Journal of Nonlinear Analysis and Optimization
Vol. 15, Issue. 2 : 2024
ISSN :**1906-9685**

DESIGN AND SIMULATION OF SMART FLOORING TILES USING TWO-PHASED TRIANGULAR BIMORPH PIEZOELECTRIC ENERGY HARVESTER

[1]Dr. Malliga Lakshmanan, [2]K. Harshitha, [3]K. Naga Sai Vineesha, [4]K. Sharanya

[1] Professor, Dept of ECE , MALLA REDDY ENGINEERING COLLEGE FOR WOMEN(Autonomous), Hyderabad, TS, India

[2,3,4] U.G Student, Dept of ECE , MALLA REDDY ENGINEERING COLLEGE FOR WOMEN(Autonomous), Hyderabad, TS, India.

1.ABSTRACT

This paper investigates the design, simulation, and optimization of smart flooring tiles integrated with a two-phase triangular bimorph piezoelectric energy harvesting system, designed to transform the mechanical energy from human footsteps into electrical energy. The system addresses the challenge of low power output by incorporating a tip mass and a stopper mechanism, which allows for the capture of electricity twice from each footstep, enhancing energy conversion. Piezoelectric sensors embedded in the tiles detect the mechanical stress caused by footsteps and convert it into electrical energy. This energy is then used to power an ESP32 camera for security purposes in high-traffic areas. To compensate for the relatively low power output of the piezoelectric sensors, a high-voltage battery and solar panels are integrated to ensure a consistent power supply. An ADC module is used to convert the analog voltage into a usable digital form. In addition to powering the ESP32 camera, the system also features a charging port to power mobile devices. Simulations of the energy harvester, conducted using COMSOL Multiphysics software, analyze the impact of various physical parameters, such as acceleration and the distance between the stopper and the beam, on energy efficiency. The results indicate that triangular bimorph beams outperform rectangular beams in energy harvesting efficiency, providing a more effective solution for sustainable power generation in urban environments.

2.INTRODUCTION

The growing global demand for renewable

https://doi.org/10.36893/JNAO.2024.V15I2.128

and eco-friendly energy solutions has spurred extensive research into alternative methods of energy generation. Among these, piezoelectric energy harvesting has gained attention as an efficient and sustainable way to convert mechanical energy into electrical energy. With the increasing emphasis on smart cities and green technologies, integrating such innovative energy solutions into everyday infrastructure has become a significant focus. This project, titled "Design and Simulation of Smart Flooring Tiles Using Two-Phased Triangular Bimorph Piezoelectric Energy Harvester," addresses the dual challenge of energy sustainability and urban utility. By leveraging the mechanical energy generated by human footsteps, the smart flooring tiles aim to provide an eco-friendly means of generating electricity. The novel two-phased triangular bimorph structure is engineered to maximize energy conversion efficiency while maintaining durability, making it suitable for high-traffic areas. To enhance the practical applicability of the system, this project incorporates features such as a tip mass and stopper mechanism, which enable the harvesting of energy twice from a single footstep. Additionally, the integration of auxiliary power sources, including high-voltage batteries and solar panels, ensures a reliable power supply for devices like ESP32 cameras used in security applications.

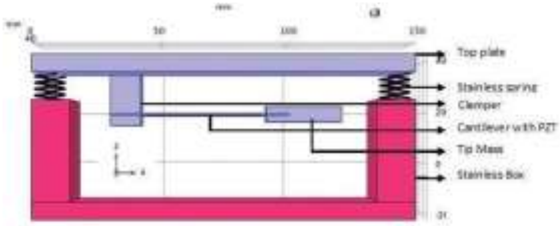
3.LITERATURE SURVEY

ArunKumar, Ayush Kumar, Akshat Kamboj, 2017, Design of Footstep Power Generator using Piezoelectric Sensors. This paper explores the design and implementation of a footstep power generator that uses piezoelectric sensors. It highlights the energy harvesting potential of piezoelectric materials when they are subjected to pressure from footsteps.

Shradha Panghate, Pratik Barhate, Hemant Chavan, 2020, Footstep Power Generation System using RFID for Charging. This paper examines a footstep power generation system that utilizes RFID for charging. It emphasizes the integration of energy harvesting technologies for sustainable charging solutions in smart buildings and environments.

Rajeev Ranjan Tiwari, Rahul Bansal, Pushyamithra Gupta, 2019, Footstep Power Generation. The authors explore footstep power generation technologies, with a particular focus on the use of piezoelectric materials. The study highlights different designs and methods aimed at improving the efficiency of energy generation.

4.EXISTING SYSTEM



The figure above illustrates the fundamental structure of the designed model. In this system, a vertically movable plate undergoes downward displacement under the load of a human footstep until it is halted by a stopper formed by the four walls of the box. The plate then returns to its original top position due to the spring effect, facilitated by springs positioned at each corner of the box.When the cantilever reaches its top position, the tip mass introduces a shift in mechanical strain. This design enables the generation of two distinct levels of mechanical strain energy from a single footstep.

