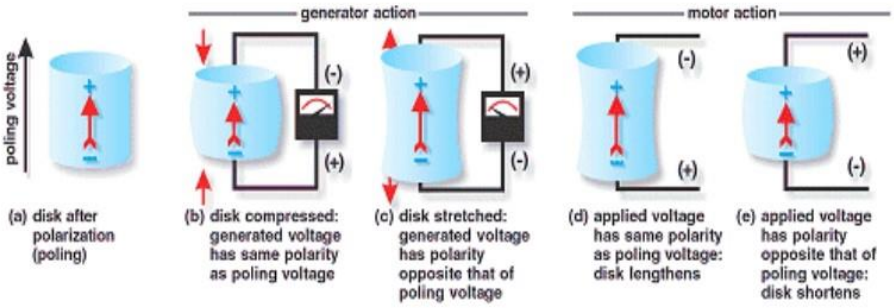


Figure 3 working mechanism of piezo electric sensor

When a force or pressure is applied to the piezoelectric material, it undergoes deformation. This can be in the form of bending, squeezing, or stretching. The mechanical stress causes a slight displacement of positive and negative charges within the crystal lattice structure of the material.As the piezoelectric material deforms, the displacement of charges creates an imbalance. Positive charges concentrate on one surface, while negative charges accumulate on the opposite surface. This charge separation leads to the generation of an electric potential or voltage across the material.The generated voltage is directly proportional to the applied mechanical stress or pressure. The magnitude and polarity of the voltage depend on the specific characteristics of the piezoelectric material used. This electric signal can be in the form of an AC voltage or a charge.To measure the generated voltage, electrodes are attached to the surfaces of the piezoelectric material. These electrodes allow the electrical signal to be conducted and captured for further analysis. The voltage signal can be amplified, conditioned, and processed using associated electronics to extract relevant information about the measured quantity (e.g., force, acceleration, pressure, vibration).

IV. METHODOLOGY

The proposed system is designed to harness the power of piezoelectric sensors, which generate electrical voltage in response to mechanical vibrations. The system consists of several components working together to capture, measure, process, and utilize this generated power.

The Piezoelectric sensors are the core of the system and are responsible for converting mechanical vibrations into electrical voltage. They are strategically placed in locations where vibrations are expected, such as near machinery or in areas with human movement. The electrical voltage generated by the piezoelectric sensors is measured by a current sensor. It provides accurate information about the magnitude of the generated voltage. The measured current sensor data is sent to an Arduino Nano board. This microcontroller board is responsible for processing the data and performing calculations to determine the power output of the piezoelectric sensor system. Based on the data received from the Arduino Nano board, a control signal is sent to a MOSFET switch. The MOSFET switch acts as a relay and is responsible for connecting or disconnecting a buck converter to the output of the piezoelectric sensor.

