CHAPTER 1

PIEZOELECTRICITY

1.1 INTRODUCTION

Piezoelectricity is a property of some materials that lies in generating electrical voltage when mechanical force is applied to them. Piezoelectric materials have two important properties that are defined as direct & converse effects. The direct effect is the property of some materials to develop electric charges when mechanical stress is exerted on them. While the converse effect is the opposite of the direct effect. This effect can be used significantly in our daily lives as a transducer. A piezoelectric transducer consists of two metallic plates separated by a crystal from quartz or other piezoelectric material. When subjected to mechanical stress, one or both of the plates vibrates; these vibrations will be transferred to the crystal, and this will produce a low alternating voltage. This AC voltage will be transferred to the metallic plates and amplified to an equal value to the mechanical stress.

The ceramic piezoelectric can be found in sonar devices to locate the presence of objects under water such as submarines, this process is done using the transfer of electric signals through the piezoelectric material. This leads to a high-frequency mechanical vibration that moves through the water, these vibrations will collide with an object and be reflected until it finds another piezoelectric material that will convert these vibrations into electricity. The time spent sending and receiving the signal is used to calculate how far this object is from the source of vibrations (sonar). In certain materials, squeezing (compression) or stretching (tension) disrupts the balance of positive and negative charges. This creates a voltage, like a tiny battery. The stronger the squeeze or stretch, the bigger the voltage. This is the piezoelectric effect, and it's useful for making sensors that convert pressure into electricity. By capturing wasted mechanical energy from vibrations or pressure changes, piezoelectric materials could be used to power low-power devices.

The Figure 1.1 shows diagrams of a material under no stress, tension, and compression, demonstrating how it reacts to different mechanical forces.

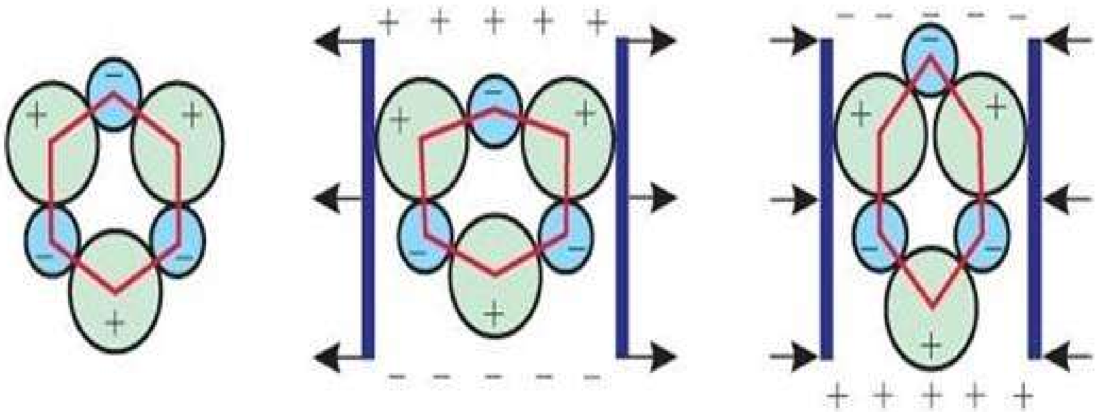

Figure 1.1 Piezoelectric effect in Quartz

Piezoelectric materials have always played a very significant role in acoustics. Piezoelectric materials play a crucial role in generating, transmitting, and detecting surface acoustic waves. Piezoelectric materials can be found also in computers, printers, etc.

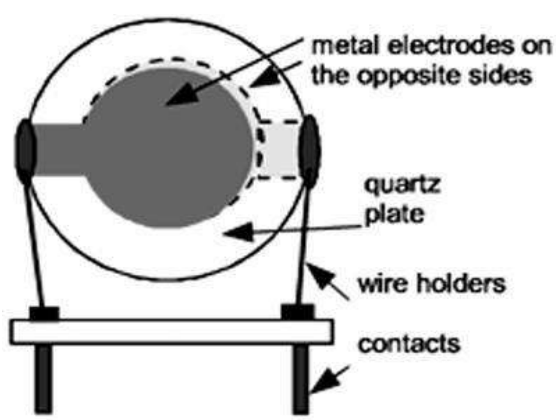

Figure 1.2 Piezoelectric quartz transducer

The Figure 1.2 shows the piezoelectric quartz transducer, a device that uses the piezoelectric effect of quartz to convert mechanical energy into electrical energy or vice versa. It features a quartz plate with metal electrodes, wire holders, and contacts, all encased in a circular housing with an arrow indicating the direction of applied force or generated motion. This type of transducer is commonly used in sensors, actuators, and frequency generation applications.

