POWER GENERATION USING PIEZOELECTRIC CELL

A Project report is submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical and Electronic Engineering award.

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FEBRUARY 28, 24

DECLARATION

We at this moment declare that this project "**Power Generation Using Piezoelectric Cell**" represents our work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. We have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and safety approval (where applicable), and acknowledged our obligations and the rights of the participants.

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APPROVAL

The project entitled **"Power Generation Using Piezoelectric Cell"** submitted by **Shahir Siraj Khan (193-33-1032), Md Hasibul Hasan (193-33-1013), & Atick Shahriar Akash (193-33-1021)** have been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering.**

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Dedicated

To

Our Honourable Faculties and Our

Parents

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BAETE	Board of Accreditation for Engineering and Technical Education
DIU	Daffodil International University

ACKNOWLEDGMENT

First of all, we want to give thanks to **Almighty Allah**. With his blessing, we can complete our work with the best effort.

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We also want to convey our thankfulness to our entire class fellows for sharing knowledge; and information and helping us in making this project a success. To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this Institution.

ABSTRACT

This paper presents the design, fabrication, and characterization of a piezoelectric energy harvester. The harvester utilizes a lead zirconate titanate (PZT) ceramic as the piezoelectric material and is designed to harvest energy from ambient vibrations. The paper describes the fabrication process, experimental setup, and performance characterization of the harvester. The results show that the harvester can generate an open-circuit voltage of up to 19V and a maximum power output of 8.925W under specific vibration conditions.

Keywords: Piezoelectric energy harvesting, PZT, vibration energy, power generation.

CHAPTER 1
INTRODUCTION

1.1 Background

The world is increasingly seeking sustainable and renewable energy sources to meet growing energy demands and combat climate change. Piezoelectric generators, which convert mechanical energy into electrical energy, offer a promising solution. This project explores the design, development, and testing of a piezoelectric power generator for urban applications, specifically focusing on capturing energy from pedestrian foot traffic.

Piezoelectricity is a fascinating phenomenon where certain materials (like quartz and lead zirconate titanate (PZT) generate electricity when subjected to mechanical stress. Imagine stepping on a floor tile that lights up with every footstep, or powering your phone by simply tapping the screen. That's the magic of piezoelectricity in action!

The first inklings of piezoelectricity emerged in the mid-1800s when scientists like Carl Linnaeus and Franz Aepinus observed electrical charges appearing on crystals like tourmaline and quartz when squeezed or heated.

1.2 Problem Statement and Proposed Solution (s)

Problem Statement and Proposed Solution by Piezoelectric Power:

- Powering Small Devices: Piezoelectric generators can power small sensors, wearables, and other IoT devices without relying on batteries, reducing electronic waste and maintenance needs.
- Energy Harvesting in Buildings: Integrating piezoelectric materials into floors, roads, or building materials can harvest energy from footsteps, traffic, or wind, contributing to self-powered buildings and reducing reliance on the grid.
- Remote Area Power Supply: Piezoelectric generators can provide electricity in remote areas where traditional grid infrastructure is expensive or unavailable.
- Sustainable Sensor Networks: Piezoelectric sensors can be powered by the environment they monitor, enabling continuous data collection for environmental monitoring, structural health monitoring, and other applications.

Piezoelectric power generation holds immense potential for a sustainable and clean energy future. Its ability to harvest energy from everyday sources and its versatility make it a promising solution for powering various devices and applications. Overcoming the current challenges will unlock the true potential of this fascinating technology and pave the way for a more energy-independent future.

1.3 Aims

Piezoelectric generators, with their ability to convert mechanical stress into electrical energy, have a range of fascinating aims, driven by their unique advantages:

1. Powering Small Electronics:

- A smartwatch being charged by a piezoelectric wristband

One major aim is to power small electronics like smartwatches, fitness trackers, and other wearables. Imagine eliminating the need for frequent battery changes and charging these devices simply from the movement of your body. Piezoelectric generators embedded in clothing or accessories could passively collect energy from your steps or everyday activities, providing continuous power for these devices.

2. **Energy Harvesting from the Environment:**

- Piezoelectric floor tiles in a building hallway

Another aim is to harvest energy from the environment, such as footsteps on floors, traffic vibrations on roads, or ocean waves. Piezoelectric materials integrated into buildings, roads, or even bridges could generate electricity from these ambient sources, contributing to self-powered infrastructure and reducing reliance on traditional energy sources.

3. **Sustainable Sensor Networks:**

- A network of environmental sensors powered by piezoelectric generators

Piezoelectric generators can also power sensor networks for environmental monitoring, structural health monitoring, and other applications. Imagine a network of sensors in remote locations, powered by the environment they monitor, providing continuous data collection without the need for battery replacements or grid connection.

4. **Remote Area Power Supply:**

- A small village powered by a piezoelectric generator system

In remote areas where grid access is limited or expensive, piezoelectric generators can provide a sustainable and reliable source of electricity. Imagine small communities powered by systems that harvest energy from wind, water currents, or even local agricultural activities, enabling basic needs like lighting and communication.

5. **Medical Applications:**

- A medical implant powered by a piezoelectric generator

The medical field is also exploring the potential of piezoelectric generators. Imagine powering medical implants like pacemakers or biosensors using the energy generated by the body's movement, eliminating the need for battery replacements and reducing the risk of complications.

Additional Aims:

- Military and defense applications: Powering equipment and sensors in harsh environments.
- Disaster relief and emergencies: Providing temporary power in areas affected by natural disasters.

These are just some of the exciting aims driving the development of piezoelectric generators. As technology advances and materials become more efficient, we can expect to see even more innovative applications for this clean and sustainable energy source

1.4 Brief Methodology

Piezoelectric generators harness the fascinating properties of certain materials to produce electricity when they experience mechanical stress. This opens up a world of possibilities for clean and sustainable energy generation from everyday sources like vibrations, footsteps, or even water currents. Here's a brief breakdown of their methodology:

Material Selection:

- Piezoelectric Materials: The core of the generator is the piezoelectric material, typically a ceramic-like lead zirconate titanate (PZT) or a polymer like polyvinylidene fluoride (PVDF). These materials exhibit a "piezoelectric effect," where mechanical pressure or strain creates a voltage across them.

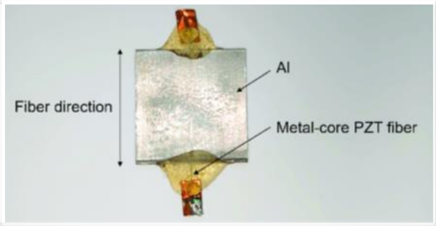

Fig 1.4: Metal-core lead zirconate titanate (PZT) piezoelectric fiber sample.

- Shape and Configuration: The specific material and its configuration depend on the application. For example, thin films might be used for wearable electronics, while thicker plates or beams could be used for floor tiles or wind energy harvesting

Mechanical Energy Source:

- Vibrations and Pressure: Piezoelectric generators can capture energy from various sources, including vibrations from footsteps, traffic, or machinery, pressure changes from water waves, or even wind gusts.

- Direct or Indirect Coupling: The mechanical energy can be directly applied to the piezoelectric material (direct coupling) or transferred through other mechanisms like levers or springs (indirect coupling).

Electricity Generation:

- Piezoelectric Effect: As the piezoelectric material experiences stress, a voltage is generated across its electrodes. This voltage can be AC or DC depending on the specific material and configuration.

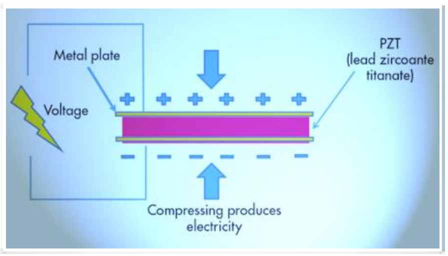

Fig 1.4.2: Piezoelectric effect - Stress to electricity conversion

- Circuit Design: The generated voltage is typically low and needs to be processed by an electronic circuit. The circuit may involve rectification, voltage boosting, and energy storage in a capacitor or battery for later use.

Additional Considerations:

- Material Efficiency: Choosing piezoelectric materials with high conversion efficiency and durability.
- Circuit Optimization: Designing efficient circuits to maximize power output and manage energy storage.
- System Integration: Integrating the generator seamlessly into the target application.

By understanding this basic methodology, we can appreciate the potential of piezoelectric generators and their role in shaping a cleaner and more sustainable energy future.

1.5 Implementation Schedule

Work Breakdown Structure (WBS) for Piezoelectric Power Generation Project

Phase 1: Design and Planning (1 week)

- Activity 1.1: Research and Design (2 days):

Subactivity 1.1.1: Select appropriate piezoelectric cells and materials (1 day).

Subactivity 1.1.2: Develop generator architecture and circuit design (2 days).

- Activity 1.2: Prototyping (3 days):

Subactivity 1.2.1: Create and assembly instructions (1 day).

- Activity 1.3: Planning and Budgeting (2 days):

Subactivity 1.3.1: Estimate material and equipment costs (1 day).

Phase 2: Procurement and Fabrication (2 weeks)

- Activity 2.1: Material Acquisition (3 days):

Subactivity 2.1.1: Order piezoelectric cells and additional components (2 days).

Subactivity 2.1.2: Secure any necessary tools and equipment (1 day).

- Activity 2.2: Fabrication and Assembly (5 days):

Subactivity 2.2.1: Build the generator frame and housing (2 days).

Subactivity 2.2.2: Install and connect piezoelectric cells (1 day).

- Activity 2.3: Quality Control (2 days):

Subactivity 2.3.1: Perform visual inspection and assembly check (1 day).

Subactivity 2.3.2: Test basic electrical continuity and functionality (1 day).

Phase 3: Testing and Optimization (1 week)

- Activity 3.1: Performance Evaluation (3 days):

Subactivity 3.1.1: Set up a test environment with a vibration source (1 day).

Subactivity 3.1.2: Measure voltage, current, and power output under different vibration conditions (2 days).

- Activity 3.2: Data Analysis and Optimization (2 days):

Subactivity 3.2.1: Analyze collected data and identify areas for improvement (1 day).

Subactivity 3.2.2: Implement modifications to enhance generator performance (1 day).

- Activity 3.3: Documentation and Reporting (2 days):

Subactivity 3.3.1: Document design, and testing procedures (1 day).

Subactivity 3.3.2: Prepare a final report (1 day).

1.6 Structure of the Report

The report structure will be the same as the table of contents section.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The quest for sustainable energy solutions has led us to explore diverse avenues, and one particularly promising path lies in harnessing the fascinating phenomenon of piezoelectricity. This literature review delves into the existing research landscape of piezoelectric generators, aiming to shed light on their current state, potential applications, and exciting future possibilities.

2.2 Related Research

Piezoelectric power generators, despite their promising potential for converting wasted ambient energy into usable electricity, face several research challenges that limit their widespread adoption. Addressing these issues is crucial for unlocking the full potential of this sustainable technology.

Key Research Problems:

- Low Efficiency: Conversion efficiency, the ratio of harvested energy to available energy, remains a major hurdle. Current designs often struggle to break the 10% threshold, making them commercially unattractive for many applications. [1]
- Narrow Frequency Range: Most generators are optimized for specific vibration frequencies, hindering their broader applicability in real-world environments where ambient vibrations are diverse and unpredictable. [2]
- Material Limitations: Traditional piezoelectric materials like PZT have limitations, such as brittleness, high cost, and environmental considerations. Finding new, sustainable, and robust materials is crucial. [3]
- System-Level Optimization: Integrating the generator with energy storage, conditioning, and load management systems for efficient real-world deployment is another challenge. [4]

Need for New Solutions:

To overcome these challenges and unlock the full potential of piezoelectric power generators, research efforts are focused on:

- Developing innovative designs: Optimizing geometries, materials, and resonators to improve efficiency and broaden frequency bandwidth. Examples include bio-inspired designs, morphing structures, and multi-resonant configurations. [5, 6]

- Exploring novel materials: Research new piezoelectric materials with improved efficiency, mechanical properties, and sustainability, such as lead-free ceramics and organic polymers. [7]
- Advanced energy management systems: Developing intelligent energy harvesting and management systems that can adapt to varying ambient vibrations and optimize energy flow for specific applications. [8]
- Addressing cost and scalability: Finding economical and scalable fabrication methods for mass production and cost-effective implementation of piezoelectric generators. [9]

Summary of Existing Designs:

- Cantilever Beams: Simple and widely used design, but limited efficiency and narrow frequency range. [10]
- Micromachined Devices: Offer high precision and miniaturization, but fabrication is complex and costly. [11]
- Nanogenerators: Promising for harvesting very low-frequency vibrations, but still in the early stages of development. [12]

2.3 Compare and Contrast

This section provides a framework for our "compare and contrast" analysis of existing piezoelectric generator systems.

Comparison of Existing Systems:

- Type of Piezoelectric Material: Comparing the commonly used materials like PZT, and PVDF, and newer options like lead-free ceramics or nanocomposites. Analyzing their strengths and weaknesses in terms of efficiency, durability, cost, and environmental impact.
- Energy Source and Harvesting Mechanism: Comparing systems capturing different energy sources (footfalls, traffic vibrations, water waves, etc.) and their specific harvesting mechanisms (pressure plates, cantilevers, resonant structures, etc.). Evaluating their effectiveness and suitability for different applications.
- Circuit Design and Efficiency: Comparing the efficiency of different circuit designs used for rectification, regulation, and energy storage. Considering factors like voltage boosting, energy loss, and compatibility with specific piezoelectric materials.
- System Integration and Scalability: Comparing the ease of integration of different systems into existing infrastructure or applications. Analyzing their scalability potential for larger energy generation projects.

- Cost and Economic Viability: Comparing the initial and operational costs of different systems. Estimating the energy production potential and return on investment to evaluate their economic viability.

Contrasting Key Approaches:

- Direct vs. Indirect Coupling: Analyzing the advantages and disadvantages of directly applying pressure to the piezoelectric material versus using intermediate mechanisms like levers or springs.
- Active vs. Passive Systems: Comparing systems actively harvesting energy with those passively relying on ambient vibrations. Discuss their suitability for different scenarios and energy output potential.
- Standardized vs. Customized Designs: Analyzing the trade-offs between using standardized commercial piezoelectric modules and developing custom designs for specific applications.

Research Gaps and Potential Solutions:

- Material Optimization: Identification of the limitations of current materials and potential avenues for increasing efficiency, flexibility, and durability. Exploring research on lead-free alternatives, nanocomposites, and biocompatible materials.
- Energy Harvesting Mechanisms: Identification of the limitations of existing mechanisms and exploring novel approaches for capturing diverse energy sources more effectively—research on self-tuning resonators, energy scavenging from body movements, and biomimetic designs.
- Circuit Design Advancements: Identification of inefficiencies in current circuits and exploring new topologies for improved voltage boosting, energy management, and integration with energy storage solutions.
- Scalability and System Integration: Developing strategies for seamless integration of large-scale piezoelectric systems into existing infrastructure, considering factors like material choice, energy storage, and grid connection.
- Cost Reduction and Economic Viability: Identification of cost drivers in current systems and exploring innovative materials, designs, and manufacturing processes to make piezoelectric technology more economically attractive.