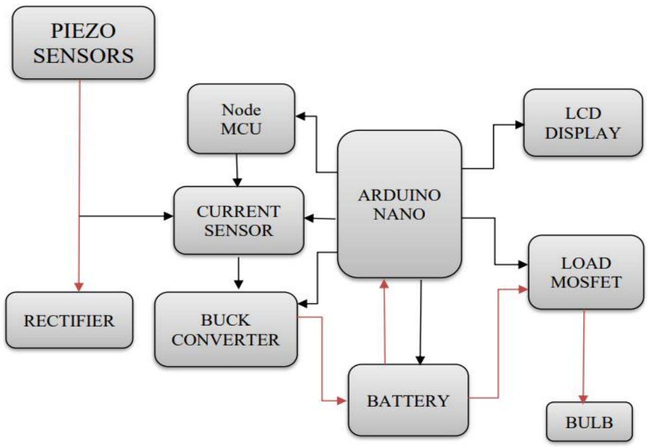


Figure 4 :Block Diagram of Power Generation Using Piezoelectric Sensors

The buck converter is an essential component that converts the high voltage, low current output of the piezoelectric sensor into a low voltage, high current output. This conversion is necessary to make the generated power suitable for powering a load, such as a bulb or other electrical devices. The low voltage, high current output from the buck converter is used to power a load, which could be a bulb or any other electrical device or system requiring electrical power. To enable wireless monitoring and control of the system, a NodeMCU board is utilized. This board supports wireless communication through protocols like Wi-Fi. It receives data from the Arduino Nano board and can send commands to both the MOSFET switch and the buck converter, allowing remote control and monitoring of the power generation system. The NodeMCU board facilitates wireless communication between the system components. It can transmit and receive data, enabling real-time monitoring of power generation and remote control over the system. By integrating these components, the proposed system enables the efficient utilization of piezoelectric power generation. It captures mechanical vibrations, converts them into electrical voltage, measures and processes the generated power, and provides a means for wireless monitoring and control. This system has the potential to provide renewable and sustainable energy for various applications.

V. IMPLEMENTATION

The flow described involves a comprehensive and automated monitoring and control system for power generation and distribution using piezoelectric sensors. The process begins by initializing the piezoelectric sensors. This involves setting up the sensors and ensuring they are ready to measure mechanical energy or pressure.The piezoelectric sensors convert the mechanical energy or pressure into electrical signals. The system reads the voltage generated by the sensors to quantify the amount of energy or pressure applied. In addition to voltage, the system may also measure the current flowing through the sensors using a current sensor. This provides information about the electrical energy being generated.

The voltage and current data obtained from the sensors are sent to an Arduino Nano board. The Arduino Nano acts as a microcontroller that processes and analyzes the data. The Arduino Nano processes the voltage and current data to calculate the power output. Power is determined by multiplying the voltage and current values, giving an indication of the amount of electrical power being generated. Based on the calculated power output, the Arduino Nano generates control signals. These control signals are used to regulate the system and optimize power generation and distribution.The control signals generated by the Arduino Nano are sent to a MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) switch. The MOSFET switch acts as a control element that connects or disconnects the buck converter.

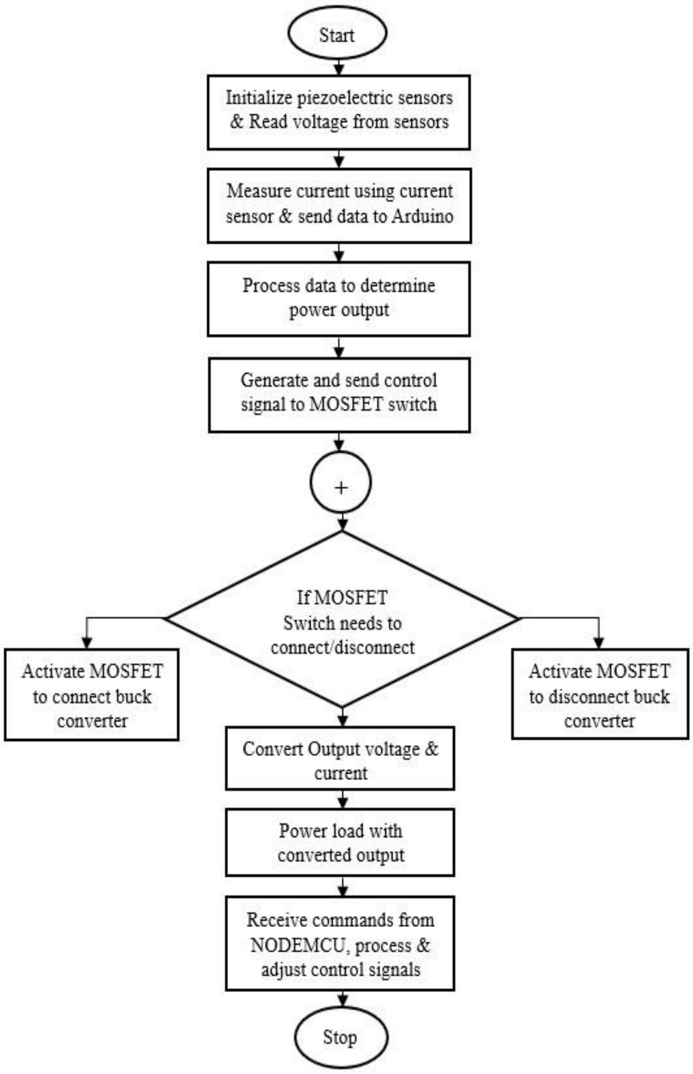


Figure 25 Flow Diagram of Power Generation Using Piezoelectric Sensors.