1.2 WORKING PRINCIPLE

Piezoelectric plates function based on a fascinating interplay between mechanical stress and electrical polarization at the atomic level. These materials possess a non-centrosymmetric crystal structure, meaning the positive and negative charge centers are not perfectly balanced. When a mechanical force is applied to the plate, it disrupts this internal arrangement. In specific crystal directions, this distortion causes the positive and negative charges to shift, effectively squeezing positive charges towards one face of the plate and negative charges towards the opposite face. This charge separation creates a potential difference, or voltage, across the thickness of the plate. The magnitude and polarity of the voltage depend on the applied force and the material properties. This is the direct piezoelectric effect.

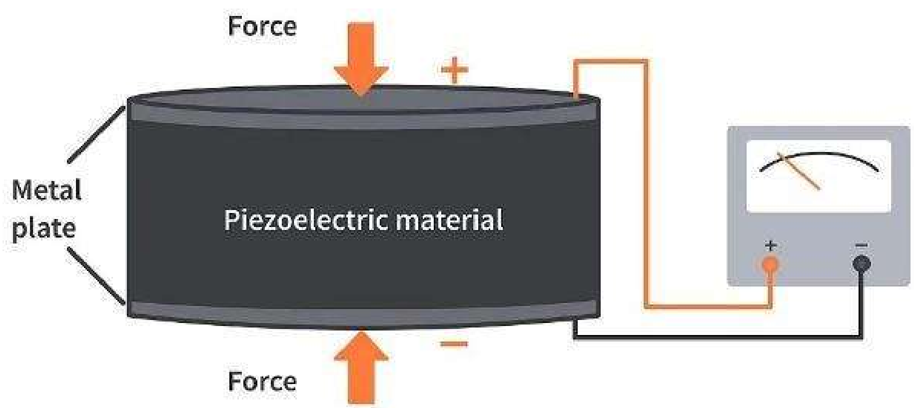

Figure 1.3 Direct Piezoelectric Effect

The Figure 1.3 illustrates the direct piezoelectric effect, showing a cylindrical piezoelectric material with force applied to its top and bottom surfaces. It's connected to a gauge via wires, indicating the generation of electrical charge in response to the applied mechanical stress. This property makes them highly valuable for sensor and actuator applications. Conversely, applying an electric field across the plate can also induce a physical deformation. The electric field influences the alignment of the internal charges, attempting to restore the balanced state. This results in a minute mechanical strain or change in the plate's dimensions, known as the converse piezoelectric effect. The specific mechanism behind this phenomenon varies depending on the material. However, the core principle remains the same - a coupling between mechanical and electrical states at the atomic level translates into a voltage generation under pressure and vice versa. This allows piezoelectric plates to act as both sensors, converting mechanical stress into electrical signals, and actuators, transforming electrical energy into physical movement.

1.3 WEARABLE TECHNOLOGY

The growth is particularly fueled by the smart wristwear segment, which holds a significant market share. This segment encompasses devices like smartwatches and fitness trackers, perfectly complementing the functionality of our self-powered backpack. Imagine a scenario where the backpack not only charges itself but also keeps your smartwatch powered throughout the day. Furthermore, the rise of the wireless hearables market, projected to reach over USD 80 billion by 2027, signifies the increasing user preference for cord-free experiences. Our backpack's ability to generate its own power aligns with this trend, offering a convenient and sustainable way to keep these hearables charged during extended use. This project positions itself at the forefront of this booming wearable tech market, addressing the need for long-lasting power solutions and paving the way for a future of truly self-sufficient wearable devices. The core insight of wearable technology, particularly relevant to our self-powered backpack utilizing piezoelectric plates, lies in seamlessly integrating functionality with everyday activities. By leveraging the kinetic energy generated from user movement, the backpack eliminates the dependency on traditional batteries and fosters a sustainable approach to powering wearable devices. This aligns perfectly with the growing consumer demand for convenient, long-lasting, and eco-friendly wearable tech solutions.

1.3.1 Impact of Electronic Waste

- Toxic Battery Waste:

  Our ever-growing dependence on electronics creates a hidden threat: electronic waste, or e-waste. A significant portion of this waste comprises batteries, which contain a cocktail of toxic materials like mercury, lead, cadmium, and lithium. These hazardous elements pose a severe threat to our environment if not disposed of responsibly. Improper disposal can lead to these toxins leaching into the soil and water, contaminating ecosystems and posing health risks to humans and wildlife.

- Improper Disposal and Environmental Impact:

  Landfills are not equipped to handle these hazardous materials safely. Over time, battery casings can degrade, releasing these toxins into the surrounding soil and groundwater. This contamination can then enter the food chain, impacting wildlife and eventually reaching humans. Improper incineration of e-waste releases harmful fumes containing these heavy metals into the air, polluting the atmosphere and posing respiratory health risks.

- Global Problem:

  The environmental impact extends beyond our borders. A significant amount of e-waste from developed countries is shipped to developing nations for unregulated processing, exposing workers to hazardous materials and further contaminating local environments.

- Self-Powered Wearable Backpack:

  This project aims to reduce reliance on disposable batteries and contribute to a more sustainable future for electronics. By developing a self-powered wearable backpack using piezoelectric technology, it can eliminate the need for traditional batteries and their associated environmental hazards.

