

Design And Development of Thermoelectric Generator For Waste Heat Energy Harvesting

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Abstract: This paper presents the design and development of a thermoelectric generator (TEG) prototype for waste heat energy harvesting. The system operates on the principle of the Seebeck Effect, where a voltage is generated due to the temperature difference across two surfaces. A thermoelectric module is placed between a hot surface and a cooled surface to create a temperature gradient, enabling direct conversion of heat energy into electrical energy.

The proposed system consists of a heat source, TEG module, heat sink for cooling, DC-DC boost converter, and an energy storage unit. Since the generated voltage is low and unstable, a boost converter is used to increase and regulate the output voltage for practical applications. The performance of the system is evaluated under different temperature conditions by measuring output voltage and power.

Experimental results indicate that the output voltage and power increase with an increase in temperature difference, and efficient cooling enhances overall system performance. The developed prototype provides a simple, reliable, and eco-friendly solution for harvesting waste heat energy. The system can be applied in low-power applications such as IoT devices and remote sensors.

I. INTRODUCTION

The increasing demand for energy and the depletion of conventional energy resources have led to the development of alternative and renewable energy technologies. One of the promising methods is thermoelectric energy generation, which converts heat directly into electrical energy without the use of moving parts. This method is highly reliable, silent, and requires minimal maintenance.

Thermoelectric generators (TEGs) operate based on the principle of the Seebeck Effect, where a voltage is generated due to the temperature difference across two dissimilar materials. In many practical situations, a large amount of heat energy is wasted in industries, buildings, and electronic devices. This unused heat can be effectively utilized to generate electricity using TEG systems.

The main objective of this work is to design and develop a thermoelectric generator prototype that can efficiently harvest waste heat energy and convert it into usable electrical power for low-power applications.

II. LITERATURE REVIEW

Several researchers have explored the application of thermoelectric generators in waste heat recovery systems. Previous studies have demonstrated that TEGs can be effectively used in automotive exhaust systems, industrial processes, and solar thermal applications to generate electrical energy.

However, the efficiency of thermoelectric systems remains relatively low due to limitations in material properties and insufficient temperature difference. Researchers have focused on improving efficiency by using advanced thermoelectric materials, optimizing heat transfer, and enhancing cooling mechanisms.

III. SYSTEM DESIGN AND METHODOLOGY

The proposed thermoelectric energy harvesting system consists of several key components, including a heat source, thermoelectric generator module, heat sink for cooling, DC-DC boost converter, and an energy storage unit such as a battery.

The thermoelectric module is placed between the hot and cold surfaces to create a temperature gradient. The heat source provides thermal energy, while the heat sink helps maintain a lower temperature on the opposite side. The generated electrical output is then processed using a boost converter to obtain a stable and usable voltage level.

3. BLOCK DIAGRAM

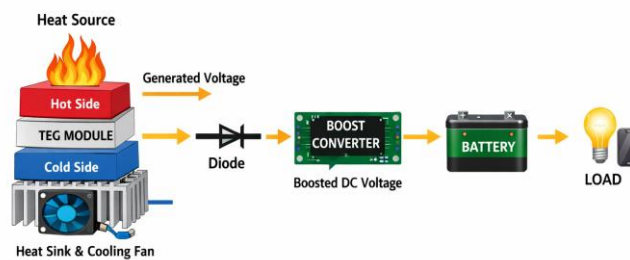


Fig -1. Block Diagram

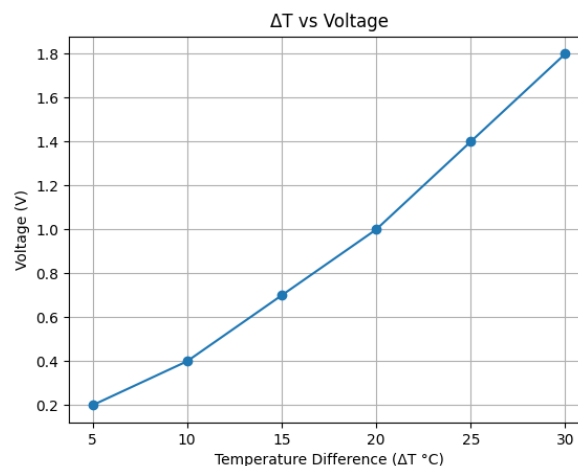
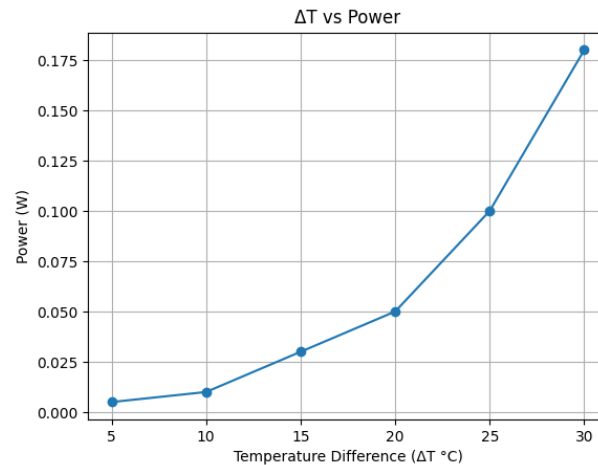


Fig -2. ΔT vs Voltage



IV. CONCLUSION

The performance of the thermoelectric generator prototype was evaluated under different temperature conditions. It was observed that the output voltage and power increased as the temperature difference across the module increased.

- **Voltage increases with temperature difference:**

As the temperature gradient increases, more charge carriers move across the material, resulting in higher voltage generation. This confirms the direct relationship between temperature difference and electrical output.

- **Cooling improves efficiency:**

Efficient cooling on the cold side plays a significant role in maintaining a higher temperature difference. The use of heat sinks and cooling fans helps improve system performance and enhances overall power generation.

The experimental results demonstrate that the developed prototype is capable of generating electrical energy from waste heat, making it suitable for low-power applications such as sensors and IoT devices.

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