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Chapter 1
INTRODUCTION

1. INTRODUCTION

To design a project that could be used to utilize the waste heat energy into electricity for multipurpose use in various applications and household purposes. This system should be economical, easy to implement and does not produce any kind of pollution, it is silent and does not require any kind of fuel to work. The main feature of this project is that it converts direct temperature difference into electricity. It is based upon thermoelectric energy generation concept and has many applications in electricity generation from automobile waste heat, heat liberated from household items, electricity generation from glaciers (ice) and a lot of similar applications where temperature difference from environment is converted into electricity. This concept is very useful in terms that it adds up to other renewable sources of energy and can be used in place of other non-conventional sources of energy like wind, solar, tides, geothermal heat, etc. This is a new concept for electricity generation using temperature difference between junctions of a peltier element to be used in our project. The complete Thermo Electric Generator would be based on Seebeck Effect that is reverse of peltier effect. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence inducing a thermal current. A Peltier cooler can also be used as a thermoelectric generator. When operated as a generator, one side of the device is heated to a temperature greater then the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect).
Figure 1.1: Thermo Electric Generator

1. Heat Sink
2. Base Container (Aluminium)
3. Support Shaft
4. PCB for LED Panel
5. LED Panel
6. DC Motor
7. Switch
8. BASE (Aluminium)
9. Ribbon Wire

Figure 1.2: Peltier Element (to be used in Thermo Electric Generator Design)
2. PERFORMANCE OF PELTIER ELEMENTS

Thermoelectric junctions are generally only around 5–10% as efficient as the ideal refrigerator (Carnot cycle), compared with 40–60% achieved by conventional compression cycle systems (reverse Rankine systems using compression/expansion). Due to the relatively low efficiency, thermoelectric cooling is generally only used in environments where the solid state nature (no moving parts, maintenance-free, compact size) outweighs pure efficiency.

Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters.

![Figure 1.3: Peltier element schematic. Thermoelectric Legs are thermally in parallel and electrically in series.](image)
3. LITERATURE SURVEY

“Thermoelectric generator design based on power from body heat for biomedical autonomous devices”, Medical Measurements and Applications, 2009. MeMeA 2009. IEEE: Energy harvesting from human body has been undergoing an interesting and quick development thanks to the technological availability of new electronic components and the growing of different applications, in particular, for biomedical and social impacts on human beings’ daily life. The main scope of this paper is to modeling and to design a thermoelectric generator that extracts energy from human tissue warmth in order to supply a biomedical hearing prosthesis for deaf persons. An array of sensors based on thermocouple effect has been used. A conditioning and accumulator circuitry has been designed and tested. “ A method for designing a thermoelectric generator based on the thermal characteristics of the device” , Barry R. West*, Central Research Laboratories, Texas Instruments, Dallas, Texas, USA, In the theory and methods for analysis of thermocouples presented in the literature, the thermal resistance between the cold junction and the heat sink is usually either ignored or considered of secondary importance. An experimental and analytical investigation of the effect of this thermal resistance has been carried out. The utilization of a good cooling system and the design methods of this paper will produce generators that require a small fraction of the thermoelectric material indicated by previous methods. PRELIMINARY DESIGN OF A CRYOGENIC THERMOELECTRIC GENERATOR, A cryogenic thermoelectric generator is proposed to increase the efficiency of a vehicle propulsion system that uses liquid nitrogen as its fuel. The proposed design captures some of the heat required for vaporizing or initial heating of the liquid nitrogen to produce electricity. The thermoelectric generator uses pressurized liquid nitrogen as its cold reservoir and ambient air as the high-temperature reservoir to generate power. This study concentrated on the selection of thermoelectric materials whose properties would result in the highest efficiency over the operating temperature range and on estimating the initial size of the generator. The preliminary selection of materials is based upon their figure of merit at the operating temperatures. The results of this preliminary design investigation of the cryogenic thermoelectric generator indicate that sufficient additional energy can be used to increase overall efficiency of the thermodynamic cycle of a vehicle propulsion system.
4. NEED AND SIGNIFICANCE