1.4 ADVANTAGES

Piezoelectric plates represent a breakthrough in wearable energy harvesting, perfectly suited for applications like our self-powered backpack. Their inherent properties offer a compelling value proposition. Firstly, they possess the remarkable ability to convert the kinetic energy of everyday movements, such as walking, into usable electricity. This eliminates the cumbersome need for bulky batteries, fostering a more sustainable and environmentally friendly approach. The backpack leverages the piezoelectric effect, transforming the mechanical stresses of your movements into electrical power. This inherent design elegance not only streamlines the backpack's form factor but also minimizes its environmental footprint by reducing reliance on disposable batteries.

Second, piezoelectric materials are incredibly reliable and long-lasting. Unlike batteries, they don't degrade easily and can withstand many years without losing performance. They are also versatile, coming in various shapes and sizes for seamless integration into the backpack design without compromising comfort or aesthetics. Additionally, their high power density allows them to generate significant power relative to their size and weight, making them ideal for powering low-power wearable electronics. Finally, piezoelectric materials require minimal maintenance. They have no moving parts and operate silently, making them a user- friendly solution.

On top of these core advantages, piezoelectric plates offer even more benefits for our backpack application. They are highly scalable, allowing us to add more plates and increase energy harvest based on user needs. They also function passively, requiring no external power source, making them self-sufficient. The maturity of this technology ensures reliable performance and readily available materials for backpack design. While the upfront cost might be slightly higher than traditional batteries, their extended lifespan and minimal maintenance translate to significant cost savings in the long run.

1.5 EXISTING APPLICATIONS

i. Frequency Control and Timing:

Piezoelectricity shines in applications demanding precise timing. Materials like quartz exhibit a very stable resonant frequency when a voltage is applied (converse piezoelectric effect). This makes them ideal for creating highly accurate quartz clocks and electronic circuit resonators. These tiny resonators help maintain stable frequencies in various electronic devices like filters and oscillators.

ii. Sensors:

The ability of piezoelectrics to generate a voltage under pressure (direct piezoelectric effect) makes them excellent pressure sensors. They're widely used in Touch screens, Microphones and Hydrophones. Acoustic Sensors are used in microphones to convert sound waves into electrical signals, which is the foundation of how microphones work. Industrial settings also use them to measure fluid flow and pressure.

iii. Actuators:

The converse piezoelectric effect, where an electric field causes the material to deform, allows piezoelectrics to function as actuators. Piezoelectric elements precisely control the ink droplets fired onto the paper in inkjet printers. High-frequency vibrations generated by piezoelectric transducers in cleaning baths create microscopic bubbles that effectively remove dirt and contaminants. Piezoelectric actuators precisely control the fuel injection process, leading to improved engine efficiency and reduced emissions. Actuators are used in headphones and speakers to generate sound waves that cancel out unwanted noise. Piezoelectric transducers are used to generate and receive ultrasound waves for medical imaging applications.

CHAPTER 2

REVIEW OF LITERATURE

Affa Rozana Abdul Rashid, Nur Insyierah Md Sarif, Khadijah Ismail, (2021), "Development of Smart Shoes Using Piezoelectric Material". This paper reviews the principles, methods, and applications of PFEH technologies. First, the popular piezoelectric materials used and their properties for PEEHs are summarized. Then, the force interaction with the ground and dynamic energy distribution on the footprint as well as accelerations are analyzed and summarized. The energy flow is divided into four processing steps: (i) how to capture mechanical energy into a deformed footwear, (ii) how to transfer the elastic energy from a deformed shoes into piezoelectric material, (iii) how to convert elastic deformation energy of piezoelectric materials to electrical energy in the piezoelectric structure, and (iv) how to deliver the generated electric energy in piezoelectric structure to external resistive loads or electrical circuits.

Weili, Deng., Long, Jin., Weiqing, Yang., (2023), "Piezoelectric Materials Design for High-Performance Sensing". This paper discusses the preparation of high-quality piezoelectric materials. It is the cornerstone for the development of high-performance sensors and novel applications. The phase structure engineering of piezoelectric materials, including the morphotropic phase boundary (MPB) of piezoelectric ceramics and the active phase of piezoelectric polymers, is an effective way to modulate piezoelectric properties. With regard to preparation, Kang et al developed composition ceramics of Pb(Mg,W)O3 to prepare acoustic emission sensors for nondestructive testing. The PNN-PZT-PMW was manufactured via a conventional mixed-oxide method, using Li2CO3 and CaCO3 as sintering aids. After doping with Sm, the as-prepared ceramics exhibited excellent piezoelectric properties, including a dielectric constant of 2824, a piezoelectric coefficient d33 of 630 pC/N, and a planar electromechanical coupling co efficient kp of 0.665.

