



Design and Development of a Waste Electrical Device Recycling System for Energy Harvesting

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ABSTRACT

The conversion of electrical device waste into usable electrical energy is a growing area of interest in sustainable technology and energy recovery. This process aims to mitigate energy loss, reduce environmental impact, and promote the efficient use of resources by reclaiming or recycling energy from discarded electrical devices. Various methods, such as regenerative braking systems, energy harvesting from waste heat, piezoelectric devices, and microbial fuel cells, offer innovative solutions for recovering energy from waste materials. Additionally, e-waste recycling and biogas power plants contribute by repurposing electronic waste and organic materials into usable energy. These technologies provide viable alternatives for harvesting energy from waste, enhancing the sustainability of electrical devices, and contributing to a

circular economy. This paper explores the potential of these energy conversion techniques, their applications, and their role in transforming discarded materials into valuable energy sources. With the development of technology, human efforts are reduced, but the energy consumption has increased. In this paper, the electrical energy is generated from waste heat energy with the help of thermoelectric cooler (TEC) module. Depending on the temperature difference applied to the module, electricity is generated. To charge real-time applications, the generated electric potential is uplifted with the help of conversion circuit practically.

INTRODUCTION

The increasing global reliance on electrical and electronic devices has led to a surge in electronic waste (e-waste), posing significant environmental and resource

challenges. Effective recycling systems for waste electrical devices are critical to mitigate these issues and extract valuable resources. Beyond traditional recycling, the development of systems aimed at harvesting energy from e-waste represents an innovative approach to sustainability. These systems harness the residual energy or repurpose components to generate electricity, aligning with circular economy principles. This paper explores the design and development of a waste electrical device recycling system tailored for energy harvesting, emphasizing its potential to reduce environmental impacts, recover critical materials, and provide alternative energy sources. By integrating advanced technologies and efficient processes, the proposed system seeks to address the dual objectives of resource conservation and energy recovery, offering a sustainable solution to the growing e-waste crisis.

LITERATURE SURVEY

Singh and Verma, 2023 "Economic Viability of E-Waste Energy Recovery"

The cost-benefit analysis of recovery systems demonstrated that energy recovery could reduce e-waste disposal costs by 30% in urban areas.

Ahmed et al., 2022 "Lifecycle Assessment of E-Waste Energy Systems" Analysis of the environmental impact of recycling

technologies revealed substantial reductions in carbon footprint through the integration of energy recovery in the recycling process.

EXISTING SYSTEM

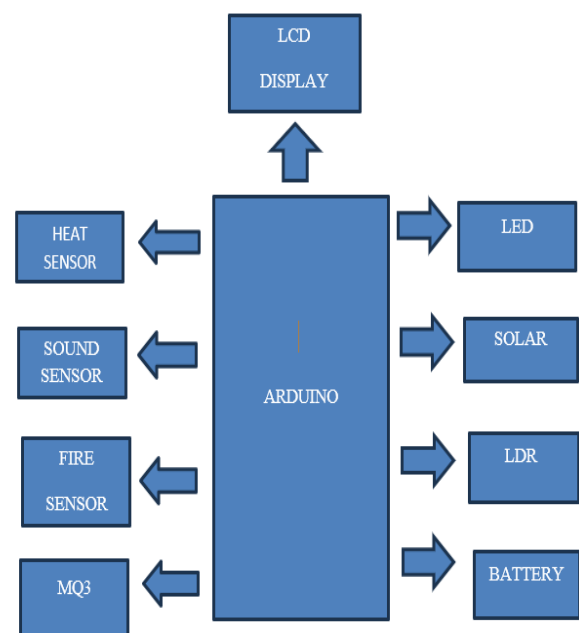
The design and development of a waste electrical device recycling system for energy harvesting involves a holistic approach to manage e-waste sustainably while efficiently recovering energy. The system starts with the collection and automated sorting of electronic waste, utilizing AI-powered tools to classify components by material type. Hazardous materials are safely removed, while reusable and energy-dense components—such as batteries and plastics—are identified for further processing. Advanced dismantling technologies, both mechanical and chemical, are used to extract valuable materials like gold, silver, and copper from circuit boards. Non-recyclable plastics and other materials are subjected to thermal treatments such as pyrolysis or gasification to produce syngas, which powers turbines for electricity generation. Additionally, lithium-ion batteries are either refurbished for energy storage or processed through electrochemical recovery to extract critical materials like lithium and cobalt.