DISADVANTAGES

- Low Power Output
- Limited Efficiency
- Durability Concerns
- Cost of Components
- Installation Complexity

5.PROPOSED SYSTEM

The proposed system is an advanced smart flooring tile that incorporates a two-phase triangular bimorph piezoelectric energy harvester. This design efficiently converts mechanical energy from human footsteps into electrical energy, providing a sustainable solution for urban energy harvesting. The system has potential applications in energy generation, security surveillance, and mobile device charging. The following sections provide a detailed explanation of the system's components, mechanisms, and functionalities.

SYSTEM OVERVIEW

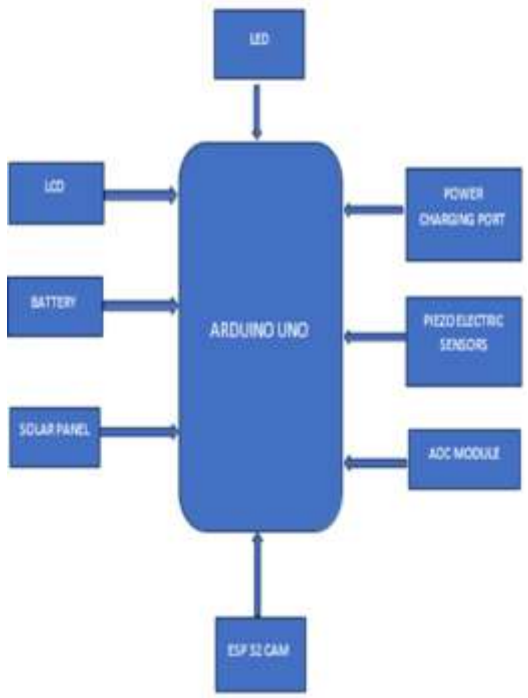
The smart flooring tile is made up of several essential components: - Piezoelectric Sensors: Integrated into the flooring to convert mechanical force from footsteps into electrical charge. - Two-Phased Triangular Bimorph Design: Optimized to enhance energy generation efficiency through mechanical vibrations. - Tip Mass and Stopper Mechanism: Increases energy conversion by capturing energy twice with each footstep. - Arduino Uno Microcontroller: Acts as the central control unit, managing energy distribution and system operations. - ESP32 Camera: Provides real-time security surveillance. - LED Indicators and LCD Display: Provide real-time feedback on system performance and monitoring. - ADC Module: Converts low-voltage analog signals from the piezoelectric sensors into digital format for more efficient energy processing. - Battery: Stores the harvested energy to ensure continuous operation. - Solar Panel: Supports the system during periods of low foot traffic. - Mobile Charging Port: Offers convenience for public use. The system is designed to operate autonomously, ensuring reliability and sustainability, making it perfect for high-traffic public spaces like malls, train stations, airports, and stadiums.

ADVANTAGES:

- Low Power Output
- Limited Efficiency

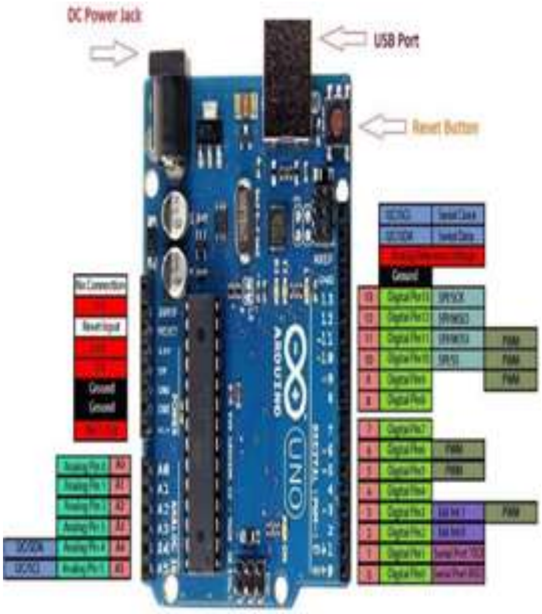
- Durability Concerns
- Cost of Components
- Installation Complexity