M. S. Zitouni and M. Wahbah, (2022), “Piezoelectric Energy Harvesting for Wearable and Implantable Devices”. This paper explains about the energy harvesting devices aim to harness the wasted energy from various energy sources available in their environment including thermal energy, kinetic energy, electrostatic energy, and solar energy. By utilizing the human body motion, piezoelectric energy can be generated. The human body motion can be either external or internal including movements, breathing, and blood pressure. This plays a critical role in the development of self-powered wearable and implantable biomedical devices, that can be used for personalized medical treatment and health monitoring through processing and analysis of continuously collected physiological signals. Thus, this article presents a study of the state of the art energy harvesting from human body methods that utilize the piezoelectric effect.

Binoy, Bera., Madhumita, Das, Sarkar., (2016), “Piezoelectric Effect, Piezotronics and Piezophototronics: A Review”. The paper provides a comprehensive overview of the piezoelectric effect, piezotronics, and piezophototronics, highlighting their significance in advancing electronic and optoelectronic technologies. Piezoelectricity is the generation of electrical potential in a substance due to changes in pressure.It occurs in crystals with non-central symmetry, creating a piezopotential when stress is applied.Materials like ZnO, GaN, and InN in the wurtzite structure family exhibit significant piezoelectric effects, impacting charge carrier transport due to their multiple functionalities. Piezotronics: Piezotronics involves the utilization of piezoelectric potential in nanodevices to control electronic transport at the interface of materials. It enables the modulation of charge carrier transport properties, leading to the development of novel electronic devices. Piezophototronics: Piezophototronics combines piezoelectricity, photonic excitation, and semiconductor properties to enhance the performance of optoelectronic devices. By integrating piezoelectric potential with photonic and electronic processes, piezophototronic devices can achieve improved functionalities and efficiency .

Walter, M., Roberts., (2021), “Piezo electric apparatus for generating electricity”. The research paper describes a variable pressure piezoelectric generator that utilizes a unique setup involving a furnace chamber, a refrigerant chamber, and a condensing chamber to generate electricity. Liquid refrigerant in the refrigerant chamber is vaporized by the heat from the furnace, flows through the condensing chamber, and then condenses back into liquid form. Piezoelectric elements are positioned in the condensing chamber in the path of the pressurized refrigerant. An apertured plate with varying aperture sizes is placed between pairs of piezoelectric elements, causing pressure variations in the refrigerant. These pressure variations result in mechanical forces being exerted on the piezoelectric elements, leading to the generation of electricity. The process demonstrates a novel way of converting heat energy into electrical energy using piezoelectric elements in a variable pressure system.

Kang, Chong, Yun., Kim, Jin, Sang., Choi, Ji, Won., Baek, Seung, Hyub., Kim, Seong, Keun., Kim, Sang, Tae., Jung, In, Ki., Shin, Youn, Hwan, (2019), “Piezoelectric Energy Harvester Module”. This paper introduces a piezoelectric energy harvester module consisting of a housing with a bottom unit and a side wall unit, a cover unit sealing the housing, and at least one piezoelectric energy harvester panel curved with a constant radius of curvature. The module's simple structure allows for direct structural deformation of the piezoelectric harvester through external impact. It efficiently converts external impact into electric energy, enabling more effective energy extraction from impacts with high deformation and unspecified frequency. The key features of the piezoelectric energy harvester module include: Housing with a bottom and side wall unit. Piezoelectric energy harvester panel fixed between the bottom and cover units. Curved panel with a constant radius of curvature. Efficient energy conversion from external impacts. Overall, the module offers a practical and efficient solution for harvesting energy from external impacts through piezoelectric conversion.

I. Kanno, (2019) ,“Piezoelectric Pzt Thin Films: Deposition, Evaluation and Their Applications”. This paper concludes that Lead-free piezoelectric thin films are essential for technological advancements, with a focus on KNN and ZnO films for miniaturizing piezoelectric devices. Various characterization methods like the resonant spectrum method and pneumatic loading method are discussed for evaluating piezoelectric thin films. Piezoelectric thin films offer advantages such as highly sensitive sensors, large displacements, and low voltage actuators in different applications. The applications of piezoelectric materials emphasize a high piezoelectric coefficient, providing insights into future prospects and integration for real-world applications. This paper highlights the significance of lead-free piezoelectric thin films, the characterization techniques used to evaluate them, and the diverse advantages they offer in sensor technology and actuator applications. Additionally, it discusses the potential for future developments and practical implementations of piezoelectric materials in various fields.

Jeet, Malhotra., Shantanu, Patil., Gunchita, Kaur, Wadhwa., Vikas, Kumar, (2020), “Energy Harvesting Applications using Piezoelectric Sensors”. The paper addresses the global energy crisis and the shift towards renewable energy due to the depletion of fossil fuels and the impact of global warming. It highlights the inefficiency and cost-ineffectiveness of current renewable energy solutions, especially in developing countries like India, facing energy shortages and large populations. The researchers aim to introduce innovative ways to convert mechanical energy into electrical energy using piezoelectric sensors, offering potential solutions to the energy crisis in India. The paper provides detailed explanations and calculations to support the feasibility and effectiveness of using piezoelectricity for energy harvesting applications, emphasizing its potential impact on addressing energy challenges.