PROPOSED SYSTEM

In today's technological age, electronic devices and equipment offer ever-expanding functionality, with a growing reliance on rechargeable and replaceable batteries for power. However, the conversion of non-renewable energy sources to electricity results in nearly 66% thermal losses, highlighting the urgent need to capture and utilize these heat energy leaks. Heat is a major driver of environmental changes, making it crucial to either reduce its impact or convert it into a useful form. This need for energy efficiency and sustainability has spurred the research presented in this paper. Energy harvesting refers to the process of capturing energy from the environment and converting it into a usable form, based on its availability. Thermoelectric transducers play a key role in this energy harvesting approach. Heat conversion is achieved through the Seebeck and Peltier effects, which allow the direct transformation of heat into electricity. By selecting specific thermoelectric materials and modules, it is possible to significantly reduce waste heat. Thermoelectric transducers offer reliable DC power conversion with the use of thermoelectric modules. These systems are cost-effective, compact, and lightweight, making them versatile and suitable for a wide range of applications. Their low-maintenance nature contributes to a long operational life, and they are environmentally friendly, making

them ideal for use in scientific, industrial, military, and aerospace applications. Waste heat, a significant byproduct of industrial processes, automotive systems, and power generation, is often released into the environment, resulting in inefficiencies and contributing to environmental degradation. Harvesting and repurposing this waste heat offers a promising solution to both improve energy efficiency and reduce environmental impact.

BLOCK DAIGRAM

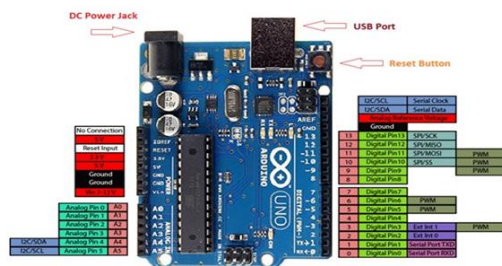


HARDWARE DESCRIPTION

ARDUINO

Thermoelectric generators (TEGs) have emerged as promising solid-state devices for recovering waste heat from internal combustion engines (ICEs). By directly

converting heat into electricity, TEGs offer the potential to reduce the size of the alternator in ICEs. However, the integration of new devices into the engine exhaust system can increase back pressure, which in turn reduces the overall efficiency of the engine. This study explores the feasibility of integrating TEGs into the engine's muffler system without compromising its primary function, in order to recover waste heat from the exhaust gases. The findings indicate that thermoelectric modules (TEMs) can be effectively incorporated into the muffler, allowing for efficient electricity generation from the available exhaust heat.



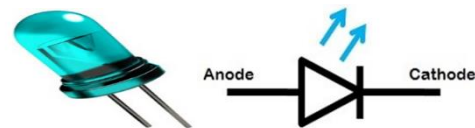
LCD DISPLAY

The **I2C 1602 LCD module** is a 2-line by 16-character display that is connected to an I2C daughter board. The I2C interface simplifies the connection process, requiring only two data lines, along with +5 VDC and GND for operation.



LED

A **light-emitting diode (LED)** is a **p-n junction diode** that is specially doped and made from a unique type of semiconductor material. When current flows in the forward bias, the diode emits light, which is why it is called a light-emitting diode.