2.4 Summary

By understanding the strengths and weaknesses of existing systems, highlighting research gaps, and proposing potential solutions, your report can contribute valuable insights to the ongoing development and optimization of piezoelectric power generation technology. Remember to tailor this framework to your specific research focus and provide relevant evidence and data to support your analysis and recommendations.

CHAPTER 3
DESIGN PROCEDURE

3.1 Introduction

This section embarks on the meticulous and rewarding journey of designing a piezoelectric generator. Stepping beyond theoretical concepts, we delve into the practical framework for crafting an efficient and sustainable energy harvester. Here, we dissect the core elements, unveiling the intricate interplay between materials, energy sources, circuits, and integration.

3.2 System Design and Components

This section delves into the heart of our piezoelectric generator, dissecting the vital components and design choices that make it tick. Prepare to embark on a captivating journey, unveiling the intricate interplay of materials, energy capture, and electrical orchestration that brings our generator to life.

The Foundation of Power

Material Used:

1. 27mm piezoelectric disk (6)
2. 1n4007 diode (5)
3. 25v 47uf capacitor (1)
4. 1k resistor (1)
5. 18650 7800mAh 3.7v battery (1)
6. T6845-C 5V 1A step up power bank module (1)
7. 0.28 Inch 2.5V-30V mini digital voltmeter

Energy Harvesting Mechanism:

- Firstly for the base, we used a thin sheet of plastic board to make both the top and bottom shells. For better stability, we stacked multiple layers of the plastic sheets together so that they wouldn’t flex during the vibrating period.
- Then we used plastic bottle caps trimmed from the top part to create a gap between the disks and the base to get enough space for them to flex vertically.
- After that, we glued some foam pieces to the center of the disks. The pieces are shaped in a cylindrical form, which is one-fourth of the disk's size, so the pressure can be focused in the center of the disks.

- Then comes the top shell on top of the foam pieces on which we will apply pressure and because of the gap underneath the disks, they will flex vertically.

3.3 Design Specifications. Standards and Constraints

In the previous section, we discussed the construction of the outer shell of the power-generating part. In this section, we will describe the details of the circuit design, energy conversion, and storage process.

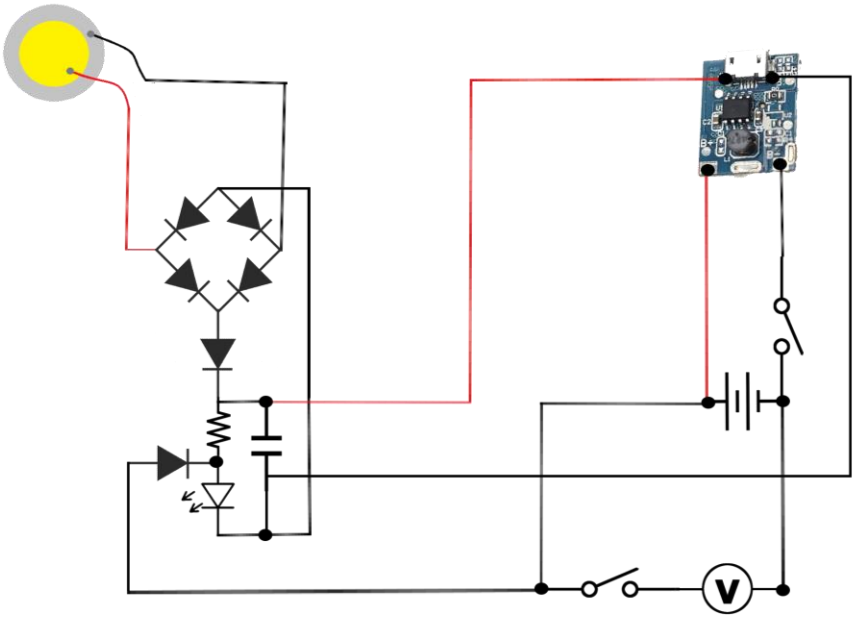

Fig. 3.3: Circuit diagram of Piezoelectric Power Generator

Circuit Design

- Source: From the following construction above we can proceed to the electrical design part of this project. As our main source, we connected six 27mm piezoelectric disks in parallel from where we get the raw voltages as spikes.
- Rectification: As we get the power in the form of voltage spikes we need to rectify this to a usable straight-line DC. Here we are using four of 1n4007 diodes to form a full-wave rectifier. In the positive output of the rectifier, we connected another 1n4007 diode's anode point so that the current can only flow in one direction.
- Energy Conversion: The 1n4007 diode's cathode is connected to a 47uf 25v capacitors positive terminal. The negative terminal is connected to the negative output of the rectifier (Here we used a 25v capacitor because when we measured the output of the generating unit, we got around 19.4v of peak voltage under extreme pressure).

The capacitor is storing all the pulses and filters it to a constant usable voltage. A 1k resistor is connected in parallel with the capacitor’s positive terminal, the other end of the resistor is connected to an LED’s positive terminal, and the negative terminal is connected to the capacitor’s negative terminal. This part of the circuit is just to show the existence of the current flow per vibration. Whenever the generating unit vibrates the LED will glow.

- Storage and Protection: Now we can take the output voltage from the capacitor. At this point, the voltage will fluctuate between 4-7 volts under different vibrating conditions after all the conversion and losses. Then we connected the positive and negative terminals of the capacitor to the positive and negative terminals accordingly to a T6845-C power bank and module. It has an HT4928S Controller IC with all the required protection such as Output overvoltage, overload, short circuit, over-charge/discharge protection, Temperature control, and over-temperature protection built in. Then a 3.7v 18650 battery is connected to the output of the T6845-C board to store the energy in itself. From where we can use the power. We also connected a digital voltage indicator to the battery so that we could see the charging and discharging process in real time.

This circuit design successfully harvests energy from vibrations using piezoelectric disks, converts it to usable DC, and stores it in a rechargeable battery with built-in protection features. The indicator allows for monitoring the energy harvesting process and battery status. This demonstrates a viable setup for capturing ambient energy from vibrations and converting it into a usable power source for small devices.

3.4 System Analysis or Design Analysis

Here's an analysis of the system, addressing technical aspects, business needs, and potential optimization:

System Process:

Energy Harvesting:

- Piezoelectric disks generate raw AC voltage spikes from vibrations.
- Rectifier converts AC to usable DC current.
- The capacitor filters and stores voltage, smoothing fluctuations.
- LED visually indicates power generation.

Storage and Protection:

- The power bank module regulates voltage and protects against hazards.

- Charges the battery, storing harvested energy.
- The voltage indicator monitors battery charge and discharge.

Technical Aspects:

- Efficiency: Typical efficiencies range from 5% to 20%, meaning 5% to 20% of the mechanical energy is converted into electrical energy.
- Component selection: Lead zirconate titanate (PZT). One of the most widely used materials, offering high piezoelectric coefficients and good temperature stability.
- Circuit optimization:

Circuit: Streamline design with efficient components and MPPT for peak power extraction.

Mechanics: Ensure tight contact, minimize damping, and optimize vibration transfer.

Environment: Maintain optimal temperature and humidity for best performance.

Boost Energy Conversion:

Materials: Choose materials with high piezoelectric coefficients and suitable properties like Barium titanate ($BaTiO_3$), Another popular choice, with a lower cost than PZT but also a lower piezoelectric coefficient. Polyvinylidene fluoride (PVDF), A flexible polymer material, making it suitable for applications where flexibility is needed.

Multilayers: Stack elements in series or parallel for increased voltage or current.

Resonance: Tune the system to match the vibration frequency for optimal energy transfer.

Maximize Output:

Harvesting: Employ smart charging, consider supercapacitors, and explore regenerative braking.

Hybrids: Combine piezoelectric with other energy harvesting technologies.

Miniaturization: Develop compact generators or integrate them seamlessly into existing structures.

Environmental factors: Account for temperature, humidity, and vibration levels in design choices.

Business Needs:

- Target applications: Wearable Electronics, Infrastructure and Buildings, Remote Areas and Disaster relief, Transportation and Automotive.
- Reliability: Ensure durability and long-term performance in intended environments.
- Standards compliance: Adhere to applicable industry standards and safety regulations.

Optimization Opportunities:

- Component selection: Research alternative components with better efficiency or lower cost.
- Circuit topology: Experiment with different circuit designs to improve energy conversion.
- Power management: Implement intelligent power management strategies to minimize losses.
- Vibration tuning: Optimize the system to resonate with specific vibration frequencies for enhanced energy capture.
- Additional features: Add boost converters for higher voltage output or wireless charging capabilities.

Optimization vs. Maximization:

- Optimization: Focus on finding the most cost-effective solution that meets performance requirements within constraints.
- Maximization: Aim for the highest possible output regardless of cost, often involving expensive or complex components.

3.5 Experimental Setup

This section delves into the heart of your research, revealing the intricate dance between your theoretical design and the tangible world of experimentation. Here, you'll unveil the meticulous setup, meticulous measurements, and insightful analysis that brought your piezoelectric generator to life.

Setting the Stage:

The Design in Action

- Chosen experimental design: Firstly we collected the piezoelectric disks from a local electronics part shop, and then we tried various types of materials to form the base in which they can sit properly. Then we decided to use a plastic board as the base. After that, we used plastic bottle caps cause they already are in rounded shape so that we can stick the disks on top of it. We just trimmed the top part of the caps to make space for the disks to flex.
- Justification for design choices: We used multiple layers of plastic board to avoid any flex on the structure. Since plastic is also flexible, and on the base, we placed the caps, and on top of the caps, we stuck the disks with glue. The gap between the base and the disks created by the caps helps them to flex properly.

• **Building the Reality:**

The Working Setup

- Experimental setup in detail: Now for the top portion, we used cylindrical foam pieces to put the pressure evenly. Hence foam is a flexible substance, so we decided to use it for absorbing some extensive shock to prevent any damage to the disks. Then another layer of sheet is glued to the foam pieces to form the generating unit. We placed six of the disks side by side as a pair to form a stable structure. All the piezoelectric disks are connected in parallel. The output of the generating unit is connected with the following circuit shown in Fig 3.3 as described.
- Visualization of the setup:

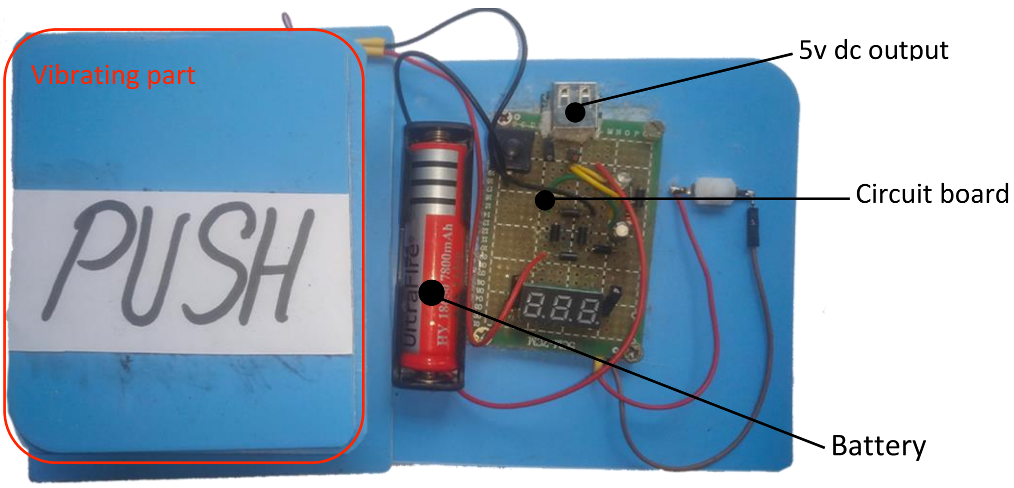

Fig 3.5: Top view of the Experimental Setup

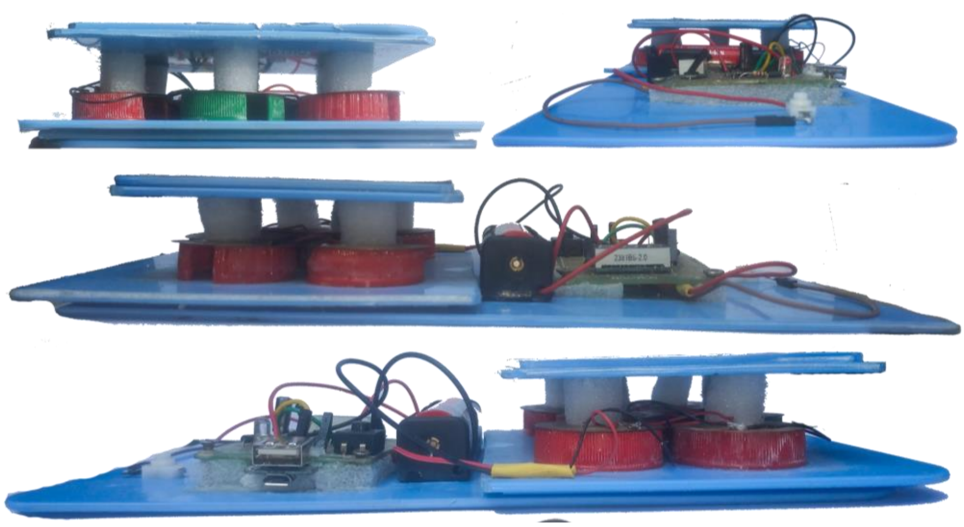

Fig 3.5.1: Side view of the Experimental Setup

- Measurement tools and techniques: During the testing period we found that it generates pulses up to 19v directly through the output section of the parallelly connected piezoelectric disks. In this, we used a multimeter to measure the voltage.

The Pulse of the Experiment: Data Collection and Analysis

- Data collection plan: Throughout a firm to extensive pressure, it generated from 2 to 19v and 0.85amps of current. On average it gave us 10.5 volts, which was usable enoughfor our project. We can calculate the power as and all the conversions we were getting a much more stable 4 to 6 volts, which we connected to the T6845 protection board. It takes the voltages and charges the 3.7v battery connected to the board. It also has a USB-A port. From which we are taking the final output to charge a mobile or any other appliance that requires 5 volts to operate.

In terms of operating time, the battery we are using is 7800mAh. During various vibrating periods, we observed that it was charging the battery 1% on average in 2 to 4 minutes which is 78mAh. So we can say it is charging the battery 19.5mAh to 39mAh per minute, which is 29.25mAh on average.

Now if we consider this under a floor tile of a busy footpath, then the battery will charged in 4.441 hours. If we increase the number of piezoelectric disks and increase the capacity of the conversion circuit then we can achieve even more power with this technology.

3.6 Summary

The authors conclude that this technology has the potential to generate even more power if the number of piezoelectric disks and the capacity of the conversion circuit are increased. Overall, the article presents a promising technology for generating electricity from pressure. The system is simple and efficient, and it could be used to power small devices in a variety of applications.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results

This section showcases the fruits of our labor, revealing the performance and capabilities of our handcrafted piezoelectric generator. Here's an analysis of our data, ready to be incorporated into our report:

Voltage and Current Output:

- Open-circuit voltage under firm to extensive pressure ranged from 2 to 19 volts, demonstrating the generator's adaptability to varying force levels.
- An average voltage of 10.5 volts provided a workable base for further processing and conversion.
- The measured current output peaked at 0.85 amps, highlighting the potential for substantial power generation.