CHAPTER 3

EXISTING SYSTEM

Piezoelectric materials are a promising solution for capturing energy from vibrations (VEH). Their unique crystalline structure allows them to convert mechanical stress, like bending from walking, into electricity. This electricity can be harvested using strategically placed electrodes. To maximize efficiency, the harvester's design should resonate with the vibrations it encounters, like tuning a radio. This optimal matching allows for the most energy transfer and electrical output, although the power itself is typically low (microwatts to milliwatts). However, this is sufficient for powering low-power devices like wireless sensors and wearable electronics due to their minimal energy needs.

Shoe inserts with piezoelectric bending beams are a leading contender for VEH applications. Studies have shown that piezoelectric materials can harvest a small percentage of a person's walking energy, enough to power low-power electronics. Advancements in flexible materials further support the use of piezoelectricity in footwear, with proposals for powering devices like GPS trackers directly from footsteps. Piezoelectric ceramics for a 90 kg person showed 0.4% or 1.43mW of walking energy can be harvested. Experimental results from 2009, report a “6-layer heel footwear harvesters have an average power output of 9 mW/shoe at a walking speed of 4.8 km/h”. Another study reports 55.6 µJ of energy, peak power of 1.6mW generated with each footstep. One study reported walking or running generating 10 – 20 µJ per step. Piezoelectricity at the shoe is further supported by recent developments in flexible piezoelectric materials.

CHAPTER 4

PROPOSED METHOD

Piezoelectric materials have been explored for energy harvesting in footwear for some time. This project takes that concept and applies it to a new location - the backpack. This opens up possibilities for capturing energy from upper body movements and potentially generating more consistent power compared to footsteps (which can vary in frequency and intensity). By incorporating piezoelectric materials in backpacks, we can explore the possibility of wearable power generation beyond shoes.

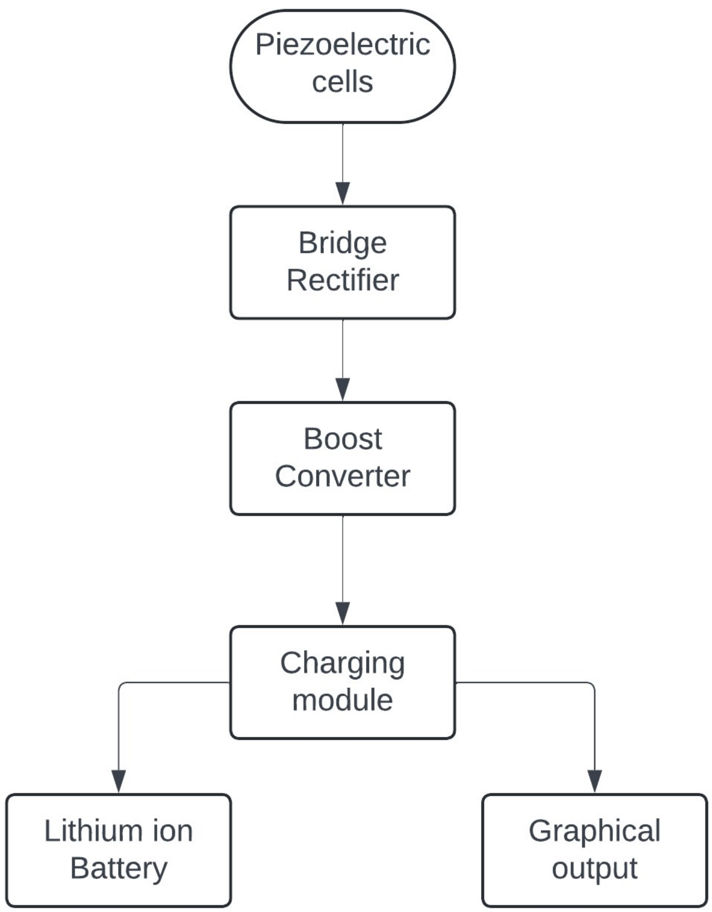

Figure 4.1 Flow Diagram of piezoelectric energy harvesting

The Figure 4.1 is a flow diagram that outlines the components and process of an electrical energy harvesting system. It includes piezoelectric cells, a bridge rectifier that converts AC to DC, a boost converter to increase voltage, a charging module, a lithium-ion battery, and an ESP32 WiFi module for graphical output. This demonstrates an application of energy harvesting technology.

Thin, piezoelectric transducer discs will be strategically placed on the backpack straps to capture energy from movement and carrying weight. Encapsulation ensures their durability against wear and tear. A compact rectifier circuit converts AC voltage from the elements to DC. A rechargeable lithium-ion battery stores the harvested energy, with a capacity chosen based on desired usage. The battery integrates seamlessly within the backpack for optimal weight distribution. A miniature boost converter can elevate the voltage for charging devices like phones (requires additional circuitry). This component would be housed near the hip belt for easy access to charging ports.