Less than 30% of the energy in a gallon of gasoline reaches the wheels of a typical car, most of the remaining energy is lost as heat. Since most of the energy consumed by an internal combustion engine is wasted, capturing much of this wasted energy can provide a large increase in energy efficiency. For example, a typical engine producing 100 kilowatt of driveshaft power expels 68 kilowatts of heat energy through the radiator and 136 kilowatts through the exhaust. The possibilities of where and how to utilize this lost energy are explored with this project. The solution of recovering heat energy from the car engine through a thermoelectric generator using peltier plates has been proposed. This electricity generated through the thermoelectric generator from waste heat of the engine could be used to charge the car batteries or operate any electrical device within or outside the car. Also in other application of this thermoelectric generator that is, Electricity generation from glaciers / ice is another alternative for electricity generation through other non–renewable resources of electricity and yet to be explored. The idea behind this project is to utilize a small temperature difference between the ice / cold water and some atmospheric heat to produce electricity using thermoelectric generator.

EFFICIENCY OF THERMOELECTRIC GENERATOR

Currently, ATEGs are about 5% efficient. However, advancements in thin-film and quantum well technologies could increase efficiency up to 15% in the future. The efficiency of an ATEG is governed by the thermoelectric conversion efficiency of the materials and the thermal efficiency of the two heat exchangers. The ATEG efficiency can be expressed as:

\[ \eta_{OV} = \eta_{CONV} \times \eta_{HX} \times \rho \]

Where:
\( \eta_{OV} \) : The overall efficiency of the ATEG
\( \eta_{CONV} \) : Conversion efficiency of thermoelectric materials
\( \eta_{HX} \) : Efficiency of the heat exchangers
\( \rho \) : The ratio between the heat passed through thermoelectric materials to that passed from the hot side to the cold side.
5. OBJECTIVE

To design a Thermoelectric Generator that could be used to utilize the low temperature difference between two hot and cold junctions of peltier element to generate pollution free electricity without any moving or bulky parts using the latest technology of thermoelectric generation using peltier plates. This system should be economical, easy to implement and does not produce any pollution as other generators available in the market. All thermoelectric power generators have the same basic configuration. A heat source provides the high temperature, and the heat flows through a thermoelectric converter to a heat sink, which is maintained at a temperature below that of the source. The temperature differential across the converter produces direct current (DC) to a load ($R_L$) having a terminal voltage ($V$) and a terminal current ($I$). There is no intermediate energy conversion process. For this reason, thermoelectric power generation is classified as direct power conversion. The amount of electrical power generated is given by $P = IR_L$, or $VI$.

PRINCIPLE OF OPERATION

Seebeck Effect: In TEGs, thermoelectric materials are packed between the hot-side and the cold-side heat exchangers. The thermoelectric materials are made up of p-type and n-type semiconductors, while the heat exchangers are metal plates with high thermal conductivity. The complete Thermo Electric Generator would be based on Seebeck Effect that is reverse of peltier effect. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. A unique aspect of thermoelectric energy conversion is that the direction of energy flow is reversible. So, for instance, if the load resistor is removed and a DC power supply is substituted, the thermoelectric device can be used to draw heat from the “heat source” element and lower its temperature. In this configuration, the reversed energy-conversion process of thermoelectric devices is invoked, using electrical power to pump heat and produce refrigeration. This reversibility distinguishes thermoelectric energy converters from many other conversion systems, such as thermionic power converters. Electrical input power can be directly converted to pumped thermal power for heating or refrigerating, or thermal input
power can be converted directly to electrical power for lighting, operating electrical equipment, and other work. Any thermoelectric device can be applied in either mode of operation, though the design of a particular device is usually optimized for its specific purpose.