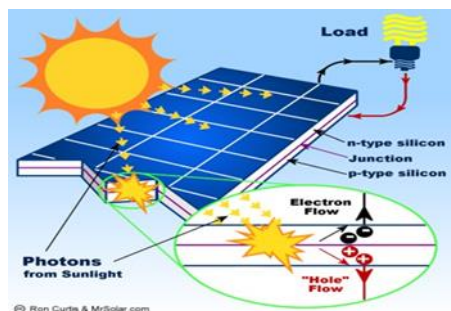


The LED symbol closely resembles that of a standard diode, with the addition of two small arrows pointing outward to indicate the emission of light. This is referred to as a Light Emitting Diode (LED). The LED consists of two terminals: the anode (+) and the cathode (-). LEDs are typically constructed by depositing three layers of semiconductor material onto a substrate, forming a straightforward structure. The top layer is a P-type region, the middle layer is the active region, and the bottom layer is an N-type region. These layers are arranged

sequentially. In this structure, the P-type region contains "holes" (positively charged carriers), the N-type region contains "electrons" (negatively charged carriers), and the active region is where the holes and electrons combine, leading to light emission when the LED is forward biased.

SOLAR PANEL

Solar panels are devices that capture sunlight and convert it into electricity or heat. Solar energy originates from the sun, and solar panels also known as photovoltaic (PV) panels transform sunlight, which consists of energy particles called photons, into electricity that can be used to power electrical devices. These panels have a wide range of applications, including providing energy for remote power systems such as cabins, telecommunications equipment, and remote sensing. They are also commonly used in residential and commercial solar electric systems for generating electricity.



A solar panel is essentially a collection of solar (photovoltaic) cells that generate electricity through the photovoltaic effect. These cells are arranged in a grid-like pattern across the panel's surface. Therefore, a solar panel can also be referred to as a set of photovoltaic modules mounted on a supporting structure. A photovoltaic (PV) module is a packaged assembly of 60 solar cells connected together in a 6x10 configuration. Solar panels capture clean, renewable energy from sunlight and convert it into electricity, which can then be used to power electrical loads. They are made up of several individual solar cells, each consisting of layers of silicon, phosphorous (which provides a negative charge), and boron (which provides a positive charge). When the panels absorb photons from the sunlight, they generate an electric current. The energy from photons striking the surface of the solar panel causes electrons to be knocked out of their atomic orbits and released into the electric field created by the solar cells. This field then directs the free electrons into a controlled current. This process is known as the Photovoltaic Effect. In most homes, there is more than enough roof space to install the necessary number of solar panels to meet all of its energy needs. Any excess electricity generated is fed back into the main power grid, providing credits for electricity use at night.

LIGHT DEPENDENT RESISTOR(LDR)

A Light Dependent Resistor (LDR), also known as a photoresistor, is a device whose resistance varies depending on the amount of incident electromagnetic radiation. As a result, they are light-sensitive components. LDRs are also referred to as photoconductors, photoconductive cells, or simply photocells. They are made from semiconductor materials with high resistance. Various symbols can represent an LDR, with one of the most commonly used symbols shown below. The arrow indicates the direction of light falling on the device.

BATTERY

A battery is a device that stores chemical energy and converts it into electrical energy to power various devices and systems. It consists of one or more electrochemical cells, each containing two electrodes (an anode and a cathode) and an electrolyte that allows ions to flow between them. When connected to an external circuit, chemical reactions occur at the electrodes, generating an electric current. Batteries are categorized into primary (non-rechargeable) and secondary (rechargeable) types, and are used in a wide range of applications, from small devices like watches and smartphones to larger systems like electric vehicles and grid storage. Ongoing advancements in

battery technology aim to enhance energy density, lifespan, safety, and environmental sustainability.

MQ-3 SENSOR

The MQ-3 is a commonly used gas sensor designed to detect alcohol concentrations in the air, making it suitable for breathalyzer systems and other alcohol-sensing applications. It features a tin dioxide (SnO_2) sensing layer that changes its electrical resistance when exposed to alcohol vapors. The sensor is highly sensitive to alcohol and offers a quick response time, though it can also detect other gases such as benzene, methane, and propane, with slightly less accuracy. Operating at a heater voltage of 5V, the MQ-3 is easy to integrate into microcontroller systems for real-time monitoring. Its affordability, ease of use, and versatility make it popular for both DIY projects and industrial applications.