This system employs the ESP32 module for the user interface; in a web-based application called Thingspeak, the use of this module to display the battery voltage and level percentage. Thin, flexible wires connect the piezoelectric elements for minimal user discomfort. Strategic placement and encapsulation of all electronics ensure a natural backpack feel. Piezoelectric backpacks offer several advantages over shoes, including higher energy output due to larger surface areas for energy harvesting elements and reduced wear and tear, leading to greater durability. They provide better comfort and practicality as they don't impact the user's walking experience and can be used in a variety of activities such as hiking and commuting. Additionally, backpacks have more space for integrating storage batteries and other features like solar panels, making them versatile and appealing to a broader market, including students, travelers, and outdoor enthusiasts.

4.1 HARDWARE DESCRIPTION

Piezoelectric cells:

Piezoelectric cells are like tiny pressure generators, converting squeezes or vibrations into electricity and vice versa. Made from special materials like crystals or ceramics, they find uses in everything from guitar pickups to ultrasound machines, making them versatile tools for the tech world.

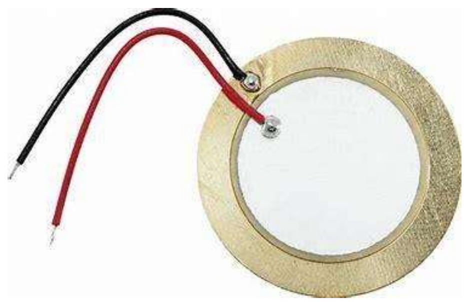

Figure 4.2 Piezoelectric cells

The Figure 4.2 shows a circular piezoelectric cell with red and black wires, illustrating a device commonly used in sensors and actuators.

Bridge Rectifier:

A bridge rectifier uses four diodes in a clever bridge configuration. During each half cycle of the AC input, two diodes conduct electricity in the same direction, effectively rectifying both positive and negative halves of the waveform. This makes it more efficient than some other rectifier circuits, and you'll find bridge rectifiers in many power supplies for your everyday devices.

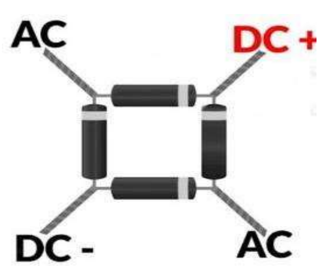

Figure 4.3 Bridge Rectifier

The Figure 4.3 illustrates a bridge rectifier which converts alternating current (AC) to direct current (DC) using four diodes arranged in a square pattern. The AC input terminals are labeled “AC” and the DC output terminals are labeled “DC+” and “DC-”. This rectifier is commonly used in power supplies and battery chargers. Its simple design ensures efficient conversion of AC to DC.

Boost Converter:

A boost converter, also called a step-up converter, is a handy circuit that takes a low DC voltage and increases it to a higher DC voltage. It's like a tiny voltage booster for your electronics.

Figure 4.4 Boost Converter

The Figure 4.4 is a picture of a Boost Converter, which is an electronic circuit designed to increase (boost) the voltage from its input (supply) to its output (load). It achieves this by using a switch and an inductor to store and release energy, essentially pushing the voltage up. While it boosts voltage, it reduces output current, but that's the trade-off for getting that extra voltage kick.

ESP32:

ESP32s are microcontrollers, which means they are small, self-contained computers that can be used to control electronic devices. They typically include a central processing unit (CPU), memory, and input/output (I/O) pins that can be used to connect to sensors and other devices.

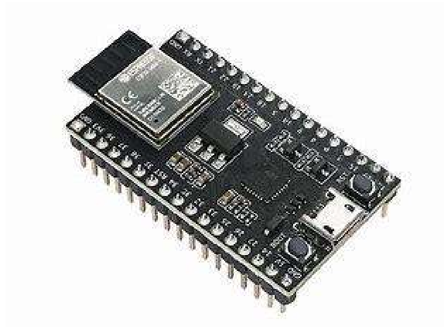

Figure 4.5 ESP32

The Figure 4.6 depicts an ESP32 microcontroller board, commonly used in IoT projects for its Wi-Fi and Bluetooth capabilities. It’s a compact, board with silver pins and various small components, including a marked Wi-Fi/Bluetooth module. it is a versatile and low-power option for wireless communication in electronic applications.

Integrated Wireless Connectivity: ESP32 eliminates the need for extra modules by having built-in Wi-Fi and Bluetooth Low Energy. This simplifies design, reduces cost, and offers both internet connectivity and low-power communication with other devices.

Processing Power: The dual-core processor provides ample power to handle complex tasks like data analysis and running multiple programs, making it suitable for demanding IoT projects.