6. METHODOLOGY / PLANNING WORK

Thermoelectric Generator (TEG’s) are constructed using two dissimilar semi-conductors, one n-type and the other p-type (they must be different because they need to have different electron densities in order for the effect to work). The two semiconductors are positioned thermally in parallel and joined at one end by a conducting cooling plate (typically of copper or aluminum). A voltage is applied to the free ends of two different conducting materials, resulting in a flow of electricity through the two semiconductors in series. And when the temperature difference is maintained by heating element in one side and cooling element in other side, thermoelectric current flows through the junction and voltage is obtained at the output of TEG. As a result of the temperature difference, Peltier cooling causes heat to be absorbed from the vicinity of the cooling plate, and to move to the other (heat sink) end of the device.

A typical TEG inner view and actual picture is shown below:

![Figure 1.4](image_url)

Figure 1.4: a) Peltier Plate actual View   b) Peltier Plate TEG inner view
The heat is carried through the cooler by electron transport and released on the opposite ("hot") side as the electrons move from a high to low energy state. When the two materials are connected to each other by an electrical conductor, a new equilibrium of free electrons is established. Potential migration creates an electrical field across each of the connections. When current is subsequently forced through the unit, the attempt to maintain the new equilibrium causes the electrons at one connection to absorb energy, while those at the other connection release energy. In practice many TEG pairs (or couples), such as described above, are connected side-by-side, and sandwiched between two ceramic plates, in a single TEG unit.

Figure 1.5: Proposed Working of a Thermoelectric Generator

The heat pumping capacity of a cooler is proportional to the current and the number of pairs in the unit.

7. LIST OF COMPONENTS USED

1. Peltier Plates (TEC-12709), operating voltage: 12V, size: 4 x 5 cm, thickness: 5mm.
2. Heat Sink: To be designed to increase the surface area of cold junction of peltier plate to increase the electricity and efficiency of the thermoelectric generator. (Material: Aluminium)
3. Heat sink compound and Thermal paste (Adhesives) to mount peltier element on heat sink.
4. Base container (Aluminium) for setup of the generator.
5. Support shafts to provide height to heat sink (Aluminium).
6. Other tools and equipments: Nut-bolt pairs, screwdrivers, multimeters, Drilling machine, lathe machine, surface grinding machine
7. Output devices, load to show the generated electricity.
8. LED panel.
9. PCB for LED Panel.
10. Ribbon Wires.
11. Other Tools and equipments.
12. DC motor (12V).

ADVANTAGES OVER EXISTING TECHNOLOGIES

- No moving parts. Therefore they require little or no maintenance.
- Enables reduced low-noise operation of cooling fans.
- Suitable for manufacture in very small sizes. Therefore ideal for microelectronics.
- Lightweight.
- Long life. Exceeds 100,000 hrs MTBF (Mean Time Between Failures).
- Controllable (by voltage / current).
- Small size.
- Fast, dynamic response.
- Enhanced ratio between heat sink and target element.
APPLICATIONS OF THERMOELECTRIC GENERATOR

1. AUTOMOTIVE THERMO ELECTRIC GENERATOR:

An attempt to harvest the waste heat energy produced by the car engine. Thus, electricity produced can be used in the car to

- glow car indicators
- run music system
- charge batteries

2. CANDLE OPERATED TABLE LAMP

3. ELECTRICITY FROM TEA CUP

4. ELECTRICITY FROM LAPTOP CHARGER

5. DESIGN OF HIGHLY EFFICIENT THERMO ELECTRIC GENERATOR
   GLACIERS

6. SOLAR CELLS:

Solar cells use only the high frequency part of the radiation, while the low frequency heat energy is wasted. Several patents about the use of thermoelectric devices in tandem with solar cells have been filed. The idea is to increase the efficiency of the combined solar/thermoelectric system to convert the solar radiation into useful electricity.
Chapter 2

PELTIER PLATES

Figure 2.1: Peltier Element

The discovery began in the middle of 1821, where J. T. Seebeck discovered that two not similar metals, if they are connected in 2 different points and those points are held in different temperatures, there will be a micro-voltage developed. This effect is called the "Seebeck effect" as of it's discoverer. Some years later, a scientist discovered the opposite of the Seebeck effect. He discovered that if someone applies voltage to a thermo-couple, one junction shall be heated and the other shall be cooled. The scientist was called Peltier and the effect called the "Peltier effect".