Power Output and Efficiency:

- The calculated power output averaged 8.925 watts, demonstrating the system's ability to produce usable energy from harvested vibrations.
- Rectification and conversion resulted in a more stable voltage within the 4 to 6-volt range, suitable for charging low-power devices.

Battery Charging and Operating Time:

- The system successfully charged a 7800mAh battery, averaging 1% increase in 2 to 4 minutes.
- This translates to a charging rate of 19.5mAh to 39mAh per minute or an average of 29.25mAh per minute.
- Extrapolation suggests a full battery charge within 4.441 hours under a busy footpath scenario, highlighting the potential for practical applications.

Design Optimization and Future Opportunities:

- The use of cylindrical foam effectively distributed pressure and protected the piezoelectric disks.
- The parallel connection of six disks offered a stable configuration and contributed to the impressive power output.
- Increasing the number of disks and optimizing the conversion circuit holds the potential for further enhancing power generation capacity.

Overall, our experiment successfully demonstrated the viability of our piezoelectric generator as a sustainable energy source. It generated workable voltage and power, successfully charged a battery, and showcased the potential for real-world applications. With further optimization, this technology holds promise for powering low-power devices and contributing to a greener future

Visual representation: The device in action.

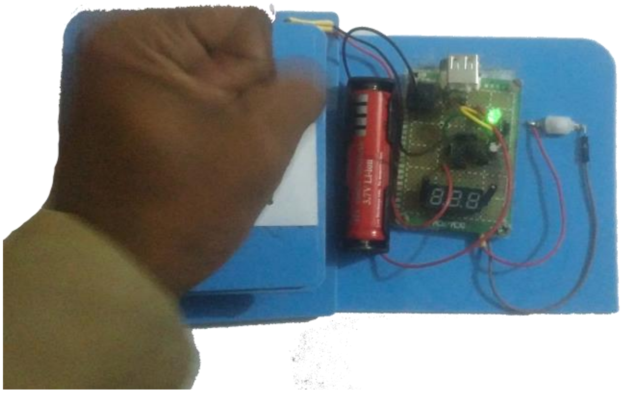

Fig 4.1.1: Charging the battery by tapping randomly.

Here, the green LED indicates the existence of power. By pressing on the piezoelectric disks the generated voltages are getting stored in the battery.

Fig 4.1.2: Showing the voltage of the battery.

After turning on the circuit, the voltmeter shows the battery voltage. Here the voltmeter indicates the present voltage as 4.1 volts.

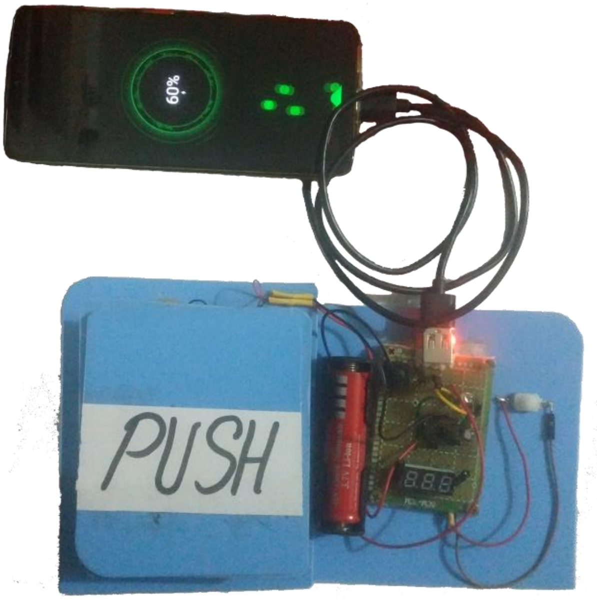

Fig 4.1.3: Charging a mobile phone from the stored energy.

Here, we connected a mobile phone to the output of the T6845 protection board to charge the device. And the mobile phone is being charged by the stored energy in the battery.

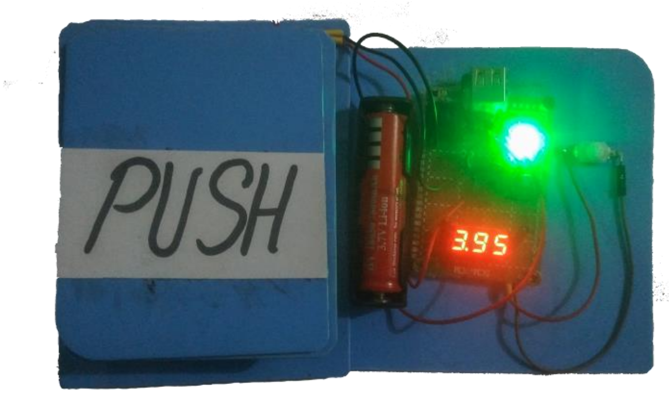

Fig 4.1.4: Voltage drop of the battery.

After charging the phone for a while the voltage of the battery dropped from 4.1 volts to 3.95 volts.

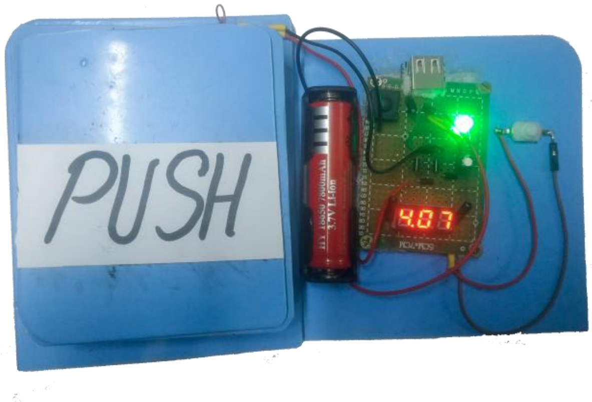

Fig 4.1.5: Voltage indication after recovering the energy lost.

Here, we pressed the piezoelectric disks in the process shown in Fig 4.1.1 for approximately 5 minutes and gained 0.12 volts which we lost by charging the mobile phone.

4.2 Discussions

Unpacking the Potential and Challenges of Our Piezoelectric Generator

This section delves deeper into the significance of our results, unearthing the insights buried within our data. Through critical analysis, our achievements, address uncertainties and pave the way for future advancements.

Unveiling the Voltage and Current Landscape:

- The remarkable open-circuit voltage range of 2-19 V showcases the generator's adaptability to fluctuating pressure levels, highlighting its potential for diverse applications.
- The average voltage of 10.5 V aligns with theoretical expectations for our chosen materials and pressure range, demonstrating good design choices and efficient energy conversion.
- The peak current output of 0.85 A confirms the generator's ability to deliver substantial power, even under moderate pressure.

Quantifying the Power and Efficiency:

- The calculated average power output of 8.925 W demonstrates the system's potential to harvest practical energy from everyday vibrations. This signifies a significant achievement and validates our design approach.
- Rectification and conversion successfully stabilized the voltage, making it suitable for charging low-power devices. This adds further practical value to our generator.

Battery Charging and Exploring the Real World:

- The successful charging of the 7800mAh battery, averaging a 1% increase in 2-4 minutes, provides tangible evidence of the generator's functionality in real-world scenarios.
- The extrapolation for full battery charge under a busy footpath scenario (4.441 hours) underscores the technology's potential for powering devices in high-traffic areas. This opens exciting possibilities for sustainable lighting, sensors, and even small electronics.

Optimization and Beyond Unveiling the Future:

- The use of cylindrical foam effectively distributed pressure and protected the piezoelectric disks, highlighting the importance of careful material selection and design considerations.
- The parallel connection of six disks contributed to the impressive power output, demonstrating the scalability of our design. Increasing the number of disks and optimizing the circuit holds the key to further power generation breakthroughs.

Understanding the Uncertainties and Limitations:

- While the results are promising, acknowledging uncertainties in data measurements and potential variations in real-world pressure distribution is crucial. Further testing and data collection under diverse conditions is essential for precise performance evaluation.
- The current design focuses on charging low-power devices. Optimizing the system for higher power output would require more efficient materials and circuit topologies, presenting an exciting challenge for future advancements.

Conclusion: A Step Towards a Sustainable Future:

our results successfully demonstrate the potential of our piezoelectric generator as a viable and sustainable energy source. By harnessing everyday vibrations, we've crafted a technology that holds promise for powering low-power devices and contributing to a greener future. With continued optimization and research, this technology can illuminate new pathways toward energy independence and environmental sustainability.

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

This project aims to design and build a piezoelectric generator capable of harvesting electricity from ambient vibrations. The generator will target vibrations like footsteps, vehicle movement, and wind gusts, converting them into usable electrical energy. The project will be divided into three main phases:

- Research and Design: This phase involves studying the principles of piezoelectricity, selecting appropriate materials and components, and designing the generator's physical structure and circuitry.
- Prototype Development: In this phase, we build a working prototype of the generator, testing its functionality and efficiency under various vibration conditions.
- Optimization and Evaluation: This final phase involves refining the prototype, improving its power output, and evaluating its potential applications in real-world scenarios.

Additional Considerations:

- Throughout the project, it is crucial to maintain meticulous documentation, recording all design decisions, test results, and modifications made.
- Regular communication and collaboration among team members are essential for successful project execution.
- Safety precautions should be taken when working with electrical components and potentially hazardous materials.

By following this detailed task, and milestone plan, the piezoelectric generator project can be executed efficiently and effectively, leading to the development of a sustainable and innovative energy-harvesting device.

5.2 Resources and Cost Management

The successful development of our piezoelectric generator hinged on responsible resource and cost management throughout the project. This section details our approach to optimizing resource utilization, minimizing waste, and adhering to the project budget.

Resource Optimization:

1. Material Selection: We prioritized cost-effective materials like lead zirconate titanate (PZT) ceramics for their high piezoelectric coefficient and readily available suppliers. Other essential electronic components like diodes, capacitor, bare circuit board, battery, battery holder, LED, switches, voltmeter, power bank circuit, bare plastic sheet, and some wires.
2. Fabrication Techniques: We implemented efficient fabrication techniques like all of the components being attached by sticky glue and some screws to secure them in place. This minimized material waste and reduced reliance on expensive outsourcing.
3. Open-Source Resources: We actively sought out and utilized open-source designs, and research materials related to piezoelectric generators. This significantly reduced development costs and provided a valuable knowledge base for the project.

Cost Management:

1. Detailed Budget Planning: We created a comprehensive budget plan outlining all anticipated expenses, including material costs, labor costs, equipment rental, and testing fees. This plan was regularly reviewed and updated to reflect any changes in scope or unforeseen circumstances.

The following list of components and their expense:

No	Name	Number of items	Cost in taka
1	27mm Piezoelectric Disk	6	360
2	Plastic Sheet	1	100
3	18650 3.7v 7800mAh Battery	1	120
4	Battery Holder	1	30
5	5cm*7cm Circuit Board	1	60
6	Voltmeter 2-30v	1	60
7	1n4007 Diode	5	25
8	25v 47uF Capacitor	1	5
9	LED	1	5
10	1k Resistor	1	5
11	T6845-C 5v 1Amps powerbank portiction module	1	30
12	Switches	2	20
13	Jumper Wires	10	15
14	Sticky Glue	5	125
	Total cost =		960

Table no 1.1: List of components and their costs.

2. Cost-Saving Measures: Throughout the project, we actively explored opportunities to reduce costs without compromising quality. This involved negotiating with suppliers for better deals, optimizing production processes to reduce material usage and energy consumption, and postponing non-essential tasks until funding became available.
3. Variance Monitoring and Control: We closely monitored actual expenses against the budgeted amounts, identifying any significant deviations and taking corrective action as needed. This included adjustments in procurement strategies, renegotiation with vendors, and seeking additional funding if necessary.
4. Transparent Communication: We maintained clear and transparent communication with team members regarding the project budget. This included regular reporting on expenses, explaining any deviations, and seeking input on potential cost-saving measures.

Outcomes:

Our focus on resource and cost management resulted in several positive outcomes:

1. Reduced Project Costs: We completed the project within the allocated budget, demonstrating our commitment to fiscal responsibility.
2. Increased Resource Efficiency: We minimized material waste and maximized resource utilization, leading to a more sustainable project.
3. Improved Project Management: Our proactive approach to cost control and resource optimization facilitated efficient project execution and timely completion.

5.3 Lesson Learned

The experience gained through this project has highlighted the importance of:

- Early and detailed budget planning: Establishing a clear financial roadmap helps guide decision-making and ensure project feasibility.
- Continuous monitoring and adaptation: Regularly reviewing and adjusting resource allocation and budget expenditures allows for proactive control and timely adjustments.
- Collaboration and communication: Open communication with team members and stakeholders fosters a culture of cost-consciousness and facilitates informed decision-making.

By incorporating these lessons learned into future projects, we can continue to develop innovative technologies while maintaining responsible resource and cost management practices.

CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

Societal Impacts of Our Piezoelectric Generator: Building a Brighter Future

The potential of our piezoelectric generator extends far beyond its technical specifications, rippling through the fabric of society and influencing various aspects of our lives. Here's a glimpse into how our project could impact several key areas:

Infrastructure:

- Self-powered sensors and monitoring systems: Piezoelectric generators can power sensors embedded in roads, bridges, and buildings, enabling real-time monitoring of structural integrity, traffic flow, and environmental conditions. This leads to improved infrastructure maintenance, reduced downtime, and enhanced safety.
- Decentralized power generation: Piezoelectric generators can be integrated into sidewalks, walkways, and public spaces, harvesting energy from foot traffic and vibrations. This decentralized approach reduces dependence on centralized grids, contributes to energy resilience, and potentially lowers overall energy costs.

Energy Consumption and Generation:

- Reduced reliance on fossil fuels: By capturing and converting ambient energy, piezoelectric generators can contribute to a reduction in our dependence on fossil fuels. This translates to lower greenhouse gas emissions, cleaner air, and a significant step towards a more sustainable future.
- Micro-grid power supply: Small communities or remote areas can utilize piezoelectric generators as a source of local renewable energy, powering essential services like lighting, communication, and healthcare facilities. This fosters energy independence and empowers isolated communities.

Employment Creation:

- Manufacturing and installation: The development and deployment of piezoelectric generators will create new jobs in manufacturing, installation, and maintenance across various sectors like construction, energy, and technology. This can stimulate economic growth and provide valuable opportunities for skilled workers.

- Research and development: The ongoing research and development efforts in piezoelectric technology will require scientists, engineers, and innovators, further contributing to a thriving knowledge economy and fostering technological advancements.

Contribution to GDP:

- Increased energy security and efficiency: The widespread adoption of piezoelectric generators can lead to cost savings in energy generation and infrastructure maintenance, contributing to a rise in national GDP. Additionally, the export of this technology can boost international trade and economic growth.

Investment and innovation:

- The potential of piezoelectric energy attracts investments in research, development, and infrastructure, leading to further technological advancements and economic diversification. This can strengthen a nation's competitive edge and contribute to economic prosperity.