6.BLOCK DAIGRAM



7.HARDWARE COMPONENTS

ARDUINO UNO

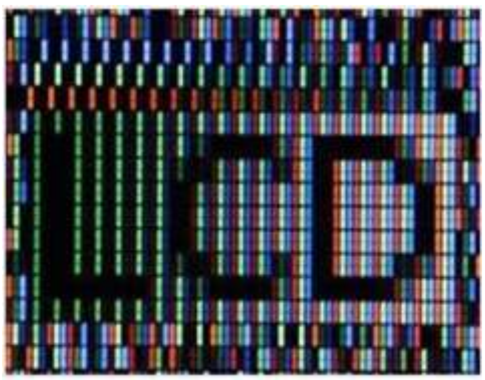


The Arduino Uno is a widely-used microcontroller board featuring the ATmega328P microchip. It offers 14 digital input/output pins (6 of which can function as PWM outputs), 6 analog inputs, a USB port for programming and power, a power jack, an ICSP header, and a reset button. Operating at a 5V logic level, the Uno can be powered via USB or an external power supply (7-12V). Popular for prototyping and experimentation, the Arduino Uno is compatible with a wide range of shields, sensors, and actuators. It is programmed through the Arduino Integrated Development Environment (IDE), simplifying the process of writing and uploading code. With its versatility, the Arduino Uno is ideal for projects ranging from simple LED blinking to more advanced robotics.

PIEZOELECTRIC SENSOR

Piezoelectricity was discovered in 1880 by Pierre and Paul-Jacques Curie, who found that certain crystals, like quartz, tourmaline, and Rochelle salt, produce a surface voltage when compressed along specific axes. This phenomenon is known as the piezoelectric effect. Piezoelectricity refers to the generation of electricity when certain crystals are deformed or bent. These crystals can also be made to bend slightly when a small current is applied, making them useful in devices requiring precise mechanical control. Examples include naturally occurring crystals like single-crystal quartz and bone, as well as artificially manufactured materials like PZT ceramics.

LCD (LIQUID CRYSTAL DISPLAY)

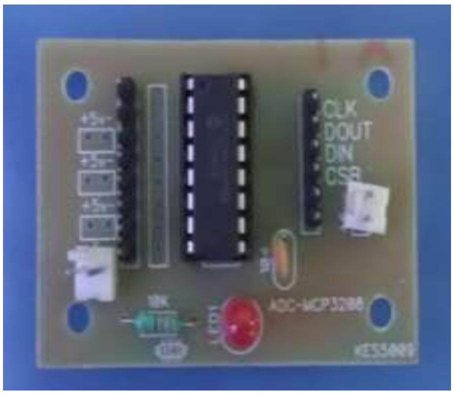


A liquid crystal display (LCD) gets its name from its use of liquid crystals, which exhibit properties of both solid and liquid states, to produce visible images. LCDs are ultra-thin screens widely used in devices such as laptops, televisions, smartphones, and portable gaming consoles. This technology enables much slimmer and more lightweight displays compared to the bulkier cathode ray tube (CRT) technology of earlier generations. Most modern smartphones with LCD technology use an active matrix display, while some older models still rely on passive display grid designs. Liquid crystal display technology is commonly used in a wide range of electronic devices due to its lower power consumption compared to LED or cathode ray tube (CRT) technologies. Unlike emitting light, an LCD works by blocking light, which is why it requires a backlight to produce visible images, as it does not generate light on its own.

LED (LIGHT EMITTING DIODE)

An LED is a light-emitting p-n junction diode made from a specific type of semiconductor with special doping. When forward-biased, the diode emits light, hence the term "light-emitting diode. The layers are arranged sequentially, with the P-type region at the top, the active region in the center, and the N-type region at the bottom. In this configuration, the N-type region contains electrons, the P-type region contains holes, and the active region in the middle hosts both electrons and holes, where light emission takes place.

ADC MODULE



An analog-to-digital converter (ADC, A/D, or A-to-D) is an electronic system that transforms analog signals, such as sound from a microphone or light captured by a digital camera, into digital signals. ADCs are also utilized for isolated measurements by converting input analog voltages or currents into digital representations of their magnitudes. A key advantage of ADCs is their ability to achieve high data acquisition rates, even when processing multiplexed inputs. The development of various ADC integrated circuits (ICs) has significantly improved the speed and accuracy of data acquisition from diverse sensors. Modern high-performance ADCs provide superior dynamic characteristics, including enhanced measurement repeatability, low power consumption, precise throughput, high linearity, and an excellent signal-to-noise ratio (SNR).

SOLAR PANEL

Solar panels are devices designed to absorb sunlight and convert it into electricity or heat. Solar energy originates from the sun, and solar panels, also referred to as "PV panels," are used to convert sunlight, which is made up of energy particles called "photons," into electricity that can power electrical devices. Solar panels have various applications, such as providing power for remote systems like cabins, telecommunications equipment, remote sensing, and generating electricity for residential and commercial solar power systems.This process is known as the Photovoltaic Effect. Typically, a home has sufficient roof space to install enough solar panels to meet its power needs, with any excess electricity produced being sent to the power grid, providing credits for electricity used at night.