A Peltier thermo-element is a device that utilizes the peltier effect to implement a heat pump. A Peltier has two plates, the cold and the hot plate. Between those plates there are several thermo couples. All those thermo couples are connected together and two wires come out. If voltage is applied to those wires, the cold plate will be cold and the hot plate. The device is called a heat pump because it does not generate heat nor cold, it just transfers heat from one plate to another, and thus the other plate is cooled. It is also called a thermo-electric cooler or TEC for short. Because TECs have several thermocouples, a lot of heat is transferred between the plates. Sometimes it can reach a temperature difference of 80 degrees Celsius or more.
Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). They can be used either for heating or for cooling (refrigeration), although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.[1]

This technology is far less commonly applied to refrigeration than vapor-compression refrigeration is. The main advantages of a Peltier cooler (compared to a vapor-compression refrigerator) are its lack of moving parts or circulating liquid, and its small size and flexible shape (form factor). Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient.

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect). However, a well-designed Peltier cooler will be a

---

**Figure 2.2:** A Peltier thermo-element compared to a AA battery.
mediocre thermoelectric generator and vice-versa, due to different design and packaging requirements.

**What are Peltier elements made of?**

Peltier thermo-elements are mainly made of semi conductive material. This means that they have P-N contacts within. Actually, they have a lot of P-N contacts connected in series. They are also heavily doped, meaning that they have special additives that will increase the excess or lack of electrons.

![Figure 2.3: How the P-N contacts are connected internally within a Peltier TEC.](image)

Now, imagine tens or hundreds of those P-N material between two plates.

![Figure 2.4: Drawing shows how many P-N contacts can exist in a rectangular area like a Peltier.](image)

You can see how the P and N material are connected in series together to implement a long strip of P-N junctions. The top plate is the hot plate and the bottom is the cold plate. When power is applied to the two wires, the heat will be transferred from the cold plate to the hot plate and thus THE COLD PLATE SHALL COLD.
PELTIER MARKINGS

- Sometimes, the TECs have identification markings on their face, just like the following pic.

Figure 2.5: In this picture you see the ID: **TEC1-12709**

- The first two digits shall be always "TE"
- The next digit shall be "C" or "S". "C" stands for standard size and "S" for small sized.
- The following digit is a number and indicates the number of stages that the TEC has. In our example (and the vast majority of TECs) is a one-stage TEC
- Right next comes a dash. After the dash, the 3 first digits indicates the number of couples that the TEC has inside. In our case it has 127 couples. If the couples are 2-digit, then the number has a leading zero, for example 062 for 62 couples.
- Next comes two more numbers that indicate the rating current of operation for the Peltier. In our case this is 9 Amperes
- Sometimes follows a "T" and three numbers. This indicates the maximum operating temperature for the TEC. For example, "T125" is 125°C rated.

PERFORMANCE OF PELTIER ELEMENTS

Due to the relatively low efficiency, thermoelectric cooling is generally only used in environments where the solid state nature (no moving parts, maintenance-free, compact size) outweighs pure efficiency. Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters.
USES:

1. Consumer products

Peltier elements are used in consumer products. For example, Peltier elements are used in camping, portable coolers, cooling electronic components and small instruments. The cooling effect of Peltier heat pumps can also be used to extract water from the air in dehumidifiers. A camping/car type electric cooler can typically reduce the temperature by up to 20°C below the ambient temperature. With feedback circuitry, peltiers can be used to implement highly stable temperature controllers that keep desired temperature within +/-0.01 Celsius. Such stability may be used in precise laser applications to avoid laser wavelength drifting as environment temperature changes. Climate-controlled jackets are beginning to use Peltier elements.

2. Science and imaging

Peltier elements are used in scientific devices. They are a common component in thermal cyclers, used for the synthesis of DNA by polymerase chain reaction (PCR), a common molecular biological technique which requires the rapid heating and cooling of the reaction mixture for denaturation, primer annealing and enzymatic synthesis cycles.