Based on the control signals received from the Arduino Nano, the MOSFET switch connects or disconnects the buck converter. The buck converter is responsible for converting the electrical output to the desired voltage and current levels. The buck converter converts the output voltage and current to the desired levels suitable for powering a load, such as a bulb or other electrical devices. The converted output from the buck converter is used to power a load, such as a bulb. This allows the electrical energy generated by the piezoelectric sensors to be utilized effectively.

The system incorporates a NodeMCU, which acts as a wireless communication module. It receives commands wirelessly from a central control unit or user interface. The received wireless commands are processed by the system. The Arduino Nano adjusts the control signals based on the commands received, allowing for remote control and monitoring of the power generation and distribution system.The entire process continues in a loop, continuously monitoring and controlling the power generation and distribution system. This ensures that the system operates efficiently and adapts to changing conditions. This comprehensive flow enables the automated monitoring and control of the power generation and distribution process, optimizing the use of piezoelectric sensors and ensuring the effective utilization of the generated electrical energy.

5.1 System Requirements

5.1.1 NodeMCU

NodeMCU is an open-source microcontroller board based on the ESP8266 system-on-chip (SoC) that provides Wi-Fi connectivity. It is programmed using the Lua scripting language and can be easily interfaced with various sensors and devices to build Internet of(IoT) applications. NodeMCU has become a popular choice for IoT projects due to its low cost, ease of use, and flexibility

Figure 3: NodeMCU

NodeMCU has a built-in Wi-Fi module that enables it to connect to the internet, allowing it to send and receive data from cloud-based services. It also has a variety of input/output (I/O) pins, which can be used to interface with various sensors and devices such as temperature sensors, humidity sensors, and LCD displays. In power generation system, NodeMCU functions as a wireless communication interface. It receives wireless commands, typically sent over a Wi-Fi network, from a remote controller or a centralized system. These commands are transmitted to the NodeMCU, which acts as a receiver.

2.3.2 Arduino Nano

The Arduino Nano is a small and versatile microcontroller board based on the ATmega328P chip. It is like the popular Arduino Uno, but in a much smaller form factor, making it ideal for projects with limited space. The Nano can be used for a wide range of applications, including robotics, automation, and electronics projects

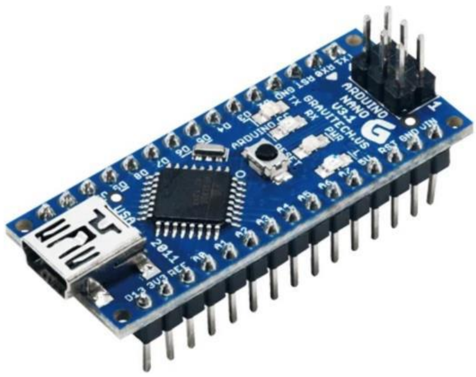


Figure 4: Arduino Nano

The Nano includes 14 digital input/output pins, 8 analog inputs, and a 16MHz clock speed. It also has a USB port for programming and power, as well as a power jack for an external power supply. The Nano can be programmed using the Arduino Integrated Development Environment (IDE), which makes it easy to write and upload code to the board. In power generation system, The Arduino Nano is used for receiving current data, generating control signals, communicating with the NodeMCU, interfacing with sensors, performing data processing, controlling the MOSFET switch, and interfacing with the buck converter to ensure effective monitoring and control of the power generation and distribution system.

2.3.3 MOSFET

A MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is a type of transistor used for switching and amplifying electronic signals.. In power generation system, The MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is employed as a crucial component to function as a switch for controlling the connection or disconnection of the buck converter. The MOSFET receives control signals from the Arduino Nano, which determine its operational state.