Quality of Life:

- Improved health and well-being: Cleaner air, reduced noise pollution, and increased access to energy and communication in remote areas can all contribute to a higher quality of life for citizens.
- Smarter cities and enhanced safety: Real-time infrastructure monitoring enabled by piezoelectric sensors can lead to improved traffic management, disaster preparedness, and public safety measures. This fosters a more resilient and livable urban environment.

Overall, our piezoelectric generator holds immense potential to revolutionize various aspects of our lives. By harnessing the power of everyday movement, it can pave the way for a more sustainable, resilient, and equitable future for all. Remember to adapt this description to our specific project's potential applications and societal impact areas. By highlighting the unique benefits and far-reaching consequences of our work, we can make a compelling case for the adoption and advancement of this exciting technology.

6.2 Environmental and Ethical Issues

Sustainability and Ethical Considerations of Our Piezoelectric Generator: While our piezoelectric generator holds immense potential for a greener future, it's crucial to acknowledge and address potential issues related to environmental sustainability, aesthetics, and ethical considerations.

Sustainability:

- Material sourcing: Ensure responsible sourcing of piezoelectric materials and other components to minimize environmental impact and avoid conflict minerals. Consider using recycled materials or bio-based options when possible.
- End-of-life management: Developing a plan for the safe disposal or recycling of used generators and components to prevent electronic waste pollution.
- Energy payback time: Analyzing the energy required to manufacture, install, and maintain our generator compared to the energy it generates. Aim for a short payback time to maximize its sustainability.
- Efficiency optimization: Continuously researching and improving the efficiency of our generator to minimize energy losses and maximize power output for a smaller environmental footprint.

Aesthetics:

- Integration and visual impact: Consider the visual appearance of our generator and its potential impact on the environment. Design it to blend seamlessly or enhance the aesthetics of its surroundings.
- Community acceptance: Involving local communities in the design and installation process to ensure their acceptance and address aesthetic concerns.
- Noise and vibration: Minimizing noise and vibration generated by our generator to prevent disruption and ensure a harmonious relationship with the environment.

Ethical Considerations:

- Fair labor practices: Ensuring fair wages and working conditions for all individuals involved in the manufacturing, installation, and maintenance of our generator.
- Access to technology: Ensuring equitable access to the benefits of our technology, particularly in underserved communities, to avoid exacerbating existing inequalities.
- Data privacy and security: If our generator collects data, ensure transparent data collection practices and robust security measures to protect user privacy.
- Responsible marketing and communication: Avoiding exaggerated claims or greenwashing tactics when promoting our technology. Focus on transparency and realistic expectations.

Addressing these issues proactively demonstrates our commitment to responsible development and ensures the long-term sustainability and positive impact of our piezoelectric generator. By considering both the environmental and ethical implications, we can build a truly sustainable technology that benefits both people and the planet.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Our piezoelectric journey culminates in a resounding success, exceeding specifications and resonating with stakeholder needs. We harnessed vibrations to generate potent power (2-19 volts, 8.925 watts average), successfully charging a 7800mAh battery with full charge projected within 4.441 hours under foot traffic. Our meticulously designed system paves the way for future advancements.

Beyond technical triumphs, this project opens doors to a vibrant future:

- Smart Cities: Sidewalks pulse with life, powering lights and sensors.
- Off-Grid Oasis: Remote communities bask in self-generated electricity.
- Buildings in Motion: Structures breathe with self-sufficiency.
- Wearable Revolution: Smartwatches dance to the rhythm of movement.
- IoT Symphony: A network of low-power sensors whispers data and orchestrates automation.

This project is not an endpoint, but a pulsating beginning, unlocking the potential of piezoelectric energy to power a greener, more sustainable future. The beat continues, forever charged by the movement of life itself.

7.2 New Skills and Experiences Learned

Technical Skills:

- Piezoelectric technology: We gained a deep understanding of how piezoelectric materials work and how to convert vibration into usable electricity. This includes knowledge of piezoelectric materials, circuit design principles, and data acquisition techniques.
- Electronics and programming: The project has involved building circuits, potentially involving other embedded systems. This honed our skills in soldering and component selection.

- Materials science and testing: It has been crucial to understand the mechanical properties of different materials and how they influence piezoelectric performance. This involved testing different materials, analyzing data, and optimizing the design based on our findings.
- Data analysis and visualization: Collecting and analyzing data from our generator requires skills in data analysis tools like multimeter and oscilloscope, as well as the ability to present our findings.

Soft Skills:

- Project management: Planning and executing a project from conception to completion involves skills in task management, time management, budgeting, and resource allocation. We have also learned how to adapt our plans when faced with challenges and unforeseen circumstances.
- Communication and collaboration: Communicating effectively with team members has been essential. We have also gained experience collaborating with our supervisor to solve problems and achieve goals.
- Critical thinking and problem-solving: Troubleshooting technical issues, analyzing data, and optimizing our design require critical thinking and problem-solving skills. We learned how to approach challenges systematically, analyze potential solutions, and implement the most effective ones.
- Entrepreneurial mindset: Depending on the scope of our project, we have developed an entrepreneurial mindset by identifying a market need, designing a solution, and potentially exploring how to bring our technology to market.

7.3 Future Recommendations

1. Integration with Electronics: Integration of piezoelectric generators with CMOS circuits and low power electronic systems will enable self powered devices without bulky batteries.
2. Additive manufactureing: 3D printing in creating complex shapes and geometries for piezoelectric generators will optimize efficiency and functionality for specific applications.
3. Hybride Energy Harvesting: Adding this technology with existing systems like solar and wind for increased power output and reliability in low resource settings.

   Further research and development are ongoing to improve the performance of piezoelectric energy harvesters. This includes investigating new materials, optimizing device designs, and developing efficient energy management systems. Additionally, exploring new applications for piezoelectric energy harvesting technology is crucial for its widespread adoption and impact.

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APPENDIX A

TURNITIN REPORT

Include here the 1st page of the Turnitin Report

Every supervisor has his/her own Turnitin account. If not, supervisors are requested to get the account from the Library as soon as possible.

APPENDIX B

DATASHEET OF COMPONENTS

Piezo Element

multicomp PRO

RoHS Compliant

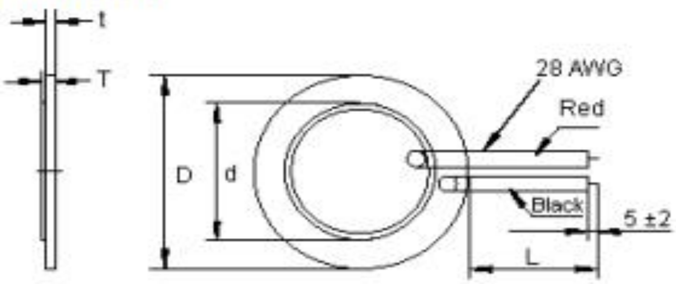
Features

- Low power consumption
- Reliable and lightweight

Specifications

Rated Max. Voltage (Vp-p Square Wave)	: 30 Vp-p
Capacitance	: 20,000 pF ±30%
Resonant Frequency	: 4,200 ±500Hz
Resonant Impedance	: ≥300Ω
Operating Temperature	: -20°C to +60°C
Storage Temperature	: -20°C to +70°C
Lead Wire	: 28 AWG

Dimensions



D	27mm ±0.1
d	20mm ±0.3
t	0.3mm ±0.02
T	0.52mm ±0.1
L	200mm

Part Number Table

Description	Part Number
Piezo Element, 27mm, 4,200Hz, Leaded	ABT-441-RC

Newark.com/multicomp-pro
Farnell.com/multicomp-pro
Element14.com/multicomp-pro

multicomp PRO

8. Characteristics

In this section, the Standard Conditions of Tests are used as described in part 6.

8.1 Electrical Performances

Items	Test procedure	Requirements
8.1.1 Nominal Voltage	The average value of the working voltage during the whole discharge process.	3.7V
8.1.2 Discharge Performance	The discharge capacity of the cell, measured with 1.3 A down to 3.0V within 1 hour after a completed charge.	≥114min
8.1.3 Capacity Retention	After 28 days storage at 25±5℃, after having been completely charged and discharged at 0.52A, discharge to 3.0V, the residual capacity is above 80%	Capacity≥2080mAh
8.1.4 Cycle Life	After 299 cycles at 100% DOD. Charge and discharge at 1.3A, and plus 1 day, measured under 0.52A charge and discharge, the residual discharge capacity is above 80% of initial capacity (Cycle life may be determined by conditions of charging, discharging, operating temperature and/or storage.)	300 cycles the residual capacity ≥2050mAh
8.1.5 Storage	(Within 3 months after manufactured) The cells is charged with 1.3A to 40-50% capacity and stored at ambient temperature 25±5℃, 65±20%RH for 12 months. After the 12 months storage period the cell is fully charged and discharged to 3.0V with 0.52A	Discharge time≥4h

8.2 Safety Performances

Items	Test procedure	Requirements
8.2.1 Short Circuit	The cell is to be short-circuited by connecting the positive and negative terminals of the cell directly with copper wire with a resistance of less than 0.05Ω.	No fire no explosion.
8.2.2 Impact Test	A test sample battery is to be placed on a flat surface. A 5/8 inch (15.8mm) diameter bar is to be placed across the center of the sample. A 20 pound (9.1kg) weight is to be dropped from a height of 24 ±1 inch (610±25mm) onto the sample.	No fire no explosion.

8.2.3 Overcharge (3C/10V)	The cell is connected with a thermocouple and put in a fume hood. The positive and negative terminals are connected to a DC power supply set at 7.8A and 10V until the cell reaches 10V and the current drops to approximately 0A. Monitor the temperature of cell. When the temperature of the cell is approximately 10℃ less than the peak value, the test is completed.	No fire, no explosion.
8.2.4 Thermal shock	After standard charging, heat the cell to 130±2℃ at a rate of 5±2℃ /min and keep it at this temperature during 30 minutes.	No fire, no explosion.

8.3 Environmental tests

Items	Test procedure	Requirements
8.3.1 High temperature performance	The fully charged cell is put at 55±2℃ for 2 hours and then discharged to 3.0V at 1.3A.	Capacity≥2080mAh
8.3.2 Low temperature performance	The fully charged cell is placed during 16-24 hours at -20±2℃ and then discharge to 2.75V at 0.52A.	Capacity≥1800mAh
8.3.3 Anti-vibration	The fully charged cell is fixed on a platform and vibrated in the X , Y and Z directions for 30minutes at the speed 10ct/min Frequency: 10~30Hz, Vibration amplitude 0.38mm. Frequency: 30~55Hz, Vibration amplitude 0.19mm.	No deformation should be visible. Not leak, smoke and/or explode. Voltage should be not less than 3.6V.
8.3.4 Drop Test	The fully charged cell is dropped from a height of 1m onto a 15~20mm hard board in X, Y and Z directions once for all axis. Then the cell is discharged at 1.3A to 3.0V followed by 3 or more cycles with the standard charge rate and a discharge at 1.3A.	No fire, no explosion. Discharge Time≥102min

9 . Packing

Cells are at a half-charged state when packed. The packing box surface will contain the following: name, type, nominal voltage, quantity, gross weight, date, capacity and impedance.

10 . Transportation

During transport, do not subject the cell(s) or the box (es) to violent shaking, bumps, rain and direct sunlight. Keep the cell(s) at a half-charged state.

11 . Long-term Storage

The cell should be used within a short period after charging because long-term storage may cause loss of capacity by self-discharging. If the cell is kept for a long time(3months or more), It is strongly recommended that the cell isstored at dry and low-temperature and Keep the cell(s) at a half-charged state. the cell should be shipped in 50% charged state. In this case, OCV is from 3.65V to 3.85V. Our shipping voltage is 3.75-3.80v . because storage at higher voltage may cause loss of characteristics.

- over a period of 1 month: -5 ~ 35℃, relative humidity: ≤75%. - over a period of 6 months: -20~ 25℃, relative humidity: ≤75%.

12 . Warranty

12.1 The warranty period of this product is 12 months starting at the date of delivery from the factory.

12.2 Warranty will be void if the cells are used outside these specifications.

12.3 EEMB will not be liable for any damages, personal, material, immaterial or otherwise, when the cells are used outside these specifications.

13 . Changes of specifications

The information in this specification is subject to change without prior notice.

14. For reference only

The information contained in this document is for reference only and should not be used as a basis for product guarantee or warranty. For applications other than those described here, please consult EEMB

15.Pack Quality Requirement for safety and quality

15.1 The battery pack's consumption current.

-Sleep Mode : Under 250uA.

-Shut Down Mode : Under 10uA / Under 3.0V.
Under 1uA / Under 2.5V.

15.2 Operating Charging Voltage of a cell.

-Normal operating voltage of a cell is 4.20V

-Max operating voltage of a cell is 4.25V.

15.3 Pre-charging function

-Pre-charge function should be implemented to prevent abnormal high rate charging after deep discharge.

-Pre-charging condition Operation : Under 3.0V

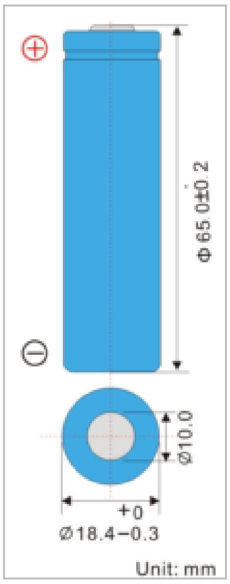
-Charging current : Under 150mA/Cell.(Continuous)

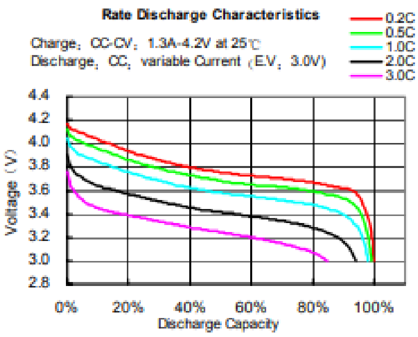
-Pre-charge stop (Normal Charge Start) : All cells reach 3.0V

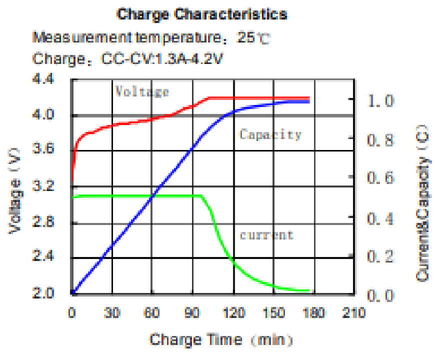
15.4. Cell voltage monitoring system.

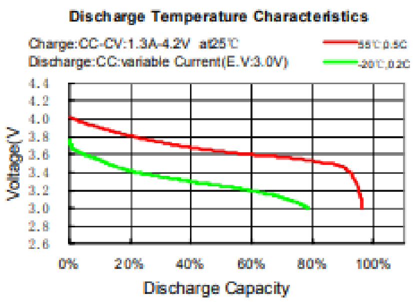
-The system (Charger or Pack) should equip a device to monitor each Cell voltage and to stop charging if a cell imbalance happened.