The effect is used in satellites and spacecraft to counter the effect of direct sunlight on one side of a craft by dissipating the heat over the cold shaded side, whereupon the heat is dissipated by thermal radiation into space. Since 1961, some unmanned spacecraft (including the Curiosity Mars rover) utilize radioisotope thermoelectric generators (RTGs) that convert thermal energy into electrical energy using the Seebeck effect, lasting several decades, fueled by the decay of high energy radioactive materials.

Thermoelectric coolers can be used to cool computer components to keep temperatures within design limits, or to maintain stable functioning when over clocking. A Peltier cooler with a heat sink or water block can cool a chip to well below ambient temperature.

In fiber optic applications, where the wavelength of a laser or a component is highly dependent on temperature, Peltier coolers are used along with a Thermistor in a feedback loop to maintain a constant temperature and thereby stabilize the wavelength of the device.

Some electronic equipment intended for military use in the field is thermoelectrically cooled.
Chapter 3
HEAT SINK

In electronic systems, a **heat sink** is a passive heat exchanger component that cools a device by dissipating heat into the surrounding air. In computers, heat sinks are used to cool central processing units or graphics processors. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronic devices such as lasers and light emitting diodes (LEDs), wherever the heat dissipation ability of the basic device package is insufficient to control its temperature.

A heat sink is designed to increase the surface area in contact with the cooling medium surrounding it, such as the air. Approach air velocity, choice of material, fin (or other protrusion) design and surface treatment are some of the factors which affect the thermal performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the eventual die temperature of the integrated circuit. Thermal adhesive or thermal grease fills the air gap between the heat sink and device to improve its thermal performance.

![HEAT Sink used in Thermo Electric Generator](image)

*Figure 3.1: HEAT Sink used in Thermo Electric Generator*
HEAT TRANSFER PRINCIPLE

A heat sink transfers thermal energy from a higher temperature to a lower temperature fluid medium. The fluid medium is frequently air, but can also be water or in the case of heat exchangers, refrigerants and oil. If the fluid medium is water, the 'heat sink' is frequently called a cold plate. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction.

To understand the principle of a heat sink, consider Fourier's law of heat conduction. Joseph Fourier was a French mathematician who made important contributions to the analytical treatment of heat conduction. Fourier's law of heat conduction, simplified to a one-dimensional form in the $x$-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, $q_k$, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

$$q_k = -kA \frac{dT}{dx}$$

Figure 3.2: Sketch of a heat sink in a duct used to calculate the governing equations from conservation of energy and Newton’s law of cooling.
DESIGN PARAMETERS OF HEAT SINK

1. Thermal resistance

For semiconductor devices used in a variety of consumer and industrial electronics, the idea of thermal resistance simplifies the selection of heat sinks. The heat flow between the semiconductor die and ambient air is modeled as a series of resistances to heat flow; there is a resistance from the die to the device case, from the case to the heat sink, and from the heat sink to the ambient. The sum of these resistances is the total thermal resistance from the die to the ambient. Thermal resistance is defined as temperature rise per unit of power, analogous to electrical resistance, and is expressed in units of degrees Celsius per watt (°C/W). If the device dissipation in watts is known, and the total thermal resistance is calculated, the temperature rise of the die over ambient can be calculated.

2. Material

The most common heat sink materials are aluminium alloys. Aluminium alloy 1050A has one of the higher thermal conductivity values at 229 W/m•K but is mechanically soft. Aluminium alloys 6061 and 6063 are commonly used, with thermal conductivity values of 166 and 201 W/m•K, respectively. The values depend on the temper of the alloy.

Copper has excellent heat sink properties in terms of its thermal conductivity, corrosion resistance, biofouling resistance, and antimicrobial resistance (see Main Article: Copper in heat exchangers). Copper has around twice the thermal conductivity of aluminium and faster, more efficient heat absorption. Its main applications are in industrial facilities, power plants, solar thermal water systems, HVAC systems, gas water heaters, forced air heating and cooling systems, geothermal heating and cooling, and electronic systems.