Versatility: ESP32's combination of features like wireless connectivity, processing power, numerous GPIO pins, and built-in functionalities like touch sensors makes it highly adaptable. This allows it to be used in a wide range of applications from wearables to complex industrial automation systems.

Abundant GPIO Pins: General-Purpose Input/Output (GPIO) pins allow ESP32 to interact with various sensors, actuators, and displays. The high number of GPIO pins on ESP32 (typically more than 30) gives you the flexibility to connect a wide range of peripherals to your project

4.2 SOFTWARE DESCRIPTION

THINGSPEAK:

ThingSpeak is an online platform designed to streamline the development of Internet of Things (IoT) applications. It removes the need for users to set up their own servers or write complex web software. This makes ThingSpeak a popular choice for prototyping and developing IoT projects, particularly those focused on collecting and analyzing sensor data.

ThingSpeak offers a variety of tools to manage your IoT data. You can collect sensor data from your devices using various protocols supported by the platform.

This data can then be visualized in real-time with charts and graphs, allowing you to easily monitor sensor readings and identify trends.

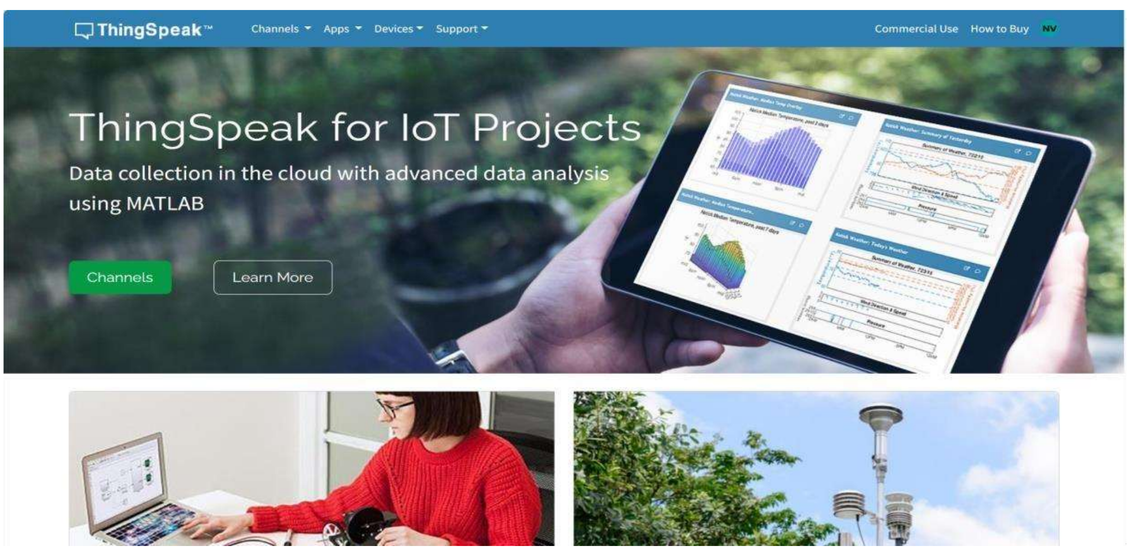

Figure 4.6 ThingSpeak website

ThingSpeak goes beyond basic data visualization. You can also leverage its optional integration with MATLAB software for advanced data analysis. This allows you to uncover deeper insights from your sensor data by identifying patterns and trends that might not be readily apparent from just looking at charts. For situations where you need to be notified of specific sensor readings, ThingSpeak allows you to set up alerts. This ensures you're aware of critical changes in your data and can take appropriate action. Additionally, ThingSpeak integrates with other services like X and Twilio. This enables you to automate actions based on your sensor data, such as sending notifications or triggering other systems.

Data Channels: You can create private channels to collect and store data from your sensors and devices. ThingSpeak also allows sharing data publicly or with specific users for collaboration.

Data Ingestion: ThingSpeak provides multiple ways to send data to your channels. You can use popular protocols like REST API and MQTT, or leverage third-party apps for data integration.

Data Visualization: ThingSpeak offers built-in tools to create charts and graphs to visualize your sensor data in real-time. This helps you easily understand trends and patterns.

Data Analysis with MATLAB: ThingSpeak integrates with MATLAB, a powerful numerical computing software. This allows you to perform advanced data analysis and calculations on your IoT data directly within the platform. ThingSpeak even provides pre-built MATLAB analytics tools for common tasks.

Event Scheduling: You can set up automated actions based on your sensor data. ThingSpeak allows scheduling events to trigger based on predefined thresholds or conditions. This enables you to react to changes in real-time.

Rapid Prototyping: ThingSpeak eliminates the need to set up servers or develop complex web software. This allows for quick and easy prototyping of IoT applications, making it ideal for experimentation and development.

CHAPTER 5

RESULTS AND DISCUSSION

This backpack presents a approach to on-the-go device charging by leveraging piezoelectric energy harvesting technology. Strategically placed piezoelectric discs within the straps convert mechanical energy from user movement into electrical energy.