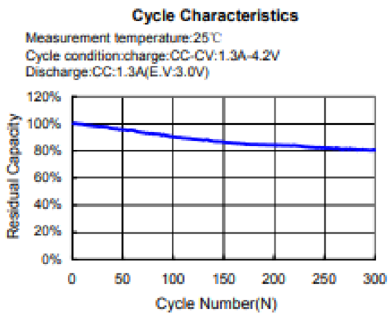
16. Dimension and Performance









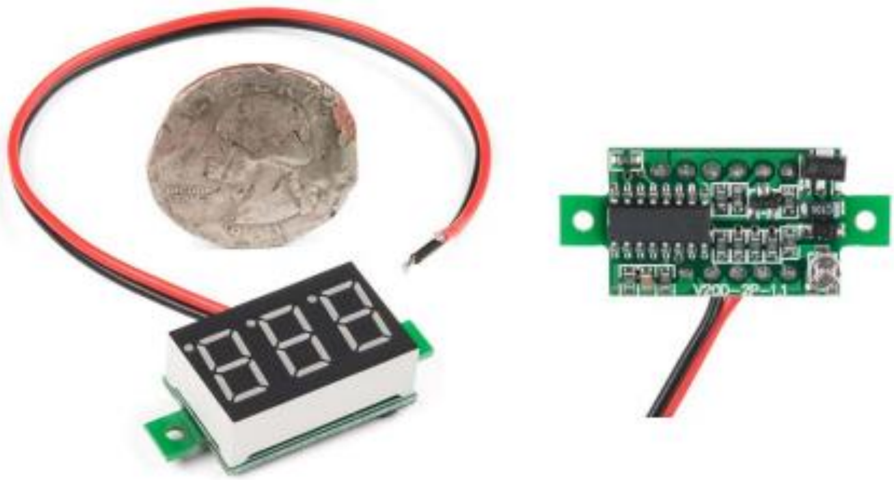


DATA SHEET OF VOLTMETER

sparkfun ELECTRONICS

Digital LED Voltmeter

PRT-14313



Description: This Digital LED Voltmeter measures the voltage at a particular point of the system it has been hooked up to and then provides a readout on its three 7-segment LEDs. This voltmeter is able to provide a readout of voltages from 2.5VDC to 30VDC within a 1% accuracy.

Features:

- Range: 2.5VDC — 30VDC
- Display: Three 0.28" Red 7-Segment LEDs
- Refresh Rate: ~1sec
- Accuracy Within 1%

DATA SHEET OF DIODE

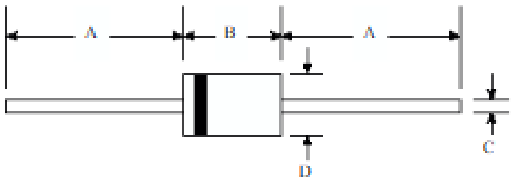
DIODES INCORPORATED

1N4001G/L - 1N4007G/L

1.0A GLASS PASSIVATED RECTIFIER

Features

- Glass Passivated Die Construction
- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Plastic Material - UL Flammability Classification 94V-0



	DO-41 Plastic		A-405	
Dim	Min	Max	Min	Max
A	25.40	—	25.40	—
B	4.06	5.21	4.10	5.20
C	0.71	0.864	0.53	0.64
D	2.00	2.72	2.00	2.70
All Dimensions in mm				

"L" Suffix Designates A-405 Package
No Suffix Designates DO-41 Package

Mechanical Data

- Case: Molded Plastic
- Terminals: Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Weight: DO-41 0.30 grams (approx)
  A-405 0.20 grams (approx)
- Mounting Position: Any
- Marking: Type Number

Maximum Ratings and Electrical Characteristics @ $T_A = 25°C$ unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001 G/GL	1N4002 G/GL	1N4003 G/GL	1N4004 G/GL	1N4005 G/GL	1N4006 G/GL	1N4007 G/GL	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ $T_A = 75°C$	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load (JEDEC Method)	I_{FSM}	30							A
Forward Voltage @ $I_F = 1.0A$	V_{FM}	1.0							V
Peak Reverse Current @ $T_A = 25°C$ at Rated DC Blocking Voltage @ $T_A = 125°C$	I_{RM}	5.0 50							µA
Reverse Recovery Time (Note 3)	t_{rr}	2.0							µs
Typical Junction Capacitance (Note 2)	C_j	8.0							pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Operating and Storage Temperature Range	T_j, T_{STG}	-65 to +175							°C

Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
2. Measured at 1.0 MHz and applied reverse voltage of 4.0V DC.
3. Measured with $I_F = 0.5A$, $I_R = -1A$, $I_{rr} = 0.25A$.

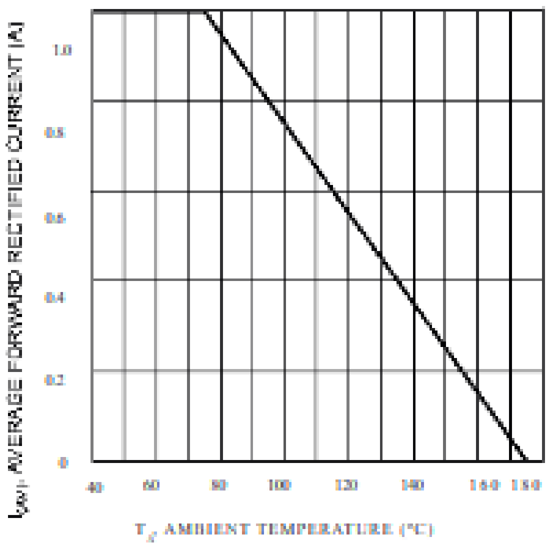


Fig. 1 Forward Current Derating Curve

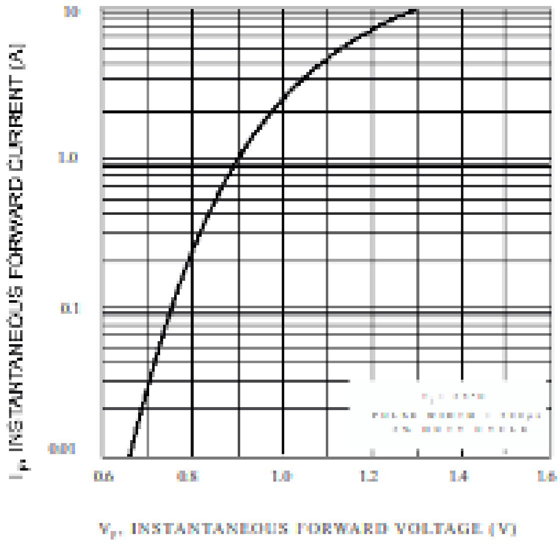


Fig.2 Typical Forward Characteristics

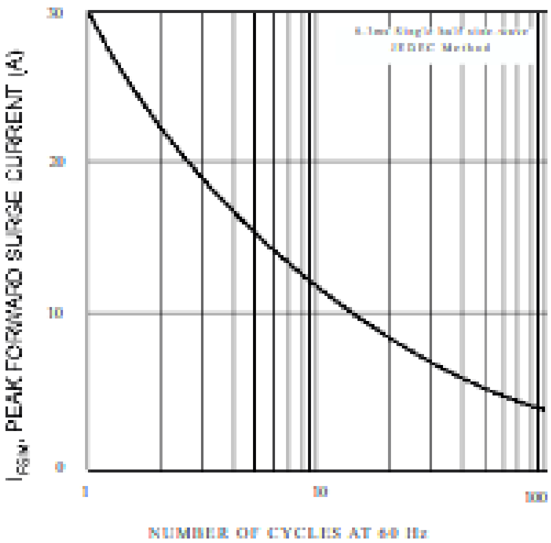


Fig. 3 Max Non-Repetitive Peak Fwd Surge Current

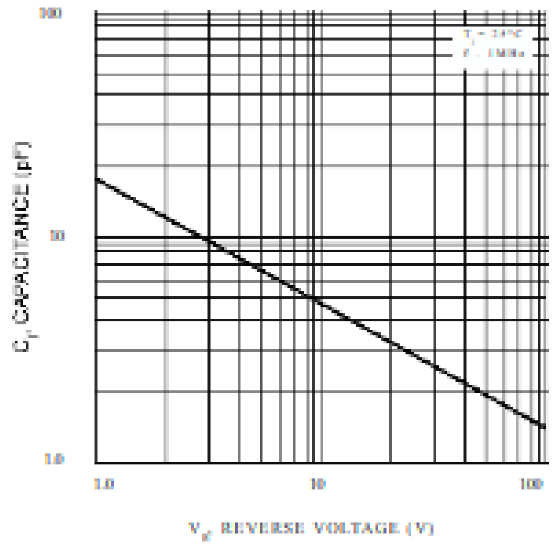


Fig.4 Typical Junction Capacitance

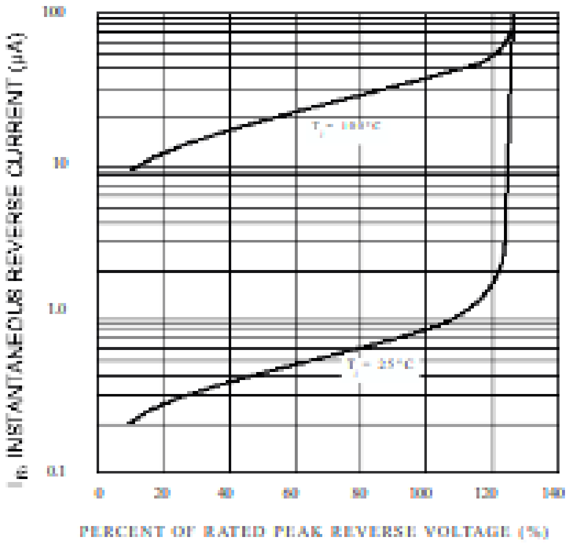


Fig.5 Typical Reverse Characteristics

DATA SHEET OF CAPACITOR

Aluminum Electrolytic Capacitors
Axial Standard Miniature

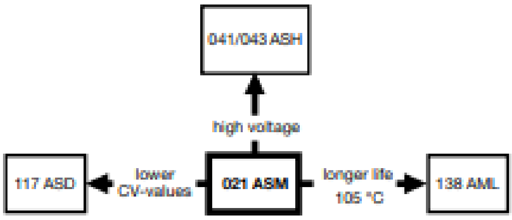


Fig. 1

QUICK REFERENCE DATA		
DESCRIPTION	**VALUE**	
Nominal case sizes (Ø D x L in mm)	4.5 x 10 to 10 x 25	10 x 30 to 21 x 38
Rated capacitance range, C_R	1 µF to 15 000 µF	
Tolerance on C_R	± 20 %	
Rated voltage range, U_R	6.3 V to 100 V	
Category temperature range	-40 °C to +85 °C	
Endurance test at 85 °C:		
U_R = 6.3 V to 25 V	1000 h	5000 h
U_R = 40 V to 100 V	2000 h	5000 h
Endurance test at 105 °C	-	2000 h
Useful life at 85 °C	2500 h	8000 h
Useful life at 40 °C, 1.4 x I_R applied	70 000 h	200 000 h
Shelf life at 0 V, 85 °C	500 h	
Based on sectional specification	IEC 60384-4 / EN 130300	
Climatic category IEC 60068	40 / 085 / 56	

FEATURES

- Long useful life: 2500 h to 8000 h at 85 °C
- Miniaturized, high CV-product per unit volume
- Charge and discharge proof
- Taped versions up to case Ø 15 mm x 30 mm available for automatic insertion
- Polarized aluminum electrolytic capacitors, non-solid electrolyte
- Axial leads, cylindrical aluminum case, insulated with a blue sleeve
- Mounting ring version not available in insulated form
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

APPLICATIONS

- General purpose, industrial, automotive, audio-video
- Coupling, decoupling, smoothing, filtering, buffering
- Portable and mobile equipment (small size, low mass)
- Low mounting height boards, vibration, and shock resistant

MARKING

The capacitors are marked (where possible) with the following information:

- Rated capacitance (in µF)
- Tolerance on rated capacitance, code letter in accordance with IEC 60062 (M for ± 20 %)
- Rated voltage (in V)
- Upper category temperature (85 °C)
- Date code in accordance with IEC 60062
- Code for factory of origin
- Name of manufacturer
- Negative terminal identification
- Series number (021)

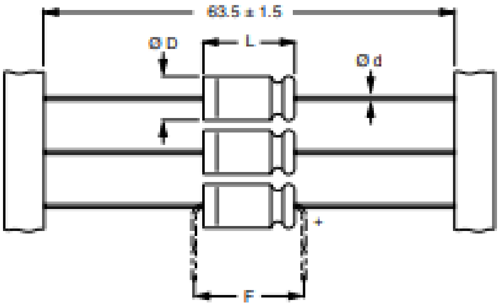
SELECTION CHART FOR C_R, U_R, AND RELEVANT NOMINAL CASE SIZES (Ø D x L in mm)

C_R (µF)	U_R (V)						
	6.3	**10**	**16**	**25**	**40**	**63**	**100**
1.0	-	-	-	-	-	4.5 x 10	4.5 x 10
2.2	-	-	-	-	-	4.5 x 10	4.5 x 10
3.3	-	-	-	-	-	4.5 x 10	-
4.7	-	-	-	-	-	4.5 x 10	4.5 x 10
10	-	-	-	-	-	4.5 x 10	6 x 10
15	-	-	-	-	-	4.5 x 10	8 x 11
	-	-	-	-	-	-	6.5 x 18
22	-	-	-	-	4.5 x 10	6 x 10	8 x 11
	-	-	-	-	-	-	6.5 x 18
33	-	-	-	-	-	6 x 10	6.5 x 18
47	-	-	-	4.5 x 10	6 x 10	8 x 11	8 x 18
	-	-	-	-	-	6.5 x 18	-

SELECTION CHART FOR C_R, U_R, AND RELEVANT NOMINAL CASE SIZES (Ø D x L in mm)

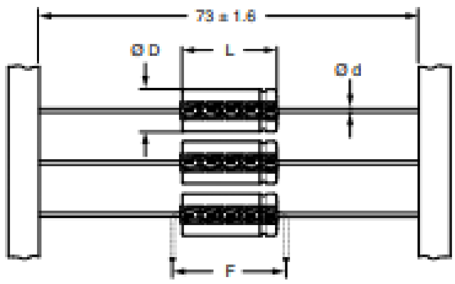
C_R (µF)	U_R (V)						
	6.3	10	16	25	40	63	100
68	-	-	4.5 x 10	-	-	8 x 11	10 x 18
	-	-	-	-	-	6.5 x 18	-
100	-	4.5 x 10	-	6 x 10	8 x 11	8 x 18	10 x 25
	-	-	-	-	6.5 x 18	-	10 x 30
150	-	-	6 x 10	8 x 11	8 x 18	10 x 18	12.5 x 30
	-	-	-	6.5 x 18	-	-	-
220	-	6 x 10	8 x 11	6.5 x 18	10 x 18	10 x 25	12.5 x 30
	-	-	-	-	-	10 x 30	-
330	-	8 x 11	6.5 x 18	8 x 18	10 x 25	12.5 x 30	15 x 30
470	8 x 11	6.5 x 18	8 x 18	10 x 18	10 x 25	12.5 x 30	18 x 30
	-	-	-	-	10 x 30	-	-
680	-	8 x 18	10 x 18	10 x 25	12.5 x 30	15 x 30	18 x 38
	-	-	-	10 x 30	-	-	-
1000	8 x 18	10 x 18	10 x 25	12.5 x 30	12.5 x 30	18 x 30	21 x 38
	-	-	10 x 30	-	-	-	-
1500	-	10 x 25	12.5 x 30	12.5 x 30	15 x 30	18 x 38	-
	-	10 x 30	-	-	-	-	-
2200	10 x 25	12.5 x 30	12.5 x 30	15 x 30	18 x 30	21 x 38	-
3300	-	12.5 x 30	15 x 30	18 x 30	18 x 38	-	-
4700	-	15 x 30	18 x 30	18 x 38	21 x 38	-	-
6800	-	18 x 30	18 x 38	21 x 38	-	-	-
10 000	-	18 x 38	21 x 38	-	-	-	-
15 000	-	21 x 38	-	-	-	-	-