Figure 5: MOSFET

By turning the MOSFET ON, current is allowed to flow through it, connecting the buck converter to the power source. Conversely, turning the MOSFET OFF interrupts the current flow, disconnecting the buck converter. This control mechanism enables the regulation of the output voltage and current levels, facilitating efficient power conversion and delivery to the load. Moreover, the MOSFET's switching operation plays a vital role in ensuring system efficiency and protection by preventing excessive power dissipation and safeguarding components from potential damage

2.3.4 DC-DC Buck Converter

A DC-DC buck converter is a type of voltage regulator that can efficiently reduce a higher input voltage to a lower output voltage. It works by using a switching transistor to control the flow of current through an inductor, which in turn stores and releases energy to regulate the output voltage

Figure 6: DC-DC Buck Converter

The DC-DC buck converter is used in the project to regulate the electrical output, converting a higher input voltage to the desired lower output voltage, and controlling the output current for efficient power delivery to the load.

2.3.5 Piezo- Sensor

A piezo sensor, also known as a piezoelectric sensor, is a device that utilizes the piezoelectric effect to convert mechanical energy into electrical signals. In the context of the overall power generation system, a piezo sensor can be used to capture mechanical vibrations or pressure changes and convert them into electrical energy.

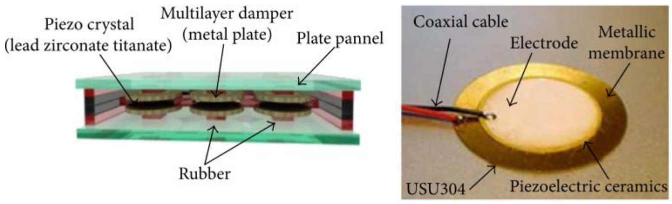


Figure 7: Piezo-Sensor

Current Sensor

Power generation system using renewable energy sources, a current sensor is an electronic device that is used to measure the electric current flowing through various components of the system. It provides valuable information about the current consumption, load conditions, and system performance.

Figure 8: Current Sensor

5.2 Software requirements

5.2.1 Arduino ide software

The Arduino IDE is an open-source software, which is used to write and upload code to the Arduino boards. The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux. It supports the programming languages C and C++. Here, IDE stands for **Integrated Development Environment.**

5.3 Hardware Requirements

In the hardware implementation of power generation using piezoelectric sensors, several components are involved. Firstly, piezoelectric sensors are used. These sensors are made of a piezoelectric material that generates electrical energy when subjected to mechanical stress or vibration. They can convert mechanical energy into electrical energy.