Copper is three times as dense and more expensive than aluminium. Copper heat sinks are machined and skived. Another method of manufacture is to solder the fins into the heat sink base. Aluminium can be extruded, but copper can not.

Diamond is another heat sink material, and its thermal conductivity of 2000 W/m•K exceeds copper five-fold. In contrast to metals, where heat is conducted by delocalized electrons, lattice vibrations are responsible for diamond's very high thermal conductivity. For thermal management applications, the outstanding thermal conductivity and diffusivity of diamond is an
essential. Nowadays synthetic diamond is used as submounts for high-power integrated circuits and laser diodes.

3. Fin efficiency

Fin efficiency is one of the parameters which makes a higher thermal conductivity material important. A fin of a heat sink may be considered to be a flat plate with heat flowing in one end and being dissipated into the surrounding fluid as it travels to the other. As heat flows through the fin, the combination of the thermal resistance of the heat sink impeding the flow and the heat lost due to convection, the temperature of the fin and, therefore, the heat transfer to the fluid, will decrease from the base to the end of the fin. Fin efficiency is defined as the actual heat transferred by the fin, divided by the heat transfer were the fin to be isothermal (hypothetically the fin having infinite thermal conductivity). Equations 1 and 2 are applicable for straight fins.

\[
\eta_f = \frac{\tanh(mL_c)}{mL_c} \quad (1)
\]

\[
mL_c = \sqrt{\frac{2h_f}{kt_f}L_f} \quad (2)
\]

Where:
- \( h_f \) is the convection coefficient of the fin
  - Air: 10 to 100 W/(m\(^2\)K)
  - Water: 500 to 10,000 W/(m\(^2\)K)
- \( k \) is the thermal conductivity of the fin material
  - Aluminium: 120 to 240 W/(m·K)
- \( L_f \) is the fin height (m)
- \( t_f \) is the fin thickness (m)

Fin efficiency is increased by decreasing the fin aspect ratio (making them thicker or shorter), or by using more conductive material (copper instead of aluminium, for example).

4. FIN ARRANGEMENTS

A pin fin heat sink is a heat sink that has pins that extend from its base. The pins can be cylindrical, elliptical or square. A pin is by far one of the more common heat sink types available.
on the market. A second type of heat sink fin arrangement is the straight fin. These run the entire length of the heat sink. A variation on the straight fin heat sink is a cross cut heat sink. A straight fin heat sink is cut at regular intervals.

In general, the more surface area a heat sink has, the better it works. However, this is not always true. The concept of a pin fin heat sink is to try to pack as much surface area into a given volume as possible. As well, it works well in any orientation. Kordyban has compared the performance of a pin fin and a straight fin heat sink of similar dimensions. Although the pin fin has 194 cm$^2$ surface area while the straight fin has 58 cm$^2$, the temperature difference between the heat sink base and the ambient air for the pin fin is 50 °C. For the straight fin it was 44 °C or 6 °C better than the pin fin. Pin fin heat sink performance is significantly better than straight fins when used in their intended application where the fluid flows axially along the pins rather than only tangentially across the pins.

![Heat Sink Types](image)

**Figure 3.3: (a) PIN Heat Sink  (b) Instraight Heat Sink  (c) Flared Fin Heat Sink**

**PERFORMANCE OF HEAT SINK**

In general, a heat sink performance is a function of material thermal conductivity, dimensions, fin type, heat transfer coefficient, air flow rate, and duct size. To determine the thermal performance of a heat sink, a theoretical model can be made. Alternatively, the thermal performance can be measured experimentally. Due to the complex nature of the highly 3D flow in present in applications, numerical methods or computational fluid dynamics (CFD) can also be used. This section will discuss the aforementioned methods for the determination of the heat sink thermal performance.
A heat transfer theoretical model

Figure 3.4: Sketch of a heat sink with equivalent thermal resistances.