Table 5.1 Output Voltage Comparison

USAGE	FORCE	VOLTAGE
Normal shoe	490N	21.69V
Wedge-heeled shoe	490N	30V
Handbag	490N	16.42V
Bag Strap with single cell	19.6N	0.3V
Bag Strap with 4 cell in parallel	19.6N	0.83V
Self Powered Backpack	40N	2V

Table 5.1 does the comparison of the output voltage range of the piezoelectric cells when used in normal shoe, wedge-heeled shoe, handbag, backpack. The Force is derived from the equation,

$$F = ma$$

where m is the mass and a is the acceleration due to gravity. To understand the range of voltages piezoelectric materials can produce, we calculated the voltage output for a specific weight (50kg).

Figure 5.1 Prototype

The Figure 5.1 is the prototype of this project which has the piezoelectric cells, battery, rectifier circuit, ESP32 module.

The Battery parameters are visualized on the Thingspeak website using ESP32 module.

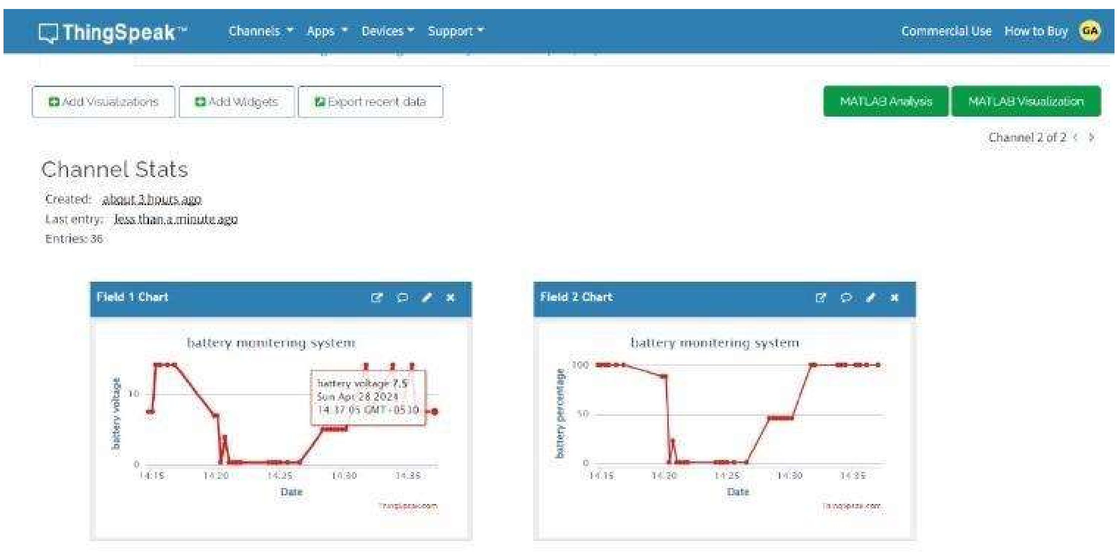

Figure 5.2 Visualization of Battery Parameters

The Figure 5.2 illustrates the visualization of battery monitoring system with the help of ThingSpeak. The ESP32 microcontroller within the backpack is programmed to periodically measure the voltage of the lithium-ion battery. This voltage is directly correlated with the battery's remaining capacity, allowing estimation of battery percentage. The ESP32 can then transmit this data, along with timestamps, wirelessly to ThingSpeak. Users can access ThingSpeak through a web interface and visualize the battery voltage (or calculated percentage) over time using graphs and charts. This allows for remote monitoring of the backpack's battery performance.

CHAPTER 6

CONCLUSION

The burgeoning wearable technology market demands innovative solutions for powering devices. This project explores a self-powered wearable backpack that harvests energy from user movement and weight using piezoelectric materials. This approach fosters a sustainable future for wearable tech by eliminating reliance on conventional batteries. The proposed backpack prioritizes both functionality and user comfort. Strategically placed and encapsulated piezoelectric elements on the straps convert user movement and carried weight into electricity. A rectifier circuit converts the harvested AC current to DC for storage in a rechargeable lithium-ion battery. The modular design allows for an optional boost converter to enable charging higher-power devices. To ensure a natural user experience, thin and flexible wires connect the piezoelectric elements, while strategic placement and encapsulation of all electronics contribute to a seamless design. Real-time monitoring is achieved through an ESP32 module facilitating connection with a web application (ThingSpeak) which allows users to conveniently check battery voltage and level.

Piezoelectric bags promise significant advancements across consumer electronics, various industry sectors, and education. By harnessing kinetic energy, they can charge devices like smartphones and wearables, providing a sustainable power solution. This technology benefits military personnel, outdoor enthusiasts, and healthcare by offering reliable power in remote locations and for continuous operation of medical devices. Additionally, piezoelectric bags serve as valuable educational tools in STEM, demonstrating renewable energy concepts and supporting research into hybrid energy systems, promoting innovation in sustainable energy solutions.