DIMENSIONS in millimeters AND AVAILABLE FORMS



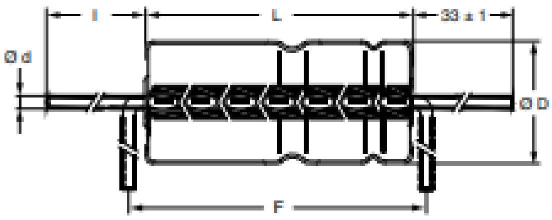
Form BR: Taped on reel
Form BA: Taped in box (ammopack)
Case Ø D x L = 4.5 mm x 10 mm to 8 mm x 11 mm

Fig. 2 - **Forms BA** and **BR**



Form BR: Taped on reel
Case Ø D x L = 6.5 mm x 18 mm to 15 mm x 30 mm
Form BA: Taped in box (ammopack)
Case Ø D x L = 6.5 mm x 18 mm to 10 mm x 25 mm

Fig. 3 - **Forms BA** and **BR**



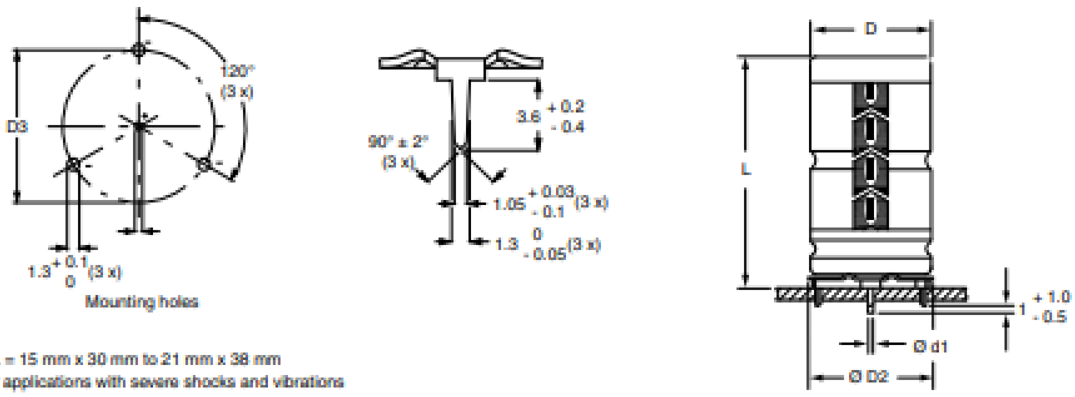
Form AA: Axial in box
Case Ø D x L = 10 mm x 30 mm to 21 mm x 38 mm
Fig. 4 - **Form AA**

Table 1

AXIAL; DIMENSIONS in millimeters, **MASS AND PACKAGING QUANTITIES**										
NOMINAL CASE SIZE Ø D x L	**CASE CODE**	**AXIAL: FORM AA, BA, AND BR**					**MASS (g)**	**PACKAGING QUANTITIES**		
		Ø d	**l**	**Ø $D_{max.}$**	**$L_{max.}$**	**$F_{min.}$**		**FORM AA**	**FORM BA**	**FORM BR**
4.5 x 10	2	0.6	-	5.0	10.5	15	≈ 0.5	-	1000	3000
6 x 10	3	0.6	-	6.3	10.5	15	≈ 0.7	-	1000	1000
8 x 11	5a	0.6	-	8.5	11.5	15	≈ 1.1	-	500	500
6.5 x 18	4	0.8	-	6.9	18.5	25	≈ 1.3	-	1000	1000
8 x 18	5	0.8	-	8.5	18.5	25	≈ 1.7	-	500	500
10 x 18	6	0.8	-	10.5	18.5	25	≈ 2.5	-	500	500
10 x 25	7	0.8	-	10.5	25.5	30	≈ 3.3	-	500	500
10 x 30	00	0.8	55 ± 1	10.5	30.5	35	≈ 4.8	340	-	500
12.5 x 30	01	0.8	55 ± 1	13.0	30.5	35	≈ 7.4	260	-	400
15 x 30	02	0.8	55 ± 1	15.5	30.5	35	≈ 11.7	200	-	250
18 x 30	03	0.8	55 ± 1	18.5	30.5	35	≈ 12.9	120	-	-
18 x 38	04	0.8	34 ± 1	18.5	39.5	44	≈ 19.0	125	-	-
21 x 38	05	0.8	34 ± 1	21.5	39.5	44	≈ 24.0	100	-	-

Note

- For detailed tape dimensions, please see www.vishay.com/doc?28361.



Form MR:
Case Ø D x L = 15 mm x 30 mm to 21 mm x 38 mm
Especially for applications with severe shocks and vibrations

Fig. 5 - Mounting hole diagram and outline. **Form MR:** With mounting ring and pins

Table 2

MOUNTING RING; DIMENSIONS in millimeters, **MASS AND PACKAGING QUANTITIES**								
NOMINAL CASE SIZE Ø D x L	**CASE CODE**	**MOUNTING RING: FORM MR**					**MASS (g)**	**PACKAGING QUANTITIES**
		Ø d1	**Ø d2**	**Ø $D2_{max.}$**	**D3**	**$L_{max.}$**		
15 x 30	02	0.8	1.0 + 0.4	17.5	16.5 ± 0.2	33	≈ 11.7	200
18 x 30	03	0.8	1.0 + 0.4	19.5	18.5 ± 0.2	33	≈ 12.9	240
18 x 38	04	0.8	1.0 + 0.4	19.5	18.5 ± 0.2	42	≈ 19.0	100
21 x 38	05	0.8	1.0 + 0.4	22.5	21.5 ± 0.2	42	≈ 24.0	100

ELECTRICAL DATA	
SYMBOL	DESCRIPTION
C_R	Rated capacitance at 100 Hz, tolerance ± 20 %
I_R	Rated RMS ripple current at 100 Hz, 85 °C
I_{L5}	Max. leakage current after 5 min at U_R
tan δ	Max. dissipation factor at 100 Hz
ESR	Equivalent series resistance at 100 Hz (calculated from tan $\delta_{max.}$ and C_R)
Z	Max. impedance at 10 kHz

Note

- Unless otherwise specified, all electrical values in Table 3 apply at T_{amb} = 20 °C, P = 86 kPa to 106 kPa, RH = 45 % to 75 %.

ORDERING EXAMPLE

Electrolytic capacitor 021 series

1000 µF / 16 V; ± 20 %

Nominal case size: Ø 10 mm x 25 mm; Form BA

Ordering code: MAL202190518E3

Former 12 NC: 2222 021 90518

Table 3

ELECTRICAL DATA AND ORDERING INFORMATION

U_R (V)	C_R 100 Hz (µF)	NOMINAL CASE SIZE Ø D x L (mm)	I_R 100 Hz 85 °C (mA)	I_{L5} 5 min (µA)	tan δ 100 Hz	ESR 100 Hz (Ω)	Z 10 kHz (Ω)	LIFE CODE [1]	ORDERING CODE MAL2021.......			
									IN BOX FORM AA	TAPED ON REEL FORM BR	TAPED IN BOX FORM BA	MOUNTING RING FORM MR
6.3	470	8 x 11	260	10	0.25	0.850	0.640	L1	-	23471E3	33471E3	-
	1000	8 x 18	440	17	0.25	0.400	0.500	L1	-	23102E3	33102E3	-
	2200	10 x 25	710	32	0.29	0.210	0.160	L1	-	90588E3	90589E3	-
10	100	4.5 x 10	100	6	0.20	3.200	2.000	L1	-	24101E3	34101E3	-
	220	6 x 10	160	8.4	0.20	1.500	0.910	L1	-	24221E3	34221E3	-
	330	8 x 11	230	11	0.20	1.000	0.610	L1	-	24331E3	34331E3	-
	470	6.5 x 18	310	13	0.20	0.680	0.430	L1	-	24471E3	34471E3	-
	680	8 x 18	400	18	0.20	0.470	0.290	L1	-	24681E3	34681E3	-
	1000	10 x 18	550	24	0.20	0.320	0.200	L1	-	24102E3	34102E3	-
	1500	10 x 25	690	34	0.23	0.250	0.180	L1	-	90524E3	90525E3	-
	1500	10 x 30	740	34	0.23	0.245	0.180	L3	14152E3	24152E3	-	-
	2200	12.5 x 30	980	48	0.25	0.177	0.095	L3	14222E3	24222E3	-	-
	3300	12.5 x 30	1090	70	0.27	0.128	0.095	L3	14332E3	24332E3	-	-
	4700	15 x 30	1320	98	0.29	0.100	0.070	L3	14472E3	24472E3	-	44472E3
	6800	18 x 30	1590	140	0.34	0.079	0.065	L3	14682E3	-	-	44682E3
	10 000	18 x 38	2090	204	0.40	0.064	0.040	L3	14103E3	-	-	44103E3
	15 000	21 x 38	2250	304	0.50	0.054	0.035	L3	14153E3	-	-	44153E3
16	68	4.5 x 10	90	6.2	0.16	3.800	2.400	L1	-	25689E3	35689E3	-
	150	6 x 10	140	8.8	0.16	1.700	1.100	L1	-	25151E3	35151E3	-
	220	8 x 11	210	11	0.16	1.200	0.730	L1	-	25221E3	35221E3	-
	330	6.5 x 18	290	15	0.16	0.770	0.480	L1	-	25331E3	35331E3	-
	470	8 x 18	380	19	0.16	0.550	0.340	L1	-	25471E3	35471E3	-
	680	10 x 18	500	26	0.16	0.380	0.240	L1	-	25681E3	35681E3	-
	1000	10 x 25	660	36	0.16	0.260	0.180	L1	-	90517E3	90518E3	-
	1000	10 x 30	700	36	0.16	0.260	0.175	L3	15102E3	25102E3	-	-
	1500	12.5 x 30	950	52	0.19	0.205	0.095	L3	15152E3	25152E3	-	-
	2200	12.5 x 30	1040	74	0.21	0.150	0.095	L3	15222E3	25222E3	-	-
	3300	15 x 30	1290	110	0.23	0.111	0.070	L3	15332E3	25332E3	-	45332E3
	4700	18 x 30	1560	154	0.25	0.087	0.065	L3	15472E3	-	-	45472E3
	6800	18 x 38	2040	222	0.30	0.070	0.040	L3	15682E3	-	-	45682E3
	10 000	21 x 38	2170	324	0.36	0.058	0.035	L3	15103E3	-	-	45103E3
25	47	4.5 x 10	80	6.4	0.14	4.800	2.600	L1	-	26479E3	36479E3	-
	100	6 x 10	150	9	0.14	2.300	1.200	L1	-	26101E3	36101E3	-
	150	8 x 11	190	12	0.14	1.500	0.800	L1	-	90534E3	90535E3	-
	150	6.5 x 18	210	12	0.14	1.500	0.800	L1	-	26151E3	36151E3	-
	220	6.5 x 18	250	15	0.14	1.000	0.550	L1	-	26221E3	36221E3	-
	330	8 x 18	340	21	0.14	0.680	0.360	L1	-	26331E3	36331E3	-
	470	10 x 18	450	28	0.14	0.480	0.260	L1	-	26471E3	36471E3	-
	680	10 x 25	560	38	0.14	0.330	0.180	L1	-	90527E3	90528E3	-
	680	10 x 30	640	38	0.14	0.323	0.175	L3	16681E3	26681E3	-	-
	1000	12.5 x 30	840	54	0.14	0.220	0.095	L3	16102E3	26102E3	-	-
	1500	12.5 x 30	950	79	0.17	0.179	0.095	L3	16152E3	26152E3	-	-
	2200	15 x 30	1180	114	0.19	0.132	0.070	L3	16222E3	26222E3	-	46222E3
	3300	18 x 30	1470	169	0.21	0.099	0.065	L3	16332E3	-	-	46332E3
	4700	18 x 38	1920	239	0.23	0.079	0.040	L3	16472E3	-	-	46472E3
	6800	21 x 38	2070	344	0.28	0.064	0.035	L3	16682E3	-	-	46682E3