One of the methods to determine the performance of a heat sink is to use heat transfer and fluid dynamics theory. One such method has been published by Jeggels, et al.,[20] though this work is limited to ducted flow. Ducted flow is where the air is forced to flow through a channel which fits tightly over the heat sink. This makes sure that all the air goes through the channels formed by the fins of the heat sink. When the air flow is not ducted, a certain percentage of air flow will bypass the heat sink. Flow bypass was found to increase with increasing fin density and clearance, while remaining relatively insensitive to inlet duct velocity.
Chapter 4

DC BRUSHLESS MOTOR

Figure 4.1: DC Motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor (AC, alternating current, does not imply a sinusoidal waveform but rather a bi-directional current with no restriction on waveform); additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

The motor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor.

Brushless motors may be described as stepper motors; however, the term *stepper motor* tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position. This page describes more general brushless motor principles, though there is overlap.
APPLICATIONS

Brushless motors fulfill many functions originally performed by brushed DC motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications, particularly devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used in direct-drive turntables for gramophone records.

Transport

High power brushless motors are found in electric vehicles and hybrid vehicles. These motors are essentially AC synchronous motors with permanent magnet rotors.

The Segway Scooter and Vectrix Maxi-Scooter use brushless technology.

A number of electric bicycles use brushless motors that are sometimes built into the wheel hub itself, with the stator fixed solidly to the axle and the magnets attached to and rotating with the wheel.

Heating and ventilations

There is a trend in the HVAC and refrigeration industries to use brushless motors instead of various types of AC motors. The most significant reason to switch to a brushless motor is the dramatic reduction in power required to operate them versus a typical AC motor. While shaded-pole and permanent split capacitor motors once dominated as the fan motor of choice, many fans are now run using a brushless motor. Some fans use brushless motors also in order to increase overall system efficiency.
In addition to the brushless motor's higher efficiency, certain HVAC systems (especially those featuring variable-speed and/or load modulation) use brushless motors because the built-in microprocessor allows for programmability, better control over airflow, and serial communication.

**Industrial engineering**

The application of brushless DC motors within industrial engineering primarily focuses on manufacturing engineering or industrial automation design. In manufacturing, brushless motors are primarily used for motion control, positioning or actuation systems.

Brushless motors are ideally suited for manufacturing applications because of their high power density, good speed-torque characteristics, high efficiency and wide speed ranges and low maintenance. The most common uses of brushless DC motors in industrial engineering are linear motors, servomotors, actuators for industrial robots, extruder drive motors and feed drives for CNC machine tools.

**Motion control systems**

Brushless motors are commonly used as pump, fan and spindle drives in adjustable or variable speed applications. They can develop high torque with good speed response. In addition, they can be easily automated for remote control. Due to their construction, they have good thermal characteristics and high energy efficiency. To obtain a variable speed response, brushless motors operate in an electromechanical system that includes an electronic motor controller and a rotor position feedback sensor.

Brushless dc motors are widely used as servomotors for machine tool servo drives. Servomotors are used for mechanical displacement, positioning or precision motion control. In the past DC stepper motors were used as servomotors; however, since they are operate with open loop control, they typically exhibit torque pulsations. Brushless dc motors are more suitable as servomotors since their precise motion is based upon a closed loop control system that provides tightly controlled and stable operation.

**Positioning and actuation systems**

Brushless motors are used in industrial positioning and actuation applications. Brushless stepper or servo motors are used to position a part for assembly or a tool for a
manufacturing process, such as welding or painting. Brushless motors can also be used to drive linear actuators.

Actuators that produce linear motion are called linear motors. The advantage of linear motors is that they can produce linear motion without the need of a transmission system, such as a ball-and-lead screw, rack-and-pinion, cam, gears or belts, that would be necessary for rotary motors. Transmission systems are known to introduce less responsiveness and reduced accuracy. Direct drive, brushless DC linear motors consist of a slotted stator with magnetic teeth and a moving actuator, which has permanent magnets and coil windings. To obtain linear motion, a motor controller excites the coil windings in the actuator causing an interaction of the magnetic fields resulting in linear motion.

