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Generating electricity in cold regions by using thermoelectric effect

The Thermoelectric effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Using this concept we are going to observe how a Peltier module changes its efficiency when used with different materials and to understand the concept how to use this technique to harvest electricity in the coldest regions even without heat source or with the heat that is being wasted.

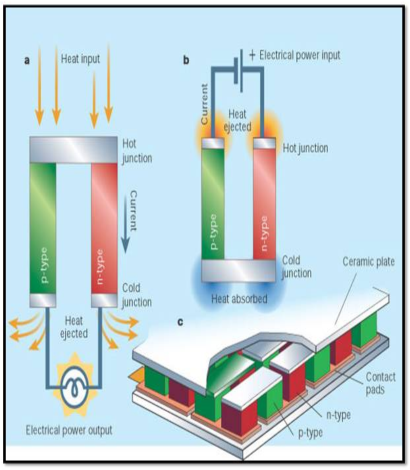
Thermoelectric generators are devices that convert heat or temperature differences directly into electrical energy, using a phenomenon called the Seebeck effect. In 1821, Thomas Johann Seebeck discovered that a thermal gradient formed between two dissimilar conductors produces a voltage. The flow of charge carriers between the hot and cold regions sequentially creates a voltage difference. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences (or vice versa); the local current density is given by

$$\mathbf{J} = \sigma(-\nabla V + \mathbf{E}_{\text{emf}})$$

where V is the local voltage and σ is the local conductivity. In general, the Seebeck effect is described locally by the creation of an electromotive field

$$\mathbf{E}_{\text{emf}} = -S\nabla T$$

where S is the Seebeck coefficient (also known as thermopower), a property of the local material, and ∇T is the gradient in temperature T. The Seebeck coefficients generally vary as function of temperature, and depend strongly on the composition of the conductor. For ordinary materials at room temperature, the Seebeck coefficient may range in value from −100 μV/K to +1,000 μV/K.



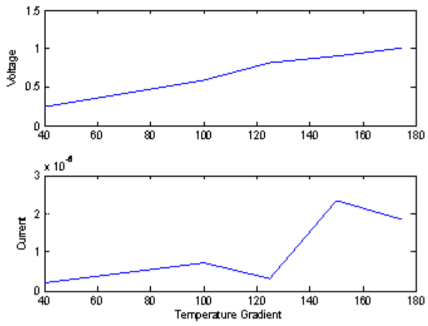
A Peltier device has a plurality of P-type semiconductor devices and N-type semiconductor devices that are alternately arranged in relation to each other. The top portions of the P-type and N-type semiconductor devices are combined with a ceramic cooling plane, and the bottom portions thereof are combined with a ceramic radiating plane. In the cooling plane, a current output from a DC (direct current) power supply flows from the N-type semiconductor devices to the P-type semiconductor devices. Considering the above current flow as a flow of electrons, electrons flow from a P-type lower energy level to a N-type higher energy level. Consequently, the temperature at places combining the top portions of the P-type and N-type semiconductor devices with the cooling plane decreases by absorbing the surrounding thermal energy and thereby a temperature of the cooling plane decreases.

Material and methods of research

From the above paragraph we can understand in simple terms that by using this device we can generate electricity but the amount of voltage generated cannot be constant and also sometimes it might not be equal to 1 V. So now here we use an electronic device known as DC-DC booster (AA Battery charger) which increases the output voltage to approximately 5.5 V with a minimum input voltage of 0.8 V. This device plays a key role in this experiment as when there are not suitable temperature conditions to give out the required temperature difference which is sufficient enough to be stored in a Li-ion battery then this DC-DC booster boosts up the voltage sufficient enough to charge a battery which is commonly used in cellular phones these days. All these components are readily available in the market for economical prices.

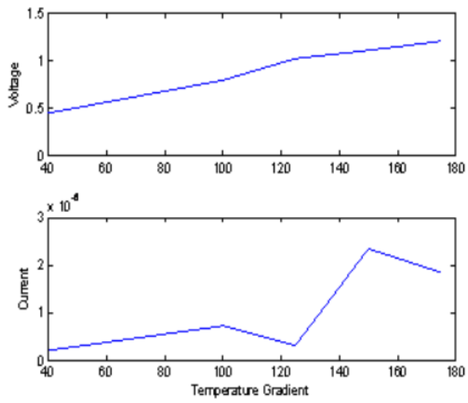
At this normal setup when the heat is absorbed by the peltier element, the cold side also get heated up and to reduce this effect we can use aluminium heat sink or aluminium foil on the cold side of the element which helps the cold side to stay cool and a glass plate at the hot side of the element if the heating temperature is very high, as glass plate acts as an insulator and prevents the peltier module from being damaged by heat easily. This setup also increases the efficiency of the peltier module i.e., even at lower temperatures the voltage generated would be rather varying positively than compared with the previous setup which doesn't include any extra materials.

Results and Analysis



Graph 1: Table of voltage and current as a function of temperature gradient (Beaker of Ice)

Table of voltage and current as a function of temperature gradient (Beaker of Ice) [2]



Graph 2: Table of voltage and current as a function of temperature gradient (Aluminum foil heat sink)

Table of voltage and current as a function of temperature gradient (Aluminum foil heat sink) [2]

As described above the voltage generated when the peltier element is just placed between a hot source and a cold source is much lower when it is connected to an AA battery charger and also when it is included with the materials like aluminium heat sink and a glass plate. As to prove this there was an experiment conducted by Scott Lee, University of Hawaii [2], to demonstrate the difference in the voltage occurred in different setups. According to the experiment, the peltier module was placed on a heat source and on top of it there was a block of ice which acted a cold source. The voltage and the current was measured using multi-meter which are shown in Graph 1. After sometime it has been observed that with the increase in temperature on the hot side, the temperature on the cold side also started to rise up which in turn melted the ice.

To minimize this effect there was an aluminium foil placed between the ice block and the peltier module. To avoid over heating of the module from the hot side a glass plate was placed between the heat source and the peltier module. After this setup the results were quite different than the previous one. As we can see in Graph 2, there has been slight increase in voltage and the thermal gradient was quite stable. It was also observed that, the block of ice that had the larger surface area produced a reasonable voltage ranging from 2 volts to 3 volts, which was sufficient for running the battery charging circuit, as long as a dc/dc converter was used to further step up the voltage.

Conclusion

Thermoelectric generation can be a suitable energy source in space, especially in situations where other power sources cannot operate. An alternative energy source is photovoltaics, which actually have a much higher efficiency (up to approximately 40 %, as compared to approximately 5 % for a thermoelectric generator). We can use this type of electricity generation for portable or mobile generation. In rural areas where the setup costs of solar panels are expensive this kind of energy can be very useful. In cold regions where the temperature is tremendously low we can create electricity using this technique with the heat that is being wasted and save it.

In conclusion, this kind of energy is useful in every place where the heat is being wasted or where there are extremely cold weather conditions.

References

1. Johansson D. AA Battery Charger (voltage booster) // URL: http://www.instructables.com/id/Adjustable-Voltage-Step-up-07-55V-to-27-55V/?utm_source=pm&utm_medium=related-instructables&utm_campaign=related_test
2. Scott Lee, Thermoelectric Devices // URL: http://www.spacegrant.hawaii.edu/reports/22_FA09-SP10/SLee_FA09.pdf
3. Disalvo F.J. Thermoelectric Cooling and Power Generation. Science, № 285 (5428), 1999. P. 703–706.

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