ELECTRICAL DATA AND ORDERING INFORMATION

U_R (V)	C_R 100 Hz (µF)	NOMINAL CASE SIZE Ø D x L (mm)	I_R 100 Hz 85 °C (mA)	I_{L5} 5 min (µA)	tan δ 100 Hz	ESR 100 Hz (Ω)	Z 10 kHz (Ω)	LIFE CODE [1]	ORDERING CODE MAL2021....... IN BOX FORM AA	TAPED ON REEL FORM BR	TAPED IN BOX FORM BA	MOUNTING RING FORM MR
	22	4.5 x 10	60	5.8	0.11	8.000	3.200	L2	-	27229E3	37229E3	-
	47	6 x 10	110	7.8	0.11	3.800	1.500	L2	-	27479E3	37479E3	-
	100	8 x 11	170	12	0.11	1.800	0.700	L2	-	90537E3	90538E3	-
	100	6.5 x 18	190	12	0.11	1.800	0.700	L2	-	27101E3	37101E3	-
	150	8 x 18	250	16	0.11	1.100	0.470	L2	-	27151E3	37151E3	-
	220	10 x 18	330	22	0.11	0.800	0.320	L2	-	27221E3	37221E3	-
	330	10 x 25	430	30	0.11	0.530	0.210	L2	-	27331E3	37331E3	-
40	470	10 x 25	520	42	0.11	0.370	0.180	L2	-	90514E3	90515E3	-
	470	10 x 30	590	42	0.12	0.404	0.175	L3	17471E3	27471E3	-	-
	680	12.5 x 30	800	58	0.12	0.297	0.110	L3	17681E3	27681E3	-	-
	1000	12.5 x 30	900	84	0.12	0.190	0.110	L3	17102E3	27102E3	-	-
	1500	15 x 30	1120	124	0.15	0.159	0.070	L3	17152E3	27152E3	-	47152E3
	2200	18 x 30	1390	180	0.17	0.118	0.065	L3	17222E3	-	-	47222E3
	3300	18 x 38	1810	268	0.19	0.090	0.040	L3	17332E3	-	-	47332E3
	4700	21 x 38	1940	380	0.21	0.072	0.035	L3	17472E3	-	-	47472E3
	1.0	4.5 x 10	12	4.1	0.09	150.0	55.00	L2	-	28108E3	38108E3	-
	2.2	4.5 x 10	21	4.3	0.09	65.00	25.00	L2	-	28228E3	38228E3	-
	3.3	4.5 x 10	25	4.4	0.09	44.00	17.00	L2	-	28338E3	38338E3	-
	4.7	4.5 x 10	31	4.6	0.09	31.00	12.00	L2	-	28478E3	38478E3	-
	10	4.5 x 10	50	5.3	0.08	13.00	5.500	L2	-	28109E3	38109E3	-
	15	4.5 x 10	55	5.9	0.08	8.500	3.700	L2	-	28159E3	38159E3	-
	22	6 x 10	90	6.8	0.08	5.800	2.500	L2	-	28229E3	38229E3	-
	33	6 x 10	100	8.2	0.08	3.900	1.700	L2	-	28339E3	38339E3	-
	47	8 x 11	140	10	0.08	2.700	1.200	L2	-	90541E3	90542E3	-
	47	6.5 x 18	150	10	0.08	2.700	1.200	L2	-	28479E3	38479E3	-
63	68	8 x 11	160	13	0.08	1.900	0.810	L2	-	90544E3	90545E3	-
	68	6.5 x 18	170	13	0.08	1.900	0.810	L2	-	28689E3	38689E3	-
	100	8 x 18	250	17	0.08	1.300	0.550	L2	-	28101E3	38101E3	-
	150	10 x 18	320	23	0.08	0.850	0.370	L2	-	28151E3	38151E3	-
	220	10 x 25	430	32	0.08	0.600	0.250	L2	-	90511E3	90512E3	-
	220	10 x 30	480	32	0.08	0.614	0.260	L3	18221E3	28221E3	-	-
	330	12.5 x 30	610	46	0.08	0.409	0.190	L3	18331E3	28331E3	-	-
	470	12.5 x 30	700	63	0.08	0.287	0.130	L3	18471E3	28471E3	-	-
	680	15 x 30	890	90	0.08	0.199	0.095	L3	18681E3	28681E3	-	48681E3
	1000	18 x 30	1170	130	0.08	0.135	0.075	L3	18102E3	-	-	48102E3
	1500	18 x 38	1530	193	0.11	0.122	0.045	L3	18152E3	-	-	48152E3
	2200	21 x 38	1780	281	0.13	0.099	0.040	L3	18222E3	-	-	48222E3
	1.0	4.5 x 10	14	4.2	0.08	130.0	90.00	L2	-	29108E3	39108E3	-
	2.2	4.5 x 10	20	4.4	0.08	58.00	41.00	L2	-	29228E3	39228E3	-
	4.7	4.5 x 10	30	4.9	0.08	27.00	19.00	L2	-	29478E3	39478E3	-
	10	6 x 10	65	6	0.08	13.00	9.000	L2	-	29109E3	39109E3	-
	15	8 x 11	77	7	0.08	8.500	6.000	L2	-	90547E3	90548E3	-
	15	6.5 x 18	85	7	0.08	8.500	6.000	L2	-	29159E3	39159E3	-
	22	8 x 11	95	8.4	0.08	5.800	4.100	L2	-	90551E3	90552E3	-
	22	6.5 x 18	100	8.4	0.08	5.800	4.100	L2	-	29229E3	39229E3	-
	33	6.5 x 18	120	10.6	0.08	3.900	2.700	L2	-	29339E3	39339E3	-
100	47	8 x 18	160	13.4	0.08	2.700	1.900	L2	-	29479E3	39479E3	-
	68	10 x 18	220	17.6	0.08	1.900	1.300	L2	-	29689E3	39689E3	-
	100	10 x 25	300	24	0.08	1.300	0.900	L2	-	90531E3	90532E3	-
	100	10 x 30	340	24	0.07	1.150	1.000	L3	19101E3	29101E3	-	-
	150	12.5 x 30	490	34	0.07	0.645	0.610	L3	19151E3	29151E3	-	-
	220	12.5 x 30	560	48	0.08	0.610	0.560	L3	19221E3	29221E3	-	-
	330	15 x 30	740	70	0.09	0.420	0.400	L3	19331E3	29331E3	-	49331E3
	470	18 x 30	980	98	0.09	0.310	0.290	L3	19471E3	-	-	49471E3
	680	18 x 38	1260	140	0.09	0.195	0.180	L3	19681E3	-	-	49681E3
	1000	21 x 38	1470	204	0.10	0.160	0.150	L3	19102E3	-	-	49102E3

Note

[1] Determines the applicable row in the table "Endurance Test Duration and Useful Life"

ADDITIONAL ELECTRICAL DATA			
PARAMETER	**CONDITIONS**	**VALUE**	
		AXIAL	**MOUNTING RING**
Voltage			
Surge voltage		$U_s \leq 1.15 \times U_R$	
Reverse voltage		$U_{rev} \leq 1$ V	
Current			
Leakage current	After 1 min at U_R	$I_{L1} \leq 0.006\ C_R \times U_R + 4\ \mu A$	
	After 5 min at U_R	$I_{L5} \leq 0.002\ C_R \times U_R + 4\ \mu A$	
Inductance			
Equivalent series inductance (ESL)	Case Ø D x L mm:		
	4.5 x 10	Typ. 10 nH	-
	6 x 10	Typ. 22 nH	-
	8 x 11	Typ. 85 nH	-
	6.5 x 18	Typ. 25 nH	-
	8 x 18	Typ. 40 nH	-
	10 x 18	Typ. 61 nH	-
	10 x 25	Typ. 38 nH	-
	10 x 30	Typ. 38 nH	-
	12.5 x 30	Typ. 46 nH	-
	15 x 30	Typ. 48 nH	Typ. 39 nH
	18 x 30	Typ. 50 nH	Typ. 39 nH
	18 x 38	Typ. 54 nH	Typ. 39 nH
	21 x 38	Typ. 59 nH	Typ. 39 nH

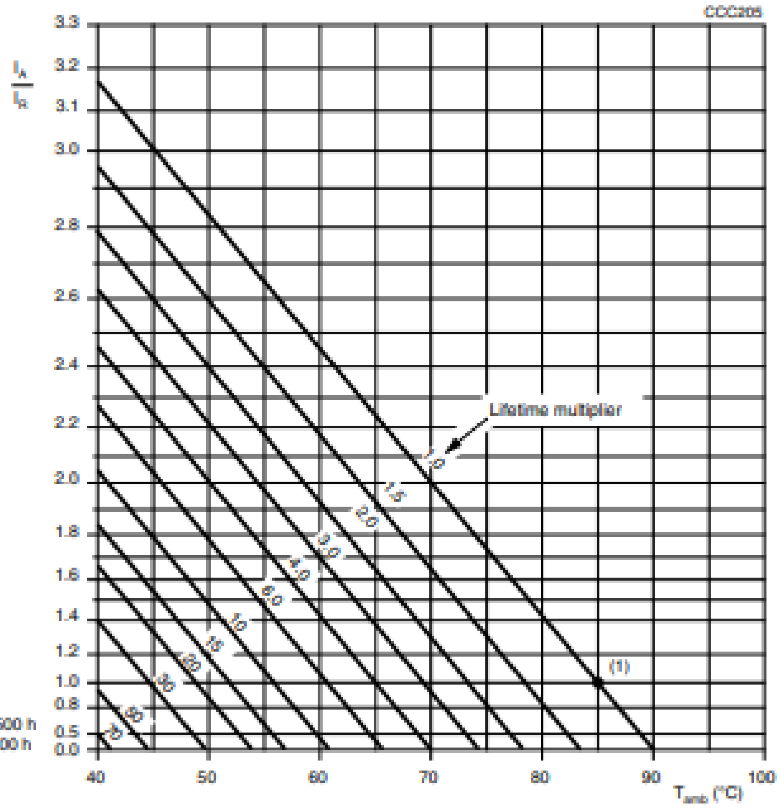
RIPPLE CURRENT AND USEFUL LIFE

Table 4

ENDURANCE TEST DURATION AND USEFUL LIFE			
LIFE CODE	**ENDURANCE AT 85 °C (h)**	**ENDURANCE AT 105 °C (h)**	**USEFUL LIFE AT 85 °C (h)**
L1	1000	-	2500
L2	2000	-	2500
L3	5000	2000	8000

Note

- Multiplier of useful life code: CCC205



I_A = Actual ripple current at 100 Hz
I_R = Rated ripple current at 100 Hz, 85 °C

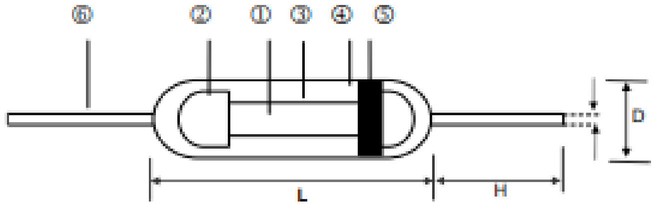
(1) Useful life at 85 °C and I_R applied:
Case Ø D x L = 4.5 mm x 10 mm to 10 mm x 25 mm: 2500 h
Case Ø D x L = 10 mm x 30 mm to 21 mm x 38 mm: 8000 h

Fig. 6 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 5

MULTIPLIER OF RIPPLE CURRENT (I_R) AS A FUNCTION OF FREQUENCY						
U_R	FREQUENCY (Hz)					
	50	100	300	1000	3000	≥ 10 000
	I_R MULTIPLIER					
6.3	0.95	1.00	1.07	1.12	1.15	1.20
10	0.95	1.00	1.07	1.12	1.15	1.20
16	0.95	1.00	1.07	1.12	1.15	1.20
25	0.90	1.00	1.12	1.20	1.25	1.30
40	0.90	1.00	1.12	1.20	1.25	1.30
63	0.85	1.00	1.20	1.30	1.35	1.40
100	0.85	1.00	1.20	1.30	1.35	1.40

DATA SHEET OF RESISTOR



①	Ceramic Rod	④	Non-flame Paint With Sol Vent-proof
②	Tinned Iron Caps	⑤	Colour Code
③	Carbon Film	⑥	Lead Wire

■Dimensions

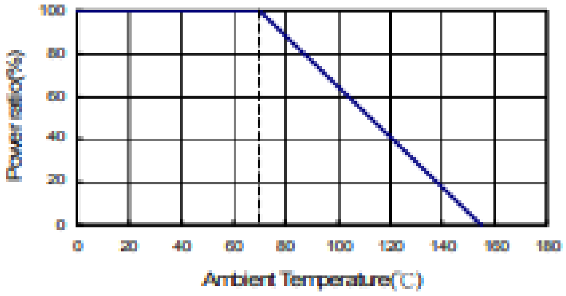
Unit: mm

Type	L	D	H	d	Weight (g) (1000pcs)
Carbon 0.125W	3.3+0.4/-0.2	1.8±0.3	29.3±2.0	0.452.3±0.03	92
Carbon 0.25W	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 0.5W (H)	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 1W (H)	9.0±0.5	3.2±0.5	26±2.0	0.65±0.03	352
Carbon 2W (H)	11.5±1.0	4.5±0.5	35±2.0	0.78±0.03	775

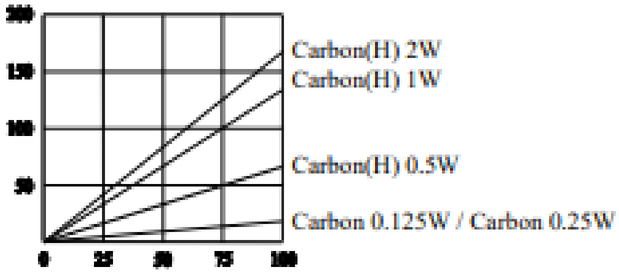
■Part Numbering

RS-	Carbon-	1R-	5%-	0.125W
Series				Power rating @ 70℃
	Carbon Carbon(H)	0.5R: 0.5 Ω	±5%	0.125W

■Derating Curve



■Hop-Spot Temperature



■Environmental Characteristics

Item	Requirement	Test Method
Short Time Overload	±(0.75%+0.05Ω)	**JIS-C-5201-1 5.5** RCWV*2.5 or Max. overload voltage for 5 seconds
Insulation Resistance	>1000MΩ	**JIS-C-5201-1 5.6** Apply $100V_{DC}$ for 1 minute
Endurance	±(3%+0.05Ω)	**JIS-C-5201-1 7.10** 70±2°C, Max. working voltage for 1000 hrs with 1.5 hrs "ON" and 0.5 hrs "OFF"
Damp Heat with Load	100KΩ±3% 100KΩ±5%	**JIS-C-5201-1 7.9** 40±2°C, 90~95% R.H. Max. working voltage for 1000 hrs with 1.5 hrs "ON" and 0.5 hrs "OFF"
Solderability	90% min. Coverage	**JIS-C-5201-1 6.5** 245±5°C for 3 seconds
Dielectric Withstanding Voltage	By Type	**JIS-C-5201-1 5.7** Apply Max. Overload Voltage for 1 minute
Temperature Coefficient	< 100KΩ +350ppm~-500ppm 100KΩ~1MΩ -0ppm~-700ppm > 1 MΩ -0ppm~-1500ppm	Resistance value at room temperature and room Temperature+100°C
Pulse Overload	±(1%+0.05Ω)	**JIS-C-5201-1 5.8** 4 times RCWV for 10000 cycles with 1 second "ON" and 25 seconds "OFF"
Resistance To Solvent	No deterioration of coatings and markings	**JIS-C-5201-1 6.9** Trichroethane for 1 min. with ultrasonic
Terminal Strength	Tensile: 2.5 kg	Direct Load for 10 seconds In the direction off the terminal leads

■ Rated Continuous Working Voltage(RCWV) = $\sqrt{P*R}$
■ Storage Temperature: 25±3°C; Humidity < 80%RH

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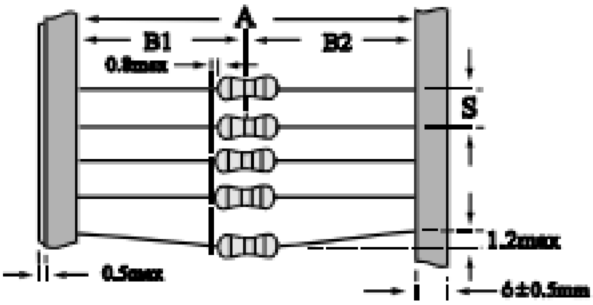
■Electrical Specifications

Type \ Item	Power Rating at 70°C	Operating Temp. Range	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Resistance Range ±5%
Carbon	0.125W	-55 ~ +155°C	150V	300V	300V	0.1Ω - 22MΩ
Carbon	0.25W		250V	500V	500V	1Ω - 10MΩ
Carbon(H)	0.5W		300V	500V	500V	0.1Ω - 22MΩ
Carbon(H)	1W		400V	800V	800V	1Ω - 10MΩ
Carbon(H)	2W		500V	1000V	1000V	0.1Ω - 10MΩ

■Taping/Packing Specifications

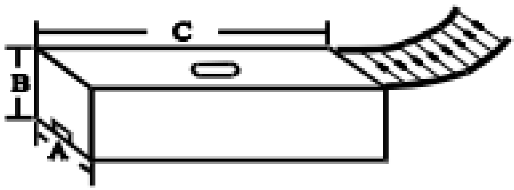
Packing Methods (Ammo)



Unit: mm

Type \ Packaging	Packing Methods A	B1-B2	S
Carbon 0.125W	52+1/-0	1.2	5
Carbon 0.25W	52+1/-0	1.2	5
Carbon 0.5W (H)	52+1/-0	1.2	5
Carbon 1W (H)	52+1/-0	1.5	5
Carbon 2W (H)	52+1/-0	1.5	10

Ammo Packing



Unit: mm

Type \ Packaging	Packing Methods			Ammo Packing			
	A	B1-B2	S	A	B	C	Qty
Carbon 0.125W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.25W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.5W (H)	26+1/-0	1.0	5	80	105	264	5,000
Carbon 1W (H)	73+1/-0	1.5	5	103	82	265	1,000
Carbon 2W (H)	73+1/-0	1.5	10	103	96	265	1,000

■Marking & Resistance Tolerance

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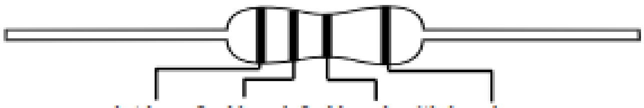


±5%	E-24	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2	9.1

Cold	Digit	Multiplier	Tolerance	
	-	-	-	-
	-	10^{-2}	-	-
	-	10^{-1}	±5.0%	J
	0	10^{0}	-	-
	1	10^{1}	-	-
	2	10^{2}	-	-
	3	10^{3}	-	-
	4	10^{4}	-	-
	5	10^{5}	-	-
	6	10^{6}	-	-
	7	10^{7}	-	-
	8	10^{8}	-	-
	9	10^{9}	-	-

DATA SHEET OF PROTECTION BOARD

HOTCHIP

HT4928S Ver1.1 1/6

www.hotchip.com.cn — Mobile power management solution

Product description

The HT4928S is a highly integrated mobile power supply Management chip, built-in charge management module, LED indicator Block, boost discharge management module, and use small SOP8 Package, the periphery can be composed of very few components Powerful mobile power solution.