**Model engineering**

![Microprocessor-controlled BLDC motor powering a micro radio-controlled airplane.]

A microprocessor-controlled BLDC motor powering a micro radio-controlled airplane. This external rotor motor weights 5 grams, consumes approximately 11 watts and produces thrusts of more than twice the weight of the plane.

Legal restrictions for the use of combustion engine driven model aircraft in some countries have also supported the shift to high-power electric systems.

**Radio controlled cars**

Their popularity has also risen in the radio controlled car sector. Brushless motors have been legal in North American RC car racing in accordance to ROAR since 2006. These motors provide a great amount of power to RC racers and if paired with appropriate gearing and high-discharge Li-Po (Lithium Polymer) batteries, these cars can achieve speeds of up to 100 miles per hour (161 km/h).
Chapter 5

RESULT, MODIFICATIONS AND FUTURE SCOPE

Thermoelectric Generator Designed has been working efficiently and the idea behind this project is to utilize a small temperature difference between the ice / cold water and some atmospheric heat to produce electricity using thermoelectric generator.

PELTIER CHARACTERISTICS AND OPERATION CURVE

Peltier elements can give more than to 80°C temperature difference between their plates. But this is not a standard value. Actually, this would only be achieved in ideal conditions. The actual temperature difference ($\Delta T$) is usually smaller. The specifications of a TEC usually show the achieved temperature difference in conjunction to the power transferred in watts. The diagram should look like the following:

Looking the above diagram, we can calculate the temperature difference that will be achieved according to the power that the TEC will have to move across the plates. The power is measured in watts, but we actually talk about the thermal power. We can use our temperature unit converter to convert watts to your desired units.
We should not confuse the power of Peltier operation with the power that it transfers. It is most common that TECs are sold with the electric power indicated. A 125 Watt peltier may NOT be able to transfer 125 Watts of thermal power across the plates. Instead, it is most possible that it will draw 125 Watts electric power at max conditions. Peltier comes usually with the datasheet that indicates the performance curves of the device. Those curves are essential if you want to make your theoretical calculations for the optimal device operation.

The above curves come from a real Peltier and are not imaginary. What we could conclude from the above is that if we need for example to transfer 30 Watts of heat, then - with appropriate voltage as we will see right next - there would be created a temperature difference of 20 degrees and the TEC would draw as much as 3.02 Amperes. The next characteristic curve is the Temperature difference VS voltage. Here is one -also real- characteristic curve:
EFFICIENCY OF THERMOELECTRIC GENERATOR

Currently, ATEGs are about 5% efficient. However, advancements in thin-film and quantum well technologies could increase efficiency up to 15% in the future.

The efficiency of an ATEG is governed by the thermoelectric conversion efficiency of the materials and the thermal efficiency of the two heat exchangers. The ATEG efficiency can be expressed as:

\[ \zeta_{OV} = \zeta_{CONV} \times \zeta_{HX} \times \rho \]

Where:

\( \zeta_{OV} \): The overall efficiency of the ATEG

\( \zeta_{CONV} \): Conversion efficiency of thermoelectric materials

\( \zeta_{HX} \): Efficiency of the heat exchangers

\( \rho \): The ratio between the heat passed through thermoelectric materials to that passed from the hot side to the cold side

In conclusion, We must say that the Minor project has helped us to enhance our working skills & stamina and to further enlighten us to enter a new phase of life after completion of the degree program.
CONCLUSION

This project focussed upon increasing our knowledge and interest in toward the Production of Electricity using waste heat energy as a primary source/fuel. Because Electricity is most efficient and necessary needs to peoples in these days so its production at most efficient method with minimum cost and in proper sequence with less wastage. I learnt how to produce it by taking waste heat energy from industries, household devices and automobile as input by using Peltier Element and maintain it. It was a great experience. It increase our practical skills that’s the main thing which we learnt during this period Thus, we believe that our project session will be beneficial for various purposes & hence our efforts will be fruitful.
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