ESP32 CAM

The ESP32-CAM is a compact, low-power

camera module based on the ESP32 microcontroller. It comes equipped with an OV2640 camera and includes a built-in TF card slot for data storage. With 4MB of PSRAM, it supports buffering of images for video streaming and other tasks, enabling higher image quality without causing the ESP32 to crash. Additionally, the module includes an onboard LED for flash functionality and several GPIO pins for connecting external peripherals.

The ESP32-CAM operates using the ESP32 chip, which handles processing and communication tasks. Upon powering up, the ESP32 bootloader initializes and runs the firmware stored in its memory. It connects to the OV2640 camera module via the SPI interface to capture images. The camera sends the image data to the ESP32 for processing, which can either compress the image or stream it directly over Wi-Fi to an external device. The board can serve images or video through a web server, allowing remote access via a browser. If a microSD card is inserted, the ESP32 can store images and videos on the card and also upload them to a cloud service or server using Wi-Fi. Additionally, the ESP32 can interact with other devices like sensors or actuators through its available GPIO pins, though the number of exposed pins is limited.

BATTERY POWER SUPPLY

A battery is a portable, reliable power supply offering mobility and convenience that traditional line-operated power supplies cannot provide. It is composed of multiple electrochemical cells connected in series or parallel to achieve the desired voltage. For example, Fig. 3.3.4 illustrates a Hi-Watt 9V battery. One commonly used type of battery is the carbon-zinc dry cell, which consists of alternating layers of a carbon electrode, an electrolyte paste, and a zinc electrode. These layers are stacked to produce the required voltage, with standard outputs of 1.5V, 3V, 6V, 9V, 22.5V, 45V, and 90V. During discharge, lead transforms into lead sulfate, and sulfuric acid becomes water. During recharging, lead sulfate is reversed back into lead and lead dioxide. In recent years, nickel-cadmium (NiCd) batteries have gained popularity. These sealed, rechargeable batteries are valued for their durability and ability to deliver consistent performance over multiple charging cycles.

8.SOFTWARE DESCRIPTION

ARDUINO SOFTWARE (IDE)

Sketches are programs developed using the Arduino Integrated Development Environment (IDE). These sketches are written in the text editor and saved with a .ino file extension. The editor supports features like cut, copy, paste, find, and replace for efficient code editing. The message area displays error messages and provides feedback during the process of compiling and saving. Detailed error messages and other information are output to the console through the Arduino IDE. The bottom-right corner of the window shows the selected board and serial port in use. The toolbar buttons allow users to upload sketches to the board, create new projects, open existing ones, verify code, and access the serial monitor for communication.

9.APPLICATION

- ✓ Powering Low-Energy Devices: Generates electricity to power LED lights, IoT sensors, or other small electronic devices in smart buildings. Provides a renewable energy source for low-power appliances like temperature monitors or occupancy sensors.
- ✓ Off-Grid Energy Solutions: Serves as a sustainable energy source in remote locations or disaster-prone areas with limited access to electricity. Reduces dependence on conventional energy grids in urban and rural settings.
- ✓ Integration with Microgrids: Channels harvested energy into local microgrids to support decentralized energy systems. Offers a scalable solution for energy management in large facilities.

10.CONCLUSION

The "Design and Simulation of Smart Flooring Tiles Using Two-Phased Triangular Bimorph Piezoelectric Energy Harvester" introduces an innovative method for sustainable energy generation by converting mechanical energy from human footsteps into electrical energy. The two-phased triangular bimorph structure, along with the tip mass and stopper mechanism, improves energy harvesting efficiency, offering a more effective alternative to traditional designs. Simulations in COMSOL Multiphysics optimized key parameters, such as acceleration and beam geometry, to maximize energy output. The system's integration with supplementary power sources, including solar panels and high-voltage batteries, guarantees a reliable, continuous power supply. This ensures its capability to power devices such as ESP32 cameras, mobile charging ports, and other smart technologies. This project not only advances renewable energy technologies but also aligns with the concept of smart cities by incorporating energy harvesting into urban infrastructure. Its versatility, cost-effectiveness, and dual-purpose functionality make it a viable solution for meeting energy demands in high-traffic areas. By merging innovation with practicality, this project paves the way for future advancements in piezoelectric energy harvesting and supports the global move toward a more sustainable and energy-efficient future.

REFERENCES

Design and simulation of smart flooring tiles using two-phased triangular bimorph piezoelectric energy harvester | IEEE conference publication | IEEE Xplore Performance analysis of footstep power generation using piezoelectric sensors | IEEE conference publication | IEEE Xplore Development and analysis of footstep power harvester – A case study for the viability of the device in Surigao City | IEEE conference publication | IEEE Xplore Power generation using footsteps for mobile charging | IEEE conference publication | IEEE Xplore Arun Kumar, Ayush Kumar, Akshat Kamboj - "Design of footstep power generator using piezoelectric sensors" International conference on innovations in information, embedded, and communication systems (ICIIECS) - IEEE - Mar 2017.