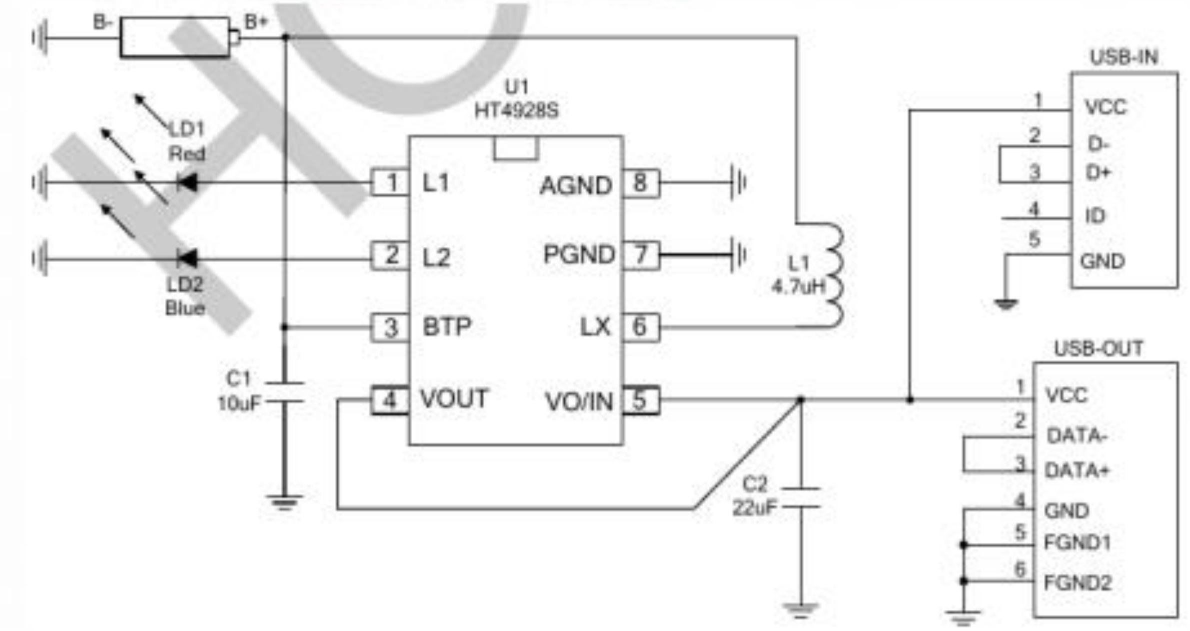
Main features

◆ Highly integrated, few peripheral components;
◆ Built-in fixed 0.8A linear charging mode;
◆ turbulent / constant current / constant voltage three-stage charging, constant voltage 4.20V (typical), supporting charging of 0V battery;
◆ Built-in charging can automatically reduce the charging current according to the temperature rise. 130 degrees begins to decline, and the minimum can be reduced to 0;
◆ The charging input has anti-backflow function, no need for anti-reverse irrigation diode;
◆ Boost uses synchronous rectification circuit, the efficiency is up to 91%, Low heat, fixed 5.1V output, no external resistor required
◆ Output current 0.8A (typical value at 3.6V battery), with Constant power output function, complete overcurrent, short circuit protection
◆ Load insertion automatically starts boost, load removal Automatic sleep
◆ Battery low voltage reminder function;
◆ Single/dual lamp charging and discharging instructions;
◆ Common input/output port, intelligent identification charging/discharging of electricity;
◆ 4KV ESD;
◆ Fixed switching frequency 1MHZ;
◆ Battery overcharge and over discharge protection;
◆ SOP8 small package

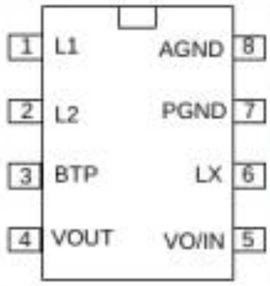
Typical application

◆ Mobile power
◆ LED lighting system
◆ Toys

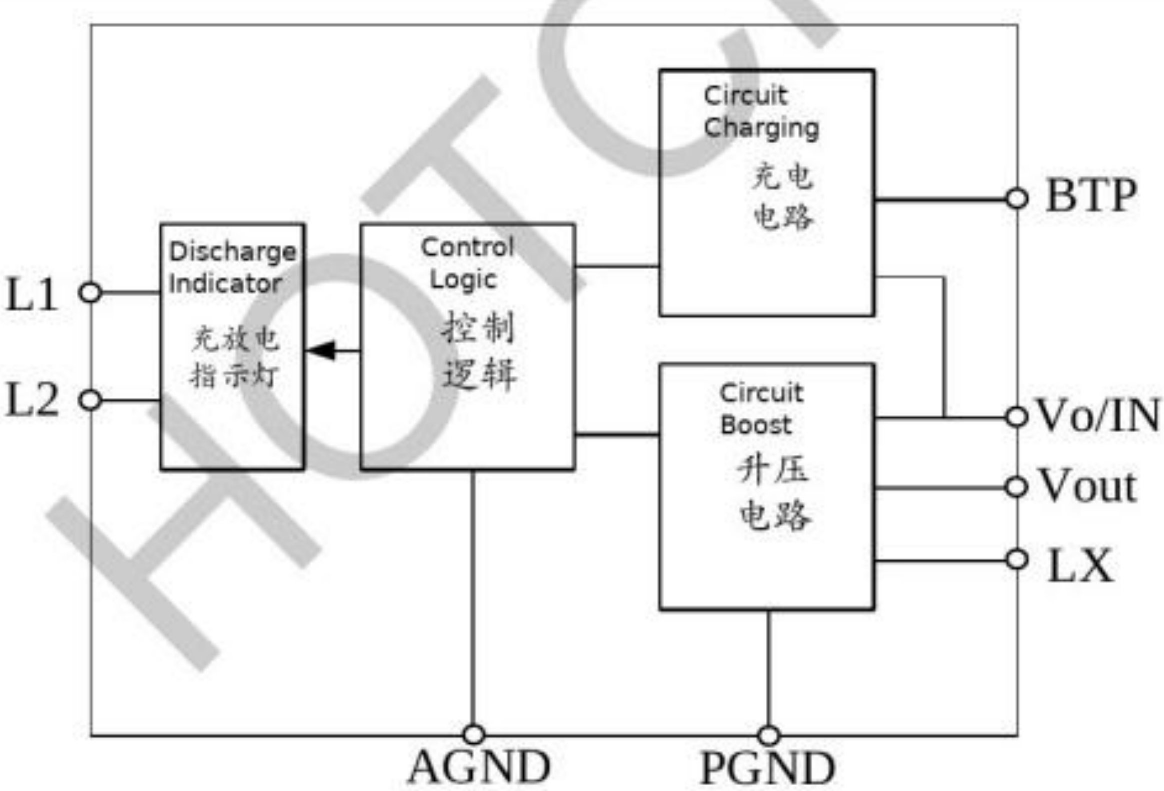
Typical application circuit diagram



Pin definition

SOP8	Pin name	Pin number	Function Description
	L1	1	Indicator light 1
	L2	2	Indicator light 2
	BTP	3	Battery end
	VOUT	4	Output voltage feedback
	VO/IN	5	Output/input
	LX	6	Inductance
	PGND	7	Power ground
	AGND	8	Analog ground

Circuit internal structure block diagram



Typical parameters

(Except for special instructions, all parameters are measured at room temperature and the potential at the GND terminal is 0)

Symbol	Description	Test Conditions	Unit	Min	Typ	Max
System parameters						
V IN	Input voltage range		V	4.5	5	5.5
Vbat	Battery voltage		V	2.95		4.4
Charging parameter						
V IN power down monitor	VIN from low to high	Vin>BAT	mV		250	
	VIN from high to low	Vin>BAT	mV		50	
V float	Floating charge threshold voltage		V	4.158	4.20	4.242
Ichg	Recharging current	VIN=4.75-5.25V	A		0.8	
V TRKL	Turbulent flow	VBAT from low to high	V		2.8	
V TRHYS	Trickle charging hysteresis voltage		mV		100	
V RECHG	Recharge threshold voltage		V		4.1	
Discharge parameter						
V o	Boost system output voltage		V	4.95	5.1	5.25
Iout	Output current	BAT=3.6V Vout>4.8V	A		0.8	
V OVP	Output overvoltage protection		V		5.8	
V OVP_DIS			V		5.4	
V UVLO	Boost undervoltage protection	BAT from high to low	V		2.95	
V UVLO_R	Boost undervoltage recovery	BAT from low to high	V		3.20	
I BAT1		Vout=5.5V No Switching	mA		0.2	
I BAT2		Vout=4.5V Switching	mA		1	
Iauto_off	Automatic shutdown load current	BAT=3.6V Cout=20uF	mA		60	
Iq	Quiescent Current	BAT=3.6V	uA		13	30
F OSC	Working frequency		MHz		1	
OTP	Over temperature protection		degC		150	
OTP_HYS	Hysteresis		degC		20	

Function and parameters

Charging management module

1. The charging current is internally set to 0.8A
2. Battery voltage is lower than 2.8V with pre-charging function (current =Ich*10%)
3. Support charging 0V battery
4. Three-stage charging: turbulent, constant current, constant voltage charging
5. The charging current decreases with the increase of temperature, and it is opened at 130 °C. Start to decrease;

Boost module

1. Standby state detection load is greater than 10uA (typ) current When the boost is automatically started, when the output load is less than 60mA Type value) delays 8 seconds to automatically enter standby mode
2. Synchronous rectification boost, up to 91% conversion efficiency, output Fixed voltage 5.1V
3. After the output current exceeds 0.8A, the voltage starts to decrease.
4. Overvoltage protection is performed after the output voltage is greater than 5.8V, when the output is Automatic recovery after the voltage drops to 5.4V
5. With output overcurrent protection and short circuit protection, through plugging and unplugging Automatic load release
6. Switching frequency 1MHz
7. During the discharge process, if the temperature reaches 150 degrees, the overheat protection Automatically turn off the output and enter standby.

Automatic conversion module

1. Support side charging, that is, the external charger simultaneously charges the mobile phone Electricity, also charging mobile power
2. During the boosting process, automatically detect whether the external charger is plugged in. In, after detecting the insertion of the charger, according to the external current Automatically distribute current to charge mobile power and mobile phones
3. If the charger is removed, the boost is automatically started.

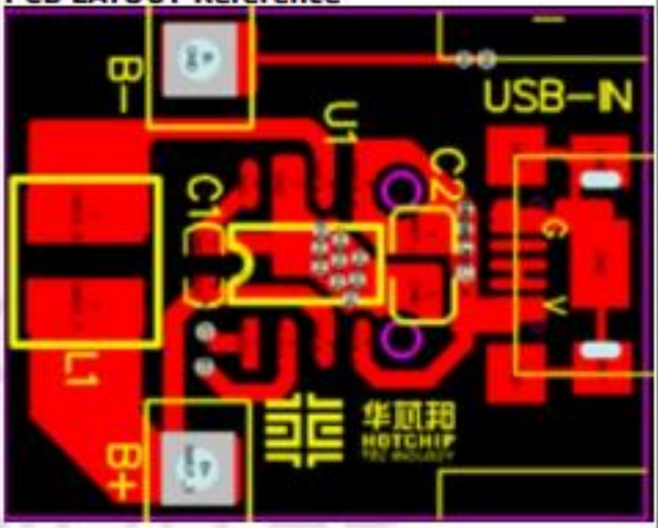
Charge and discharge indicator

1. When charging, the indicator lights LD1 and LD2 flash alternately. The indicator light LD2 is on;
2. When the battery is fully charged, plug in the charging indicator LD2 during charging. On, the LD2 indicator goes off after unplugging the phone for 8 seconds.
3. If the battery voltage is lower than 3.2V during discharge, the indicator light LD2 Flashes until 2.95V undervoltage shutdown; when the battery voltage rises to Before 3.2V, the load LD2 indicator will flash for 8 seconds, but Boost will not start.
4. If LD1 is not connected, it will be in single LED mode.

Charger detection during single port discharge

1. During the charging process of the mobile phone, the system will generate a week at the output. a charger detection signal with a pulse width of 4 mS for 2 seconds;
2. When there is no charger inserted, at 4mS pulse, output The voltage was reduced to 4.7V, and it was judged that the charger was not inserted outside.
3. When the charger is inserted, when the voltage is greater than 4.7V, the system automatically enters 4mS pulse, output voltage trickle state.

PCB LAYOUT Reference



C1, C2 should be close to the chip within 2mm, and go to the chip pin The line is as short as possible; to prevent the heat of L1 from affecting the chip, L1 can be a little farther away. Connected by thick wire at around 5-10mm

Electrostatic protection CMOS circuits are electrostatically sensitive devices that are manufactured and shipped. The following precautions must be taken during the process to prevent CMOS circuit damage due to electrostatic discharge	Check: 1. The operator should be grounded through the static-discharge wrist strap; 2. The outer casing of the production equipment must be grounded; 3. The tools used in the assembly process must be grounded; 4. Must be packaged or shipped in semiconductor packaging or antistatic materials.

Package information

SOP8 package appearance