ISO/OSI Layer 5-7	MQTT
ISO/OSI Layer 4	TCP
ISO/OSI Layer 3	IP

SOUND SENSOR



A sound sensor is an electronic device designed to detect and measure sound levels in the environment. It converts acoustic waves into electrical signals, which can then be processed and analyzed. Sound sensors typically include a microphone, an amplifier, and a signal processing unit. These sensors are commonly used in applications such as voice recognition systems, security alarms, industrial monitoring, and robotics. Advanced sound sensors can not only detect sound but also distinguish between specific frequencies, enabling them to identify particular sounds or speech patterns. Their sensitivity and accuracy make them essential in both consumer electronics and industrial systems.

HEAT SENSOR



A heat sensor, also referred to as a temperature sensor, is a device used to measure thermal energy in an environment or object and convert it into a readable signal. These sensors operate based on various principles, such as thermal expansion, changes in electrical resistance, or the detection of infrared radiation. Common types include thermocouples, thermistors, infrared sensors, and resistance temperature detectors (RTDs). Heat sensors are widely used in applications such as climate control systems, industrial process monitoring, fire detection, and medical devices like thermometers. Their accuracy and reliability make them essential for ensuring safety, efficiency, and comfort in many systems and devices.

FIRE SENSOR

A fire sensor is a device designed to detect the presence of fire or its byproducts, such as smoke, heat, or flames, providing an early warning of a potential fire hazard. It utilizes various technologies, including optical sensors for smoke detection, thermal sensors for heat, and infrared or ultraviolet sensors for identifying flames. Fire sensors are commonly integrated into fire alarm systems in residential, commercial, and industrial buildings, improving safety by triggering alarms or activating fire suppression systems. They are crucial for reducing the risk of property

damage, injuries, and fatalities by enabling a rapid response to fire incidents.



8.SOFTWARE DESCRIPTION

The Arduino Integrated Development Environment (IDE) is a software platform that includes a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a set of menus. It connects to Arduino and Genuino hardware to upload programs and facilitate communication with the devices. Note: Versions of the Arduino Software (IDE) before 1.0 saved sketches with the .pde extension. These files can still be opened in version 1.0, but you will be prompted to save the sketch with the .ino extension when saving.

CONCLUSION

The work presented in this paper focuses on harvesting electrical energy from heat leakage using thermoelectric modules and converting this electrical potential to the required voltage ranges through conversion circuitry. The theoretical and mathematical

contributions of combining the Seebeck and Peltier effects are provided, along with necessary precautions. Both simulation and practical evaluations of this approach have been conducted. This combination improves efficiency and reduces costs, particularly with the use of thermoelectric cooler (TEC) modules. A block diagram and the corresponding circuit diagram of the system design are presented to enhance the potential. The paper also compares TEC and thermoelectric generators (TEG). The simulation of temperature difference conversion into electricity was carried out, and the results were tested on various practical waste heat-producing objects. The electrical potentials obtained are in the millivolt range. An ultra-low step-up converter circuit is employed for real-time applications such as mobile charging, LED lighting, and battery charging. Thermoelectric waste heat recovery systems present a promising solution for converting waste heat into electrical energy. Despite existing challenges, ongoing research and development are expected to enhance efficiency, lower costs, and drive broader adoption across various industries. As the world moves toward a more sustainable and energy-efficient future, thermoelectric waste heat recovery systems are set to play a crucial role. These systems offer numerous benefits, making them an attractive option for waste heat

recovery. One of their key advantages is energy efficiency. Many industrial and high-energy-consuming systems generate significant amounts of waste heat that is often released into the environment. Thermoelectric systems capture this waste heat and convert it into electricity, greatly reducing energy loss and improving overall efficiency.

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