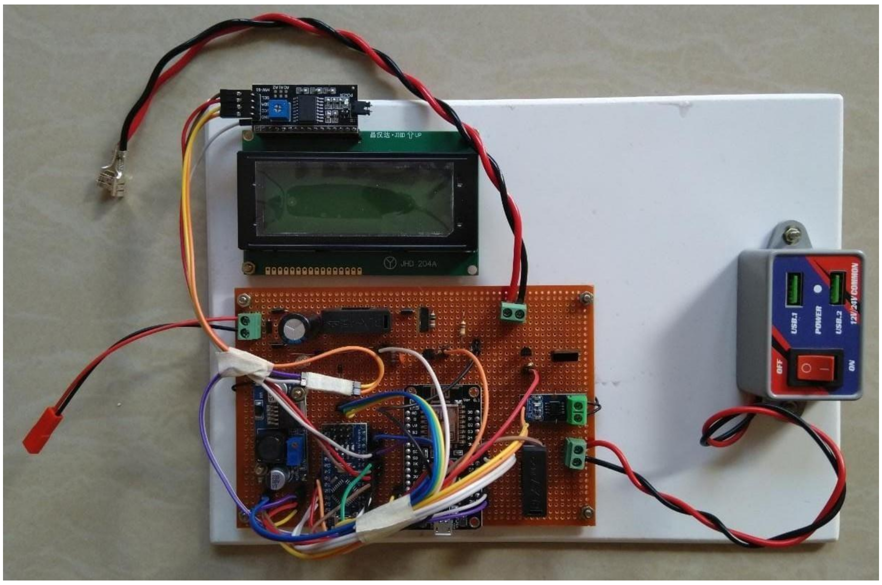


Figure 9: Control Board of Power Generation Using Piezoelectric Sensors

The piezoelectric sensors are typically placed in strategic locations where they can capture and convert mechanical vibrations or movements into electrical signals. These locations can include areas with high foot traffic, machinery with vibrations, or structures experiencing constant movement. To harness and utilize the electrical energy generated by the piezoelectric sensors, a power conditioning circuit is employed. This circuit helps in converting the low-level electrical signals produced by the sensors into a usable form. It includes components like amplifiers, rectifiers, and voltage regulators to ensure the generated energy is stable and suitable for powering electronic devices or storing in batteries. Additionally, energy storage systems may be incorporated to store the generated electrical energy for later use. This can involve the use of batteries, supercapacitors, or other energy storage technologies. These systems ensure a continuous power supply even when there is no immediate demand or during periods of low sensor activity. Overall, the hardware implementation of power generation using piezoelectric sensors involves the strategic placement of the sensors, a power conditioning circuit to convert the electrical signals, and optionally, energy storage systems to store the generated energy for future use

VI. RESULTS AND DISCUSSIONS

The proposed system allows for the conversion of mechanical energy from pressure into electrical energy. This energy can be used to power low-energy devices or stored for later use. By utilizing piezoelectric sensors to capture ambient pressure, the proposed system promotes sustainable energy generation. It harnesses existing mechanical energy sources and reduces reliance on traditional power generation methods. The ability to generate electricity from piezoelectric sensors offers the potential for remote power generation. It can be particularly useful in areas where access to traditional power grids is limited or nonexistent.

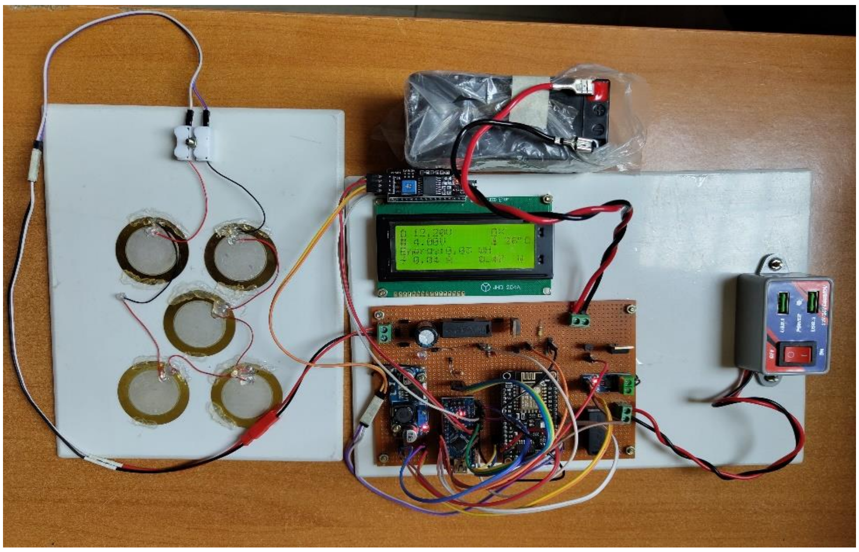


Figure 10 Output Power Generated

By capturing and converting otherwise wasted mechanical energy into electrical energy, the project improves overall energy efficiency. It optimizes the utilization of available resources and reduces energy wastage. The proposed system can lead to potential cost savings by utilizing the generated energy for powering low-energy devices or reducing reliance on conventional power sources. It can have long-term financial benefits, especially in applications where continuous power supply is required.

CONCLUSION

Power generation using piezoelectric sensors offers benefits like converting mechanical energy into electrical energy, promoting sustainability by harnessing existing sources. It enables remote power generation, increases energy efficiency, and provides potential cost savings. This approach reduces environmental impact, tapping into unused energy. Piezoelectric sensors are versatile and scalable, adaptable to different applications. They contribute to a greener and more efficient future in power generation, reducing reliance on non-renewable sources. This technology has the potential to revolutionize energy production and distribution, maximizing resource utilization while minimizing environmental harm. It offers a sustainable and decentralized solution, expanding access to electricity in remote areas. By harnessing the power of piezoelectricity, we can pave the way for a more sustainable and environmentally friendly energy landscape.

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